CENTER FOR NUCLEAR WASTE REGULATORY ANALYSES

TRIP REPORT

SUBJECT: Meeting with magma-repository interaction consultants

DATE/PLACE: September 24–26, 2001, University of Bristol, Bristol, England

AUTHOR: Brittain Hill

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PERSONS PRESENT: Prof. Stephen Sparks, Dr. Anne-Marie LeJeune (University of Bristol), Prof. Andrew Woods (BP Institute, Cambridge University), and Dr. Onno Bokhove (University of Twente)

BACKGROUND AND PURPOSE OF TRIP:

Rising basaltic magma is a pressurized fluid, with sufficient force to fracture rock and dilate the fractures to widths of 1 meter or more. In the unlikely but credible event that rising magma intersects proposed high-level waste repository drifts at Yucca Mountain, staff will need a technical basis to evaluate the range of possible magma-repository interaction effects. NRC and CNWRA staff have been working with consultants at the University of Bristol, Cambridge University, and the University of Twente to develop and test models for likely magma-repository interaction processes. Current NRC and DOE models show these potential effects can significantly affect risk calculations for the proposed repository system.

There are no known natural analogs for a basaltic dike intersecting a relatively large, open cavity hundreds of meters below ground. Understanding the potential risks to public health and safety from this process will require development and verification of models that examine a range of igneous conditions and repository designs. Because there are no unique solutions to the evaluation of this process, staff will need to independently develop and test models in order to review DOE work. In addition, independent investigations will likely result in alternative conceptual models for magma-repository interactions, which will need to be assessed for risk significance. These independent investigations will build confidence that the NRC is using a range of scientific methods to understand potential risks, and provide a defensible technical basis for licensing decisions should the DOE submit a License Application for Yucca Mountain.

SUMMARY OF PERTINENT POINTS

Hill traveled to Bristol, England on September 24–26, 2001, to meet with the consulting team. We reviewed the results of ongoing dike-drift experiments using a gas-poor syrup as an analog for rising basaltic magma. By measuring flow processes and rates across different pressure gradients in the experimental apparatus, we are able to quantify decompression effects if a confined, pressurized fluid (e.g., magma) intersects an open drift 300 m below the Earth's surface. Additional decompression experiments are planned for later this year with a gas-bearing syrup, which is more analogous to the water-bearing magmas in the Yucca

Mountain region. Results of these experiments are being combined with numerical models for decompression-induced flow effects. After reviewing the collected data, we planned additional experiments to provide the range of data needed to support the numerical modeling.

Previous work has 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 10–40 MPa pressures, however, do not exceed the apparent strength of intact waste packages. For slower, more realistic openings of fractures into drifts and allowing for moderate degassing of the magma, transient shock pressures are likely on order of 1–2 MPa. Although these lower-pressure conditions still lead to accelerated magma flow into an intersected drift, flow rates do not appear sufficient to immediately fracture drift walls or directly disrupt waste packages. A limited scope of work is planned in fiscal year 2002 to complete studies of the initial magma-repository interaction effects. We will finish calculations bounding the lower-pressure physical conditions and document these calculations in a short publication. Plans were developed for completing gas-bearing analog experiments this year in San Antonio. We will model the results of these experiments using the methods described in Bokhove and Woods (2000). Depending on available resources, we plan to summarize the results of the experiments and modeling in a focused, peer-reviewed publication.

The second focus of the meeting was to discuss a range of possible conditions associated with sustained flow of magma through or near proposed repository drifts. If rising magma reaches the Earth's surface, a preferred flow path will localize in the subsurface. This flow path may pass vertically through the proposed repository drifts, or perhaps be deflected horizontally through a part of the drift system (e.g., Woods et al., 2001). These alternative pathways may create significantly different high-level waste source terms for a volcanic eruption. A key process to understanding the flow phenomena is evaluating how gas may segregate from the magma in response to the different pathways. Gas segregation could result in convective circulation effects near the conduit, or keep high-level waste from potentially disrupted waste packages out of the dispersed volcanic tephra. In addition to flow segregation, likely pressures and temperatures in the flow are important to constrain in order to evaluate waste package response to a sustained igneous event. Work planned for fiscal year 2002 will evaluate the two principle flow pathways through a combination of numerical and analog experimental models. Analog experiments at the University of Bristol will focus on the development of a vertical conduit through a subsurface drift. This work will evaluate the potential for magma circulation in the drift, which is induced by the dynamics of flow in the intersecting vertical conduit. Analog experiments at Cambridge University will examine flow processes associated with a segment of horizontal flow through a proposed drift. The goal of this work is to better understand how gas may separate from magma in the horizontal flow pathway, potentially leading to separate two-phase flow regimes. If these regimes are stable, the resulting stratified flow may have limited ability to entrain waste in the dispersive phase of the eruption. In contrast, quasi-stable flow may lead to convective overturns within the system, facilitating waste entrainment and dispersal. Both experimental systems will be modeled numerically, expanding on methods developed in previous work at the University of Twente.

In addition to the technical discussions, we reorganized the in-progress milestone "Interactions between ascending basaltic magma and underground tunnels" (IM 01402.461.150). This report will present the results of analog experiments for initial flow conditions with a gas-poor syrup.

We also discussed ways that models may need to evaluate a range of DOE repository designs, and addressed several contracting and quality assurance issues. Several of the consultants may visit the CNWRA during late November or early December 2001, in conjunction with other trips.

CONCLUSIONS:

Investigations on the initial stage of potential magma-repository interactions have bounded a range of likely shock pressures and flow rates. Under some conditions, the initial flow of magma into an intersected drift may create transient pressures that exceed local wall-rock strength but do not exceed the apparent strength of intact waste packages. Other conditions that appear more realistic result in significantly lower shock pressures, which do not exceed local wall-rock strength. Verification of numerical models with analog experimental results in fiscal year 2002 will essentially complete this part of the magma-repository investigation. The emphasis of work in fiscal year 2002 is to better understand the effects of sustained magma flow through different pathways that intersect proposed repository drifts. A series of analog experiments and numerical models are planned to evaluate flow processes for (i) a vertical subvolcanic conduit that intersects a horizontal drift, and (ii) a segment of horizontal flow through an intersected drift, with vertical flow above and below the drift horizon. These investigations will provide a technical basis to evaluate the possible range of source-terms for igneous event risk calculations, and review DOE work in this area during fiscal year 2002.

PROBLEMS ENCOUNTERED:

None. Airline travel between Dallas-Fort Worth and London Gatwick was easy and new security precautions added about 30 minutes additional time for baggage check-in and gate security.

PENDING ACTIONS:

I will keep staff informed about the possibilities of meeting with consultants during their potential visits.

RECOMMENDATIONS:

Interested staff should plan to meet informally with CNWRA consultants during their site visits in late November to early December, 2001. Staff could discuss the results of recent and ongoing investigations, and likely participate in an experimental run.

REFERENCES:

Bokhove, O. and A.W. Woods. "Explosive Magma-Air Interactions by Volatile-Rich Basaltic Melts in a Dike-Drift Geometry." IM 20.01402.461.040. San Antonio, Texas: CNWRA. 2000.

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