The Campi Flegrei Deep Drilling Project: using borehole data to model caldera unrest

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Campi Flegrei is a densely populated, active caldera immediately west of Naples in southern Italy. It has a well-documented history of unrest since Roman times, involving caldera-wide uplift and subsidence with peak vertical movements on the order of 10 m. Geodetic data suggest that the unrest has been driven by changes in pressure at depths of about 3-4 km or less. The pressure change has been attributed to the intrusion of magma or to disturbances in geothermal fluids within the shallow crust. A major goal is to determine the relative contribution of each process, because the potential for eruption is significantly enhanced if magma movement emerges as the primary component.

Uncertainties in the physical properties of crustal rock at depth are a key source of ambiguity in interpreting unrest. Of particular interest are better-constrained values of permeability and rock strength, because these parameters (1) determine the efficiency of fluid flow through geothermal systems and (2) constrain the stresses required for magma intrusion. Reducing the uncertainties is a primary goal of the Campi Flegrei Deep Drilling Project (CFDDP), which is supported by the International Continental Scientific Drilling Program (ICDP). A 500-m deep pilot hole was drilled from July to December 2012, ahead of the main 3.5-km borehole scheduled for the next year.

An adapted leak off test (LOT) was performed along an 84-m free section at the bottom of the borehole, in order to measure the in-situ permeability and tensile strength of crustal material (predominantly grey tuff). The permeability test was performed by injecting water at pressures greater than hydrostatic and then recording the pressure decrease with time after the water pump had been switched off. The measurements yielded average permeabilities of $2x10^{-13}$ to $4.3x10^{-13}$ m^2. These values are larger than those obtained from laboratory samples (about 0.01-0.1 m in dimension) and represent the effective permeabilities at the length scales of at least 1-10 m that are appropriate for modelling the large-scale flow of geothermal fluids. The associated values for bulk tensile strength were 5.7-6.4 MPa. Such values are typical of the shallow crust and provide upper limits on the overpressure in a magma body than can be supported by surrounding rock without inducing bulk failure and the possibility of magma escape.