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Fracture Permeability and Saturation Effects on the Seismic Attributes of Pre-Thermally Stressed Rocks from a Philippine Geothermal Field

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Geothermal systems are seeing increased importance and use in order to reduce reliance on fossil-based power generation around the world. However, to fully exploit these systems calibrating surface seismic models using controlled laboratory experiments is crucial. Specifically, key rock physics data such as fluid-saturation, fracture network density, and permeability is needed, especially since the routinely used seismic methods (both passive and active) are seeing increase usage in geothermal exploration and development. Here we report a new laboratory study examining seismic attributes of andesitic rocks from a Philippine geothermal field (Southern Negros Geothermal Field - SNGF) that have undergone different stages of thermal treatment. These data are compared with baseline data from a granite taken from Cornwall (UK), acting as a control. In both cases, samples (100mm long and 40mm diameter cylinders) are pre-treated by heating to temperatures ranging from 200-800 ^{o}C to induce thermal damage. Two small notches are drilled into the sides of the cylinders on opposite ends across the diameter, and two small 3mm drill holes drilled into the ends of the cores offset to intercept the 30-degree fracture plane that is generated when samples are subjected to a conventional triaxial experiment. In this way, the development of the natural fracture and damage zone has an orientation dictated by the setup, and with access at each end via the 3mm miniature ‘boreholes’. This setup allows the experiment to evaluate permeability of natural fracture surface and damage zone, in addition to key attributes (P/S wave elastic velocity, Acoustic Emission, static moduli) while fractures develop and permeability forms.

Fracture permeability in samples with varying thermal treatment was calculated at different levels of confining pressure. Initial results indicate a base level ranging from 10^{-18} m^2 in untreated Westerly granite, 10^{-16} m^2 in untreated SNGF andesite. This increases to 10^{-15} m^2 at 800 ^{o}C. During fracture development, the fluid flow along the newly generated faults are significantly higher, with an effective permeability ranging from $10^{-15}$to 10^{-13}m^2 modelling the fluid flow conduit along a ‘slot’ encompassing the fracture damage zone. These data are then modelled by reference to post-test SEM and fracture data, and with respect the evolving P/S data to link these well controlled geophysics data to field scale seismic surveys. In this way, we present a new ‘joint inversion’ between the effects of temperature on fracture development and permeability, and how this is manifested in terms of seismic data. These newly methods will be important in interpreting seismic models of volcanic geothermal fields generated from surface instruments.