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RESPONSES TO U.S. NUCLEAR REGULATORY COMMISSION (NRC) STAFF
COMMENTS ON STUDY PLAN 8.3.1.8.1.2 (PHYSICAL PROCESSES OF
MAGMATISM AND EFFECTS ON THE POTENTIAL REPOSITORY) (SCPB: N/A)

References: (1) Ltr, Holonich to Milner, dtd 9/14/94
(2) Ltr, Brocoum to Holonich, dtd 6/19/95

The U.S. Department of Energy (DOE) received the NRC staff concerns, comments, and questions on Study Plan 8.3.1.8.1.2 (Physical Processes of Magmatism and Effects on the Potential Repository) (Reference 1). The DOE understands that the staff has four concerns with the study plan. The bases for these concerns are contained in the ten comments and two questions provided in Reference 1. Reference 1 specified that only the ten comments and two questions are being tracked as study plan open items by the NRC. We recognize that these concerns are subsumed by the comments and questions. The DOE recently stated that responses to open items on Study Plan 8.3.1.8.1.2 were in preparation (Reference 2). This letter transmits the DOE's responses to the NRC's ten comments and two questions related to this study plan (enclosure 1).

The DOE regards the responses provided in Enclosure 1 as sufficient to resolve the ten comments and both questions. The DOE also considers that the information in these responses is adequate to address the four concerns. Accordingly, the DOE requests that the NRC provide notification that all of the comments and both questions related to Study Plan 8.3.1.8.1.2 have been resolved.

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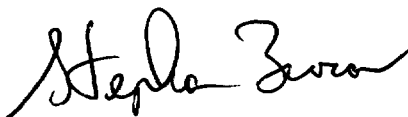
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AMSL:TWB-4198

Enclosures:

1. Responses to the NRC
Comments and Questions
on Study Plan 8.3.1.8.1.2
2. List of References Cited in
the Responses to the NRC
Comments and Questions on
Study Plan 8.3.1.8.1.2

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Enclosure 1

Responses to the NRC Comments on Study Plan 8.3.1.8.1.2 (Physical Processes of Magmatism and Effects on the Potential Repository)

NRC Comment 1

The NRC continues to have concerns with DOE's use of the tripartite probability and how the results of the volcanism investigations will be incorporated into the assessments for determining compliance with the overall system performance objective.

Recommendation

DOE should demonstrate in this study plan and in Study Plans 8.3.1.8.1.1 and 8.3.1.8.5.1 ("Characterization of Igneous Features") that the program of investigation for igneous processes and events is being guided by an appropriate consideration of the technical and regulatory requirements.

DOE Response

Volcanism studies, as described in Study Plans 8.3.1.8.1.1, 8.3.1.8.1.2, and 8.3.1.8.5.1 are not designed to establish compliance with system performance objectives. To assess system compliance is the responsibility of the Total System Performance Assessment (TSPA) and supporting modeling activities as described in the Site Characterization Plan (SCP). Instead, volcanism studies are designed to aid the DOE in evaluating the characteristics of the site relative to the siting criteria in 10 CFR 60.122 and to provide information to TSPA as a part of system performance assessments. The DOE now recognizes that the form and potential implications of the tripartite probability as described in volcanism study plans has created confusion over the scope of planned volcanism studies. Accordingly, the DOE agrees that the tripartite probability is of questionable utility and validity for the assessment of volcanic hazards. The DOE intends to change the form of the tripartite probability to better represent the DOE's volcanic hazards assessment strategy. The hazard assessment will utilize probabilistic volcanic hazard assessment (PVHA) methods to evaluate the probability of disruption of the potential repository by igneous activity. The hazard assessment will be formulated as a conditional probability which includes the recurrence rate (E1) and the probability of disruption of a specified area given the specified recurrence rate (E2|E1). The PVHA, as redefined, does not include evaluation of the probability of the release of radionuclides to the accessible environment (E3). The assessment of the

probability of radionuclide release is intended to be part of the iterative TSPA evaluation. The aspects of TSPA that evaluate the release of radionuclides from a combined evaluation of the occurrence probability of magmatic events (eruptive and subsurface processes) are referred to as probabilistic volcanic risk assessment (PVRA). The DOE intends to conduct volcanism studies where PVHA will be a part of the data used as input to TSPA. The TSPA evaluations will provide the basis for demonstrating compliance with regulatory requirements for siting in 10 CFR 60.122 and system performance in 10 CFR 60.112.

The variables that define magmatic effects, as presented in the reviewed study plan, are divided into two study components. The first, which is the main part of Study 8.3.1.8.1.2, involves gathering data and evaluating the effects of eruptive and subsurface igneous activity in order to define the ranges of eruptive and subsurface processes associated with magmatic activity that could affect a repository or repository system. These data will be fed into and further evaluated in Study 8.3.1.8.1.1 (Probability of Magmatic Disruption of the Repository). Per this study plan, the data will be used to construct cumulative probability distribution curves for data obtained through studies of volcanic effects using Monte Carlo-type simulations to define the range and uncertainty of significant data parameters. These probability distribution curves, when established for a range of variables that measure eruptive and subsurface effects, will in turn be used in performance assessment studies for further evaluation and calculation of the risk of the release of radionuclides as part of the probabilistic volcanic risk assessment. The latter evaluations will incorporate eruptive and subsurface magmatic activity as subclasses of potential disruptive events that could affect the performance of the repository and repository system. Thus the evaluation of the significance of potential releases from future magmatic activity will be in the form of iterative performance assessments. The DOE intends to revise Study Plans 8.3.1.8.1.1 and 8.3.1.8.1.2 to reflect these changes in emphasis and method and will consider this NRC comment and recommendation in making the revisions. The DOE expects to transmit the study plan revisions to the NRC in October 1995.

The studies described in Study Plans 8.3.1.8.1.1 and 8.3.1.8.1.2 have been designed to ensure that individual aspects of magmatic processes (e.g., eruptive effects) are not eliminated prematurely from the investigations. The evaluations of possible magmatic effects are intended to consider all aspects of magmatic processes (defined to include eruptive and subsurface processes) as a part of the process to determine which ones are relevant. The DOE intends to revise the study plans to clarify the point that the consequences of magmatic events (derived from iterative performance assessments) will be determined by evaluating all of the accompanying processes, where each process is characterized

probabilistically from field and modeling studies. Sensitivity analyses may be used to estimate changes in the magnitudes of risk expressed as radiological releases through changing parameter values in iterative TSPA. The DOE expects this type of evaluation to be helpful for analyzing parameters and prioritizing studies. The DOE also anticipates relying on the results of TSPA using data from PVHA to demonstrate compliance with the overall system performance objectives (10 CFR 60.112) and the siting criteria (10 CFR 60.122(a)(1)).

The DOE considers that the information provided in this response is sufficient to resolve this comment.

NRC Comment 2

The study plan does not address how volatile contents of basaltic eruptions will be described and assessed.

Recommendation

The study plan should be revised to indicate how the volatile contents will be described and assessed for the basalts of the Yucca Mountain region.

DOE Response

The DOE intends to revise Study Plan 8.3.1.8.1.2 to state more explicitly the range of volatile contents that will be addressed. However, the DOE does not plan to carry out exhaustive analyses to attempt to estimate the volatile contents of basalts from the Yucca Mountain region, because knowledge of volatile contents in magma provides less information on eruption processes than do simple and routine analyses of lava and pyroclastic facies in the volcanic deposits. Obtaining detailed volatile content data can be both time consuming and costly, and must be carefully weighed against the benefits of obtaining that information. As briefly reviewed by Valentine and others (1992), the effects of exsolved volatiles in driving basaltic eruptions are strongly influenced by the dynamics of magma ascent and the exsolution concentration of volatile phases, including the separation of two-phase flow at relatively shallow depth. Because of this influence, the magmatic volatile content that can be inferred using phase equilibria, or other methods (e.g., fluid inclusions) may have little relationship to the gas content at the vent during a basaltic eruption. For example, the equilibrium water content of magmas during the 1984 eruptions of Pu'u O'o has been estimated to be approximately 0.5% by mass, and yet the mass fraction erupting from the vent has been estimated to be as high as 2%, even ranging as high as nearly 4% (Head and Wilson, 1987; Vergnolle and Jaupart, 1990). (Note - the example of Pu'u O'o is used because it is very well documented; the use is not intended to infer an analogy with volcanoes near Yucca Mountain). Clearly this is an example of how measurement of magmatic volatile contents would give misleadingly low estimates of explosiveness of an eruption if one uses homogeneous flow models (Wilson and Head, 1981). It is now well established that magmatic volatile content can be strongly overprinted by other fluid dynamic processes and therefore is not a straightforward predictor of eruption dynamics (this is true for eruptions of all compositions--for example, a rhyolite eruption with constant volatile content can change from highly explosive to effusive eruption depending on how volatiles escape from the conduit).

In addition, at this point in the studies, the relationship between volatile content and the interpretation of potential

eruptive effects is not clear. The studies have identified a more important parameter for constraining bounds on eruptive effects: the quantity of debris that can be entrained from a repository and erupted onto the surface. Even if volatile contents could be used as accurate predictors of eruption processes using homogeneous flow models (Wilson and Head, 1981), the connection between the hydrodynamics of magma rise and wall rock entrainment is not obvious because the dynamics of the entrainment process are not well constrained. Many workers assume that entrainment occurs or is most important at or above the fragmentation depth (where the vapor volume fraction in a rising magma becomes high enough that the flow becomes one continuous gas phase with magma fragments). Because the fragmentation depth can be computed using a homogeneous flow approximation, one might then make the assumption that the entrainment depth could be predicted with information on magmatic volatile content. However, this is only an assumption, and assumptions must be clearly identified and used with caution when addressing specific regulatory concerns. Furthermore, this assumption could be invalid for the following reasons: (1) the homogeneous flow approximation is not accurate for basaltic magmas because of their low viscosity and resulting separated two phase flow; (2) data on depth of origin of upper crustal xenoliths show that entrainment occurs well below the predicted fragmentation level (Valentine and others, 1994; Valentine and Groves, 1995); (3) any theoretical treatment would involve simplifications and assumptions about the geometry of volcanic plumbing systems that may be difficult to defend; and (4) even if the entrainment depth could be simply predicted, the mechanisms of entrainment are poorly constrained (e.g., Macedonio and others, 1994; Valentine and Groves, 1995), so that theoretical prediction of entrainment quantities is not practical.

To summarize, the DOE considers that the best way to understand eruption mechanisms and explosiveness is to study the volcanic facies in the field in the Yucca Mountain region and to gather data from analog volcanoes that exhibit the same range of facies, but where the depth of origin and volume fraction of xenoliths can be quantified, rather than to rely on ill-constrained theory. Application of volatile contents to magmatic evolution (Activity 8.3.1.8.1.2.3) will rely mainly on literature values and petrographic constraints, unless there are compelling reasons to obtain detailed volatile data. Based on research to date, the DOE does not consider the acquisition of data on volatile contents of basaltic magmas to be critical to the planned magmatic effects studies.

The DOE considers that the information provided in this response is sufficient to resolve this comment.

NRC Comment 3

Proposed models of Hawaiian- and Strombolian-type eruptions do not encompass the range of eruption styles possible for basaltic volcanoes of the YMR and thus may underestimate the effects of basaltic eruptions on repository performance.

Recommendation

Models of basaltic eruptions in the Yucca Mountain region should consider a range of potential explosivities [sic], including eruptions that are more energetic than typical Strombolian eruptions.

DOE Response

In the next revision of the study plan the DOE intends to include eruptions that are commonly called "violent Strombolian." These eruptions feature lava fountains that are more strongly and continuously sustained than those of classic Strombolian eruptions, and may be associated with convective eruption plumes that reach altitudes of 10 km. Unfortunately the confusion about the definition of the term Strombolian is an issue inherited from the volcanological literature. For example, the widely used textbook by Cas and Wright (1987) defines Strombolian eruptions as having eruption column heights up to 10 km.

As stated in the response for Comment 2, the eruptive effects studies are focused on xenolith entrainment (as an approximation of debris entrainment from the potential repository) at analog sites that exhibit the same eruptive facies as basaltic volcanoes near Yucca Mountain. This will ensure that the appropriate range of explosiveness is covered. For example, centers such as Mirriam Crater and Sunset Crater in the San Francisco Volcanic Field of central Arizona are being considered for xenolith studies. (In fact, Sunset Crater was studied for xenolith content during an early phase of volcanism studies (Crowe and others, 1983)). Both of these centers have features which indicate they were formed by energetic, basaltic, cone-forming eruptions (e.g., the Sunset Crater eruption has been classified as subplinian). The DOE has considered the implications of the scoria facies at Lathrop Wells cone for eruption mechanisms. For example, the following excerpt is from Valentine and others (1992):

The main cone at Lathrop Wells consists almost entirely of loose scoria, which would suggest relatively higher discharge rates, although sparse bombs on the crater rim suggest that the eruption may have closed with a brief Strombolian phase.

The DOE is also studying centers that exhibit strongly hydrovolcanic, Hawaiian, and classic Strombolian facies

(Valentine and others, 1994; Valentine and Groves, 1995).

At this point the eruptive effects studies are focused on xenolith contents rather than on modeling of eruption column dynamics. Such modeling, while academically interesting, would be of little programmatic use without adequate knowledge of the amount of debris that would be available for dispersal (i.e., the source term). Estimation of the quantity of debris that would be available for introduction into the eruption column is the goal of the xenolith entrainment studies. As indicated in the study plan, eruption column modeling will be pursued if the eruptive effects model is found to be sensitive to the magnitude of the source term, but at this point modeling of the eruption column would be premature.

The DOE disagrees with the NRC's suggestion in the Basis for Comment 3 that "the eruptive style of these cones may be more accurately described as Plinian." The term "Plinian" requires eruptions with higher degrees of fragmentation and dispersal (larger volume and more violent) than those which have occurred near Yucca Mountain at any time since the cessation of caldera-related silicic volcanism. Usage of this term is an exaggeration of the nature of basaltic volcanism in the region.

One possible source of misunderstanding of this issue may derive from the recognition of the presence of widely dispersed basaltic ash in trenches flanking Yucca Mountain. These ashes could lead to inferences concerning the dispersal distances of the explosive eruptions of the Lathrop Wells center. However, careful examination of the ashes has shown that ash found in at least one distal locality did not originate from the Lathrop Wells center. More importantly, almost all the basaltic ash in trenches shows evidence of eolian reworking. Not recognizing the effects of eolian processes on the ash dispersal patterns may have led to a misclassification of the eruption characteristics.

The DOE regards the information provided in this response as sufficient to resolve this comment.

NRC Comment 4

Thermal and degassing effects may be poorly presented at inactive basaltic volcanoes and thus cannot be quantified adequately using the methods proposed in the study plan.

Recommendation

DOE should consider using analogs of active basaltic volcanoes to accurately constrain the extent and duration of thermal and degassing effects associated with small-volume basaltic intrusions and eruptions.

DOE Response

Thermal and degassing effects are being constrained in this study not only by studies at analog sites, but also by extensive modeling approaches. Moreover, the DOE disagrees with the statement that these "effects...cannot be quantified adequately using the methods proposed in the study plan." Some field sampling of fumaroles and soil gases at Paricutin volcano in Mexico is currently being planned and is scheduled for the summer of 1995; this will build on the work in the published literature (e.g., Connor, 1989). Paricutin is probably the only reasonable, "active" analog for such studies because it is an isolated system, as opposed to other basaltic events of recent times that are typically parts of much larger systems. These larger systems are poor analogs because any hydrothermal processes associated with an individual vent are likely to be heavily influenced by the processes and features of the much larger system. Even Paricutin has some shortcomings as an analog, including the fact that it is more than an order of magnitude larger in volume than any of the Quaternary centers near Yucca Mountain. Useful insights may be gained from limited studies of active centers and by review of scientific literature on these centers. However, to embark upon a detailed study of the hydrothermal system of a volcano such as Paricutin would be of limited programmatic value relative to the large effort that would be required to do the study correctly. Much of the information gained would be unique to the volcano and the associated hydrothermal system studied, and may not be directly applicable to volcanism in the Yucca Mountain region. (For example, in addition to its larger volume, Paricutin is thought to have had a shallow magma chamber that would dominate long-term thermal and degassing effects, while volcanoes such as Lathrop Wells appear to have deep (>25 km) chambers).

The DOE intends to include a description of how published information from studies of active analogs will be used in Revision 1 of Study Plan 8.3.1.8.1.2. In addition, the revision will contain detailed descriptions of zeolite and clay stability studies at analog intrusive sites. These studies are now under

way at two sites (Paiute Ridge, Nevada and Grants Ridge, New Mexico) and will be used to identify and describe the effects of shallow intrusion of basalt into previously altered (mainly zeolitized) and unaltered silicic tuffs, respectively. Similar studies at other sites may be initiated as well. The DOE intends to discuss the evolution of the clay and zeolite stability studies in Revision 1 of Study Plan 8.3.1.8.1.2.

Information from active analogs and alteration processes in ancient analogs (Grants Ridge, Paiute Ridge) will be used for two aspects in the magmatic hazard assessment: (1) the lateral extent of alteration processes around small basaltic intrusions of various geometries will provide input for E2 calculations, since these data will in part define the "effects envelope," the area within which an intrusion would need to occur in order to affect repository performance, and (2) these data will be used to determine the effects of magmatic processes on the natural and engineered barriers. For example, if an intrusion can be expected to change the sorptive properties of rocks around the repository, then the resulting change in radionuclide transport to the water table can be quantified via performance assessment. All of this would necessarily be carried out within a probabilistic framework.

The DOE considers the information in this response as sufficient to resolve this comment.

NRC Comment 5

Studies of eruptive effects...apparently will be terminated if the probability of repository release is calculated to be $\leq 10^{-8}$ year⁻¹. As has been stated in previous study plan comments, the use of the tripartite probability is not sufficient to meet the regulatory requirements of 10 CFR Part 60. In addition, the tripartite probability does not quantify the radiological releases possible for the disruptive event.

Recommendation

This study plan should clearly address how releases will be calculated taking into account the scheduled activities from other activities and study plans.

DOE Response

The concerns described in the "Basis" for Comment 5 and relating to the tripartite probability, are addressed in the response to Comment 1 which clarifies how the probability of release of radionuclides will be calculated through performance assessment studies. Study Plan 8.3.1.8.1.2 is being revised to redefine the probability model and remove references to and descriptions of the tripartite probability. This revision is scheduled for submittal to the NRC in October 1995. The study plan activities will be confined strictly to the description and evaluation of magmatic effects as parts of the probabilistic volcanic hazard assessment (PVHA) for the potential repository. No evaluation of the risk of release of radionuclides is planned under the scope of the revised study plan. The risk of release will be evaluated as a performance assessment activity using input from Study Plans 8.3.1.8.1.1 and 8.3.1.8.1.2.

Concerns about underestimating the "energetics" [sic] (energy level) of basaltic eruptions in the Yucca Mountain region are addressed in the response to Comment 3. The statement in the "Basis" for Comment 5, "the models do not account for hydromagmatic eruptions that occurred at Lathrop Wells..." suggests some confusion regarding the study plan, where the importance of hydromagmatic eruptions is repeatedly noted. For example, the text on pages 9-12 of the study plan includes the following statement, "We will examine scoria, hydrovolcanic, and lava deposits at these and other analog centers to establish the abundance and depth of derivation of lithic fragments...." Section 3.1.1, which describes the general approach for eruptive effects studies includes the following statements: (1) "First, we will examine the depth of derivation of lithic fragments...by studying the abundance and lithology of lithic fragments in surface basalts of both magmatic and hydromagmatic eruptions." and (2) "The purpose of the analog approaches is to determine the amount of debris that could be brought up from repository.

depth....This will depend on total eruptive volume and on the mode of eruption (hydrovolcanic explosions, magmatic explosions, or lava effusion)."

Revision 1 of Study Plan 8.3.1.8.1.2 will contain a description of the sequencing of activities between this study plan and Study Plans 8.3.1.8.1.1 and 8.3.1.8.5.1. The DOE intends to use sensitivity analysis and knowledge of volcanic and magmatic processes, and the associated effects, to prioritize the remaining effects studies.

The DOE considers the information in this response as sufficient to resolve this comment.

NRC Comment 6

Detailed studies of the effects of alteration of zeolite due to magmatic intrusion apparently will not be conducted unless the results of risk assessment indicate significant radionuclide release could result. It is not clear how such a decision could be made without first having the results of detailed geohydrologic and geochemical studies and the detailed information that this activity is intended to obtain.

Recommendation

DOE should consider either revising this study plan to reflect the detailed field and modeling studies needed to better constrain alteration processes associated with basaltic intrusions into silicic tuffs, or provide the basis why these investigations would not be integrated with geohydrologic and geochemical studies.

DOE Response

The DOE disagrees with the NRC comment that priorities cannot be established for volcanic effects studies until all studies have been completed. Decisions concerning the priorities for conducting different aspects of studies of volcanic effects are based on two criteria: (1) the occurrence probability of volcanic events (data input from Study Plan 8.3.1.8.1.1), and (2) the results of iterative performance assessment of the repository and repository system (data input from Total System Performance Assessment [TSPA]). The occurrence probability of volcanic events has been described in many publications (recently, for example, in Connor and Hill (1995); the radiological releases associated with some possible volcanic events were assessed in DOE's TSPA 91. Thus data exist currently that can be used to guide decisions for establishing priorities in studies of eruptive and subsurface effects. Further, both PVHA and TSPA are iterative, and the level of detail of both studies will increase as the results of continuing site characterization studies are included in the respective analyses. The DOE intends to use TSPA as a tool to establish priorities in site characterization studies. Further because TSPA is iterative, reopening studies is not precluded if sensitivity analyses shows that they are important to total system performance.

Since Revision 0 of Study Plan 8.3.1.8.1.2 was written, significant evolution in the DOE's consideration of and approach to hydrothermal alteration processes has occurred. Studies that were initiated in the spring of 1994 for Activity 8.3.1.8.1.2.2 (Subsurface Effects) are now providing detailed geochemical and mineralogical information about the effects of basaltic masses intruding into silicic tuffs having varying degrees of pre-intrusion alteration (see also response to Comment 4). This

work is being carried out using a combination of field-based studies coupled with iterative modeling. Personnel working on this aspect of Subsurface Effects are also involved in geohydrologic and geochemical modeling, and in mineralogy and petrology studies being conducted for other study plans. This sharing of staff resources ensures full integration and application of common approaches. Revision 1 to Study Plan 8.3.1.8.1.2 will describe and discuss this integrated study approach.

The DOE intends to prioritize this work by using TSPA iterations. Specifically, ~~in the mineralogy and petrology studies~~ indicated above, the DOE intends to use TSPA iterations to determine the sensitivity of repository performance to various hydrothermal alteration scenarios which change the radionuclide sorption characteristics of the potential host units. The method will evaluate the changes in sorption characteristics compared to other system performance variables.

The DOE considers the information in this response as sufficient to resolve this comment.

NRC Comment 7

There are five Quaternary volcanic centers located in Crater Flat, not four as stated in the study plan.

Recommendation

The Little Cones represent two discrete volcanic centers and should not be counted as one event. Calculations utilizing cone or vent counts should be modified to reflect the presence of two discrete volcanoes at Little Cones.

DOE Response

The DOE intends to evaluate the sensitivity of the probability of disruption of the proposed repository to alternative models of event- and cone-counts. The DOE considers it premature to conclude that there are uniquely five Quaternary volcanic centers in Crater Flat and instead intends to use a range of models of event counts for the Quaternary volcanic centers of Crater Flat. (For example, see the Volcanism Status Report (Crowe, 1995, Chapter 7) which was provided to the NRC for information and reference. However, the DOE does not wish to complicate the resolution of this study plan comment by introducing material that is neither discussed nor cited in the subject study plan. The DOE evaluations will consider the impact of multiple alternative event-count models in studies of volcanic effects and have already used single and multiple event models for the Little Cone in probabilistic volcanic hazard analysis (PVHA).

The DOE considers the information in this response as sufficient to resolve this comment.

NRC Comment 8

Planned lithic fragment studies in the Yucca Mountain Region will inadequately characterize the ability of projected basaltic volcanism to fragment and erupt subsurface material, unless an appropriate range of Quaternary volcanoes in this region are examined.

Recommendation

DOE should consider conducting lithic fragment studies at least at Lathrop Wells and the Sleeping Butte cones in addition to the planned studies at Red and Black Cones.

DOE Response

As noted in the response to Comment 2, the DOE endorses lithic fragment studies as the best way to understand eruption mechanisms and explosiveness. Lithic fragment studies are in progress at Lathrop Wells, and the DOE intends to initiate studies at Sleeping Butte cones as recommended. Statements describing these studies will be provided in Revision 1 of study plan 8.3.1.8.1.2, which is scheduled for transmittal to the NRC in October 1995. Based on the results of studies at Red Cone and Black Cone, the DOE expects to use lithic studies at these and other Crater Flat centers to produce estimates of the total lithic volume fractions.

The DOE considers the information in this response as sufficient to resolve this comment.

NRC Comment 9

The proposed studies for wall-rock fragmentation and subsurface effects do not appear to account for the modification in lithostatic pressure that will occur due to repository construction and operation.

Recommendation

Calculations should be made to determine what subsurface depth beneath analog volcanoes best represents the expected confining pressure and wall-rock characteristics of the backfilled repository horizon and adjacent areas. This range in values should be incorporated in the various analog studies and consequence models.

DOE Response

The DOE intends to incorporate descriptions of the calculations recommended into Revision 1 of Study Plan 8.3.1.8.1.2 to be completed in October 1995. Analog studies are already being carried out at volcanoes underlain by rocks featuring different mechanical properties at various depths. Some evaluations include unconsolidated sediments that may be similar to backfill. The DOE also intends to describe methods to address confining pressure issues noted in the recommendation in Revision 1 to Study Plan 8.3.1.8.1.2.

Generally, the range of conditions being considered in the analyses is sufficiently broad that the depth and pressure constraints noted in the recommendation will be incorporated in studies of volcanic effects. The DOE is considering the mechanisms of magma and wall-rock fragmentation under low confining pressures and is confident that the modeling efforts will adequately constrain these processes. The DOE is also considering sensitivity analyses to quantify the effects of decreased confining pressures on total system performance. Given the uncertainties in studies of volcanic effects, it is not clear that the effects of the repository tunnel or alternative waste package designs are necessarily key data needs for studies of eruptive effects. Finally, the TSPA models have included, and will continue to include, alternative repository design parameters in performance assessment studies of possible radiological releases.

The DOE regards the information in this response as sufficient to resolve this comment.

NRC Comment 10

The planned activities, especially Activity 8.3.1.8.1.2.3 appear to exclude consideration of the volcanics at Buckboard Mesa. Not including Buckboard Mesa into petrogenetic models will result in an incomplete understanding of the range of magmatic processes possible in the YMR, and may lead to erroneous conclusions regarding magma system dynamics.

Recommendation

Include the Buckboard Mesa volcano in models of post-5 Ma volcanism in the YMR.

DOE Response

The DOE intends to incorporate this recommendation into Revision 1 of Study Plan 8.3.1.8.1.2; this revision is scheduled for transmittal to the NRC in October 1995. In addition, the basalt of Buckboard Mesa has been included in probabilistic volcanic hazard assessments. (For example, see the Volcanism Status Report Crowe and others, 1995. This report was provided to the NRC for information and reference. However, the DOE does not wish to complicate the resolution of this study plan comment by introducing material that is neither discussed nor cited in the subject study plan.) The DOE intends to include consideration of these basalts in Activity 8.3.1.8.5.1.4.

The DOE considers the information in this response as sufficient to resolve this comment.

NRC Question 1

How will DOE establish the ranges of either the number or volume of various eruptive events which have occurred?

Recommendation

DOE should consider revising this study plan to describe how the frequency and volume of ash fall in the Yucca Mountain region during the Pliocene and Quaternary will be determined and factored into the various calculations on probability and consequence.

DOE Response

The number and volume of eruptive events are obtained from Study Plans 8.3.1.8.1.1 and 8.3.1.8.5.1. Usage of these data for effects studies is described in Study Plan 8.3.1.8.1.2, and the DOE intends to clarify the uses of these data for effects studies in Revision 1. The evaluation of volcanic hazards is described in Revision 2 of Study Plan 8.3.1.8.1.1, and refinements to the description will be provided in Revision 3. The DOE intends to do consequence analysis, which is the risk of release of radionuclides because of magmatic disruption of the repository or the repository system, as part of the total system performance assessment activity.

The DOE notes that this question seems to reflect a concern similar to that reflected in NRC Comment 5 on Study Plan 8.3.1.8.5.1. As explained in the response to that comment, the eruption volumes were calculated by taking areal distributions of map units and assigning unit thickness using a combination of field measurements and thickness extrapolations based on observed and hypothetical models of thickness versus distance relations for scoria-fall sheets of small volume basaltic volcanic centers. The areal assignments incorporated drillhole and aeromagnetic data as well as extrapolations to reconstruct centers that have been modified by erosion. The density corrections for calculating dense rock equivalents (DRE) involves correcting the data to magmatic volumes assuming a melt density of 2.8 gm/cm^3 and measuring or assigning density values for different volcanic deposits. Because of the unique nature of magma volume estimations, the calculations of magma volume estimates have been documented in scientific notebooks. (Note: The method the DOE has used to calculate eruptive volumes and the results of those calculations are described in the Volcanism Status Report [Crowe and others, 1995] beginning on page 7-44. The Volcanism Status Report was provided to the NRC for information and reference. However, the DOE does not wish to complicate the resolution of this study plan comment by introducing material that is neither discussed nor cited in the subject study plan.)

The calculation of volume of basalt is addressed in Study Plan 8.3.1.8.1.1, on pages 33 and 34. The main importance of the volume calculation is in estimating recurrence rates using the volume-predictable method. Because there has been an approximate exponential decline in magma volumes through time (factor of 30), the probabilistic volcanic hazard assessment (PVHA) is relatively insensitive to the magma volume estimates. The DOE intends to publish revised volume calculations when Activity 8.3.1.8.1.1.1 is funded (currently planned for FY 96).

In Revision 2 to Study Plan 8.3.1.8.1.1, the DOE stated its intention to develop ~~technical procedures~~ to calculate estimates of magma volumes. Based on the experience of calculating magma volumes and the fact that each calculation is unique, the DOE no longer intends to develop these procedures. This change in the DOE's approach will be described in Revision 3 to Study Plan 8.3.1.8.1.1 which the DOE intends to transmit to the NRC in October 1995.

The DOE regards the information provided above as sufficient to resolve this comment.

NRC Question 2

How are the terms "Crater Flat Volcanic Zone" and "Crater Flat" used in this study plan?

Recommendation

Clarify the usage of the term "Crater Flat" in this study plan. If the use of the term "Crater Flat" was intended to limit the activities under [activity] 8.3.1.8.1.2.3, provide an explanation/justification as to how the full range of eruptive styles found in the ~~YMR~~ will be characterized.

DOE Response

The phrase "Crater Flat volcanic zone" is used to describe the area encompassing the distribution of Quaternary or Plio-Quaternary volcanic rocks in the Yucca Mountain region (excluding the basalt of Buckboard Mesa in the definition of the latter). The phrase "Yucca Mountain Region" is used to define the area included by the distribution of Plio-Quaternary volcanic events in the Yucca Mountain region and includes the basalt of Buckboard Mesa. It is nearly identical to the Area of Most Recent Volcanism described by Smith and others (1990). These definitions are from Crowe and Perry (1989). The phrase "Crater Flat" refers to the Crater Flat physiographic basin. In Revision 1 of the study plan the DOE intends to clarify the usage of these phrases to avoid confusion. The DOE certainly did not intend to imply that usage of the term "Crater Flat" rather than the term "Crater Flat Volcanic Zone" might be used as the basis to limit the scope of the investigations.

The DOE considers the information in this response as sufficient to resolve this comment.

Enclosure 2

**List of References Cited in the Responses
to the NRC Comments on Study Plan 8.3.1.8.1.2**

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