PROCEEDINGS, 43rd Workshop on Geothermal Reservoir Engineering
Stanford University, Stanford, California, February 12-14, 2018
SGP-TR-213

Geothermal Reservoir Characterization Using Distributed Temperature Sensing at Brady Geothermal Field, Nevada

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Keywords: Brady, Distributed Temperature Sensing, DTS, Thermal diffusivity, Borehole dynamics

ABSTRACT

Distributed temperature sensing (DTS) systems provide near real-time data collection that captures borehole spatiotemporal temperature dynamics. Temperature data were collected in an observation well at an active geothermal site for a period of eight days under geothermal production conditions. Collected temperature data showcase the ability of DTS systems to detect changes to the location of the steam-water interface, visualize borehole temperature recovery — following injection of a cold-water “slug” — and identify anomalously warm and/or cool zones. The high sampling rate and spatial resolution of DTS data also shows borehole temperature dynamics that are not captured by traditional pressure-temperature survey tools. Inversion of thermal recovery data using a finite-difference heat-transfer model produces a thermal-diffusivity profile that is consistent with laboratory-measured values and correlates with identified lithologic changes within the borehole. Used alone or in conjunction with complementary data sets, DTS systems are useful tools for developing a better understanding of both reservoir rock thermal properties as well as within and near borehole fluid movement. The work presented herein has been funded in part by the Office of Energy Efficiency and Renewable Energy (EERE), U.S. Department of Energy, under Award Number DE-EE0006760.

The results from this study have recently been published as: Patterson, J. R., M. Cardiff, T. Coleman, H. Wang, K. L. Feigl, J. Akerley, and P. Spielman (2017), Geothermal reservoir characterization using distributed temperature sensing at Brady Geothermal Field, Nevada, The Leading Edge, 36, 1024a1021-1024a1027. http://dx.doi.org/10.1190/tle36121024a1.1

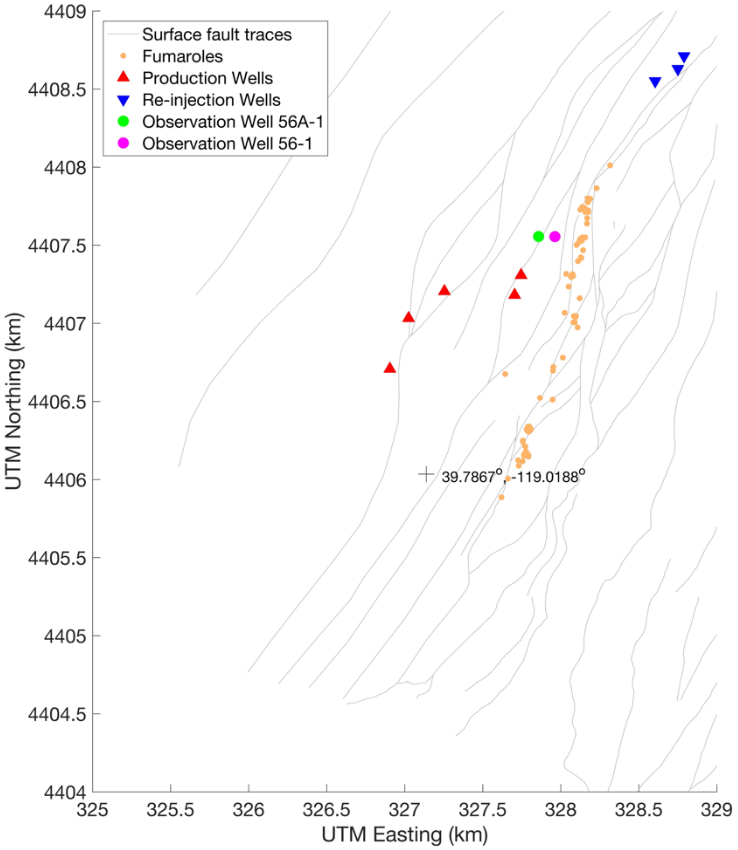

Figure 1: Plan view map of Brady Geothermal Field near Fernley, NV. Identified fiducial point represents location of site well 15-12. Figure and caption from Patterson et al. (2017), copyright SEG.

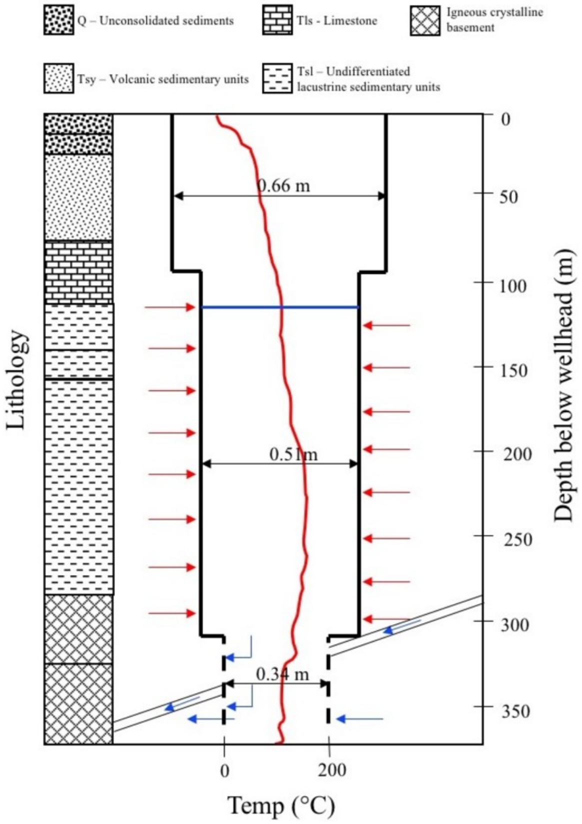

Figure 2: Brady observation well 56-1 construction, lithology, and pre-DTS installation observations. Well construction information provided by ORMAT, Inc. Lithology based on a current geologic model (Siler et al. 2016). Temperature profile (red line) based on initial P-T survey. Arrows indicate conceptual model for heat diffusion (red arrows) and water movement (blue arrows). Water level in well is approximately 120 m below wellhead (blue line). Figure and caption from Patterson, Cardiff et al. (2017), copyright SEG.

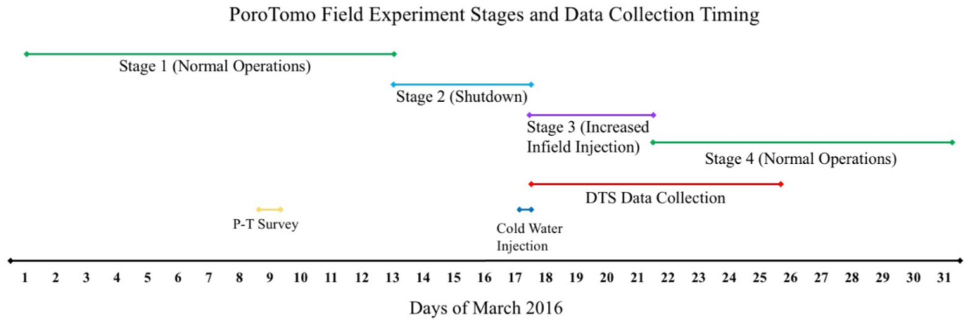

Figure 3: Gantt diagram showing stages and timing of the integrated PoroTomo field experiment, period of DTS data collection, date of cold-water slug injection, and date of previous P-T survey. Figure and caption from Patterson, Cardiff et al. (2017)

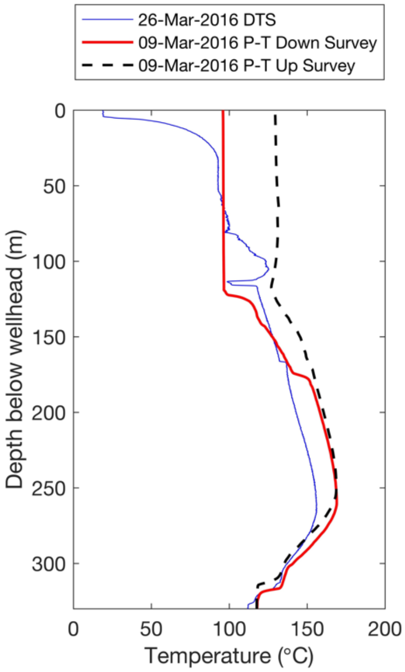

Figure 4: Temperature log in observation well 56-1 at Brady comparing the data provided by traditional logging tools(P-T survey) and DTS systems. The temperature log given by the DTS shows identical temperature trends when compared to traditional logging methods. Difference between down-going and up-going P-T survey illustrates the effect of thermal inertia on this tool. Figure and caption from Patterson, Cardiff et al. (2017), copyright SEG.

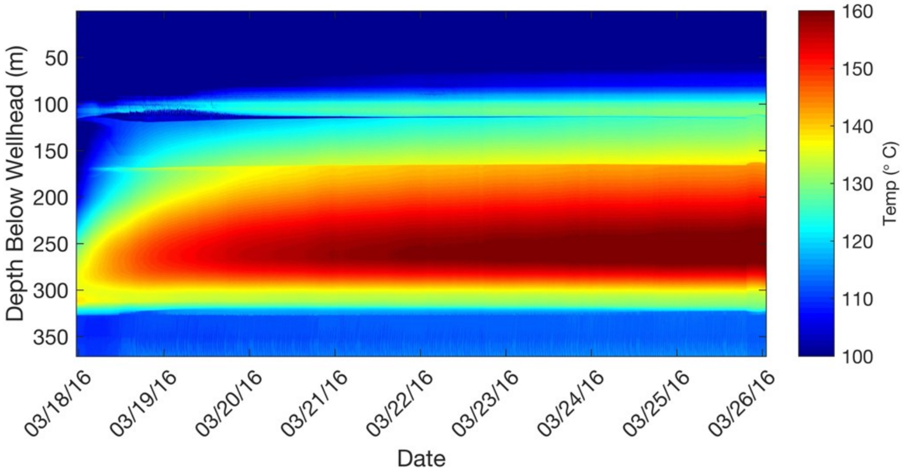

Figure 5: Depth profile temperature time series showing borehole temperature recovery following a cold-water slug injection into well 56-1. A maximum temperature zone approximately 50 m in thickness is centered at 250 m depth. An inverse temperature gradient begins at approximately 275 m terminating in a persistent cold zone below approximately 325 m depth. Figure and caption from Patterson, Cardiff et al. (2017), copyright SEG.

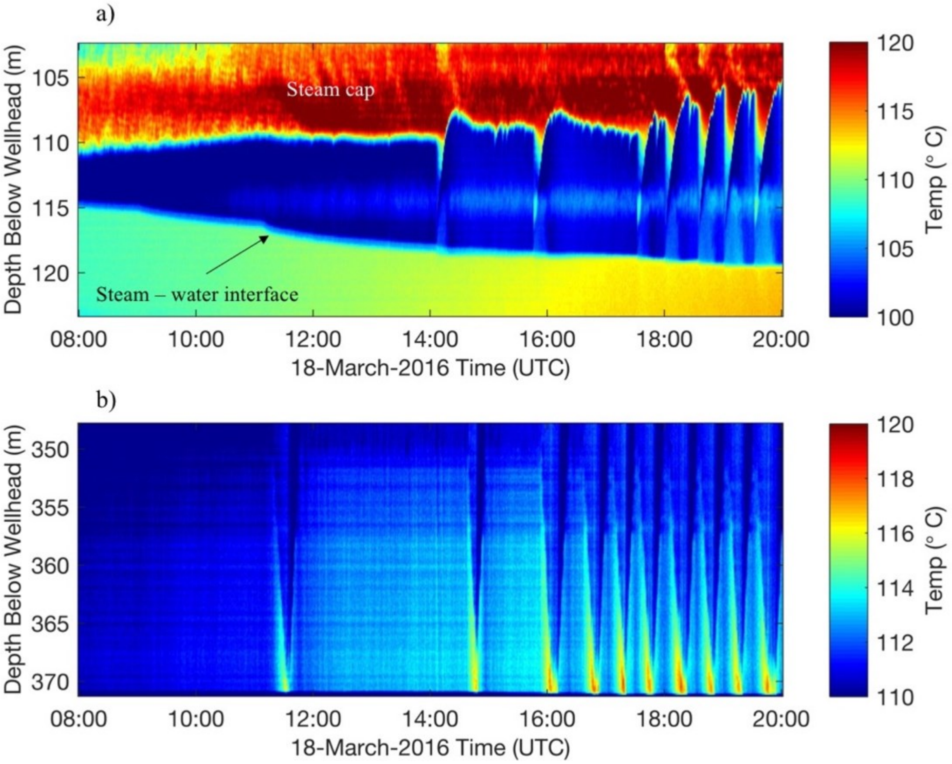

Figure 6: 12-hour time series collected March 18, 2016. a) The steam – water interface increases in depth with increasing time. The onset of phase change at the interface occurs as water level decreases resulting in depressurization. b) The first evidence of forced convection into the open interval below 350 m depth is seen approximately 11 hours after the onset of pumping with evolution of periodic convection pulses occurring at 30 minute intervals. Figure and caption from Patterson, Cardiff et al. (2017), copyright SEG.

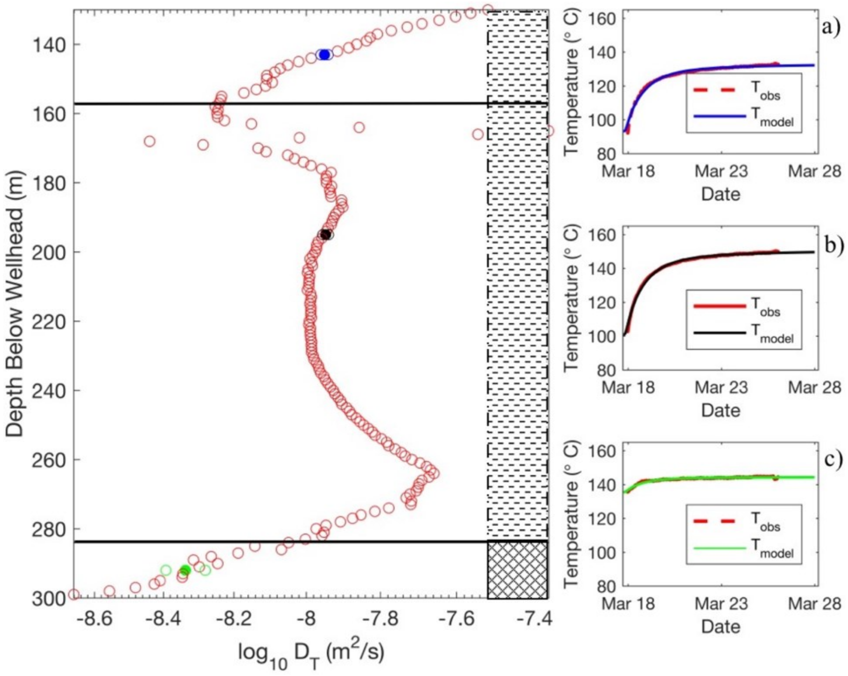

Figure 7: Vertical profile of thermal diffusivity estimates throughout the fluid-filled and cased portion of the Brady observation well. Horizontal black lines represent lithologic contacts identified in geologic modeling efforts by Siler et al. (2016). Modeled data fit shown at representative depths - a) 144 m b) 196 m c) 293 m. Figure and caption from Patterson, Cardiff et al. (2017), copyright SEG.

ACKNOWLEDGMENTS

The authors wish to acknowledge the generous contributions of ORMAT Technologies who provided site access for installation of fiber-optic DTS systems at the Brady Geothermal Field. The authors also acknowledge expertise and thought-provoking questions provided by Doug Miller of Silixa Ltd. This research was supported by grants DE-EE0005510 and DE-EE0006760 from the U.S. Department of Energy Geothermal Technologies Office. The data used are listed in the references in the "The Leading Edge" article by Patterson et al., 2017, and can be found on the Geothermal Data Repository at https://gdr.openei.org/submissions/853.

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