

The evolution of a hydrothermal system: P-T-t constraints from geothermal exploration well GAR-1

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The Washington Cascades represent an underutilized geothermal resource. This volcanic arc contains 7 Quaternary volcanic centers, more than 30 thermal springs, and an estimated 300 MWe of undiscovered geothermal reserves. However, despite several decades of reconnaissance and increasing government incentives, viable commercial geothermal resources remain elusive.

The most recent effort at development culminated in 2011 with the drilling of geothermal exploration well GAR-1 (1433 m) at Garland Mineral Springs. Garland Mineral Springs was identified as a favorable target for development based on a large ($>8,000 \text{ m}^2$) surface manifestation of warm ($>25^\circ\text{C}$) spring waters and high CO_2 and magmatic He discharge. Within the well, promising shallow temperature gradients in excess of $80^\circ\text{C}/\text{km}$ reverted to lower gradients ($\sim 32^\circ\text{C}/\text{km}$) at depths $>600 \text{ m}$. The well encountered pervasively bleached granite and CO_2 charged artesian pressures, however, low flow rates and low temperatures necessitated that the project be abandoned.

Snohomish Public Utility District has made available to the Fracture Research and Application Consortium all of the cuttings from GAR-1. Analysis of this material represents a rare opportunity to address questions about the evolution of geothermal systems in the North Cascades, and about the maintenance of permeability in crystalline rock in general. I will explore the evolution of Garland Mineral Springs using a complimentary suite of techniques, including petrography, microstructural and fluid inclusion analysis of vein material, and thermochronology of minerals in the host rock. These techniques are particularly well suited to the lithologies and temperature conditions encountered in this borehole, and may provide constraints on the pressure-temperature-time (P-T-t) history of the geothermal system.

Petrographic characterization includes thin section analysis to identify primary and secondary mineralogy, a constraint that is lacking from current geochemical models of Cascade thermal springs. Vein textures will be further described using SEM-CL imaging. SEM-CL is used to distinguish post-kinematic infilling from syn-kinematic (i.e. “crack-seal”) textures indicative of multiple opening episodes, and may help differentiate between tectonic or geochemical controls on permeability. Euhedral and vein-quartz obtained from the cuttings will be examined for fluid inclusion assemblages. Microthermometry will be conducted on inclusions to identify homogenization temperatures, and, if appropriate, Raman-spectroscopy will be used to constrain fluid pressures during formation. The P-T evolution of vein minerals will be coupled with T-t histories obtained from apatite and zircon (U-Th)/He (AHE, ZHE) and fission track (AFT, ZFT) thermochronology. These minerals are abundant in felsic plutonic units like those encountered in GAR-1 and are sensitive to a wide range of temperatures (ZFT $\sim 250^\circ\text{C}$; ZHE $\sim 200^\circ\text{C}$; AFT $70\text{-}110^\circ\text{C}$; AHE $\sim 60^\circ\text{C}$). The lower end member thermochronometers include temperatures recorded in GAR-1 ($\sim 15\text{-}85^\circ\text{C}$), while the upper end members would capture the theoretical temperature limit (i.e. boiling conditions) in the upper $\sim 1/3$ of the well.

Petrographic, fluid inclusion, and chronometric analysis will help to constrain the types and rates of geochemical processes involved in this geothermal system. These constraints may in turn provide new insight into assessments at other known thermal features throughout the Cascades.

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