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Elastic and Transport Properties of Steam-Cured Pozzolanic-Lime Rock Composites Upon CO_2 Injection

Dan Emery and Tiziana Vanorio
Stanford Rock Physics Laboratory, Geophysics Department, Stanford University, USA

Understanding the effect of pozzolanic ash-lime reactions on the rock physics properties of the resulting rock microstructure is important for monitoring unrest conditions in volcanic-hydrothermal systems as well as for devising concrete with enhanced performance. By mixing pozzolana ash with lime, the ancient Romans unwittingly incorporated these reactions in the production of their famous concrete. Recently, it has been discovered that a fiber-reinforced, concrete-like rock is forming naturally at depth of 1.5 km within the Campi Flegrei volcanic-hydrothermal systems due to upwelling lime-rich fluids permeating a pozzolana rich layer. This study aims to investigate possible physico-chemical conditions contributing to both enhance and undermine the properties of the subsurface rocks of volcanic-hydrothermal systems and, in turn, build upon those processes that the ancient Romans exploited to create their famous concrete. We prepared samples by mixing the pozzolana volcanic ash, slaked lime, aggregates of Neapolitan Yellow tuff, and seawater from Campi Flegrei in the same ratios as the ancient Romans. To mimic the conditions of the caldera, we used alkaline water from a well in the Campi Flegrei region rich in sulfate, bicarbonate, calcium, potassium, and magnesium ions. Yet, the samples were cured for 28 days in steam-rich environment to favor hydration and hence, enhancing the stability of calcium- alumino-silicate hydrates and setting strength of the rock samples.
We measured baseline properties of porosity, permeability, P-wave velocity, and S-wave velocity of the samples as well as imaged the fibrous microstructure. P and S-wave velocities were used to derive bulk, shear, and Young's moduli. Subsequently, samples were injected with an aqueous carbon dioxide, CO_2 (aq), solution and the changes in their microstructure and physical properties measured. Exposure of the concrete-like rock samples to CO_2 –rich fluid lowers pH below 12.5, thus affecting the stability of the fibrous calcium- alumino-silicate hydrates. Since the low permeability of the concrete-like rock samples (0.02 mD), samples were first thermally shocked while measuring the evolution of porosity and permeability as a function of the number of thermal shocks. We show that steam- and alkaline- rich environments help form an impermeable rock with enhanced elastic and thermal properties. Injection of an acidic, CO_2 -rich solution, which mimics new flux of CO_2 into a volcanic-hydrothermal system, has the potential of inducing microstructural changes due to the chemical instability of the fibrous rock matrix.