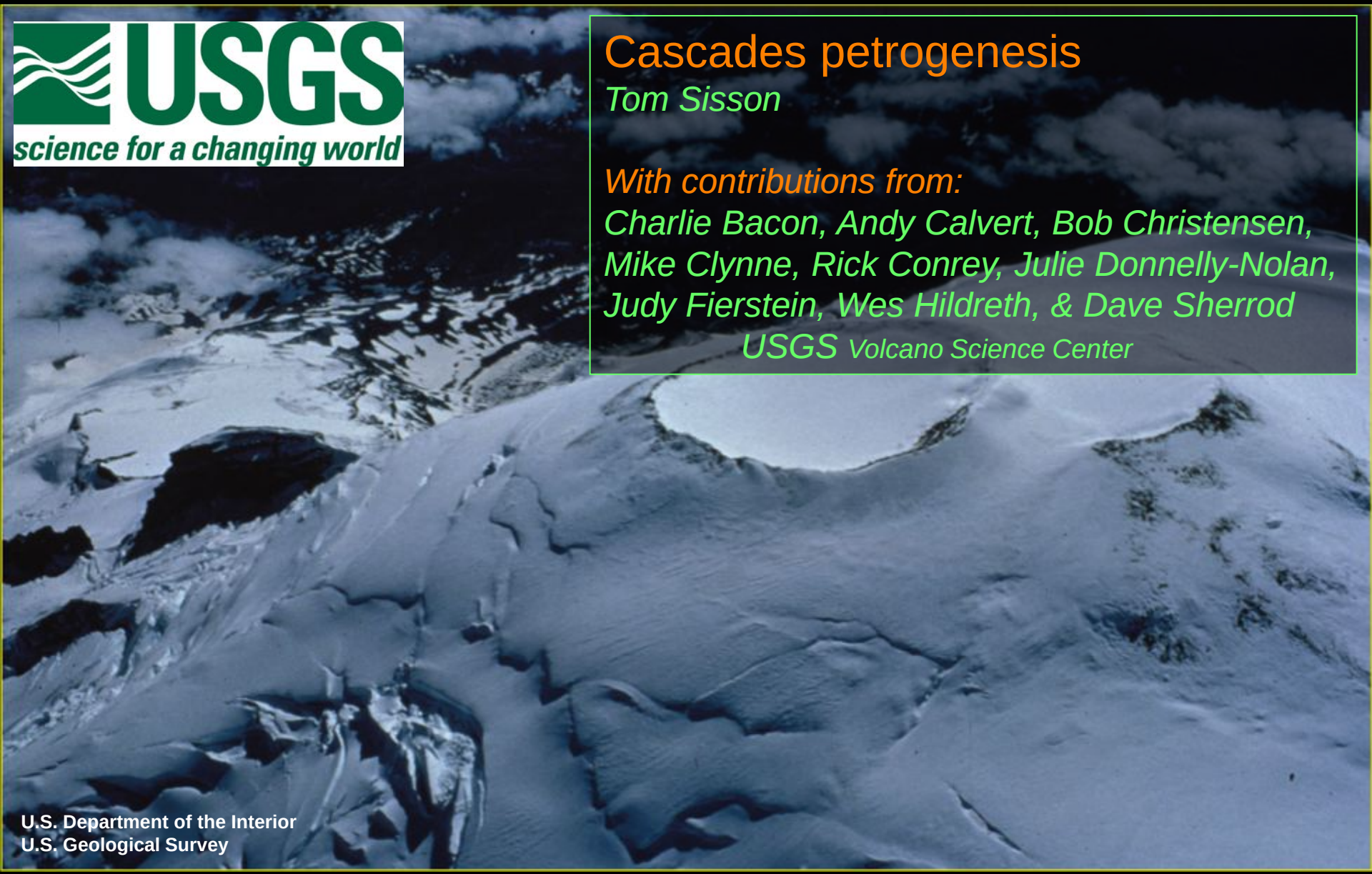
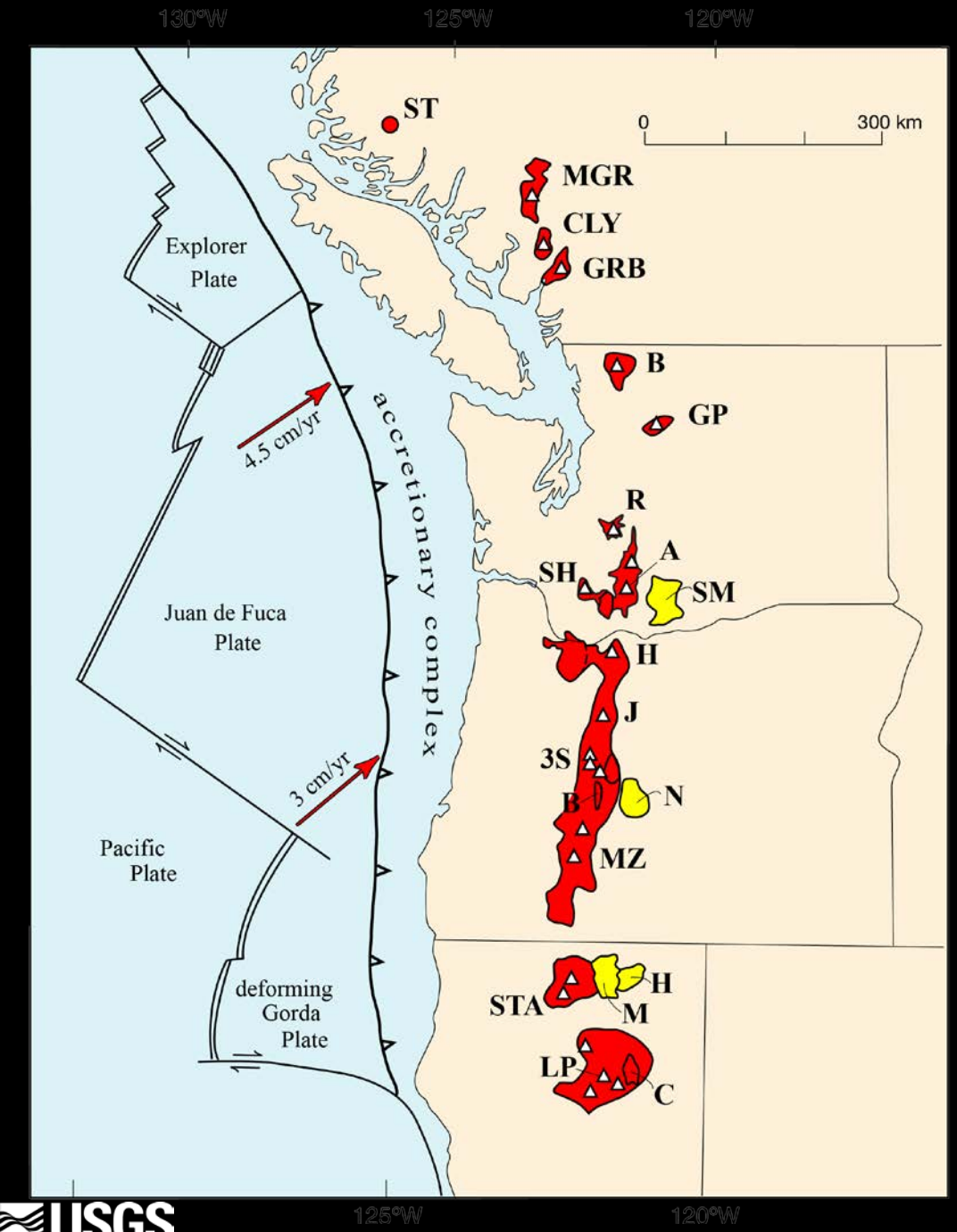


Cascades petrogenesis

Tom Sisson

With contributions from:
Charlie Bacon, Andy Calvert, Bob Christensen, Mike Clynne, Rick Conrey, Julie Donnelly-Nolan, Judy Fierstein, Wes Hildreth, & Dave Sherrod
USGS Volcano Science Center

U.S. Department of the Interior
U.S. Geological Survey

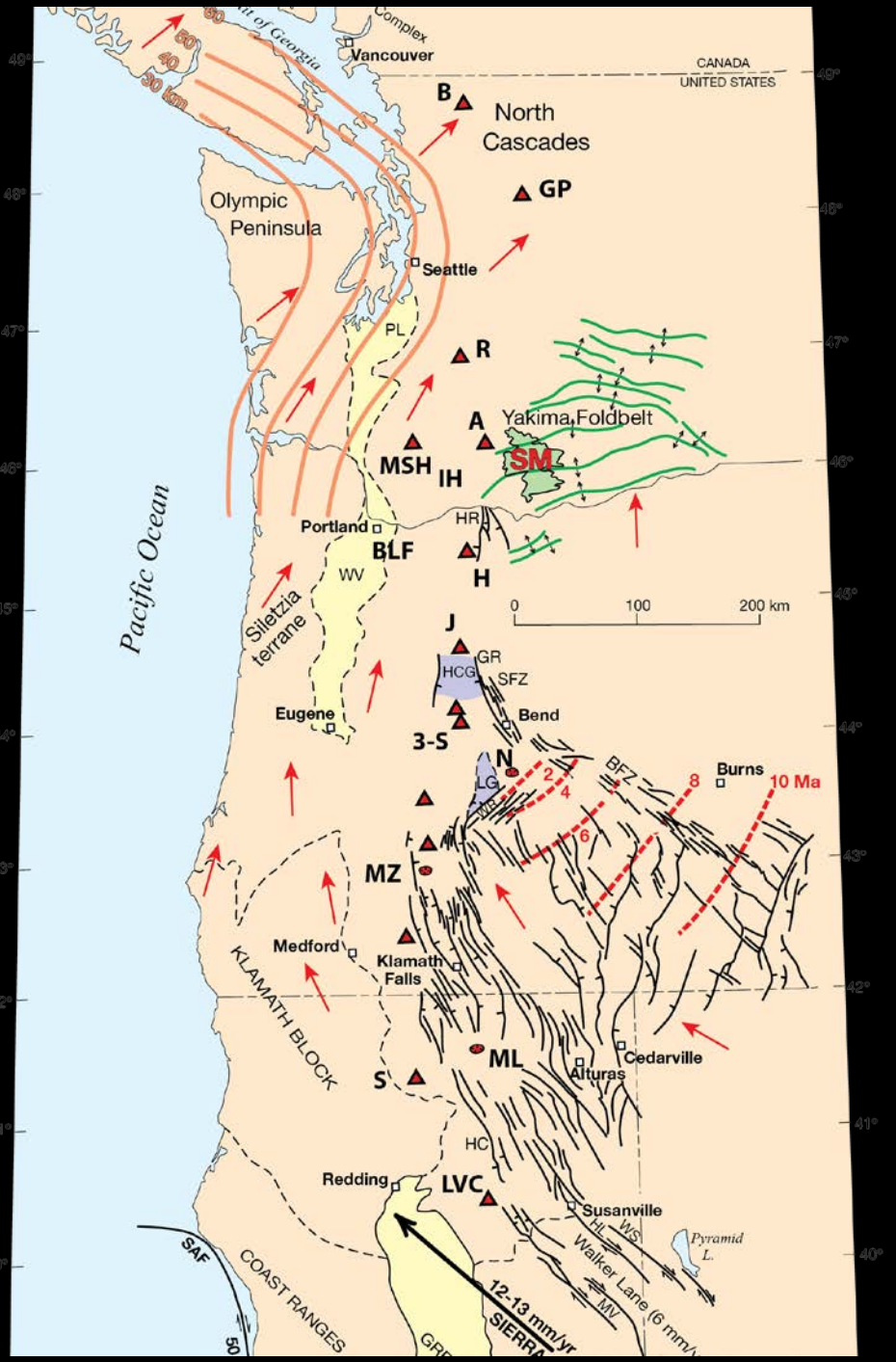


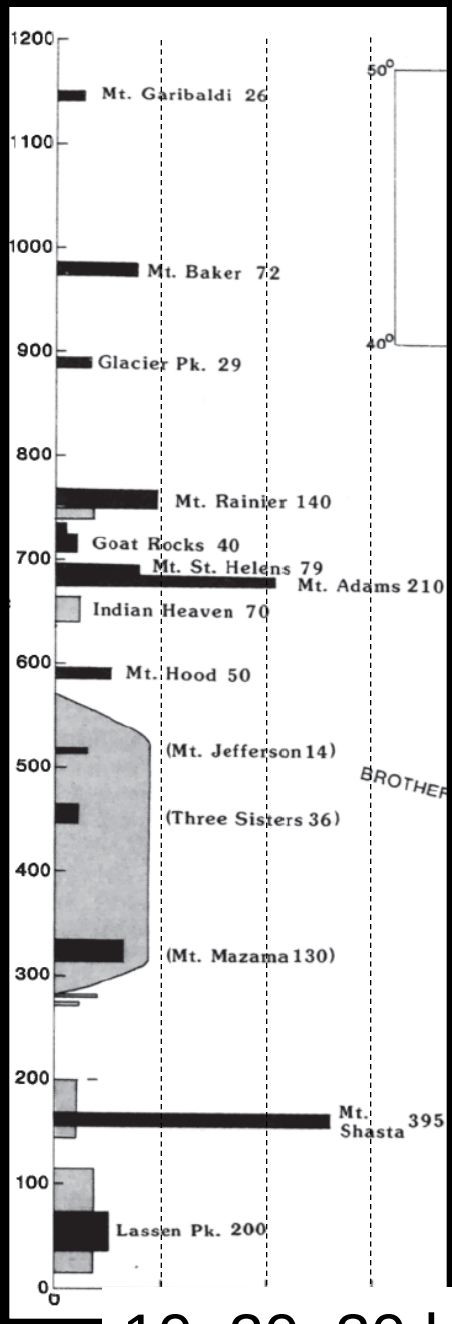
Quaternary Cascade Arc

1,200-1,400 km arc length
2,300 vents, main arc
1,100 vents, rear arc
~25 big edifices & volcanic fields
3 sizeable mafic rear-arc fields

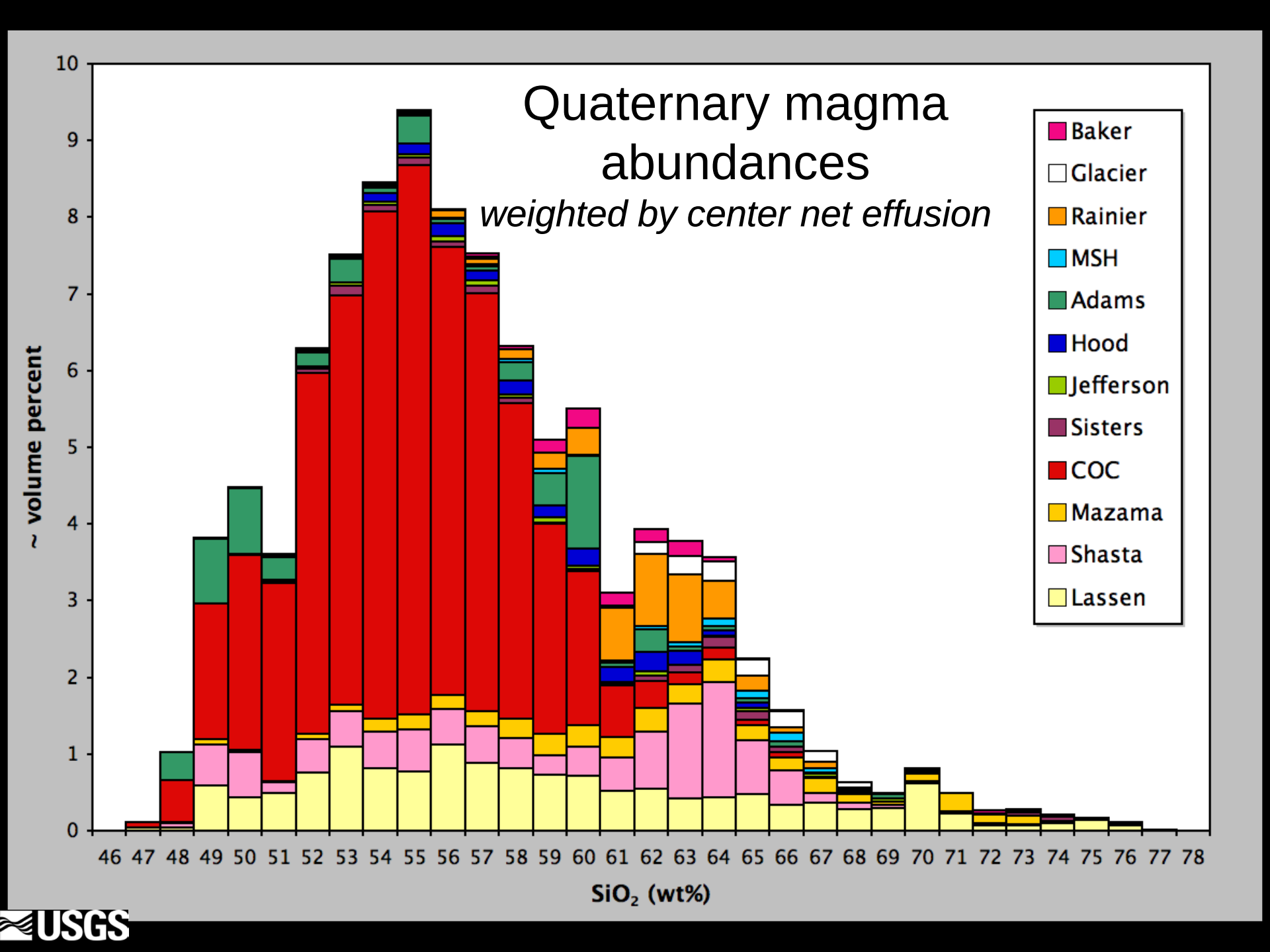
Erupted volume (2 Myr), main arc:
3,600-5,100 km^3
includes 1,500-3,000 km^3 *central OR*
(Sherrod & Smith, 1990)
~6,400 km^3
(Hildreth, 2010)
rear arc: ~1,300 km^3

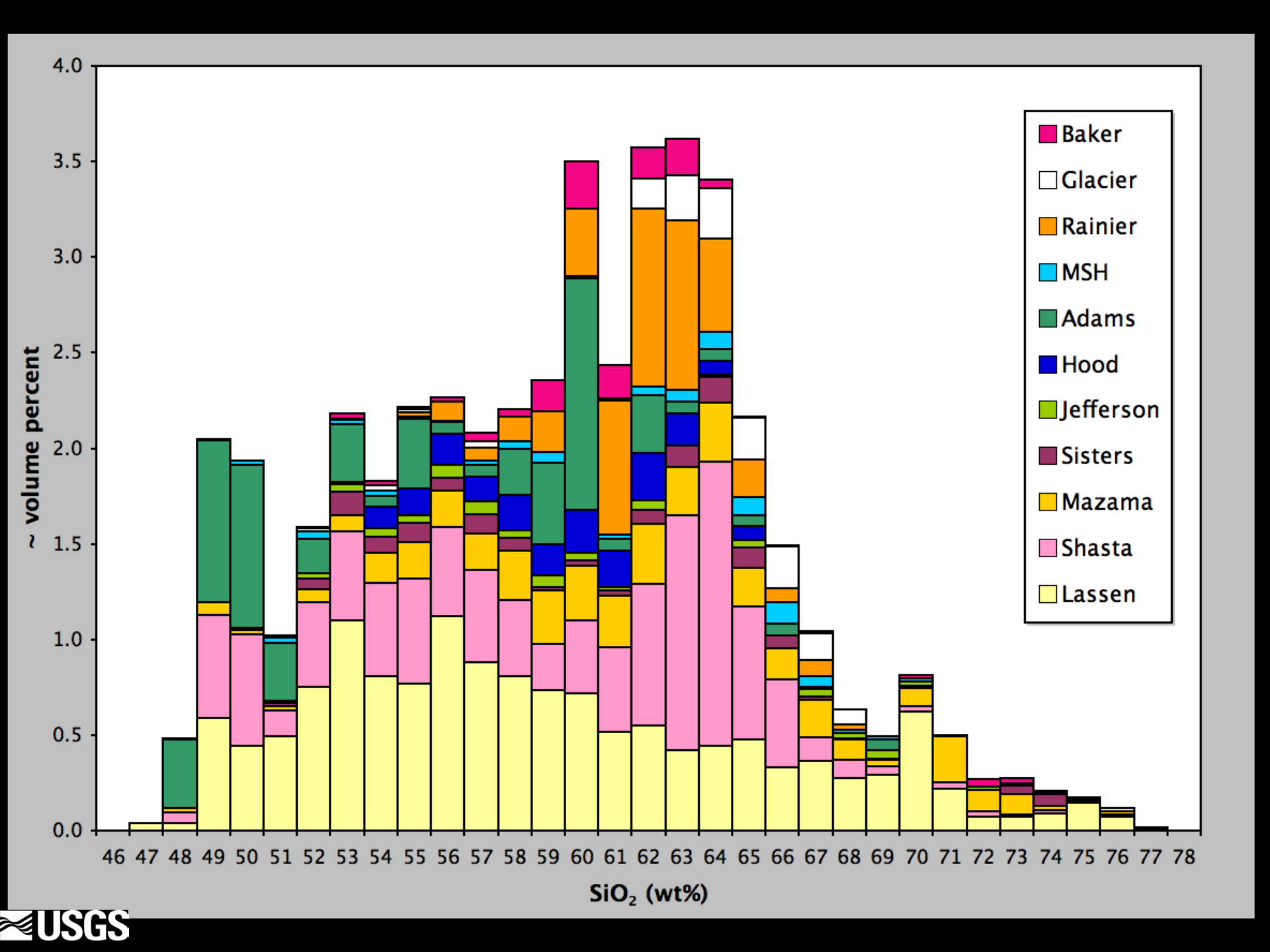
USGS



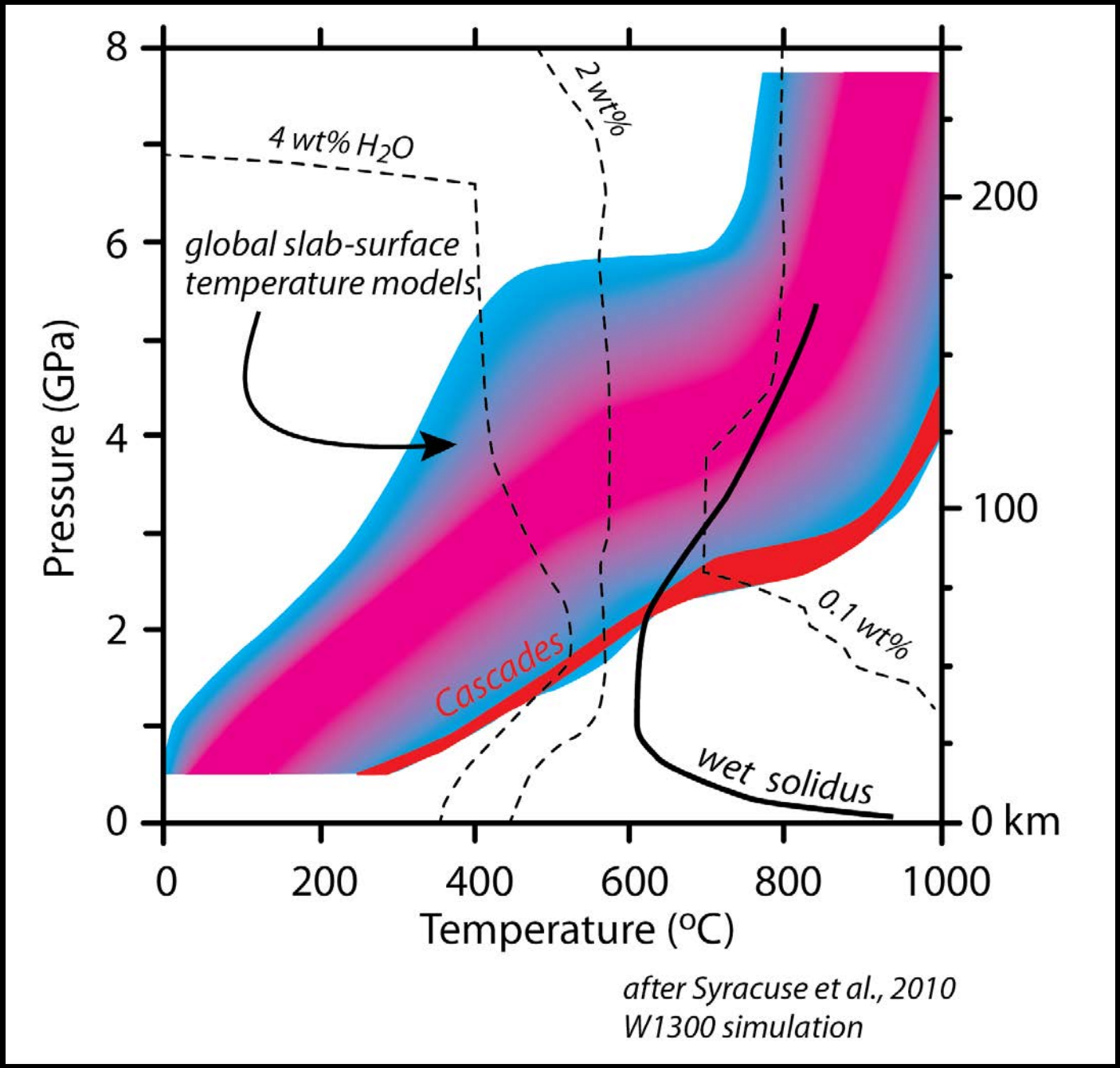


10 20 30 km^3/km

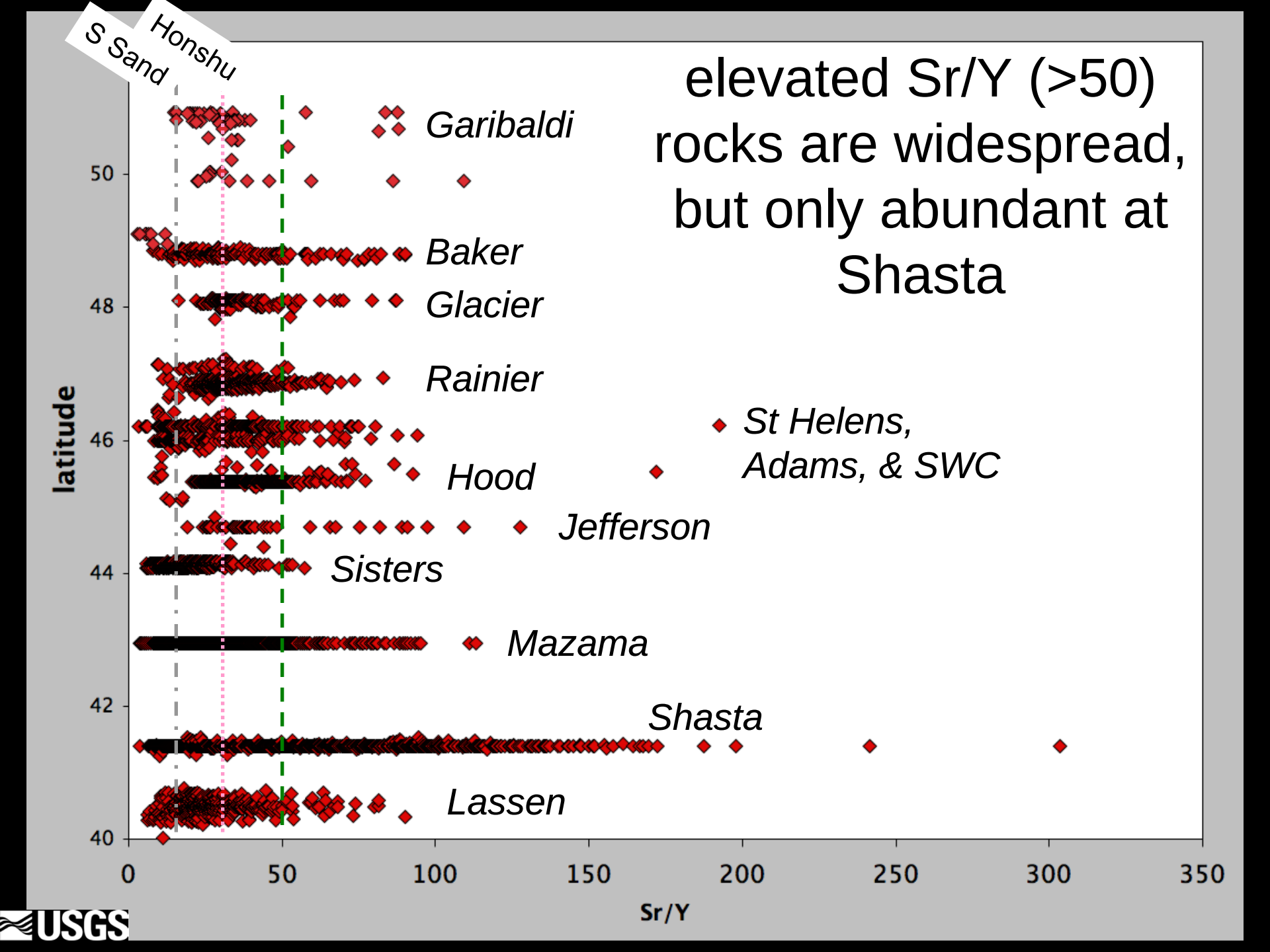

Quaternary magma abundances
weighted by center net effusion
~ volume percent
SiO2 (wt%)
Baker
Glacier
Rainier
MSH
Adams
Hood
Jefferson
Sisters
COC
Mazama
Shasta
Lassen
0
1
2
3
4
5
6
7
8
9
10
46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78

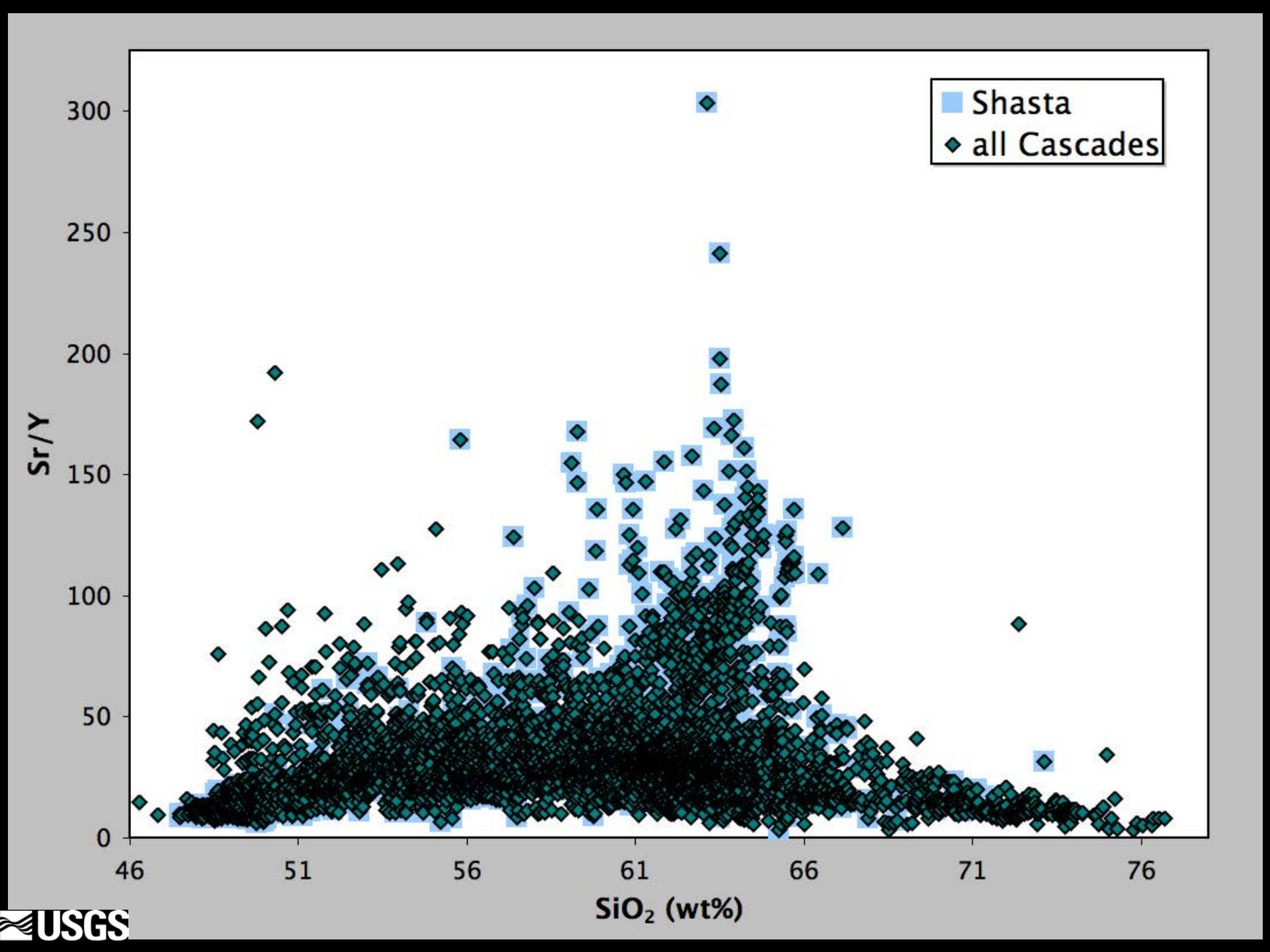

4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
~ volume percent
46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78
SiO2 (wt%)
Baker
Glacier
Rainier
MSH
Adams
Hood
Jefferson
Sisters
Mazama
Shasta
Lassen

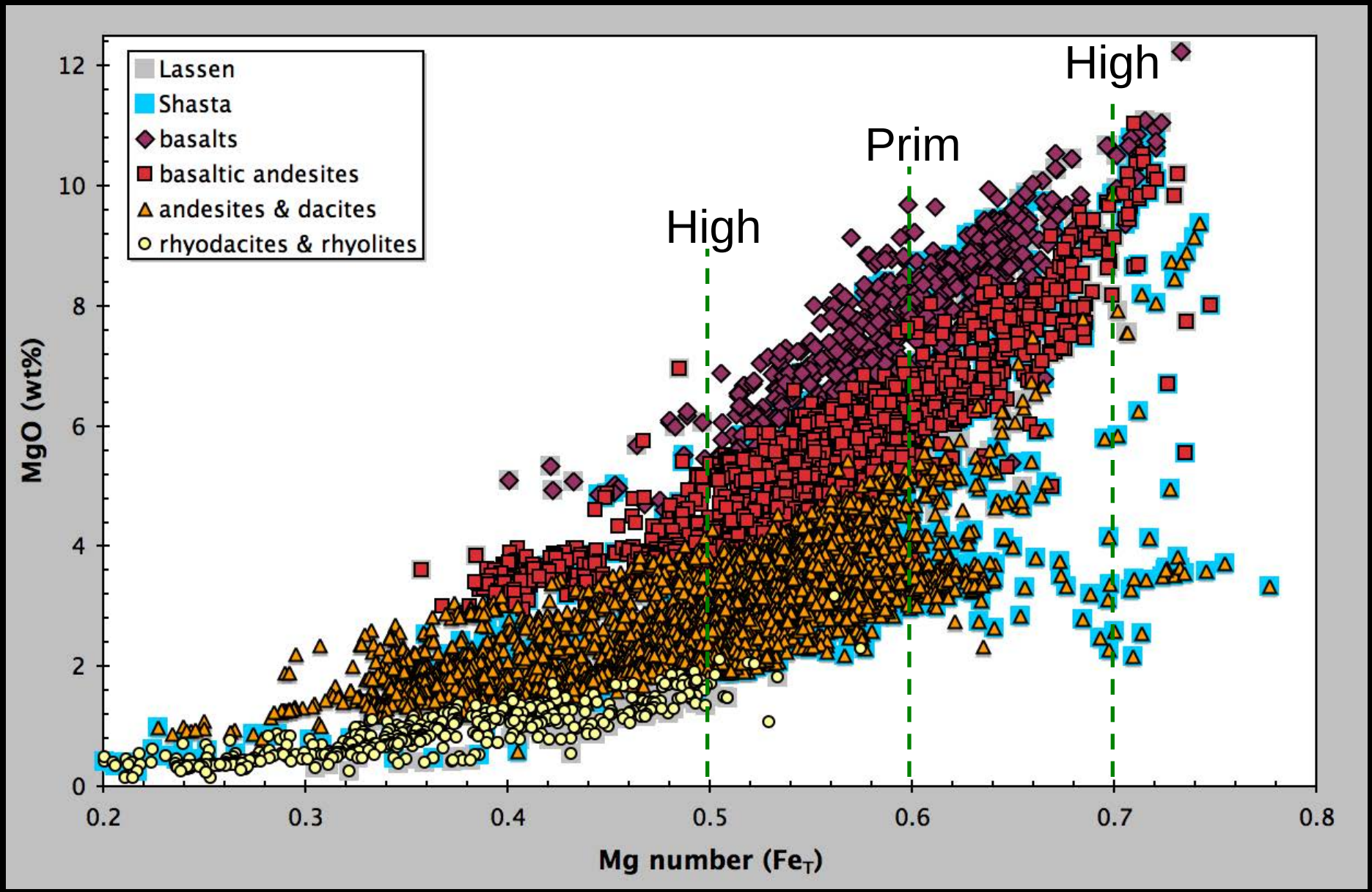
USGS

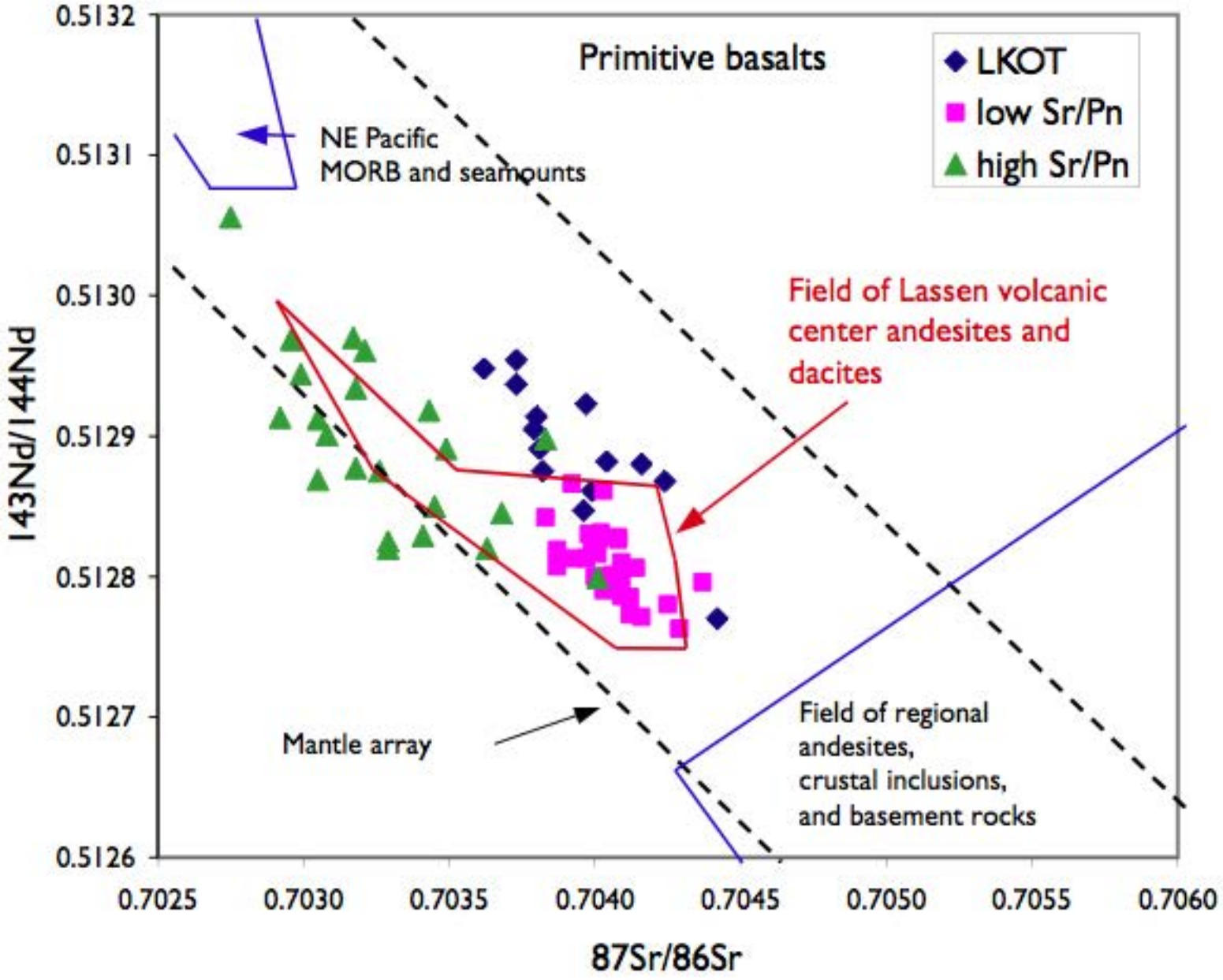

8
6
4
2
0
Pressure (GPa)
200
100
0 km
0
200
400
600
800
1000
Temperature (°C)
4 wt% H_2O
2 wt%
global slab-surface
temperature models
Cascades
0.1 wt%
wet solidus
after Syracuse et al., 2010
W1300 simulation

USGS

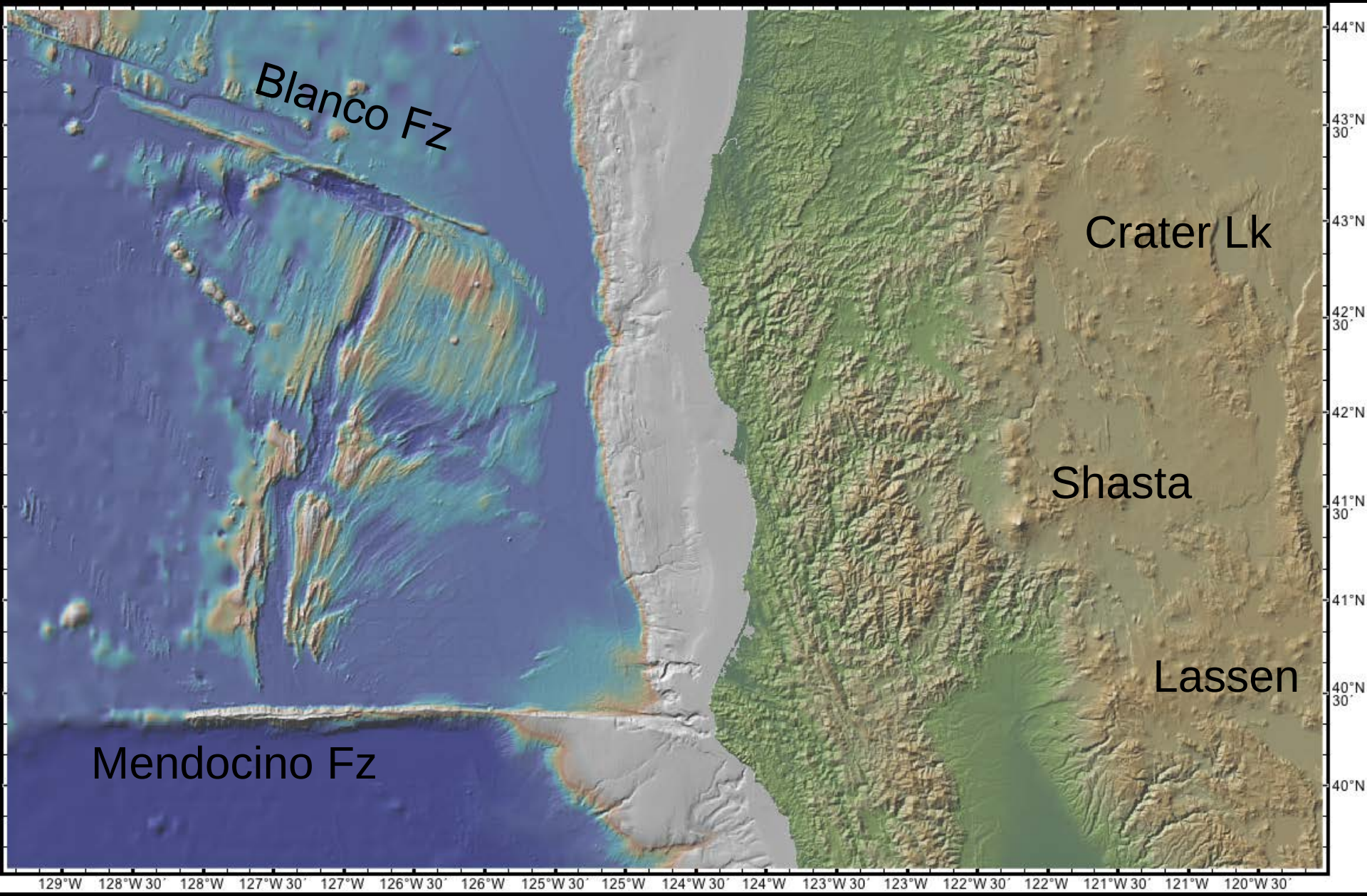

S Sand
Honshu
elevated Sr/Y (>50) rocks are widespread, but only abundant at Shasta
Garibaldi
Baker
Glacier
Rainier
St Helens, Adams, & SWC
Hood
Jefferson
Sisters
Mazama
Shasta
Lassen
latitude
50
48
46
44
42
40
0
50
100
150
200
250
300
350
Sr/Y
USGS


Shasta
all Cascades
Sr/Y
300
250
200
150
100
50
0
46
51
56
61
66
71
76
SiO2 (wt%)


Lassen
Shasta
basalts
basaltic andesites
andesites & dacites
rhyodacites & rhyolites
High
Prim
High
MgO (wt%)
Mg number (Fe$_T$)
0
2
4
6
8
10
12
0.2
0.3
0.4
0.5
0.6
0.7
0.8

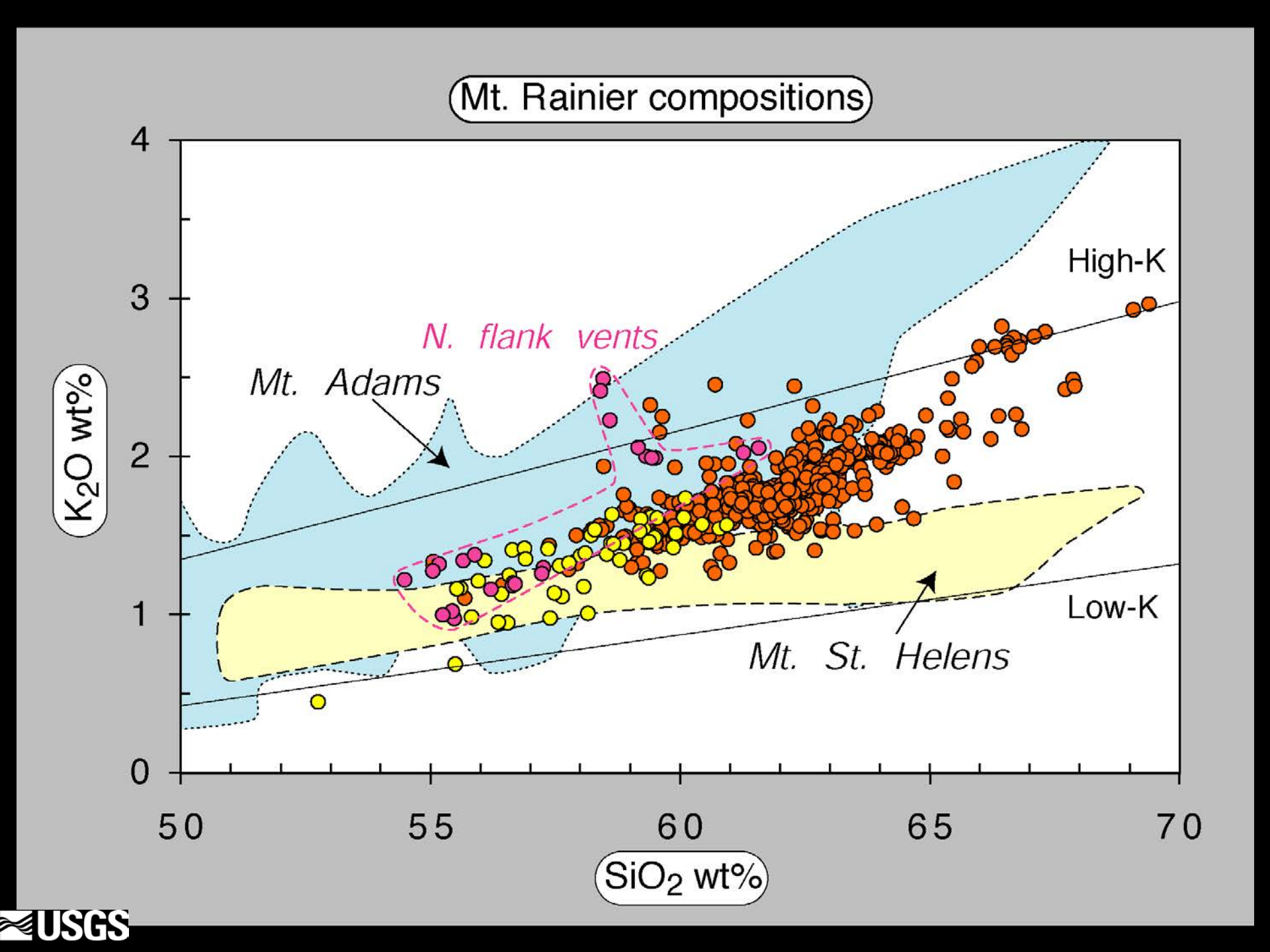

Primitive basalts
LKOT
low Sr/Pn
high Sr/Pn
NE Pacific
MORB and seamounts
Field of Lassen volcanic
center andesites and
dacites
Mantle array
Field of regional
andesites,
crustal inclusions,
and basement rocks
143Nd/144Nd
87Sr/86Sr
0.5132
0.5131
0.5130
0.5129
0.5128
0.5127
0.5126
0.7025
0.7030
0.7035
0.7040
0.7045
0.7050
0.7055
0.7060

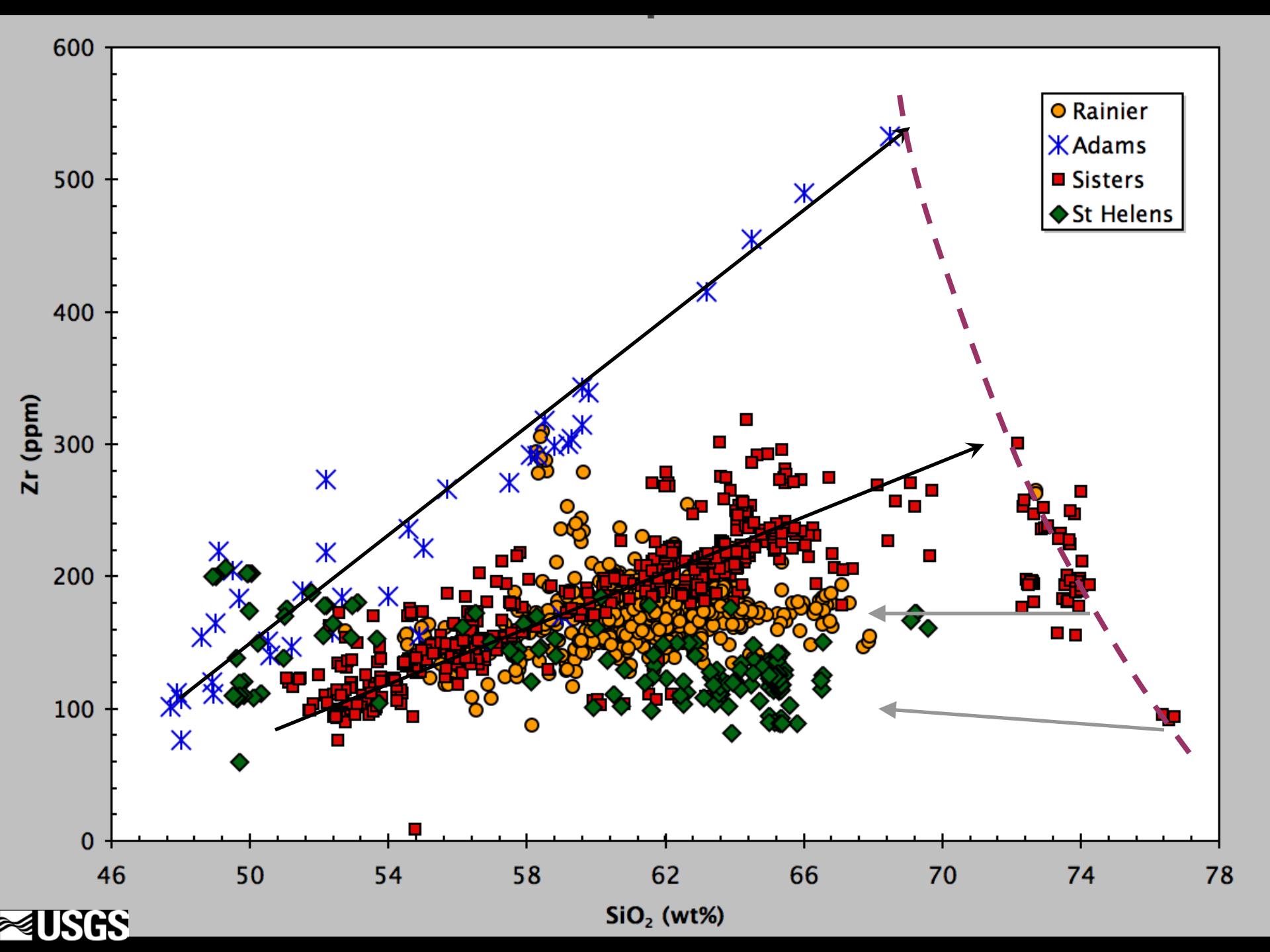
USGS

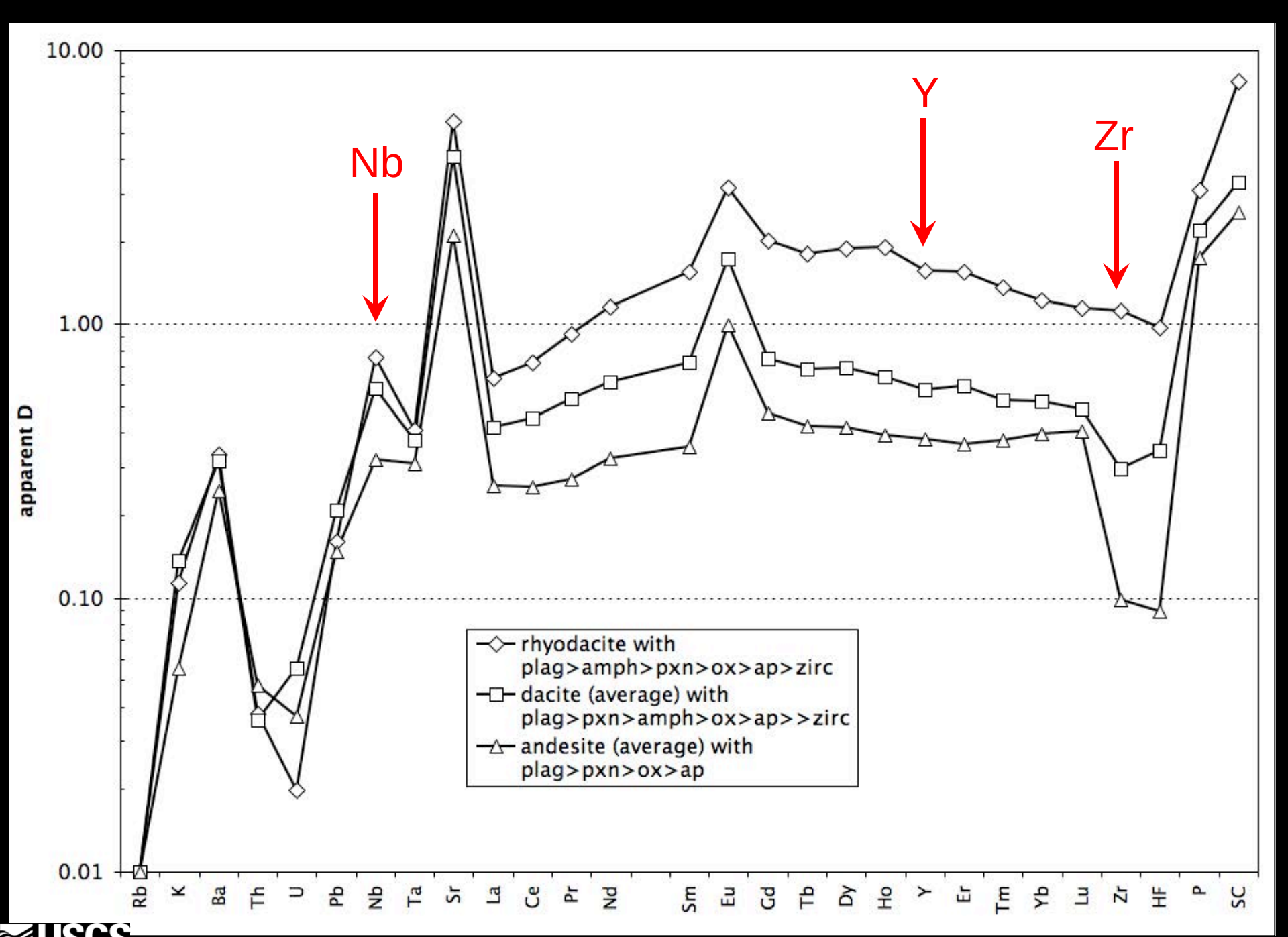

Blanco Fz
Crater Lk
Shasta
Lassen
Mendocino Fz
44°N
43°N 30´
43°N
42°N 30´
42°N
41°N 30´
41°N
40°N 30´
40°N
129°W
128°W 30´
128°W
127°W 30´
127°W
126°W 30´
126°W
125°W 30´
125°W
124°W 30´
124°W
123°W 30´
123°W
122°W 30´
122°W
121°W 30´
121°W
120°W 30´

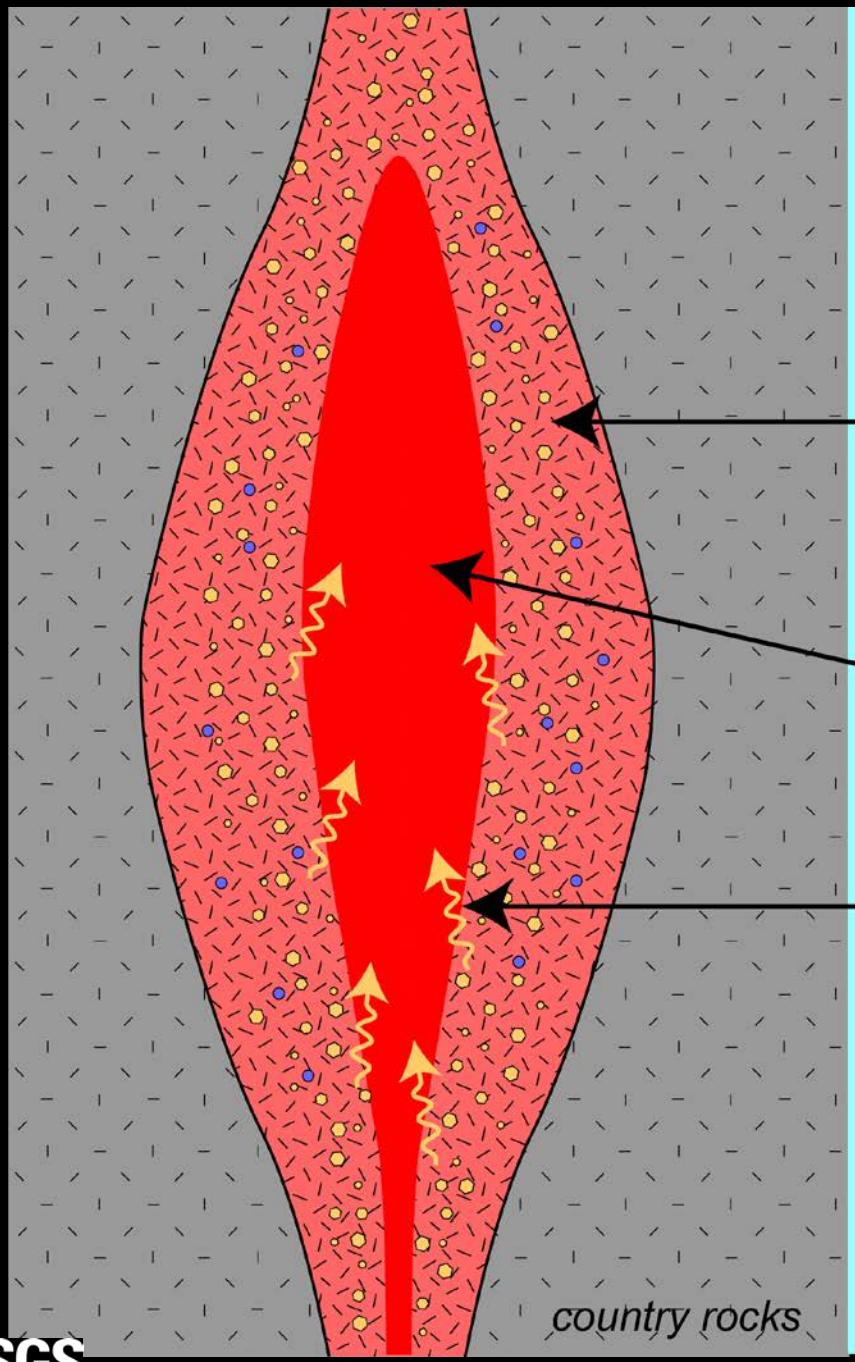
Crustal-level processes

basaltic andesite & andesite quenched magmatic inclusions (enclaves)


Mt. Rainier compositions
4
3
2
1
0
K_2O wt%
High-K
N. flank vents
Mt. Adams
Low-K
Mt. St. Helens
50
55
60
65
70
SiO_2 wt%
USGS


Rainier
Adams
Sisters
St Helens
Zr (ppm)
600
500
400
300
200
100
0
46
50
54
58
62
66
70
74
78
SiO2 (wt%)
USGS


10.00
1.00
0.10
0.01
apparent D
Nb
Y
Zr
rhyodacite with plag>amph>pxn>ox>ap>zirc
dacite (average) with plag>pxn>amph>ox>ap>>zirc
andesite (average) with plag>pxn>ox>ap
Rb
K
Ba
Th
U
Pb
Nb
Ta
Sr
La
Ce
Pr
Nd
Sm
Eu
Gd
Tb
Dy
Ho
Y
Er
Tm
Yb
Lu
Zr
HF
P
SC



Earlier largely solidified intrusions with evolved interstitial melt, and possibly, vapor

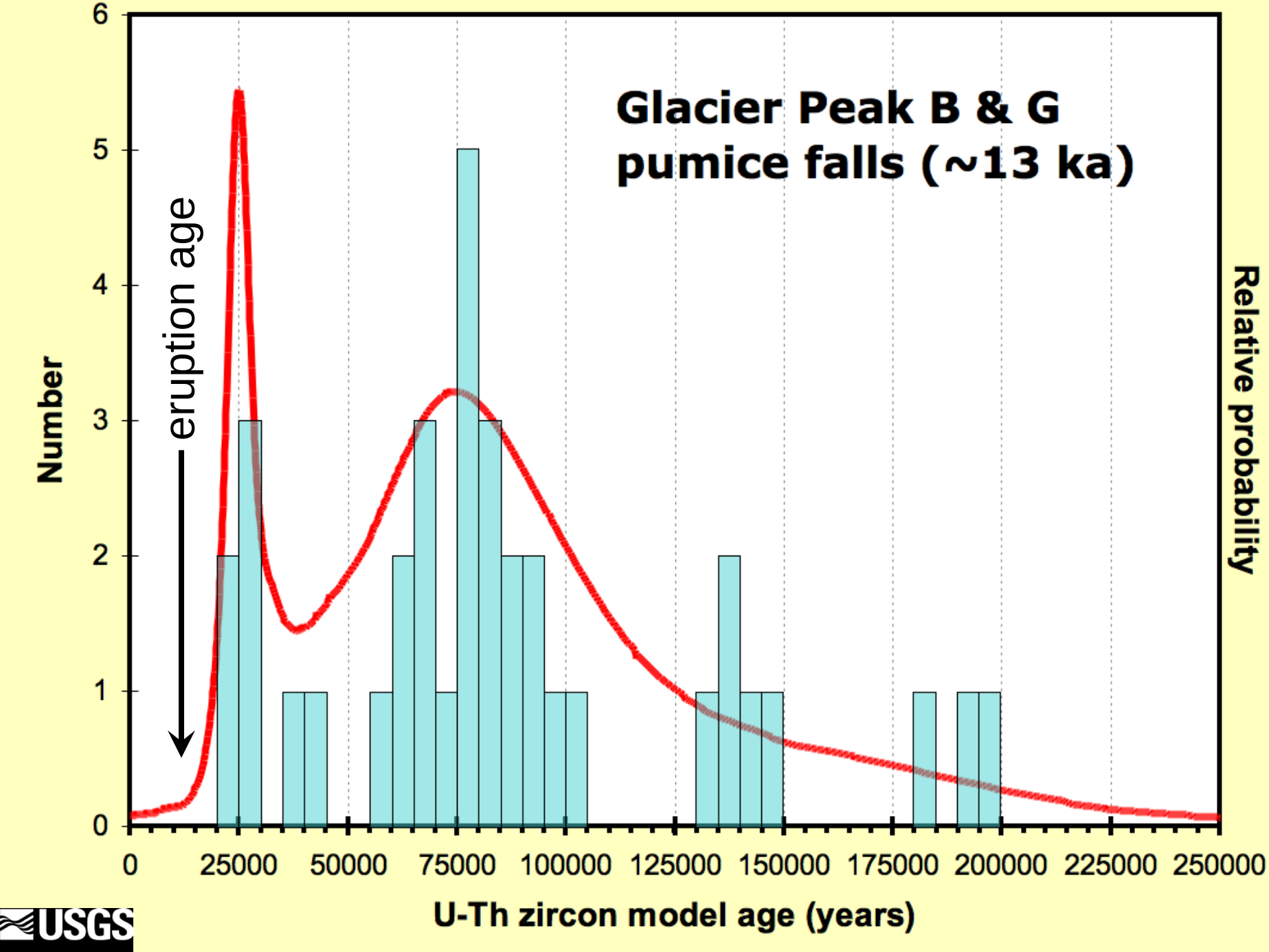
New ascending magma injection

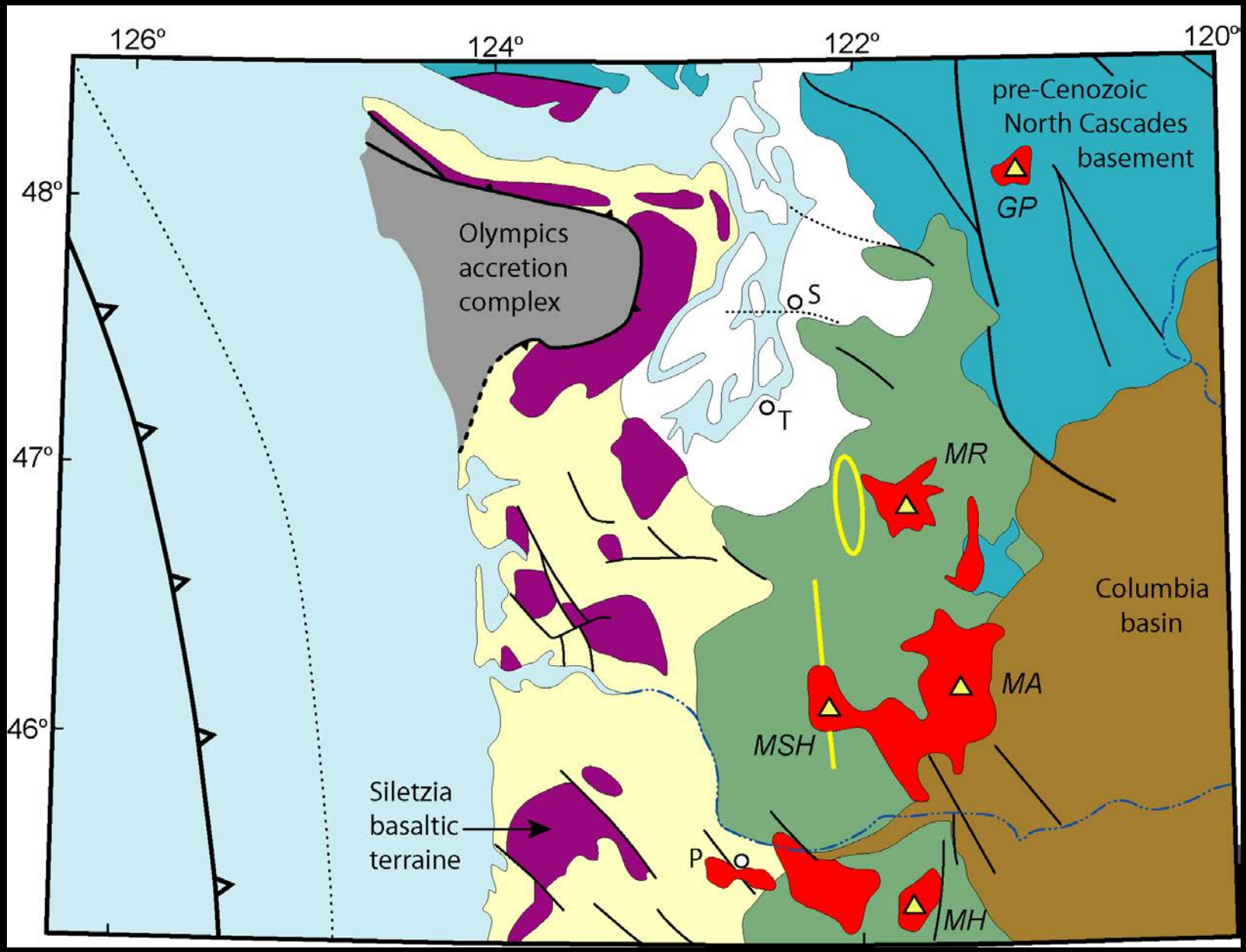
Evolved melts mix with new magma injection

after Langmuir, 1989

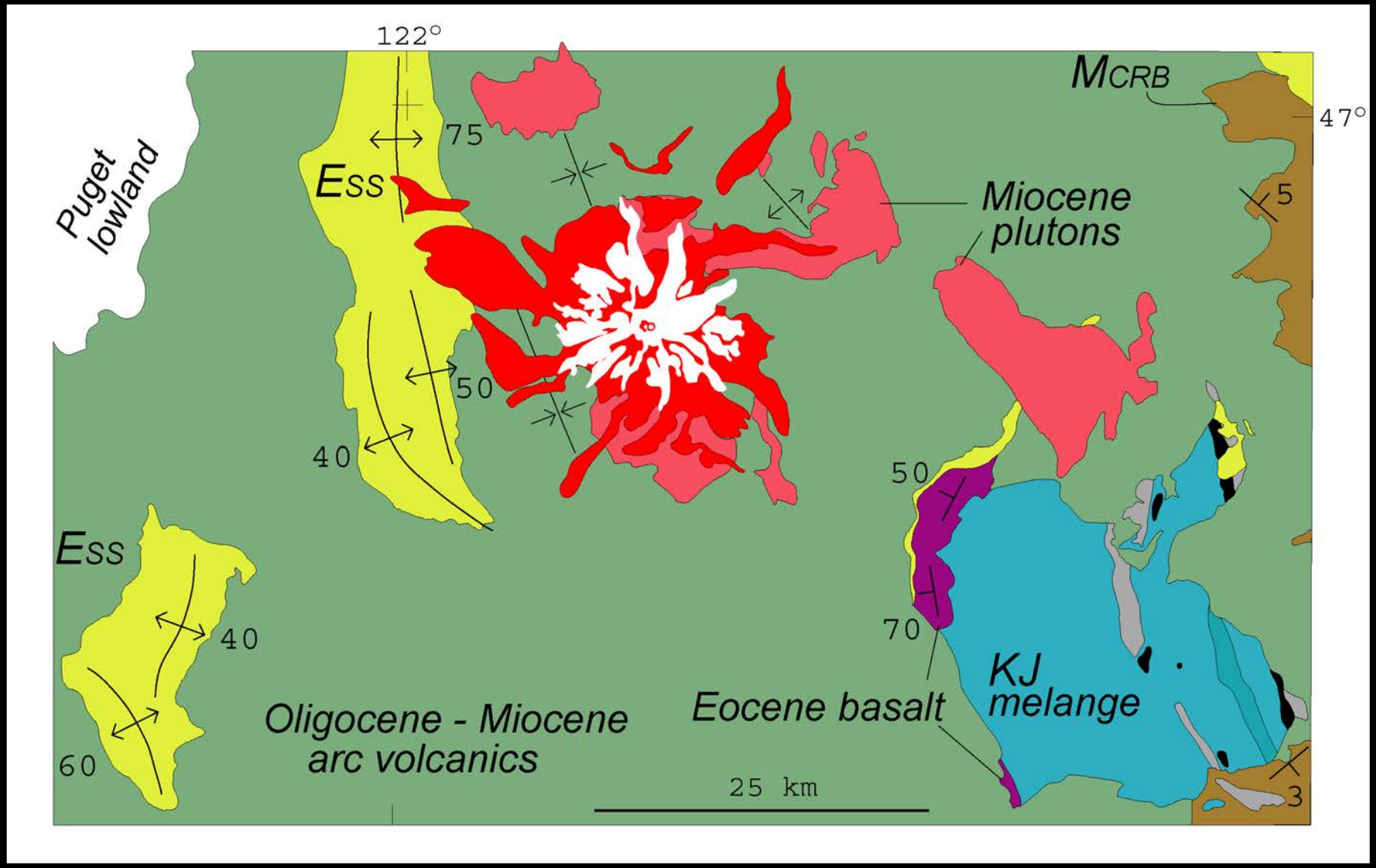
USGS


USGS

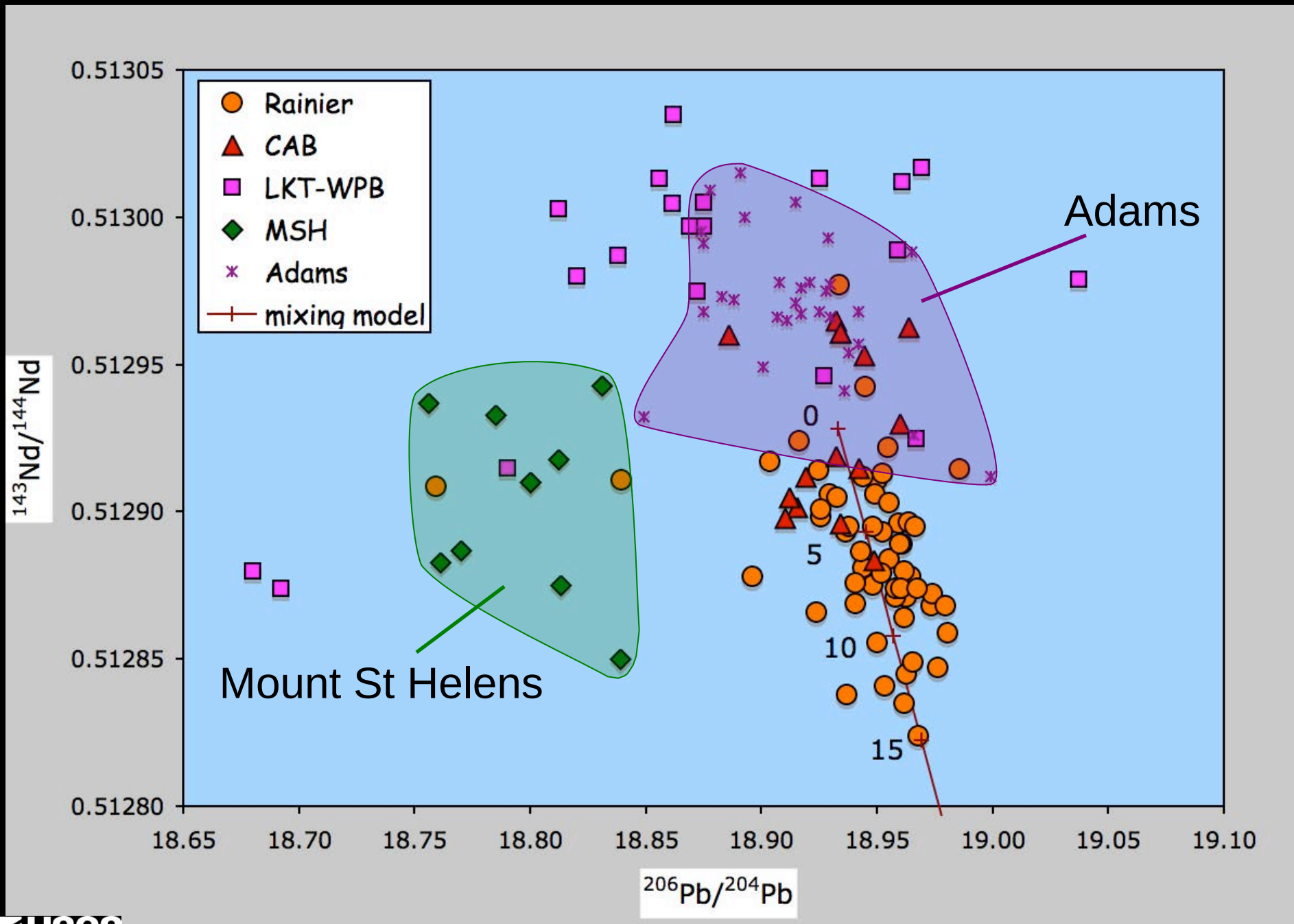

Glacier Peak B & G
pumice falls (~13 ka)
eruption age
Number
Relative probability
0
1
2
3
4
5
6
0
25000
50000
75000
100000
125000
150000
175000
200000
225000
250000
U-Th zircon model age (years)

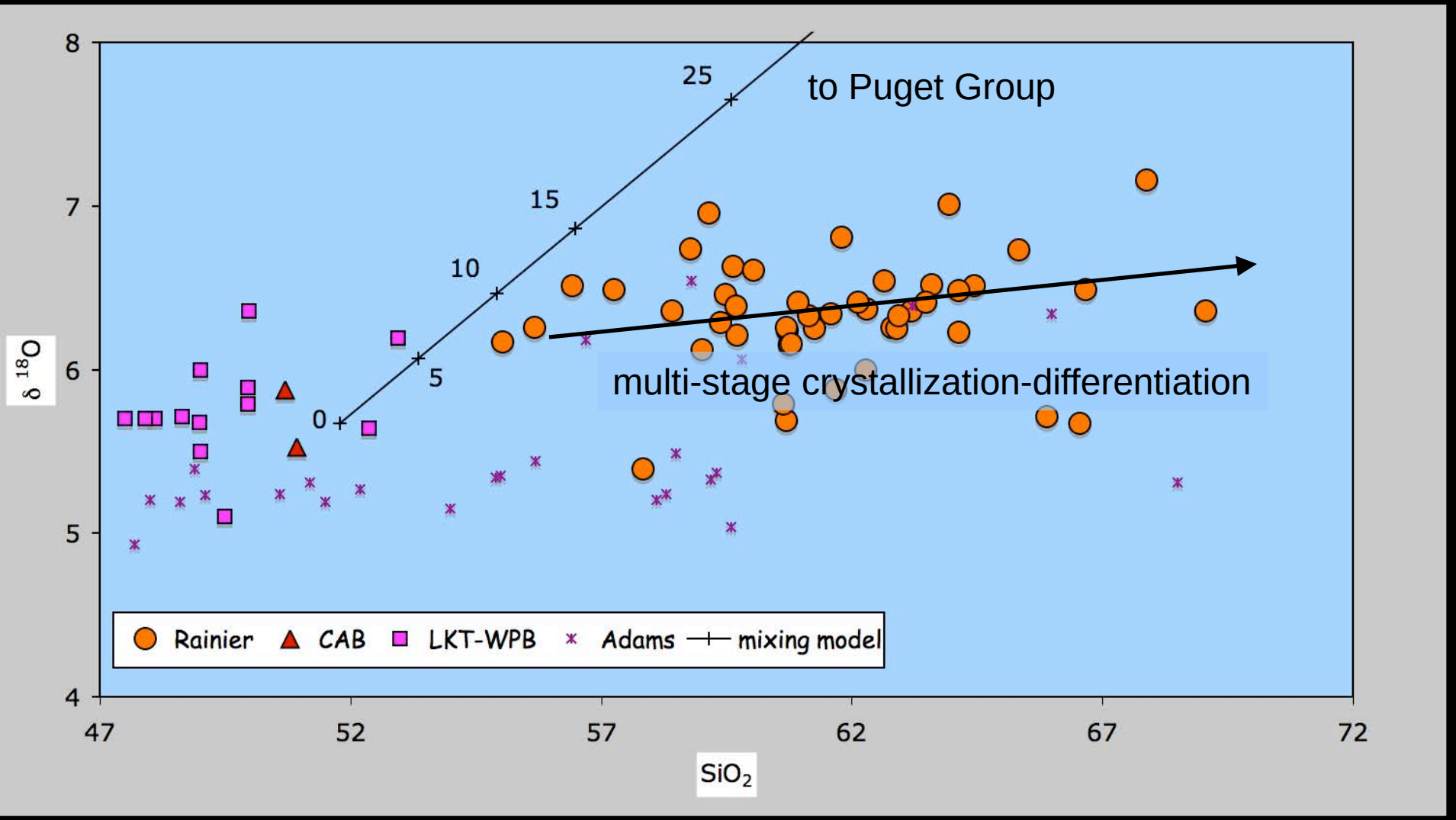

126°
124°
122°
120°
48°
47°
46°
pre-Cenozoic
North Cascades
basement
GP
Olympics
accretion
complex
S
T
MR
Columbia
basin
MA
MSH
Siletzia
basaltic
terraine
P
MH

USGS

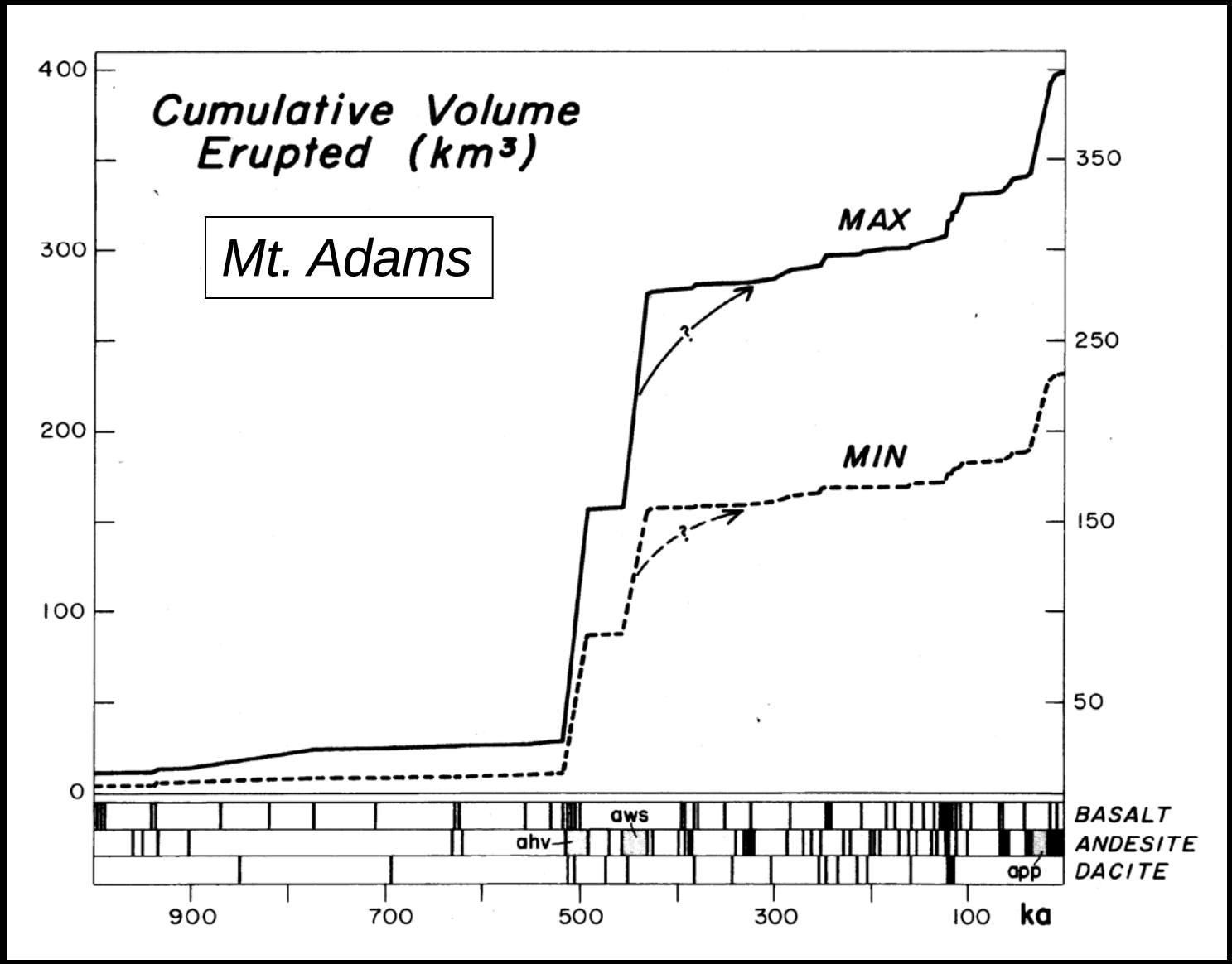

122°
47°
MCRB
Puget lowland
Ess
75
50
40
Miocene plutons
5
50
70
Ess
40
60
KJ melange
Eocene basalt
Oligocene - Miocene arc volcanics
25 km
3

USGS

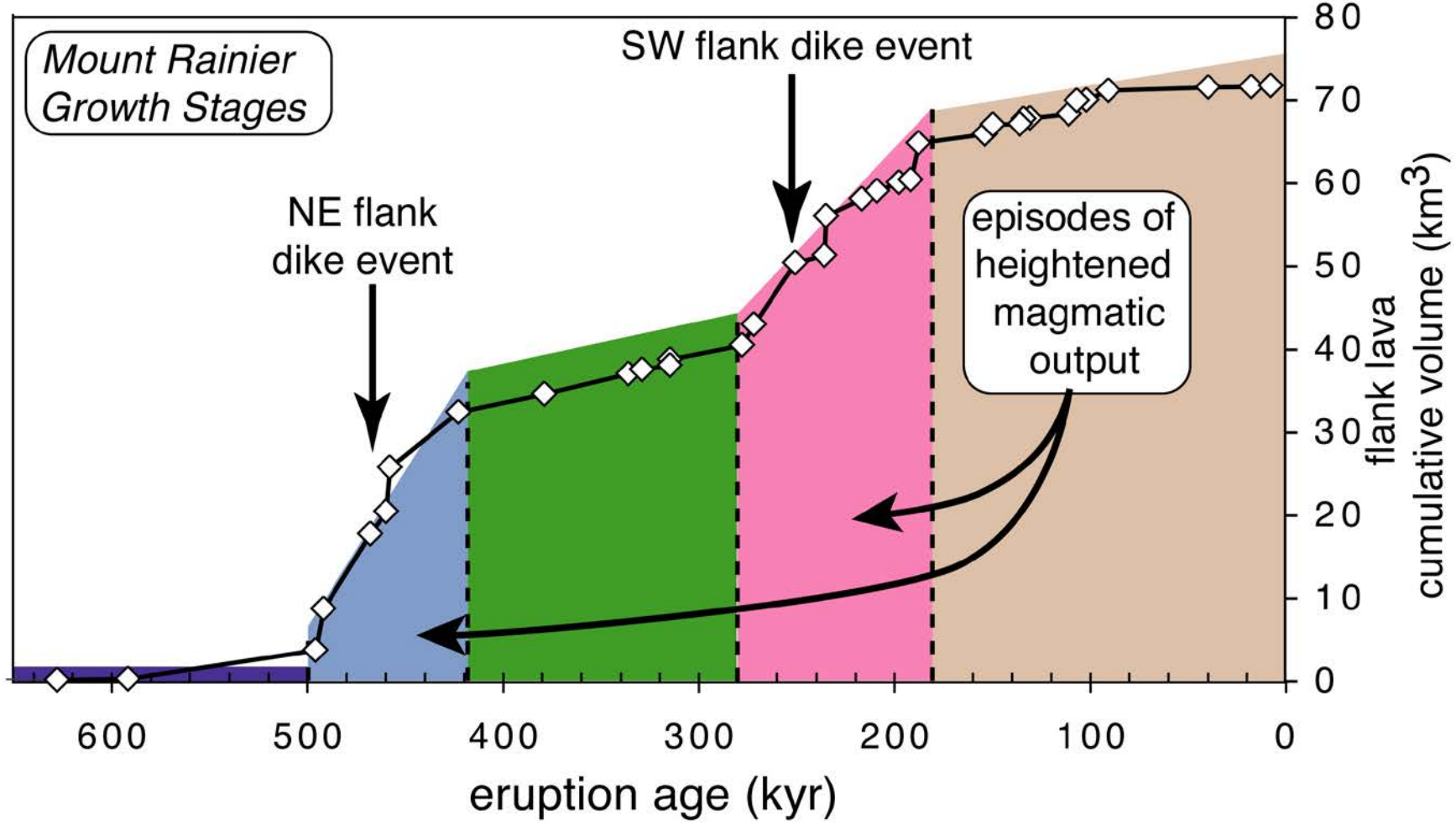

Rainier
CAB
LKT-WPB
MSH
Adams
mixing model
Adams
Mount St Helens
0
5
10
15
0.51305
0.51300
0.51295
0.51290
0.51285
0.51280
143Nd/144Nd
18.65
18.70
18.75
18.80
18.85
18.90
18.95
19.00
19.05
19.10
206Pb/204Pb


to Puget Group
multi-stage crystallization-differentiation
25
15
10
5
0
Rainier
CAB
LKT-WPB
Adams
mixing model
δ 18O
SiO2
8
7
6
5
4
47
52
57
62
67
72

USGS

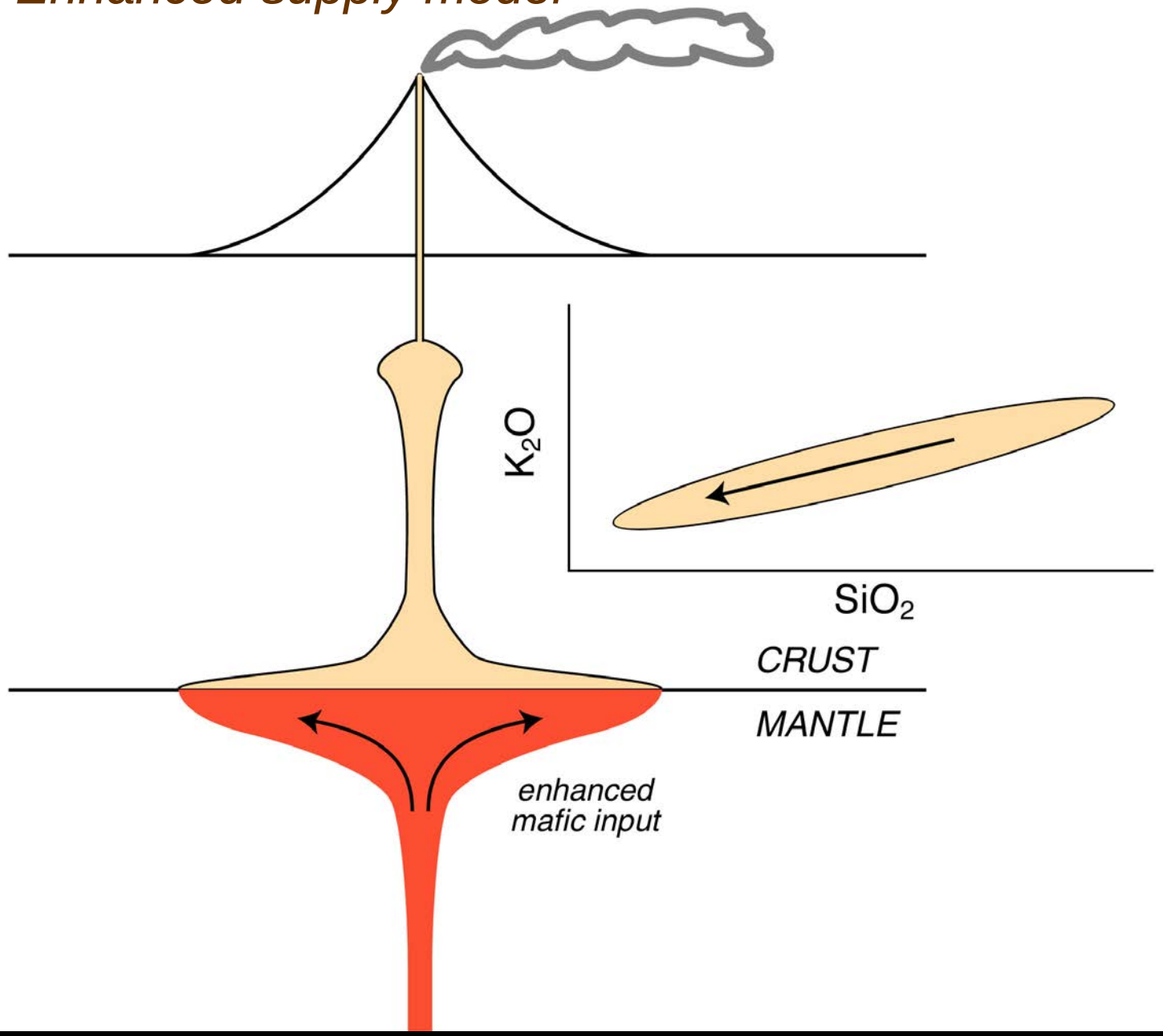

Cumulative Volume Erupted (km³)
Mt. Adams
MAX
MIN
400
300
200
100
0
350
250
150
50
aws
ahv
app
BASALT
ANDESITE
DACITE
900
700
500
300
100
ka

USGS

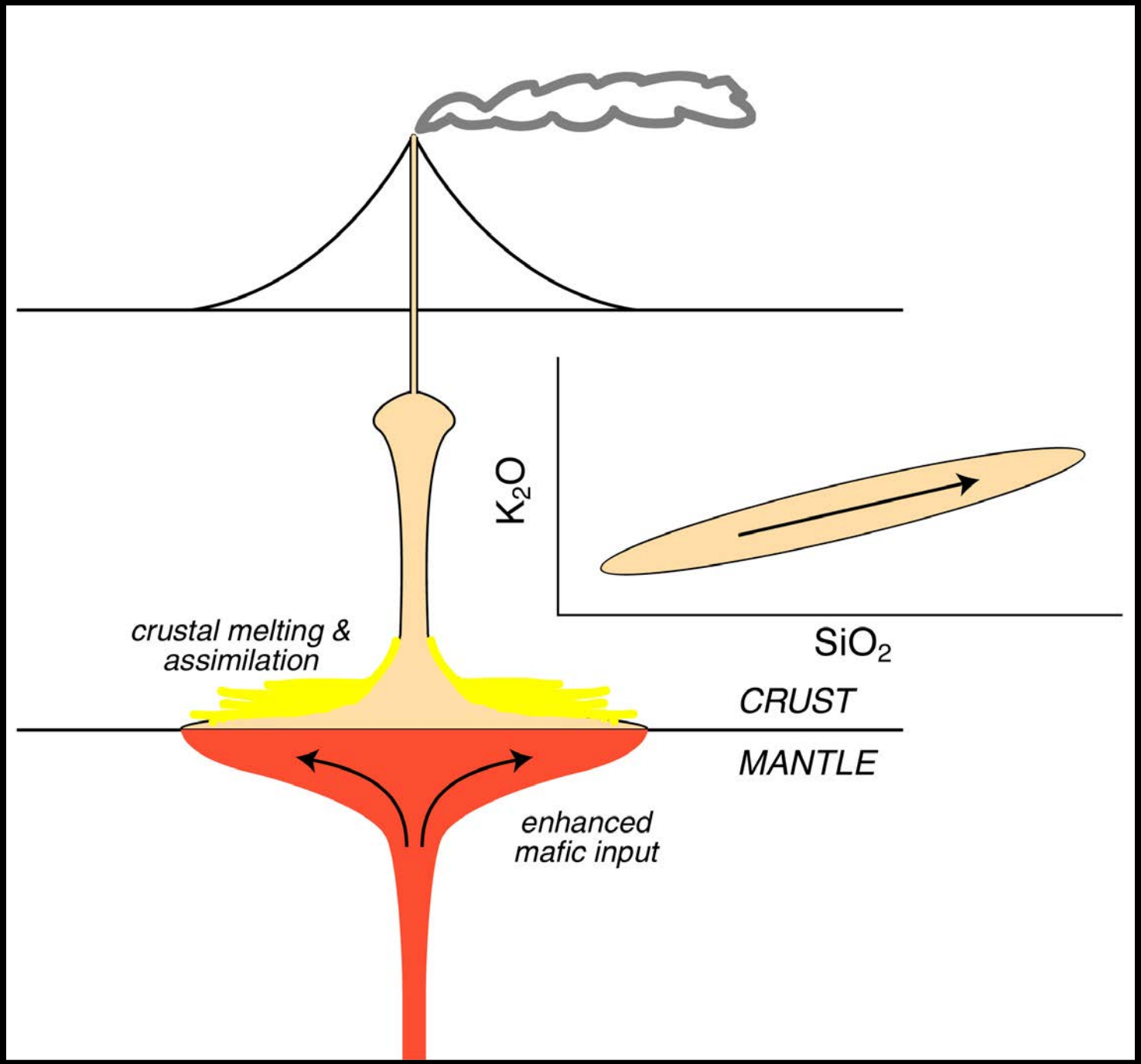

Mount Rainier
Growth Stages
SW flank dike event
NE flank
dike event
episodes of
heightened
magmatic
output
80
70
60
50
40
30
20
10
0
flank lava
cumulative volume (km3)
600
500
400
300
200
100
0
eruption age (kyr)

USGS

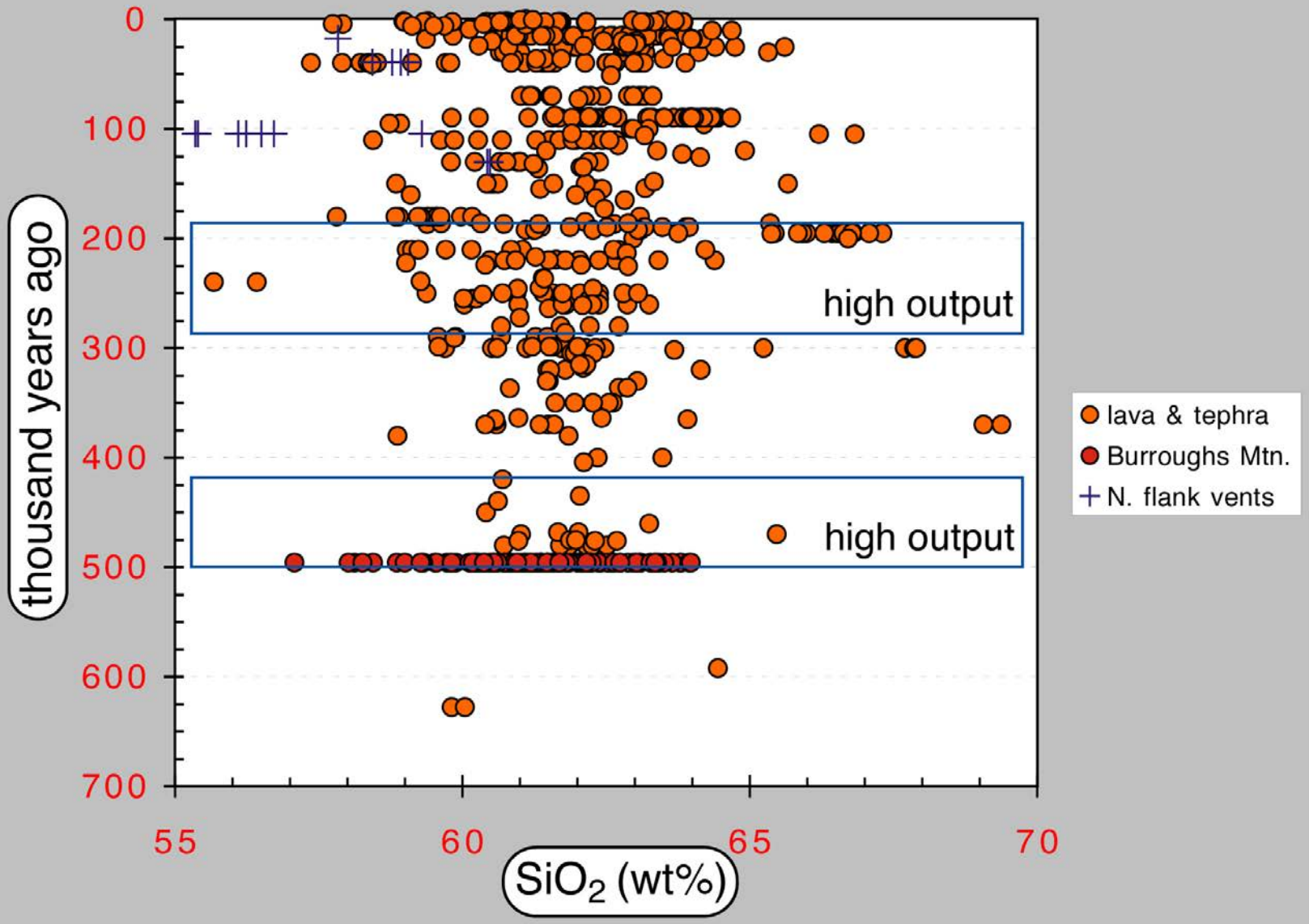
Enhanced supply model



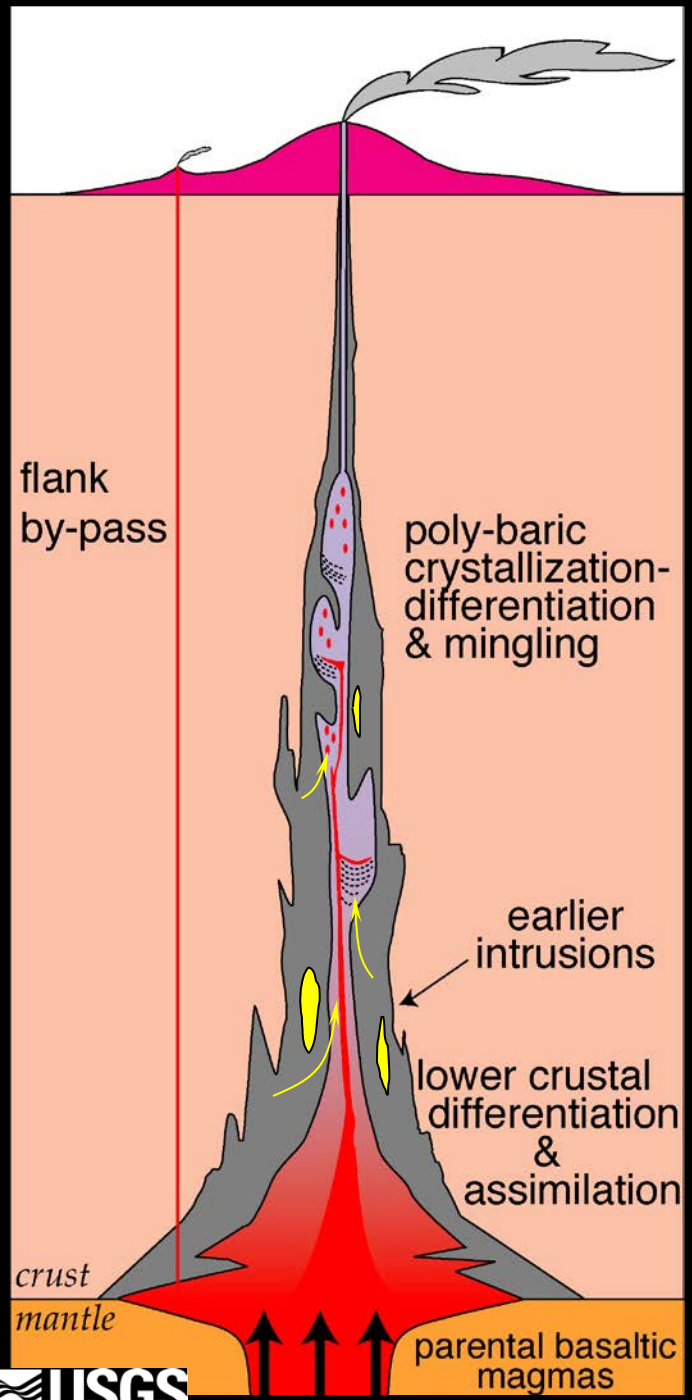
USGS


K_2O
SiO_2
crustal melting &
assimilation
CRUST
MANTLE
enhanced
mafic input

USGS

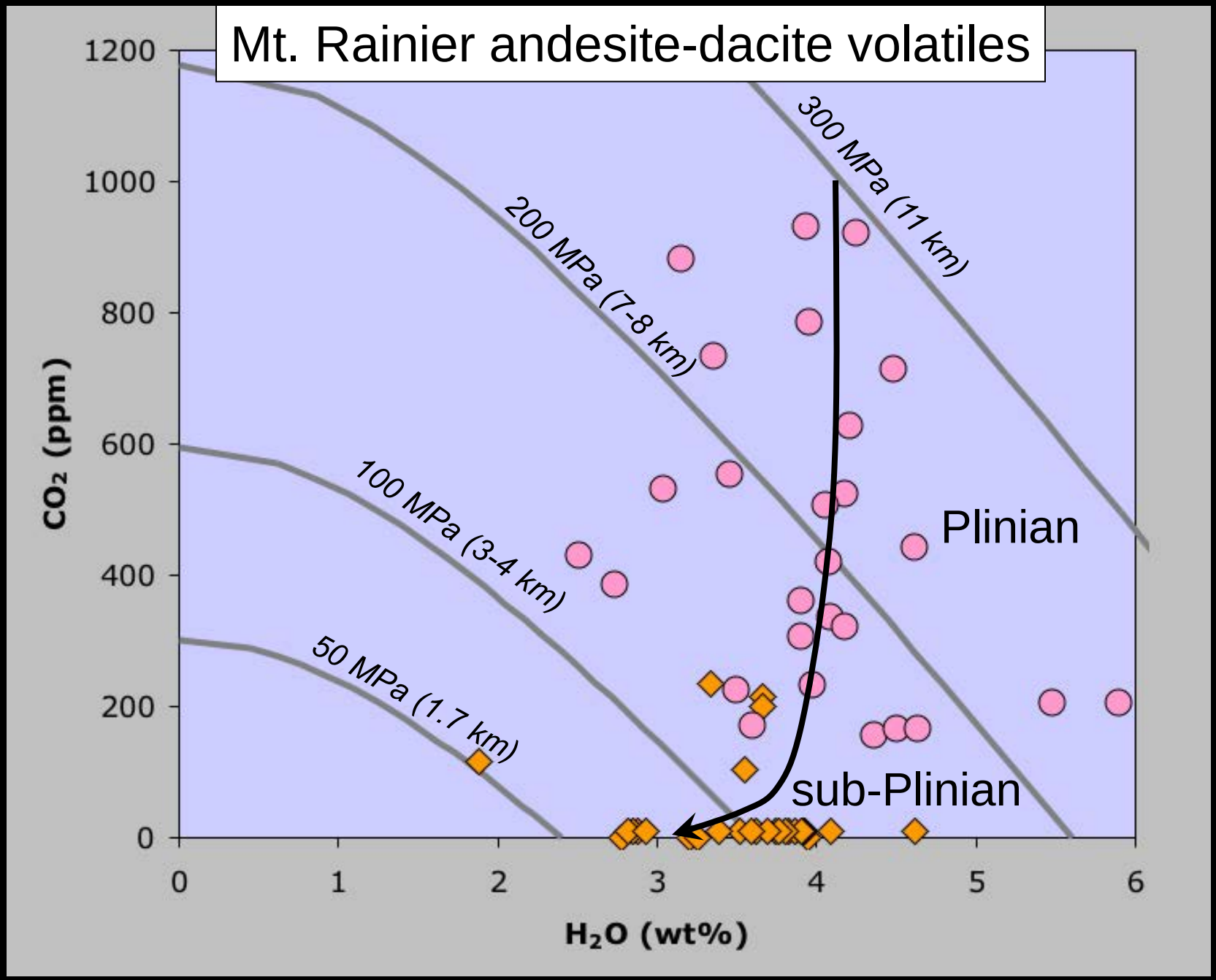

0
100
200
300
400
500
600
700
thousand years ago
high output
high output
lava & tephra
Burroughs Mtn.
N. flank vents
55
60
65
70
SiO2 (wt%)

USGS



Outstanding problems

- Why do the volcanoes differ in differentiation style?
- Why do they grow in pulses?
- Why do they reuse the same places?
- Where do most of the magmas reside and why?
- Why do batches of long-lived silicic magma sometimes segregate and ascend?
- How do tectonics influence magma ascent?
- Why are some of the volcanoes so much bigger than others?
- What balance between differentiation and true assimilation?
- Is the slab melting? Everywhere?
- As a hot-slab endmember, why are most Cascades magmas so ordinary?


Mt. Rainier andesite-dacite volatiles
1200
1000
800
600
400
200
0
CO₂ (ppm)
0
1
2
3
4
5
6
H₂O (wt%)
300 MPa (11 km)
200 MPa (7-8 km)
100 MPa (3-4 km)
50 MPa (1.7 km)
Plinian
sub-Plinian