Please Note: The enclosed letter to DOE documents a Technical Exchange and Management Meeting on the Key Technical Issue, "Igneous Activity," conducted on June 21-22, 2001. The meeting summary is included as an enclosure to the letter. Attachment 1 to the meeting summary lists the agreements made by the NRC/DOE at the meeting, Attachments 2-3 provide additional detail on proposed and existing agreements, Attachment 4 is the agenda, and Attachment 5 is the attendance list. Due to the size of Attachment 6 (presenter's slides), they are not included in this mailing. If you are interested in viewing or printing this attachment, it can be obtained from the NRC website (www.nrc.gov) under the ADAMS icon (or you can go directly to the ADAMS homepage at www.nrc.gov/NRC/ADAMS. If you do not have access to the website and/or are interested in getting a hard copy of Attachment 6, please contact Ms. Darlene Higgs at 301-415-6711 or e-mail at gdh1@nrc.gov.

Summary Highlights of NRC/DOE Technical Exchange and Management Meeting on Igneous Activity

June 21-22, 2001
Las Vegas, Nevada

Introduction and Objectives

This Technical Exchange and Management Meeting on Igneous Activity is one in a series of meetings related to the U.S. Nuclear Regulatory Commission (NRC) key technical issue (KTI) and sufficiency review and the U.S. Department of Energy (DOE) site recommendation decision. Consistent with NRC regulations on prelicensing consultations and a 1992 agreement with the DOE, staff-level resolution can be achieved during prelicensing consultation. The purpose of issue resolution is to assure that sufficient information is available on an issue to enable the NRC to docket a proposed license application. Resolution at the staff level does not preclude an issue being raised and considered during the licensing proceedings, nor does it prejudge what the NRC staff evaluation of that issue will be after its licensing review. Issue resolution at the staff level, during prelicensing, is achieved when the staff has no further questions or comments at a point in time regarding how the DOE is addressing an issue. The discussions recorded here reflect NRC's current understanding of aspects of igneous activity most important to repository performance. This understanding is based on all information available to date which includes limited, focused, risk-informed reviews of selected portions of recently provided DOE documents (e.g., Analysis and Model Reports (AMRs) and Process Model Reports (PMRs)). Pertinent additional information (e.g., changes in design parameters) could raise new questions or comments regarding a previously resolved issue.

Issues are "closed" if the DOE approach and available information acceptably address staff questions such that no information beyond what is currently available will likely be required for regulatory decision making at the time of any initial license application. Issues are "closed-pending" if the NRC staff has confidence that the DOE proposed approach, together with the DOE agreement to provide the NRC with additional information (through specified testing, analysis, etc.) acceptably addresses the NRC's questions such that no information beyond that provided, or agreed to, will likely be required at time of initial license application. Issues are "open" if the NRC has identified questions regarding the DOE approach or information, and the DOE has not yet acceptably addressed the questions or agreed to provide the necessary additional information in a potential license application.

The objective of this meeting was to discuss and review the progress on resolving the igneous activity KTI, specifically Subissue 2 (see Attachment 1 for the description of the subissues). The quality assurance (QA) aspect of this KTI was determined to be outside the scope of the meeting and is being tracked in NRC's ongoing review of the DOE's QA program.

Summary of Meeting

At the close of the Technical Exchange and Management Meeting, the NRC staff stated that Subissue 1 remains "closed-pending" and Subissue 2 remains "open." Specific NRC/DOE agreements made at the meeting are provided as Attachment 1. Proposed NRC agreements to which DOE has not agreed are provided as Attachment 2. Modifications to existing NRC/DOE agreements are provided as Attachment 3. The agenda and the attendance list are provided as Attachments 4 and 5, respectively. Copies of the presenters slides are provided as Attachment 6. Highlights from the Technical Exchange and Management Meeting are listed below.

Highlights

1) Opening Comments and Overview

NRC opened the meeting with an overview of igneous activity (see "Overview of Igneous Activity Meeting" presentation given by Bret Leslie) and stated that this meeting would address part of DOE's performance assessment related to igneous activity. NRC discussed what performance assessment is and the terms and definitions used. NRC discussed igneous activity, the terms used, and the general areas of igneous activity which would be discussed during the meeting. NRC stated that posters and handouts which discuss performance assessment and igneous activity were available during the meeting and that NRC staff would be available to discuss specific issues during the breaks and after the meeting.

NRC then presented comments on igneous activity models with respect to performance assessment (see "Comments on Igneous Activity Models with respect to Performance Assessment" presentation given by Richard Codell). NRC stated that DOE: (1) needs to characterize igneous activity model uncertainty and propagate it through the model abstractions, and (2) is responsible to provide justification for the use of ASHPLUME and associated NRC codes in the performance assessments. NRC discussed some areas of model uncertainty and the NRC performance assessment code.

NRC then provided a general overview on the status of igneous activity issue resolution (see "NRC Introductory Comments" presentation given by John Trapp). NRC stated that although it would not discuss them in depth, a status of each existing NRC/DOE agreement and proposed path forward for each NRC concern to be discussed during the meeting are captured in its table.

2) Technical Discussions - Magma-Drift Interactions

NRC presented the scenario of a magma dike interacting with drifts (see Explosive Magmatic Eruptions into Subsurface Tunnels" presentation given by Onno Bokhove). NRC stated that during its presentation, it would be addressing two questions (1) does the pressure in the tunnels increase beyond critical pressure levels, and (2) where and when can we expect rock fracture and, hence, new pathways to the surface? NRC stated that rock hydrofracturing is assumed to occur at 5 MPa at approximately 300 meters (repository depth) below grade. NRC then discussed a magma flow model and the equations used to create the numerical model. NRC discussed the results from the model. NRC noted that this model makes the general assumptions that (1) the drift is five meters in diameter, (2) the drift does not contain waste packages, drip shields, backfill, or debris from rock collapse, (3) the end of the tunnel is an impermeable barrier, (4) there is no loss of energy into the walls, (5) the geometry of the drift-dike system is prescribed and does not change during the initial transient, and (6) standard volatile content (e.g., two percent water) and other properties of alkali basalts were used. NRC further stated that this model is a first step in exporing magma-drift interaction and that more work needs to be done to understand additional aspects (i.e., how waste packages affect magma flow, how geometry of the dike and tunnel system affects the shock wave, the importance of rock fall, etc.). NRC stated that as the dike interacts with the drift, magma entering the drift creates a shock wave in the drift. The amplitude of the shock wave increases on reflection at the closed end of the drift and eventually the wave is propagated back down the drift into the dike. Based on the results of this first-order model, NRC stated that critical rock-fracture pressures (approximately 5 MPa) may be exceeded in magma-repository interactions, especially at the tunnel ends and to a lesser degree at the tunnel roof near the dike-drift intersection.

The next NRC presentation discussed the possible consequences of one set of scenarios for magma-drift interaction (see "Magma-Drift Interactions" presentation given by Andy Woods). Three possible scenarios were described. Case (a) involves the dike continuing its original path up to the surface after filling the drift. Case (b) involves the development of a new path from the drift where the magma moves upward to the surface (a point of weakness due to existing fractures or topography change). Case (c) involves the magma filling the drift and escaping through the access drift. NRC stated that the cross-sectional area of the drift system is of comparable magnitude to the dike indicating that magma can be diverted into the drift. NRC discussed how the volume from the eruption of the local cones is one to two orders of magnitude more than the volume of the repository, suggesting that a quasi-steady flow may develop. NRC presented the pressure and velocity profiles for magma flow as a function of depth for each case, assuming the magma-volatile mixture behaves as a pseudo-fluid using standard properties of alkali basalt. The model does not include the effects of gas-magma separation, which may complicate the flow, or the response of the engineered or geological structure to the flow. The model predicts flow rates of order 100 meters per second at the surface, typical of stromblian activity.

During these two presentations, DOE asked, and NRC answered a number of questions concerning the model, the assumptions used, and the results. These questions are discussed below.

Effects of changes in volatile content were addressed in one dimensional parametric studies. Changes in water content from 1 to 2.5 percent only had a minor effect on calculated pressures and flow rates. Questions were raised on the effects of engineered structures such as waste packages, drip shields, and naturally occurring rockfall on magma flow processes. Although those features will likely induce turbulence, they are not modeled explicitly. In addition, changes in the geometry of drift end and the presence of backfill will likely affect calculated pressures and flow rates. NRC is considering how to evaluate these effects in future models. NRC is also concerned how topography may affect the location of vertical breakout from magma-filled drifts and mechanisms for capturing an appropriate volume of ascending magma in a dike by flow into a drift.

DOE then discussed the NRC concerns expressed during an Appendix 7 meeting held on May 18, 2001 (see "Magma-Drift Interactions, Magma-Waste Package Interactions, and Magma-Waste Form Interactions" presentation given by Eric Smistad and Greg Valentine). DOE stated that during the Appendix 7 meeting, NRC presented a new igneous activity consequence model that depicts the magma-repository interactions more mechanistically. DOE stated that it has not had enough time to evaluate this new model and acknowledged that additional work to evaluate the new consequence model may be warranted and desirable to support any potential license application, but that it needs further study of the consequence models before defining that additional work. DOE stated that its objective for this area is to continue the dialogue on the new model.

DOE then discussed each of the six NRC concerns (see Attachment 2 for description of concerns) regarding magma-drift interactions. DOE presented a synopsis of each concern and work on each concern done to date. For each concern, DOE stated that it has addressed the NRC concern in a limited or simplified manner. Following an NRC caucus on magma-drift interactions, NRC questioned whether DOE would be in a position to state whether it felt these concerns need to be addressed and if DOE could provide the NRC with any initial plans to address these concerns. DOE stated that project planning for FY2002-2004 is just beginning and has not sufficiently progressed to address these concerns, as well as the NRC concerns related to magma-waste package, magma-waste form, and miscellaneous items. NRC stated that it would document these concerns in this meeting summary (see Attachment 2) so that DOE will have the areas where NRC believes additional information is needed. In addition, NRC stated that the remaining topics (magma-waste package, magma-waste form, and miscellaneous items) did not need to be presented because the information contained in the slides did not discuss DOE plans and activities to address the concerns. Further, NRC stated that since NRC and DOE will not be able to agree on a path forward for these concerns, the consequences subissue will remain "open."

3) Technical Discussions - Magma-Waste Package Interactions, Magma-Waste Form Interactions, and Miscellaneous Items

These areas were not discussed, as noted above.

4) Technical Discussions - TSPA Supplement Sensitivity Analyses

DOE discussed several issues associated with its Total System Performance Assessment (TSPA) supplemental sensitivity analysis methodology (see Total System Performance Assessment Supplemental Sensitivity Analyses: Igneous Activity" presentation given by Peter Swift). Specifically, DOE addressed (1) sensitivity to alternative wind speed data, (2) sensitivity to uncertainty in waste particle diameter, (3) relative dose contributions from waste package damage due to igneous intrusion in Zones 1 and 2, and (4) a bounded approach to ash redistribution. DOE stated that new information developed since the Total System Performance Assessment - Site Recommendation (TSPA-SR) Revision 00, ICN 01, is being documented in the fiscal year 2001 Supplemental Science and Performance Analyses (SSPA) and will subsequently be provided to NRC in either approved calculations or analysis and model reports.

Regarding sensitivity to alternative wind speed data, DOE stated that the wind speed distribution used in supplemental analyses is based on 300 millibar data (average elevation 9400 meters above sea level). DOE concluded that calculated probability-weighted mean annual doses are moderately sensitive to wind speed uncertainty (new data increase probability-weighted dose by approximately a factor of two). NRC questioned whether the wind data was averaged for all wind directions and heights. DOE stated that all directions at 300 millibar were used in the average. NRC also questioned whether DOE had evaluated the higher wind speeds that may exist during future glacial periods. DOE stated that it felt the present data used is conservative in this respect. Following the NRC caucus on this issue, the staff stated that the DOE approach appears reasonable and that it would review the documents noted in Attachment 3 (IA.2.09).

Regarding sensitivity to uncertainty in waste particle diameter, DOE stated that calculated probability-weighted mean annual doses are insensitive to current uncertainties in waste particle diameter within this range (0.00005 to 0.1 cm, modes between 0.0002 and 0.02 cm). Following the NRC caucus on this issue, the staff stated that the DOE approach appears reasonable and that it would review the documents noted in Attachment 3 (IA.2.02).

Regarding the relative contributions to calculated annual dose from waste package Zone 1 and Zone 2, DOE showed that Zone 1 is the major contributor to igneous groundwater dose. DOE also discussed modifications to the cumulative distribution functions (CDFs) for the number of packages damaged by intrusion. DOE stated that the new information has led to recalculation of the CDFs. NRC questioned why the upper end of the range of Zone 1 increased significantly. DOE stated that this increase is due to very infrequent intersection of a dike along the length of a drift. DOE then presented the effect of recalculating distributions for the number of waste packages damaged by igneous intrusion for both Zone 1 and 2. Following the NRC caucus on this issue, the staff stated that DOE addressed the issue as requested and that the staff would review the documents noted in Attachment 3 (IA.2.10). NRC noted that the proposed magma-drift and magma-waste package agreements need to be addressed.

Regarding the TSPA-SR, Revision 00, ICN 01 approach to the effects of ash redistribution, DOE discussed its conclusion that for the same set of input parameters, conditional dose at any time following an eruption can be no greater than the conditional dose that would result if the eruption occurred in that year (i.e., doses do not get worse than they are in the first year). DOE further stated that it considers that this approach provides a technical basis to demonstrate that the modeling assumptions in TSPA-SR, Revision 00, ICN 01 are conservative. In calculating expected annual dose, however, DOE indicated that they use a soil removal rate that is representative of all farm lands, rather than conservatively assuming no soil removal. NRC questioned how this approach provided a conservative basis to ignore potential inputs to soil from wind and water remobilization. DOE responded that other conservatisms such as directing the plume towards the critical group and using transition-phase BDCFs already achieved a level of conservatism sufficient to ignore direct modeling of remobilization effects. NRC staff disagreed that the DOE approach is a conservative basis to calculate expected annual dose, and that the long-term effects of remobilization could affect risk calculations significantly. NRC also stated that the conclusion that doses could not increase above the first year dose was only valid if the doses were mainly from inhalation. DOE stated that most of the dose in the igneous scenario is from the inhalation pathway.

Following the NRC caucus on this issue, the staff stated that DOE has not addressed the NRC concern. DOE needs to address how the process is conservative with respect to risk (i.e., expected annual dose) and that this topic should be classified as "open." NRC further noted that as a result of the proposed NRC Agreement 11 (see Attachment 2), existing agreement IA.2.06 has been superceded. Agreement IA.2.06 can be listed as complete and should reference NRC proposed Agreement 11 as the basis for completion.

5) Technical Discussions - Biosphere Items

DOE then discussed biosphere-igneous activity interactions (see Biosphere-Igneous Activity Interactions" presentation given by A. Smith). DOE then addressed each of the NRC concerns presented at the May 18, 2001, Appendix 7 meeting.

Regarding the comparison of static versus disturbed conditions, DOE stated that scoping calculations used time-activity budgets based on the behavior of a farmer. Dust loads for post-volcanic conditions and farming activities were calculated to confirm that the static measurements were appropriate. NRC questioned what the environment was like where mass loading values for working outdoors under nominal conditions were measured. DOE indicated that these measurements were taken in a semi-arid environment.

Regarding the average annual static concentrations versus eight-hour workday disturbed conditions, DOE stated that the duration of exposure was based on assumed behaviors of farmers, that the distribution of exposure time to outdoor concentrations ranged from 8.0 to 10.8 hours per day, and that this method considers disturbed conditions.

Regarding the basis for extrapolating total suspended particulates (TSPs) concentrations, DOE stated that it is re-evaluating the ratios used to determine TSPs and is considering using measured values of TSPs in future calculations rather than estimates based on PM_{10} concentration.

Regarding the assumption that concentration of resuspended particles returns to background values within 10 years, DOE stated that the combination of the 10-year period and the assumption of no removal of material are considered to be conservative. NRC asked DOE to clarify what it meant by the "assumption of no removal of material." DOE stated that material was not removed from the system during the calculation of the BDCFs, which was a short time period compared to the time steps in TSPA.

Regarding the mass loading above a tephra deposit, DOE stated that BDCFs that include soil removal were not used in TSPA-SR. DOE further stated that more conservative BDCFs were used and that when generating BDCFs, credit was taken for stabilization (no credit was taken for removal). NRC questioned DOE's justification for the assumption that mass loading returned to nominal values within 10 years of the eruption. DOE clarified that by sampling a transition-phase mass loading value between the first year value and the value for nominal conditions and using this value to calculate dose at all later times, the time period for the return to nominal conditions does not matter.

Regarding external exposure from high level waste contaminated ash, DOE stated that an appropriate shielding factor for external exposure would be incorporated in a future update to the Input Parameter Values for External and Inhalation Radiation Exposure Analyses AMR. DOE further stated that the effect of external exposure is negligible on TSPA-SR results.

Regarding the effects of climate change on disruptive events BDCFs, DOE stated that the inhalation pathway is dominant for the volcanic eruption BDCFs. DOE further stated that climate change with increased precipitation would lead to more rapid stabilization and increased loss from leaching and thus leads to reduced re-suspension of radionuclides. DOE stated that it was not taking credit for these processes.

As a result of additional discussions, the NRC and DOE reached six additional agreements for Subissue #2 (see Attachment 1). Since additional agreements are needed for Subissue #2, the subissue remains "open." NRC also noted as a result of these six new agreements, existing agreement IA.2.07 has been superceded. Agreement IA.2.07 can be listed as complete and should reference to these six new agreements as the basis for completion.

6) University of Nevada - Las Vegas Presentation

A presentation on new information was given by Professor Eugene Smith from the University of Nevada - Las Vegas (see " New Observations about Basaltic Volcanism near Yucca Mountain: Implications for Volcanic Hazard Studies"). The presentation was broken into three areas, patterns of volcanism, control of volcanism, and implications and recommendations.

Professor Smith presented maps showing volcanism from 9.5 to 0.02 million years ago. He concluded that volcanism is episodic and that a temporal link exists between volcanism in the Lunar Crater-Crater Flat areas. NRC questioned the distribution of volcanoes shown. Particularly, volcanoes south of Amargosa Desert were not included. Professor Smith indicated that the needed geochronological information was not available for these volcanoes. Therefore, they are not included. NRC stated that it is crucial to consider the time and spatial scales of clustering of volcanoes. NRC also questioned if the maps show individual cinder cones. Professor Smith said the maps do show individual cones. Professor Smith also concluded that volcanic fields change shape with time and new cinder cones rarely occur at sites of older events. The NRC questioned these conclusions and stated that on the scale of the maps he is showing, volcanoes occur in discrete clusters. The plots covered millions of years while the regulatory period is 10,000 years. The NRC stated that one needs to be careful with the timescales used to maintain an appropriate risk perspective.

Professor Smith then discussed the control of volcanism and the melting depth in the region from the eastern Sierra Nevada to the Colorado Plateau. Professor Smith concluded that the melting depth increases from the eastern Sierra Nevada area reaching a maximum in the central Great Basin before decreasing gradually toward the Colorado Plateau. Professor Smith also concluded that hot, deep melting exists beneath Crater Flat-Lunar Crater. DOE questioned Professor Smith's assessment. DOE suggested that the bulk of evidence supports lithosphere melting models for generation of basaltic magma, rather than melting of dry asthenosphere. DOE indicated that the evidence for large-scale mantle plumes in the Yucca Mountain Region is weak. DOE suggested that the presence of low velocity zones at great depth (200-300 km) is not relevant to melt generation in the asthenosphere and does not support a mantle plume model.

Professor Smith then summarized his conclusions and recommendations. He stated that deep melting exists beneath the central Basin and Range and that this is consistent with a mantle hot spot. Professor Smith recommended (1) that probability models that depend on steady state recurrence rates may not adequately describe the volcanic hazard, (2) that probability studies should consider the episodic nature of volcanism and the possibility that another flare-up may occur in the near future, (3) that past patterns may not be an indication of future activity, (4) that probability models should consider the changing shape of volcanic fields and the observation that past activity may not be a key to future events, and (5) that probability models should be calibrated by going back in time. NRC noted that the probability model in use has been calibrated against patterns of basaltic volcanism in a variety of tectonic settings. NRC indicated that probability models currently in use do account for spatial clustering. NRC noted that temporal clustering, while important for understanding volcanic activity in the region, occurs on a very long time scale compared to the performance period. Therefore, uncertainty in the recurrence rate of volcanism can be treated with a temporally homogeneous model. DOE noted that there are two clusters, not a belt.

7) Existing Agreements

NRC and DOE also discussed several existing igneous activity agreements. A number of these agreements reference TSPA-SR, Revision 1, which DOE has stated will not be available in June 2001 as agreed to. After discussion on these agreements, DOE proposed changes to the wording to reference other documents. The reworded agreements are provided in Attachment 3.

In addition, as noted above, existing NRC/DOE Agreements IA.2.06 and 2.07 have been superceded and can be listed as complete. These agreements have been superceded by agreements and proposed agreements documented in this meeting summary.

8) Public Comments

None.

for, 6/22/01 — 6/22/2001

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Summary of the Resolution of the Key Technical Issue on Igneous Activity - Agreements Reached

Subissue #	Subissue Title	Status	NRC/DOE Agreements
1	Probability of future igneous activity	Closed-Pending	See agreements from August 29-31, 2000.
2	Consequences of future igneous activity	Open	IA.2.11 - Provide an analysis that shows the relationship between any static measurements used in the TSPA and expected types and durations of surface disturbing activities associated with the habits and lifestyles of the critical group. DOE will provide an analysis that shows the relationship between any static measurements used in the TSPA and expected types and durations of surface disturbing activities associated with the habits and lifestyles of the critical group in a subsequent revision to the AMR Input Parameter Values for External and Inhalation Radiation Exposure Analysis (ANL-MGR-MD-000001) or equivalent document. This will be available to the NRC in FY02. IA.2.12 - Provide clarifying information on how PM10 measurements have been extrapolated to TSP concentrations. This should include consideration of the difference in behavior between PM10 and TSP particulates under both static and disturbed conditions. DOE will provide clarifying information on how PM10 measurements have been extrapolated to TSP concentrations. This will include consideration of the difference in behavior between PM10 and TSP particulates under both static and disturbed conditions in a subsequent revision to the AMR Input Parameter Values for External and Inhalation Radiation Exposure Analysis (ANL-MGR-MD-000001) or equivalent document. This will be available to the NRC in FY02.

			IA.2.13 - Provide the justification that sampling of range of transition period BDCFs is necessarily conservative in evaluating long-term remobilization processes. DOE will provide the justification that sampling of range of transition period BDCFs is necessarily conservative in evaluating long-term remobilization processes in a subsequent revision to the AMR Input Parameter Values for External and Inhalation Radiation Exposure Analysis (ANL-MGR-MD-000001) or equivalent document. This will be available to the NRC in FY02. IA.2.14 - Provide information clarifying the method used in TSPA to calculate how deposit thickness effects the average mass load over the transition period. DOE will provide information clarifying the method used in TSPA to calculate how deposit thickness effects the average mass load over the transition period in a subsequent revision to the AMR Input Parameter Values for External and Inhalation Radiation Exposure Analysis (ANL-MGR-MD-000001) or equivalent document. This will be available to the NRC in FY02. IA.2.15 - Clarify that external exposure from HLW-contaminated ash, in addition to inhalation and ingestion, was considered in the TSPA. Include in this clarification the consideration of external exposure during indoor occupancy times, or provide basis for dwelling shielding from outdoor gamma emitters. DOE will clarify that external exposure from HLW-contaminated ash, in addition to inhalation and ingestion, was considered in the TSPA. DOE will include in this clarification the consideration of external exposure during indoor occupancy times, or provide basis for dwelling shielding from outdoor gamma emitters in a subsequent revision to the AMR Input Parameter Values for External and Inhalation Radiation Exposure Analysis (ANL-MGR-MD-000001) or equivalent document. This will be available to the NRC in FY02.

			IA.2.16 - Document that neglecting the effects of climate change on disruptive event BDCFs is conservative. DOE will document that neglecting the effects of climate change on disruptive event BDCFs is conservative in a subsequent revision to the AMRs Input Parameter Values for External and Inhalation Radiation Exposure Analysis (ANL-MGR-MD-000001) and Disruptive Event Biosphere Dose Conversion Factor Analysis (ANL-MGR-MD-000003) or equivalent document. This will be available to the NRC in FY02.

Summary of the Resolution of the Key Technical Issue on Igneous Activity - Agreements Not Reached

Subissue #	Subissue Title	Status	NRC/DOE Agreements
1	Probability of future igneous activity	Closed-Pending	N/A
2	Consequences of future igneous activity	Open	1) Evaluate the stress distribution and strain response on existing or new geologic structures resulting from thermal loading of HLW. The evaluation should include appropriate spatial variations in overlying topography and appropriate spatial and temporal variations in thermal load. DOE acknowledges the NRC proposed agreement and will address this agreement as part of the consolidated response to NRC's proposed agreement items for the consequence subissue. 2) Evaluate how the presence of engineered repository structures (e.g., drifts, waste packages, etc.) can affect magma flow processes for the duration of an igneous event. Include in this evaluation the potential effects on initial magma flow characteristics, diversion of ascending magma into repository structures, reestablishment of multiple flow-paths to the surface, two phase flow, reaction of the geologic and engineered system to over and under pressure, gas separation, heat transfer, magma recirculation, and range of steady and nonsteady flow conditions that could occur for the duration of an igneous event. DOE acknowledges the NRC proposed agreement and will address this agreement as part of the consolidated response to NRC's proposed agreement items for the consequence subissue.

			3) Evaluate how the presence of repository structures may affect magma ascent, conduit localization, and evolution of the conduit and flow system. Include in this evaluation the potential effects of topography and stress, in addition to a range of physical conditions appropriate for the duration of igneous events. DOE acknowledges the NRC proposed agreement and will address this agreement as part of the consolidated response to NRC's proposed agreement items for the consequence subissue. 4) Evaluate the mechanical strength of natural or engineered barriers that are proposed to restrict magma flow within intersected drifts. A range of physical conditions appropriate for the duration of igneous events should be used in the evaluation. DOE acknowledges the NRC proposed agreement and will address this agreement as part of the consolidated response to NRC's proposed agreement items for the consequence subissue. 5) If significant amounts of backfill or rockfall are thought to occur in repository drifts, evaluate the effects of these materials on magma flow processes throughout the duration of an igneous event. The analysis should include the potential effects of entrainment, meltback, and displacement of backfill. DOE acknowledges the NRC proposed agreement and will address this agreement as part of the consolidated response to NRC's proposed agreement items for the consequence subissue. 6) Evaluate how ascent and flow through repository structures may incorporate HLW located along all potential flow paths that may occur during an igneous event. The evaluation should include such processes as segregation, two phase flow, heat transfer, convective flow, gas circulation of the magma, and evolution of the conduit and flow system. DOE acknowledges the NRC proposed agreement and will address this agreement as part of the consolidated response to NRC's proposed agreement items for the consequence subissue.

			7) Evaluate waste package response to stresses from dynamic magmatic pressurization, internal pressurization, gravitational loading, and heating, using appropriate at-condition strength properties and magma flow paths, for duration of an igneous event. DOE acknowledges the NRC proposed agreement and will address this agreement as part of the consolidated response to NRC's proposed agreement items for the consequence subissue. 8) Evaluate aging effects on materials strength properties when exposed to basaltic magmatic conditions for the duration of an igneous event. Include in this evaluation the potential effects of subsequent seismically induced stresses on substantially intact waste packages. DOE acknowledges the NRC proposed agreement and will address this agreement as part of the consolidated response to NRC's proposed agreement items for the consequence subissue. 9) Evaluate the response of Zone 3 waste packages, or waste packages covered by backfill or rockfall, if exposed to magmatic gasses at conditions appropriate for an igneous event. DOE acknowledges the NRC proposed agreement and will address this agreement as part of the consolidated response to NRC's proposed agreement items for the consequence subissue. 10) Evaluate the physical and chemical response of HLW and cladding after heating and potential disruption of waste package and contents, for waste packages remaining in drifts. Particular attention should be given to effects that may result in increased solubility potential relative to undisturbed HLW forms. DOE acknowledges the NRC proposed agreement and will address this agreement as part of the consolidated response to NRC's proposed agreement items for the consequence subissue.

			11) Provide a technical basis to support conclusions that the risk effects (i.e., effective annual dose) of eolian and fluvial remobilization are bounded by conservative modeling assumptions in the TSPA-SR, Rev00, ICN1. Particular attention should be paid to: (i) rate of mobilization off slopes, (ii) rate of transport in Fortymile Wash drainages, (iii) rate of transport from eolian processes, (iv) deposition rate at proposed critical group location, (v) changes in particle-size distributions during fluvial transport. DOE acknowledges the NRC proposed agreement and will address this agreement as part of the consolidated response to NRC's proposed agreement items for the consequence subissue. 12) Provide an independent technical basis for the method of HLW incorporation used in DOE models, including consideration of particle aggregation and the effect on waste transport. DOE acknowledges the NRC proposed agreement and will address this agreement as part of the consolidated response to NRC's proposed agreement items for the consequence subissue. 13) Provide support that the inherent assumption in the mass loading model that the concentration of radionuclides on soil in the air is equivalent to the concentration of radionuclides on soil on the ground does not underestimate dose (i.e., radionuclides important to dose do not preferentially attach to smaller particles). DOE acknowledges the NRC proposed agreement and will address this agreement as part of the consolidated response to NRC's proposed agreement items for the consequence subissue.

CHANGES TO EXISTING IGNEOUS ACTIVITY NRC/DOE AGREEMENTS

IA.2.02 - Document results of sensitivity studies for particle size, consistent with (1) above. DOE agreed and will document the waste particle size sensitivity study in ~~TSPA-SR, Rev. 1~~ a calculation document. This will be available to the NRC in ~~June 2001~~ FY2002.

IA.2.03 - Document how the tephra volumes from analog volcanos represent the likely range of tephra volumes from Yucca Mountain Region (YMR) volcanos. DOE agreed and will document the basis for determining the range of tephra volumes that is likely from possible future volcanoes in the YMR in ~~TSPA-SR, Rev. 1 or demonstrate that TSPA-SR results are insensitive to uncertainties in the reasonably expected volumes of tephra in the YMR~~ the Eruptive Processes AMR (ANL-MGR-GS-000002). This will be available to the NRC in ~~June 2001~~ FY2002.

IA.2.04 - Document that the ASHPLUME model, as used in the DOE performance assessment, has been compared with an analog igneous system. DOE agreed and will complete calculation CAL-WIS-MD-000011 that will document a comparison of the ASHPLUME code results to observed data from the 1995 Cerro Negro eruption. This will be available to the NRC in January 2001. DOE will consider Cerro Negro as an analog and document that in ~~TSPA-SR Rev. 1~~ the Eruptive Processes AMR (ANL-MGR-GS-000002). This will be available to the NRC in ~~June 2001~~ FY2002.

IA.2.05 - Document how the current approach to calculating the number of waste packages intersected by conduits addresses potential effects of conduit elongation along a drift. DOE agreed and will document the way in which the change in geometry of the repository drifts affects the number of waste packages incorporated into the volcanic conduit. Possible consequences of conduit elongation parallel to drifts will be documented in TSPA-SR Rev. 1, available to the NRC in June 2001. This agreement has been superceded by the proposed NRC Agreements in Attachment 2.

IA.2.06 - Develop a linkage between soil removal rate used in TSPA and surface remobilization processes characteristics of the Yucca Mountain region (which includes additions and deletions to the system). DOE agreed and will document its approach to include uncertainty related to surface-redistribution processes in TSPA-SR, Rev. 0. DOE will revisit the approach in TSPA-SR, Rev. 1. This documentation will be available to the NRC in June 2001. This agreement has been superceded by the proposed NRC Agreement 11 in Attachment 2.

IA.2.07 - Document the basis for airborne particle concentrations used in TSPA in Rev. 1 to the Input Values for External and Inhalation Radiation Exposure AMR. DOE agreed and will provide documentation for the input values in the Input Parameter Values for External and Inhalation Radiation Exposure Analysis AMR [ANL-MGR-MD-000001] Rev. 1. This will be available to NRC in January 2001. This agreement has been superceded by the NRC/DOE Agreements IA.2.11 to 2.16 in Attachment 1.

IA.2.09 - Use the appropriate wind speeds for the various heights of eruption columns being modeled. DOE agreed and will evaluate the wind speed data appropriate for the height of the eruptive columns being modeled. This will be documented in ~~TSPA-SR, Rev. 1~~ a calculation document. This will be available to the NRC in ~~June 2001~~ FY2002.

IA.2.10 - Document the ICNs to the Igneous Consequences AMR and the Dike Propagation AMR regarding the calculation of the number of waste packages hit by the intrusion. Include in these or other documents (1) the intermediate results of the releases from Zone 1 and 2, separately, and (2) the evaluation of thermal and mechanical effects, as well as shock, in assessing the degree of waste package damage in Zone 1 and 2. DOE agreed and will provide ICN 1 of the following AMRs: Igneous Consequences Modeling for TSPA-SR AMR [ANL-WIS-MD-000017], the Dike Propagation Near Drifts AMR [ANL-WIS-MD-000015], the Characterize Framework for Igneous Activity at Yucca Mountain, Nevada AMR [ANL-MGR-GS-000001], and the Calculation Number of Waste Packages Hit by Igneous Intrusion [CAL-WIS-PA-000001]. This will be available to the NRC in January 2001. DOE will provide the results showing the relative contributions of releases from Zones 1 and 2 in ~~TSPA-SR, Rev. 1~~ a calculation document. This will be available to the NRC in ~~June 2001~~ FY2002. DOE will provide the evaluation of thermal mechanical effects on waste package damage in Zones 1 and 2 in ICN 1 of the Dike Propagation Near Drifts AMR [ANL-WIS-MD-000015]. This will be available to the NRC in January 2001.

AGENDA
IGNEOUS ACTIVITY TECHNICAL EXCHANGE
June 21-22, 2001
Texas Station Hotel and Casino
2101 Texas Star Lane
Las Vegas, Nevada

June 21, 2001

8:00 - 8:15 AM	Opening Remarks - NRC, DOE, State of Nevada, AUGs
8:15 - 8:30 AM	Overview of Meeting for Observers - NRC
8:30 - 10:00 AM	Magma-Drift Interactions - NRC (Woods and Bokhove)
10:00 - 10:15 AM	BREAK
10:15 - 11:15 AM	Magma-Drift Interactions - DOE (Smistad, Valentine)
11:15 - 12:15 PM	Caucus on Magma-Drift Interactions
12:15 - 12:30 PM	NRC - DOE Discussion
12:30 - 1:30 PM	LUNCH
1:30 - 2:00 PM	Magma-Waste Package Interactions (DOE-Valentine)
2:00 - 3:00 PM	Caucus on Magma-Waste Package Interactions
3:00 - 3:15 PM	NRC - DOE Discussion
3:15 - 3:30 PM	BREAK
3:30 - 4:00 PM	Magma-Waste Form Interactions (DOE-Valentine)
4:00 - 4:30 PM	Caucus on Magma-Waste Form Interactions
4:30 - 4:45 PM	NRC - DOE Discussion
4:45 - 5:15 PM	Total System Performance Assessment Supplemental Sensitivity Analysis (DOE – Swift)
5:15 - 5:30 PM	Closing Remarks
5:30 PM	Adjourn Day 1

Attachment 4

AGENDA
IGNEOUS ACTIVITY TECHNICAL EXCHANGE
June 21-22, 2001
Texas Station Hotel and Casino
2101 Texas Star Lane
Las Vegas, Nevada

June 22, 2001

8:00 - 8:30 AM	Special Topic (Gene Smith, UNLV)
8:30 - 9:30 AM	Biosphere Items (DOE - Smith)
9:30 - 10:30 AM	Caucus on Biosphere Items
10:30 - 10:45 AM	NRC - DOE Discussion
10:45 - 11:00 AM	BREAK
11:00 - 11:30 AM	NRC - DOE Discussion
11:30 - 12:00 PM	Closing Remarks
12:00 PM	Adjourn Day 2

Techical Exchange - Igneous Activity
Thursday, June 21, 2001
Texas Station
Las Vegas, Nevada
Sign In Sheet

	Name (Please Print)	Company	Phone #
✓	WILLIAM MELSON	SMITHSONIAN/ NWTRB	
✓	Norman Henderson	BSC	(702)295-5323
	SUSAN ZIMMERMAN	State of NV	775 687 3744
	James Weldy	CNWRA	(210)522-6800
	Stefan Mayer	CNWRA	(210) 522-6816
✓	Eugene Smith	UNLV	702-895-3971
✓	BILL HINZE	ACNW/PURDUE	765-583-2530
	Bimal Mukhopadhyay	MTS/BAH, Inc	702-794-5420
✓	Jim Curtiss	Winston & Strawn	202-371 5751
	Nick DiNunzio	DOE	202-586-8953
	TOM THORNTON	BSC	702-295-4483
	John Savino	MTS	702 794-5524
	Bob Levich	DOE/YMP	702-794-5449
✓	Kathy Gaither	SNL	505-844-5019
✓	Don Krier	LANL	505-665-7834
✓	Edward Gaffney	LANL	505-665-6387
	Charles Harrington	LANL	505-667-1853
✓	Larry Saraka	BSC	202-488-6745
	Bob Bradbury	MTS/S&W	702-794-5424
	Frank Perry	LANL	5056673644

Attachment 5

Techical Exchange - Igneous Activity
Thursday, June 21, 2001
Texas Station
Las Vegas, Nevada
Sign In Sheet

	Name (Please Print)	Company	Phone #
	David Brooks	NRC	301 415 7284
	Jim Andersen	NRC	301-415-5717
	John TRAPP	NRC	301-415-8063
	Britt Hill	CNWRA	210-522-6087
	Chuck Connor	CNWRA	2105226649
	Richard Codell	NRC	301 415-8167
	LARRY McKAGUE	CNWRA	301-522-5183
	STEVE SPARKS	BRISTOL UNIVERSITY UK	44 1179 545419
	Onno Bokhove	University of Twente (NL)	31 53 489 3412
	Andy Woods	Cambridge Univ UK	44 1223 765702
	Bret Leslie	U.S. NRC	301 415 6652

Techical Exchange - Igneous Activity
Thursday, June 21, 2001
Texas Station
Las Vegas, Nevada
Sign In Sheet

	Name (Please Print)	Company	Phone #
✓	Dennis R. Williams	DOE YM	(702) 794-5526
✓	Eric Smistad	DOE YM	702-794-5073
✓	Tim Gunter	DOE/YM	702-794-1343
✓	Don Beckman	BSC/Licensing	702-295-4352
✓	Terry Crump	BSC/Licensing	702 295-7476
✓	Greg Valentine	LANL/BSC/DE Dep	505 665 0259
✓	Peter Swift	BSC/SNL	505 2844817
	John McCord	BSC/DES	(505) 246-1600
✓	John Gibbons	BSC/PMC	509 898 4176
	Kathryn A. Mrotek	BAH/MTS	702-~~[illegible]~~ 794-5570
✓	Pasu Pasupathi	BSC/waste package	702-295-4587
✓	Drew Coleman	DOE	702-~~[illegible]~~ 794-5537
✓	Richard Quittmeyer	ISSi	702-295-3551

Techical Exchange - Igneous Activity
Thursday, June 21, 2001
Texas Station
Las Vegas, Nevada
Sign In Sheet

	Name (Please Print)	Company	Phone #
	MICK APTED	MONITOR SCIENTIFIC	303-985-0005
✓	DAN McGREGOR	BSC/DE-DEKS	512-425-2076
✓	Darrell Gardner	BSC Licensing	702 295 5316
✓	Jennivieve Novero	BSC/BAA	702-295-5312
	R.M. LATTA	US NRC	702-794-5048
✓	Angela Brittain	BSC	702-295-5337
✓	NARASI SRIDHAR	CNWRA	210 522-5538
✓	PETER YEN	BSC	415-768-7438
	Kurt Rautenstrauch	BSC	702-295-4952

Techical Exchange - Igneous Activity
Friday, June 22, 2001
Texas Station
Las Vegas, Nevada
Sign In Sheet

Name (Please Print)	Company	Phone #
MARY MANNING - REPORTER	LAS VEGAS SUN NEWSPAPER	(702) 259-4065
SUSAN ZIMMERMAN	State of NV	775 687-3744
Richard R. Parizek	NWTRB Penn State Un	814-2380618
Leon Reiter	NWTRB	703-235-4490
[illegible] never mind		
KALYNDA Tilges	Citizen Alert	702-796-5662
COLIN MACILWAIN	NATURE	202-626-2510
GRANT HUDLOW	ASI	775,727,0866
ANTHONY J. SMITH	DEES	702-295-4040
Sally Devlin Public	Want transcript for mailing	775 727-6803
George Hellstrom	DOE, YMSCO	702-794-5519

Attachment 6

Presenter's Slides

Overview of Igneous Activity Meeting

Las Vegas, Nevada
June 21-22, 2001

Presented by
Bret Leslie
U.S. Nuclear Regulatory Commission
bwl@nrc.gov (301) 415-6652

- Meeting will address the part of the Department of Energy's (DOE) performance assessment related to igneous activity.

- Performance Assessment is

  - Systematic analysis of what could happen at a repository. This means answering three questions:
    - what can happen?
    - how likely is it?
    - what can result?

  - Conducted by
    - Collecting data
    - Developing conceptual and mathematical models
    - Combining models and evaluating performance

  - One of many NRC safety requirements

Performance Assessment terms and definitions

- **Scenario** - another way of saying "what can happen?"
- **Probability** - another way of saying "how likely?"
- **Consequence** - another way of saying "what can result?"
- **Scenario analysis** - an evaluation of what can happen
- **Features, Events, and Processes (FEPs)** - factors that are necessary to describe what can potentially happen to the repository.
  - Examples include: design of the repository, construction of the repository, strength of the waste containers and how well they resist corrosion, the nature of the waste, and natural events such as volcanoes.

- <u>Igneous Activity</u> is
  - Process of formation of rocks from molten rock.
  - Defined by the NRC as predicting the consequence and probability of igneous processes affecting the repository in relationship to overall system safety objective.

- Additional general information is available
  - Handouts, and posters on wall
  - NRC and Center for Nuclear Waste Regulatory Analyses staff will be glad to address your concerns, answer your questions, and discuss with you topics that remain unclear to you, during breaks in the meeting, or after the meeting

Igneous Activity terms and definitions

- **Magma** - molten rock with crystals and gas bubbles
- **Intrusive** - magma flow below ground surface
- **Extrusive** - magma flow above ground surface
- **Volcanic** - extrusive process at a volcano
- **Tephra** - pieces of magma flung out of a volcano
- **Ash** - pieces of tephra smaller than 0.5 inches
- **Volatiles** - gases such as steam
- **Biosphere** - environment in which people live

- **Meeting will address the DOE's treatment of igneous activity in their performance assessment**
  - How would rising magma interact with a tunnel, and what results from the interaction?
  - How would flowing magma interact with waste packages, and what results from the interaction?
  - How would flowing magma interact with the contents of waste packages, and what results from the interaction?
  - How would volcanic ash derived from an eruption thru the repository move in the environment, and what are the results of these ash movements?

- Our independent review of the DOE's performance assessment currently questions how DOE treated
  - Magma interactions with a tunnel
  - Magma interactions with waste packages
  - Magma interactions with wastes within packages
  - Volcanic ash movement in the environment
    - During an eruption
    - During long-term erosion

Comments on Igneous Activity Models with respect to Performance Assessment

Richard Codell
Performance Assessment Section
Environmental and Performance Assessment Branch
Division of Waste Management, NMSS
U.S. Nuclear Regulatory Commission

For presentation at NRC/DOE Igneous Activity Technical Exchange, Las Vegas Nevada, June 21-22, 2001

NRC Concerns for Igneous Activity (IA) Models Included in Performance Assessments

- DOE needs to characterize IA model uncertainty and propagate it through the model abstractions.

- DOE is responsible to provide justification for the use of ASHPLUME and associated NRC codes in the performance assessments (both what is presently included, and possible omissions).

Some Areas of Model Uncertainty

- **Alternative magma/drift interactions.**
- **Alternative magma/fuel interactions.**
- **Alternative intrusive models.**
- **Alternative models of fuel incorporation into ash.**
- **Alternative models of transport of ash (air and water).**
- **Alternative models of relationship between concentration in deposited ash and inhaled concentration.**

NRC's Performance Assessment Code

- **NRC has developed its own total system performance assessment code, TPA (current version 4.1), for performing independent assessments of proposed Yucca Mountain repository.**

- **NRC continually updates its TPA code. Re-evaluations are based on new insights and data.**

- **TPA version 5.0 currently under development.**

- **The codes currently used in TPA 4.1, including ASHPLUME, will be re-evaluated for possible modifications in TPA 5.0.**

NRC INTRODUCTORY COMMENTS

NRC/DOE TECHNICAL EXCHANGE ON IGNEOUS ACTIVITY
JUNE 21-22, 2001

JOHN S. TRAPP, NRC
TEL: 301-415-8063, E-MAIL: JST@NRC.GOV

IA TECHNICAL CONCERNS - Status based on review of documents received to date.

CONSEQUENCE	STATUS
1. Magma/Repository Interactions.	Need more complete analysis
2. Waste Package/Magma Interaction:	Need more complete analysis
3. Waste Form/Magma Interaction.	Need more complete analysis
4. Wind characteristics:	Closed pending TSPA-SR (Rev1)
5. Mass Loading	Closed pending more discussion
6. Remobilization.	Closed pending TSPA-SR (Rev1), likely needs more complete analysis
7. Inhalation - PM10–PM100.	Closed
8. Self evacuation.	Closed
9. Model for airborne transport.	Closed, but may need to be re-opened based on 1 and 2 above
10. Model for groundwater transport.	Closed for IA, but would recommend that DOE re-examine release rates in light of uncertainties of IA source term in TSPA-SR
11. Integration of results from all pathways.	Closed
12. Volcanic type.	Closed for type, volume closed pending TSPA-SR (Rev1)

PROBABILITY	
1. Use of NRC values in sensitivity studies.	Closed
2. Review of new aeromagnetic data.	Closed pending results of studies

Probability of igneous activity at or near the proposed repository site.

1) In addition to DOEs licensing case, include for Site Recommendation and License Application, for information purposes, the results of a single point sensitivity analysis for extrusive and intrusive igneous processes at 10E-7.

DOE agreed that the analysis will be included in TSPA-SR Rev. 0 and will be available to the NRC in November 2000.

Status: Closed per letter of April 30, 2001

2) Examine new aeromagnetic data for potential buried igneous features (see U.S. Geological Survey, Open-File Report 00-188, Online Version 1.0), and evaluate the effect on the probability estimate. If the data survey specifications are not adequate for this use, this action is not required.

DOE agreed and its initial evaluation of the report with proposed actions resulting from the review will be available to the NRC by October 11, 2000.

Status: Closed pending completion of analysis

Consequences of igneous activity within the repository setting.

1) Re-examine the ASHPLUME Code to confirm that particle density is appropriately changed when waste particles are incorporated into the ash.

DOE agreed and will correct the description in the ICN to AMR, Igneous Consequences Modeling for TSPA-SR [ANL-WIS-MD-000017] as needed to address the concern. This will be available to the NRC in January 2001.

Status: Closed per letter of April 30, 2001

2) Document results of sensitivity studies for particle size, consistent with (1) above.

DOE agreed and will document the waste particle size sensitivity study in TSPA-SR, Rev. 1. This will be available to the NRC in June 2001.

Status: Closed pending results of sensitivity studies in TSPA-SR Rev 1 or equivalent analysis.

3) Document how the tephra volumes from analog volcanos represent the likely range of tephra volumes from Yucca Mountain Region (YMR) volcanos.

DOE agreed and will document the basis for determining the range of tephra volumes that is likely from possible future volcanoes in the YMR in TSPA-SR, Rev. 1 or demonstrate that TSPA-SR results are insensitive to uncertainties in the reasonably expected volumes of tephra in the YMR. This will be available to the NRC in June 2001.

Status: Closed pending results in TSPA-SR Rev 1 or equivalent analysis.

4) Document that the ASHPLUME model, as used in the DOE performance assessment, has been compared with an analog igneous system.

DOE agreed and will complete calculation CAL-WIS-MD-000011 that will document a comparison of the ASHPLUME code results to observed data from the 1995 Cerro Negro eruption. This will be available to the NRC in January 2001.

DOE will consider Cerro Negro as an analog and document that in TSPA-SR Rev. 1. This will be available to the NRC in June 2001.

Status: Closed per letter of April 30, 2001

5) Document how the current approach to calculating the number of waste packages intersected by conduits addresses potential effects of conduit elongation along a drift.

DOE agreed and will document the way in which the change in geometry of the repository drifts affects the number of waste packages incorporated into the volcanic conduit. Possible consequences of conduit elongation parallel to drifts will be documented in TSPA-SR Rev. 1, available to the NRC in June 2001.

Status: Analysis appears insufficient based on arguments in 1/29/01 briefing by DOE and lack of appropriate analyses in ICNs to relevant AMRs. Closed pending acceptance of TSPA-SR or equivalent analysis.

6) Develop a linkage between soil removal rate used in TSPA and surface remobilization processes characteristics of the Yucca Mountain region (which includes additions and deletions to the system).

DOE agreed and will document its approach to include uncertainty related to surface-redistribution processes in TSPA-SR, Rev. 0. DOE will revisit the approach in TSPA-SR, Rev. 1. This documentation will be available to the NRC in June 2001.

> **Status:** NRC questions conservatism of proposed approach. 1/29/0 briefing by DOE indicates only "models revisiting" will occur. May affect expected annual dose significantly. Closed pending acceptance of TSPA-SR or equivalent analyses.

7) Document the basis for airborne particle concentrations used in TSPA in Rev. 1 to the Input Values for External and Inhalation Radiation Exposure AMR.

DOE agreed and will provide documentation for the input values in the Input Parameter Values for External and Inhalation Radiation Exposure Analysis AMR [ANL-MGR-MD-000001] Rev. 1. This will be available to NRC in January 2001.

> **Status:** Based on review of Input Parameter Values for External and Inhalation Radiation Exposure Analysis AMR [ANL-MGR-MD-000001] Rev. 1, this item needs discussion.

8) Provide additional justification on the reasonableness of the assumption that the inhalation of particles in the 10-100 micron range is treated as additional soil ingestion, or change the BDCFs to reflect ICRP-30.

DOE agreed and will review how 10-100 micron particles are considered in the model for the eruptive scenario. The results will be documented in Input Parameter Values for External and Inhalation Radiation Exposure Analysis AMR [ANL-MGR-MD-000001] Rev. 1. This will be available to the NRC in January 2001.

Status: Closed per letter of April 30, 2001

9) Use the appropriate wind speeds for the various heights of eruption columns being modeled.

DOE agreed and will evaluate the wind speed data appropriate for the height of the eruptive columns being modeled. This will be documented in TSPA-SR, Rev. 1. This will be available to the NRC in June 2001.

Status: Note that wind speeds were not corrected in ICN1 to the Igneous Consequence Modeling to the TSPA-SR AMR. Closed pending acceptance of TSPA-SR, Rev.1, or equivalent analysis.

10) Document the ICNs to the Igneous Consequences AMR and the Dike Propagation AMR regarding the calculation of the number of waste packages hit by the intrusion. Include in these or other documents (1) the intermediate results of the releases from Zone 1 and 2, separately, and (2) the evaluation of thermal and mechanical effects, as well as shock, in assessing the degree of waste package damage in Zone 1 and 2.

DOE agreed and will provide ICN 1 of the following AMRs: Igneous Consequences Modeling for TSPA-SR AMR [ANL-WIS-MD-000017], the Dike Propagation Near Drifts AMR [ANL-WIS-MD-000015], the Characterize Framework for Igneous Activity at Yucca Mountain, Nevada AMR [ANL-MGR-GS-000001], and the Calculation Number of Waste Packages Hit by Igneous Intrusion [CAL-WIS-PA-000001]. This will be available to the NRC in January 2001.

> **Status:** Based on review of above documents analysis appears insufficient. Thermal, chemical, and physical conditions appropriate for the duration of basaltic igneous events have not been considered and that significant credit is taken by the DOE for waste-package and waste-form resilience during igneous events. Alternative interpretations of available data indicate an order of magnitude more WP may fail than accounted for in the DOE TSPA-SR calculations

DOE will provide the results showing the relative contributions of releases from Zones 1 and 2 in TSPA-SR, Rev. 1. This will be available to the NRC in June 2001.

> **Status:** As the relevant AMRs have not evaluated an appropriate range of conditions, release rates are likely underestimated and the analyses in TSPA-SR Rev. 1 will not address this concern without additional analysis.. Closed pending acceptance of TSPA-RS or equivalent analysis

DOE will provide the evaluation of thermal mechanical effects on waste package damage in Zones 1 and 2 in ICN 1 of the Dike Propagation Near Drifts AMR [ANL-WIS-MD-000015]. This will be available to the NRC in January 2001.

> **Status:** Based on review of ANL-WIS-MD-000015, analysis insufficient. In addition to inadequate analysis of WP failure, this AMR does not adequately address the magnitude and duration of magma flow into repository drifts or how the presence of subsurface drifts may affect igneous eruptive processes.

Igneous Activity Technical Exchange Discussion Iteems			
Magma-Drift Interactions			
Topic	NRC Synopsis	Proposed Path Forward	Notes
1) Thermal mechanical effects of HLW emplacement	Models that propose stress accumulation due to HLW thermal-mechanical effects need to evaluate appropriate strain response on existing or new structures, in addition to spatial and temporal variations in thermal loading.	1. DOE will evaluate the strain response on existing or new geologic structures resulting from thermal loading of HLW. The evaluation will include appropriate spatial variations in overlying topography, and include appropriate spatial and temporal variations in thermal load.	
2) Magma Flow	Evaluate effects of DOE proposed design alternatives on magma flow processes for the duration of an igneous event.	2. DOE will evaluate how the presence of engineered repository structures (e.g., drifts, shafts) can affect magma flow processes for the duration of an igneous event. Include in this evaluation the potential effects on initial magma flow characteristics, diversion of ascending magma into repository structures, reestablishment of multiple flow-paths to the surface, and range of steady and nonsteady flow conditions that could occur for the duration of an igneous event.	
3) Magma ascent/conduit localization	Evaluate how the ascent of basaltic magma may be affected by the presence of subsurface repository structures. In particular, evaluate how vertical ascent may localize conduit formation at intersected drifts rather than randomly or in pillars.	3. DOE will evaluate how the presence of repository structures may affect magma ascent characteristics and conduit localization. Include in this evaluation the potential effects of topography, in addition to a range of physical conditions appropriate for the duration of igneous events	Supercedes 8/00 agreement

Topic	NRC Synopsis	Proposed Path Forward	Notes
4) Incomplete Closure of drifts	Evaluate mechanical strength of debris accumulations or barriers that may occur at ends of intersected drifts, for an appropriate range of physical conditions that occur during an igneous event.	4. DOE will evaluate the mechanical strength of natural or engineered barriers that are proposed to restrict magma flow within intersected drifts. A range of physical conditions appropriate for the duration of igneous events will be used in the evaluation.	
5) Mechanical Degradation or Collapse of Drift	Evaluate how the presence of engineered backfill or naturally occurring rockfall may affect magma flow processes for duration of an igneous event.	5. If significant amounts of backfill or rockfall are thought to occur in repository drifts, DOE will evaluate the effects of these materials on magma flow processes throughtout the duration of an igneous event.	
6) Volcanic HLW source term	Evaluate how magma ascent and flow pathways that are affected by repository structures (e.g., Woods et al., 2001) could potentially entrain more HLW than currently modeled with circular conduits.	6. DOE will evaluate how ascent and flow through repository structures may incorporate HLW located along all potential flow paths that may occur during an igneous event.	

Magma-Waste Package Interactions			
Topic	NRC Synopsis	Proposed Path Forward	Notes
1) Canister failure (dynamic)	Evaluate canister response to stress from dynamic magmatic repressurization, gravitational loading, and potential differential thermal expansion, using appropriate at-condition strength properties and flow paths, for duration of event.	DOE will evaluate waste package response to stresses from dynamic magmatic repressurization, internal pressurization, gravitational loading, and potential differential thermal expansion, using appropriate at-condition strength properties and magma flow paths, for duration of an igneous event.	
2) Canister Failure (long term)	Evaluate ageing effects on materials strength properties when exposed to basaltic magmatic conditions for the duration of an igneous event.	DOE will evaluate ageing effects on materials strength properties when exposed to basaltic magmatic conditions for the duration of an igneous event. Include in this evaluation the potential effects of seismically induced stresses on substantially intact waste packages.	
3) Canister degradation due to degassing	Evaluate response of Zone 3 waste packages, or waste packages covered by backfill or rockfall, if exposed to magmatic gasses at conditions appropriate for an igneous event.	DOE will evaluate the response of Zone 3 waste packages, or waste packages covered by backfill or rockfall, if exposed to magmatic gasses at conditions appropriate for an igneous event.	
4) Damage to waste packages	Number of waste packages intersected by magma.	Evaluate range of DOE design options and alternative flow-path models, as discussed in magma-drift interactions section.	8/00 agreement
ibid.	Thermo-mechanical effects on waste package damage in zones 1 and 2	Items (1–2) in this section.	8/00 agreement
ibid.	Relative contributions to dose from releases in zones 1 and 2. See 8/00 agreements.	Continue to evaluate if differences in canister failure modes remain in DOE models, including Zone 3.	8/00 agreement

Magma-Waste Form Interactions			
Topic	NRC Synopsis	Proposed path Forward	Notes
1) Magma Interacts w/ Waste	Evaluate the physical and chemical response of HLW and cladding after heating and potential disruption of WP and contents, for WP remaining in drifts. In particular, evaluate effects that may result in increased solubility potential relative to undisturbed HLW forms.	DOE will evaluate the physical and chemical response of HLW and cladding after heating and potential disruption of WP and contents, for WP remaining in drifts. Particular attention will be given to effects that may result in increased solubility potential relative to undisturbed HLW forms.	

Miscellaneous Items			
Topic	NRC Synopsis	Proposed Path Forward	Notes
1) Remobilization of waste	Develop a technical basis to support conclusions that the effects of eolian and fluvial remobilization are bounded by conservative modeling assumptions in the TSPA-SR Rev0 ICN1. Demonstrate how more realistic models that account for: i) rate of mobilization off slopes, ii) rate of transport in Fortymile Wash drainages, iii) rate of transport from eolian processes, iv) deposition rate at proposed critical group location, v) changes in particle-size distributions during fluvial transport, would not lead to higher calculations of risk.	DOE will develop a technical basis to support conclusions that the effects of eolian and fluvial remobilization are bounded by conservative modeling assumptions in the TSPA-SR Rev0 ICN1. Particular attention will be paid to: i) rate of mobilization off slopes, ii) rate of transport in Fortymile Wash drainages, iii) rate of transport from eolian processes, iv) deposition rate at proposed critical group location, v) changes in particle-size distributions during fluvial transport.	8/00 agreement
2) Aeromagnetic data	Develop technical basis to determine location and age of buried basaltic features. Provide forward model of aeromagnetic data to demonstrate that additional basaltic features are not present but undetected in magnetically "noisy" areas within about 30 km of the proposed repository site	DOE will develop a technical basis to determine location and age of buried basaltic features. Provide forward model of aeromagnetic data to demonstrate that additional basaltic features are not present but undetected in magnetically "noisy" areas within about 30 km of the proposed repository site	8/00 agreement
3) ASHPLUME: Wind velocity	Discuss incorporation of new wind-velocity data into the DOE TSPA model. Discuss method used to average wind velocity in TSPA models (i.e., account for time laterally advecting in plume).	DOE will discuss how the new wind-velocity data are being incorporated into the DOE TSPA model. Average wind velocities will need to account for the differences in time that particles are laterally advecting versus settling from the plume.	8/00 agreement
4) ASHPLUME: Incorporation	Develop an independent technical basis for the method of HLW incorporation used in DOE models	DOE will develop an independent technical basis for the method of HLW incorporation used in DOE models	

Topic	NRC Synopsis	Proposed Path Forward	Notes
5) Model validation	Develop methodology to validate models of basaltic igneous processes in the TSPA. Of particular concern are the models that account for interactions between magma and engineered systems, which lack apparent natural analogs.	Although no specific agreement is needed, DOE should discuss how models developed to evaluate igneous processes will be validated.	Will likely be discussed in detail in TSPA Technical exchange
6) Model uncertainty	Develop methodology to evaluate the uncertainty associated with models of basaltic igneous processes in the TSPA. Demonstrate that uncertainties arising from model validation (item 5) are incorporated into the TSPA results.	Although no specific agreement is needed, DOE should discuss how uncertainties in models developed to evaluate igneous processes will be incorporated into TSPA results.	Will likely be discussed in detail in TSPA Technical exchange
7) Alternative conceptual models	Develop methodology to evaluate the risk significance of alternative conceptual models, such as models presented in Woods et al. (2001). Include an evaluation of the cumulative effects of multiple alternative conceptual models.	Although no specific agreement is needed, DOE should discuss how the risk significance of alternative conceptual models will be evaluated.	Will likely be discussed in detail in TSPA Technical exchange

Biosphere Items Related to Igneous Activity			
Topic	NRC Synopsis	Proposed Path Forward	Notes
1) Airborne particle concentrations: Comparison of static vs disturbed conditions	Strengthen relationships between measurements of airborne particle concentrations for static conditions and appropriate levels of surface disturbance associated with the habits and lifestyles of critical group members.	1. DOE will provide an analysis that shows the relationship between any static measurements used in the TSPA and expected types of subsurface disturbing activities associated with the habits and lifestyles of the critical group	
2) Airborne particle concentrations: Average annual static concentrations vs. 8-hr workday disturbed conditions.	Strengthen relationships between measurements of annual airborne particle concentrations under static conditions, and durations of exposure to disturbed and undisturbed conditions of critical group.	2. DOE will provide information showing the relationship of measurements of annual airborne particle concentrations under static conditions to concentrations and exposure times characteristic of disturbed and undisturbed conditions of the critical group.	
3) Airborne particle concentrations: Basis for extrapolating TSP concentrations.	Clarify relationship used to extrapolate total suspended particulate concentrations (TSP) from PM10 measurements. Strengthen discussion of how TSP can be determined for disturbed conditions based on other PM10 measurements, as surface disturbance will likely increase the proportion of coarser particles (10-100 μm) in the breathing zone relative to static entrainment conditions (i.e., gravitationally induced settling of coarse particles may be more significant for static than disturbed conditions).	3. DOE will provide clarifying information on how PM10 measurements have been extrapolated to total suspended particulate concentrations (TSP). This will include consideration of the difference in behavior between PM10 and TSP particulates under both static and disturbed conditions.	

..... Topic	NRC Synopsis	Proposed Path Forward	Notes
4) Airborne particle concentrations: Remobilization effects	Evaluate potential changes in airborne particle concentration in response to fluvial and eolian flux through the critical group location. Although transition-period particle concentrations are viewed by the DOE as conservative, the lower parts of that range may not be conservative for the first decades following an eruption due to rapid remobilization effects. This also affects the item 5.	4. DOE will provide information showing the potential effects of post eruptive eolian and fluvial processes on the airborne particulate concentrations.	
5) Airborne particle concentrations: Recovery period	Additional data are needed to support the assumption that the concentration of airborne particles returns to background values within 10 years after the eruption. In particular, DOE needs to demonstrate that input of fine particulates through wind and water remobilization would not significantly affect the proposed mass-load reduction factor.	5. DOE will supply additional data to support the assumption that the concentrations of airborne HLW-contaminated particles returns to background values within 10 years following an eruption.	
6) Airborne particle concentrations: Soil buildup	DOE needs to demonstrate that processes removing radionuclides from the soil (i.e., decay, erosion, and leaching) do not cause a significant change in the concentration of radionuclides in the soil over the first 10 years following the eruption. The mixing of temporal variability and parameter uncertainty in the development of the mass loading above a tephra deposit will only provide correct results if other time-dependent processes do not result in a significant change in the concentration of radionuclides in the soil during the 10 year period that is averaged.	6. DOE will provide information demonstrating how radionuclide removal processes such as decay, erosion and leaching effect the concentrations of radionuclides in the soil with emphasis on the first 10 years following eruption.	

Topic	NRC Synopsis	Proposed Path Forwrd	Notes
7) Airborne particle concentrations: thin deposits	DOE needs to support the assumption that the average mass load over the first 10 years following an eruption is directly proportional to the thickness of the deposit. Models currently sample from a loguniform distribution between the nominal mass load representing a thin deposit and the average mass load for a thick deposit. Although the effects of airborne remobilization have not been evaluated, deposits less than several mm may be removed relatively quickly and thus not influence significantly the average mass load over the 10 years following the eruption. However, once a critical thickness of deposit is reached, a fines-depleted surface layer forms that protects lower levels of the deposit. Subsequent surface disturbance exposes the protected, lower levels of the deposit, which would increase mass load significantly in the form of a step function. Also, redistribution effects may cause initially thin deposits to have an effect on the 10-year average mass load at the critical group location.	7. DOE will provide information demonstrating the relationship of average mass load to deposit thickness.	
8) External exposures	Dose pathways for direct release discussed in TSPA-SR (p, 3-206) list inhalation and ingestion, but do not list external exposure from HLW-contaminated ash. In addition, external exposure is not considered for indoor occupants even though the dwelling may be surrounded by HLW-contaminated ash containing high energy gamma emitters.	8. DOE should clarify that external exposure from HLW-contaminated ash, in addition to inhalation and ingestion, was considered in the TSPA. Include in this clarification the consideration of external exposure during indoor occupancy times, or provide basis for dwelling shielding from outdoor gamma emitters.	Recently deferred from TSPA TE discussions on model abstractions
9) Effects of climate change on BDCFs	Disruptive events BDCFs apparently are not affected by climate change, whereas BDCFs for the "nominal case" are affected climate change (DE BDCF AMR).	9. DOE should include consideration of the effects of climate change on DE BDCFs.	Recently deferred from TSPA TE discussions on model abstractions

Explosive Magmatic Eruptions into Subsurface Tunnels

Onno Bokhove

Faculty of Mathematical Sciences, University of Twente, The Netherlands

(School of Mathematics, Bristol)

Funding

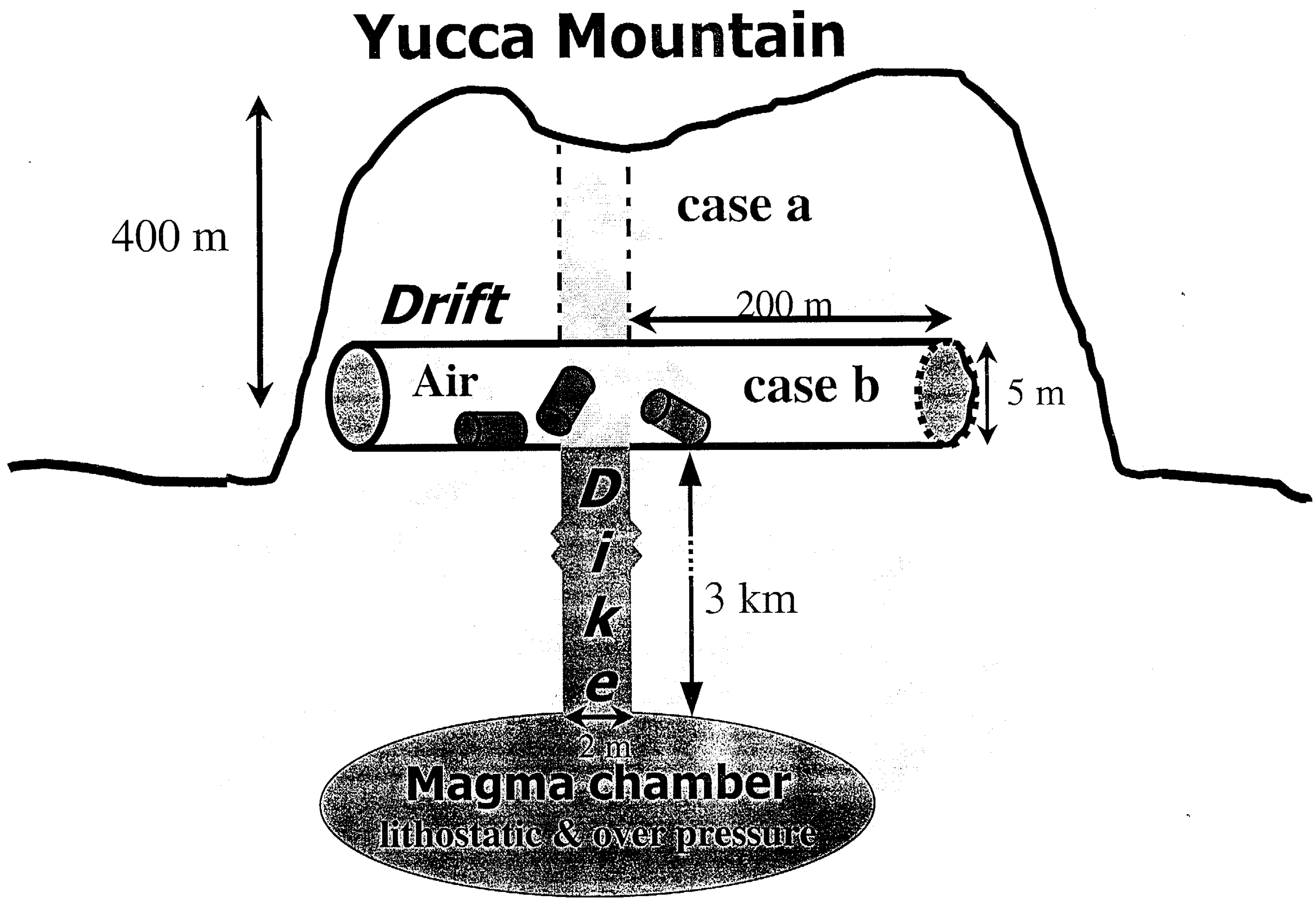
Center for Nuclear Waste Regulatory Analyses, SwRI, U.S.A.

Team

Connor, Hill, LeJeune, Sparks, Woods, B.

B. & *Woods*, 2001, JGR, in review

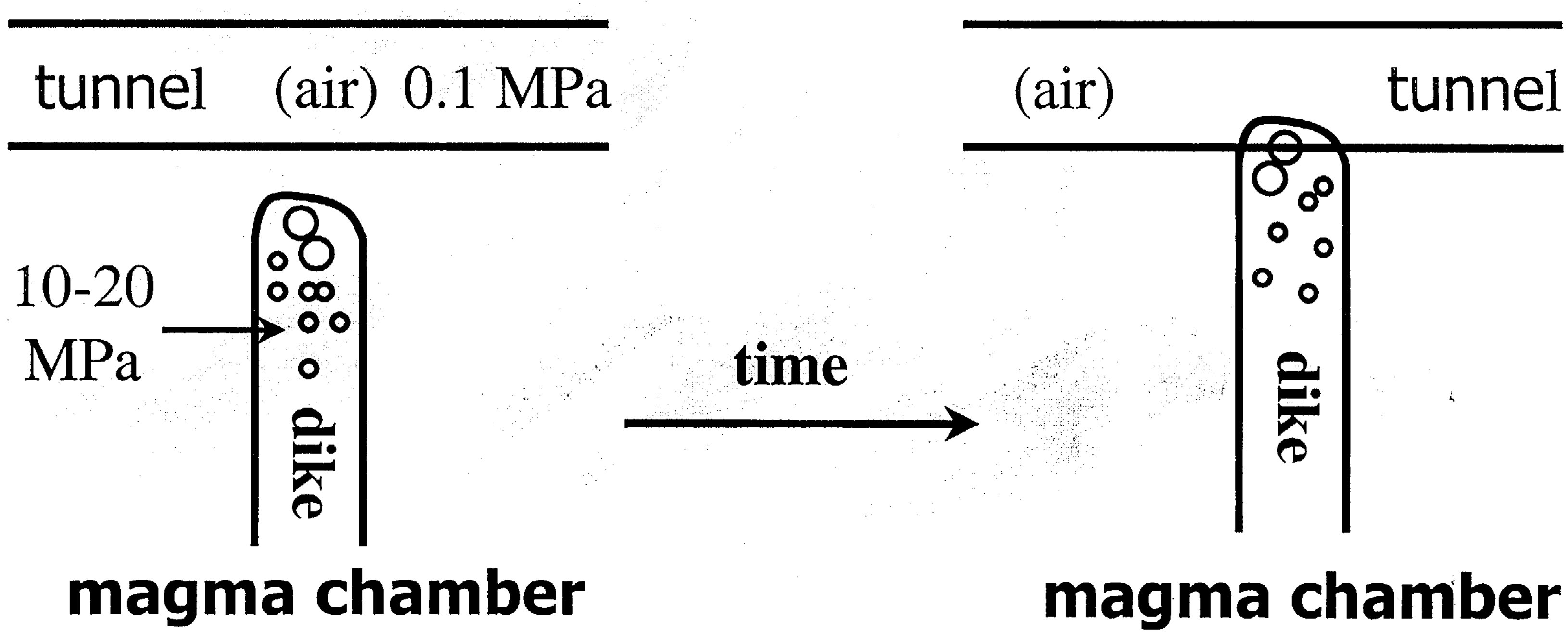
***Woods et al.* 2001, Science, submitted**



Yucca Mountain
400 m
case a
Drift
200 m
Air
case b
5 m
Dike
3 km
2 m
Magma chamber
lithostatic & over pressure

Scenario

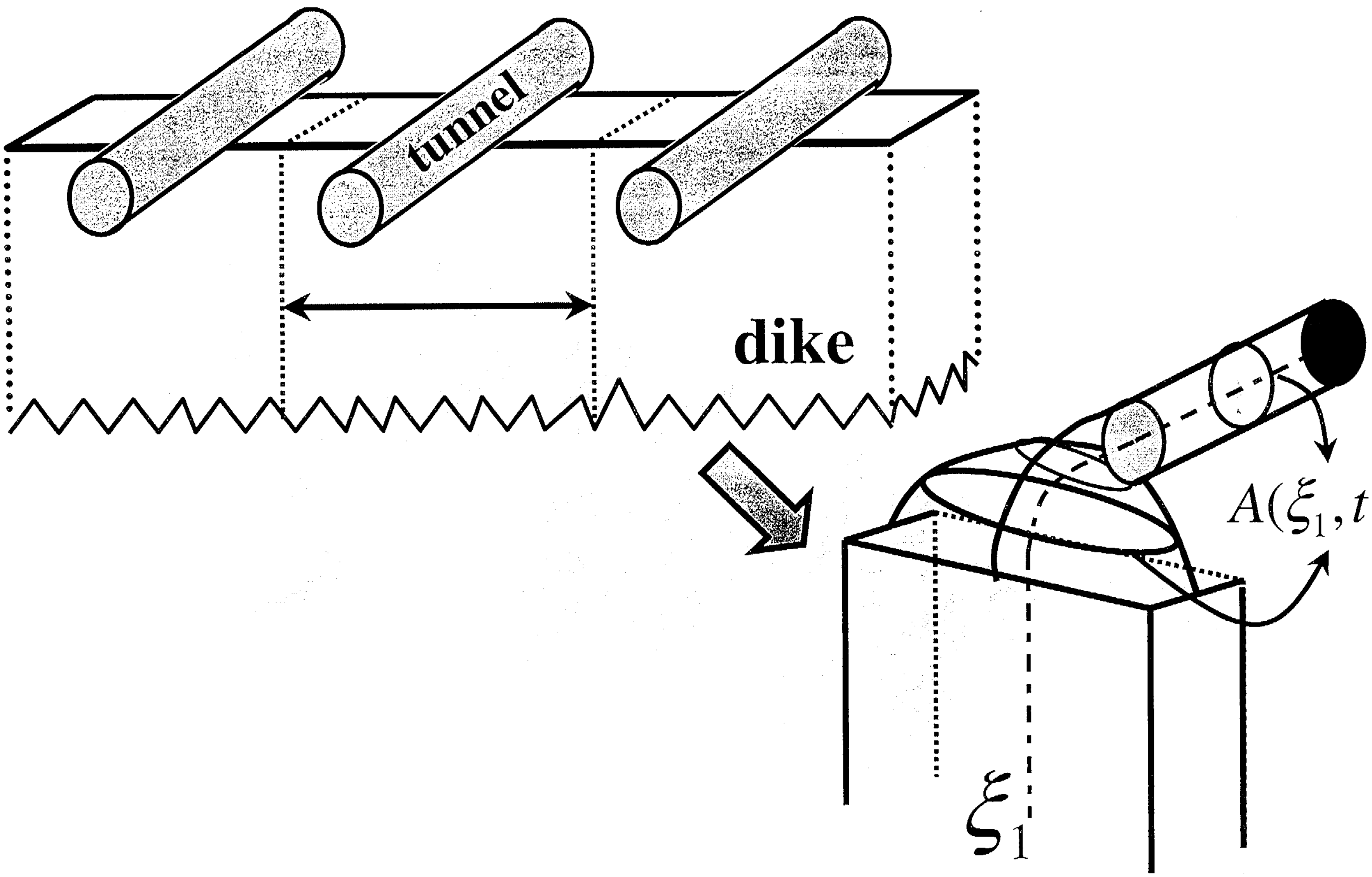
- Magma dike travels through rock (1-2 m/s) and meets tunnel at time t=0.



Research Questions

- I. Does the pressure in the tunnels increase beyond critical pressure levels?
- II. Where and when can we expect rock fracture and, hence, new pathways to the surface?
- Rock hydrofracturing ~5 MPa at 300 m

Flow tube model



Magma model

- Multi-phase magma as pseudo one-phase fluid:

$$\rho = \left[\frac{n(p) R_v T_m}{p} + \frac{1 - n(p)}{\sigma} \right]^{-1} \qquad n(p) = n_0 - s_H \sqrt{p}$$

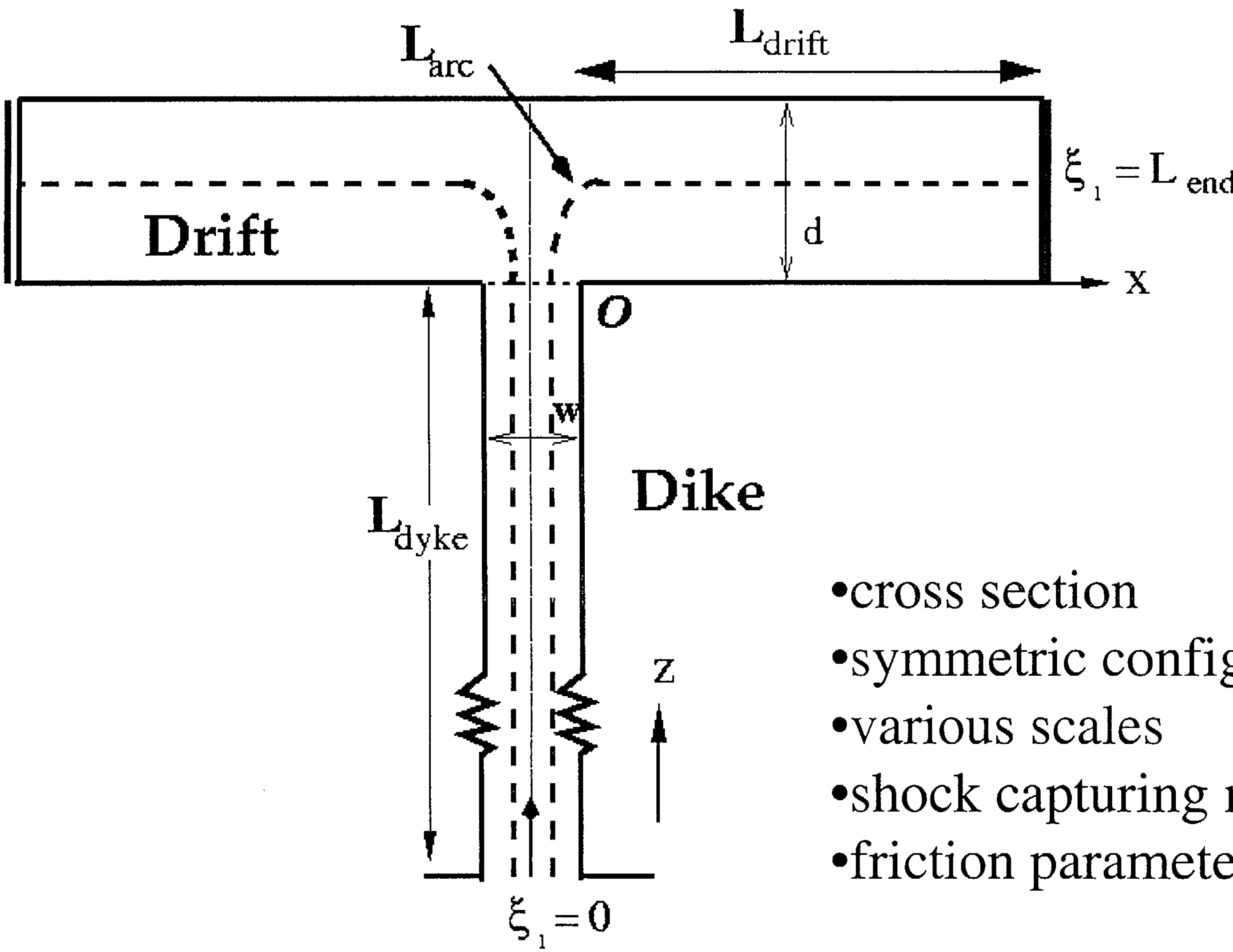
- 3D averaged 1D continuity equation:

$$\frac{\partial(\rho A)}{\partial t} + \frac{1}{h_1} \frac{\partial}{\partial \xi_1} (\rho A u) = 0$$

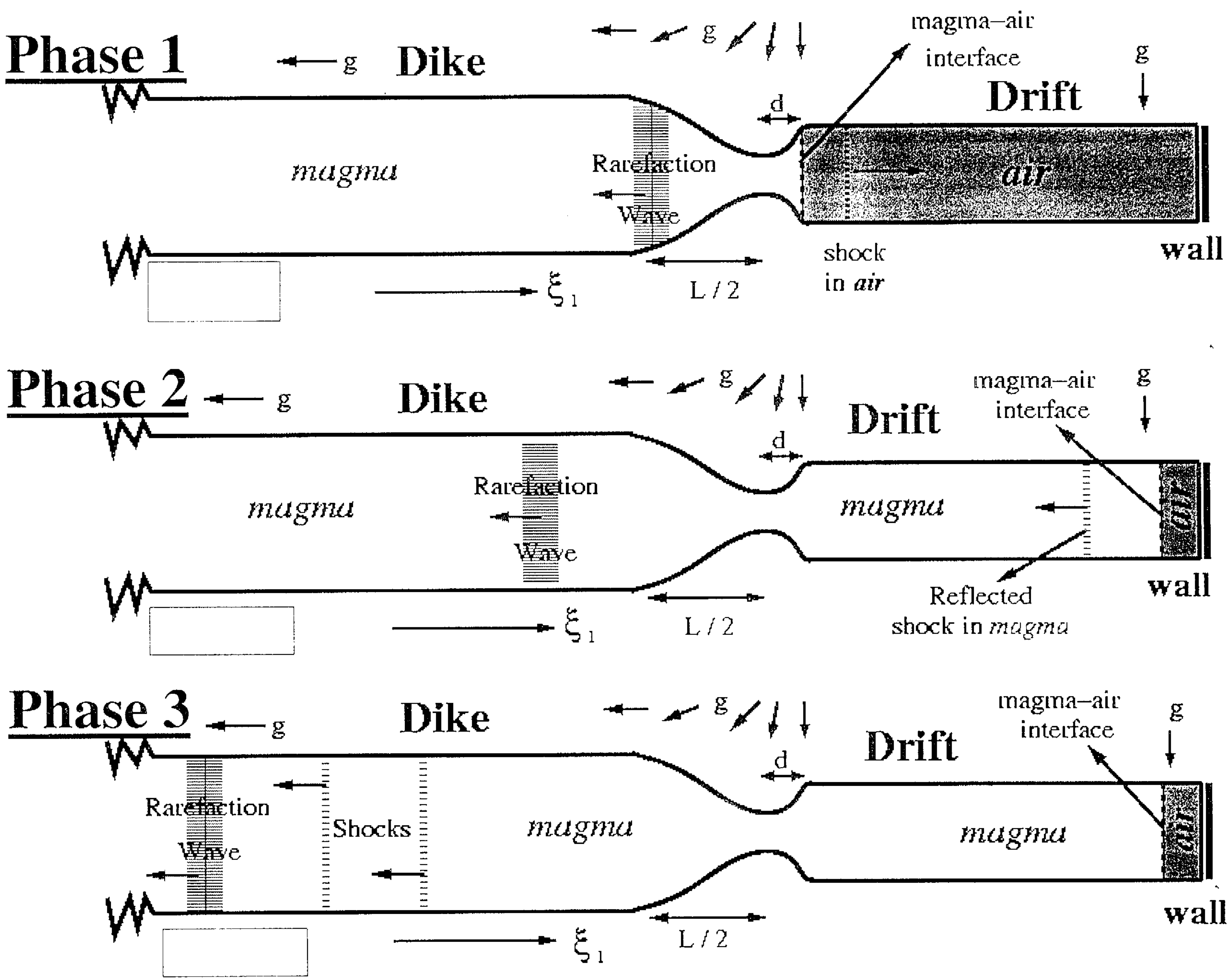
- 3D averaged 1D momentum equation:

$$\frac{\partial(\rho A u)}{\partial t} + \frac{1}{h_1} \frac{\partial}{\partial \xi_1} \left(\rho A u^2 + pA\right) = -AF_1 + \frac{p}{h_1} \frac{\partial A}{\partial \xi_1} - \frac{\rho g A}{h_1} \frac{\partial z}{\partial \xi_1}$$

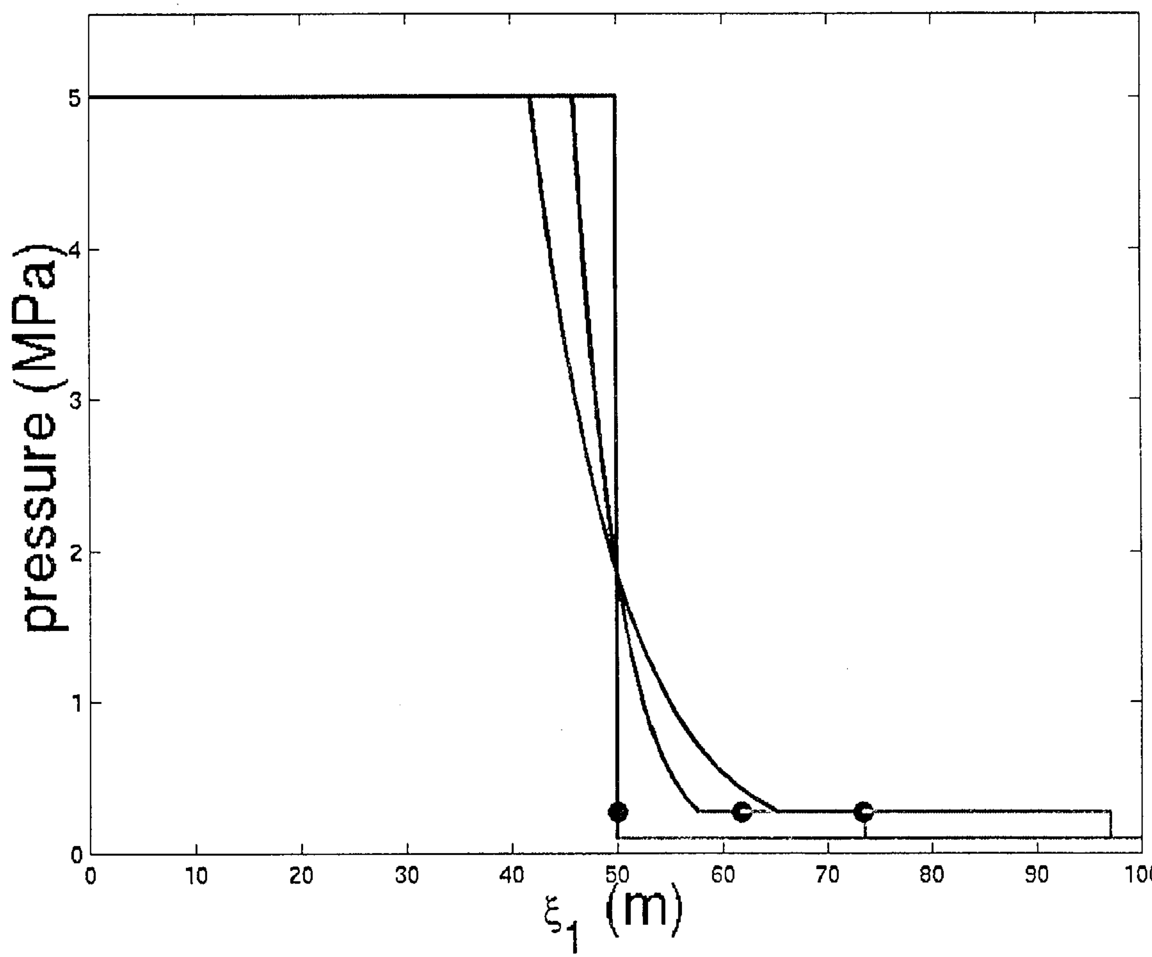
Magma-repository interactions



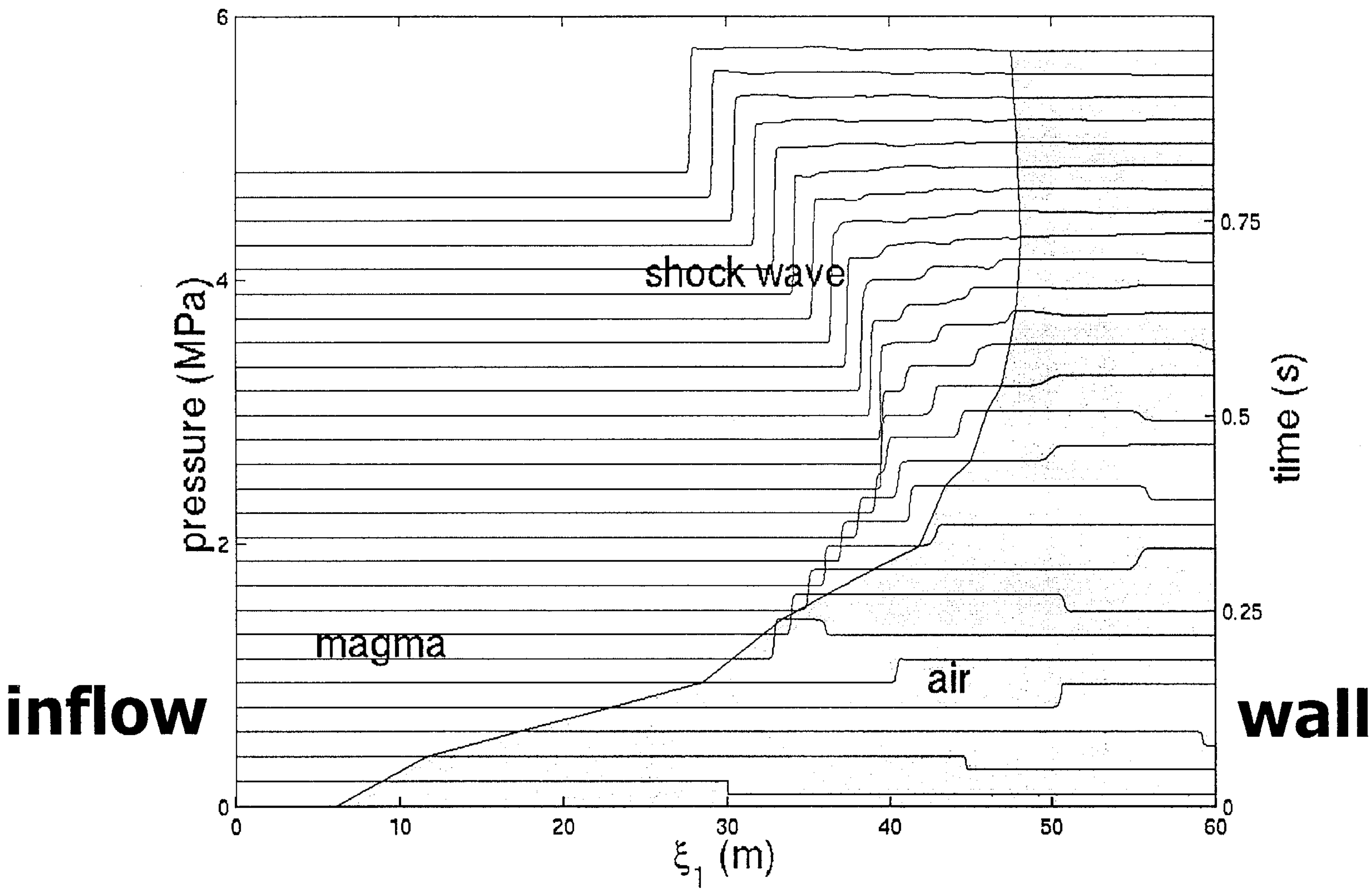
- cross section
- symmetric configuration
- various scales
- shock capturing numerics
- friction parameterized


Phase 1
g
Dike
g
magma–air
interface
g
Drift
d
magma
Rarefaction
Wave
air
shock
in air
wall
ξ1
L / 2
Phase 2
g
Dike
g
magma–air
interface
g
Drift
d
magma
Rarefaction
Wave
magma
air
Reflected
shock in magma
wall
ξ1
L / 2
Phase 3
g
Dike
g
magma–air
interface
g
Drift
d
Rarefaction
Wave
Shocks
magma
magma
air
wall
ξ1
L / 2

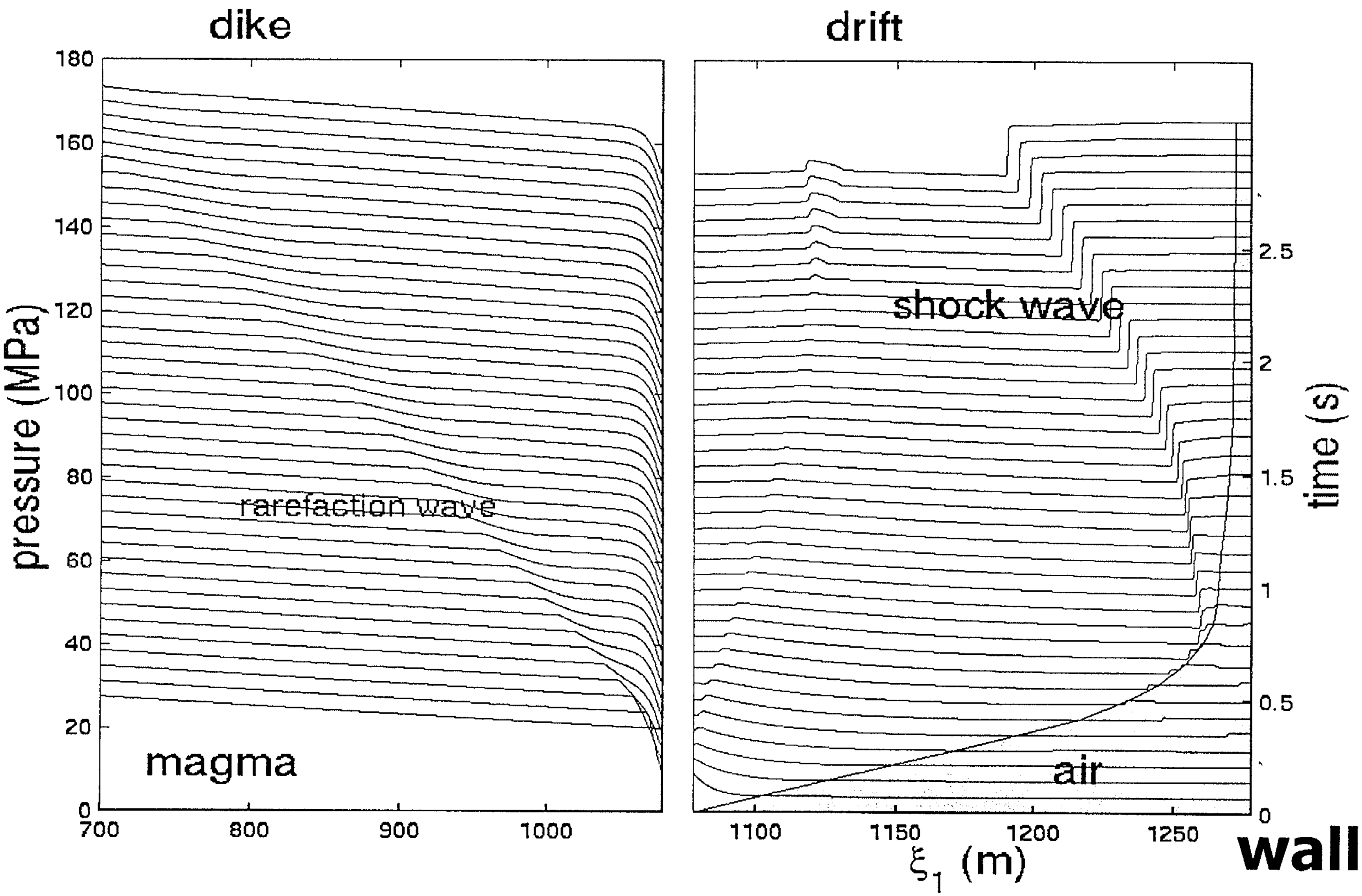
Phase 1: shock tube

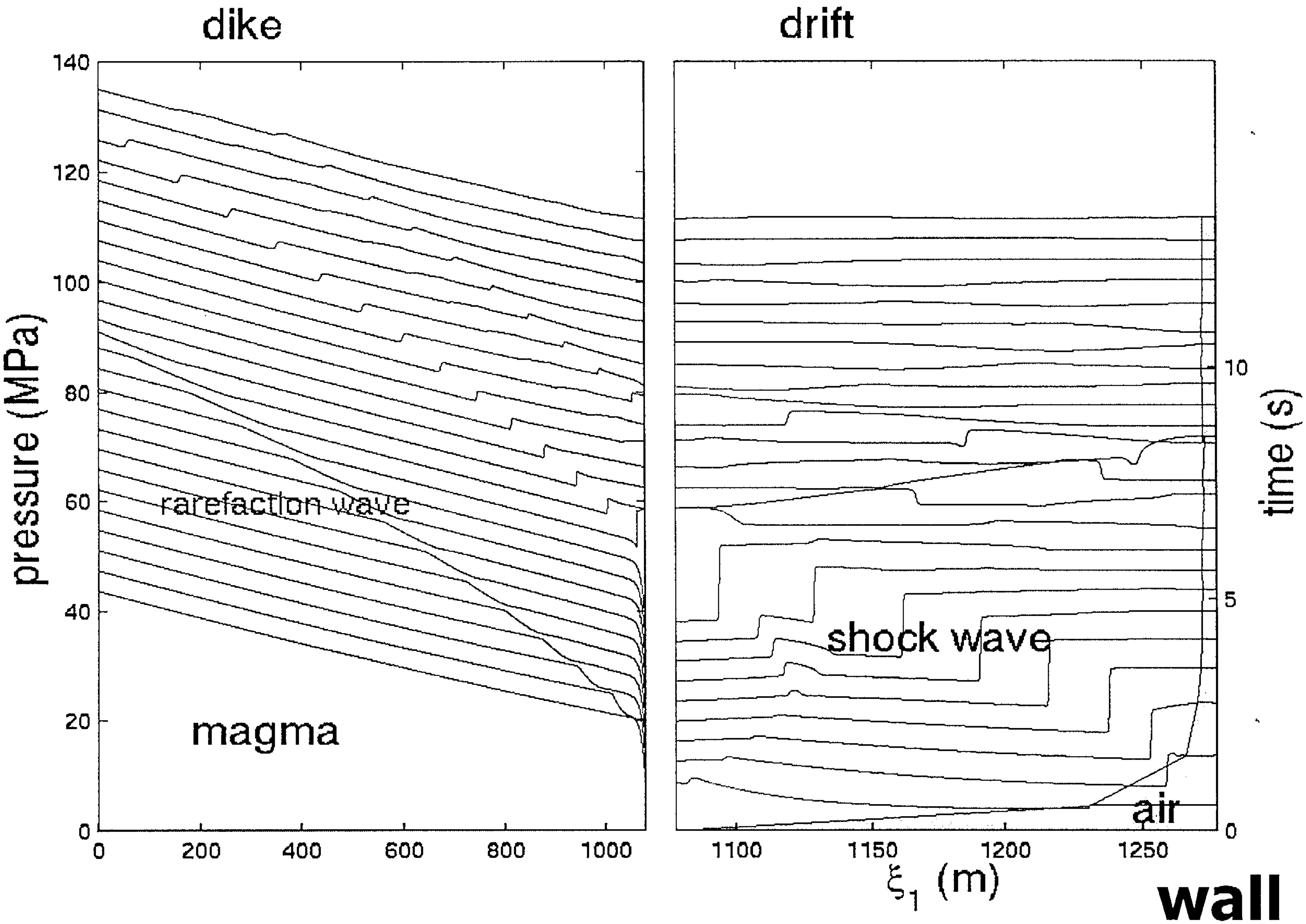


Phase 2: shock amplification

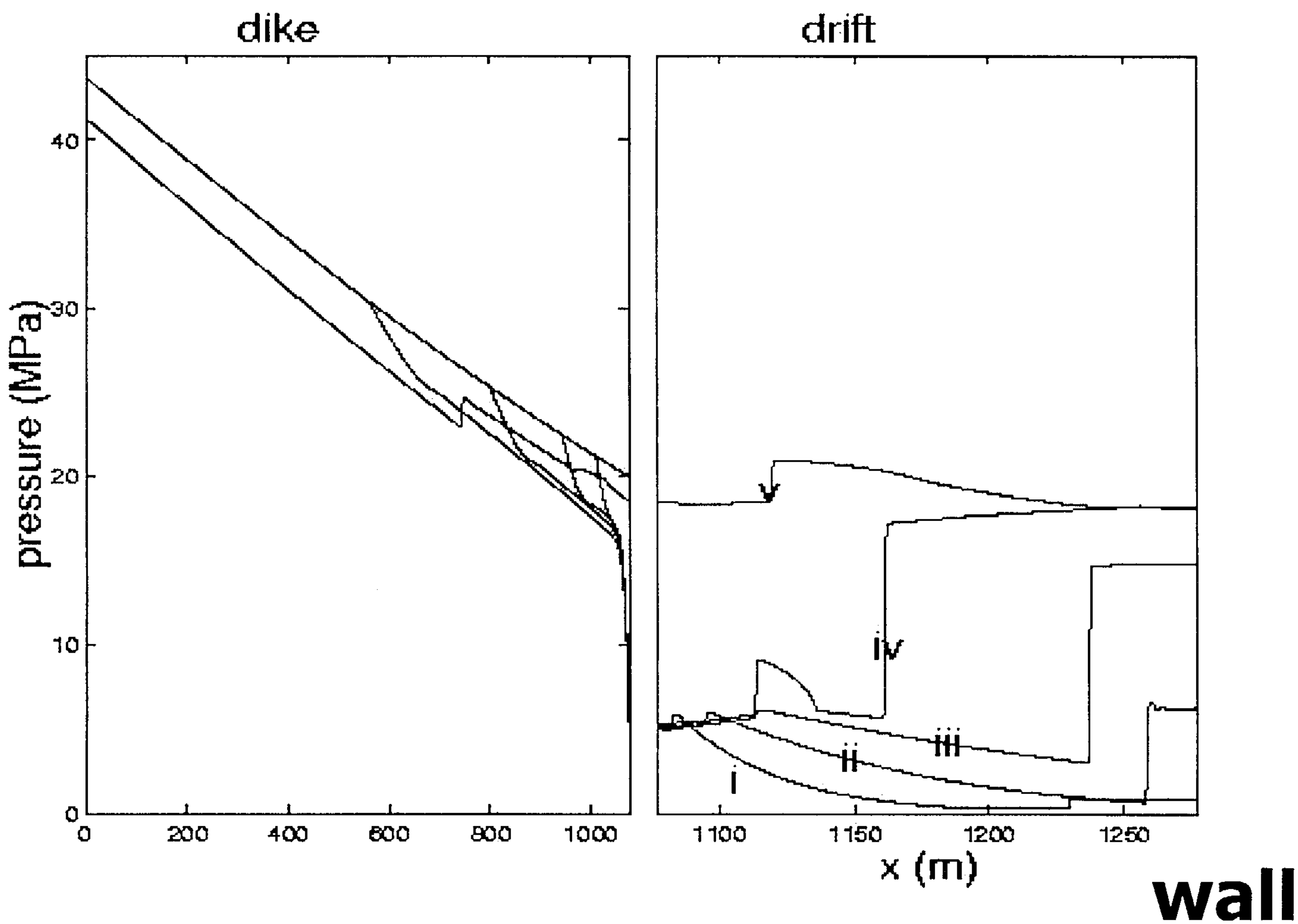


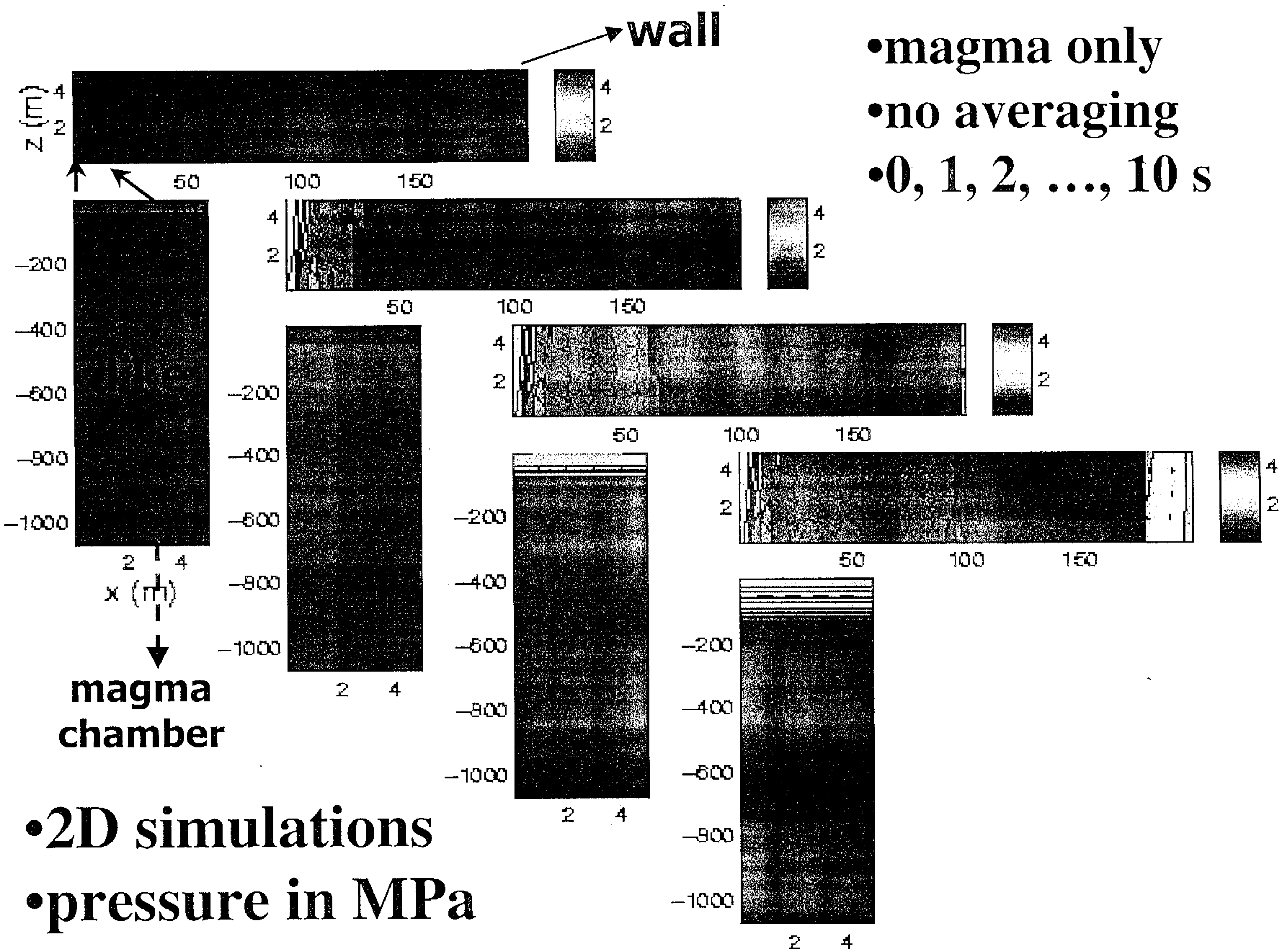
Reference simulations




dike
drift
pressure (MPa)
time (s)
rarefaction wave
magma
shock wave
air
ξ_1 (m)
wall
140
120
100
80
60
40
20
0
0
200
400
600
800
1000
1100
1150
1200
1250
10
5
0

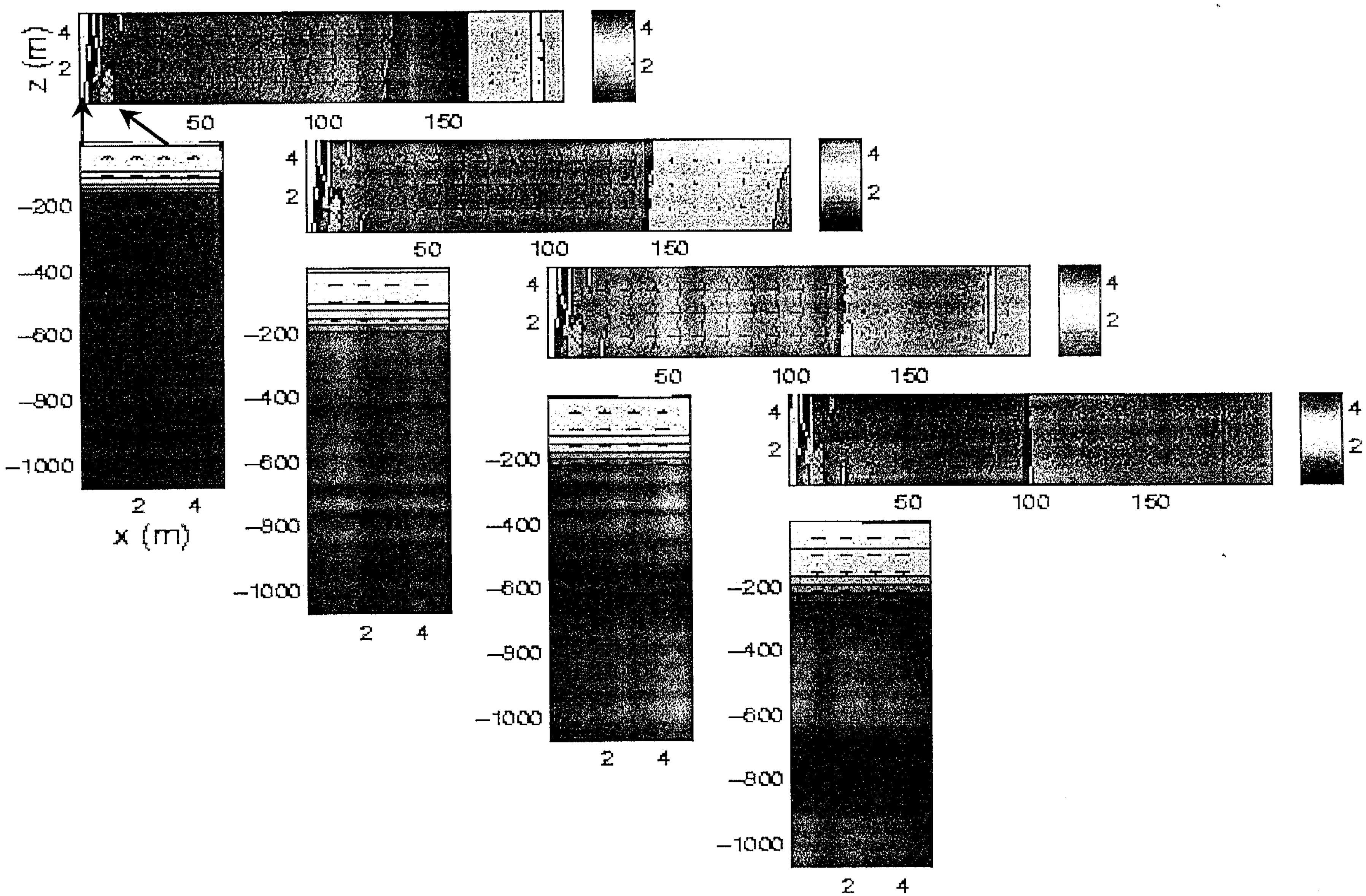
Selected Pressure Profiles



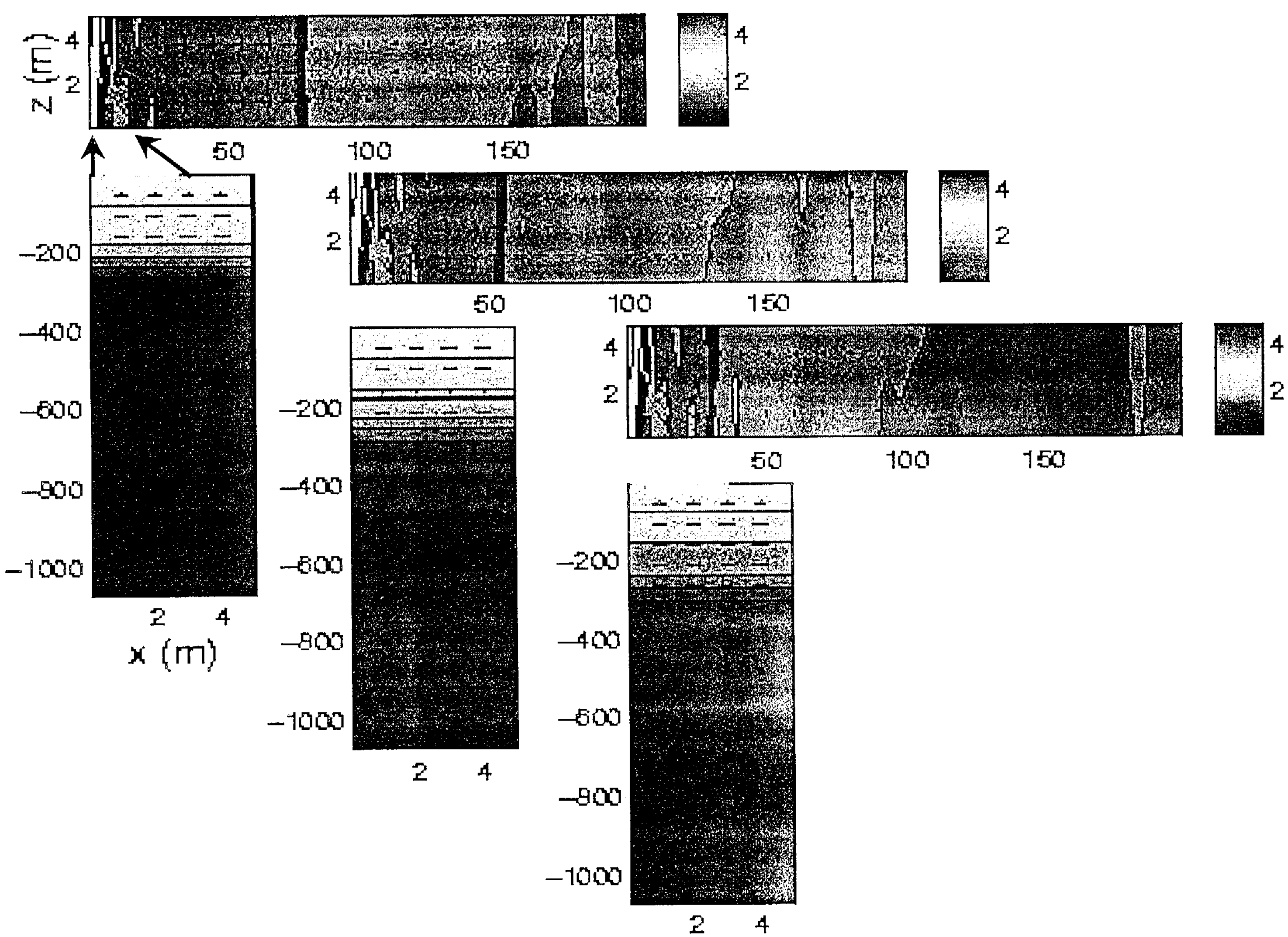


- magma only
- no averaging
- 0, 1, 2, …, 10 s

- 2D simulations
- pressure in MPa

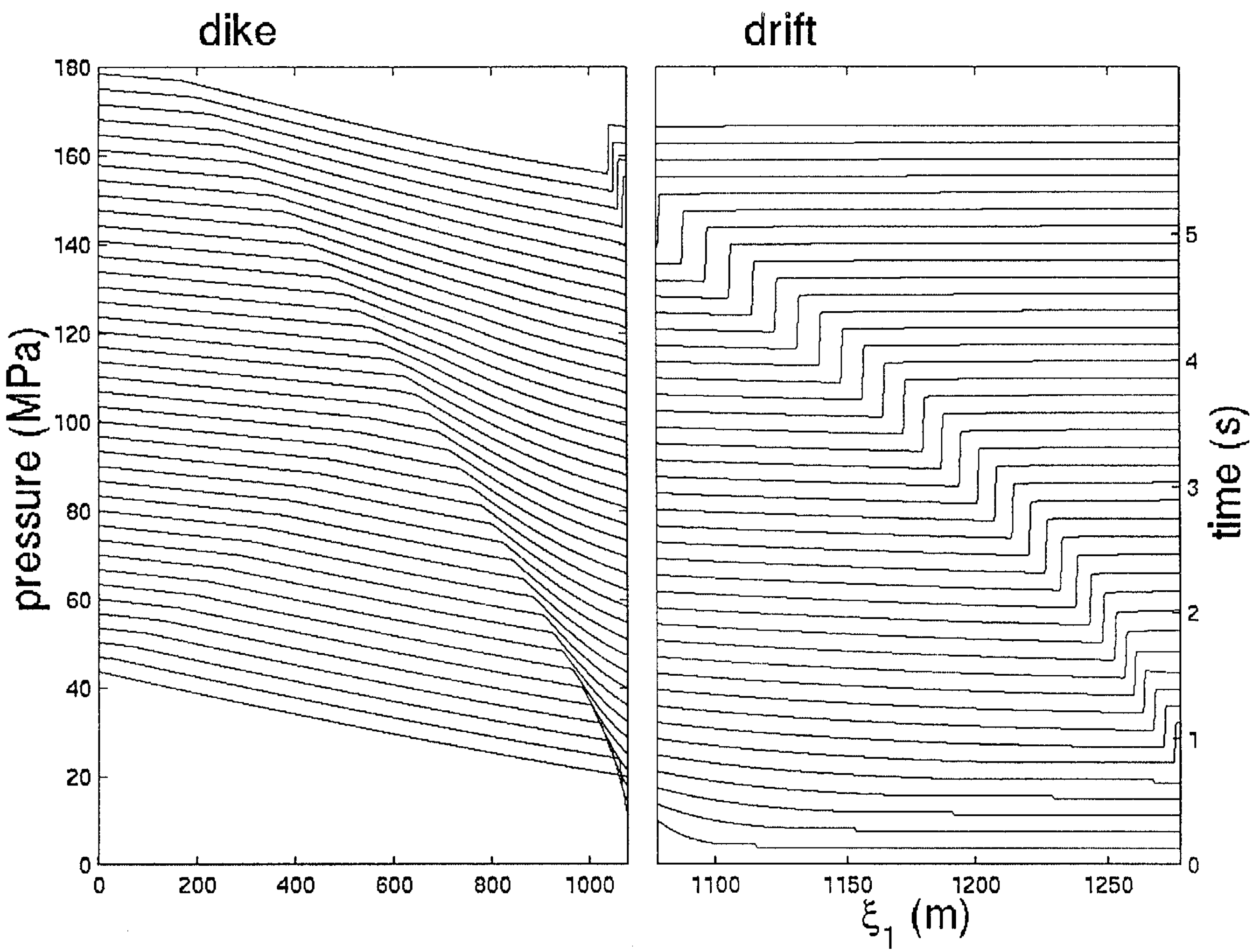


z (m)
x (m)



z (m)
x (m)

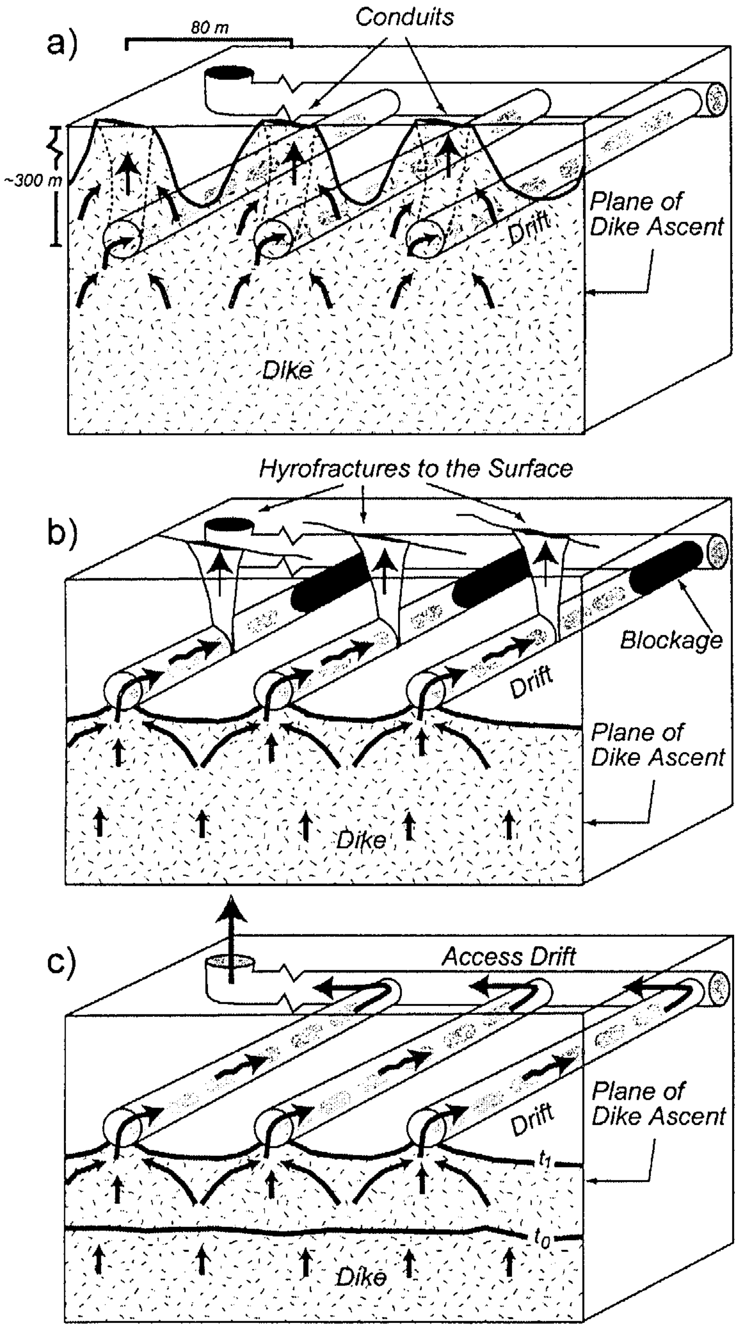
2D averaged 1D simulation



Conclusions

- I. Critical ***rock-fracture pressures*** ~5 MPa are ***exceeded*** in magma-repository interactions, especially
- II. most dominantly at ***the closed tunnel end*** (1D and 2D simulations) and at ***the tunnel roof*** near the dike-drift intersection (preliminary 2D simulations).

- ***Explosive magma-air interactions*** are characterized by a shock-tube, shock reflection & amplification, and decay/radiation phase.
  -***1D Parameter study*** reveals robustness of reference similation.



Woods et al.,
Figure 4

CONCLUSIONS

Timing and location of rock fracturing will control formation
of new pathways to surface

Possible Future Work

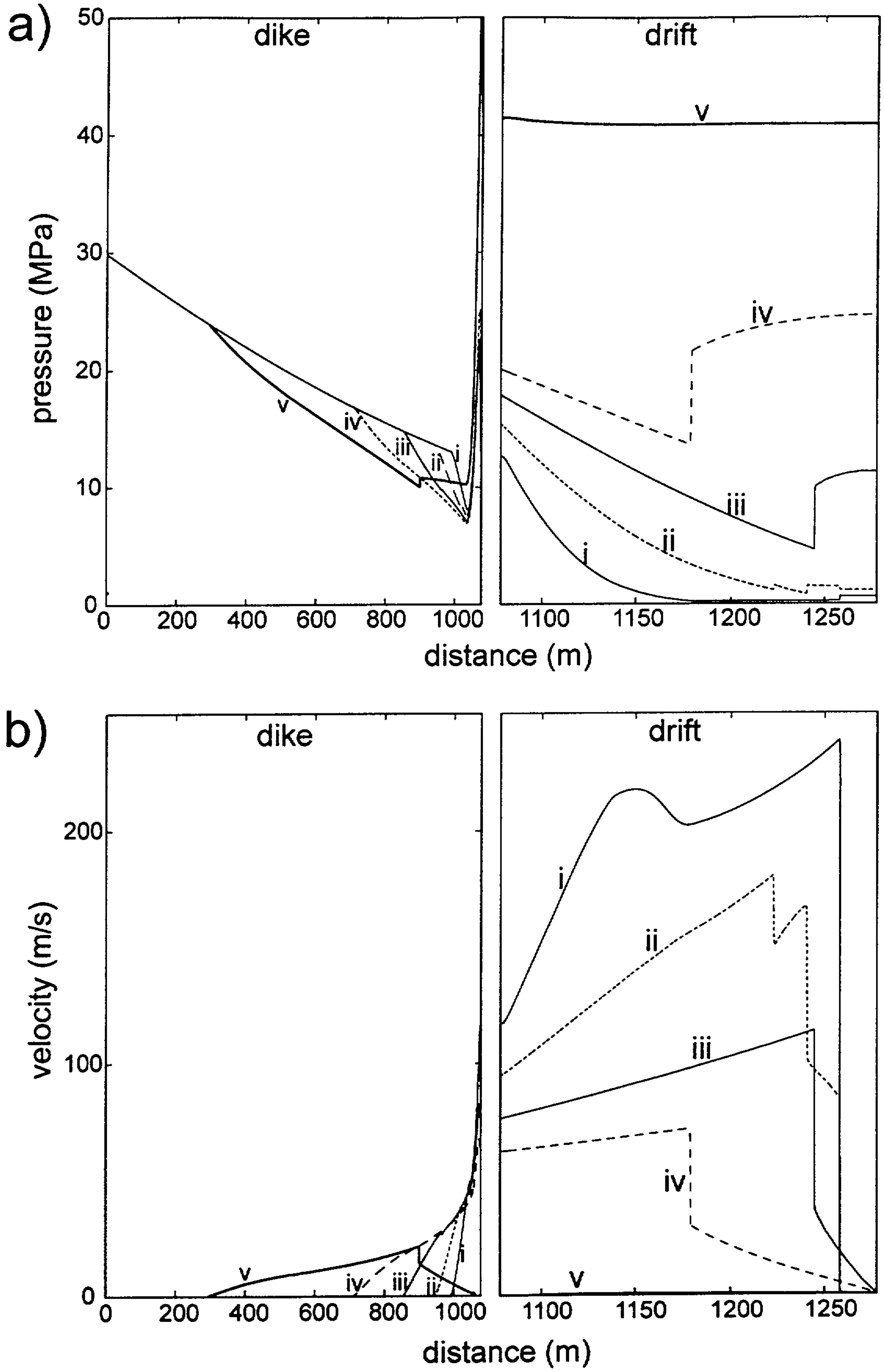
- Evolution of ***transient magma-repository dynamics*** to ***hydraulic quasi-steady flow*** to surface in 1D model:
  - a) vertical dike to surface
  - b) new vertical pathways due to fracture at end tunnels
  - c) larger (horizontal) base tunnel

- Modeling of analog materials with ***laboratory experiments***
- ***2D simulations***: shock amplification against roof
- Implications for possible transport of waste to surface

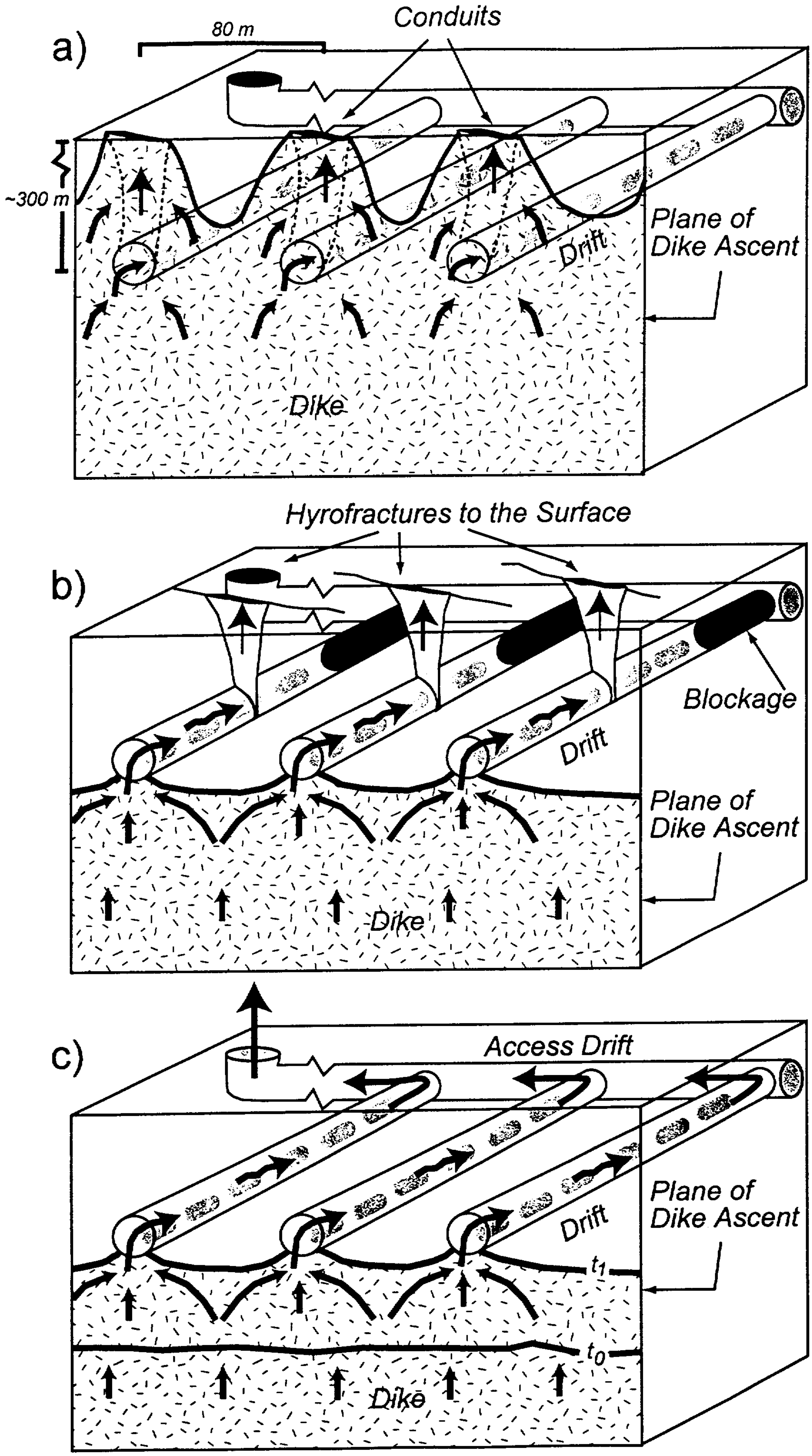
- ***Rock-fluid mechanics***

MAGMA - DRIFT INTERACTION

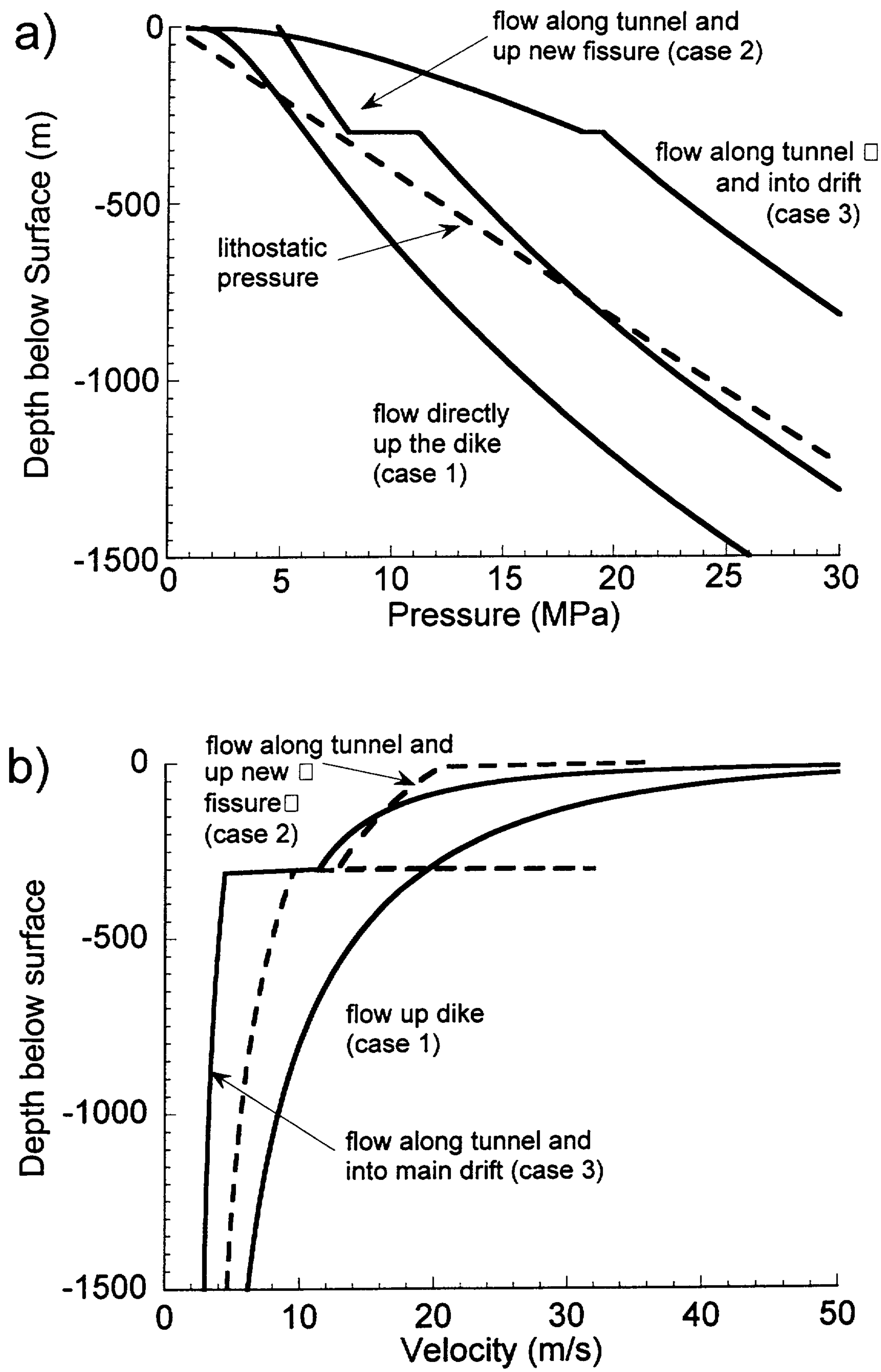
BY: ANDY WOODS



Woods et al.,
Figure 3



Woods et al.,
Figure 4



Woods et al.,
Figure 5

U.S. Department of Energy
Office of Civilian Radioactive Waste Management

Magma-Drift Interactions, Magma-Waste Package Interactions, and Magma-Waste Form Interactions

Presented to:
DOE-NRC Technical Exchange on Key Technical Issues
Topics Related to Igneous Activity

Presented by:
Eric Smistad
U.S. Department of Energy
G.A. Valentine
Disruptive Events Department Manager

June 21-22, 2001
Las Vegas, Nevada

YUCCA MOUNTAIN PROJECT

Outline

- Overview
- Discussion of items associated with the Consequences subissue topics of magma-drift interactions, magma-waste package interactions, magma-waste form interactions, and the Probability subissue topic of aeromagnetic data
- Summary

Overview

- At the May 18, 2001 Appendix 7 meeting, a new igneous activity consequence model that depicts the magma-repository interactions more mechanistically was described
- DOE acknowledges that additional work to evaluate the new consequence model may be warranted and desirable to support any potential license application but requires further study of the consequence models before defining that additional work
- The objective of this meeting is to continue the dialogue on the Center for Nuclear Waste Regulatory Analyses (CNWRA) consequence model

Magma-Drift Interactions

- **Action or information needs identified by the NRC**
  - Evaluate stress accumulation from high-level waste (HLW) thermal-mechanical effects
  - Evaluate effects of DOE-proposed design alternatives on magma ascent and flow processes
  - Evaluate mechanical strength of debris accumulations or barriers
  - Evaluate how the presence of backfill or rockfall may affect magma flow processes
  - Evaluate effects of subsurface repository structures on the ascent of basaltic magma
  - Evaluate potential for ascending magma to entrain more HLW than currently modeled with circular conduit

Evaluate Stress Accumulation From HLW Thermal-Mechanical Effects

- **Issue: Models that propose stress accumulation due to HLW thermal-mechanical effects need to evaluate appropriate strain response on existing or new structures, in addition to spatial and temporal variations in thermal loading**

- **Current Work to Date**

  – **Changes in stress from excavation and possible effects on dike interactions with the drift are addressed in a simplified manner in the *Dike Propagation Near Drifts* Analysis and Model Report (AMR) (ANL-WIS-MD-000015, REV 00 ICN 01, Section 6.3.1)**

Evaluate Stress Accumulation Due to HLW Thermal-Mechanical Effects

(continued)

- **References**
  - *Dike Propagation Near Drifts*, **ANL-WIS-MD-000015, REV 00 ICN 01 (November 13, 2000)**
  - *Characterize Eruptive Processes at Yucca Mountain, Nevada*, **ANL-MGR-GS-000002, Rev 00 (May 17, 2000)**
- **Discussion**

Effects of Proposed Design Alternatives on Magma Ascent and Flow Processes

- **Issue: Evaluate effects of DOE proposed design alternatives on magma ascent and flow processes for the duration of an igneous event**
- **Current Work to Date**
  - **DOE has examined the effects of certain design alternatives on the probability of intersection of a dike with the repository (ANL-MGR-GS-000001)**
  - **DOE has considered effects of magma flow in emplacement drifts (ANL-WIS-MD-000015 and CAL-WIS-PA-000001)**

Effects of Proposed Design Alternatives on Magma Ascent and Flow Processes

(continued)

- **References**
  - ***Characterize Framework for Igneous Activity at Yucca Mountain*, Nevada, ANL-MGR-GS-000001, REV 00 (November 6, 2000)**
  - ***Dike Propagation Near Drifts*, ANL-WIS-MD-000015, REV 00 ICN 01 (November 13, 2000)**
  - ***Number of Waste Packages Hit by Igneous Intrusion*, CAL-WIS-PA-000001, REV 01 (November 15, 2000)**
- **Discussion**

Mechanical Strength of Debris Accumulations or Barriers

- **Issue: Evaluate mechanical strength of debris accumulations or barriers that may occur at ends of intersected drifts, for an appropriate range of physical conditions that occur during an igneous event**
- **Current Work to Date**
  - **DOE analysis documented in the *Dike Propagation Near Drifts* AMR (ANL-WIS-MD-000015, REV 00 ICN 01)**
    - Does not assume or rely on drift seals to contain magma
    - Considered that the high-energy nature of the system causes the drifts to become plugged or clogged with debris and materials from flowing magma and gases, cooling magma, and repository components

Mechanical Strength of Debris Accumulations or Barriers
(continued)

- **References**
  - *Dike Propagation Near Drifts*, ANL-WIS-MD-000015, REV 00, ICN 01 (November 13, 2000)
- **Discussion**

Presence of Backfill or Rockfall May Affect Magma Flow Processes

- **Issue: Evaluate how the presence of backfill or rockfall may affect magma flow processes for the duration of the eruption**
- **Current Work to Date**
  - **This issue is closely related to the issue of Mechanical Strength of Debris Accumulations or Barriers**
  - **As noted previously,**
    - DOE's analysis does not rely on presence of backfilled emplacement drifts
    - DOE expects drifts to become clogged with debris and materials from flowing magma and gases, cooling magma, and repository components

Presence of Backfill or Rockfall May Affect Magma Flow Processes

- **References**
  - *Dike Propagation Near Drifts*, **ANL-WIS-MD-000015, REV 00 ICN 01 (November 13, 2000)**
- **Discussion**

Effects of Subsurface Repository Structures on the Ascent of Basaltic Magma

- **Issue: Evaluate how the ascent of basaltic magma may be affected by the presence of subsurface repository structures. In particular, evaluate how vertical ascent may localize conduit formation at intersected drifts rather than randomly or in pillars**
- **Current Work to Date**
  - **Possible effects of subsurface structures on the ascent of magma and localization of conduits were examined in the AMR, *Dike Propagation Near Drifts* (ANL-WIS-MD-000015)**

Effects of Subsurface Repository Structures on the Ascent of Basaltic Magma

(continued)

- **References**
  - *Dike Propagation Near Drifts*, ANL-WIS-MD-000015, REV 00 ICN 01 (November 13, 2000)
  - *Characterize Eruptive Processes at Yucca Mountain, Nevada*, ANL-MGR-GS-000002, REV 00 (May 17, 2000)
  - *Igneous Consequence Modeling for the TSPA-SR*, ANL-WIS-MD-000017, REV 00 ICN 01 (November 21, 2000)
- **Discussion**

Potential for Ascending Magma to Entrain More HLW

- **Issue: Evaluate how the presence of repository drifts may alter magma ascent pathways and potentially entrain more HLW than currently modeled with circular conduit**
- **Current Work to Date**
  - **Potential for entrainment of waste was examined in the calculation, *Number of Waste Packages Hit by Igneous Intrusion* (CAL-WIS-PA-000001), and the AMR, *Igneous Consequence Modeling for TSPA-SR* (ANL-WIS-MD-000017)**

Potential for Ascending Magma to Entrain More HLW

(continued)

- **References**
  - *Number of Waste Packages Hit by Igneous Intrusion*, CAL-WIS-PA-000001, REV 01 (November 15, 2000)
  - *Igneous Consequence Modeling for the TSPA-SR*, ANL-WIS-MD-000017, REV 00 ICN 01 (November 17, 2000)
- **Discussion**

Magma-Waste Package Interactions

- **Action or information needs identified by the NRC**
  - Evaluate aging effects on materials strength properties when exposed to basaltic magmatic conditions
  - Evaluate canister response to stress from dynamic magmatic repressurization, gravitational loading, and potential differential thermal expansion
  - Evaluate Zone 3 canisters, or canisters covered by backfill, response when exposed to magmatic gases
  - Number of waste packages intersected by magma
  - Thermo-mechanical effects on waste package damage in Zones 1 and 2
  - Relative contributions to dose from releases in Zones 1 and 2

Aging Effects on Materials Strength Properties When Exposed to Basaltic Magma

- **Issue: Evaluate aging effects on materials strength properties when exposed to basaltic magmatic conditions for duration of event**
- **Current Work to Date**
  - **Effect of magma on waste packages is considered under features, events, and processes (FEP) 1.2.04.04.00, Magma Interacts with Waste**
  - **End-cap breach is used because the end cap is the locus for the largest stress and deformation resulting from increased heat and pressure**
  - **The end-cap weld damage is used as a "surrogate" to estimate the extent of damage**
  - **The end-cap breach was chosen as an approximation of the size of opening necessary to permit rapid gas flow and pressure equilibration**

Aging Effects on Materials Strength Properties When Exposed to Basaltic Magma
(continued)

- **Current Work to Date (continued)**
  - **Sampling the area of the breach from a distribution that includes much larger hole sizes is intended to account for both uncertainty regarding the nature of the magmatic fluids and the package response and spatial variability in the extent of damage within the drifts (ANL-WIS-MD-000017, Section 6.2)**
- **References**

  - ***Igneous Consequence Modeling for the TSPA-SR*, ANL-WIS-MD-000017, REV 00 ICN 01 (November 17, 2000)**
  - ***Waste Package Behavior in Magma*, CAL-EBS-ME-000002, REV 00 (October 13, 1999).**

- **Discussion**

Canister Response to Stress

- **Issue: Evaluate canister response to stress from dynamic magmatic repressurization, gravitational loading, and potential differential thermal expansion, using appropriate at-condition strength properties and flow paths for duration of event. Analyses also need to consider impact and creep failure at elevated temperatures**

- **Current Work to Date**
  - **The behavior of waste packages in magma has been analyzed in CAL-EBS-ME-000002, REV 00**

- **Reference**
  - ***Waste Package Behavior in Magma*, CAL-EBS-ME-000002, REV 00 (October 13, 1999)**

- **Discussion**

Canister Response to Magmatic Gases

- **Issue: Evaluate Zone 3 canisters, or canisters covered by backfill, response when exposed to magmatic gases at conditions appropriate for a basaltic igneous event**
- **Current Work to Date**
  - **DOE considers this issue to be related to the issue of canister response to stress**
  - **The behavior of waste packages in magma has been analyzed in the calculation, *Waste Package Behavior in Magma* (CAL-EBS-ME-000002, REV 00)**
- **Reference**
  - ***Waste Package Behavior in Magma*, CAL-EBS-ME-000002, REV 00 (October 13, 2000)**
- **Discussion**

Number of Waste Packages Intersected by Magma

- **Issue: Number of waste packages intersected by magma**
- **Current Work to Date**
  - **DOE has analyzed the number of waste packages intersected by magma in the calculation Number of *Waste Packages Hit by Igneous Intrusion* (CAL-WIS-PA-000001)**
  - **This issue is covered by an existing agreement item related to conduit elongation (KIA0205)**
- **Reference**
  - ***Number of Waste Packages Hit by Igneous Intrusion*, CAL-WIS-PA-000001, REV 1 (November 15, 2000)**
- **Discussion**

Waste Package Damage in Zones 1 and 2

- **Issue: Thermo-mechanical effects on waste package damage in Zones 1 and 2**
- **Current Work to Date**
  - **Damage to waste packages in Zones 1 and 2 has been described in the AMR, *Igneous Consequences Modeling for TSPA-SR* (ANL-WIS-MD-000017)**
  - **Relative contributions from Zones 1 and 2 are discussed in a separate presentation for this Technical Exchange**
- **References**
  - ***Igneous Consequence Modeling for the TSPA-SR*, ANL-WIS-MD-000017, REV 00 ICN 01 (November 17, 2000)**
- **Discussion**

Releases From Zones 1 and 2

- **Issue: Relative contributions to dose from releases in Zones 1 and 2**
- **Current Work to Date**
  - **DOE has addressed the issue of relative contributions to dose from releases in Zones 1 and 2 in a supplemental sensitivity analysis as discussed in another presentation**
  - **This issue is covered by an existing agreement item (KIA0210)**
- **Discussion**

Magma-Waste Form Interactions

- **Action or information needs identified by the NRC**
  - **Physical and chemical response of HLW and cladding after heating and potential disruption of waste package (WP)**

Physical and Chemical Response of HLW and Cladding

- **Issue: Evaluate the physical and chemical response of HLW and cladding after heating and potential disruption of WP and contents, for WP remaining in drifts. In particular, evaluate effects that may result in increased solubility potential relative to undisturbed HLW forms**
- **Current Work to Date**
  - **In the eruptive scenario, no credit is taken for cladding**
- **References**
  - ***Igneous Consequence Modeling for the TSPA-SR*, ANL-WIS-MD-000017, REV 00 ICN 01 (November 17, 2000)**
- **Discussion**

Significance of New Aeromagnetic Data

- **Issue: Develop technical basis to determine location and age of buried basaltic features. Provide forward model of aeromagnetic data to demonstrate that additional basaltic features are not present but undetected in magnetically "noisy" areas within about 30 km of the proposed repository site**
- **Current Work to Date**
  - **DOE provided the results of the initial evaluation of the aeromagnetic data to the NRC during the Structural Deformation and Seismicity Technical Exchange in October 2000**
  - **DOE is continuing to evaluate the information**
- **Discussion**

Summary

- New information on magma-repository interactions was identified at the May 18, 2001 DOE-NRC Appendix 7 meeting
- DOE is reviewing the new igneous consequences models related to magma-repository interactions
- DOE anticipates additional interactions on these subjects with the NRC