UNITED STATES
NUCLEAR REGULATORY COMMISSION
ADVISORY COMMITTEE ON NUCLEAR WASTE
WASHINGTON, DC 20555 - 0001

ACNW R-0240

June 8, 2006

The Honorable Nils J. Diaz
Chairman
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

SUBJECT: FUTURE VOLCANISM AT YUCCA MOUNTAIN - COMMENTS ON THE IGNEOUS INTRUSION SCENARIO

Dear Chairman Diaz:

During its 168th and 169th meetings, the Advisory Committee on Nuclear Waste (ACNW) was briefed on modeling of processes related to the potential risk from igneous activity at the proposed Yucca Mountain repository. An accompanying letter deals with a recent report on fluvial redistribution of contaminated tephra (ash) in the vicinity of the proposed Yucca Mountain repository. This letter reports the ACNW's observations and recommendations on briefings during both meetings by the Electric Power Research Institute (EPRI), a consultant to the Center for Nuclear Waste Regulatory Analyses (CNWRA), and a consultant to the ACNW that pertain to the igneous intrusive scenario. The ACNW finds that progress is being made in studying this scenario and its potential impact on risk to the Reasonably Maximally Exposed Individual (RMEI). As suggested in ACNW's letter of December 9, 2005 to the Commission, the NRC staff should give increased consideration to the intrusive scenario which involves rapid solidification of magma intruding the waste emplacement drifts.

Two principal scenarios are associated with potential igneous activity relevant to the proposed Yucca Mountain repository. The volcanic (extrusive) scenario in which the waste encountered by intruding magma is carried to the surface and distributed over the surrounding region in the volcanic tephra (ash) has been the subject of intensive study. However, the intrusive release scenario could also be important to risk because of premature release of radionuclides to the groundwater from waste containers damaged by the magma and the possibility that radionuclides encountered by intruding magma would be released to the surface at flank eruptive vents.

At the 168th meeting of the ACNW a representative of the Electrical Power Research Institute (EPRI) discussed their recently released report on the consequences of a hypothetical future intrusive igneous event at Yucca Mountain (EPRI, 2005). In addition, at the 169th meeting of the ACNW two briefings were presented that pertain to specific aspects of the intrusive release scenario. A consultant to the CNWRA briefed the ACNW on studies performed by the CNWRA on "Modelling the Dynamics of Simultaneous Flank and Summit Eruptions of Basaltic Magma" and a consultant to the ACNW reviewed the interim results of a continuing ACNW study on the effects of magma solidification on interactions with the proposed repository and the waste containers.

EPRI Intrusive Scenario Study

EPRI in their report on the intrusive scenario considers that previous estimates of magma ascent rate and temperature of a basaltic dike intersecting the proposed repository have been overestimated. Based on the work of Nicholis and Rutherford (2004), EPRI concludes that magma crystallinity and viscosity would be much higher than previously assumed, resulting in rapid solidification of magma if it enters the repository drifts. As a result, magma could have limited penetration into the waste emplacement drifts and only a relatively small number of waste containers could be directly contacted by magma. EPRI predicts that some waste containers located on both sides of a magma plug would be likely to fail early due to high temperature effects. EPRI's performance assessment indicates that probability-weighted dose due to magma intrusion would be less than for the nominal (base) case. EPRI has therefore concluded that the probability-weighted doses would comply with regulations and that no further activities need be pursued to address the intrusive igneous scenario.

Observations:

1) The intrusive scenario evaluated in the EPRI report addresses some of the concerns raised in the December 9, 2005 ACNW letter to the Commission related to rapid solidification of magma intruding into the waste emplacement drifts of the repository and the resulting limited impact upon the waste containers.

2) The EPRI report suggests that the position of the NRC with respect to the effects of intruding magma upon the waste containers and the potential for flank vents carrying contaminated waste to the surface may be overly conservative.

Recommendation:

The EPRI report on the intrusive-release scenario presents a viable alternative concerning the impact of intruding magma on the repository and waste containers. As such it should be evaluated by the NRC staff as an alternative to their current position on the interaction between intruding magma and the Yucca Mountain repository and in particular with regard to the number of containers damaged.

CNWRA Modeling of Simultaneous Summit and Flank Eruptions

Many basaltic volcanic eruptions involve the simultaneous discharge of magma from multiple vents with a range of eruption styles and rates including both violent explosions and effusive lava flows. The CNWRA's study (Woods et al., 2006) reviews simultaneous flank and summit eruptions at analog basaltic volcanoes and investigates partitioning of magma flux, and thus the relative importance of explosive discharge versus effusive lava flows, between summit and flank vents. Woods et al. used both numerical and experimental modeling to study the key controls on the flux partitioning. The authors state with reference to their experimental studies, "Although the effects of two-phase flow are difficult to evaluate with tractable numerical models, analog experiments can provide useful insights on the effects of gas and magma segregation on flow partitioning." The experiments primarily measure the flux of water under pressure through simulated summit and flank vents with varying concentration of air bubbles in the water. The results of the CNWRA study, although admittedly simplified from actual conditions, illustrate how the elevation differential of the vents and the distance of flank vents from the main (summit)

magma conduit, as well as the volatile content of the magma and the partitioning of the volatiles between the vents control the relative eruption rates between summit and flank vents. In the introduction to this briefing a staff member from NRC's Office of Nuclear Material Safety and Safeguards described this as an interim study which to date has not led to published conclusions regarding its impact on risk from igneous activity at Yucca Mountain.

Observations:

1) The results of the CNWRA modeling of simultaneous summit and flank eruptions will be of interest to the wider community of volcanology.

2) The results of the study may be of limited importance and use in evaluating the dynamics of and risk from intruding magma at Yucca Mountain because of differences between the study models and the actual geological situation as noted during the presentations and recognized in the report.

Recommendation:

If further modeling of simultaneous eruption from summit and flank vents is conducted it is important that a clear connection be established between the experimental conditions and those anticipated in an actual intrusive igneous event at the proposed Yucca Mountain repository.

Solidification Effects on Magma/Repository Interactions

A consultant to the ACNW presented an interim report of the characteristics of the Yucca Mountain basaltic magmas, including the characteristic rheology, solidification of these magmas upon reaching the surface, and the potential impact of their solidification on the proposed repository and its contents. The basaltic magma typical of this region when deep in the crust is likely to contain 2-4 % (by mass) dissolved volatiles (principally H_2O and CO_2) which significantly affects the crystallization and viscosity of the magma. The temperature of crystallization is lowered and the viscosity of the magma is reduced at depth by the presence of volatile species, making the magma more mobile. As the magma approaches the surface, and the prevailing pressure decreases to 1 atmosphere, these volatiles escape from the magma which then undergoes rapid crystallization and a large increase in viscosity, which strongly reduces its mobility.

The ACNW consultant has examined the change in magma viscosity with depth and has shown that the magma viscosity is likely to be a factor of about 10^6 larger than in the subsurface when the magma reaches the surface and the repository drifts. Thus lava may only travel 10 meters or less into a repository drift instead of flowing long distances. The effect of this lava quenching on the surface of a waste container is that approximately a 10 cm thickness of quenched glassy lava forms in about a minute. The consultant also presented several examples of similar quenching of magmas that have been observed in nature.

The ACNW and its consultant hold differing views from the NMSS staff regarding whether magmas reaching the surface remain high in dissolved volatiles and thus retain their mobility. The ACNW consultant pointed out that the volatiles are present as bubbles that have exsolved from the magma and that the magma itself is low in volatiles and thus magma mobility is markedly decreased. This view was supported by the volcanology consultant of the Nuclear

Waste Technical Review Board who participated in the discussion based on his studies of the volatile content of volcanic rocks. The staff alternatively supports the view that such magma remains mobile at atmospheric pressure.

Observations:

1) A scenario in which modification of basaltic magma viscosity occurs upon encountering the proposed repository leading to limited flow (< 10 meters) of the magma into the repository and rapid quenching of the magma around waste containers is viable and needs to be considered.

2) There is growing evidence that a failure to consider rapid solidification of magma on entering the proposed repository and encountering waste containers may lead to a conservative estimation of risk from igneous activity at Yucca Mountain.

Recommendation:

Consideration should be given to the potential for increased viscosity of basaltic magma at Yucca Mountain reaching the repository when evaluating the effect of magma flow into the repository, the partitioning of magmatic flux between summit and flank vent eruptions, and the risk from igneous activity to the RMEI associated with the repository.

Sincerely

/RA/

Michael T. Ryan
Chairman

References:

1. EPRI (Electric Power Research Institute), Program on Technology Innovation: Potential igneous processes relevant to the Yucca Mountain repository: Intrusive-release scenario, EPRI Tech. Rept. 1011165, 2005.

2. Nicholis, M.G. and M.J. Rutherford, Experimental constraints on magma ascent rate for the Crater Flat volcanic zone Hawaiite, *Geology,* 32(6), 489–492, 2004.

3. Woods, A., C. Gladstone, and B. Hill, Dynamic controls on summit and flank eruptions of basalt, submitted to Bulletin of Volcanology, 2006.

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