CENTER FOR NUCLEAR WASTE REGULATORY ANALYSES

TRIP REPORT

SUBJECT: Conduct technical meeting with consultants for magma-repository interaction investigations

DATE/PLACE: July 22–25, 2002, Bristol, England

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SUBJECT

Conduct technical meeting with consultants for magma-repository interaction investigations.

DATES OF TRAVEL AND COUNTRIES/ORGANIZATIONS VISITED

July 22–25, 2002. University of Bristol, England.

AUTHOR, TITLE, AND AGENCY AFFILIATION

Brittain E. Hill, Senior Research Scientist, Center for Nuclear Waste Regulatory Analyses

SENSITIVITY

None.

BACKGROUND/PURPOSE

As part of the Igneous Activity KTI issue resolution process, numerical and analog experimental models for the potential interactions between rising magma and proposed repository drifts are being conducted by staff and consultants at the University of Bristol, Cambridge University, and the University of Twente (Netherlands). Dr. Hill is the CNWRA principal investigator for the Igneous Activity KTI. This work directly supports the review of DOE models that demonstrably affect risk calculations for total-system performance at Yucca Mountain. The purpose of this meeting was to discuss the results of recent investigations, compare results of experimental data with model calculations, plan the next stages of work to integrate models and evaluate remaining uncertainties, and discuss approaches for presenting the results in journal articles.

ABSTRACT: SUMMARY OF PERTINENT POINTS/ISSUES

Previous investigations have shown that the initial stages of potential interactions between ascending basaltic magma and subsurface drifts likely create transient physical conditions that are within the design basis for intact waste canisters. Prolonged exposure to flowing magma, however, may result in conditions that exceed this design basis. During this meeting in Bristol, staff and consultants resolved technical review comments on an in-preparation journal article for flow processes in low-volatile magmas. They discussed the results of recently conducted low-volatile experiments for magma-repository interactions and concluded an appropriate range of physical conditions were represented. Results were analyzed from experiments on pressure-gas volume relationships for analog fluids, which will be used to test the results of numerical models. The team conducted an initial comparison of the results from high-volatile and low-volatile experiments, and determined that several additional high-volatile experiments likely are needed for an accurate comparison. They reviewed progress on the construction of experimental apparatuses to evaluate possible steady-state flow processes, including volatile segregation and potential waste entrainment effects. The team also discussed a new model for magma flow that includes elastic dike-wall

responses to various flow effects. No policy matters arose and no issues emerged that need management attention. The meetings were highly productive and achieved the goals planned for the meetings. The issue of potential magma-repository interactions is contentious with the DOE, and the ongoing CNWRA investigations are important for developing an effective NRC review capability in this area. Because these investigations are being conducted by an international research team, periodic meetings must be held to ensure that the work remains focused on emerging and risk-significant technical issues.

DISCUSSION

Previous work focused on understanding the range of physical conditions associated with the initial interaction between rising magma and a subsurface drift. In summary, this work shows that for instantaneous openings and nondegassed magmas, a transient shock wave may develop with pressures that likely exceed the hydrofracturing strength (about 5 MPa) of rock at 300 m depth. These possible 10–20 MPa pressures, however, do not exceed the apparent strength of intact waste packages. Using slower openings of fractures into drifts and allowing for degassing of the magma, transient shock pressures are likely on order of 1–2 MPa. Although these conditions lead to rapid magma flow into an intersected drift, flow rates do not appear sufficient to immediately fracture drift walls or directly disrupt waste packages.

During the previous eight months, additional experiments were conducted to evaluate potential flow effects for interaction of a volatile-free magma and subsurface drifts. These experiments capture the likely ranges of pressures and flow rates envisioned for basaltic magmas that have low abundances of gas bubbles, which might be found in degassed dike tips. The team reviewed the results of these experiments and determined that an appropriate range of physical conditions was evaluated, and that these experiments provide a basis for comparison with ongoing high-volatile content experiments. Results of these investigations will be presented in a CNWRA report on Interactions Between Ascending Basaltic Magma and Underground Tunnels, which is currently in review.

Additional experiments also were conducted in FY2002 to determine the pressure-gas volume relationships for mixtures of gum resin and acetone. These mixtures are used as analogs to gas-bearing basaltic magma. Pressure-gas volume relationships are important to quantify accurately, as they are sensitive parameters in models for decompression-induced magma flow. The team reviewed these data and determined that some kinetic effects of degassing probably were not accounted for in the experiments. Additional data analyses are ongoing to determine if the pressure-volume relationships can be modeled as a simplified system with calculated uncertainty, or if additional experiments are needed to quantify pressure-volume relationships more accurately.

The team plans to evaluate numerical models developed for magma-repository interactions using results from experimental investigations. These tests involve quantifying the model parameters from experimental data, and using the numerical models to calculate expected flow conditions such as pressure and flow rate. These modeled conditions will be compared with volatile-free and volatile-bearing experiments, and appropriate uncertainties will be quantified. The team determined that the volatile-free experiments encompass the needed range of conditions, however, several additional volatile-bearing experiments may be needed for an accurate comparison of flow processes. The team discussed how to summarize these investigations into a peer-reviewed publication, which can be used to build confidence in the modeling approach.

One concern raised with the numerical model for initial dike-drift interactions (Woods et al., 2002) is that the mechanical effects of dike opening were not evaluated. The team discussed ways to modify the initial model to account for simplified elastic dike-wall effects. These effects will allow the dike opening in the drift to be sensitive to magma flow pressure in the dike, for a range of gas contents in the magma. This approach will help determine how much magma may be diverted into an intersected drift, or would likely continue ascent without diversion into a drift. A limited scope of work is planned in FY2003, pending budget approval, to evaluate elastic dike-wall effects. The team also discussed how this work could be presented in a peer-reviewed publication.

The team reviewed progress in constructing experimental apparatuses to evaluate a range of conditions associated with sustained magma flow through subsurface structures. Previous work has focused on evaluating the initial stages of potential dike-drift interaction. If magma continues to ascend following these initial interactions, a pathway to the surface will likely develop. Sustained flow may localize on a vertical conduit, or divert horizontally for some distance down an intersected drift. For the vertical conduit, consultants at the University of Bristol are constructing a closed flow loop attached to a horizontal tube with a closed end. As fluid flows through the vertical segment of the loop, the team will evaluate the potential convection or flow effects in the horizontal tube induced by the vertical flow. A similar approach is used at Cambridge University for a model of horizontal conduit flow, except the flow loop is open through a horizontal tube. The team planned a series of experiments using a range of flow rates, fluid viscosities, and gas contents that are analogous to expected flow conditions for basaltic magmatism. They also discussed possible experiments that could use high-density materials to evaluate waste entrainment effects for these flow conditions. Initial experiments will be conducted early in FY2003, pending budget approval.

Potential magma-repository interactions are a controversial topic in the Yucca Mountain repository program. No appropriate natural analogs exist for this process, and the conditions for potential flow are complex and have large heterogeneities. In addition, the physical conditions of basaltic magmatism are not well understood, which leads to significant uncertainties in important model parameters. Nevertheless, the likelihood of these interactions occurring is greater than one in 10,000 during the 10,000 yr performance period. Staff will need to develop an independent review capability to evaluate the DOE licensing approach to evaluating these potential magmatic effects on repository performance. Because no generally accepted methodologies exist to evaluate magma rise and potential interaction with subsurface structures, staff is working with internationally-recognized experts to develop an appropriate understanding of these processes. The results of these investigations will provide an independent technical basis for staff review of the DOE license application, and allow staff to evaluate the risk significance of potential uncertainties and alternative conceptual models.

PENDING ACTIONS/PLANNED NEXT STEPS FOR NRC

NRC and CNWRA staff will coordinate development of FY2003 operations plans by setting priorities for remaining investigations within available resources. Because the goal of this task is to complete all technical investigations by the end of FY2003, an additional meeting with the consultants is likely necessary in the Spring of 2003. This meeting will ensure that final investigations are addressing risk-significant processes, and allow for discussion of emerging issues from the DOE program.

POINTS FOR COMMISSION CONSIDERATION/ITEMS OF INTEREST

As an item of potential Commission interest, results of some initial investigations were published in *Geophysical Research Letters* on July 11, 2002. Although this report has received adverse comments from some consultants to the NWTRB and ACNW, model and parameter justification appears sufficient to warrant publication in this peer-reviewed journal. Staff anticipates that the DOE will soon conduct investigations to evaluate these processes. Based on the potential risk significance of magma-repository interactions, developing an adequate review capability in this topic remains a high priority in planned CNWRA investigations.

ATTACHMENTS

None.

"ON THE MARGINS"

None.

SIGNATURES:

Brittain Hill
Senior Research Scientist

August 16, 2002
Date

CONCURRENCE:

Larry McKague, Manager
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08/16/02
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