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Characterizing Rock Physical Properties in the Nevados de Chillán Geothermal System

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In geothermal systems the thermo-physical properties of the rocks change as they interact with fluids passing through the volcanic system and during discrete events such as earthquakes and magma intrusion. To characterize a geothermal system and the flow of fluid through a sub-volcanic complex, targeted rock physical tests are needed for the rocks of the area conducted at natural P-T conditions. Here, we present rock property characterization of the main geological units of the active Nevados de Chillan Geothermal System, located in the Southern Volcanic Zone (SVZ), an area with some of the largest geothermal potential in the Andes.

Six representative blocks of the geothermal host reservoir and overlying strata were collected from the volcanic basement. The main geomechanical units of this system are (from oldest to youngest): 1) andesites, tuffs and breccia of the Cura-Mallin Formation (Miocene country rocks); 2) granodiorites and diorites of the Santa Gertrudis Bullileo Batholith (15.7 Ma and 5.9 Ma, respectively); and 3) hornfels from the contact between the granitoids and country rocks. Cylindrical core samples (26 mm diameter x 65 mm length) from each block were used to quantify density, porosity, and ultrasonic wave velocities at different confining pressures. All tests were carried out at the Rock Deformation Laboratory, University of Manchester. Polished thin sections were prepared from blocks of the same orientation as the cored directions and analyzed using petrographic.

Granodiorite has the lowest porosity at between <1 to 2% and the fastest P- and S-wave velocities (5.5 to 5.9 km/s and 3.1 to 3.5 km/s, respectively). The diorite has a higher porosity of between 4 to 6% which coincides with lower ultrasonic velocities (3.5 to 5.0 km/s and 3.5 to 5.0 km/s, respectively). This can be explained by the higher presence of macro, micro-fractures, and alteration minerals in the diorite. Hornfels has possess similar porosities (>2%) to the granodiorite and 4.8 to 5.7 km/s P-wave velocities and 2.7 to 3.3 km/s S-wave velocities. The andesitic lavas have porosities ranging 3-7%, while the tuffs and breccias have porosities of 12-30%. Elastic waves

velocities in the andesitic lavas are around 2 km/s faster than the pyroclastic rocks.

Tests with cycles of increasing and decreasing hydrostatic pressure (up to approximately 150 MPa) show that granodiorite and diorite exhibit sharp increases in P-wave velocity (Vp). This is attributable to the stiffening of the rock from the progressive closure of pre-existing cracks. Above 40 MPa, the rate of increase in Vp with pressure reduces markedly, implying that the remaining porosity is less compliant. This is consistent with the maximum burial depth of the rocks suggesting that those cracks formed because of bringing the rocks to the surface.

Finally, in terms of microstructural observations, the granodiorites, diorites and hornfels have large intragranular and intergranular fractures with very high aspect ratio, which are commonly oriented and therefore impart anisotropy. In contrast, the andesitic, tuffs and breccias porosity is higher than the crystalline rocks and is mainly composed of intergranular pores with low aspect ratios and relatively isotropic.