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Linking permeability to crack density evolution in thermally stressed rocks under cyclic loading

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We explore the influence of incremental crack damage induced from cyclic loading on the mechanical and transport properties of thermally stressed crystalline rocks in shallow crustal conditions that are representative for volcanic edifices and high thermal gradient in the upper crust. The behavior of a lava flow basalt from Mt. Etna volcano, containing an high level of pre-existing crack damage induced from natural thermal cooling (Mt. Etna basalt) is contrasted with the response of crystalline rock (Westerly granite) with little initial crack damage. Selected samples of Westerly granite were thermally-treated at 500° and 800°C in order to study the role of induced thermal stressing on increasing crack damage. Permeability and water volume content were measured throughout the loading history together with deformation modulus. Permeability show a reduction at low stresses followed by an increase at intermediate stresses and ultimately a steady magnitude at failure. We use water volume content as a proxy for fluid storage and show that both permeability and storage evolve with damage and evolution of crack density. We use mechanistic models of crack evolution to make constrained predictions of the evolution in porosity and permeability via equivalent medium theories. These observations are used to address important questions regarding the coupled role of damage state and stressing in controlling the transport properties of rocks.