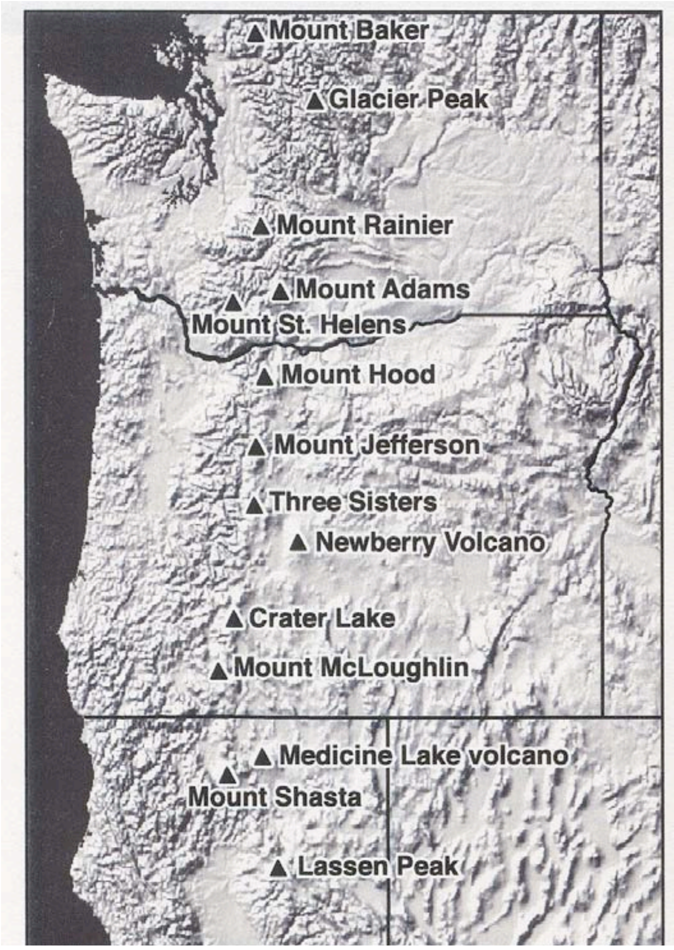


The Cascade volcanic arc:

Now we will discuss the petrologic evidence for the processes of:

Fractional crystallization
Assimilation
Magma Mixing
Recharge by primitive magma

FARM – this process is common

Caused by natural episodicity of recharge of magma chambers by "fresh" primitive mantle melts
and
the crystallization of these magmas in the shallow crust
and
inevitable melting of crust by the heat released by crystallization.

Guffanti and Weaver: Distribution of Cascade Volcanic Vents

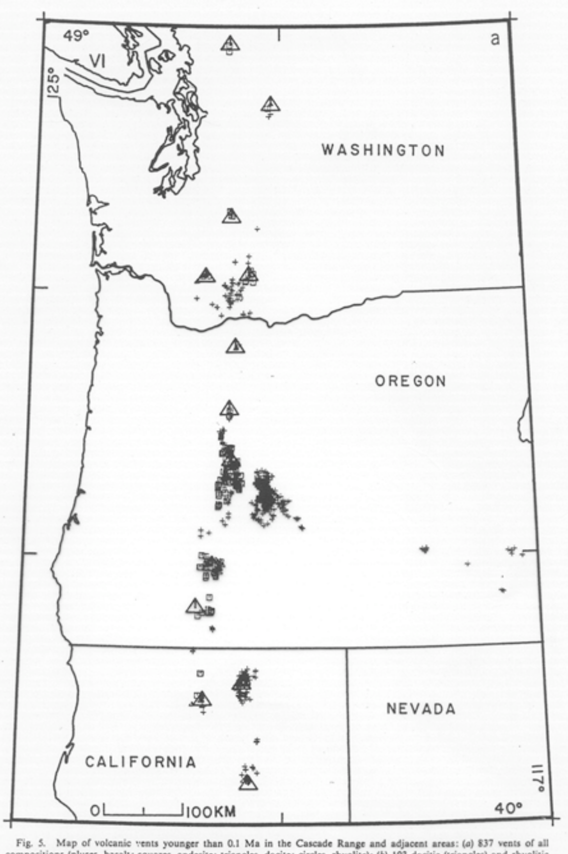
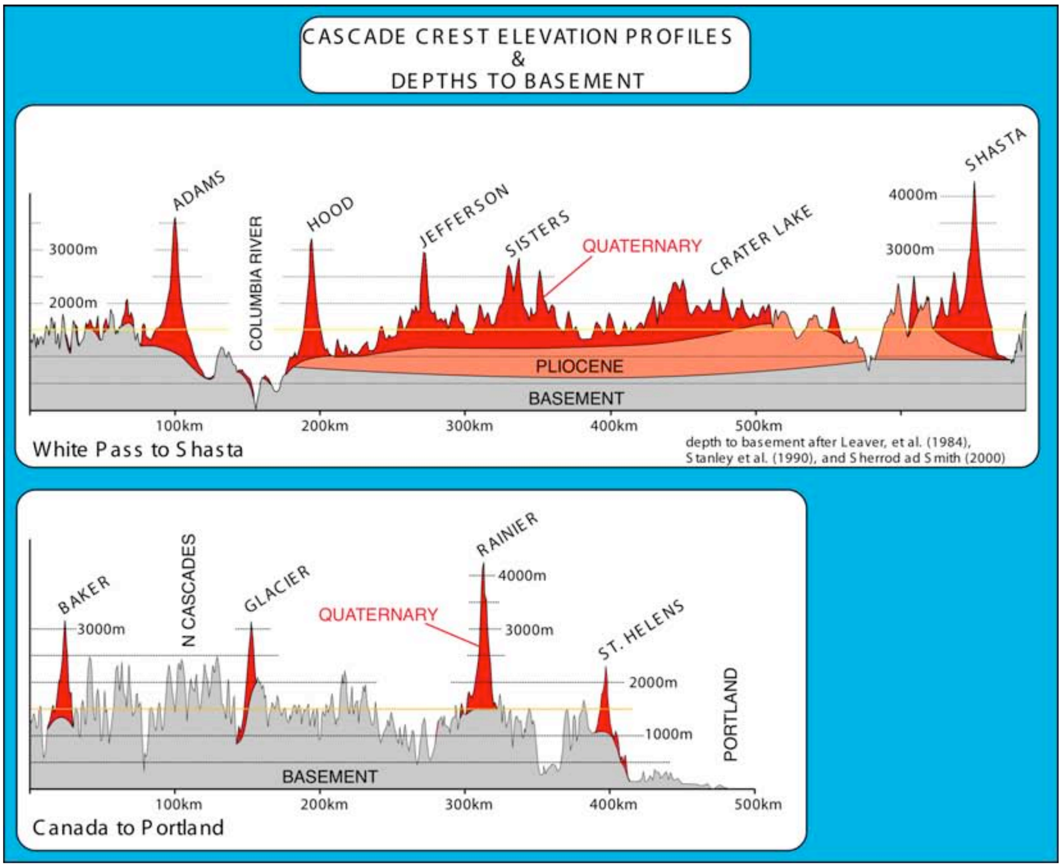


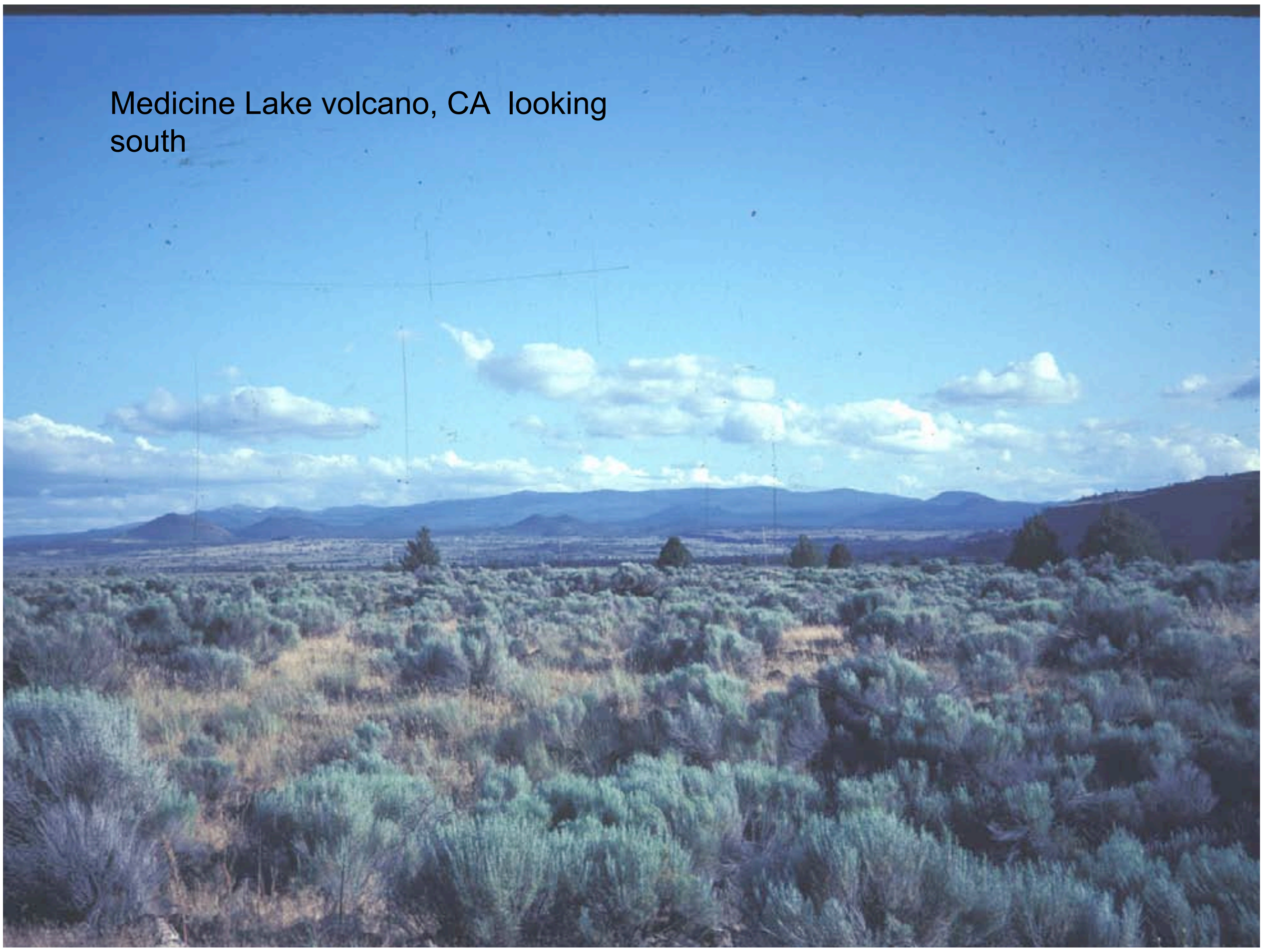
Fig. 5. Map of volcanic vents younger than 0.1 Ma in the Cascade Range and adjacent areas: (*a*) 837 vents of all compositions (pluses, basalt; squares, andesite; triangles, dacite; circles, rhyolite); (*b*) 103 dacitic (triangles) and rhyolitic (circles) vents. Large triangles in Figure 5*b* are major Quaternary volcanoes lacking rhyolitic or dacitic vents younger than 0.1 Ma.

Variation in magmatic intensity in the Cascades from north to south in the last 100,000 years.

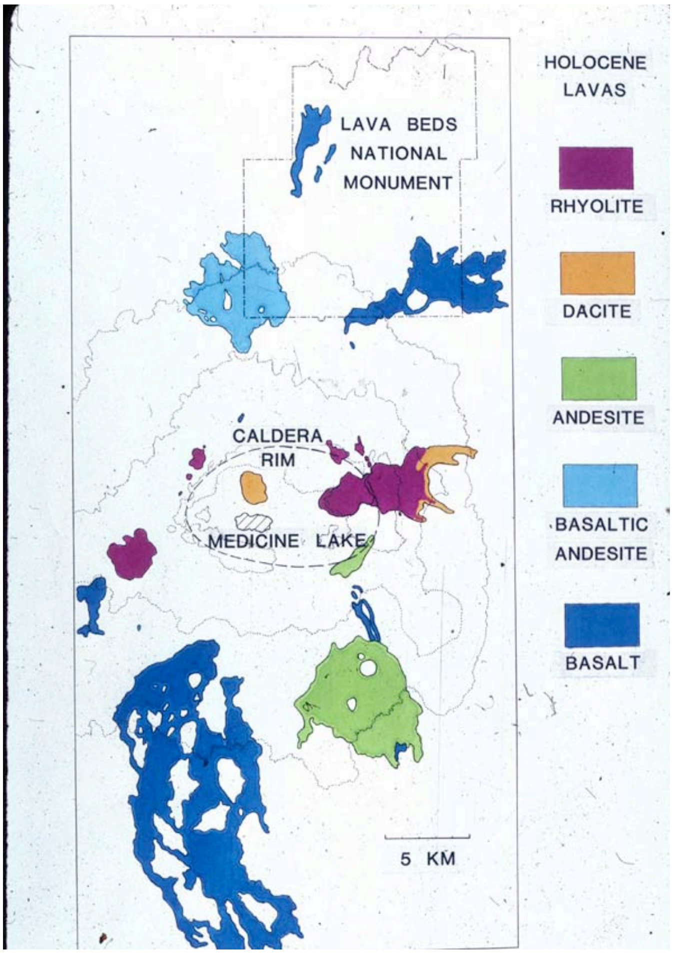
Note the paucity of volcanism in the north and the focus of voluminous activity in central Oregon (Newberry volcano) and in northern California (Medicine Lake and Mt. Shasta).

Guffanti et al. (1988)





Medicine Lake volcano, CA looking south



Volcanic activity on Medicine Lake since the end of the last glaciation at ~11,000 years before present.

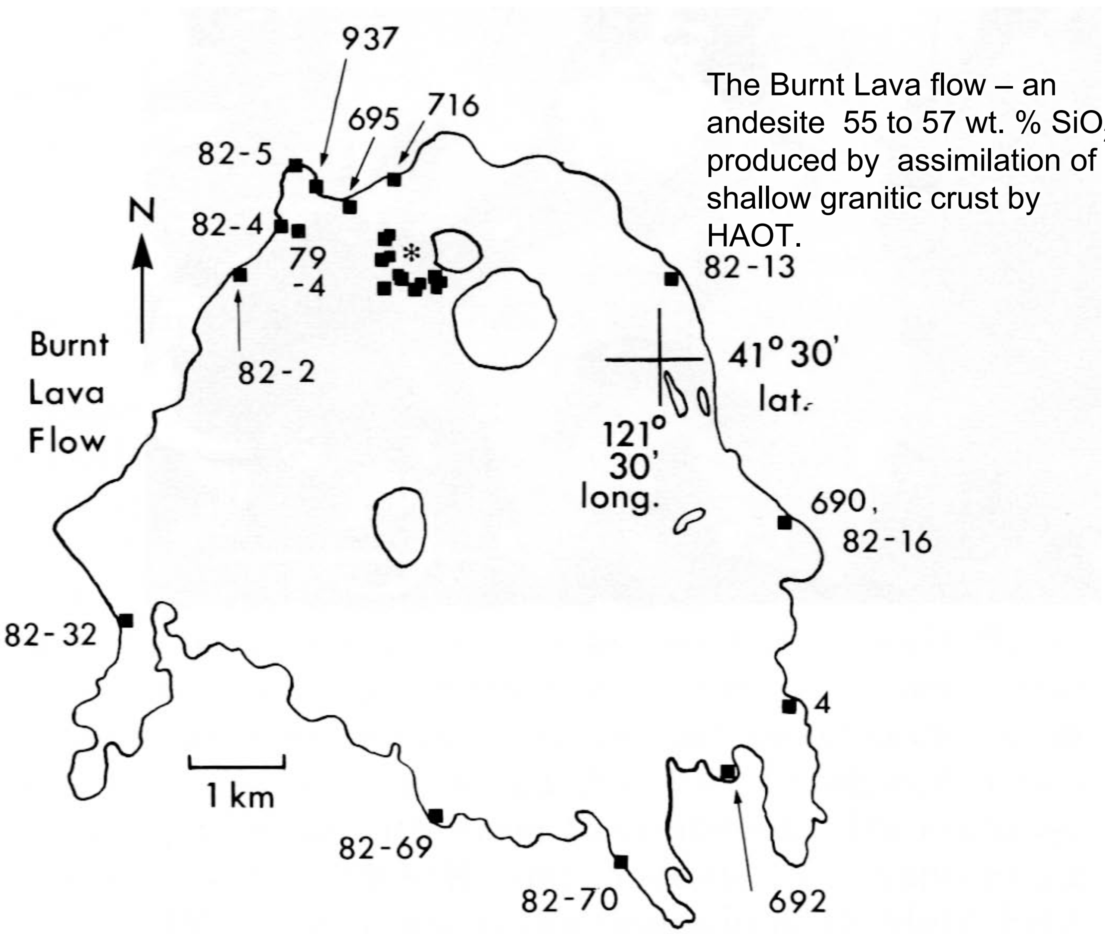
First we will discuss the interaction of DRY mantle – derived high alumina olivine tholeiites (HAOT) with shallow granitic crust at

Giant Crater lava field and Burnt Lava.

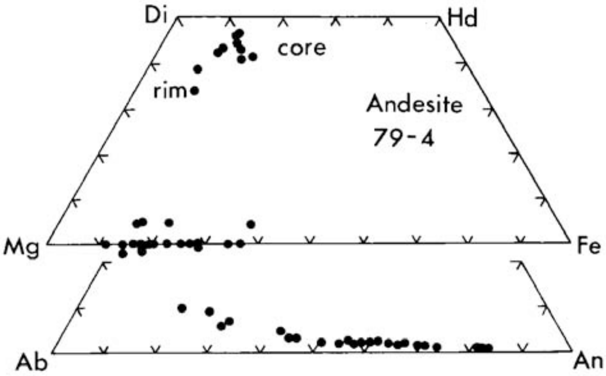
The FARM process here produces andesite.

The next discussion will involve the rhyolites and WET basaltic andesites at Med. Lake.

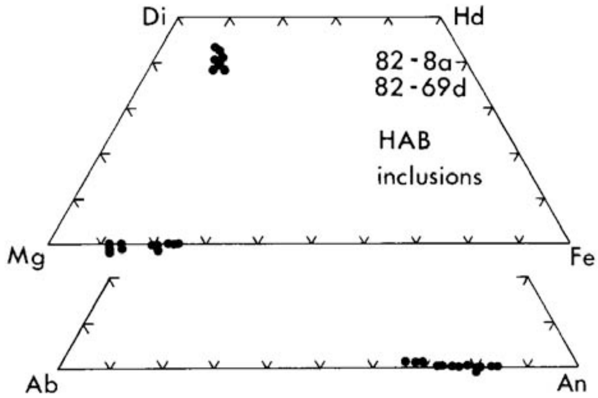
Here the FARM process produces rhyolite.



The Burnt Lava flow – an andesite 55 to 57 wt. % SiO_2 produced by assimilation of shallow granitic crust by HAOT.

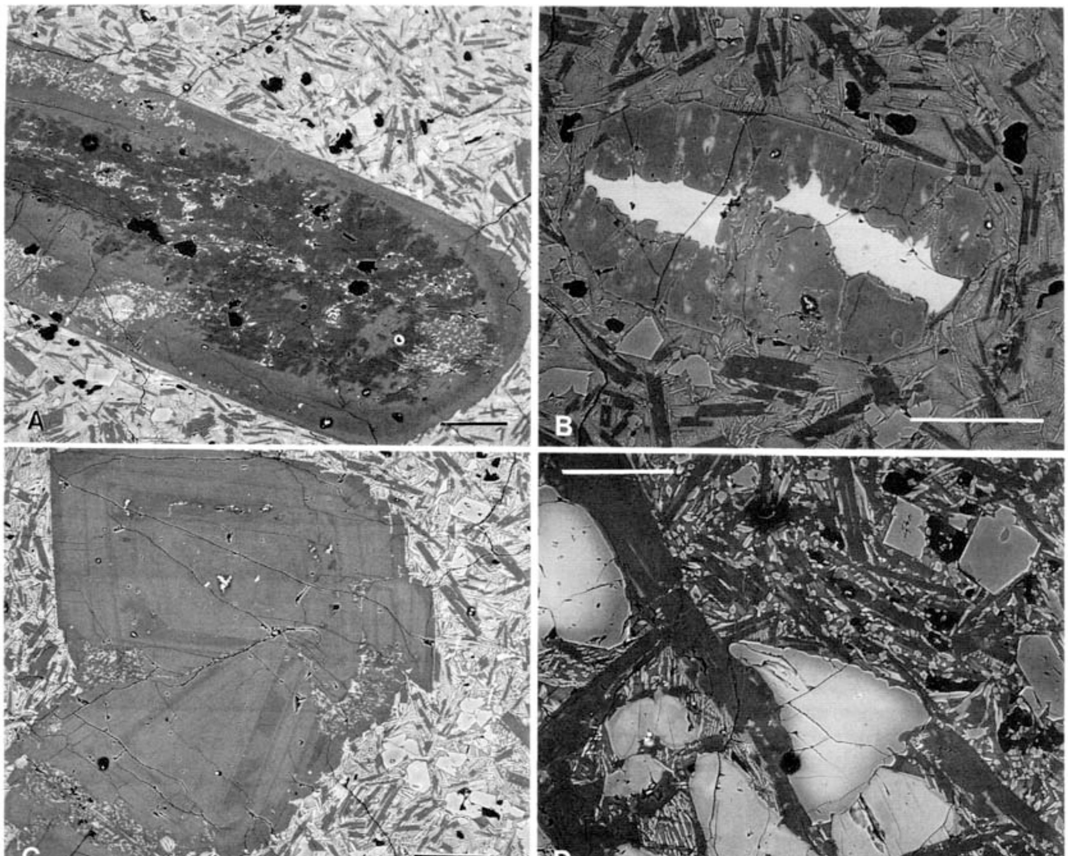


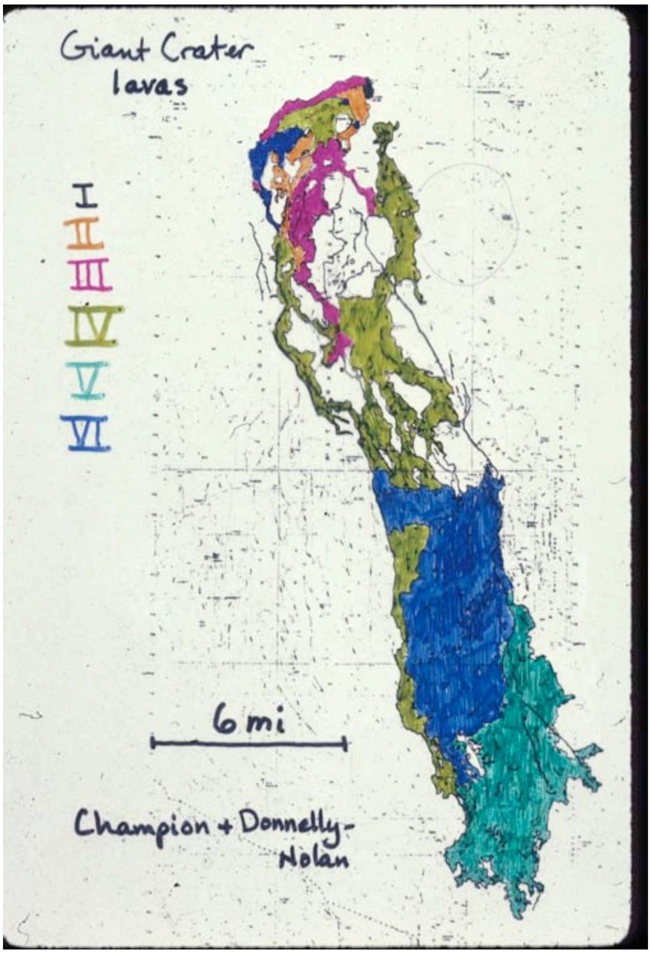
Mineral assemblages in the andesite of Burnt lava – notice the wide range in plagioclase composition, the large spread in olivine Fo content and the iron-rich cpx cores with Mg-rich rims.



Mineral compositions in quenched HAOT blobs.

Back-scattered images of disequilibrium mineral assemblages





The compositionally zoned Giant Crater lava field.

~ 6 km^3 of magma erupted from a set of vents in a 10 to 50 year time period ~10,200 years before present.

As the eruption proceeded more primitive lavas were carried further from the vents in a series of lava tube systems.

The latest and most primitive lavas – Groups 5 and 6 – are present at the end of the flow system.

The early and most "contaminated" lavas are closest to the vents (1, 2 and 3)

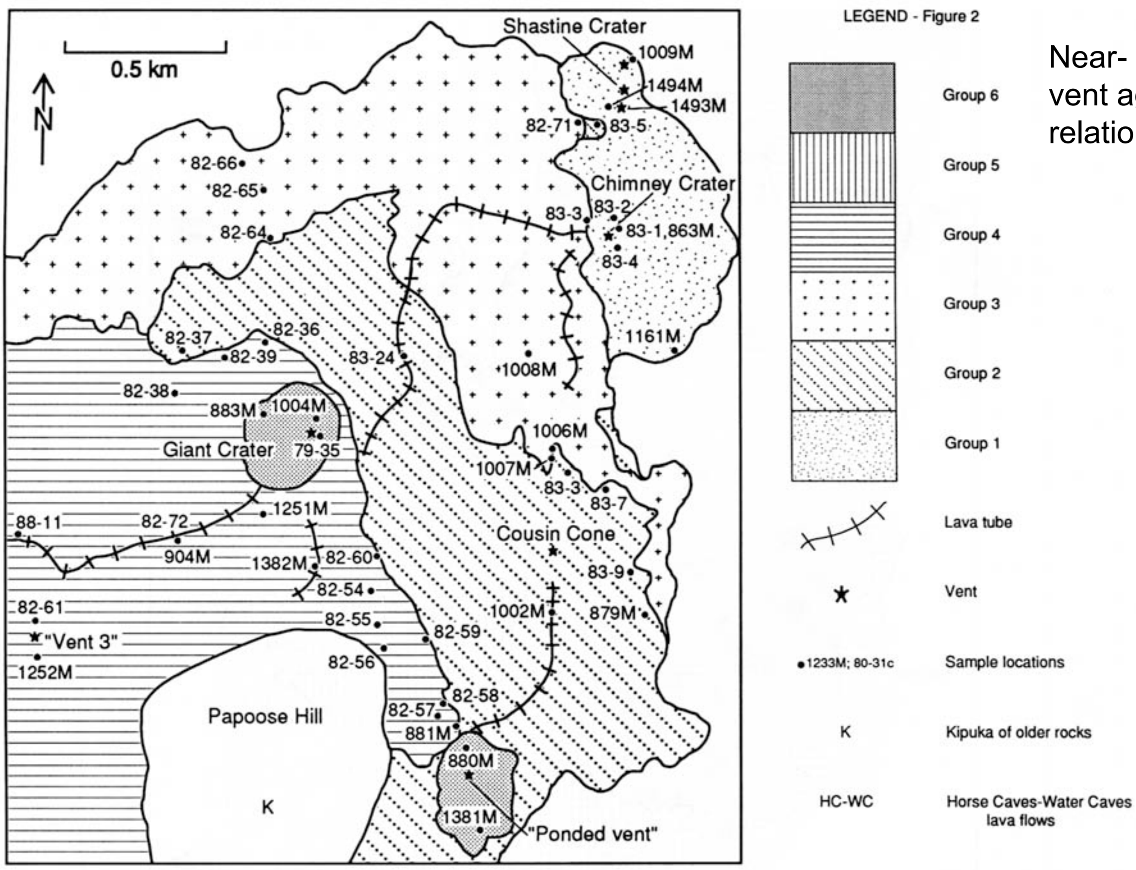


Fig. 2. (continued)

Near-vent age relations


Giant Crater, looking NW

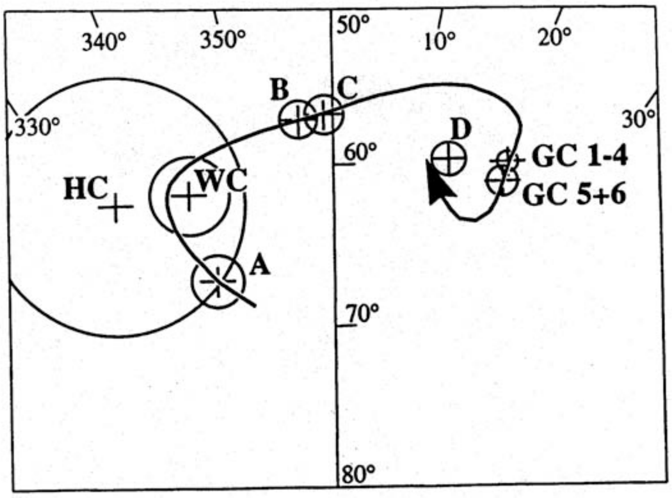
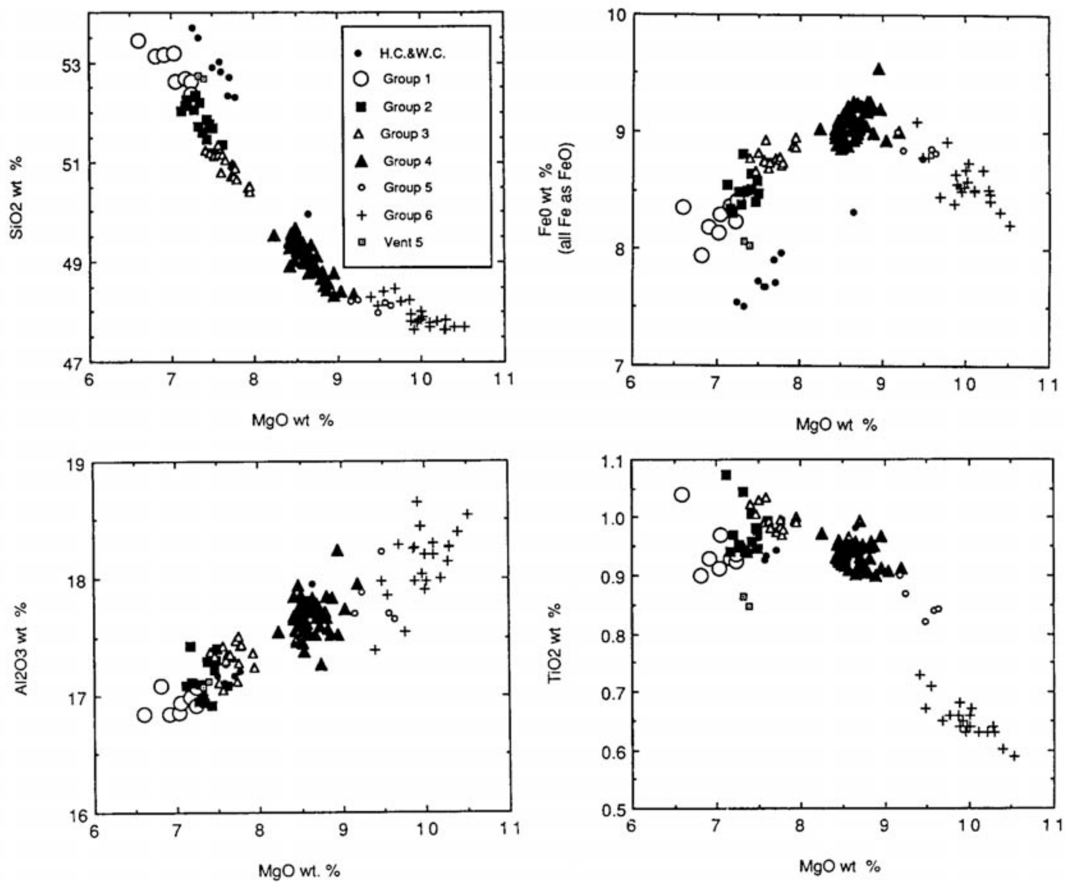


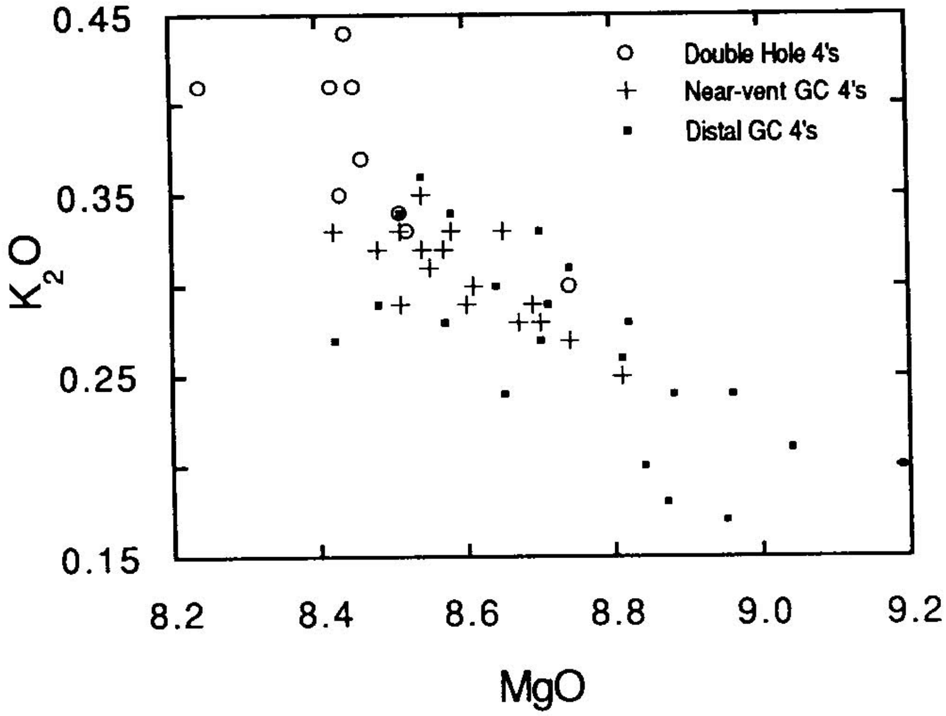
Figure 6. Enlarged part of equal-area diagram of paleomagnetic directions and circles of 95% confidence used to reconstruct the path of secular variation for the Pacific Northwest between about 11,000 and 10,000 years B.P. GC 1–4, GC 5+6, HC, and WC are directions presented in this paper for the Giant Crater, Horse Caves, and Water Caves lava flows. Directions A (Bottleneck Lake flows; minimum age of 11,000 ± 100 years B.P.), B (Heifer Reservoir flows; minimum age of 10,670 ± 150 years B.P.), C (Shoshone Ice Caves field; minimum age of 10,130 ± 350 years B.P.), and D (Pronghorn Reservoir flows; minimum age of 10,240 ± 120 years B.P.) are data from *Kuntz et al.* [1986a, b] and *Champion* [1980]. Solid arrow is forward path of secular variation through ~10,500 years B.P. episode of basaltic volcanism at the Medicine Lake Highlands [*Donnelly-Nolan*

Paleomagnetic evidence of the time duration of the emplacement of the Giant Crater lava field.

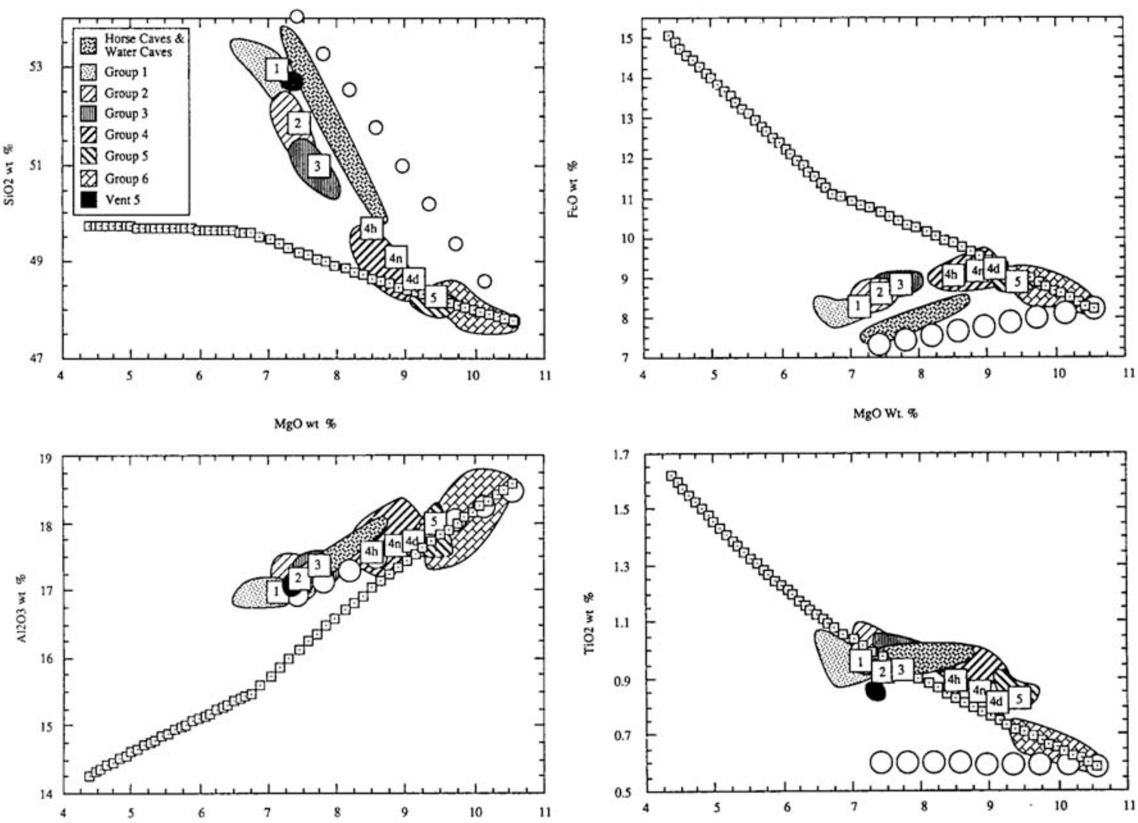
Note the small deviation in direction recorded by the Groups 1 to 6 .

B,C and D are other nearby flows that with ages well constrained by ^{14}C dating.



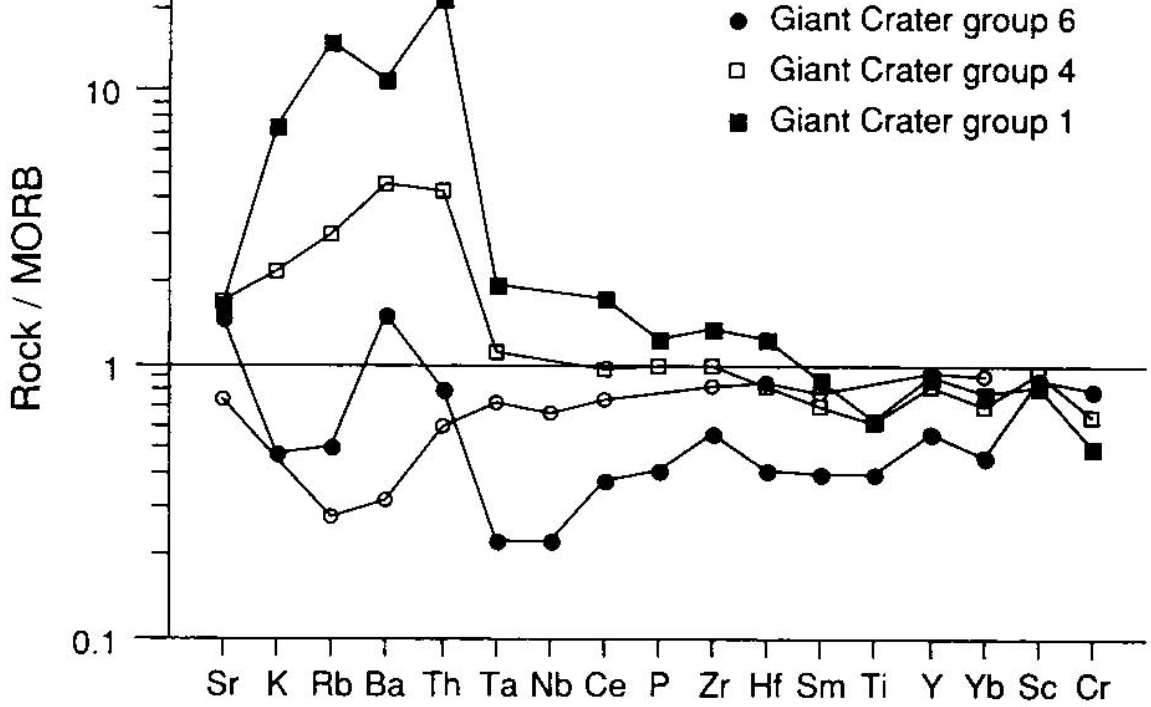


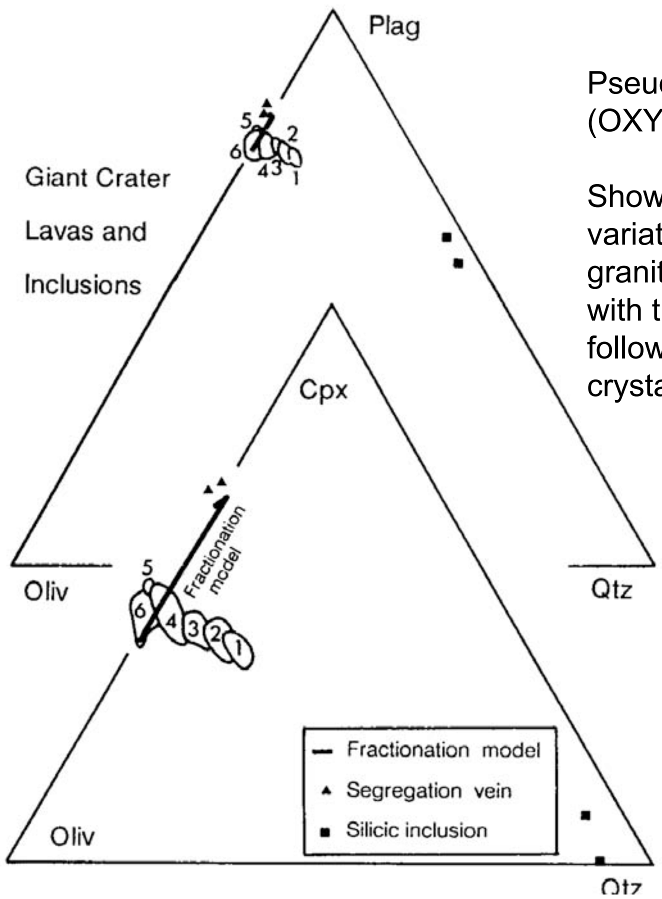
Even within single eruptive units the magma shows evidence for compositional zoning produced by magma chamber processes.



Models of fractional crystallization (squares) and continuous AFC with R =1.5 (circles).

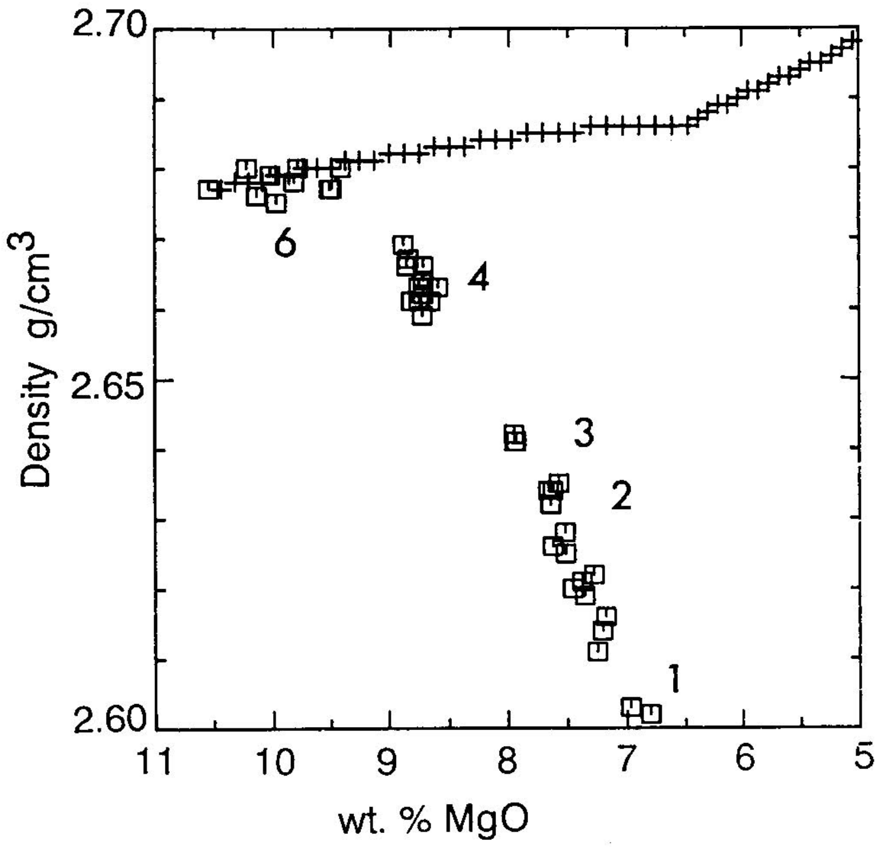
Group 1 lavas were highly contaminated by crustal melts





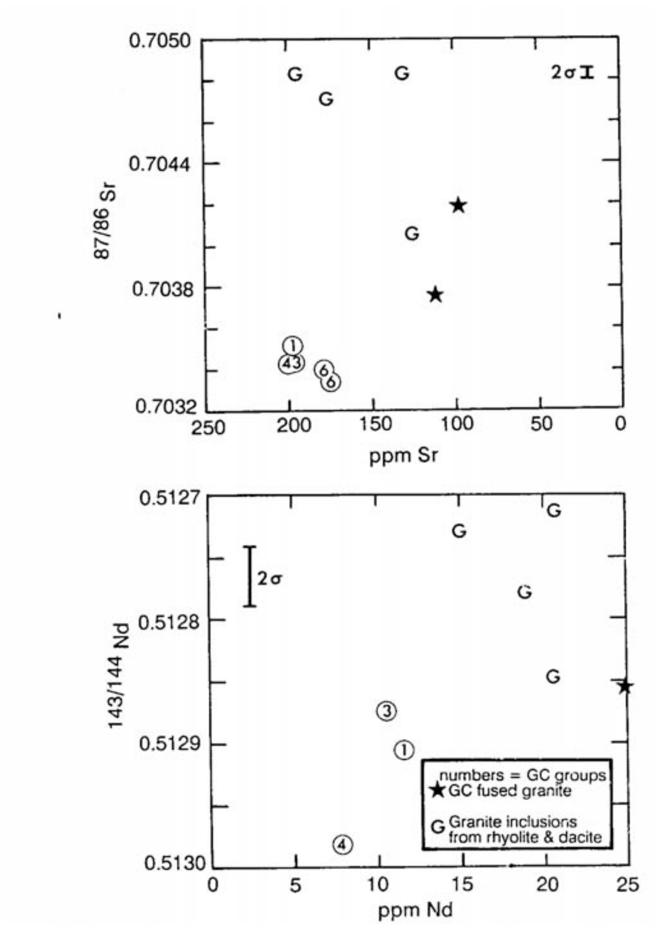
Pseudoternary projections (OXYGEN UNITS)

Showing the compositional variations in the lava and granitic inclusions compared with the expected path followed by fractional crystallization.

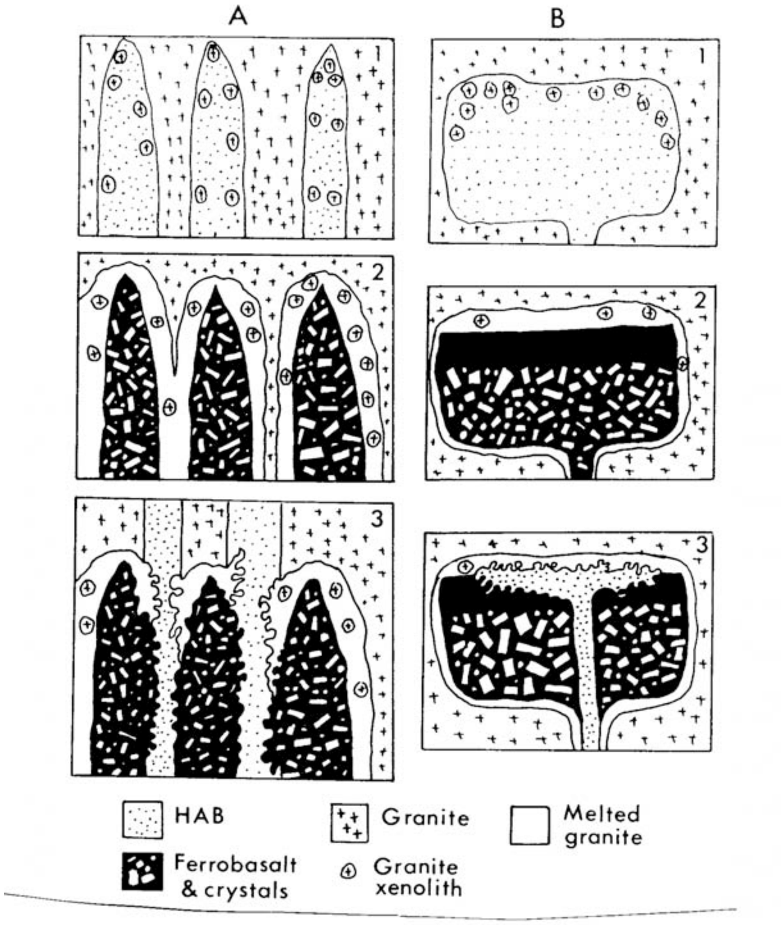


Calculated densities of the Giant Crater lava compared with the melt density path followed by fractional crystallization (FC) of a Group 6 parent magma.

Clearly FC would produce and iron-rich dense melt that would pond in the base of the magma chamber.

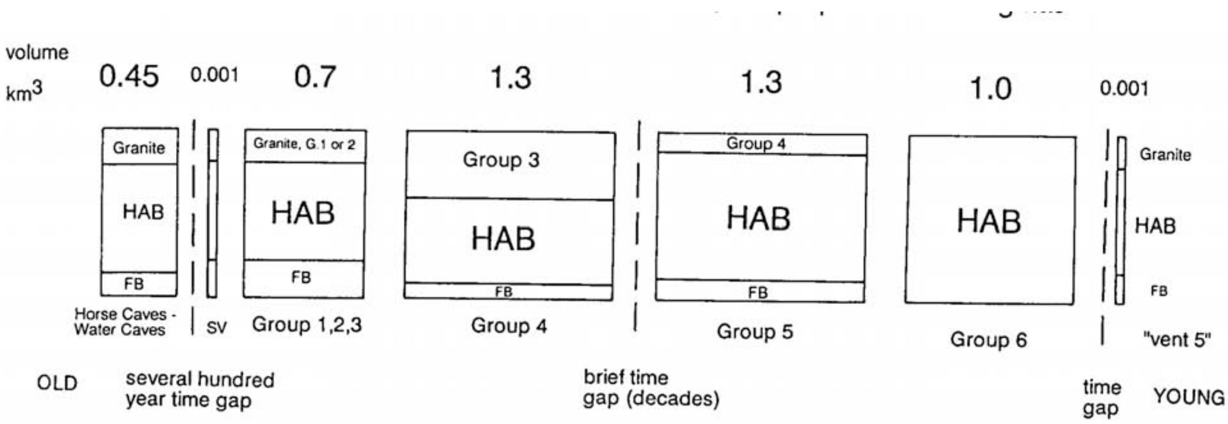


Isotopic variations are consistent with contamination of mantle derived HAOT with granitic country rock that is found as inclusions in the Giant Crater lavas and in other nearby lavas.

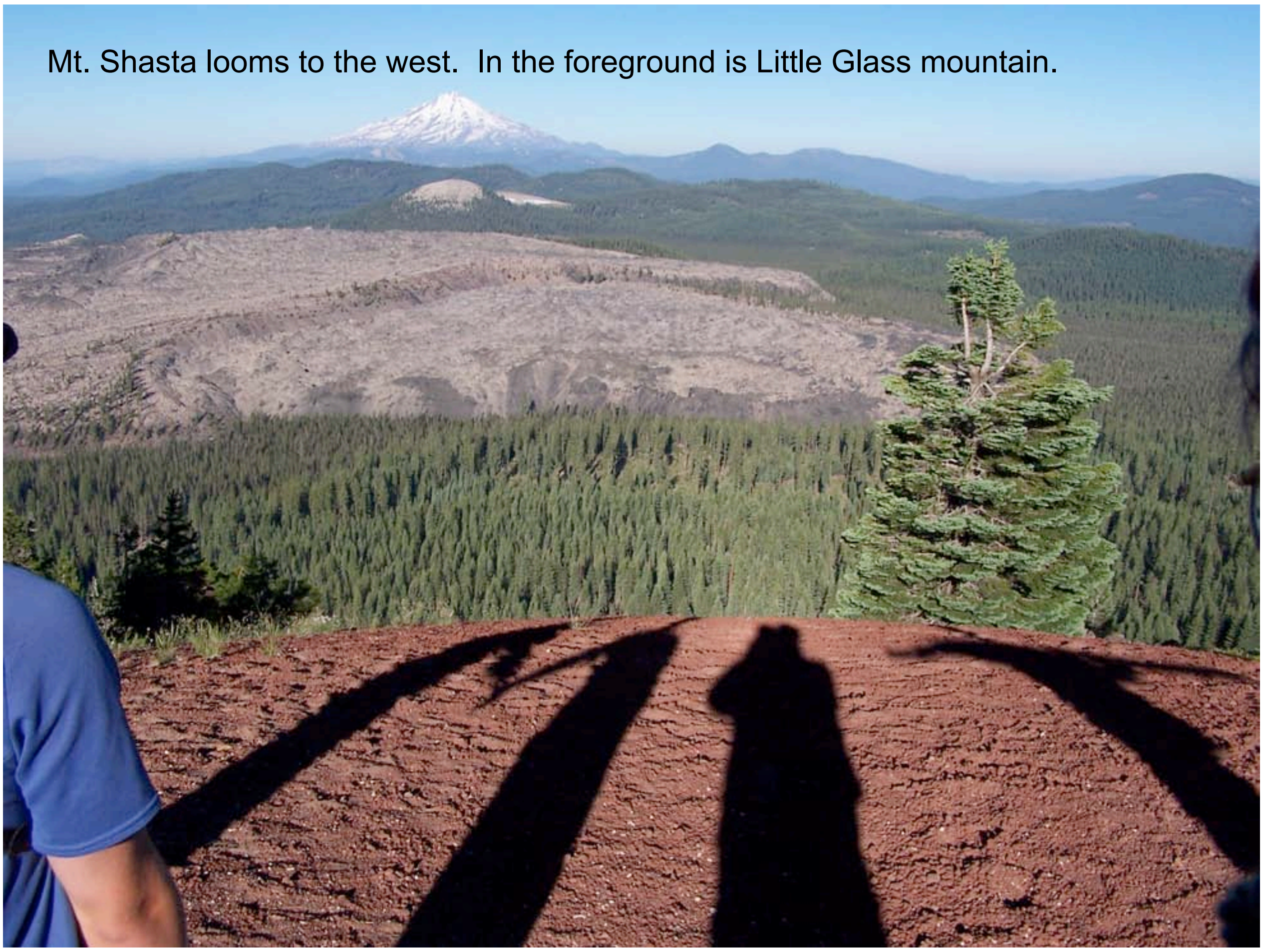


A model for Fractionation, assimilation, recharge and mixing that can account for the observed magmatic evoution of the giant Crater system.

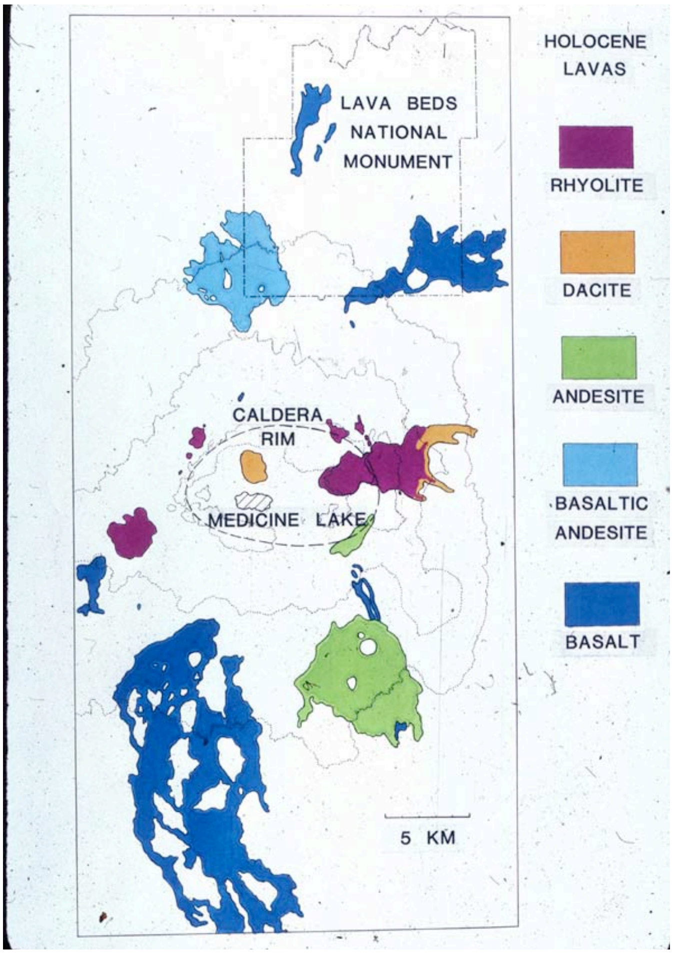
Giant Crater was more likely a “chamber” right hand side – rather than a plexus of dikes (left hand cartoons).



More importantly, a detailed look at the isotopes, major and trace element geochemistry of the Giant Crater lavas suggest that there were several stages of magma replenishment by primitive mantle derived HAOT. The cartoon above summarizes mass balance models for the progressive evolution of the /giant Crater magma chamber with time.



Mt. Shasta looms to the west. In the foreground is Little Glass mountain.

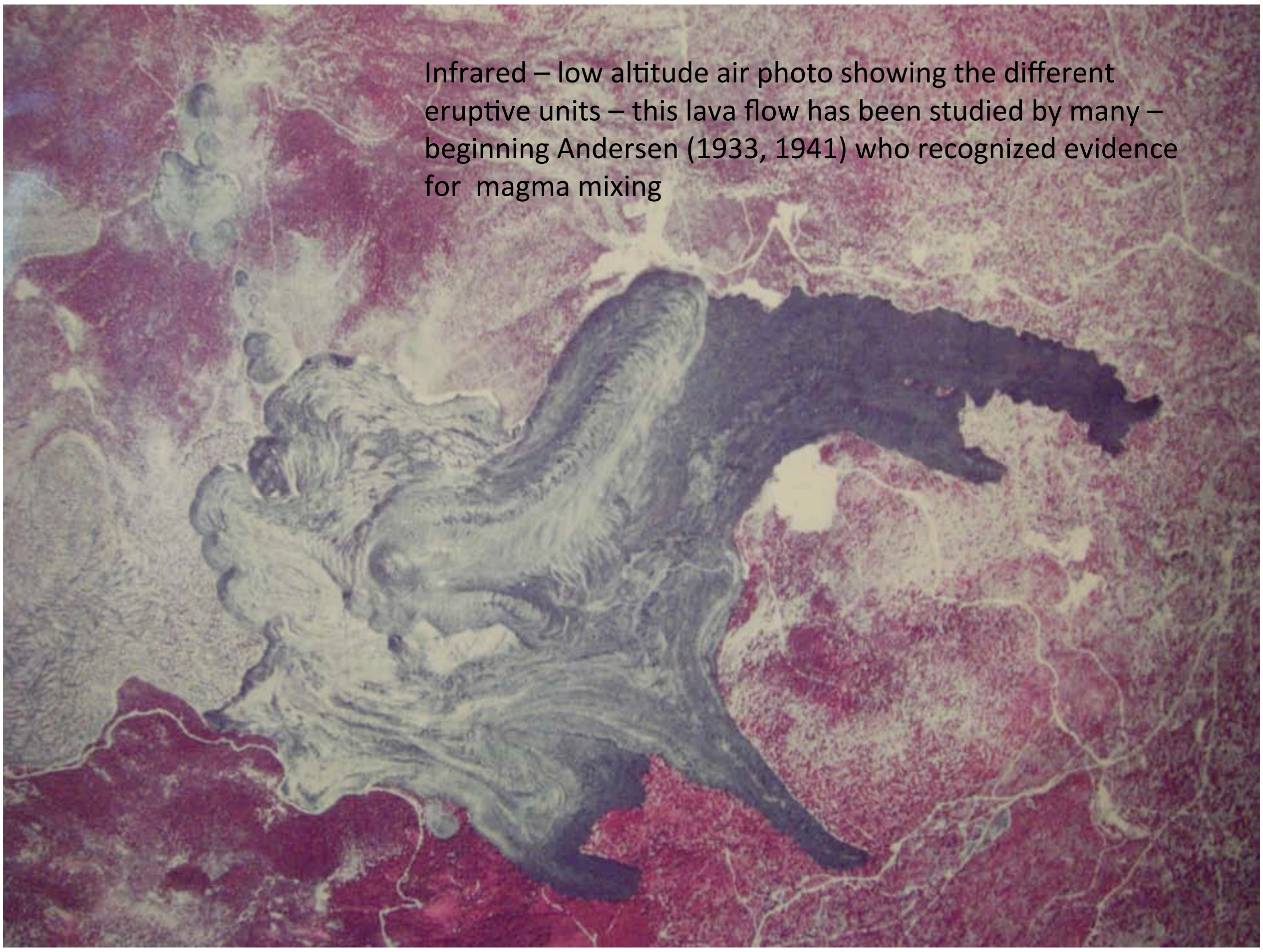


In addition to the DRY HAOT magmas at Medicine Lake there are “hydrous” magmas that have been erupted at the volcano.

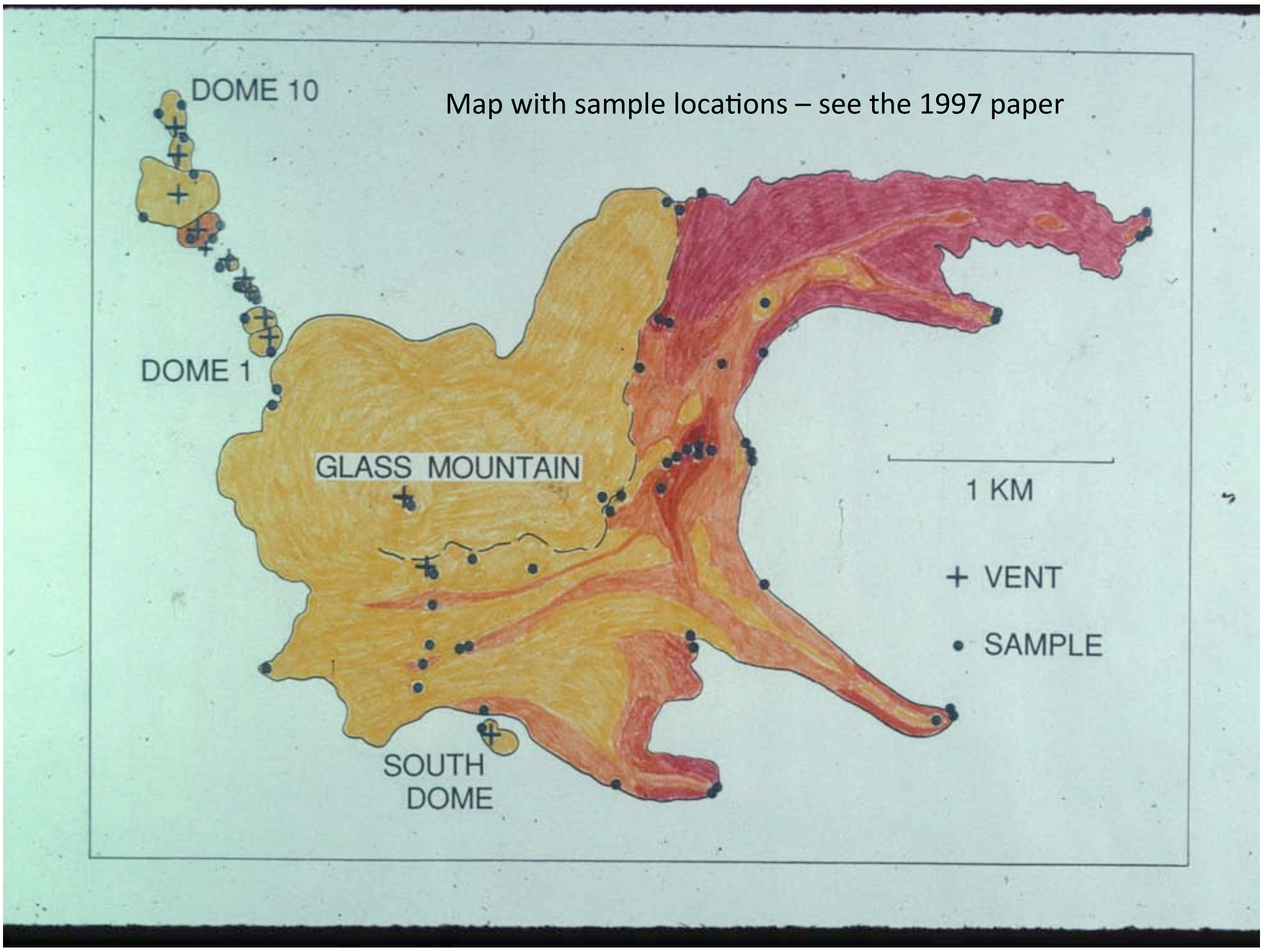
We shall see that it is these magmas that undergo fractional crystallization (FC) to rhyolite, presumably because of the different crystallization path followed by an H_2O-rich melt – one that does not involve iron-enrichment and plagioclase depletion

– Rather H_2O-rich fractional crystallization involves iron depletion and plagioclase enrichment.

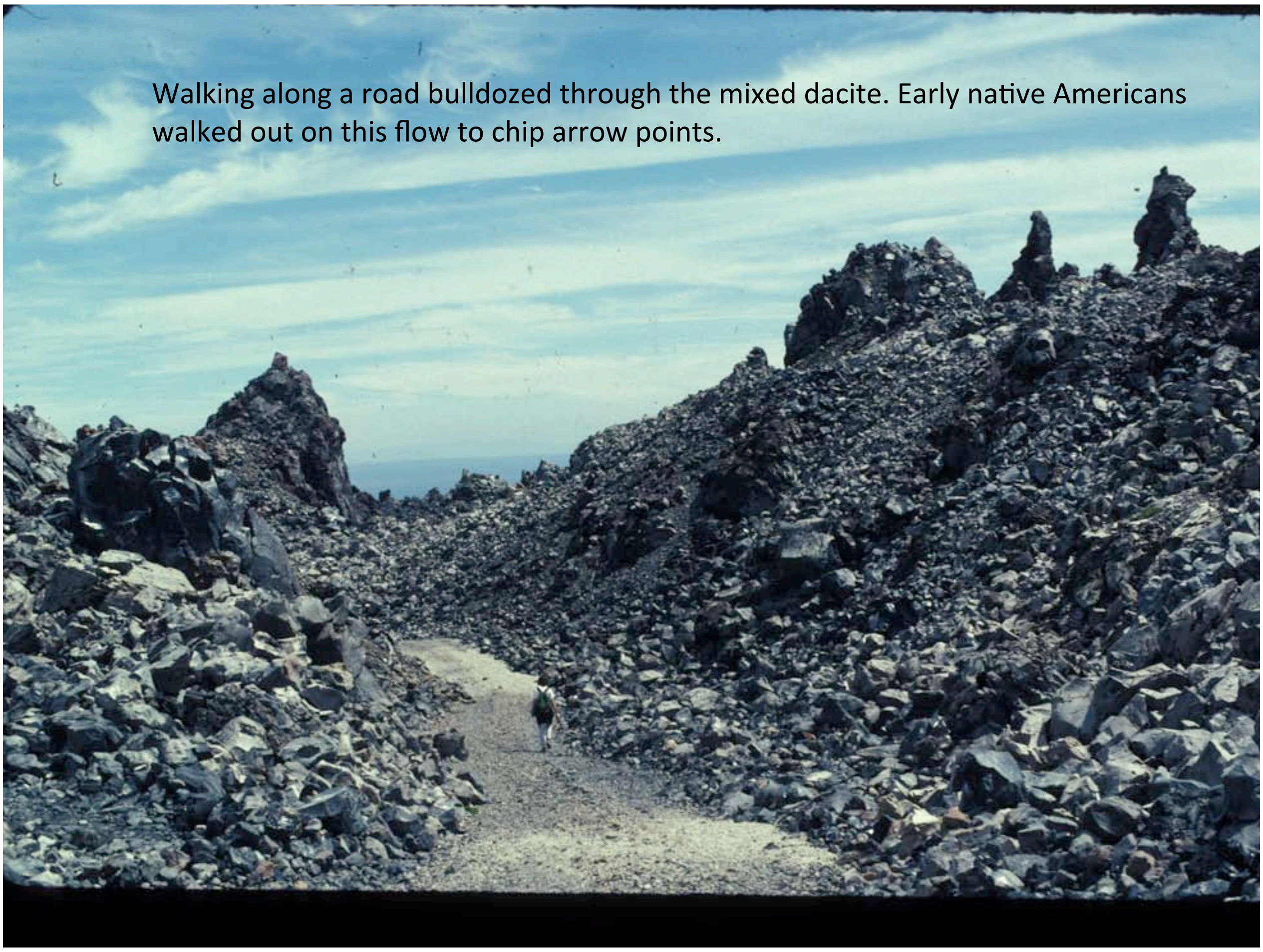
Again, FARM is an important part of FC in a crustal environment.



Infrared – low altitude air photo showing the different eruptive units – this lava flow has been studied by many – beginning Andersen (1933, 1941) who recognized evidence for magma mixing

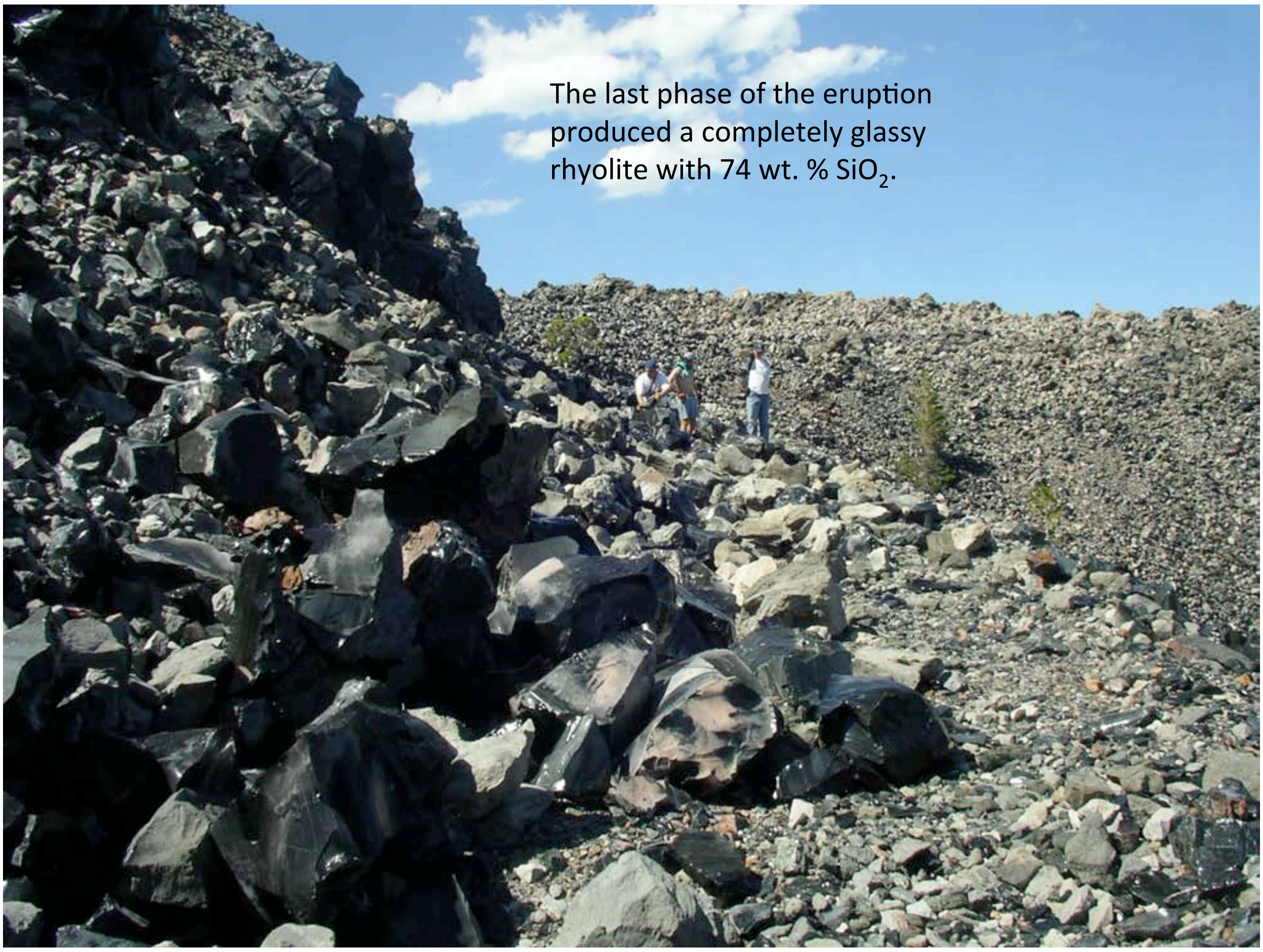


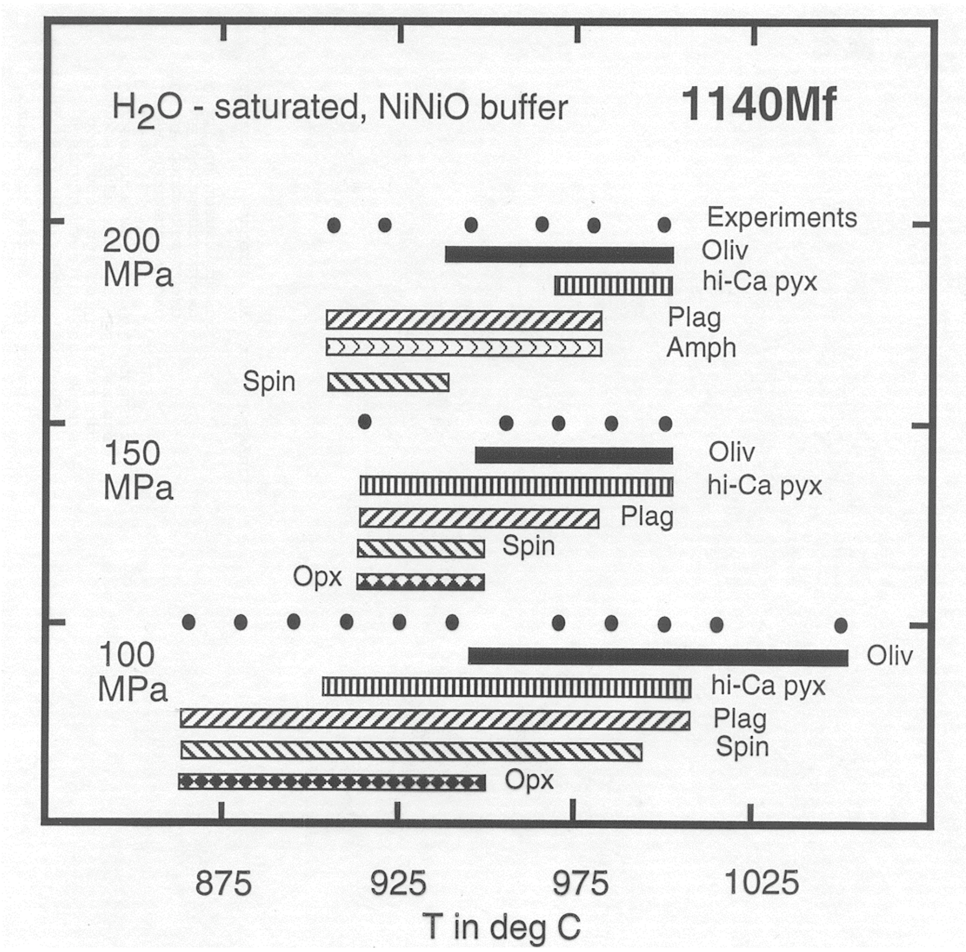
Map with sample locations – see the 1997 paper



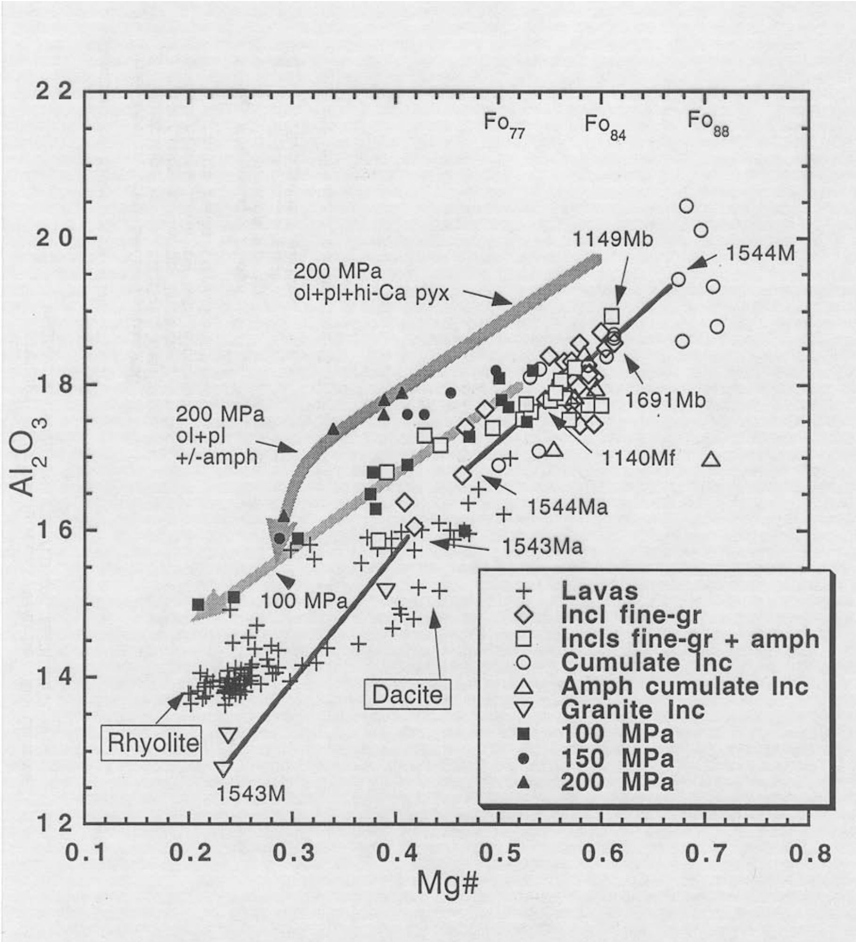
Walking along a road bulldozed through the mixed dacite. Early native Americans walked out on this flow to chip arrow points.

Mixed Dacite lava

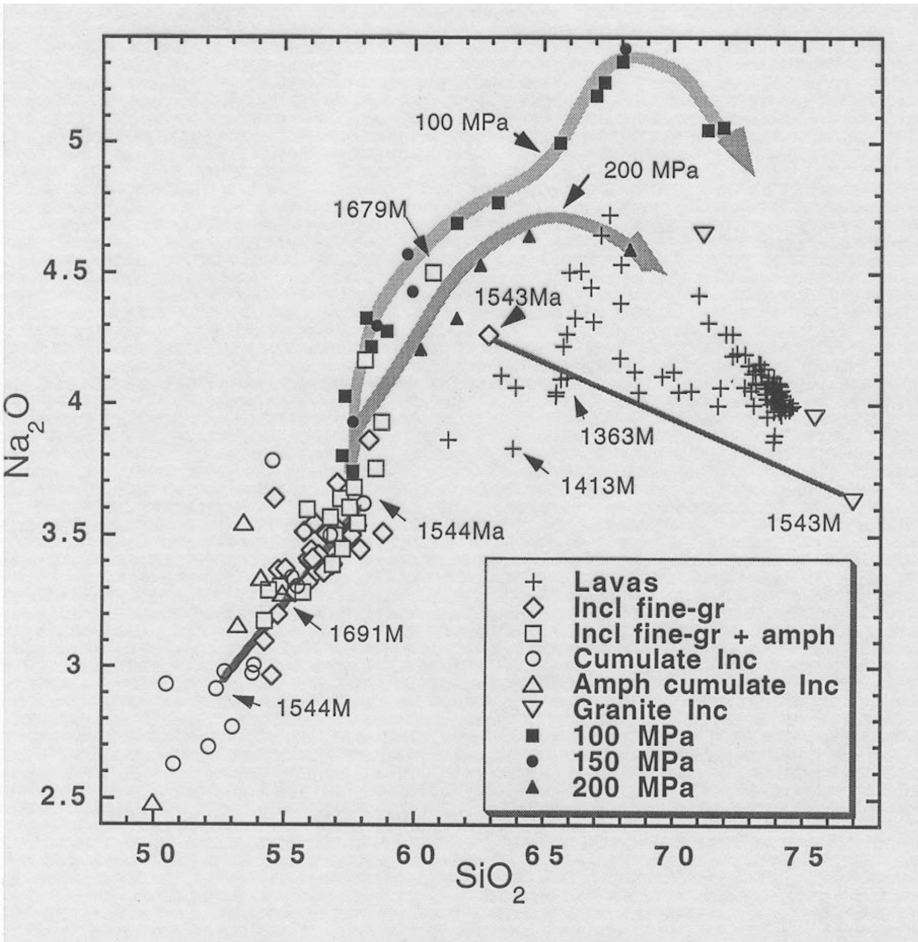




H_2O-saturated experiments on an aphyric andesitic inclusion to place constraints on the path followed by fractional crystallization under H_2O-rich conditions at crustal pressures

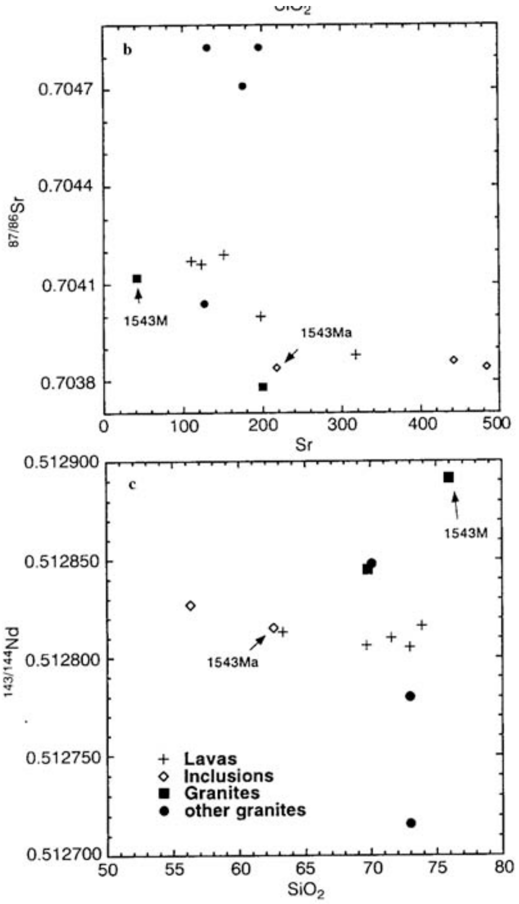


Comparison of experimentally produced crystallization paths with the compositional variability observed in the lavas and in the inclusion erupted in the lavas.



Experimental liquid lines of descent , mixed lavas and inclusions.

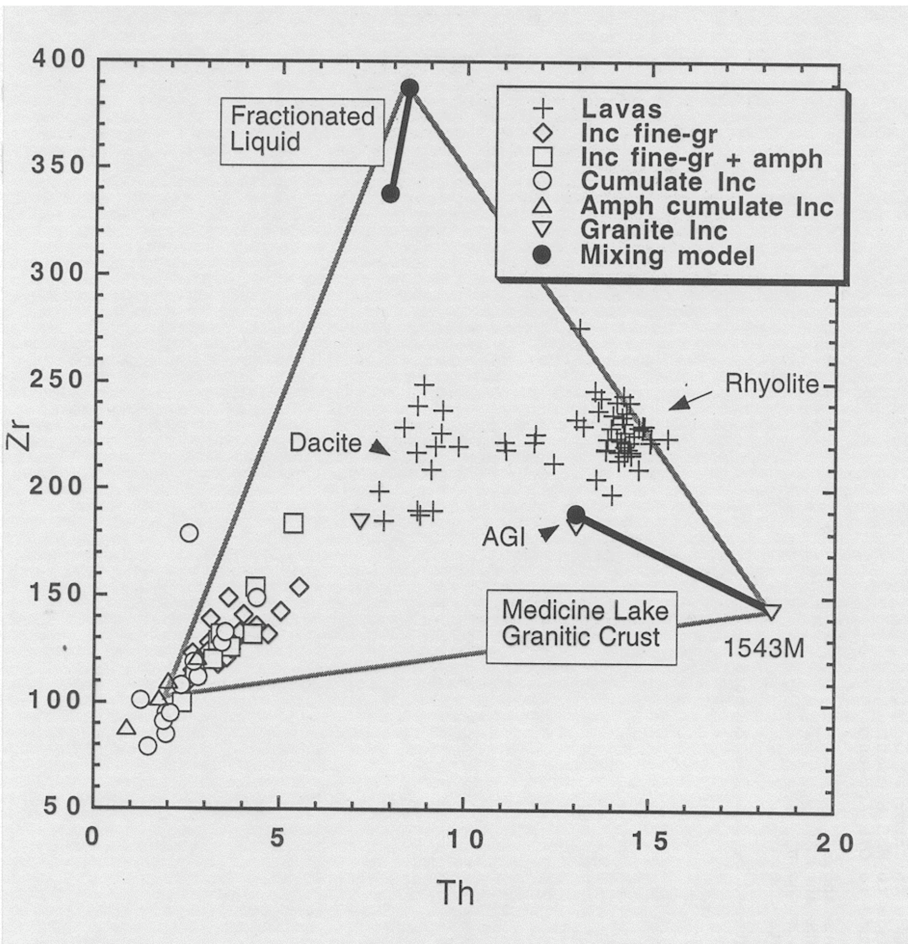
Note 1543M is a granite inclusion that is partly melted and is enclosed by an andesitic rind (1543Ma) representing the magma that was in contact with it as it melted. We'll see the isotopic compositions of these two in a little bit.



Here are the isotopes.

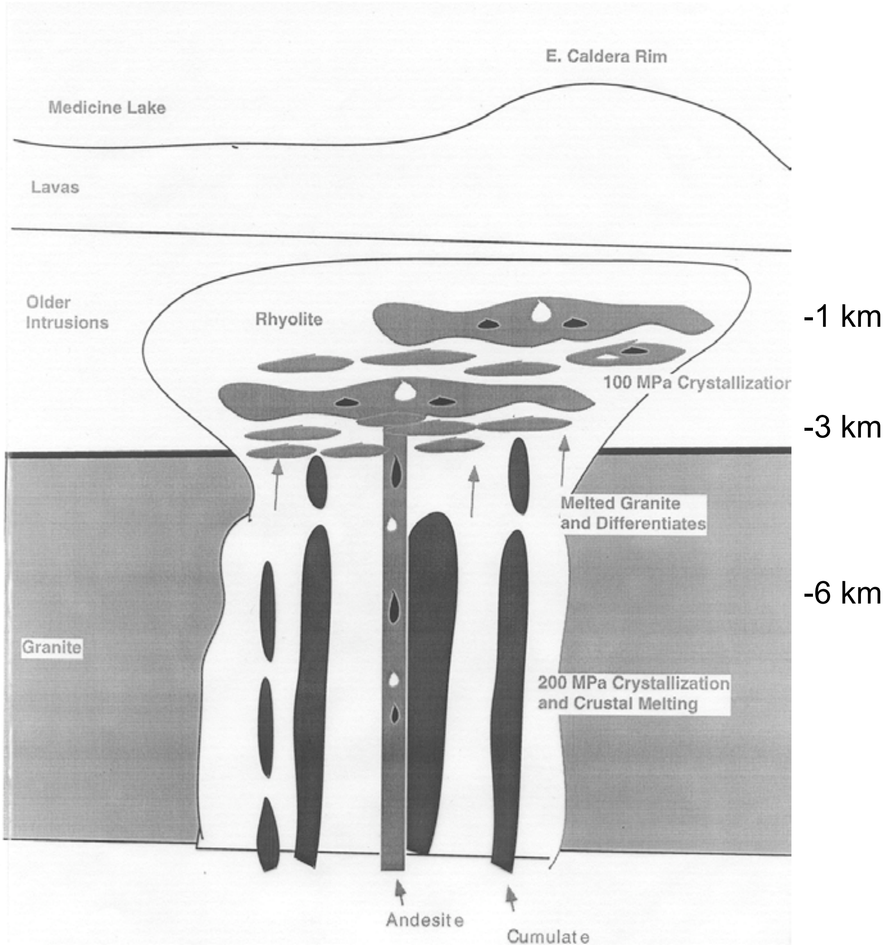
In Sr isotope space, the andesites are least radiogenic but have much higher Sr abundances than the melted granite crust

The rhyolites and rhyodacites are definitely contaminated by a crustal component- other trace element constraints allow us to develop a clearer picture of the extent of crustal contamination.



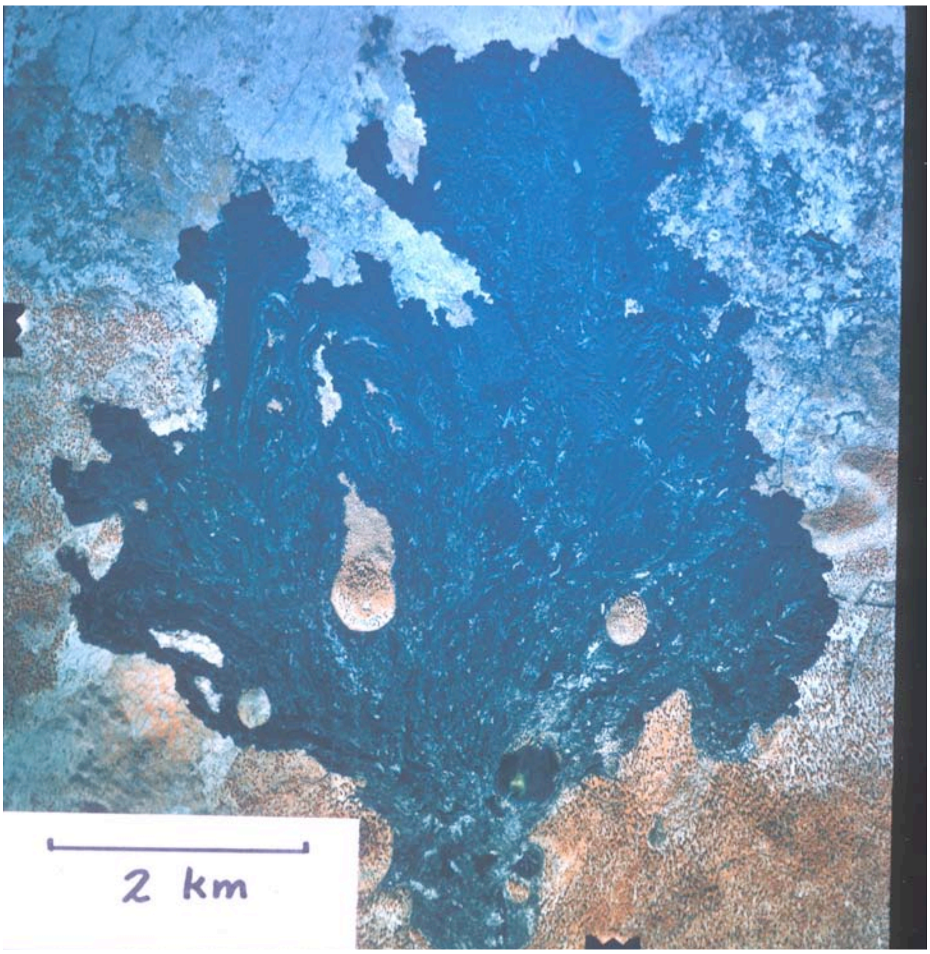
Trace element models of fractional crystallization of a hydrous basaltic andesite parent produce residual liquids high in Zr and Th. The crust beneath the volcano is depleted in these elements.

Abundance variations indicate that the rhyolites are 60 to 80 wt. % melted granitic crust.



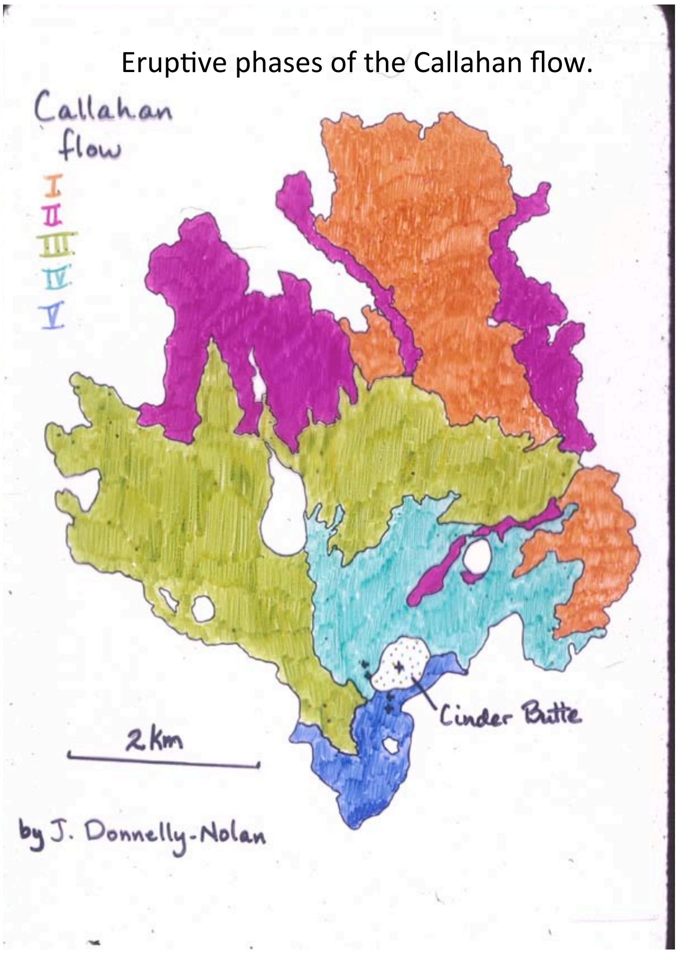
This model for the magma chamber beneath Glass Mountain is constrained by drill core data and seismic evidence.

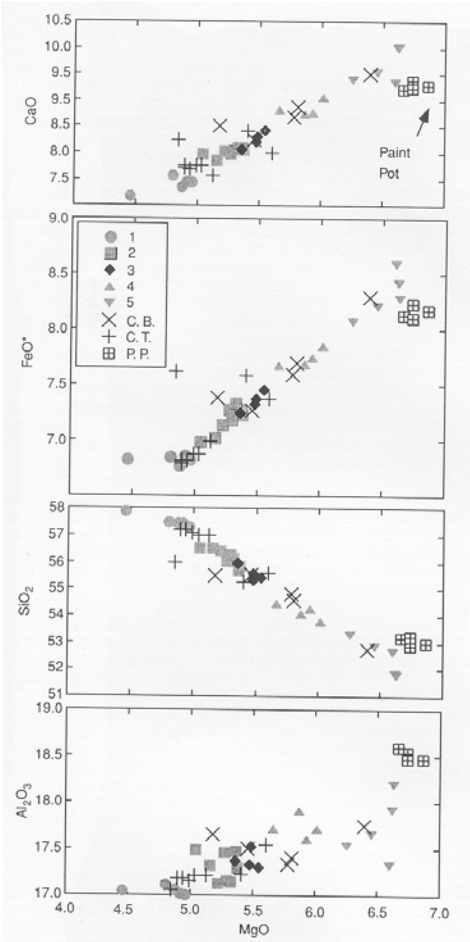
This evidence shows a melt lens currently at a depth shallower than the depth of fractional crystallization recorded in cumulate inclusions. Upon mixing to form the dacite, the andesite inclusions record a shallower depth in their mineral compositions.

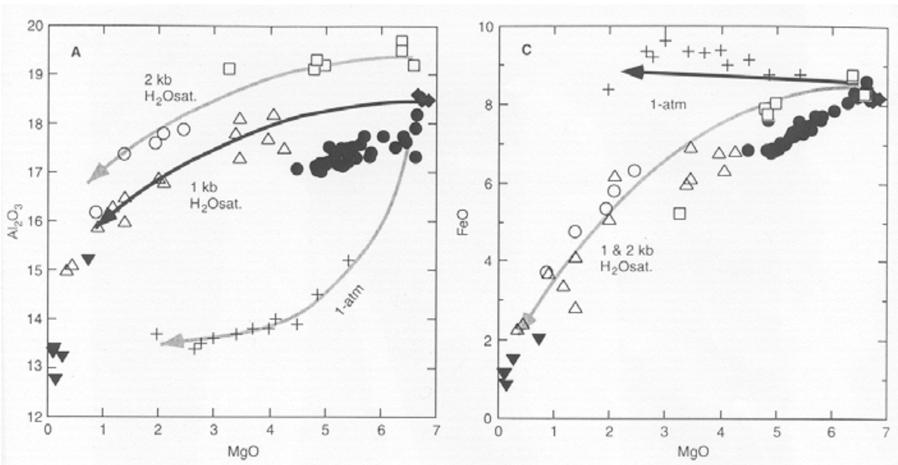


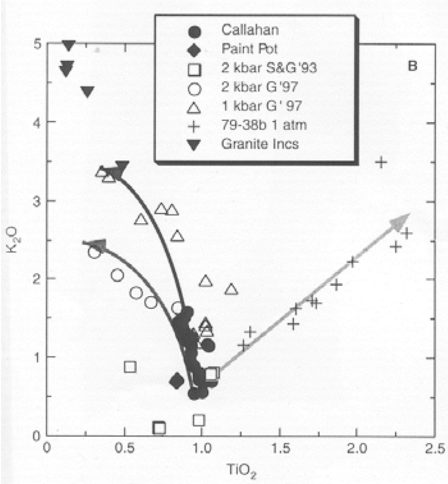
The 1100 year old Callahan flow is a "wet" basaltic andesite that is compositionally similar to the quenched andesite inclusions in the Glass Mountain rhyolite.

This lava is also compositionally zoned.









The low-pressure (anhydrous) crystallization path followed by this primitive basaltic andesite diverges dramatically from the path followed when the melt contains significant (~ 4-6 wt. %) H_2O.

Solid symbols = lavas
Open symbols = H_2O experiments
Plus symbols = anhydrous experiments

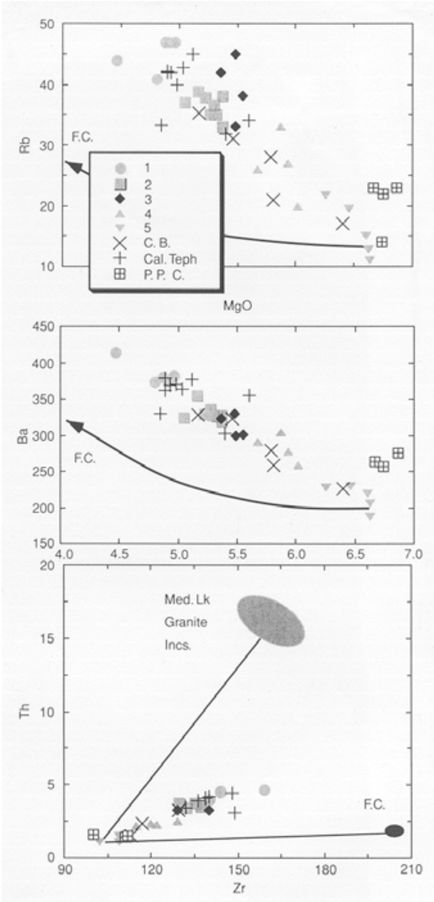
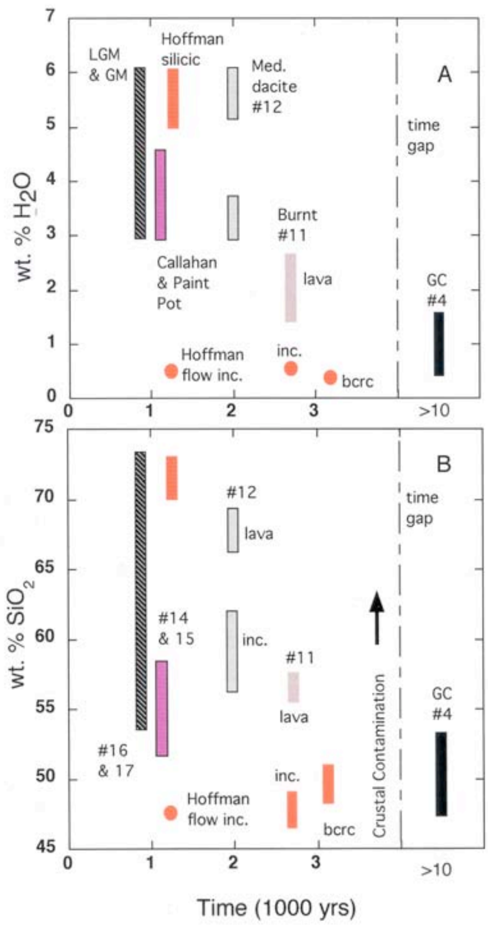


Fig. 7 Variations in trace element abundances in Callahan lava groups and tephra and in the Paint Pot Crater flow lavas. Complete

Incompatible trace element variations require that significant amounts of granitic crust are assimilated during the shallow crystallization and differentiation of these hydrous basaltic andesites.



As a result of the careful mapping and dating of the Holocene lavas at Medicine Lake, we can track the input of hydrous and anhydrous melts into the magmatic system.

Note the rapid alternation of H_2O-rich and anhydrous mantle melts into the Medicine Lake back-arc plumbing system. The time interval of switching from dry to wet to dry is very well constrained here.

These geologic constraints suggest that dry and wet melting in arcs is taking place in close temporal and spatial association in the arc system. More on this as we move west to Mt. Shasta.


Medicine Lake