STATEMENT OF WORK

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TASK I: August-September 2000

There is a probability of volcanic activity in the proposed nuclear waste repository site at Yucca Mountain in the range of 10^{-3}-10^{-4} over the next 10^4 years (e.g., Connor et al., 2000). These relatively high rates raise important questions about the nature of any volcanic flows which may ensue when wet basaltic magma, ascending in a dike, meets a series of subsurface repository drifts. The goal of this work is to improve and quantify our understanding of the shock-reflection interactions by extending and comparing previously developed one-dimensional numerical models of magma-repository interactions to two-dimensional test models.

Key questions arising from the one-dimensional modeling work (Bokhove and Woods, 2000) are:

- How do the shock and rarefaction wave turn into the drift after the magma dike breaks into the drift?

- What is the influence of gravity on the reflected shock wave at the end of the drift?

These questions need to be answered as an integral part of a risk-informed performance assessment, which includes an estimate of the number of waste packages disrupted and available for transport due to the magma flow.

To answer these questions, higher-dimensional flow calculations will be developed. Considering the time constraints, three-dimensional simulations and extensive parameter studies are unfeasible. Furthermore, the combined modeling of the air and multiphase magma with their separate equations of state (as in Bokhove and Woods, 2000) is technically difficult due to the complicated evolution of the magma-air interface.

The following simplifications are therefore proposed:

(i) Magma and air are modeled as one magmatic fluid in which air is modeled as a high-volatile content magmatic gas. The drift is thus filled initially with a magmatic gas at atmospheric pressure. A comparison of one-dimensional calculations for a magmatic fluid only with our full one-dimensional magma-air calculations

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shows that the initial shock amplification phase is more violent by a factor of 3-5 in the latter case when magma and air are modeled side by side. Nevertheless, the dynamics and final state in both approaches are qualitatively and to a lesser extent quantitatively similar.

(ii) A two-dimensional core code for magma dynamics will be developed for a two-dimensional elongated rectangular dike and drift in a vertical plane. These two rectangular dike an drift domains will be coupled together numerically with local preservation of mass and momentum at the dike-drift intersection.

(iii) Corresponding two-dimensional flow calculations for a realistic range of parameters will be compared with one-dimensional simulations of a corresponding one-dimensional flow tube model. The latter model is an averaged flow tube model of the planar two-dimensional version of the dike and drift geometry outlined in (ii). This set-up allows us to evaluate the one-dimensional flow-tube geometries.

(iv) Computer codes in this project will be installed on CNWRA computer systems and bought under CNWRA quality assurance, with the assistance of CNWRA staff. The two-dimensional codes will be developed such that extensions to the averaged three-dimensional geometry are readily achievable. (see the second statement of work, task 2).

In summary, the goal is to use two-dimensional flow calculations to assess the two-dimensional nature of shock and rarefaction wave interactions at the dike-drift entrance and the drift end. This information is of vital importance to establish the potential location of fracture formation by wet basaltic magma flows along repository drifts in the Yucca Mountain site.

TASK 2: 1st October-31st September 2000

There is a probability of volcanic activity in the proposed nuclear waste repository site at Yucca Mountain in the range of 10^{-3}-10^{-4} over the next 10^4 years (e.g., Connor et al., 2000). These relatively high rates raise important questions about the nature of any volcanic flows which may ensue when wet basaltic magma, ascending in a dike, meets a series of subsurface repository drifts. The goal of this work is to improve and quantify our understanding of these interactions by extending previously developed one-dimensional numerical models of magma-repository interactions to two dimensions.

The key remaining questions are:

1) How high are transient high pressure gradients along the repository drift?

2) Are these pressure gradients large enough to cause the drift wall to fail?

3) In particular, does the development of high pressure shock reflection events at the end of the drift promote fracture and breakthrough to the surface far away from the original dike-drift intersections?

4) Alternatively, could the initial pulse of the complicated rarefaction-shock wave interaction on the roof directly after breakthrough also cause fracture to occur near the dike-drift intersection?

These questions on the magma fluid dynamics need to be answered to adequately constrain the source term used in risk-informed performance assessments (including the number of waste packages disrupted and available for transport).

To answer these questions, it is necessary to develop more detailed two-dimensional flow calculations of magma-air interactions in the dike-drift geometry.

Two-dimensional calculations are much more involved than the one-dimensional calculations in Bokhove and Woods (2000). Consequently, a large parameter study as in Bokhove and Woods (2000) is unrealistic within the scope of ten months. Furthermore, the combined modeling of the air and multiphase magma with their separate equations of state (as in Bokhove and Woods, 2000) is technically difficult due to the complicated evolution of the magma-air interface. Considering the time constraints, I therefore propose the following simplifications.

(i) Magma and air are modeled as one magmatic fluid in which air is modeled as a high-volatile content magmatic gas. The drift is thus filled initially with a magmatic gas at atmospheric pressure. A comparison of one-dimensional calculations for a magmatic fluid only with our full one-dimensional magma-air calculations shows that the initial shock amplification phase is more violent by a factor of 3-5 in the latter case when magma and air are modeled side by side. Nevertheless, the dynamics and final state in both approaches are qualitatively and to a lesser extent quantitatively similar.

(ii) The cylindrical drift geometry is slightly simplified to a cylinder with a (narrow) horizontal floor and roof. This simplification is necessary for technical numerical reasons so that the average lateral width times the density does not become zero.

(iii) The three-dimensional flow in dike and drift is averaged in the lateral y-direction with characteristic width B(x,z), resulting in two-dimensional flow in the dike and drift. Deep into the magma dike this lateral width B=80m, the typical distance between the repository drifts, and further into the drift B(x,z)=B(z). The complicated three-dimensional flow around the dike-drift intersection has thus been replaced by a laterally averaged flow in a flow tube. Variables such as pressure then depend only on time, x and z. This averaging procedure is similar to the flow tube model in the one-dimensional study (Bokhove and Woods, 2000) and does require a prescribed flow-tube geometry.

(iv) To relieve this flow-tube restriction, the flow in the dike, averaged across its width W=1-2m in the x-direction (x=[0,W]), and in the drift, averaged in the lateral y-direction, is then coupled at the dike-drift intersection. Since the flows in dike and drift are now averaged in directions perpendicular to one another the coupling at their intersection requires careful attention to ensure that mass and momentum are conserved locally.

(v) Specific parameter studies will be undertaken in consultation with the CNWRA staff. In these parameter studies, particular care will be given to establishment of quantitative scaling relations with physical analog experiments.

(vi) Computer codes in this project will be installed on CNWRA computer systems and bought under CNWRA quality assurance, with the assistance of CNWRA staff.

In summary, the goal is to use two-dimensional flow calculations to establish the potential location of fracture formation by wet basaltic magma flows along repository drifts in the Yucca Mountain site.