UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

September 14, 1994

Mr. Ronald Milner, Associate Director for
Program Management and Integration
Office of Civilian Radioactive Waste Management
U.S. Department of Energy, RW 30
1000 Independence Avenue
Washington, D.C. 20585

SUBJECT: REVIEW OF THE U.S. DEPARTMENT OF ENERGY (DOE) STUDY PLAN ON "PHYSICAL PROCESSES OF MAGMATISM AND EFFECTS ON THE POTENTIAL REPOSITORY" (8.3.1.8.1.2)

Dear Mr. Milner:

On October 1, 1993, DOE transmitted the subject study plan to the Nuclear Regulatory Commission for review and comment. The NRC staff has completed its review of the subject study plan using the "Review Plan for the NRC Staff Review of DOE Study Plans, Revision 2" (dated March 10, 1993). Based on its review of the study plan, the staff considers the material submitted consistent, to the extent possible at this time, with the revised NRC-DOE "Level of Detail Agreement and Review Process for Study Plans" (letter from Shelor to Holonich; dated March 22, 1993).

A major purpose of the review is to identify concerns with studies, tests, or analyses that, if started, could cause significant and irreparable adverse effects on the site, the site characterization program, or the eventual usability of the data for licensing. Such concerns would constitute "objections," as that term has been used in earlier NRC staff reviews of DOE documents related to site characterization (e.g., "Consultation Draft Site Characterization Plan" and the "Site Characterization Plan (SCP) for the Yucca Mountain Site"). It does not appear that the conduct of the activities described in this study plan will have adverse impacts on repository performance and the review of this study plan identified no objections with any of the activities proposed.

As part of its study plan review, the NRC staff also determines whether or not detailed comments or questions are warranted. The NRC staff's review of the subject study plan has resulted in the identification of a number of technical concerns. The specific concerns that the staff has identified include:

(1) The staff continues to be concerned with the use of the "tripartite" probability. The tripartite probability may not be adequate to demonstrate compliance with 10 CFR Part 60 requirements and runs the risk of incomplete consideration of the igneous phenomena in a regulatory framework.
(2) The study plan does not appear to adequately address how the volatile contents of

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(2) The study plan does not appear to adequately address how the volatile contents of basaltic eruptions will be determined, the full range of eruptive mechanisms which have affected the Yucca Mountain Region, the number and volume of eruptions which have occurred in the region, thermal and degassing effects, investigations of incorporation of lithic fragments into basaltic magmas, and the modification of *in-situ* stress due to the presence of a repository.

(3) The locations of investigations appears to be restricted such that the full range of potential repository effects will not be investigated.

(4) Decisions to terminate or not initiate investigations appear to be made based on an incomplete understanding of the igneous phenomena.

These concerns have resulted in the identification of ten comments and two questions. The enclosed comments and questions will be tracked by the NRC staff as open items similar to those questions previously raised by the NRC staff in its 1989 Site Characterization Analysis (SCA).

Finally, the NRC staff wishes to note that in its letter transmitting this study plan, DOE indicated that SCA Comment 49 was addressed. While the underlying basis for this comment has not been adequately addressed, the concerns that were the basis for Comment 49 have been raised in this and other related study plan reviews. Specifically, the concerns contained within Comment 49 are the subject of NRC Comments 4 and 8 on Study Plan 8.3.1.8.1.1 ("Probability of Magmatic Disruption of the Repository (Revision 2)," dated April 2, 1993), and Comment 1 of this review. Based on its review of this study plan, the NRC staff considers that these three comments supercede SCA Comment 49 and are a more effective way to track the concern. Therefore, the NRC staff has closed SCA comment 49.

If you have any questions concerning this review, please contact Michael P. Lee at 301/415-6677.

Sincerely,
/s/
Joseph J. Holonich, Chief
High-Level Waste and Uranium Recovery
Projects Branch
Division of Waste Management
Office of Nuclear Material Safety
and Safeguards

Enclosure: As stated
cc: See Attached List

OFC	HLUR	E	HLUR	E	ENGB	E	ENGB	E	ENGB	E
NAME	MLee		WBelke*		JSTrapp		KMcConnell*		MBell*	
DATE	09/14/94		08/22/94		09/14/94		08/22/94		08/22/94	
OFC	PAHB		HLUR	E	HLUR					
NAME	MFederline		RJohnson		JHolonich					
DATE	09/[illegible]/94		09/15/94		09/15/94					

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R. Loux, State of Nevada
T.J. Hickey, Nevada Legislative Committee
J. Meder, Nevada Legislative Counsel Bureau
C. Schank, Churchill County, NV
D. Bechtel, Clark County, NV
J. Hoffman, Esmeralda County, NV
L. Fiorenzi, Eureka County, NV
B. Mettam, Inyo County, CA
M. Baughman, Lincoln County, NV
R. Williams, Lander County, NV
V. Poe, Mineral County, NV
L. Bradshaw, Nye County, NV
M. Murphy, Nye County, NV
P. Niedzielski-Eichner, Nye County, NV
F. Sperry, White Pine County, NV
R. Nelson, YMPO
D. Weigel, GAO
W. Barnard, NWTRB

STUDY PLAN 8.3.1.8.1.2
PHYSICAL PROCESSES OF MAGMATISM AND EFFECTS ON THE POTENTIAL REPOSITORY

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.

Basis
The NRC staff has expressed its concerns with the tripartite probability previously in such places as: (1) its earlier comments (dated February 8, 1994) on Study Plan 3.1.8.1.1 ("Probability of Magmatic Disruption of the Repository," dated April 1993); (2) during the June 9, 1993, Technical Exchange on the Volcanism Status Report; and (3) in the August 1993 letter transmitting the Center for Nuclear Waste Regulatory Analyses' comments on the status report (see NRC, 1993). The continued use of this expression by DOE suggests that the program for volcanism is not focused on determining if the site is "qualified" in accordance with 10 CFR Part 960 or determining if the site will meet the requirements of 40 CFR Part 191 as implemented by 10 CFR Part 60, but rather is focused solely on the disqualification condition of 10 CFR Part 960, a very narrow concern.

The tripartite probability, as the name implies is a three part probability function. While slightly different definitions of this probability function have been given by DOE, this probability function is expresses on page 30 of the study plan as:

$$Pr_{dq} = [E3 \text{ given } E2 \text{ given } E1]$$

where:

Pr_{dr} is the probability of disqualification.

E1 is the recurrence rate of future volcanic events in the Yucca Mountain region. It is calculated as the annual probability of a volcanic event or the probability of a volcanic event during the required isolation period of a repository. The volcanic event of significance (the only event for which DOE has calculated a probability) is the formation of a new volcanic center.

E2 is the disruption parameter. It is defined as the probability that the repository is disrupted by the formation of a new volcanic center, given the occurrence of a new volcanic center during the containment [isolation] period of a repository.

E3 is the release probability. It is defined as the probability that the quantity of radioactive waste which is released to the accessible environment exceeds the regulatory requirements, given that the repository is disrupted by ascending magma in association with the formation of a new volcanic center.

E1 and *E2*, when multiplied, produce the probability that the repository is disrupted, **given only those conditions under which a new volcanic center is developed.** If it is assumed that only the formation of a new volcanic center is of concern, this probability is the probability that must be considered in evaluating the EPA Standard. If, as is stated on page 8, Pr_{dr} is the probability that will be used to demonstrate compliance, such attempts will not be adequately supported, as Pr_{dr} is the probability of *E1* times *E2* times *E3*.

The overall system performance objective (10 CFR 60.112 referencing the EPA Standard), is a key regulatory requirement that requires consideration of igneous activity, because it places limits on radionuclide releases over 10,000 years from all initiators. This standard is based on the summation of total releases which may reach the accessible environment in a 10,000 year period. There must be less than 1 chance in 10 that summation of total releases during this period from all significant processes and events, weighted by the limits given in Appendix A of the standard, do not exceed 1 and there must be less than 1 chance in 1000 that the summation of weighted, total releases will not exceed 10.

The standard is based on the summation of total releases during the period of performance. It is not based on the releases from one event during the period of performance or the subset of releases, such as consideration of the releases from only eruptive effects (*E3*). The decision logic, which is described in such places as page 31 and page 33 of the study plan is faulty, and if carried to conclusion, could lead to an incomplete consideration of the phenomena of igneous activity in site characterization and regulatory compliance.

The EPA standard has suggested that "**categories** of processes and events" [emphasis added] need not be considered if they are estimated to have less than one chance in 10,000 of occurring in 10,000 years. The staff agrees with the position that was taken in the proposed modification to 10 CFR Part 60 to conform to the EPA Standard (NRC, 1986). It is important to recognize the caveat that the NRC placed on this probability bounds at that time. As is stated, "... the term 'categories' is used to refer to general classes of processes and events, such as faulting, volcanism, or drilling. Subsets of these general categories, such as drilling which intersects a canister or fault displacement of a specific magnitude, may need to be retained if the general category has been finely divided into a large number of specific processes and event descriptions, each with reduced probabilities of occurrence ...." (51 *FR* 22292)

In order to demonstrate compliance with the EPA Standard it is necessary to quantify releases which have an associated probability of 10E-3 or greater. Exclusion of classes of processes and events that significantly effect this probability is not acceptable. The decision to include all significant processes and events (the 1 chance in 10,000 in 10,000 years) in the analysis is in agreement with common practice in statistical decision theory to carry the calculations at least one order of magnitude lower than the decision point to assure that this decision point has been correctly calculated. In addition, because of the formulation of the standard itself, it is possible to have two processes and/or events each with a probability of occurrence less than 1 chance in

1000 in 10,000 years, which when summed together in accordance with the procedures for developing a CCDF, could result in a probability of greater than 1 chance in 1000 in 10,000 years that the EPA Standard would not be met. Subdivision of processes and events, and elimination of these processes and events from consideration of their total effects on the probability space and consequences could lead to faulty conclusions regarding the site's ability to meet the EPA Standard.

The probability bounds have been placed at 1 chance in 10,000 in 10,000 years. While it is sometimes convenient to approximate this number by using one chance in 10E-8 per year the numbers are not equivalent either mathematically or geologically. Comparing a probability of occurrence of 1 chance in 10,000 in 10,000 years to the probability calculated in accordance with the tripartite probability only compounds the error.

If this study plan wishes to reference the performance allocation tables of the SCP as guidelines (DOE, 1988), the study plan should also reference the NRC comments on performance allocation (NRC, 1989) such as Comment 2, which remain open, and how the use of performance allocation in this study plan resolves the NRC comments.

If the probability of igneous activity affecting the repository is greater that 1 chance in 10,000 in 10,000 years all aspects of not only the igneous activity itself, but the other related processes and events which could occur during the same 10,000 year period need to be considered. This would most likely include such things as the mechanical effects of the dike propagation and the effects on the engineered barrier and waste packages, the sidewall erosion and assimilation of material in the magma, both physically and chemically, the mechanical effects which center around the main pipe which normally result in a cone of disruption which also could disrupt the engineered barrier and waste package, possible introduction of hydrothermal fluids, the thermal pulse, the effects of degassing, and the possible effect of multiple eruptions.

While these effects might be similar to the effects which would be expected in undisturbed country rock, the mechanical, chemical and thermal perturbations of the repository must be considered. In addition, during the 10,000 year period there will be normal fluid movement in the saturated and unsaturated zone, possible effects from drilling, faulting, and other processes which could occur during this period and the releases from these processes and events must be summed with the igneous releases to obtain the value which must be compared to the regulations. Only when the total release from all significant processes and events, including synergistic effects, has been properly summed into a scenario which represents a 10,000 year period, not just the effects from an event, will the concern that the analysis for igneous activity effecting the repository has been appropriately considered be resolved.

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 appropriated consideration of the technical and regulatory requirements.

References

Holonich, J.J., U.S. Nuclear Regulatory Commission/Division of High-Level Waste Management, Letter to D.E. Shelor, U.S. Department of Energy/Office of Civilian Radioactive Waste Management [Subject: Status of Volcanism Issues for the Proposed High-Level Site at Yucca Mountain"], August 18, 1993.

U.S. Department of Energy, "Site Characterization Plan, Yucca Mountain Site, Nevada Research and Development Area, Nevada," Office of Civilian Radioactive Waste Management, DOE/RW-0199, 9 vols., December 1988.

Shelor, D.E., U.S. Department of Energy/Office of Civilian Radioactive Waste Management, Letter to J.J. Holonich, U.S. Nuclear Regulatory Commission/Division of High-Level Waste Management [Subject: Transmittal of Study Plan 8.3.1.8.1.2, Revision 0 ("Physical Processes of Magmatism and Effects on the Potential Repository"], October 1, 1993.

U.S. Nuclear Regulatory Commission, "10 CFR Part 60, Disposal of High-Level Radioactive Wastes in Geologic Repositories; Conforming Amendments," *Federal Register*, Vol 51, No. 118, June 19, 1986, pp. 22288 - 22301.

U.S. Nuclear Regulatory Commission, "NRC Staff Site Characterization Analysis of the Department of Energy's Site Characterization Plan, Yucca Mountain Nevada," NUREG-1347, 1989.

STUDY PLAN 8.3.1.8.1.2
PHYSICAL PROCESSES OF MAGMATISM AND EFFECTS ON THE POTENTIAL REPOSITORY

Comment 2
The study plan does not address how volatile contents of basaltic eruptions will be described and assessed.

Basis
The volatile content of basaltic magma is a critical parameter for many of the modeling activities in this study. For example, the explosivity of basaltic eruptions is significantly controlled by the volatile content of ascending magma (e.g., Wilson and Head, 1981). Models of eruption dynamics in Activities 8.3.1.8.1.2.1 and 8.3.1.8.1.2.3 must utilize appropriate magmatic volatile contents in order to accurately quantify the potential effects of basaltic magmatism on repository performance.

In addition to eruption dynamics, variations in magmatic volatile contents can strongly affect the crystallization and evolutionary history of a magma system. For example, the addition of several percent H_2O to a generic basaltic magma will suppress plagioclase crystallization (Yoder and Tilley, 1962; Eggler, 1972; Grove and Baker, 1984). Models of magma system dynamics (Activity 8.3.1.8.1.2.3) thus must utilize appropriate volatile contents in order to accurately determine the petrogenetic history of basaltic magmas in the Yucca Mountain Region (YMR) and accurately evaluate the explosivity of eruptions.

Some Quaternary basaltic volcanoes in the YMR contain phenocrysts of amphibole in addition to olivine and possibly plagioclase (e.g., Vaniman and Crowe, 1981; Crowe *et al.*, 1992). Knutson and Green (1975) have shown that YMR-type basalt lacks stable amphibole at 2 weight percent H_2O but contains amphibole and olivine phenocrysts at 5 weight percent H_2O. YMR basalts with amphibole phenocrysts thus may have contained an excess of 2 weight percent magmatic H_2O and possibly as much as 5 weight percent H_2O.

The study plan does not address the specifics of how volatile contents will be determined for basaltic magmas of the YMR. Although a range of volatile contents apparently will be considered in modeling activities, it is not stated what this range will be. From the information presented in this study plan it does not appear that the appropriate range of volatile contents which are representative of the Quaternary eruptions in the Yucca Mountain Region are being considered.

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

References

Crowe, B., R. Morley, S. Wells, J. Geissman, E. McDonald, L. McFadden, F. Perry, M. Murrell, J. Poths, and S. Forman, "The Lathrop Wells Volcanic Center: Status of Field and Geochronology Studies," *Proceedings of the Third International High-Level Radioactive Waste Management Conference,* American Nuclear Society, La Grange Park, IL, pp. 1,997 - 2,013, (1992)

Eggler, D.H., "Water-Saturated and Undersaturated Melting Relations in a Parícutin Andesite and an Estimate of Water Content in the Natural Magma," *Contributions to Mineralogy and Petrology,* 34:261-271 [1972].

Grove, T.L., and M.B. Baker, "Phase Equilibrium Controls on the Tholeiitic Versus Calc-Alkaline Differentiation Trends," *Journal of Geophysical Research,* 89:3253-3274 [1984].

Knutson, J., and T.H. Green, "Experimental Duplication of a High-Pressure Megacryst/cumulate Assemblage in a Near-Saturated Hawaiite," *Contributions to Mineralogy and Petrology,* 52:121-132 [1975].

Shelor, D.E., U.S. Department of Energy/Office of Civilian Radioactive Waste Management, Letter to J.J. Holonich, U.S. Nuclear Regulatory Commission/Division of High-Level Waste Management [Subject: Transmittal of Study Plan 8.3.1.8.1.2, Revision 0 ("Physical Processes of Magmatism and Effects on the Potential Repository"], October 1, 1993.

Vaniman, D., and B. Crowe, "Geology and Petrology of the Basalts of Crater Flat: Applications to Volcanic Risk Assessment for the Nevada Nuclear Waste Storage Investigations," Los Alamos National Laboratory, Report LA-8845-MS, 1981.

Wilson, L., and J.W. Head III, "Ascent and Eruption of Basaltic Magma on the Earth and Moon," *Journal of Geophysical Research,* 86:2971-3001 [1981].

Yoder, H.S., and C.E. Tilley, "Origin of Basaltic Magmas: An Experimental Study of Natural and Synthetic Rock Systems," *Journal of Petrology,* 3:342-532 [1962].

STUDY PLAN 8.3.1.8.1.2
PHYSICAL PROCESSES OF MAGMATISM AND EFFECTS ON THE POTENTIAL REPOSITORY

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.

Basis
Hawaiian (i.e., gas-jets and magma fountains) and Strombolian (i.e., fountains and ballistic ejecta) models of eruption dynamics are used in the study plan as characteristic of YMR basaltic eruptions. The high degree of magma fragmentation and relatively distant ejecta dispersal for eruptions such as occurred at Lathrop Wells and at the Sleeping Butte cones strongly suggest that the eruptive style of these cones may be more accurately characterized as Plinian. For example:

- The cinders at Lathrop Wells are highly fragmented (Crowe *et al.*, 1983) and lack the agglutination common for typical Strombolian eruptions (e.g., Blackburn *et al.*, 1976; Head and Wilson, 1989).

- The volume of pyroclastic material at Lathrop Wells and the Sleeping Butte volcanoes is unusually large relative to the volume of associated lava flows (Crowe *et al.*, 1983), which likely indicates relatively explosive eruptions (e.g., Wood, 1980).

- In addition, basaltic ash in Solitario Canyon fault at Trench 8, located approximately 20 kilometers north of the Lathrop Wells cone, may be from an eruption of the Lathrop Wells cone. Basaltic ash from presumably Quaternary eruptions also occurs in the Bow Ridge fault zone in Trench 14 on the east side of Yucca Mountain and in several other trenches on the west side of Yucca Crest. This distance of ash dispersal is not characteristic of typical Strombolian eruptions (e.g., Walker, 1973).

This relatively high explosivity is not unique to the YMR, but has been observed in several historically active small basaltic volcanoes throughout the world. For example:

- The 1992 eruption of Cerro Negro volcano in Nicaragua resulted in a convective ash-column 3.5 to 7 kilometers high, which was sustained for about 18 hours (GVN, 1992; Connor *et al.*, 1993). Ash from this basaltic eruption was transported in excess of 50 kilometers, with 1 centimeter-thick ash beds occurring up to 45 kilometers southwest of the volcano (Connor *et al.*, 1993).

- The 1975 basaltic eruption at Tolbachik, Russia, had sustained ash-column heights in excess of 10 kilometers, with ash transported in excess of 500 kilometers from the volcano (e g., Fedotov *et al.*, 1991; Tokarev, 1983). Although these eruptions are small volume and thus not Plinian in the strictest sense (Simkin *et al.*, 1981), they are significantly more energetic than eruptions characterized as Strombolian (Walker, 1973; Blackburn *et al.*, 1976).

The generalized DOE models fail to encompass the range of explosivity that appeared to have occurred in some YMR Quaternary eruptions. Although some of the models referred to in this study plan are developed for highly explosive Plinian eruptions (i.e., Valentine and Wohletz, 1989; Valentine *et al.*, 1992), it does not appear that these models will be used to evaluate eruptions more energetic than Strombolian.

The staff notes the reference to Link *et al.* (1982) as having provided earlier estimates of radiological consequences. Link *et al.* (1982) assumed that the distal edge of the ash fall extended only 8 kilometers, and therefore significantly underestimated the volume of ash and associated radiological consequences.

Recommendation
Models of basaltic eruptions in the YMR should consider a range of potential explosivities, including eruptions that are more energetic than typical Strombolian eruptions.

References
Blackburn, E.A., L. Wilson, and R.S.J. Sparks, "Mechanisms and Dynamics of Strombolian Activity," *Journal of the Geological Society of London,* 132:429-440 [1976].

Connor, C.B, L. Powell, W. Strauch, M. Navarro, O. Urbina, and W.I. Rose, "The 1992 Eruption of Cerro Negro, Nicaragua: An Example of Plinian-Style Activity at a Small Basaltic Cinder Cone," *EOS, Transactions of the American Geophysical Union,* 74-43:640 [1993].

Crowe, B., S. Self, D. Vaniman, R. Amos, and F. Perry, "Aspects of Potential Magmatic Disruption of a High-Level Radioactive Waste Repository in Southern Nevada," *Journal of Geology*, 91:259-276 [1983].

Fedotov, S.A., S.T. Balesta, V.N. Dvigalo, A.A. Razina, G.B. Flerov, and A.M. Chirkov, "The New Tolbachik Volcanoes," in S.A. Fedotov and Yu. P. Masurenkow, eds., "Active Volcanoes of Kamchatka," Nauka Press, Moscow, pp. 275-279, 1991.

Global Volcanism Network, "Violent Strombolian Activity at Cerro Negro," *Bulletin of the Global Volcanism Network,*" 17:2-4 [1992].

Head, J.W., III, and Wilson, L., "Basaltic Pyroclastic Eruptions: Influence of Gas-Release Patterns and Volume Fluxes on Fountain Structure, and the Formation of Cinder Cones, Spatter Cones, Rootless Flows, Lava Ponds and Lava Flows," *Journal of Volcanology and Geothermal Research,* 37:261-271 [1989].

Link, R. L., S. E. Logan, H.S. Ng, F.A. Rockenbach, K. Hong, "Parametric Studies of Radiological Consequences of Basaltic Volcanism," Sandia National Laboratories, SAND 81-2375, 1982.

Shelor, D.E., U.S. Department of Energy/Office of Civilian Radioactive Waste Management, Letter to J.J. Holonich, U.S. Nuclear Regulatory Commission/Division of High-Level Waste Management [Subject: Transmittal of Study Plan 8.3.1.8.1.2, Revision 0 ("Physical Processes of Magmatism and Effects on the Potential Repository"], October 1, 1993.

Simkin, T., L. Seibert, L. McClelland, D. Bridge, C. Newhall, and J.H. Latter, *Volcanoes of the World,* Stroudsburg, PA., Hutchinson Ross Publishers, 1981.

Tokarev, P.I., "Calculation of Magma Discharge, Growth in the Height of the Cone and Dimensions of the Feeder Channel of Crater I in the Great Tolbachik Fissure Eruption, July 1975," in S.A. Fedotov and Ye. K. Markhinin, eds., "The Great Tolbachik Fissure Eruption, Geological and Geophysical Data 1975-1976," Cambridge, Cambridge University Press, pp. 27-35, 1983.

Walker, G.P.L., "Explosive Volcanic Eruptions -- A New Classification Scheme," *Geologische Rundsche,* 62:431-446 [1973].

Wood, C.A., Morphometric Evolution of Cinder Cones," *Journal of Volcanology and Geothermal Research,* 7:387-413 [1980].

STUDY PLAN 8.3.1.8.1.2
PHYSICAL PROCESSES OF MAGMATISM AND EFFECTS ON THE POTENTIAL REPOSITORY

Comment 4
Thermal and degassing effects may be poorly preserved at inactive basaltic volcanoes and thus cannot be quantified adequately using the methods proposed in the study plan.

Basis
After the cessation of eruptive activity, heat and mass transfer to the surface and through rock surrounding shallow intrusions continues through convective degassing and heat conduction.

Direct effects of volcano degassing would include the movement of gas through the repository block, which may result in accelerated rates of container corrosion and deterioration of the waste packages.

Indirect effects of degassing also may impact repository performance, and may include a change in the partitioning of radionuclides between aqueous and solid phases, and changes in the sorption of radionuclides.

In addition, changes in movement of groundwater and gas phases in the geologic environment, and changes in the mechanical properties of the surrounding rock, may also result from degassing and thermal loading of rock by conductive and convective heat transfer. The effects of these processes can extend for some poorly constrained distance beyond the immediate area of the main vent or magma intrusion.

Most theoretical models for dike emplacement and solidification indicate that individual dikes cool rapidly to near ambient temperatures within hours or days of the cessation of rapid mass flow (e.g., Delaney and Pollard, 1982). However, the occurrence of high-temperature fumaroles at recently active cinder cones indicates that heat and mass transfer in the entire volcanic system remains elevated for considerably longer periods of time.

For example, at Paricutin temperatures in excess of 100°C were measured at some of the diffuse fumaroles, while at the main fumarole temperatures of 473°C were measured more than 30 years after cessation of the eruption Connor (1989). Conditions responsible for this activity must be considered in order to determine the long-term impact of volcanism on repository performance.

Thermal and mass transfer processes that can affect repository performance may be poorly preserved in the rocks surrounding a basaltic volcano. Basaltic volcanoes rarely develop forced-convection hydrothermal systems of sufficient magnitude to result in wallrock alteration (e.g., Hardee, 1982). Although some dehydration reactions may occur in zeolite and clays at temperatures of approximately 100°C, as noted in Study Plan 8.3.1.8.1.2, some of these dehydration and mineralogical reactions can be reversible (e.g., Smyth, 1981; Bish, 1988) or only occur at temperatures in excess of 200°C (e.g., Bish, 1990). The presence or absence of hydrated zeolite in rock surrounding an intrusion thus may not accurately reflect the effects of a 100°C increase in temperature associated with intrusion emplacement.

Detailed zeolite and clay stability studies may provide useful constraints on wall-rock paleotemperatures. However, such studies apparently are not proposed in Study Plan 8.3.1.8.1.2. The proposed field-based investigations of subsurface alteration at analog basaltic volcanoes may thus fail to accurately delineate the region around a basaltic volcano that experienced elevated temperature and gas-flow rates.

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.

References

Bish, D.L., "Smectite Dehydration and Stability: Applications to Radioactive Waste Isolation at Yucca Mountain, Nevada," Los Alamos National Laboratory, Report LA-11023-MS, 1983.

Bish, D.L., "Long-Term Thermal Stability of Clinoptilolite: The Development of a "B" Phase," *European Journal of Mineralogy*, 2:771-777 [1990].

Connor, C.B., Anomalous Soil Mercury Concentrations at Paricutin Volcano, Michoacan - Guanjuato Volcanic Field, Mexico," *Geofisica Internaacional*, 28-5:1029-1041 [1989].

Delaney, P.T., and D.D. Pollard, "Solidification of Basaltic Magma during Flow in a Dike," *American Journal of Science*, 282:856-885 [1982].

Hardee, H.C., "Permeable Convection above Magma Bodies," *Tectonophysics*, 84:179-195 [1982].

Shelor, D.E., U.S. Department of Energy/Office of Civilian Radioactive Waste Management, Letter to J.J. Holonich, U.S. Nuclear Regulatory Commission/Division of High-Level Waste Management [Subject: Transmittal of Study Plan 8.3.1.8.1.2, Revision 0 ("Physical Processes of Magmatism and Effects on the Potential Repository"], October 1, 1993.

Smyth, J.R., "Zeolite Stability Constraints on Radioactive Waste Isolation in Zeolite-Bearing Volcanic Rocks," *Journal of Geology*, 90:195-201 [1981].

STUDY PLAN 8.3.1.8.1.2
PHYSICAL PROCESSES OF MAGMATISM AND EFFECTS ON THE POTENTIAL REPOSITORY

Comment 5
Studies of eruptive effects (Activities 8.3.1.8.1.2.1 and 8.3.1.8.1.2.3 (e.g., eruptive effects and magma system dynamics, respectively) apparently will be terminated if the probability of repository release is calculated to be $\leq 10^{-8}$year^{-1}. It is not clear how such a determination can be accurately made until the proposed studies have been completed.

Basis
It is noted on page 10 that studies of eruptive effects will be concluded if a probability of erupting sufficient volumes of waste is $\leq 10^{-8}$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.

The study plan recognizes that the quantity of repository material released can be more accurately constrained than the location of disruption (i.e., "Chapter 8.3.1.8, Postclosure Tectonics" in DOE, 1988). However, the models for eruption effects presented in this study plan (i.e., Hawaiian and Strombolian) underestimate the energetics of basaltic eruptions in the YMR. These models do not account for the hydromagmatic eruptions that occurred at Lathrop Wells (e.g., Vaniman and Crowe, 1981) and may occur during future eruptions (e.g., Crowe *et al.*, 1986). In addition, as is evidenced from the ash in the trenches in the Yucca Mountain region, there may have also been nonhydromagmatic basaltic eruptions in the YMR that were considerably more energetic than Strombolian. Both of these eruption scenarios, hydromagmatic and plinian to subplinian, are capable of dispersing significantly more repository material than those proposed for Hawaiian and Strombolian eruptions (e.g., Barr *et al.*, 1993).

Determining the amount of repository material that can potentially be erupted will require data from both Activities 8.3.1.8.1.2.1 and 8.3.1.8.1.2.3 in this study plan, in addition to input from Study Plans 8.3.1.8.1.1 ("Probability of Magmatic Disruption") and 8.3.1.8.5.1 ("Characterization of Volcanic Features"). Any calculation about the amount of repository material erupted is preliminary, unless the results of these studies are available. Thus, the proposed limitations to Activities 8.3.1.8.1.2.1 and 8.3.1.8.1.2.3 appears inappropriate until the proposed studies are completed.

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

References

Barr, G.E., E. Dunn, H. Dockery, R. Barnard, G. Valentine, B. Crowe, "Scenarios Constructed for Basaltic Igneous Activity at Yucca Mountain and Vicinity," Sandia National Laboratories, SAND91-1653, 1993.

Crowe, B.M., K.H. Wohletz, D.T. Vaniman, E. Gladney, and N. Bower, "Status of Volcanic Hazard Studies for the Nevada Nuclear Waste Storage Investigations," Los Alamos National Laboratory, LA-9325-MS, Vol. II, 1986.

Shelor, D.E., U.S. Department of Energy/Office of Civilian Radioactive Waste Management, Letter to J.J. Holonich, U.S. Nuclear Regulatory Commission/Division of High-Level Waste Management [Subject: Transmittal of Study Plan 8.3.1.8.1.2, Revision 0 ("Physical Processes of Magmatism and Effects on the Potential Repository"], October 1, 1993.

U.S. Department of Energy, "Site Characterization Plan, Yucca Mountain Site, Nevada Research and Development Area, Nevada," Office of Civilian Radioactive Waste Management, DOE/RW-0199, 9 vols., December 1988.

Vaniman, D., and B. Crowe., "Geology and Petrology of the Basalts of Crater Flat: Applications to Volcanic Risk Assessment for the Nevada Nuclear Waste Storage Investigations," Los Alamos National Laboratory, LA-8845-MS, 1981.

STUDY PLAN 8.3.1.8.1.2
PHYSICAL PROCESSES OF MAGMATISM AND EFFECTS ON THE POTENTIAL REPOSITORY

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.

Basis
Detailed studies of the subsurface effects of basaltic intrusions on zeolite alteration (Section 8.3.1.8.1.2.2, pp. 24-25) apparently will not be conducted if groundwater transport calculations indicate that insignificant radionuclide release could result from alteration effects. The basis for these calculations is that most zeolites are unstable at temperatures above about 100°C, and the decision will be made from "risk" calculations as defined elsewhere within this study plan.

As stated in Comment 1, the DOE basis for "risk", the "tripartite probability" is considered by the NRC staff to be inadequate to demonstrate compliance with 10 CFR Part 60.

Although some dehydration reactions may occur in zeolite and clays at temperatures below 100°C (Knowlton *et al.*, 1986), some dehydration and mineralogical reactions can be reversible (e.g., Smyth, 1981; Bish, 1988) or only occur at temperatures in excess of 200°C (e.g., Bish, 1990). In addition, the kinetics and composition of the solution surrounding the zeolite also can control these dehydration reactions (e.g., Smyth and Caporuscio, 1981).

The stability of zeolite around basaltic intrusions thus cannot be determined by simply calculating the zone around an intrusion that exceeds 100°C, as proposed in the study plan.

The significance of this alteration zone on groundwater transport of radionuclides also cannot be evaluated, until groundwater transport and geochemical models have been developed (e.g., "Chapter 8.3.1.3, Geochemistry" in DOE, 1988).

The apparent decision not to investigate fully the effects of alteration of rock surrounding an intrusion, unless some undetermined level of significance is achieved, appears to be premature.

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 should not be integrated with geohydrologic and geochemical studies.

References

Bish, D.L., "Smectite Dehydration and Stability: Applications to Radioactive Waste Isolation at Yucca Mountain, Nevada," Los Alamos National Laboratory, LA-11023-MS, 1988.

Bish, D.L., "Long-Term Thermal Stability of Clinoptilolite: The Development of a "B" Phase," *European Journal of Mineralogy*, 2:771-777 [1990].

Knowlton, G.D., T.R. White, and H.L. McKague, "Thermal Study of Types of Water Associated with Clinoptilolite," *Clays and Clay Minerals*, 29:403-411 [1981].

Shelor, D.E., U.S. Department of Energy/Office of Civilian Radioactive Waste Management, Letter to J.J. Holonich, U.S. Nuclear Regulatory Commission/Division of High-Level Waste Management [Subject: Transmittal of Study Plan 8.3.1.8.1.2, Revision 0 ("Physical Processes of Magmatism and Effects on the Potential Repository"], October 1, 1993.

Smyth, J.R., Zeolite stability constraints on radioactive waste isolation in zeolite-bearing volcanic rocks, *Journal of Geology*, 90:195-201 [1981].

Smyth, J.R., and F.A. Caporuscio, "Review of the Thermal Stability and Cation Exchange Properties of the Zeolite Minerals Clinoptilolite, Mordenite, and Analcime: Applications to Radioactive Waste Isolation in Silicic Tuff," Los Alamos National Laboratory, LA-8841-MS, 1981.

U.S. Department of Energy, "Site Characterization Plan, Yucca Mountain Site, Nevada Research and Development Area, Nevada," Office of Civilian Radioactive Waste Management, DOE/RW-0199, 9 vols., December 1988.

STUDY PLAN 8.3.1.8.1.2
PHYSICAL PROCESSES OF MAGMATISM AND EFFECTS ON THE POTENTIAL REPOSITORY

Comment 7
There are five Quaternary volcanic centers located in Crater Flat, not four as stated in the study plan.

Basis
There are five spatially discrete Quaternary basaltic vents in Crater Flat: Northern Cone, Black Cone, Red Cone, Little Cone North (LCN), and Little Cone South (LCS).

LCN lacks an associated lava flow, but LCS apparently is associated with a buried flow that extends at least 0.5 kilometers south of the cinder cone (e.g., Crowe and Carr, 1980).

LCN contains phenocrysts of amphibole, but amphibole is absent from LCS (e.g., Vaniman and Crowe, 1981).

The geochemical data presented in Vaniman and Crowe (1981) and Crowe *et al.* (1986) also show that LCS and LCN have some compositional distinctions.

The discrete locations, different eruptive styles, and mineralogical and geochemical differences clearly show that LCN and LCS are discrete volcanic centers.

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 the Little Cones.

References
Crowe, B.M., and W.J. Carr, "Preliminary Assessment of the Risk of Volcanism at a Proposed Nuclear Waste Repository in the Southern Great Basin," U.S. Geological Survey Open-file Report 80-357, 1980.

Crowe, B.M., K.H. Wohletz, D.T. Vaniman, E. Gladney, and N. Bower, "Status of Volcanic Hazard Studies for the Nevada Nuclear Waste Storage Investigations," Los Alamos National Laboratory Report LA-9325-MS, Vol. II, 1986.

Shelor, D.E., U.S. Department of Energy/Office of Civilian Radioactive Waste Management, Letter to J.J. Holonich, U.S. Nuclear Regulatory Commission/Division of High-Level Waste Management [Subject: Transmittal of Study Plan 8.3.1.8.1.2, Revision 0 ("Physical Processes of Magmatism and Effects on the Potential Repository"], October 1, 1993.

Vaniman, D., and B. Crowe, "Geology and Petrology of the Basalts of Crater Flat: Applications to Volcanic Risk Assessment for the Nevada Nuclear Waste Storage Investigations," Los Alamos National Laboratory, LA-8845-MS, 1981.

STUDY PLAN 8.3.1.8.1.2
PHYSICAL PROCESSES OF MAGMATISM AND EFFECTS ON THE POTENTIAL REPOSITORY

Comment 8
Planned lithic fragment studies in the YMR 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.

Basis
In the YMR, the only lithic fragment studies apparently planned are at Red and Black Cones in Crater Flat. These vents were selected due to their proximity to the USW VH-2 and VH-1 drill holes, which will be used to provide stratigraphic control.

Drill hole VH-2, which is located between Red and Black Cones, penetrated 360 meters of alluvium and 30 meters of Miocene basalt before intersecting the top of the Ammonia Tanks member of the Timber Mountain Tuff (Carr and Parrish, 1985). The upper 100 meters of alluvium consists of Cenozoic volcanic clasts with subordinate amounts of Paleozoic clasts, whereas the lower 260 meters is dominated by Paleozoic clasts (Carr and Parrish, 1985). It is not clear how tuffaceous lithic fragments will be attributed to pyroclastic units >390 meters deep or to epiclastic units <390 meters deep. In addition, alluvium dominated by Paleozoic clasts also occurs between 535 and 595 meters, which could further complicate the stratigraphic relationships of these lithic fragments.

Red and Black Cones are characterized by large volumes of lavas relative to the volume of the associated cinder cones (Crowe *et al.*, 1983). However, the Sleeping Butte and Lathrop Wells volcanoes are characterized by relatively large cinder cone volumes (Crowe *et al.*, 1983), which may indicate that these vents are more explosive than Red or Black Cones.

Lathrop Wells lacks prominent beds of agglutinated scoria, however, Red and Black Cones contain prominent agglutinated scoria deposits, which may indicate that these deposits were less fragmented (i.e., less explosive) than Lathrop Wells.

In addition, previous studies at Lathrop Wells (Crowe *et al.* (1986)), have shown that the volume percentage of lithic fragments in both the supposed hydrovolcanic deposits and the non-hydrovolcanic deposits of the Lathrop Wells cone are at least an order of magnitude greater than the commonly quoted value obtained from Crowe *et al.* (1983).

By not including Lathrop Wells and the Sleeping Butte cones in the studies to determine lithic fragment percentage, the study results may be biased to an unrealistically low value.

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.

References

Carr, W.J., and L.D. Parrish, "Geology of Drill Hole USW VH-2, and Structure of Crater Flat, Southwestern Nevada," U.S. Geological Survey, Open-File Report 85-475, 1985.

Crowe, B., S. Self, D. Vaniman, R. Amos, and F. Perry, "Aspects of Potential Magmatic Disruption of a High-Level Radioactive Waste Repository in Southern Nevada," *Journal of Geology*, 91:259-276 [1983].

Crowe, B.M., K.H. Wohletz, D.T. Vaniman, E. Gladney, and N. Bower, "Status of Volcanic Hazard Studies for the Nevada Nuclear Waste Storage Investigations," Los Alamos National Laboratory, LA-9325-MS, Vol. II, 1986.

Shelor, D.E., U.S. Department of Energy/Office of Civilian Radioactive Waste Management, Letter to J.J. Holonich, U.S. Nuclear Regulatory Commission/Division of High-Level Waste Management [Subject: Transmittal of Study Plan 8.3.1.8.1.2, Revision 0 ("Physical Processes of Magmatism and Effects on the Potential Repository"], October 1, 1993.

STUDY PLAN 8.3.1.8.1.2
PHYSICAL PROCESSES OF MAGMATISM AND EFFECTS ON THE POTENTIAL REPOSITORY

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.

Basis
An inherent assumption in the proposed analog studies of subsurface magmatic effects is that the lithostatic confining pressure represents the pressure that would be encountered by rising magma. Construction and operation of the repository, however, will modify these conditions due to the excavation and redistribution of stresses in the rock mass surrounding the openings, and from the effects of thermal loading. Following closure the stresses in the drifts, and immediately surrounding the drifts will not be equivalent to lithostatic pressure.

Even if the drifts are backfilled, the backfill can not be placed such that the backfill pressure is equivalent to lithostatic pressure. Following closure, therefore, the drifts, and the area surrounding the drifts will be in a state of stress which is probably greater than atmospheric, but less than lithostatic pressure.

The analog studies within this study plan are focused on determining the amount of wall rock that can be fragmented and erupted from depths equivalent to the present lithostatic stress at the repository horizon. This approach can potentially underestimate the amount of repository material incorporated into ascending basaltic magma, because the lower confining pressure of the repository horizon following excavation will likely enhance volatile exsolution and result in more extensive magma and wall-rock fragmentation (see, for example, Wilson and Head, 1981). Thus, the mechanisms of magma and wall-rock fragmentation from depths less than the present repository horizons may be more representative of magma-repository interactions which are to be expected.

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.

References
Shelor, D.E., U.S. Department of Energy/Office of Civilian Radioactive Waste Management, Letter to J.J. Holonich, U.S. Nuclear Regulatory Commission/Division of High-Level Waste Management [Subject: Transmittal of Study Plan 8.3.1.8.1.2, Revision 0 ("Physical Processes of Magmatism and Effects on the Potential Repository"], October 1, 1993.

Wilson, L., and J.W. Head III, "Ascent and Eruption of Basaltic Magma on the Earth and Moon," *Journal of Geophysical Research,* 86(B4):2,971-3,001 [1981].

STUDY PLAN 8.3.1.8.1.2
PHYSICAL PROCESSES OF MAGMATISM AND EFFECTS ON THE POTENTIAL REPOSITORY

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.

Basis
The CFVZ (Crowe and Perry, 1989) includes all basaltic volcanoes in the YMR younger than about 5 Ma, with the exception of the 2.8 ± 0.1 Ma Buckboard Mesa volcano. Buckboard Mesa represents one of the largest basaltic eruptions of post-caldera basalt (Crowe and Perry, 1989) in the YMR (Crowe *et al.*, 1983a).

Buckboard Mesa basaltic lavas contain xenoliths of partially melted and disaggregated granitic rock and xenocrysts of rounded quartz (Crowe *et al.*, 1983b), both of which likely indicate crustal contamination. Buckboard Mesa also is compositionally distinct from other CFVZ basalts (Crowe *et al.*, 1986).

Although Buckboard Mesa is not located in the NW-trending CFVZ, Smith *et al.* (1990) considered it a fundamental part of the YMR magmatic system.

Buckboard Mesa is spatially and temporally part of the YMR volcanic system. The relatively large volume of apparently crustally contaminated basalt at Buckboard Mesa appears unique for <5 Ma basaltic rocks of the YMR.

Determining the petrogenesis of Buckboard Mesa could yield critical information of how mantle-derived melts may stagnate or interact with the crust in this magma system. These features may not be readily discernable at CFVZ volcanoes. It is not clear why Buckboard Mesa is not being considered in any of the activities in this study plan.

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

References
Crowe, B.M., and F.V. Perry, "Volcanic Probability Calculations for the Yucca Mountain Site: Estimation of Volcanic Rates," *Proceedings of FOCUS '89, Nuclear Waste Isolation in the Unsaturated Zone*, American Nuclear Society, La Grange Park, IL, pp. 326-334, 1989.

Crowe, B.M., D.T. Vaniman, and W.J. Carr, "Status of Volcanic Hazard Studies for the Nevada Nuclear Waste Storage Investigations," Los Alamos National Laboratory, LA-9325-MS, 1983a.

Crowe, B., S. Self, D. Vaniman, R. Amos, and F. Perry, "Aspects of Potential Magmatic Disruption of a High-Level Radioactive Waste Repository in Southern Nevada," *Journal of Geology,* 91:259-276 [1983b].

Crowe, B.M., K.H. Wohletz, D.T. Vaniman, E. Gladney, and N. Bower, "Status of Volcanic Hazard Studies for the Nevada Nuclear Waste Storage Investigations," Los Alamos National Laboratory, LA-9325-MS, Vol. II, 1986.

Shelor, D.E., U.S. Department of Energy/Office of Civilian Radioactive Waste Management, Letter to J.J. Holonich, U.S. Nuclear Regulatory Commission/Division of High-Level Waste Management [Subject: Transmittal of Study Plan 8.3.1.8.1.2, Revision 0 ("Physical Processes of Magmatism and Effects on the Potential Repository"], October 1, 1993.

Smith, E.I., T.R. Feuerbach, and J.E. Faulds, "The Area of Most Recent Volcanism near Yucca Mountain, Nevada: Implications for Volcanic Risk Assessment," *Proceedings of the First International High-Level Radioactive Waste Management Conference,* American Nuclear Society, La Grange Park, IL, pp. 81-90, 1990.

STUDY PLAN 8.3.1.8.1.2
PHYSICAL PROCESSES OF MAGMATISM AND EFFECTS ON THE POTENTIAL REPOSITORY

Question 1
How will DOE establish the ranges of either the number or volume of the various eruptive events which have occurred?

Basis
On page 18 of the study plan it is stated that "The probabilities of each eruptive mechanism will be determined by the number or volume of events of each mechanism divided by the total number or volume of Pliocene and Quaternary eruptive events in the Yucca Mountain region."

Trenching activities in the Yucca Mountain region have shown the presence of relatively pure ash contained in some of the trenches, such as Trench 8. In addition, multiple ash exposures are found in some of the trenches suggesting multiple ash falls.

These ashes are on the order of 15 to 20 kilometers from the nearest known Quaternary or Pliocene basaltic volcano. To disperse ash to this distance would require a relatively energetic, explosive, eruptive mechanism, however the staff knows of nothing in the DOE literature for the Yucca Mountain area which adequately accounts for the volume of ash from these explosive events.

Crowe *et al.* (1983) use a scoria sheet to cone ratio of 5:1 even though they recognize ratios up to 13:1, and use a cut-off thickness in the calculations of 10 centimeters. From the information provided in Crowe *et al.* it would appear that the area of coverage was assumed to be on the order 100 kilometers^2, however, the presence of ash in the trenches at Yucca Mountain suggests an area of coverage on the order of 1200+ kilometers^2.

Models which neglect this volume of material may be in error as a significant volume of an explosive basaltic eruption may be represented by tephra that is more highly dispersed than in Strombolian eruptions (e.g., Walker (1973); Connor *et al.* (1993)). This dispersed tephra is poorly preserved unless it is rapidly buried by erosionally resistant deposits. Models utilizing eruption volumes (e.g., Crowe *et al.* (1983); Crowe and Perry (1989)) are inaccurate unless the highly dispersed tephra is incorporated into volume calculations.

For example, Crowe *et al.* calculated on the order of $8.5 \times 10E^7$ meters^3 of material in the scoria sheet. Based on the assumed sheet to cone volume ratio used in the calculations this could be off by a factor of 2.5 or greater, and based on the area of coverage could be off by an order of magnitude or greater. The volume of material represented by the scoria sheet from the Lathrop Wells eruption is greater then the calculated volumes of many of the cones in the Yucca Mountain region, and, therefore, is not an insignificant consideration in any calculation in which magma volumes are considered.

The staff has previously requested a copy of the procedure by which volumes of material are actually calculated (NRC, 1992) but as yet has not received this information.

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.

References

Connor, C.B, L. Powell, W. Strauch, M. Navarro, O. Urbina, and W.I. Rose, "The 1992 Eruption of Cerro Negro, Nicaragua: An Example of Plinian-Style Activity at a Small Basaltic Cinder Cone," *EOS, Transactions of the American Geophysical Union,* 74-43:640 [1993].

Crowe, B.M., and F.V. Perry, "Volcanic Probability Calculations for the Yucca Mountain Site: Estimation of Volcanic Rates," *Proceedings of FOCUS '89, Nuclear Waste Isolation in the Unsaturated Zone,* American Nuclear Society, La Grange Park, IL, pp. 326-334, 1989.

Crowe, B., S. Self, D. Vaniman, R. Amos, and F. Perry, "Aspects of Potential Magmatic Disruption of a High-Level Radioactive Waste Repository in Southern Nevada," *Journal of Geology,* 91:259-276 [1983].

Holonich, J.J., U.S. Nuclear Regulatory Commission/Division of High-Level Waste Management, Letter to J.P. Roberts, U.S. Department of Energy/Office of Civilian Radioactive Waste Management [Subject: Review of the Study Plan for Probability of Magmatic Disruption of the Repository, Comment 2"], July 1992.

Shelor, D.E., U.S. Department of Energy/Office of Civilian Radioactive Waste Management, Letter to J.J. Holonich, U.S. Nuclear Regulatory Commission/Division of High-Level Waste Management [Subject: Transmittal of Study Plan 8.3.1.8.1.2, Revision 0 ("Physical Processes of Magmatism and Effects on the Potential Repository"], October 1, 1993.

Walker, G.P.L., "Explosive Volcanic Eruptions -- A New Classification Scheme," *Geologische Rundsche,* 62:431-446 [1973].

STUDY PLAN 8.3.1.8.1.2
PHYSICAL PROCESSES OF MAGMATISM AND EFFECTS ON THE POTENTIAL REPOSITORY

Question 2
How are the terms "Crater Flat Volcanic Zone" and "Crater Flat" used in this study plan?

Basis
Specific tests and analyses in Section 8.3.1.8.1.2.3 on magma system dynamics refer to either volcanoes of the "Crater Flat Volcanic Zone" or "Crater Flat". It is unclear if the activities directed at "Crater Flat" volcanoes will only examine the Quaternary and Pliocene basalts physically located in Crater Flat, or if the activities will examine the "Crater Flat Volcanic Zone", as shown on Figure 2.

If these terms are not synonymous, then the planned activities at "Crater Flat" volcanoes do not appear sufficient to examine the full range of eruptive styles present in the YMR.

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 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.

References
Shelor, D.E., U.S. Department of Energy/Office of Civilian Radioactive Waste Management, Letter to J.J. Holonich, U.S. Nuclear Regulatory Commission/Division of High-Level Waste Management [Subject: Transmittal of Study Plan 8.3.1.8.1.2, Revision 0 ("Physical Processes of Magmatism and Effects on the Potential Repository"], October 1, 1993.

STUDY PLAN 8.3.1.8.1.2
PHYSICAL PROCESSES OF MAGMATISM AND EFFECTS ON THE POTENTIAL REPOSITORY

Comment 49
If the results of the investigations on direct release resulting from volcanic activity do not provide information which shows that either the probability and/or consequences resulting from such a scenario is lower than the tentative parameter goals stated in Table 8.3.1.8-18 and Table 8.3.5.13-10, the Yucca Mountain site will fail to meet the requirements for overall system performance.

Basis

- The concern expressed by this comment was the main basis for CDSCP Comment 36 and 95.

- The tentative parameter values were not revised within the SCP. The response to CDSCP Comment 36 and 95 focused primarily on what effects the expected values may have on the CCDF, and on justification of the use of the EPPM.

- The NRC staff agrees, with the discussion in Section 8.3.1.8, 8.3.5.13, and with the comment response presented in CDSCP Comments 36 and 95, that if the expected values of probability of volcanism are obtained, this scenario by itself would not cause the site to fail the EPA standard. The goals, however, are 2 orders of magnitude or more higher than the expected values.

- The annual probability of 10E-6 stated in the tentative goals is higher than one chance in 1000 in 10,000 years, and therefore a process or event with such a probability would have to be included in the CCDF to determine compliance with the overall system performance objective if the results of such a process or event were significant.

- Disruption and release of on the order of one tenth of one percent of the repository inventory, the other tentative goal, would result in a release to the accessible environment on the order of 170 times the EPA standard ratio based on the reference inventory presented in Table 8.3.5.13-6. Such a release, combined with the above probability, would cause the site to fail the overall system performance objective and is therefore considered significant.

- Even assuming radioactive decay through 10,000 years, the EPA ratio would exceed 1 at all times and would exceed 10 for a sufficiently long period of time that the standard would not be met, assuming the annual probability goal presented above.

- The conditional probability presented in Table 8.3.5.13-10 only states that the consequence goal will have a low probability of exceedence, and therefore has no direct effect on the calculations.

- While, as stated on page 8.3.5.13-18, an EPPM of greater than 0.01 does not necessarily imply a violation of the EPA standard, if the EPPM were calculated in accordance with the methodologies presented on page 8.3.5.13-18 and using the reference inventory presented on Table 8.3.5.13-6, the resultant value would be on the order of 1.7, which is much more than the tentative goal of 0.1 listed in Table 8.3.1.8-1 and Table 8.3.5.13-8. The NRC staff considers that an EPPM on the order of 1.7 would imply a violation in most cases.

- If radioactive decay is consider, the average release value times the value of the probability goal would result in an EPPM of greater than 0.1. The goals presented in the various tables do not appear to be internally consistent.

- Furthermore, as can be determined from the discussion on page 8.3.5.13-18, the significance of an EPPM of greater than 0.01 can not be determined without performing other calculations. While the EPPM may have some use, in this specific case the goal for the EPPM is above 0.01, therefore by itself it provides no guidance to the person performing the investigations (See also Comment 108).

- The purpose of performance allocation is to determine what components of the natural and engineered system are significant in determining if the site can meet the various performance objectives to assure that proper emphasis is placed on the various investigations. To assure that the investigator understands the significance of the technical finding, the goal should be set so that the performance objectives can be met if the goals are met.

- In the specific case of volcanism intersecting the repository, the consequences are sufficiently high that the probability goal should be set to assure that, if met, this scenario by itself would not cause the site to fail the performance objectives.

Recommendation
DOE should review the various performance measures, performance parameters and goals presented for basaltic volcanism. Goals should be set which will assure that the performance objectives could be met.

Evaluation of the DOE October 1993 Response
In Table 8.3.1.8-1b, the parameter value stated was that the annual probability of volcanic eruption that penetrates the repository should be less than 10^{-6} per year. The staff has taken this as an approximation of 1 chance in 100 in 10,000 years.

In Table 8.3.5.13-10, the performance parameter stated was that given occupance, show that less than 0.1 percent of the repository area is disrupted with a conditional probability of less than 0.1

percent of being exceeded in 10,000 years.

If it is given that the repository is being disrupted, and that less than 0.1 percent of the repository is being disrupted, using the reference inventory presented in Table 8.3.5.13-6, the inventory being disrupted is something less than 170 times the EPA ratio. This value can not be treated as a consequence of 0.001, as stated on page 11 of the study plan, as the standard is based on exceeding the ratio and the parameter is over 100 times the ratio, not 0.001 times the ratio. The conditional probability stated in Table 8.3.5.13-10 can not be taken as a probability of occupance as the statement is already made that occurrence has been given. The conditional probability of less than 0.1 percent of being exceeded is only a statement that if the activity occurs anytime during the 10,000 years that there is less that 0.1 percent chance that more than 0.1 percent of the repository would be disrupted.

Taken together, the parameter values and performance goals state that the goals are that there would be less than 1 chance in 100 in 10,000 years (say, 9 chances in 1000 in 10,000 years) that an area of the repository containing an inventory equal to something less than 170 times the EPA ratio (say 169 times the EPA ratio) will be disturbed with a chance of less than 0.1 percent that these values will not be exceeded. If the above values are plotted on a CCDF the site would be shown to be in violation of the EPA standard.

The NRC concern has been, and continues to be, trying to assure that the results of site characterization can resolve questions as to; the probabilities of magmatic activity, the consequences of magmatic activity, and the correct application of this information in attempts to demonstrate compliance with the appropriate performance objective. As the program has matured these concerns have been presented to DOE as comments on Study Plans 8.3.1.8.5.1, 8.3.1.8.1.1 and 8.3.1.8.1.2 and comments on the Volcanism Status Report (NRC, 1993). The specific concerns that gave rise to this SCP comment are addressed in Comments 4 and 8 for Study Plan 8.3.1.8.1.1, and Comment 1 for Study Plan 8.3.1.8.1.2 in the context of the ongoing studies. The staff considers that this is a more appropriate approach to track this concern.

The staff considers this comment closed.

References

Holonich, J.J., U.S. Nuclear Regulatory Commission/Division of High-Level Waste Management, Letter to D.E. Shelor, U.S. Department of Energy/Office of Civilian Radioactive Waste Management [Subject: "Status of Volcanism Issues for the Proposed High-Level Waste Site at Yucca Mountain"], August 18, 1993.

Ross, B., "A First Survey of Disruptive Scenarios for a High-Level Waste Repository at Yucca Mountain, Nevada," Sandia National Laboratory, SAND85-7117, 1987.

Rousso, S., U.S. Department of Energy/Office of Civilian Radioactive Waste Management, Letter to H. Thompson, Jr, U.S. Nuclear Regulatory Commission [Subject: Issuance of the Site Characterization Plan (SCP) for the Yucca Mountain Site to the U.S. Nuclear Regulatory Commission (Includes "Response to the NRC Point Papers on Site Characterization Plan/Consultation Draft], 1988.

Shelor, D.E., U.S. Department of Energy/Office of Civilian Radioactive Waste Management, Letter to J.J. Holonich, U.S. Nuclear Regulatory Commission/Division of High-Level Waste Management [Subject: Transmittal of Study Plan 8.3.1.8.1.2, Revision 0 ("Physical Processes of Magmatism and Effects on the Potential Repository"], October 1, 1993.

U.S. Department of Energy, "Site Characterization Plan, Yucca Mountain Site, Nevada Research and Development Area, Nevada," Office of Civilian Radioactive Waste Management, DOE/RW-0199, 9 vols., December 1988.

U.S. Nuclear Regulatory Commission, "NRC Staff Site Characterization Analysis of the Department of Energy's Site Characterization Plan, Yucca Mountain, Nevada," Office of Nuclear Material Safety and Safeguards, NUREG-1347, 1988.

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September 26, 1994

MEMORANDUM TO: William R. Ott, Acting Chief
Waste Management Branch
Division of Regulatory Applications, RES

FROM: Margaret V. Federline, Chief
Performance Assessment & Hydrology Branch
Division of Waste Management, NMSS

SUBJECT: REVIEW OF RES SOW FOR EVALUATION AND TESTING OF GROUNDWATER FLOW AND TRANSPORT MODELS (JOB CODE W6388)

We have reviewed the subject statement of work for the continuation of work by Dr. Shlomo P. Neuman at the University of Arizona. Our review yielded no comments, largely due to prior interaction between NMSS and RES staff in the overall project approval process and development of the specific statement of work. We continue to support the work described. This review was prepared by Jeffrey Pohle of my staff, who can be reached at 301-415-6703.

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