**GEOPHYSICAL EXPLORATION OF A SHALLOW GEOTHERMAL OUTFLOW AT HAWTHORNE ARMY DEPOT, NEVADA, USA**

*Paul Schwering, Sandia National Laboratories, Albuquerque, NM, USA*

*Christine Downs, Sandia National Laboratories, Albuquerque, NM, USA*

*William Cumming, Cumming Geoscience, Santa Rosa, CA, USA*

*Gabe Matson, Geologica Geothermal Group, San Francisco, CA, USA*

*Steven Sewell, Australis Geoscience Ltd., Eastbourne, NZ*

*Adam Schultz, Enthalpion Energy LLC, Philomath, OR, USA*

*Paul Bedrosian, U.S. Geological Survey, Denver, CO, USA*

Hidden geothermal systems are hydrothermal energy reservoirs which lack typical hydrothermal manifestations on the ground surface (e.g., hot springs or sinter terraces). Studies indicate that hidden systems represent a prolific potential resource base that could support critical US public and government energy priorities. The Department of Energy’s Geothermal Technologies Office funded the Basin & Range Investigations for Developing Geothermal Energy (BRIDGE) research project, led by Sandia National Laboratories (Sandia), as part of a broader initiative to advance the identification and development of hidden geothermal energy systems in the Basin & Range Province of the western USA. A primary objective of BRIDGE is to develop an economically sound exploration workflow, relying heavily on geophysical methods, to increase the likelihood of successful hidden system discovery. Resistivity methods are predominantly used to explore conventional (permeable) geothermal resources because they are sensitive to critical elements of a resource conceptual model such as 1) lithologic changes impacting the water table, 2) the existence and geometry of low-permeability clay zones, 3) fracture systems hosting geothermal fluid upflow, and 4) permeable zones that host shallower outflows.

The BRIDGE team executed an airborne electromagnetic (AEM) survey in western Nevada that covered an area of approximately 3,000 km2 during the Spring of 2022. The AEM survey was performed using a helicopter-towed array designed to provide ‘reconnaissance-level’ resistivity tomography from approximately 30 to 300 meters below ground surface. This method is effective for discovering hidden geothermal systems in three main ways: 1) detecting the dip of the top, and occasionally the bottom, of low-resistivity clay zones capping the buoyant up-dip flow of hot formation-hosted aquifers, 2) detecting where thick meteoric aquifers render shallow temperature wells ineffective at detecting deeper heat sources, and 3) detecting low-resistivity zones associated with hydrothermal alteration (often complicated in Nevada by widespread, very low-resistivity evaporitic formations). Confidence in the interpretation of resistivity features identified through AEM is improved by tying subsurface resistivity patterns to known thermal anomalies, fluid geochemistry, lithologic/hydrologic characteristics, or geologic structure.

The Hawthorne Army Depot (HAD) is a US Department of Defense property in Mineral County, Nevada that was included in the AEM survey. Previous studies identified HAD as having hidden geothermal energy resource potential from exploration drilling, geologic mapping, and potential-field geophysics. HAD, like most of the BRIDGE study areas of interest, lacked any significant exploration contribution from resistivity methods. The BRIDGE AEM survey at HAD totaled approximately 185 line-kilometers and helped characterize a clay-capped geothermal aquifer buoyantly outflowing up-dip to a temperature test well. This finding supported the design and execution of a 26-station magnetotelluric (MT) survey in the Fall of 2022 directed at investigating the deep source of the shallow outflow. Although terrestrial MT surveys are more expensive per sounding and are more affected by access constraints, they have the greatest depth of investigation of any resistivity method and can extend imaging to kilometers of depth albeit with lower resolution. Taken together, the methods are complementary for hidden geothermal system detection and provide a robust geophysical interpretation basis to inform an exploration program.

HAD provides an initial test case of the BRIDGE AEM/MT approach based on shallow outflow detected from prior temperature gradient drilling. Preliminary analysis and interpretation of the results from these two surveys, collated with data from previous shallow temperature and formation studies, have characterized a shallow hydrothermal outflow. While measured temperatures of this outflow from existing well data do not represent a significant resource where intersected by shallow temperature gradient holes (i.e., <100°C within 200 meters of ground surface), the AEM/MT results suggest that a deeper reservoir with potentially viable temperatures for geothermal power production (i.e., >120°C) is feeding the shallow outflow system. Next steps at HAD include further geophysical analysis targeted down-dip of the outflow, towards delineating the hydrothermal upflow of the reservoir, and likely confirmation drilling of the hidden geothermal system. BRIDGE will apply a similar exploration workflow to other areas of interest in the region. Sandia is managed and operated by NTESS under DOE NNSA contract DE-NA0003525.