CENTER FOR NUCLEAR WASTE REGULATORY ANALYSES

TRIP REPORT

SUBJECT: Foreign Trip Report for Brittain E. HIll
AI 06002.01.301.502

DATE/PLACE: October 8–17, 2004
Bristol (University of Bristol) and Cambridge (Cambridge University), England

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

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PERSONS PRESENT: Brittain E. HIll

SENSITIVITY:
Not applicable.

BACKGROUND AND PURPOSE OF TRIP:
Rising basaltic magma is a gas-rich pressurized fluid, with sufficient force to fracture rock and dilate the fractures to widths of 1 meter [3.3 feet]. Although the likelihood is relatively small for rising magma to intersect the potential Yucca Mountain repository site, the radiological consequences of magma intersection appear to be relatively high. To review a U.S. Department of Energy (DOE) license application for Yucca Mountain, staff will need an independent technical basis to evaluate the potential effects of rising basaltic magma interacting with subsurface repository systems. Because these effects are not discussed in the scientific literature, U.S. Nuclear Regulatory Commission (NRC) and Center for Nuclear Waste Regulatory Analyses (CNWRA) staff have been working for several years with consultants at the University of Bristol, Cambridge University, and the University of Twente (The Netherlands) to develop numerical and analog experimental models for potential magma-repository interaction processes. Previously completed investigations indicate that magma-repository interaction processes may have the potential to disrupt significantly more waste packages than modeled by the DOE. Thus, the ongoing investigations directly affect staff reviews of processes that have high significance in performance calculations for the proposed repository site. The results from this team investigation also support the NRC goals of ensuring openness in regulatory processes and effectiveness in NRC actions through use of realistic models.

ABSTRACT:
Ongoing technical investigations by consultants to the CNWRA remain focused on evaluating risk significant processes associated with potential magma-repository interactions at Yucca Mountain, Nevada. Recent investigations developed a technical basis to evaluate possible fluid exchange processes between a vertically flowing volcanic conduit and a horizontal drift. Because magma has abundant gas bubbles, horizontal flow results in bubble rise and creation

of a foam layer. Models indicate that this foam layer could form along hundreds of meters of a potentially intersected drift during the first several days of an igneous event. Density differences arising from gas segregation likely create a return flow into the erupting volcanic conduit. Models of this return flow, however, indicate very low flow velocities, which appear insufficient to disaggregate waste packages or entrain significant amounts of material. Additional models were developed to evaluate potential flow processes if the horizontal flows created a secondary pathway to the surface, away from the main vertical conduit. These types of secondary pathways are sometimes observed at erupting volcanoes. Pressure variations and flow conditions along these secondary pathways may be sufficient to disrupt waste packages and entrain high-level waste. Tephra deposits from the potential secondary pathways may have relatively limited dispersal, due to degassing effects during horizontal flow. These localized deposits, however, may serve as an enhanced source-term for surface remobilization processes that occur after a potential volcanic eruption. The completed investigations provide staff with the technical basis needed to support a high quality review of magma-flow models in the anticipated DOE license application for Yucca Mountain. No NRC policy matters were discussed during this trip. The meetings were productive and significantly enhanced staff understanding of recent advances in information used to evaluate subsurface magma-flow processes. Group meetings such as these are necessary to integrate the results of multidisciplinary team investigations into products that directly support the review of high significance uncertainties associated with risk assessments for potential igneous events.

DISCUSSION:
The purpose of this trip was to meet with a team of consultants from the University of Bristol, Cambridge University, and the University of Twente who have been conducting investigations of potential magma-repository interaction processes. Goals of the trip were to discuss the results of recently completed analog experiments and numerical models, verify that models are evaluating appropriate conditions for the proposed repository system, plan the preparation of reports, and assure that investigations continue to focus on key licensing issues affecting performance calculations.

Work at Bristol University in fiscal year 2004 continued to evaluate potential fluid dynamic effects for sustained magma flow in a vertical conduit that potentially intersects a horizontal tunnel. Because magma is a gas-rich fluid, any magma that potentially flows into a horizontal drift will likely form a foam layer through buoyant rise and coalescence of gas bubbles. However, the potential for mixing these different density zones, and possible effects on eruption characteristics, are poorly constrained. Recently conducted experiments with low bubble volumes show that density differences between degassed magma and foam layers can create return flows from the drift into the erupting conduit. Development of the upper foam layer depends on the gas volume and viscosity of the magma. Modeling of experimental results shows that for conditions representative of potential basaltic igneous events, a foam layer on the order of 1-meter [3.3-feet]-thick could develop along hundreds of meters of a potentially intersected drift during the first several days of the igneous event. Thus, return flows between the potentially intersected drift and the vertical conduit would likely occur. Initial calculations for low bubble contents, however, indicate that in unobstructed drifts (i.e., no engineered materials or rock rubble), velocities of the return flows may be on the order of 1–10 mm/s [0.003–0.03 ft/s]. These velocities do not appear sufficient to disrupt relatively intact waste packages or affect eruption characteristics significantly. The team planned several additional experiments to more fully evaluate the range of conditions appropriate for potential magma-repository interactions, including high bubble contents, and outlined a final report to document the results of these investigations.

In addition to the sustained flow experiments, investigations for quantifying pressure-gas content relationships for magma decompression experiments were completed this year. Three high-pressure experiments were completed for the initial decompression of magma into a horizontal tunnel. Several additional experiments were planned to examine decompression effects of gas-bearing magmas, which supplement the gas-absent experiments completed last year. Results of these final experiments will be evaluated using previously developed numerical models for decompression-induced flow.

The team evaluated review comments received on two journal articles for magma flow processes in elastic-walled dikes. All comments were successfully addressed by the authors, and revised manuscripts should be resubmitted within the next month. The team discussed initial results from the application of numerical models for magma flow in elastic-walled dikes to conditions appropriate for potential interactions with drifts. These initial models show complex interrelationships between magmatic pressures in the dike, elastic strains in the wall rock, and decompressive flow effects into the drift. Preliminary model results show potentially significant variations in pressure may occur during potential magma-repository interactions. Variations in magma pressure can affect models for waste package response to igneous conditions. These pressure variations also affect models for the formation of secondary magma breakouts from potentially intersected drifts.

Dr. Hill also traveled to Cambridge University, to further review modeling and experiments conducted during fiscal year 2004. This work focused on evaluating fluid-flow processes for potential horizontal diversions of magma through repository drifts, with subsequent vertical break-outs. Several igneous processes could lead to the formation of secondary flow pathways along drifts during a potential volcanic event. If such secondary pathways formed, more high-level waste could be entrained along a possible drift pathway than encountered by a simple vertical conduit. Recently completed experiments and numerical models help evaluate the flow characteristics that might develop if such secondary pathways formed during a possible igneous event. Although these flow characteristics are strongly dependent on assumptions of the gas content in the magma, potentially significant overpressure may develop in the subsurface magma system. Depending on the geometry of the secondary pathway relative to the main vertical conduit, gas-rich or gas-poor magmas can segregate from the main conduit into the secondary pathway. Although the flow rate into the secondary pathway may be slow relative to the ascent rate in the vertical conduit, fluid pressures will rapidly equilibrate between the vertical conduit and horizontal flow path. Thus, conduit overpressures and underpressures can propagate along the secondary flow pathway, causing variations in magma-flow processes that are similar to initial magma ascent processes. These types of secondary flow processes have been observed at some basaltic volcanic eruptions. Due to gas segregation effects, however, flows from secondary pathways appear relatively less dispersive than flows from the main vertical conduit. A report to document the results of these investigations is in development.

While at Cambridge University, Dr. Hill met with former CNWRA consultant Dr. Peter Baxter, who is an internationally recognized expert in the effects of volcanic hazards on human health. Data from the 1995–present Montserrat volcanic eruptions are being used to characterize airborne particle concentrations following a potential volcanic event at Yucca Mountain.

Dr. Baxter reports that many of the ash deposits at Montserrat developed a hard surface layer, which greatly inhibits the resuspension of particles. This layer is relatively an unusual feature for volcanic ash deposits, and only forms when there is an abundance of readily soluble minerals in the ash. Montserrat ash consists of significant amounts of pulverized dome rock, which contains these soluble minerals. These types of conditions, however, do not occur in basaltic ash deposits like those characteristic of past eruptions in the Yucca Mountain area. Because this surface layer at Montserrat began to develop within the first year of deposition, post-eruption ash resuspension measurements at Montserrat may not be representative of expected conditions following a potential igneous event in the Yucca Mountain region.

As a result of the completed investigations, staff has developed an extensive technical basis for the review of hazard models for potential magma-repository interactions at Yucca Mountain, Nevada. This technical basis will guide staff reviews of anticipated models and analyses by the DOE, which likely will be used in the forthcoming license application. Based on these investigations, staff has an enhanced ability to independently evaluate the risk significance of uncertainties related to proposed magma-repository interaction models and determine the significance of viable, alternative conceptual models.

PENDING ACTIONS/PLANNED NEXT STEPS FOR NRC:
Statements of work are being drafted for proposed fiscal year 2005 investigations. These investigations focus on conducting a limited number of experiments to represent a complete range of physical conditions representative of the potential repository at Yucca Mountain. Limited support also is needed to document and present the results of completed investigations. Staff plan to confer with consultants once the anticipated license application is submitted, and determine the scope of potential support for the license application review.

POINTS FOR COMMISSION CONSIDERATION/ITEMS OF INTEREST:
Staff has developed an independent technical basis to review DOE models for high level waste source terms during potential igneous events at Yucca Mountain, Nevada. Consistent with Commission guidance on the use of risk insights, these investigations focused on uncertain processes with potential for high significance to risk calculations. Alternative conceptual models for magma-flow processes during potential igneous events may significantly affect the performance calculation.

ATTACHMENTS:
None.

“ON THE MARGINS”:
None.

SIGNATURES:

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Date

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