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Measuring Geomechanical Properties of Topopah Spring Tuff at the 1-Meter Scale

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Introduction

The Yucca Mountain Site Characterization Project is studying physical and chemical properties of Topopah Spring tuff and coupled thermal, mechanical, hydrological, and geochemical processes expected in the near-field environment of the potential waste repository at Yucca Mountain, Nevada. Investigating the suitability of Topopah Spring tuff as a host rock for radioactive waste disposal includes measuring mechanical properties. Since heterogeneities vary with scale, from vugs and cracks at the hand-sample scale to fractures and vertical variations in degree of welding at the outcrop scale, mechanical properties of the tuff depend on scale. The Lawrence Livermore National Laboratory has planned a Large Block Test (LBT) to investigate rock mass properties and coupled processes at elevated temperatures in Topopah Spring tuff at the scale of a few meters[1]. This paper describes planned laboratory experiments in support of the LBT, to measure elastic properties and mechanical behavior of Topopah Spring tuff at the scale of a few cm to 1 m.

We have planned a series of tests on small blocks measuring a few tens of cm on each side, to investigate thermal-mechanical, thermal-hydrological, and thermal-chemical response of the tuff to conditions similar to the near-field environment of the potential repository. The laboratory experiments will include measurement of stress-strain behavior, acoustic emissions during heating, and elastic wave velocities in small blocks of tuff having dimensions of about 0.5 to 1 m on a side.

Laboratory Experiments on Small Blocks

While the laboratory experiments are in the initial stages of sample preparation and apparatus testing, the experiment design is sufficiently new and relevant to the conference theme to merit presentation of preliminary work. Three different experiments have been designed: 1) to measure parameters needed for determining the thermal-mechanical properties of the of the rock mass; 2) to investigate effects of temperature and stress on fracture permeability; and 3) to determine thermal-mechanical response at temperatures in the range 200 - 250 °C. Table 1 summarizes parameters to be measured in a type 1 experiment and Figure 1 shows the geometry of this experiment (uniaxial compression). Measurements of stress-strain behavior and elastic wave velocities will be made at room temperature, after which a one-dimensional thermal gradient will be established in the block using heaters at the top and bottom. The sides of the block will be insulated. Temperature and stress conditions will be measured and acoustic emissions will be monitored, for conditions described in Table 1.

Of particular interest is the question of how transformations of SiO_2 polymorphs affect mechanical properties of Topopah Spring tuff. Cristobalite and tridymite are two minerals occurring in Topopah Spring tuff that may undergo phase

TABLE 1. Testing Thermal-Mechanical Response of Rock Mass

Control Parameter	Parameter Description	Data Collected
Stress Level	max. 30 MPa	Axial force
Stress Geometry	Uniaxial compression	
Stress Path	cycled loading and unloading	
Heating	1-D vertical gradient (about 16°C/m) max. temp. 150°C, rate <10°C/hr	Temperatures
Measured Parameter		
Matrix Thermal Expansion		Displacements
Rock Mass Thermal Expansion		Displacements
Individual Fractures Thermal Expansion	(depends on availability of suitable sample)	Displacements
Thermal Conductivity		Temperatures
Temperature Field		Temperatures
Elastic Wave Velocity	P and S velocities, for dynamic moduli	Wave traveltimes
Matrix Deformation Modulus		Displacements
Fracture Stiffness		Displacements
Acoustic Emissions		# of acceleration events

transformations when heated to temperatures expected in the potential repository. These SiO_2 polymorphs make up as much as 30% by volume of Topopah Spring tuff groundmass in some parts of the formation[3]. Cristobalite inverts from a tetragonal to a cubical structure at approximately 230°C (±20°C)[4], with an accompanying 5% increase in volume[5]. The tetragonal phase, α-cristobalite, has a negative Poisson's ratio for single crystals and polycrystalline aggregates[6,7], which means that rocks containing significant amounts of this mineral may have anomalously low values for Poisson's ratio. Planned laboratory tests will include monitoring acoustic emissions resulting from expected mineral phase transformations, to improve understanding of the related mechanical damage in the tuff. Stress-strain behavior and elastic wave velocities will be measured so that static and dynamic Poisson's ratio values can be determined.

Summary

Laboratory experiments on small blocks of Topopah Spring tuff have been designed to measure rock mass deformation as well as the mechanical behavior of the rock matrix and fractures under controlled temperature and stress conditions. The measurements will make it possible to estimate relative contributions of the matrix and fractures to rock mass properties, and will increase the understanding of how cracks and fractures affect mechanical properties. The various experiments address coupled processes expected to operate in the near-field environment of the proposed waste repository. Results from the laboratory experiments will aid in interpreting results of the LBT, which will have a slightly larger spatial scale of a few m, and a longer time scale of many months.

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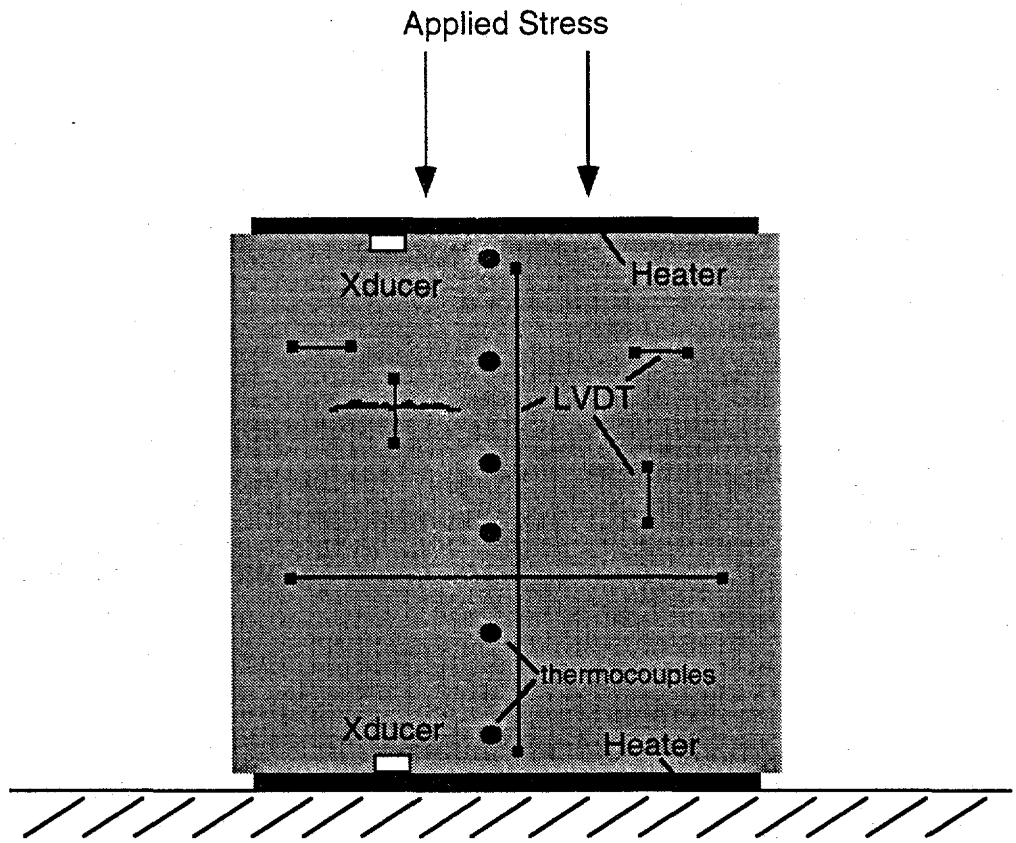

Figure 1. Schematic of test geometry for laboratory test to determine thermal-mechanical response of rock mass