Field geology and petrology of the 2004-2005 Mount St. Helens dome

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The 2004-5 eruption of Mount St. Helens began with intense seismic unrest and uplift of crater floor and glacial ice during late Sept. 2004. Following phreatic steam and ash eruptions in early Oct., spines of new lava extruded and uplift expanded to the south and east. By 27 Oct., windows of hot lava breached the eastern area of uplift, and by 4 Nov. an elongate wedge of new lava emerged and rose to a height of ~100 meters. This "whaleback" had a smooth east face mantled by white fault gouge, dipped 40-60 degrees east, and was marked by dip-parallel striations and dark colored "bathtub rings," the latter recording periods of weathering during uplift. During Nov. and Dec., the whaleback moved southward in conveyor-belt-like fashion, transporting new lava from the north end, and shedding it as hot talus to the south and west. Fractures developed by early Dec., and by early Jan., 2005, the whaleback was segmented.

Helicopter assisted bucket or dredge sampling and short-duration landings allowed rock collections on 20 Oct. (talus at the base of one of the initial spines), 27 Oct. (face of one of the spines and a rock ridge to the west), 4 Nov. (talus at the south end of the whaleback), and 3 Jan. (southwestern summit of the whaleback). 20 Oct. and the 27 Oct. rock-ridge samples were cold when collected, and are interpreted as 1986 dacite, based on chemistry, phenocryst assemblages, microphenocryst abundances and presence of variable thickness reaction rims on amphibole. The hot samples are new lava. They lie off the high end of the SiO_2-time trend for 1980-86 lavas, have lower Fe-Ti oxide temperatures (850°C), higher abundance of small plagioclase microlites, very thin or no reaction rims on amphiboles, and partly to fully devitrified matrix glass. Low abundances of volatiles in glass inclusions and matrix glass, and low emissions of SO_2, H_2S and CO_2 indicate early and extensive degassing. These features favor slow cooling, degassing and phenocryst growth in the magma at depth, followed by slow ascent to the base of the 1992-2004 shallow seismic zone at about 3 km (while remaining within the stability field for amphibole), then by more rapid and mainly steady-state ascent to the surface, accompanied by final degassing and cooling -- a multi-stage history that led to an extremely viscous, gas-poor, and crystal-rich extrusion, accompanied by limited explosive activity.

The nature and origin of the MSH 2004 Eruption from sample petrology and experiments

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Samples of the Mount St. Helens 2004-05 lava dome have been studied analytically and experimentally. The magma is a dacite, about 2wt% more silica-rich (Pallister et al., 2004) than that of1980-86. Samples of the lava were kindly supplied by USGS-CVO staff. Questions we attempt to address are (1) what are the conditions in and the storage depth of the magma being erupted, (2) is there evidence of a mingled in high-T magma, and (3) how rapidly is the magma ascending? The new magma is a hornblende-Opx-plagioclase dacite; coexisting Fe-Ti oxides indicate the temperature of last phenocryst equilibration was ~850^{o}C (11/04 sample), about 10^{o}C cooler than the 1986 magma. In the 11/04 sample, plagioclse rims range down to An_{38}. Experiments at 850^{o}C suggest pressures of 180-140 MPa, but more are needed to determine the pre-eruption pressure. The temperature may also need to be reconsidered. MSH350-1 collected on 1/3/05 contains Ti-magnetite crystals adjacent to ilmenite with Lo-Ti cores zoned to hi-Ti rims, and yield temperatures up to 950^{o}C. These zoning profiles suggest a recent (within 1-2 months) thermal effect from a high-T magma in the pre-existing cooler (older) one. While the previous samples of the 2004-5 dome contained amphibole with no rims indicating a relatively rapid magma ascent from a storage zone at greater than 100 MPa (850^{o}C), the 1/3/05 samples have hornblende with a very fine (2 micron) rim adjacent to melt. If the magma T was at 850^{o}C, the rims would suggest a decreasing ascent rate. However, if the T is 935^{o}C, the ascent rate probably has not decreased, and the experiments on amphibole stability requires this magma was >200 MPa.