**AAPG/SPE/SEG HEDBERG CONFERENCE**
***"ENHANCED GEOTHERMAL SYSTEMS"***
**MARCH 14-18, 2011 – NAPA, CALIFORNIA**

# A New and Innovative Dual Approach to Early Geothermal Exploration Using Sinter Architecture and Ground Penetrating Radar

Bridget Y. Lynne and Amy J. Dougherty
Institute of Earth Science and Engineering, The University of Auckland, Auckland, NEW ZEALAND

Silica-rich alkali chloride hot springs are a common surface feature of geothermal systems. As this water discharges at the surface it cools to less than 100 °C. Upon cooling, the silica carried in solution precipitates and accumulates to form rocks known as siliceous sinters. The silica initially deposits as opal-A silica which entombs everything it comes into contact with such as microbes that thrive in the hot spring water, pollens, diatoms, plants, and older sinter surfaces. This process silicifies and fossilises all biotic and abiotic components present in a hot spring vent or channel. The silicification of all components results in the preservation of a variety of textural fabrics where each texture reflects specific environmental conditions and hot spring settings such as: (1) vent and near-vent high temperature (>60 °C) locations; (2) mid-slope, mid-temperature (35-60 °C) channels and pools; (3) low-temperature (<35 °C) distal-apron settings. Environmentally significant sinter textures indicative of these broad temperature gradient profiles are preserved in the rock record. Therefore, sinters provide valuable records of paleobiologic, paleohydrologic and paleoenvironmental conditions in hydrothermal settings.

Geothermal systems are sensitive to subtle changes in hydrology often resulting in intermittent spring flow but their associated sinters remain preserved at the surface for thousands of years after hot spring flow has ceased. Also, the deeper hot reservoir fluid can exist at depth long after hot spring activity has stopped. Therefore the existence of a sinter deposit provides us with a direct link to a deeper geothermal reservoir that may have no present-day surface manifestations. The recognition of temperature significant sinter textures enables the locations of high temperature versus low temperature discharge sites to be identified. There are many examples around the world where geothermal power plants successfully operate but there are no present-day discharging hot springs. However, there are sinter terraces in the area indicating significant historic hot spring flow.

Sinters undergo a five-step silica phase modification from opal-A to opal-A/CT to opal-CT to opal-C and eventually to quartz. Silica phase transformation rates differ between locations. Quartzose sinters have been dated at Steamboat Springs, USA at 11,500 years BP, Opal Mound, Utah, USA at 1900 years BP and Sinter Island, New Zealand at 450 years BP. Therefore, mineralogical maturation alone cannot be used as an indicator of the age of a sinter and Accelerator Mass Spectroscopy $^{14}C$ dating is required to determine the timing of fluid flow to the surface. Regardless of the silica phase and age, textural preservation persists.

To date, the study of hot spring deposits has been restricted to surface outcrops and point source data from cores. Augmenting these existing methods with ground penetrating radar (GPR) facilitates a continuous cross-sectional view of the shallow subsurface. GPR transmits short pulses of high-frequency electromagnetic energy into the ground and detects the reflected signals identifying changes in the subsurface. This is the highest resolution geophysical technique available and is ideally suited for imaging resistive hot spring deposits. While GPR has been successfully utilized in a variety of geologic settings, it had not previously been used in geothermal environments.

Preliminary results show GPR was successful in: (1) imaging through opal-A to quartz sinter deposits to a depth greater than 10 meters with decimeter resolution; (2) locating the spatial extent of buried sinters; (3) detecting alteration of sinter deposits; (4) deciphering the subsurface spatial distribution of extinct vents including their subsurface directionality and relation to faults and fractures; (5) mapping temperature gradients preserved in extinct sinter deposits from high temperature vent to mid-temperature, mid-slope areas to distal apron, low temperature terracette settings.

This initial foray into utilizing GPR has demonstrated promising results as a non-invasive, cost-effective method for imaging a range of geothermal features in the shallow subsurface. This new application of utilising GPR to locate previously undocumented buried sinters, combined with $^{14}C$ sinter dating and textural mapping in locations where there are no surface manifestations will greatly assist in the initial stages of exploration for new blind geothermal systems.