REVIEW OF ANALYSIS AND MODEL REPORTS (AMRs)

- Dike Propagation Near Drifts -- ANL-WIS-MD-000015

OVERVIEW

Included in the packet are each of the original AMRs, a copy of each with my brief annotations and a summary sheet for each that reveals the purpose and principal conclusions, as excerpted from the original, as well as my comments.

The AMRs were reviewed during October 2000. Each of the AMRs relies principally upon geologic data, much of which is derived from field studies. In view of the lack of 1) extensive, three-dimensional rock exposures and 2) full geochemical, chronologic, petrologic and other information necessary to completely characterize the geologic evolution of this region, the analyses and models are heavily dependent upon well constrained interpretations. In general, thorough and fully considered analyses are contained in this group of AMRs. My comments generally reflect a difference of opinion leading to an alternative interpretation rather than an error or omission in the AMR.

DIKE PROPAGATION NEAR DRIFTS
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INTRODUCTION

Two basic conceptual models of how a dike and drift may interact are analyzed.

1) The drift is a relatively insignificant heterogeneity in the rock, which is intersected and otherwise provides no interaction with the dike as it propagates to the surface. Essentially, the forces driving propagation of the dike are so large that the drift is only a minor perturbation. The result is a planar (slab-like) intersection of the dike and drift. The dike repository interactions are then (1) direct physical entrainment of waste in the dike and (2) flow of gas and magma, or gas and fragments, down the drift to interact with waste containers and waste. Because energy dissipation has been ignored, the idealization would be expected to produce stronger effects in the drift than would actually occur.
2) The dike, which propagated by means of a self-generated crack, interacts strongly with the stress-altered region (which forms around the drift) and with the void space in a drift. The dikes are postulated to be emplaced normal to least principal stress as measured regionally in the near surface. For this conceptual model, the thermo-mechanical state of the mountain (and repository) is important. This is the case because the dike is interacting with a stress field that is evolving and therefore the stress state is not fixed in time. That is, when the drift is driven, the surrounding rock first tries to relax into the drift. When waste is added, the waste heat causes thermal expansion that puts the rock around the drift into compression. The compression relaxes as the repository cools. These stress alterations are large enough so that the least principal stress, currently NNW-SSE, is rotated to vertical, a circumstance which could alter how a propagating dike behaves as it encounters the stress-altered zone (perhaps producing a sill rather than a dike). After several thousand years, ass the mountain cools, the least principal stress rotates back to its original direction.

Under these conditions the dike-repository interactions are:

1) propagation of the dike into and across the drifts as describe by the intersection of the dike-crack with the drift in an evolving stress field,
2) temperature changes to the waste package temperature due to flow of magma down a blind drift,
3) flow of gas and magma, or gas and fragments down the drift to interact with containers and waste,
4) movement of waste packages and drift contents and/or direct entrainment of waste caused by gas and magma from the dike, and

5) qualitatively, the nature of the mechanics of the dike/drift interaction i.e. interaction of the self generated crack leading the dike with the stress-altered region around the drift.

The analyses yield the following conclusions that are physically possible and are not excluded by data relevant to the mountain or to a repository.

1) The thermally altered stress state of the mountain may cause propagating dikes to deviate for the order of 2000 years.
2) Disruption of waste packages caused by flow from the dike extends down the drift from the dike edge to 3 or possibly 4 waste packages.
3) Magma flow down the drift is limited to a few waste package lengths (11 to 22 m).
4) The temperature inside a magma plug (and approximately in embedded waste packages) is given by Soward (1980) with a solidification time of 70 to 82 days.
5) Gas flow down an idealized drift is about 3.5x10\2—3.5 x 10\3 m\3/sec, and suggests an isothermal model is inadequate and overestimates the flow rate.

(The above section excerpted from the AMR text.)

COMMENT

This analysis provides detailed consideration of the result of an igneous dike intruding the drifts of the repository. Challenging problems are revealed in this analysis. Among these challenges are: 1) predicting the thermal-mechanical evolution of the mountain and repository and the effects of the resulting changes to the stress state on dike propagation, 2) determining the propagation process of the dike – will it propagate by fluid-induced fracturing of the confining rock more or less independent of pre-existing fractures or will dike emplacement follow old fractures?, and 3) forecasting the response of the magma when it encounters and enters the drift.

The effect of repository heat may alter the mechanical stress state sufficiently so that consideration of the interaction of a dike must be considered during two time periods: the thermal period, when the mountain is heated enough for the least principal stress to have rotated to vertical at the repository horizon, and the post-thermal period, when the stress has returned approximately to its present orientation, i.e., least principal stress direction horizontal, about N60W according to Stock et al. (1985), Warren and Smith (1985), and Frizzell and Zoback (1987). A possible result of the stress orientation during the thermal period is that magma moving upward along a dike may spread laterally to form a sill upon encountering the stress conditions in the vicinity of the repository.

A second has to do with how the propagating crack "sees" radial and concentric fractures formed during cutting of the drift and tectonic fractures away from the drift. Do these fractures impede the angle of intersection of the propagating dike crack or is the injection direction little effected? Do dikes propagate by fluid-induced fracturing of the confining rock as postulated by Lister and Kerr (1991) and Spence and Turcotte (1985)? During this process the dike is preceded by a crack generated by the magma fluid pressure, that is generated by the bouyancy of the magma column relative to the adjacent rock column (due to density difference). What is the role of pre-existing tectonic fractures? Might basalt flow along open fractures that are appropriately oriented with respect to the current stress axes?

Lastly, what happens when (if) magma enters a drift?

This AMR provides reasonable constraints for assessing the possibilities. However, in each case multiple options persist. I have no recommendation for further restricting the possibilities.