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A transient hydrogeophysical characterization of Crystal Geyser: The first applications of electrical resistivity tomography on a cold-water geyser

Patrick A. Lagasca, M. Cathryn Ryan, Laurence R. Bentley
Department of Geoscience, University of Calgary

Theory / Method / Workflow

In 1935, Crystal Geyser (in Utah, USA) was unintentionally created by the drilling of a petroleum exploration well that penetrated a natural CO_2 reservoir. Approximately pure CO_2 gas-driven eruptions from the abandoned well have been reported since 1936 up to today (3).
Unlike most geysers, Crystal Geyser is a cold-water geyser that is driven by the degassing of dissolved CO_2 instead of the boiling of water into steam. During the largest eruptions, Crystal Geyser ejects columns of water up to five metres high for a full day (11).

In the past decade, research interest has increased at Crystal Geyser with the rising prevalence of carbon capture and storage as a technique to mitigate climate change. Recent research has developed an understanding of the geyser's eruption behaviour and subsurface fluid movement (3, 7, 11, 8, 4, 10, 5). This is because Crystal Geyser demonstrates a future scenario of the catastrophic failure of a CO_2 injection well (3, 11, 6). The current conceptual understanding of subsurface fluids was created from the monitoring of fluid pressures and fluxes from the shallow geyser conduit and ground surface. However, these fluid migration models are mostly qualitative and infer deep subsurface processes from shallow data.

To date, there are no published works of geophysical methods applied to a cold-water geyser. This study utilizes electrical resistivity tomography in conjunction with downhole monitoring to create profiles of the structural geology and transient hydrogeology of Crystal Geyser. Direct current electrical resistivity data were collected along a 2D transect of surface electrodes centred on the geyser. Three pressure transducers were distributed inside the geyser borehole to a depth of 10m. Recovered resistivity sections were created with Res2DInv, which utilizes a smoothness-constrained least-squares inversion method. Geological interpretations of geophysical data were supported by field mapping and the borehole logs of Crystal Geyser and a nearby exploration well (8, 9).

Results, Observations, Conclusions

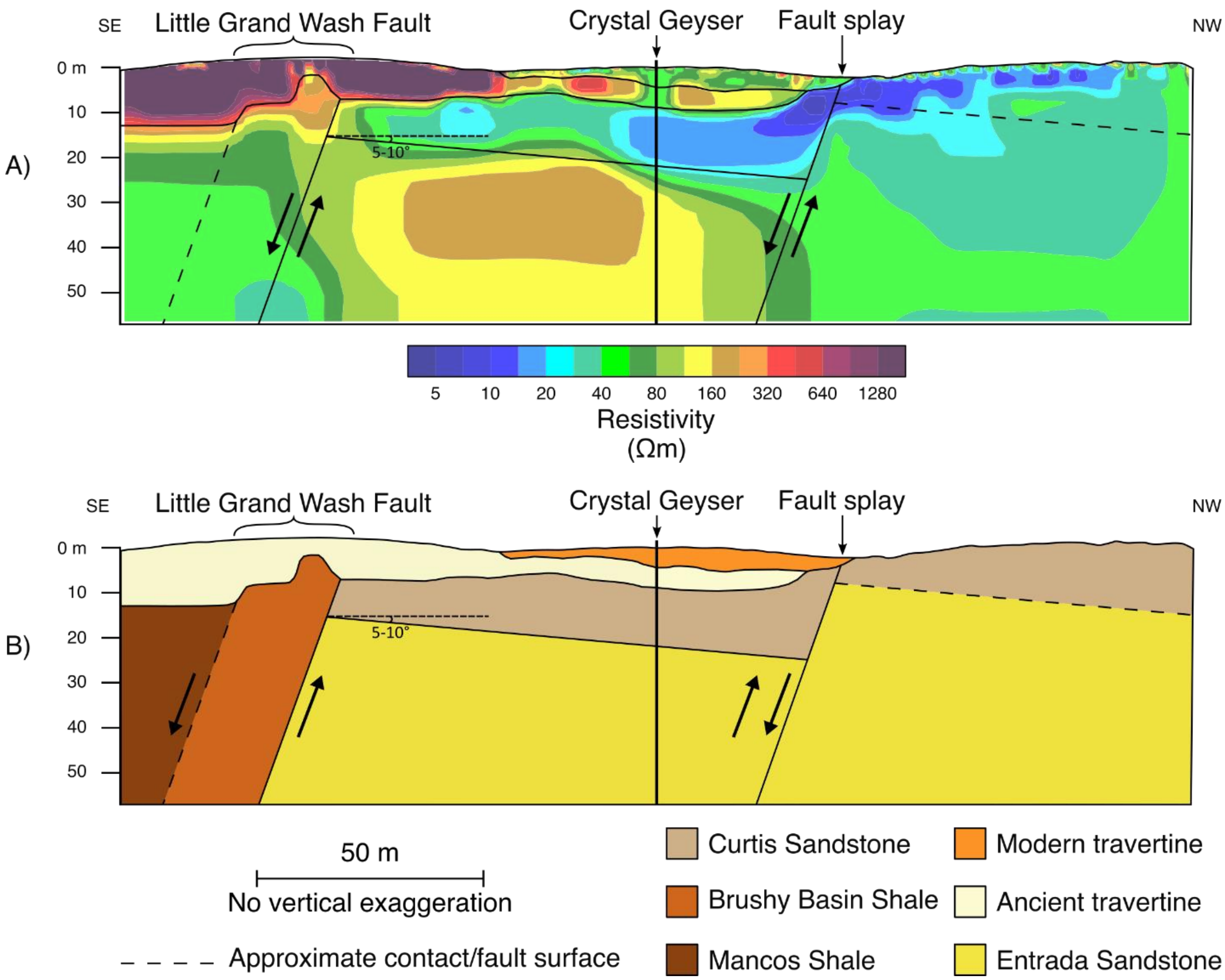

Fig. 1 A) Interpretation of geological contacts or fault surfaces of a recovered resistivity section. B) Geological interpretation with lithologies.

With the recovered resistivity profiles, we were able to affirm the locations of the primary trace of the Little Grand Wash Fault and a smaller fault splay from previous field mapping (Fig. 1A, 1B). The Little Grand Wash Fault acts as a conduit that transports CO_2 from depth to the ground surface near Crystal Geyser (7, 5). A depth profile of the contact between the modern travertine, actively deposited by the geyser, and an ancient travertine was clearly delineated by their distinct resistivity signatures (Fig. 1B). Furthermore, downhole video footage reveals a shallow cave where the well casing is destroyed. Electrical resistivity data suggests the cave may be much larger than captured in video footage.

Research is in progress to characterize the migration of groundwater and free-phase gas between the subsurface and the geyser conduit. Preliminary results suggest that elevated fractions of subsurface free-phase gas may be detected by an increased resistivity signature within the geyser conduit and adjacent subsurface. We will develop an improved transient model of subsurface fluid migration of Crystal Geyser, based on time-lapse hydrogeophysical data.

The model developed from this study will serve as an analogue to understand similar fugitive gas movement from industrial wells. Leaking industrial wells, such as CO_2 injection wells and petroleum wells, release greenhouse gases into the atmosphere and have the potential to degrade the quality of potable groundwater (1, 2). Using Crystal Geyser as an analogue to a leaky industrial well, we will describe common processes of gas leakage. Improved characterization of subsurface gas movement, gained from this study, can then be applied to guide effective detection and mitigation practices for gas leaks from operational or abandoned wells.

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