Review of the Yucca Mountain Igneous Consequences Peer Review Panel's Interim Report presented on August 23, 2002.

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The YMICPR Panel presented a comprehensive review on work that has been completed by DOE related to consequences of igneous events that might impact the Yucca Mountain repository. The Panel consists of a group of researchers well diverse in studies related to igneous activity however they did acknowledge their limitations in several critical areas such as groundwater transport, remobilization of tephra and the interaction between magma and waste packages. In addition to analyzing previous work, the Panel conducted their own analyses to support their recommended tasks in areas that they concluded were weak in DOE studies.

The Panel approached their review by beginning with magma transport and mechanical properties, followed by dike propagation, dike interaction with repository, and magma interaction with a drift(s), and ending with the consequences of the break through of magma at the surface. The review of magma transport and mechanical properties was thorough emphasizing that these properties are well constrained from thousands of data collected from volcanoes throughout the world and from established theoretical and empirical calculations. They demonstrated how the volume and general composition of magma that might erupt at Yucca Mountain Repository are constrained from field studies on volcanism within the region. Also mentioned was the sensitivity of magma flow behavior to dissolved and exsolved volatiles such as H_2O and CO_2. The presence of H_2O enhances the solubility of CO_2, which will affect the depth of exsolution and fragmentation. This means that the total volatile content of the magma will be greater as when it nears the surface.

The consequence of how the magma will interact with the drift if intersected by a dike, strongly depends on the nature of the magma near the top of the dike. When magma is within upper 500 m of the crust it will release or exsolve most of its dissolved H_2O and CO_2 which can change its flow character from a viscous liquid to a bubbly magma to a gas rich mixture of fragmented magma and gas depending on the volatile content. Prior to the Panels work, the value for estimated H_2O contained in Crater Flat, CF, basalts prior to eruption was 1-3 wt.% based on a literature search of similar basalts worldwide. The Panel estimated 2.5-4.0 wt.% H_2O in CF basalts from thermodynamic calculations based on the crystallization sequence. This demonstrated the lack of analysis that has been done and the type of analyses that need to be done to better constrain the volatile contents of magmas erupted at CF. The Panel recommended the examination of glass and fluid inclusions in phenocrysts from the Quaternary potassic trachybasalts to estimate CO_2 and to utilize up-to-date thermodynamic solubility models for CO_2, S, and H_20 to better constrain the depth of exsolution and fragmentation. This and other recommended analyses mentioned in the interim report on magma transport and mechanical properties should be considered in future DOE tasks.

The majority of the Panels presentation focused on dike propagation. The models presented involved the upward migration of a viscous magma and the results demonstrated how the crack tip might respond to the stress regime around the repository over time. The part of their presentation that appeared to be the weakest was their analysis of the consequences of the dike intersecting a drift. Existing dike propagation models are limited to 2-dimensions and viscous, incompressible magma flow. In the case of a dike intersecting a drift, the model needs to consider a 3-dimensional flow to account for the diversion of magma into the drift and its effect of the propagation of the crack tip. This model also needs to consider the range of magma flow types given that basaltic magma could contain up to 4 wt.% H_2O. Under these conditions, magma behind the crack tip will likely be a bubbly magma that will respond very differently than a liquid magma without many bubbles (with a low void fraction) when it enters the drift. A viscous magma is an incompressible fluid and does not change in volume in response to a change in pressure as would be the conditions upon entering the drift or near the crack tip. A bubbly fluid is compressible given the presence of gas bubbles and will respond to a change in pressure by expanding or compressing. For example, in the case of entering the drift or during the propagation of the crack tip, a bubbly magma will experience a decrease in pressure which will cause exsolution of volatiles which in turn will change the its transport and mechanical properties– factors that are not considered in current dike propagation model or drift flow model.

When modeling the dynamic behavior of the magma inside a drift, the initial pressure gradient becomes important as demonstrated by the Woods et al. model. A bubbly magma may expand and freeze or produce a Strombolian type of eruption inside the drift that would lead to rapid pressurization of the drift a scenario that has not been considered. No crack propagation flow model currently exists that consider a compressible bubbly flow regime along with an appropriate viscosity and solubility model. It is an area of volcanology that has mostly been studied by laboratory experiments and overly simplified numerical models. One approach to developing this type of model would be to couple a dike propagation model for a bubbly fluid and couple it to an appropriate flow model for inside the drift using the CFSLIB computer code by Gaffney. The drift model needs to include the elastic properties of the wall rock to predict failure conditions and shed new light on their "dog-leg" scenario. Given the complexity of the flow phenomenon, laboratory experiments are essential to understand the physics and to validate the numerical model. These were issues/ideas that were discussed between myself, Alan Rubin and Anthony Pearson after the Panel's presentation and should be included in their final report.

The last topic presented was the consequences of magma breaking through to the surface. Like the other topics, there are many scenarios that influence the related calculations, in this case it the TSPA calculations for eruptive doses. The Panel recommended that more studies be conducted on how the waste packages would respond not only to slow moving, low void fraction magma but also to the other type of flow regimes especially a high-speed, high-density gas-ash flow or fast moving bubbly magma. It was brought to the attention of the Panel that lava flows can carry objects that are much heavier than those predicted by theory and that laboratory or field experiments are needed to improve models on how waste packages may become mobilized. Another concern about the TSPA calculations was the neglect of secondary transportation of contaminants by wind after deposition and fragmentation of waste material from the canisters if exposed during an eruption.

The Panel's review raised many new issues as mentioned above and in the presentation and interim report. In the final report, the Panel needs to prioritize these issues and elaborate on how they should be addressed in future DOE tasks.