Resolving the plumbing system in Yellowstone National Park with electromagnetic, magnetic and geochemical data

*Carol Finn[1], Paul A Bedrosian[1], R. Blaine McCleskey[1], JoAnn Holloway[1], W. Steven Holbrook[2], Esben Auken[3]

1. USGS, 2. Virginia Technical University, 3. Aarhus University

Helicopter magnetic and electromagnetic data over the significant portions of Yellowstone National Park, reveal the plumbing system to the region's chemically variable hot springs. Geochemical data and models suggest that a deep neutral-chloride parent fluid, originating from modern precipitation and meteoric recharge from glacial times, underlies the hydrothermal systems throughout the park at depths greater than ~500 m. Boiling and removal of steam by mixing with cold and dilute groundwater at depth and near the surface, and by water-rock interaction, provide the diverse water chemistry of surface springs. Mapped fractures and faults, especially in the Norris Geyser Basin outside the modern caldera, are thought to localize many of the thermal features there and as is horizontal flow at the base of rhyolite flows within the caldera. However, the groundwater pathways that feed the iconic thermal features are largely unknown and not imaged. Groundwater significantly lowers the resistivity of porous volcanic rocks, highlighting boundaries between and within volcanic flows. Hydrothermal alteration that marks present and past fluid flow paths lowers both resistivity and magnetization. Therefore, helicopter electrical and magnetic data are ideal tools for mapping fluid pathways in the park. Hot springs in the Norris Geyser Basin are clearly associated with sinuous patterns of low resistivities (generally less than ~30 ohm-m) and magnetic lows over the Norris Geyser Basin itself, suggesting significant water saturated hydrothermal alteration. Outside the basin, not all resistivity lows correspond to magnetic lows, suggesting that the low resistivities are largely caused by groundwater, perhaps with thinner or less intense alteration. Resistivity cross-sections and susceptibility models show vertically dipping boundaries likely reflecting fracture patterns. A ~100 ohm-m horizontal to shallow dipping boundary between Lava Creek Tuff A and B relates to a water saturated layer in a moderately welded portion of the tuff that allows groundwater flow, in contrast to the highly resistive, dry massive densely welded Lava Creek Tuff itself. Cold Springs can occur where horizontal, moderate resistivity, near-surface, intraflow boundaries intersect the surface, confirming that the moderate resistivities reflect groundwater. Within the caldera, low resistivities can occur along boundaries between rhyolite lava flows. Steeply dipping boundaries also occur beneath the Geyser Basins indicating vertical flow paths for groundwater. The lack of correlation between resistivity patterns and hot spring chemistry such as pH, suggests that mixing occurs between meteoric water flowing along horizontal inter- and intra- flow boundaries into the geyser basins and fluids and gases flowing along vertical boundaries. In addition, the plumbing system for individual springs is too small and shallow to be imaged with the geophysical data, at depths <5-10 m and spatial scales <~25 m. However, the larger scale lateral and vertical flow paths are clearly imaged, with the lowest resistivities and magnetizations indicating regions of significant flow of gasses and hydrothermal fluids.

Keywords: hydrothermal, groundwater, airborne geophysics, Yellowstone