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Borehole imaging log analysis, a volcanic facies and structural analysis tool: Case examples from Hawai'i and Iceland

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Understanding sub-surface volcanic systems requires the interpretation of diverse volcanic facies with complex structures and highly variable petrophysical properties. These systems are increasingly forming targets for geothermal, hydrology, and hydrocarbon resources. Robust interpretation of these systems requires borehole data as an integral data input for developing geological models. Composite borehole and multi-borehole analysis in particular comprise important approaches, where volcanic facies types, rock properties, and complex fracture systems, such as permeable lava flow margins, hyaloclastites and sheet intrusions impart key controls onto fluid flow pathways and connectivity. This project focuses on the application of the borehole televiewer tool (BHTV) for volcanic facies interpretations, utilising high resolution acoustic image data of travel time and amplitude contrasts in open borehole sections that are commonly utilized for both structural and facies analysis.

Results from borehole logging operations of a borehole in North Iceland, and one fully cored c. 1.5 km deep borehole, from the Big Island of Hawai'i are presented to highlight the potential of the BHTV log for volcanic facies analysis. Additionally, the North Iceland example borehole ÁRS-32 images very well the contrasts of lava flows and intrusive sections tied to drill cuttings, drilling, and wireline log data. The PTA2 borehole was drilled as part of the Humu'ula Groundwater Research Project (HGRP) and penetrates a basaltic lava dominated sequence with a complex history of hydrothermal alteration. BHTV data along with sonic, spectral gamma and magnetic susceptibility were collected for an open hole section, with the BHTV set to the highest resolution settings and run at optimized logging speed for gaining the best possible imagery. By comparison with the core data, the potential for BHTV imaging revealed spectacular intra-facies features including individual vesicles, vesicle segregations, 'a'ā rubble zones, intrusive contacts, and intricate pāhoehoe lava flow lobe morphologies is demonstrated.

Planning and calibration of BHTV image log data is of importance and a number of factors including tool settings, logging speed, temperature and hole conditions can significantly deteriorate the quality of images returned by the BHTV tool. Higher quality images can more easily be obtained in lower temperature boreholes of smaller diameter, such as the fully cored PTA2 borehole and the low temperature boreholes ÁRS-32 in North Iceland, and the ÞK-18 borehole in South Iceland, all of which give exceptional imaging. However, to highlight some of these influences, we compare data from the wider diameter borehole of the K18 borehole within the Krafla high temperature field in northeast Iceland, where challenging logging conditions were present, such as encountered rock type, high temperature, borehole size, and resulting tool setting for the borehole, resulted in mixed but generally poorer BHTV image results. Despite these challenges of BHTV logging of large diameter high temperature boreholes, we conclude that the benefits of good quality BHTV data can be significant in terms of improved understanding of volcanic reservoirs, and that where possible, acquiring high resolution BHTV data should form a priority for geothermal exploration in volcanic settings, specifically where core or ditch cutting data are absent.