Ocean islands and seamounts
Commonly associated with hot spots

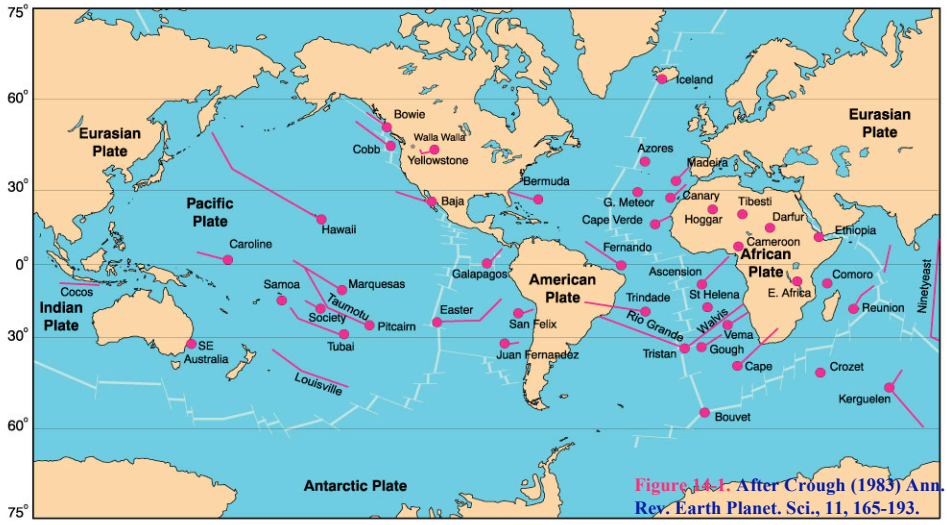
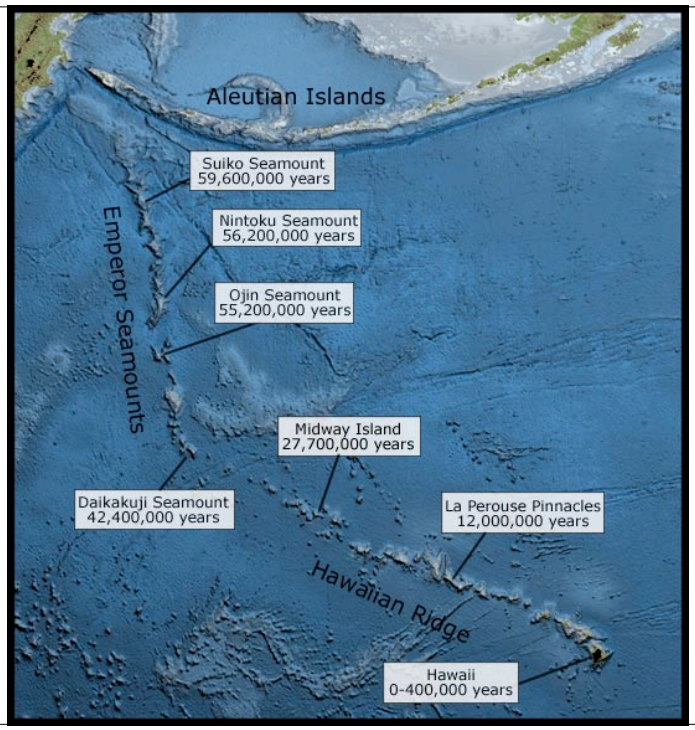
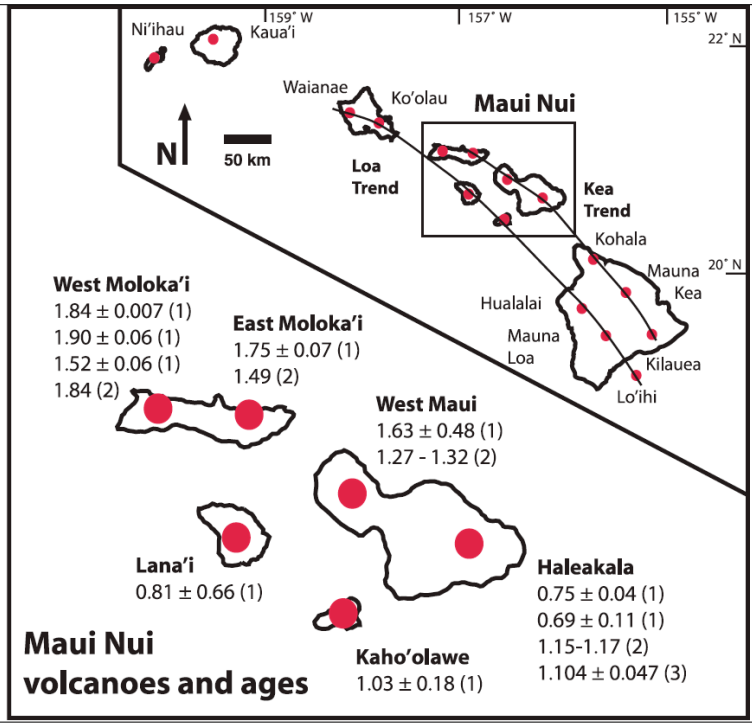
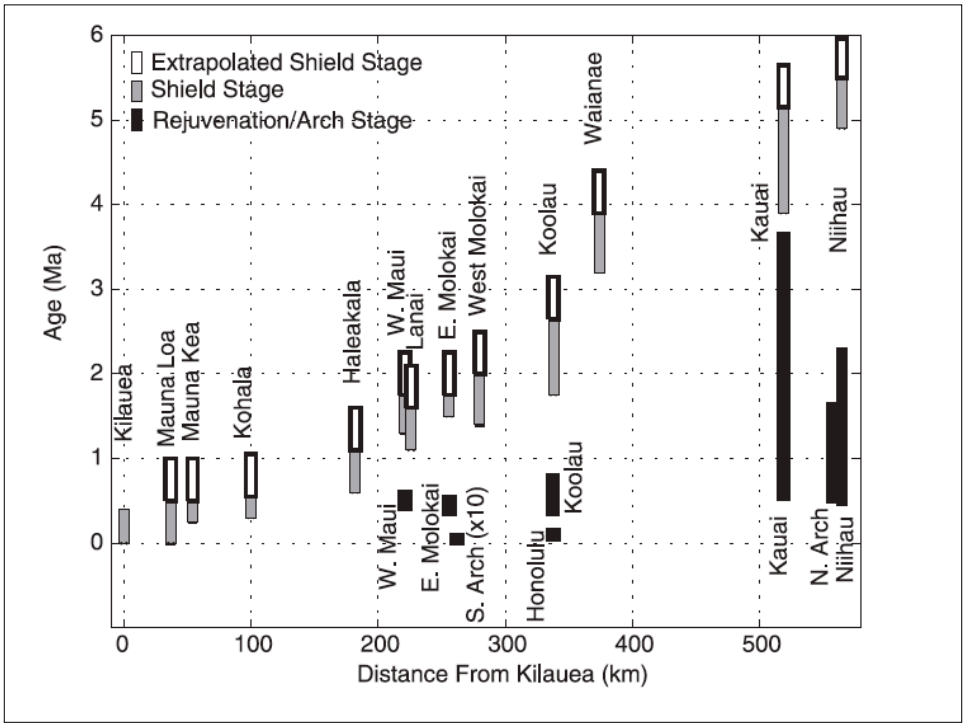
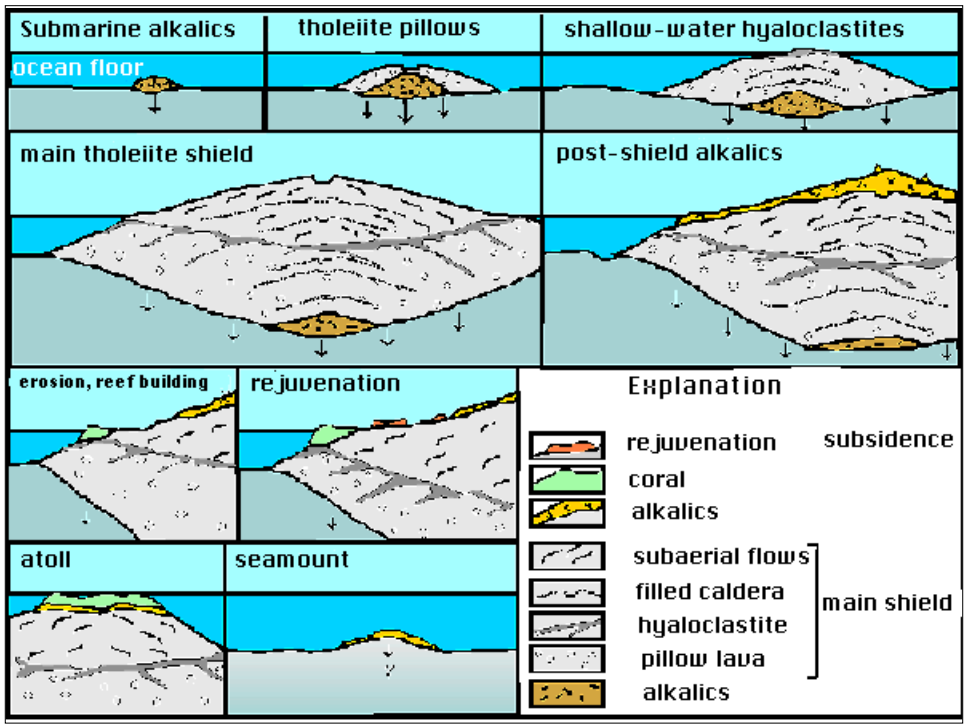


Figure 14.1. After Crough (1983) Ann. Rev. Earth Planet. Sci., 11, 165-193.




159° W
157° W
155° W
22° N
20° N
Ni'ihau
Kaua'i
Waianae
Ko'olau
Maui Nui
N
50 km
Loa
Trend
Kea
Trend
Kohala
Mauna
Kea
Hualalai
Mauna
Loa
Kilauea
Lo'ihi
West Moloka'i
1.84 ± 0.007 (1)
1.90 ± 0.06 (1)
1.52 ± 0.06 (1)
1.84 (2)
East Moloka'i
1.75 ± 0.07 (1)
1.49 (2)
West Maui
1.63 ± 0.48 (1)
1.27 - 1.32 (2)
Lana'i
0.81 ± 0.66 (1)
Haleakala
0.75 ± 0.04 (1)
0.69 ± 0.11 (1)
1.15-1.17 (2)
1.104 ± 0.047 (3)
Maui Nui
volcanoes and ages
Kaho'olawe
1.03 ± 0.18 (1)


Extrapolated Shield Stage
Shield Stage
Rejuvenation/Arch Stage
Age (Ma)
Distance From Kilauea (km)
0
100
200
300
400
500
1
2
3
4
5
6
Kilauea
Mauna Loa
Mauna Kea
Kohala
Haleakala
W. Maui
Lanai
E. Molokai
West Molokai
Koolau
Waianae
Kauai
Niihau
W. Maui
E. Molokai
S. Arch (x10)
Honolulu
Koolau
Kauai
N. Arch
Niihau



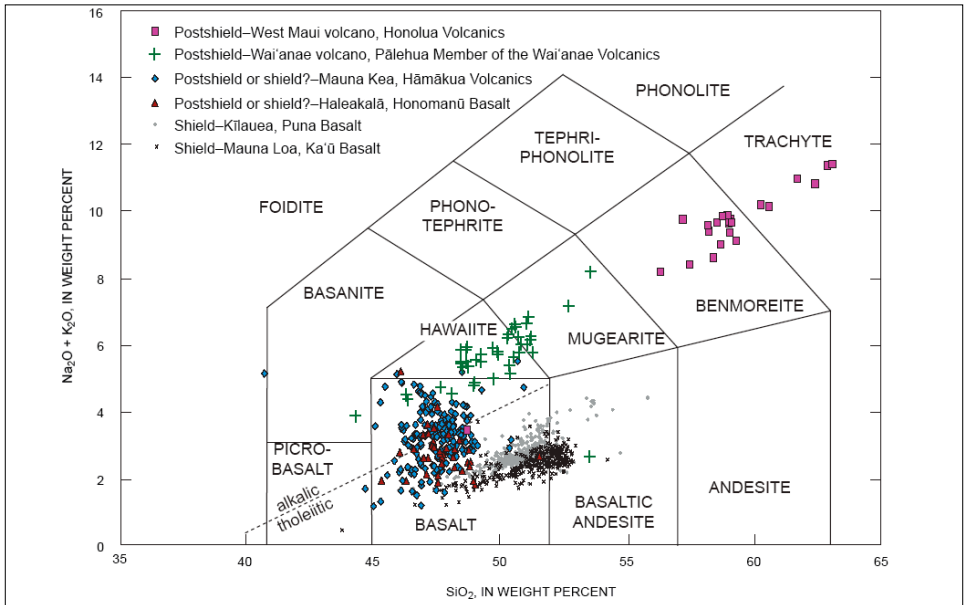
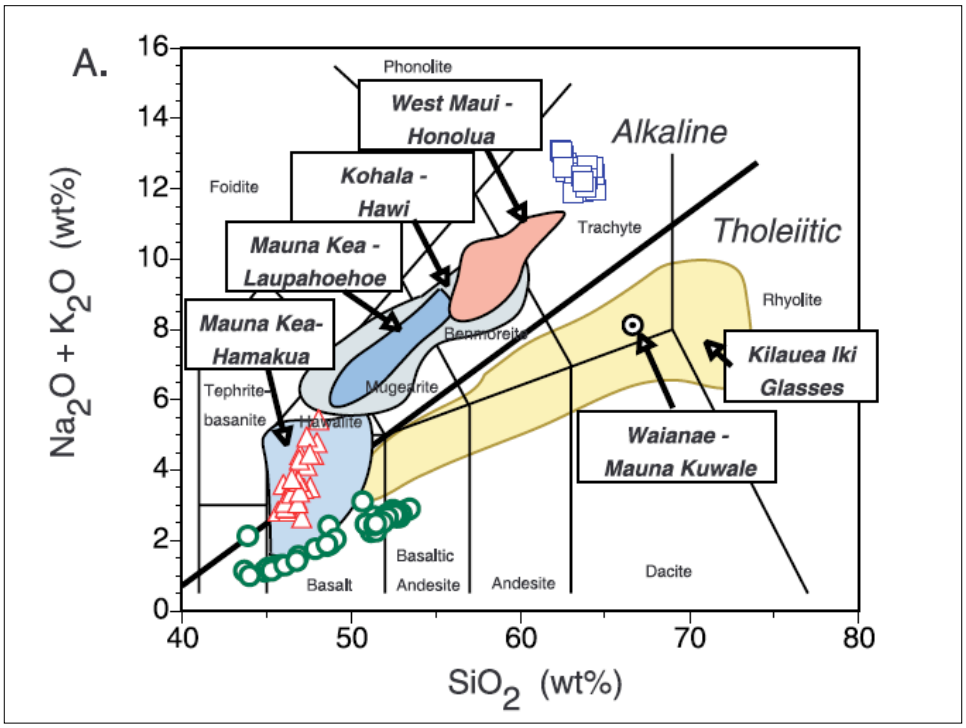
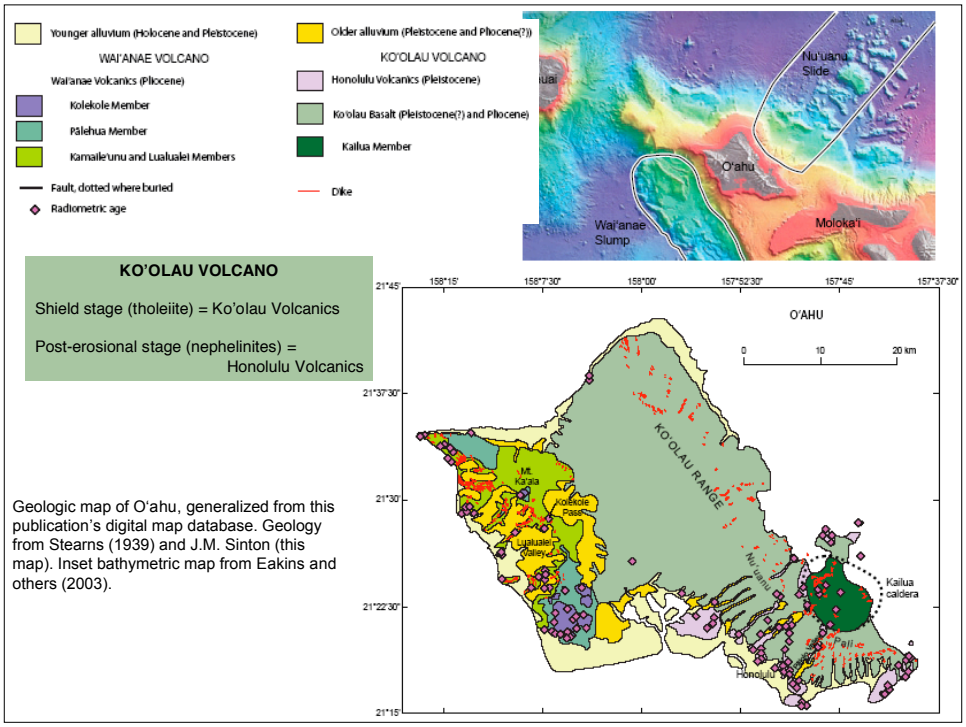
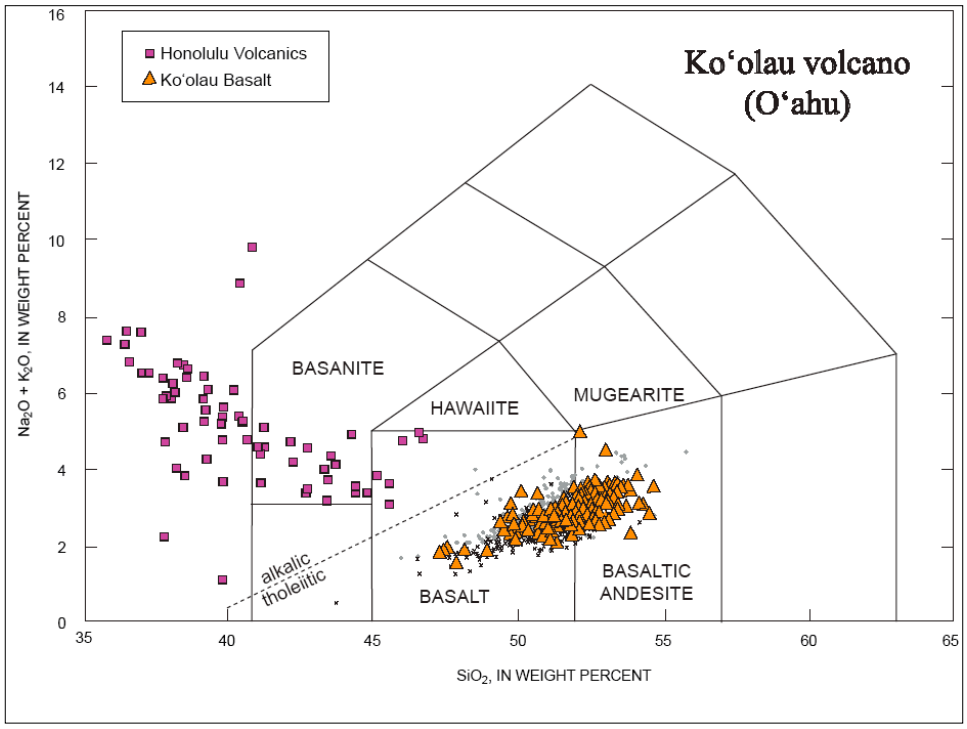


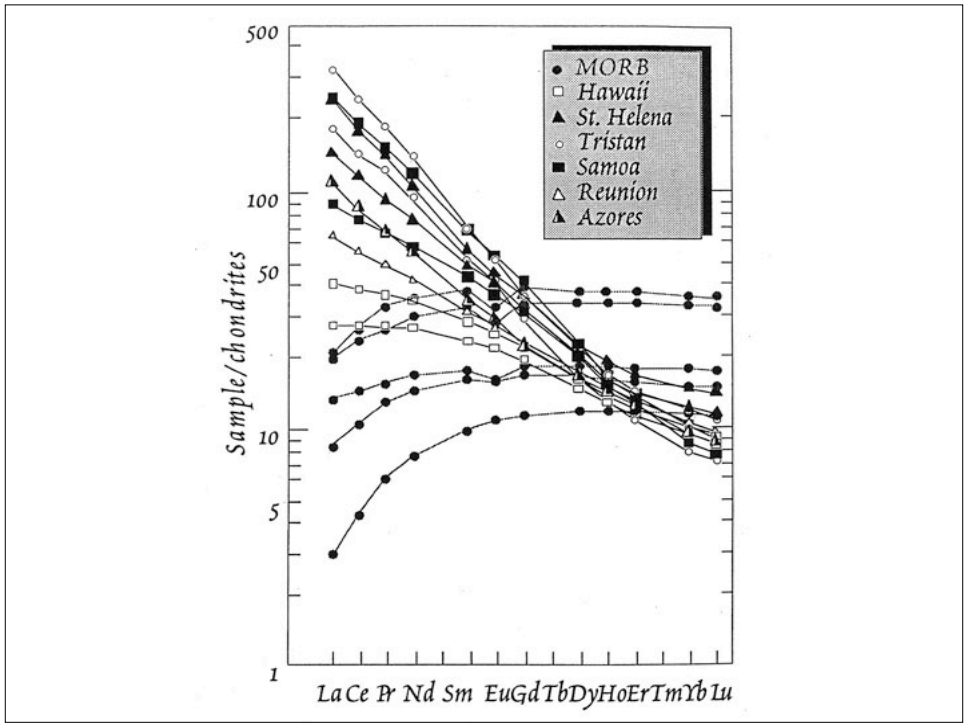
Figure 2. Alkali-silica diagram (Na_2O+K_2O versus SiO_2) composited from several volcanoes. Rock classification grid labeled (from Le Bas and others, 1986, with tephrite-basanite field shown specifically as the olivine-bearing occurrence, basanite, as found commonly in Hawai'i). Shown dashed is boundary separating tholeiitic and alkalic basalt (Macdonald and Katsura 1964). Data for Kīlauea and Mauna Loa on this and subsequent alkali-silica diagrams from Wolfe and Morris (1996b). Data sources for the other volcanoes are listed in captions to figures 11, 23, 25, and 32.





Geologic map of O'ahu, generalized from this publication's digital map database. Geology from Stearns (1939) and J.M. Sinton (this map). Inset bathymetric map from Eakins and others (2003).


Honolulu Volcanics
Ko'olau Basalt
Ko'olau volcano
(O'ahu)
BASANITE
HAWAIITE
MUGEARITE
alkalic
tholeiitic
BASALT
BASALTIC
ANDESITE
$Na_2O + K_2O$, IN WEIGHT PERCENT
SiO_2, IN WEIGHT PERCENT
0
2
4
6
8
10
12
14
16
35
40
45
50
55
60
65


MORB
Hawaii
St. Helena
Tristan
Samoa
Reunion
Azores
Sample/chondrites
500
100
50
10
5
1
La Ce Pr Nd Sm Eu Gd Tb Dy Ho Er Tm Yb Lu

Modeling Rare-Earth Elements (REE) during Mantle Melting beneath Hawaii

1) What do we use for the mantle mineralogy?
   60% olivine; 25% opx; 10% cpx; 5% garnet

2) What do we start with for initial REE concentrations?
   primitive mantle or chondritic compositions

3) What process do we model?
   equilibrium partial melting

4) What equation do we use?

An example of an olivine-clinopyroxene bearing mantle xenolith from the 1800-1801 lava flow of Hualalai. A thin coating of host lava mantles the rock (image on right is about 15 cm wide)

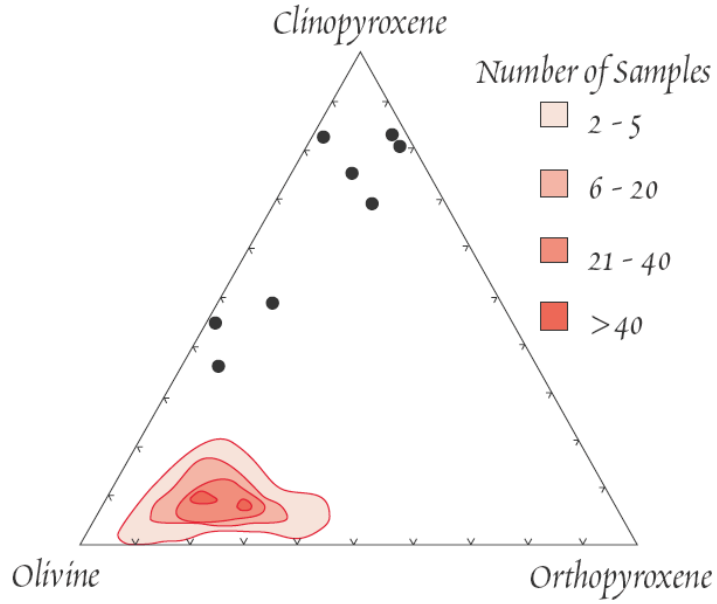
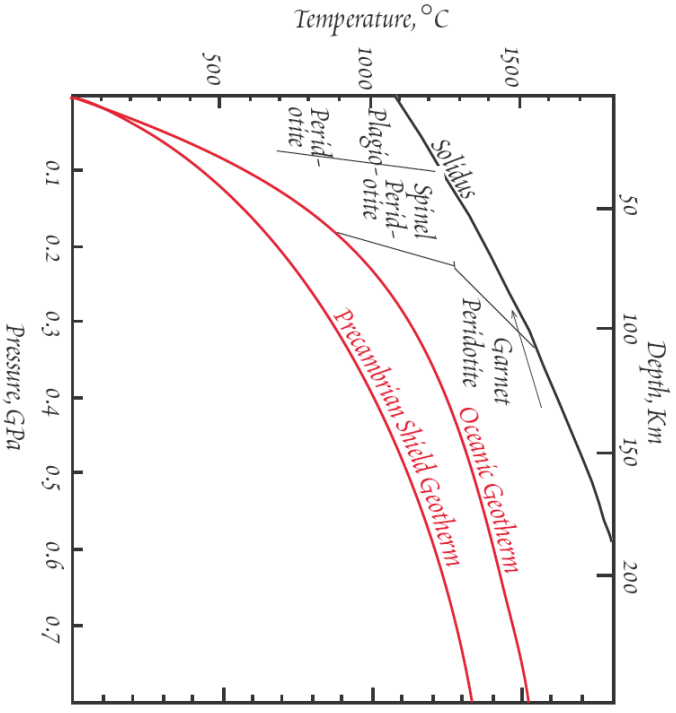


Figure 11.2. Abundances of modal mineralogy in xenoliths from Kilbourne Hole, NM.



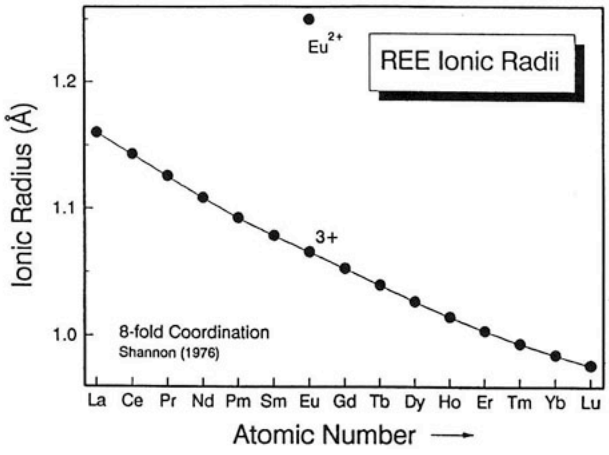
Modeling Rare-Earth Elements (REE) during Mantle Melting beneath Hawaii

4) What equation do we use?

$$C_L = \frac{C_O}{(F + D(1 - F))}$$

C_L – measure in erupted magma
C_O – unknown (assume primitive mantle)
D – calculate from lab data
F – unknown (estimate range)

How will the REE partition between minerals (solid) and melt during partial melting?



REE Model for Hawaii Mantle Melting

	Mineral proportion	D_{Cerium}	$D_{Ytterbium}$
Olivine	60%	0.001	0.002
Orthopyroxene	25%	0.003	0.05
Clinopyroxene	10%	0.1	0.28
Garnet	5%	0.02	4.0
(Spinel)	(5%)	(0.08)	(0.02)

Calculate D_{Ce} for the whole rock: $\mathbf{D_{Ce}(bulk)}$ = (0.60*0.001) + (0.25*0.003) + (0.10*0.1) + (0.05*0.02)
= 0.012

Calculate D_{Yb} for the whole rock: $\mathbf{D_{Yb}(bulk)}$ = (0.60*0.002) + (0.25*0.05) + (0.10*0.28) + (0.05*4.0)
= 0.242

(For spinel peridotite: D_{Ce}(bulk) = 0.015 D_{Yb}(bulk) = 0.043)

Modeling Rare-Earth Elements (REE) during Mantle Melting beneath Hawaii

4) What equation do we use?

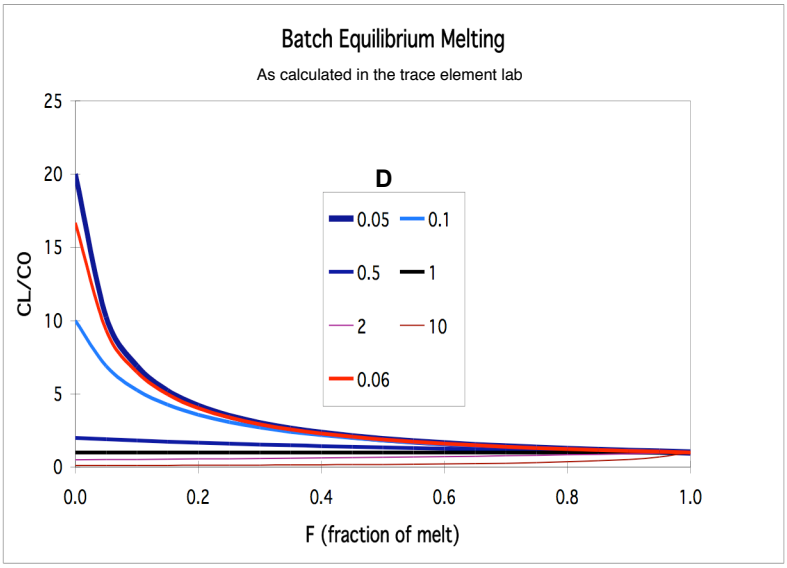
C_L – measure in erupted magma
C_O – unknown (assume primitive mantle)
D – calculate from lab data
F – unknown (estimate range)

$$C_L = \frac{C_O}{(F + D(1-F))}$$

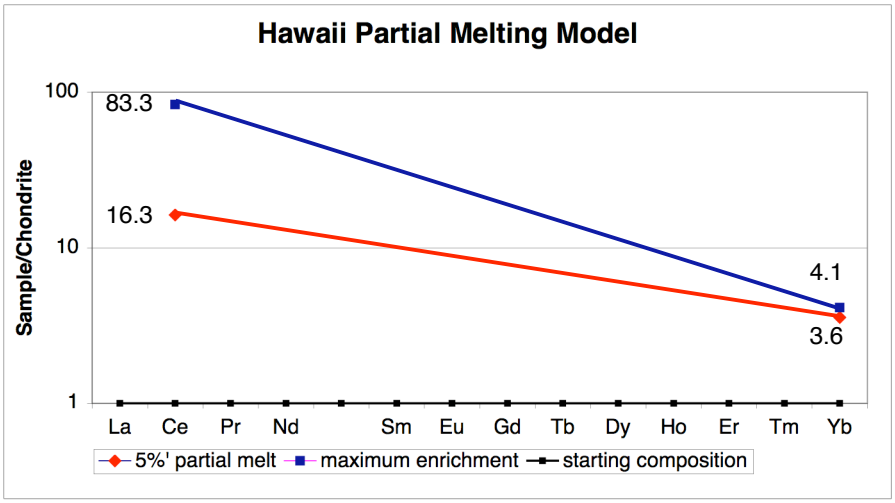
Start with an extreme value: **F = 0**

$$\frac{C_L}{C_O} = \frac{1}{D}$$

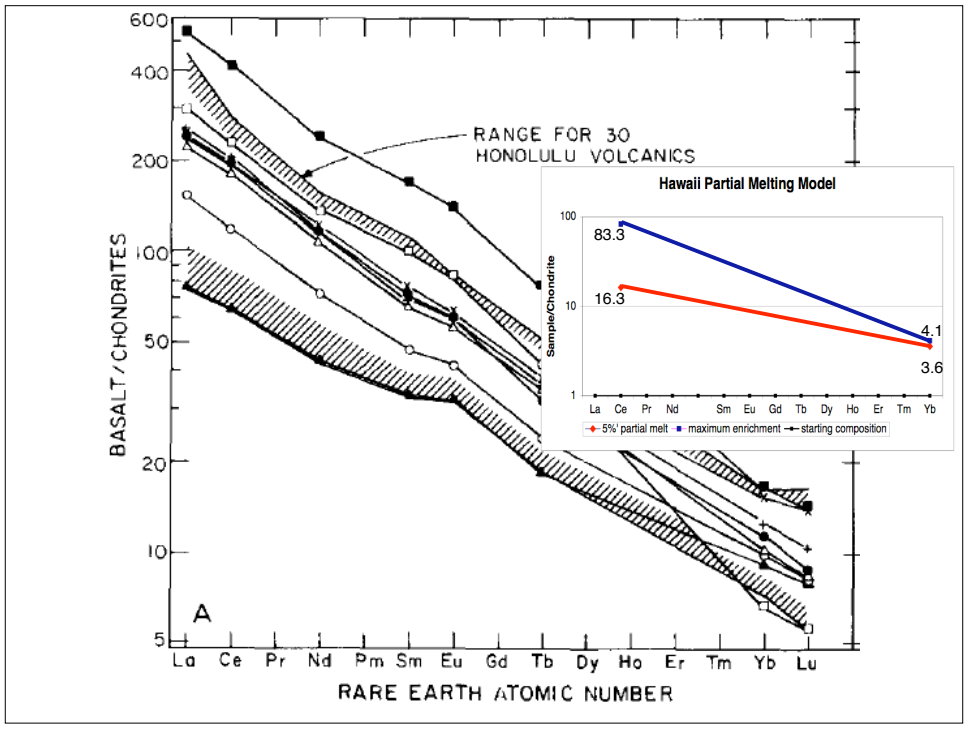
What do we expect for an extremely small fraction of partial melting? ……

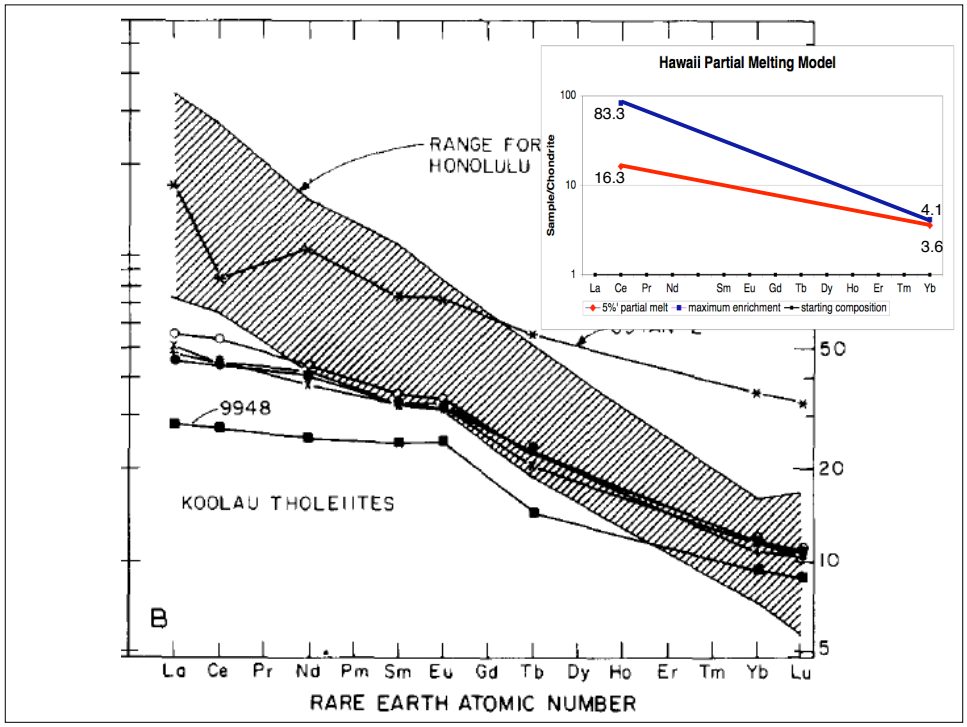


At F = 0, have the maximum enrichment possible in liquid; i.e., 1/D



Assume starting composition is chondritic (all elements at 1.0)
At F=0 get maximum enrichment of REE in melt; Ce = 83 x chond.
At more reasonable F=5%, get Ce = 16 x chond.


RANGE FOR 30
HONOLULU VOLCANICS
BASALT / CHONDRITES
600
400
200
100
50
20
10
5
A
La Ce Pr Nd Pm Sm Eu Gd Tb Dy Ho Er Tm Yb Lu
RARE EARTH ATOMIC NUMBER
Hawaii Partial Melting Model
Sample/Chondrite
100
10
1
83.3
16.3
4.1
3.6
La Ce Pr Nd Sm Eu Gd Tb Dy Ho Er Tm Yb
5%' partial melt
maximum enrichment
starting composition


RANGE FOR
HONOLULU
9948
KOOLAU THOLEIITES
50
20
10
5
B
La Ce Pr Nd Pm Sm Eu Gd Tb Dy Ho Er Tm Yb Lu
RARE EARTH ATOMIC NUMBER
Hawaii Partial Melting Model
Sample/Chondrite
100
10
1
83.3
16.3
4.1
3.6
La Ce Pr Nd Sm Eu Gd Tb Dy Ho Er Tm Yb
5%' partial melt
maximum enrichment
starting composition

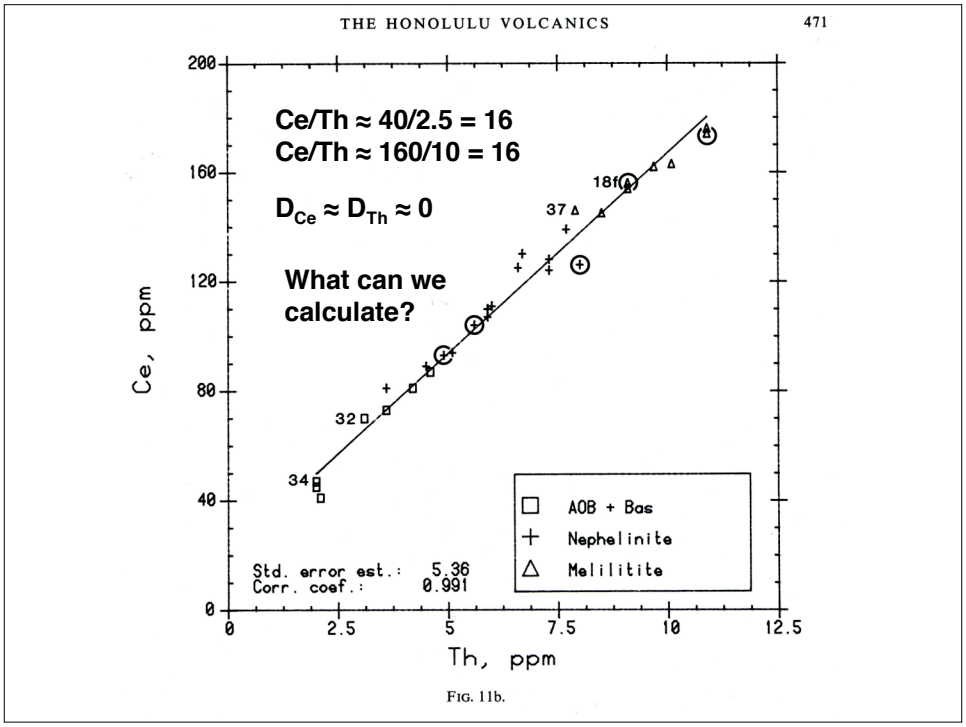


FIG. 11b.

Modeling Rare-Earth Elements (REE) during Mantle Melting beneath Hawaii

4) What equation do we use?

C_L – measure in erupted magma
C_O – unknown (assume primitive mantle)
D – calculate from lab data
F – unknown (estimate range)

$$C_L = \frac{C_O}{(F + D(1-F))}$$

For Ce and Th in Honolulu Volcanics: **D = 0**

$$\frac{C_L}{C_O} = \frac{1}{F}$$

So can we use this to put any limits on the fraction of partial melting? ……

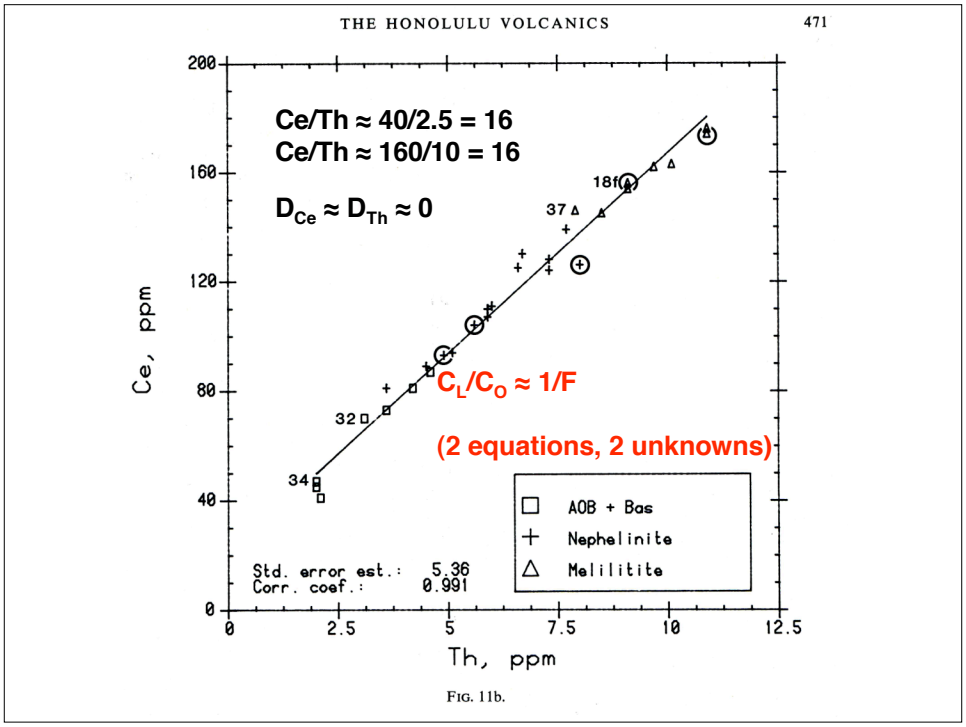


FIG. 11b.

Modeling Rare-Earth Elements (REE) during Mantle Melting beneath Hawaii

For Ce and Th in Honolulu Volcanics: **D = 0**

$$\frac{C_L}{C_O} = \frac{1}{F}$$

So can we use this to put any limits on the fraction of partial melting? ……

For 2 magmas, A & B, $[Th]_A$ = 12 ppm, $[Th]_B$ = 2.4 ppm (are values for C_L).
We don't know C_O, but since magmas are from same source, $[C_O]_A = [C_O]_B$.
Magma A formed by partial melt fraction F_A; and magma B by F_B.

Write the above equation for both magmas, and divide one by the other:

$$\frac{\frac{C_L^A}{C_O^A}}{\frac{C_L^B}{C_O^B}} = \frac{F_B}{F_A} \quad \text{since} \quad C_O^A = C_O^B \longrightarrow \frac{C_L^A}{C_L^B} = \frac{F_B}{F_A} = \frac{12}{2.4} = 5$$

Magma B formed by 5x as much melting as magma A

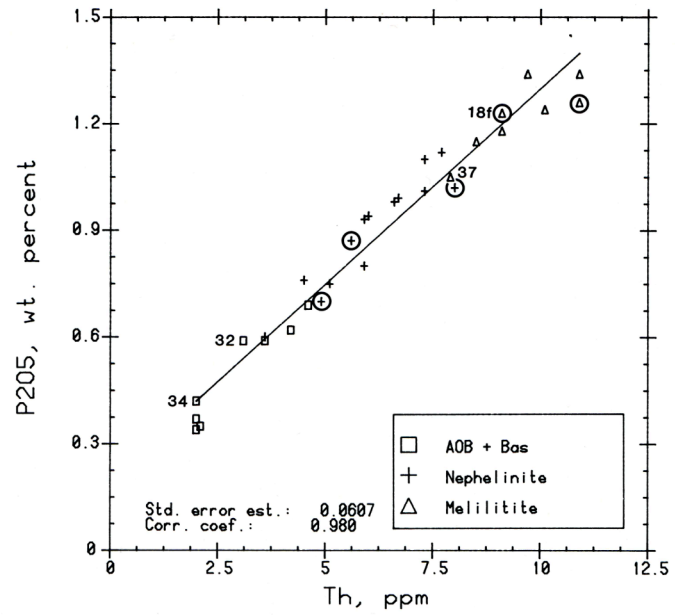


FIG. 11. P_2O_5 *vs.* Th (A) and Ce *vs.* Th (B) for lavas of Honolulu Volcanics. These elements and La are strongly incompatible (have *D* values near 0). Range of Th abundance indicates that degree of melting varies by a factor of 5·5 to generate the Honolulu Volcanics suite. One point at Th = 2 p.p.m. represents two samples. The best-fit line on the La *vs.* Th plot has a correlation coefficient of 0·966 and an intercept of 8·6. Other symbols as in Fig. 3.