Volatile fluxing and magma storage at Mount St. Helens volcano

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A major challenge of volcanology is linking the pre-eruptive movement of magma beneath a volcano to monitored signals such as seismicity and gas emissions. We have used analyses of over 210 melt inclusion (MI) and groundmass glasses from the 1980-86 eruption of Mount St. Helens to create a petrological dataset for comparison to the contemporaneous monitoring record.

H_2O in MI ranges from 0 to 6.8 wt%, with the highest values from the Plinian phase of May 18th, 1980. CO_2 contents indicate $X_{H_2O(vap)} \approx 0.80$, irrespective of H_2O, suggestive of closed system degassing with high bubble fraction. Fluctuation in $X_{H_2O(vap)}$ suggests fluxing of the the magma reservoir by gases exsolved from below. Fluxing may play a key role in the development of oscillatory zoning in plagioclase phenocrysts.

Elevated Li in MI and plagioclase phenocrysts from the cryptodome and post-May 18th samples requires transport of Li in an exsolved H_2O-rich vapour phase from deeper to shallower portions of the magma system. Maximum Li enrichment occurs at P_{tot} = 120-180 MPa, possibly due to condensation of a single vapour phase to H_2O-rich gas and Li-rich brine. Decreasing Li contents at lower P_{tot} result from continued degassing during ascent. This degassing occurs on timescales slow enough to allow Li diffusion out of the melt and into the vapour, but fast enough to inhibit significant diffusive loss of Li from plagioclase.

MI evidence for gas fluxing is supported by [210]Pb-[226]Ra disequilibrium resulting from loss and accumulation of [222]Rn-bearing vapour. The magnitude of the ^{210}Pb deficits indicate that the deeper reservoir was degassing for at least a decade prior to eruption, while ^{210}Pb excesses in the shallow reservoir are confined to periods of elevated gas flux, as evinced by SO_2 measurements.

Pre-eruptive magma storage depths, derived from MI saturation pressures, change systematically with time. The May 18 Plinian eruption discharged magma stored 5 to 11 km below sea-level (bsl). Preceding eruptions, including the lateral blast, and subsequent episodes involved shallower-stored magma. Tapping of magma from ≥2 km bsl stopped abruptly in Dec 1980, coincident with the onset of extensive shallow seismicity and a change from dominantly explosive to dominantly effusive eruption. This transition is likely a response to choking of the conduit system by highly crystallised magma. The close correspondence between petrological and monitoring records at MSH augurs well for an improved understanding of pre-cursory signals at explosive volcanoes.

Experimental Constraints on Trace Element Fluxes from Slab to Wedge

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The characteristic trace element signature of arc magmas is a consequence of the chemical flux from subducted slab to mantle wedge. The nature of this flux is determined by the different subducted lithologies, the subduction geotherm and the partitioning behaviour of trace elements between fluids, melts and slab residues. In an attempt to constrain the trace element flux that can be derived from subducted basalt we carried out H_2O-saturated experiments on a trace element-doped MORB composition at 2.5 GPa, 750-900 °C and fO$_2$=NNO.

Garnet, omphacite and rutile occur at all temperatures. Amphibole, staurolite and epidote disappear above 750 °C; allanite appears above 750 °C. The tronjhemitic glass present at all temperatures was quenched from supercritical fluid. Trace element analyses of glasses demonstrate the control exerted by residual minerals on fluid chemistry: garnet controls HREE; rutile controls Ti, Nb and Ta; and allanite buffers LREE contents of fluids to low levels and preferentially holds back Th and, to a much lesser extent, U. We agree with previous experimental [1] and metamorphic [2] studies that residual allanite has a key role in selectively retaining trace elements during subduction.

Experiments and allanite-bearing rhyolites are used to derive a model for allanite solubility in melts or fluids as a function of P, T, composition and LREE (La-Sm) content. Our model reproduces LREE concentrations in allanite-saturated melts and fluids to within a factor of 1.4 from 650-1100°C, 0-4 GPa. The extreme T-dependence of allanite solubility is very similar to that of monazite [3]. Silicic fluids from basaltic (or sedimentary) protoliths will be saturated in allanite (or monazite) except at very high temperatures. For conventional subduction geotherms the low solubility of LREE (+Th) in allanite-saturated fluids raises questions about the mechanism of LREE+Th transport from slab to wedge. We suggest either that (i) locally temperatures experienced by the slab are appreciably higher than normal, e.g. by mechanical incorporation of thin slivers of sediment into the mantle wedge, or that (ii) substantial volumes of H_2O-rich fluids must pass through the mantle wedge prior to melting. The solubility of accessory phases in fluids derived from subducted rocks clearly provides important geochemical constraints on subduction zone thermal structure.

References
[1] Hermann (2002), *Chem Geol*, **192**, 289-306
[2] Sorensen & Grossman (1993), *Chem Geol*, **110**, 269-297
[3] Montel (1993), *Chem Geol*, **110**, 127-146