Thermal Evolution of the 3 Ma to 0.1 Ma Goat Rocks Volcanic Complex, Washington Cascades

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We explore here the thermal evolution of the intermediate to felsic Goat Rocks Volcanic Complex in the southern Washington Cascade Range. This volcanic complex was active between ~3 Ma and ~110 ka and exhibits distinct compositional characteristics for each of the four major eruptive stages. We analyzed touching magnetite-ilmenite pairs from eight andesite and dacite (SiO_2 60-65 wt%) lava flows spanning in age from 2.7 Ma – 0.4 Ma. Samples represent Tieton Peak (2.7 Ma), Lost Lake andesite (2.3 Ma), Tieton andesite (Bear Creek Mountain; 1.6 Ma), Black Thumb dacite (0.8 Ma), Lake Creek volcano (0.7-0.5 Ma), and Old Snowy Mountain (0.4 Ma). Ilmenite compositions are similar in all samples (~80-90 mol% ilmenite), but magnetite compositions fall into two groups that are not controlled by silica content and are distinct in age (samples younger than 0.8 Ma vs those older than 1.6 Ma). Magnetite in younger samples contains ~20-40 mol% ulvospinel, compared to ~40-60 mol% ulvospinel in older samples. This corresponds to recorded magma temperatures of ~750-925 °C (younger) vs. ~925-1000 °C (older) (using the thermometer and oxybarometer of Anderson & Lindsley, 1985). Within the younger group, the Black Thumb and Lake Creek samples show a decrease in temperature with time, from ~850-900 °C (Black Thumb) to ~750-800 °C (late-stage Lake Creek andesite); but then higher temperature (~800-925 °C) is recorded for the oldest dated lava flow from Old Snowy Mountain ($^{40}Ar/^{39}Ar$ groundmass age of 440 ± 3 ka). This aligns with previous Ti-in-zircon results which record a decline in temperature through the Lake Creek eruptive stage (1.1-0.5 Ma). Amphibole thermobarometry also indicates hotter, deeper crystallization for Old Snowy Mountain amphiboles compared to Lake Creek amphiboles. Taken together, these results suggest that preeruptive magmas from earlier activity in the Goat Rocks volcanic complex (including the voluminous Tieton andesite) were hotter than during Lake Creek stage, when magma temperatures were lower and gradually declined, and that hotter, deeper magmas rejuvenated the system to construct Old Snowy Mountain. In addition, these youngest magmas were likely more oxidized: the Old Snowy Mountain sample records oxygen fugacity (fO_2) 0.5 to 1.5 log units higher than those from earlier stages, which record fO_2 of ~NNO ± 0.5.