Summary Report to NWTRB
Regarding the
Igneous Consequences Peer Review Report
and
Related Presentations of February 26, 2003

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This report summarizes conclusions regarding the potential consequences of igneous intrusion at the proposed Yucca Mountain repository (YMR). Comments are based on review of the "Igneous Consequences Peer Review Report," and related presentations of February 26, 2003.

1. General Comments

The[1] five-member panel comprises members with expertise in volcanology (3), fluid mechanics (1) and solid mechanics (1). The expertise of the individuals is complementary, stretches between disciplines, and all are established scientists in their respective disciplines. This expertise adequately covers the knowledge set required to describe the processes governing either the intrusion process (Chapter 2[2]) or the likely chronology of the dike intersection and ensuing eruption (Chapter 3). In this aspect, the report contains many original analyses to constrain the likely response of the repository to igneous intrusion. These analyses are useful in that they largely confirm the DoE project team's views of likely processes and add some constraint to potential outcomes. The analyses of the more intractable problem of flow localization effects, the ensuing impact on the inventory of the proposed repository (Chapter 4), and related effusive processes, is less well constrained. This required characterization of anticipated waste transport processes, stretches the expertise of the panel beyond its mandate, and few insights, over prior TSPA evaluations, are forthcoming.

The panel has dispensed its charge with impartiality, in the best scientific tradition, and has produced a thoughtful and high quality report.

2. Principal Contributions, Conclusions and Recommendations of the Panel

The panel has provided a critical and independent review of current understanding of recent intrusive and extrusive processes at Crater Flat, and reinforced its validity as the most useful analog to anticipated behavior at the potential YMR.

The panel has considered the modes of likely dike-repository interaction in exhaustive detail. The potential modes of dike-rise are consistent with prior DoE views of ascent, and controls on this ascent. *A significant new observation, over prior reports, is the incorporation of the differentially-pressured tip cavity at the leading edge of the propagating dike, some controls on its size, and the implication that this tip cavity may have on the ultimate timing and form of interaction with the repository structure.* Specifically, the tip-cavity length is demonstrated to be expected of the order of 10 m (hot repository) to 200 m (cold repository), giving a few 10s to 100s of seconds delay before the magma front reaches the repository, after the fracture tip has already passed. For the cold repository, the tip cavity is long, and the dike aperture at the magma front wide; thus, although the arrival of magma at the drift is much delayed, its entry into the drift occurs without major constriction at the drift-dike intersection, and potentially with the tip having

[1] Italics represent the opinions of the author.
[2] Final Report of the Igneous Consequences Peer Review Panel, February, 2003.

already ruptured the ground surface. Conversely, for the hot repository, the tip cavity is short, but the dike aperture at the magma front narrow; thus, although the arrival of magma at the drift is little delayed, its entry into the drift occurs with major constriction at the drift-dike intersection. This constriction will develop large viscous losses in the flowing magma, and reduce the potential for explosive impact upon ingress. The extended length of the tip cavity for the cold repository, and the reduced aperture of the tip zone for the hot repository, act similarly to reduce the severity of the explosive impact upon magma ingress to the repository, over the case where this intersection is concurrent with tip-intersection. *These observations place important bounds on initial and boundary conditions that must be utilized in realistic models to describe intrusion into the drifts. These outcomes will be further quantified by the computational fluid dynamics analyses planned by DoE.*

The potential role of thermal effects in influencing dike interaction in the early-life of a repository is also noted. The peak change in horizontal stress is estimated by the panel to be of the order of 10 MPa, and is consistent with anticipated near-repository temperatures, and reported coefficients of thermal expansion and deformation moduli *(these material properties are not documented in Table 1-2, with the other contributing parameters - this reviewer could not find them elsewhere in the report – although a stress augmentation of 10 MPa is of the order anticipated). This represents a feasible upper bound, although ultimate lateral stresses may be moderately reduced over this, if repository-driven thermal circulation in the compression band is significant – fluid circulation may remove propping asperities in fractures, and ameliorate the stress gain.* As noted by the panel, these stresses may affect ingress of the dike into the drift, and egress from it, in a mechanistically predictable manner. The development of a thermally stressed repository block will affect the penetration of a dike, as previously noted. Rock structure and the layout of the repository will affect the ability of the thermal collar to retard ingress or egress of the dike, although these effects are local, relative to the anticipated large lateral extent of the dike. These stress changes are anticipated of the order of a few MPa, and leave the development of a dog-leg or a sill as low likelihood but feasible outcomes.

This improved characterization of the likely interaction of the tip cavity with the repository will aid in the development of the consequences of this intersection. However, all previously considered forms of potential dike-repository interaction remain viable, inclusive of the dog-leg, the underlying sill, and influence of preexisting faults and topography in conditioning the anticipated form of dike intersection with the repository, and the resulting consequences of that intersection. General evaluations of the likelihood of various scenarios are provided by the panel, based on contemporary understanding of this intersection.

3. Important Gaps in the Panel Report

The potential modes of interaction in the ambient and elevated thermal condition have been confirmed with thoughtful scoping models. However, feasible remain all prior ingress and egress scenarios, including the largely disruptive "dog-leg" and "underlying sill[3]" behaviors, although the panel attributes an anticipated low probability to these scenarios. *By their nature, these scoping studies are absent the effects of structure (viz. large scale sub-vertical faults and other features), and topography, each of which may exert unquantified control on the final form of the interaction.*

[3] An underlying sill could result as the major principal stress switches from vertical to horizontal within the repository zone, as the repository heats. An underlying sill would develop a magma pool beneath the repository that could underlie a large number of drifts, and could consequently egress into a substantial number of these drifts.

The analysis of dike-repository interaction modes is extensive, and provides a basis for rationalizing anticipated outcomes of this interaction. The evaluation of in-drift interaction of the magma with the waste packages, their potential for rupture, and the constraints on the transport of the package contents to the surface remains poorly constrained. No significant findings over prior TSPA evaluations are provided.

4. Specific Comments on Analysis, Conclusions, and Recommendations

A. Volcanological setting, eruption chronology, and magma and rock properties.

The review of data on likely magma properties, and their extrapolation to expected fluid-mechanical properties at the repository level is well advanced. The review largely confirms the DoE team's prior evaluations.

B. Dike propagation, significance of tip cavity, and dike/drift interactions.

The form of the tip cavity is likely to exert a considerable effect on the form of the anticipated dike/drift interaction, as it controls both the timing of magma arrival into the drift, and the shape and size of the fissure through which the magma must pass. *The form of this anticipated intersection is rationalized in great detail in the peer-review report, as summarized in Section 2, of this report.*

C. Dog-leg scenario and its likelihood.

The panel concludes that the dog-leg scenario remains a viable form of interaction – although of unquantified small likelihood. Following the intersection of magma with the drifts, their filling is likely, as a magma column driven to the ground surface will preferentially fill the intersected drift conduits. Determining whether breakout may occur to the surface, remote from the initial intersection, may be determined by examining likely conditions along the drift. As noted in the panel meeting, these would include sequentially examining the potential for the pressured magma to break from the drift, the likelihood that the evolving fracture suffers thermal termination, and the influence of these factors on the local magma pressure that in turn drives the new fracture. These factors conspire to make egress to the surface of low likelihood, but potentially quantifiable for end-member behaviors and with the geometry of the proposed repository defined.

D. Eruptive characteristics, waste entrainment and ash dispersal

These aspects remain weakly constrained, and rely largely on observations of past activity at Crater Flat and other sites, absent interaction with an underlying repository.

5. Based on the Peer Review Panel and your own evaluation, what is the current status of the Woods et al (2002) model and its different components (e.g., generation of shock waves, the dog-leg scenario)?

Based on reduced estimates of more realistic magma overpressures at the time of intersection, the influence of the tip cavity in providing a delay for this ingress relative to the time of tip intersection, the limiting strength of the drift to gas ovepressurization, and the non-ideal conditions for shock-wave development, the evolution of massive gas overpressures seems unlikely. This low likelihood may be confirmed by current DoE studies, in progress.

As discussed previously, the likelihood that a dog-leg develops is not discounted, although the arguments related to tip cavity geometry and length, make the manifestation of this scenario progressively less likely.

6. What Additional Investigation Could Provide Significant Benefit to our Understanding of, and the Estimation of, the Risk from Igneous Activity at Yucca Mountain?

The panel has thought in great detail about the issues relating to dike-repository interaction. Eliciting some of the panel, relative to their respective areas of expertise, may be a useful mode to end the review. Importantly, this would enable probabilities to be attached to the descriptive terms used to define event likelihoods, reported in the panel report.

Respectfully submitted. Derek Elsworth