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Statement of Work, University of Bristol — October 17, 2003
Contract 99035, Modification 13
CNWRA Project 06002.01.051 (Igneous Activity KTI).
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Future volcanic activity may disrupt the proposed Yucca Mountain radioactive waste repository site during the next 10,000 years. Staff needs to develop quantitative estimates of the health and safety hazards that may result from future igneous activity. In addition, staff needs to evaluate a broad range of models and data proposed by the U.S. Department of Energy to support potential licensing of the repository. A key component of the hazards analysis is understanding how rising basaltic magma may interact with subsurface repository structures, such as tunnels or drifts. Prior work at the University of Bristol focused on laboratory experiments using materials that simulate magma and drifts. These experiments investigated the dynamics of how gas-bearing and gas-free fluids similar to magmas could suddenly decompress into subsurface openings, which can accelerate and fragment the fluids. This work is directly linked to the development and verification of numerical models that represent potential decompressive flow process. The work also involves investigations of the potential circulation of bubbly magma within tunnels due to density variations caused by separation of bubbles.

The emphasis of work in FY2004 is on the conditions of sustained flow through subsurface structures. Following potential intersection of rising magma with a tunnel, a pathway will likely be established to the surface. Magma will then flow through this pathway for days to weeks, affecting the performance of engineered structures located along or near the flow path. Convective circulations may occur in magma-filled structures due to gas exsolution and segregation. Different flow regimes may develop, depending on the volume flux of magma through the system, the size of bubbles in the magma, and the geometry of flow system. The flux of magma through the potential dike may drive a recirculating flow within a drift, which may result in significant mixing between the tunnel and dike. Conversely, there may be stagnant regions where the magma has a long residence time. Vapor bubbles also will exsolve or grow from the magma. If the bubble size is large, the bubble rise speed may be large compared to the flow within a drift, resulting in significant melt-bubble separation in the drift and the formation of a coalesced foam at the drift roof. Along with bubble rise, denser (i.e., degassed) magma may drain back into the dike/conduit system and possible be re-entrained into the ascending magma flow. Time scales forbubble segregation and flow recirculation may depend critically on the geometry of potential dike-drift intersections. Staff need to consider these processes in quantifying the likely range of temperatures, pressures, and flow dynamics of magma along these potential pathways, in order to evaluate the likely impacts on waste containment structures and effects on health and safety. Work in Modification 13 will occur in FY2004 as these tasks:

1) Use experimental apparatus constructed during FY2002 at the University of Bristol to evaluate quasi-steady flow conditions for gas-bearing magma flowing through a vertical conduit abutting an open, horizontal tunnel. This task includes collaboration and coordination with consultants at Cambridge University, England, on analysis and modeling. Conduct a systematic series of experiments evaluating two-phase flow dynamics of bubbly fluids. Results are to be presented in the form of reports, journal publications, and presentations at suitable conferences.

2) Using methods developed in #1, conduct experiments to evaluate the potential for waste package damage and high-level waste entrainment in flows that may develop between vertical conduits and horizontal tunnels. Results are to be presented in the form of reports, journal publications, and presentations at suitable conferences.

3) Complete, as time and resources permit, the analysis of results from physical analog experiments conducted at CNWRA facilities. Conduct supplemental experiments to constrain pressure-volatile relationships for gum resin-acetone system. Conduct supplemental experiments to evaluate decompression effects in volatile-bearing systems using conditions comparable to FY2003 volatile-absent experiments. Support publication of results in a suitable earth science journal.

4) As time and resources permit, incorporate experimental results from #1 into numerical models, including eventual presentation of integrated results in a report suitable for submission to a scientific journal. This task includes collaboration with consultant Dr. Onno Bokhove at the University of Twente, Netherlands.

5) Provide expert advice as required on igneous activity topics, including potential support for NRC-DOE meetings. This task includes collaboration and coordination with consultants at Cambridge University, England, and the University of Twente, Netherlands, on analysis and modeling of igneous processes.

The period of performance will be from September 30, 2003 to December 31, 2004.

Documents prepared for presentation at international meetings will be transmitted to the CNWRA no less than 45 days prior to the intended submittal date for the meeting. This time is necessary to complete CNWRA internal review of the documents, and comply with NRC contract requirements for document submittal.