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

MAY 31 1994

Mr. Dwight E. Shelor, Associate Director
for Systems and Compliance
Office of Civilian Radioactive Waste Management
U.S. Department of Energy
1000 Independence Avenue, S.W.
Washington, D.C. 20585

Dear Mr. Shelor:

SUBJECT: U.S. NUCLEAR REGULATORY COMMISSION STAFF REVIEW OF THE STUDY PLAN FOR CHARACTERIZATION OF VOLCANIC FEATURES

On March 10, 1993, the U.S. Department of Energy (DOE) transmitted Revision 1 of the study plan for "Characterization of Volcanic Features" (Study Plan 8.3.1.8.5.1) to the U.S. Nuclear Regulatory Commission for review and comment. NRC has completed its review of this document using the "Review Plan for NRC Staff Review of DOE Study Plans, Revision 2" (dated March 10, 1993). The material submitted in the revised study plan was considered to be 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's documents related to site characterization (Consultation Draft Site Characterization Plan and the Site Characterization Plan for the Yucca Mountain site). It does not appear that the conduct of the activities described in the revised 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 determines whether detailed comments or questions are warranted. The NRC staff's review of the subject study plan has resulted in the identification of seven comments and nine questions (Enclosure 1). The enclosed comments and questions will be tracked by the NRC staff as open items similar to Site Characterization Analysis comments and questions.

During the period of its review of the subject study plan, the staff also conducted reviews of another related study Plan (8.3.1.8.1.1, "Probability of Magmatic Disruption of the Repository)" and the draft Los Alamos report, "Status of Volcanic Hazard Studies for the

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Yucca Mountain Site Characterization Project." In addition, in its letter of transmittal of the subject study plan, DOE noted that the subject study plan had been revised in direct response to NRC staff comments on Study Plan 8.3.1.8.1.1. As a result of reviewing both study plans and the draft status report together, the staff became aware of new areas of concern not identified in its earlier review (letter from Holonich to Shelor, dated March 18, 1991).

In its review of Revision 0 of the subject study plan, the staff identified three questions. Enclosure 2 contains the staff's evaluation of DOE's responses to those questions.

If you have any questions concerning this letter or the enclosures, please contact Michael P. Lee, of my staff, at (301) 415-6677.

Sincerely,

Joseph J. Holonich

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

Enclosures (2): As stated

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

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In its review of Revision 0 of the subject study plan, the staff identified three questions. Enclosure 2 contains the staff's evaluation of DOE's responses to those questions.

If you have any questions concerning this letter or the enclosures, please contact Charlotte Abrams, of my staff, at (301) 415-5808.

Sincerely,

Original signed by:
Joseph J. Holonich, Chief
High-Level Waste and Uranium
Recovery Projects Branch
Division of Waste Management
Office of Nuclear Material Safety
and Safeguards

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U.S. NUCLEAR REGULATORY COMMISSION STAFF REVIEW OF REVISION 1 OF THE STUDY PLAN FOR THE "CHARACTERIZATION OF VOLCANIC FEATURES"
Study Plan 8.3.1.8.5.1

COMMENT 1

The aeromagnetic data described in Section 2.1.1 may not be sufficient to detect and resolve magnetic anomalies associated with small intrusions which are of regulatory concern.

BASIS

Probability models developed to date have dealt almost exclusively with the probability of a volcanic event in the Yucca Mountain Region during the containment period (10,000 years). These models, with the notable exception of Sheridan (1992), do not deal with the likelihood of intrusion to repository depths without accompanying volcanic activity.

This omission is largely because the extrusive-to-intrusive ratio is not known for the area. Crowe et al. (1993) have suggested that this ratio is one-to-one, that is, no intrusions occur in the Yucca Mountain Region (YMR) that reach depths of 300 m or less, without accompanying eruptions. This 1:1 ratio is based partially on the lack of aeromagnetic anomalies and the assumption that if magmas reach a shallow depth, then these magmas are likely to reach the surface (Crowe et al., 1993).

Aeromagnetic data of the type collected in the region (Kane and Bracken, 1983) are not of sufficient detail to resolve anomalies associated with thin (< 5 m in width), shallow dikes in alluvial basins, even at depths of less than 100 m. Characteristic curves can be used to illustrate this point.

Furthermore, total magnetization contrast is small between dikes and the welded tuffs of the repository block and related areas. This small contrast further reduces the possibility of detecting thin shallow dikes.

Work in other areas indicates that extrusive-to-intrusive ratios are normally quite low. At mid-ocean ridges, this ratio is often 0.1 to 0.3 based on investigations of ophiolite sections (e.g., Nicolas, 1989) and 0.1 to 0.25 based on seismic investigations of mid-ocean ridges (e.g., Harding et al., 1989). These values are similar to those proposed for Kilauea (Shaw, 1987) and Krafla (Bjõrnsson, 1985).

In continental settings, the extrusive-to-intrusive ratio might be quite different because of different rock densities, rock mechanical strengths, and the presence of pre-existing structures.

Kurtz et al. (1986) identified very shallow dike intrusions in the Craters of the Moon field that did not result in extrusive activity.

The 1980 activity at Long Valley caldera may provide another example of a dike reaching shallow depths in a continental setting without erupting. This example seems relevant because, although magma did not reach the surface, changes in hydrothermal activity and soil degassing were noted to result from this intrusion (e.g., Mastin and Pollard, 1988; Sorey et al., 1993). These occurrences indicate that shallow degassing from dikes does occur on continents in some geologic settings.

To the staff's knowledge, there is no example of a volcanic field in which the extrusive-to-intrusive ratio is known to be as high as one-to-one.

RECOMMENDATION

Consider conducting more detailed investigations, including ground geophysical surveys, in the area of volcanic centers near Yucca Mountain. In addition, this effort should also involve investigation in appropriate analog areas.

REFERENCES

Björnsson, A. 1985. Dynamics of crustal rifting in NE Iceland. *Journal of Geophysical Research* 90: 10,151-10,162.

Crowe, B.M., F.V. Perry, and G.A. Valentine. 1993. *Preliminary Draft: Status of Volcanic Hazard Studies for the Yucca Mountain Site Characterization Project.* Los Alamos National Laboratory Report: Los Alamos, NM: Los Alamos National Laboratory: 326 pp.

Harding, A.J., J.A. Orcutt, M.E. Kappus, E.E. Vera, J.C. Mutter, P. Buhl, R.S. Detrick, and T.M. Brocher. 1989. Structure of the young oceanic crust at 13 °N on the East Pacific Rise from expanding spreading profiles. *Journal of Geophysical Research* 94: 12,163-12,196.

Kane, M.F., and R.E. Bracken. 1983. Aeromagnetic map of Yucca Mountain and surrounding regions, southwest Nevada. *U.S. Geological Survey Open-File Report* 83-616.

Kurtz, M.A., D.E. Champion, E.C. Spiker, and R.H. Lefebvre. 1986. Contrasting magma types and steady-state, volume-predictable, basaltic volcanism along the Great Rift, Idaho. *Geological Society of America, Bulletin* 97: 579-594.

Mastin, L.G., and D.D. Pollard. 1988. Surface Deformation and Shallow Dike Intrusion Process at Inyo Craters, Long Valley, California. J. Geophysical Research 90: 11,121-11,126.

Nicolas, A. 1989. *Structures of Ophiolites and Dynamics of the Oceanic Lithosphere.* Kluwer Academic Publishers: Dordrecht, 493 pp.

Shaw, H.R. 1987. Uniqueness of volcanic systems. *Volcanism In Hawaii.* R.W. Decker, T.L. Wright, and P. Stauffer, eds., Reston, VA: U.S. Geological Survey. U.S. Geological Survey Professional Paper 1350: 1,357-1,394.

Sheridan, M.F. 1992. A Monte-Carlo technique to estimate the probability of volcanic dikes. *Proceedings of the Third International Conference on High-Level Radioactive Waste Management:* La Grange Park, IL: American Nuclear Society: 2: 2,033-2,038.

Sorey, M.L. B.M. Kennedy, W.C. Evans, C.D. Farrar, and G.A. Suemnicht. 1993. Helium-Isotope and Gas-Discharge Variations Associated with Crustal Unrest in Long Valley Caldera, California. 1989-1992. J.G.R.: In Press.

COMMENT 2

The accuracy of the thermoluminescence (TL) dates for the youngest soils at Lathrop Wells has not been determined in sufficient detail to resolve the volcanological concerns.

BASIS

Multiple analyses of nonbaked soil samples were presented in Crowe et al. (1992). The degree of reproducibility of the dates demonstrates the precision of the technique used to obtain these values. However, it is unclear how the accuracy of these dates will be evaluated and how the measured TL signal was acquired by the sample.

Details of the TL technique are presented in the Study Plan. Crowe et al. (1992) and this study plan state that this technique is preliminary and has not been applied to volcanic soils.

A TL date of 24.5±2.5 ka is reported in Crowe et al. (1992) for baked soil under lava Ql_3. However, other dates for members of chronostratigraphic unit 3 are three to five times older than this date. The authors state that they ". . . currently have no reasonable explanation of the age discrepancy" (Crowe et al., 1993, p. 70). Although the TL technique yields fairly precise dates, the dates do not appear to accurately reflect the age of the unit.

If the accuracy of a TL date on a baked soil is questionable, then the TL date of a nonbaked, nonconsolidated soil is even more questionable. It is difficult to adequately evaluate the technique used for the TL dates, because the analytical information presented in the original data source (Crowe et al., 1992) is limited.

Samples described in Crowe et al., 1992, were heated to only 100°C to remove the least stable time signal. However, it is recognized that electron traps below about 250-300°C are unsuitable for TL dating, and that different temperature traps have different mean lifetimes (e.g., Aitken, 1978; Geyh and Schleicher, 1990). The general application of the TL technique assumes that the mean lifetime of the trap should be ten times longer than the age to be determined. Thus, determination of a roughly 10 ka age requires measuring a deep TL trap, which exists at around 300°C (Geyh and Schleicher, 1990, p. 258). Heating to only 100°C is insufficient to determine a 10–100 ka age, because only shallow (i.e., short lifetime) traps are activated. The TL dates presented could thus reflect the roughly 10 k.y. stability of a low temperature trap and not reflect the age of the unit.

Complete analytical data, including sampling techniques and glow curves, should be presented before TL dates can be taken as ages of the sampled units. Additional justification and explanation of the methodology used on the nonconsolidated soils also must be made before TL dates can be evaluated.

The study plan states that a detailed procedure will be developed when this technique is judged, to a reasonable degree of confidence, to provide reliable estimates of the chronology of volcanic units, and that this procedure would be in place 60 days before the start of QA Level I work.

RECOMMENDATION

This study plan should present the methods that will be used for TL dating. If the referenced procedure is available, submission and subsequent review of this procedure may eliminate some NRC concerns.

REFERENCES

Aitken, M.J. 1978. Archaeological involvements of physics. *Physics Letters* C-40/5: 277-351.

Crowe, B.M., R. Morley, S. Wells, J. Geissman, E. McDonald, L. McFadden, F.V. Perry, M. Murrell, J. Porths, and S. Forman. 1992. The Lathrop Wells volcanic center: status of field and geologic studies. *Proceedings of the Third International Conference of High-Level Radioactive Waste Management.* La Grange Park, IL: American Nuclear Society: 2: 1,997-2,013.

Crowe, B.M., F.V. Perry, and G.A. Valentine. 1993. *Preliminary Draft: Status of Volcanic Hazard Studies for the Yucca Mountain Site Characterization Project.* Los Alamos National Laboratory Report: Los Alamos, NM: Los Alamos National Laboratory: 326 pp.

Geyh, M.A., and H. Schleicher. 1990. *Absolute Age Determination.* New York, NY: Springer-Verlag.

COMMENT 3

The basis for the assumption that the young tephra exposed in the quarry south of the main Lathrop Wells cone is contemporaneous with the 20 ka Black Tank cone in the Cima field does not appear to be well supported.

BASIS

The youngest eruption at Lathrop Wells is the tephra exposed in the quarry south of the main cone (Crowe et al., 1993, p. 55). It is not clear whether this tephra mantled the main Lathrop Wells cone and exerted any geomorphic control on the main cone, in contrast to the apparently young mantling eruption at Hidden Cone (Crowe et al., 1993).

Based on geomorphic evidence (Crowe et al., 1993; Wells et al., 1992), this unit is thought to be contemporaneous with the approximately 20 ka Black Tank cone in the Cima volcanic field.

Results of soil studies at the Black Tank cone do not demonstrate that chronostratigraphic unit 1 is appreciably younger (i.e., <20 ka) than the main cone at Lathrop Wells, in spite of the more youthful appearance of Lathrop Wells (Wells, et al, 1992). Crowe et al. (1993) conclude "... it is difficult and unwarranted to speculate on the extent of the time differences between the units," when referring to the different degrees of soil development between unit 3 and units 2 and 1. It is not intuitive why pedogenic features would be too indistinct to estimate the age between unit 3 and overlying units, yet would be distinct enough to distinguish <20 ka differences.

Although the pedogenic features associated with unit 1 are similar to those at Black Tank cone, it has not been demonstrated that pedogenic character can resolve ages of 20–50 k.y. difference.

RECOMMENDATION

Describe the methodology to determine the age and origin of Lathrop Wells chronostratigraphic unit 1.

REFERENCES

Crowe, B.M., F.V. Perry, and G.A. Valentine. 1993. *Preliminary Draft: Status of Volcanic Hazard Studies for the Yucca Mountain Site Characterization Project.* Los Alamos National Laboratory Report: Los Alamos, NM: Los Alamos National Laboratory: 326 pp.

Wells, S.G., L.D. McFadden, C.E. Renault, B.D. Turrin, and B.M. Crowe. 1990. Geomorphic assessment of late Quaternary volcanism in the Yucca Mountain area, southern Nevada: implications for the proposed high-level nuclear waste repository. *Geology* 18: 549-553.

COMMENT 4

It is unclear how the volume of eruptive basalts is being calculated.

BASIS

It appears that, in the past, varying methods have been used to calculate volume data and dense rock equivalent (DRE). Assuming the cone represents a simple frustum with a basal diameter of 690 m, a crater diameter of 160 m, and a height of 140 m (Crowe et al., 1983; Crowe and Perry, 1991), Lathrop Wells has a volume of 2.2×10^7 m^3. The volume reported by Crowe et al. (1983) is 1.7×10^7 m^3, which apparently corresponds to the volume of a simple cone and would underestimate the volume of the Lathrop Wells cone.

However, Crowe et al. (1993; Table 7.2) list the volume of Lathrop Wells as 1.4×10^8 m^3, but do not report separate cone and flow volumes. This volume is significantly different than the previously reported volume.

There is no description of the methods by which magmatic volumes were calculated. Vaniman and Crowe (1981) assume that magma density is 2.7 g/cm^3, but do not state the assumed lava flow densities. Fall-deposit densities also are not reported. Cone porosities are given as 25 percent, but clast densities are presumably taken from McGetchin et al. (1974), who give a range of 1.2 to 2.8 g/cm^3 and a median of 1.5 g/cm^3. Distal scoria-fall deposits are assumed to have five times the volume of the cone, but no justification is presented for this relationship.

Some of the staff concerns may be resolved if "Methods for Magma Volume Determinations for Calculating the Probability of Magmatic Disruption of the Repository and Controlled Area," a procedure listed in study plan 8.3.1.8.1.1, and previously requested (NRC, 1992), was available.

RECOMMENDATION

Provide a more complete description of parameters used to calculate eruption volumes and the assumptions used to convert volumes to dense rock equivalents. Describe the method used for compensating for the dispersed ash associated with eruptions.

REFERENCES

Crowe, B.M., and F.V. Perry. 1991. *Preliminary Geologic Map of the Sleeping Butte Volcanic Centers*. Los Alamos, NM: Los Alamos National Laboratory. Los Alamos National Laboratory Report LA-12101-MS.

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

McGetchin, T.R., M. Settle, and B.A. Chouet. 1974. Cinder cone growth modeled after Northeast Crater, Mount Etna, Sicily. *Journal of Geophysical Research* 79: 3,257-3,272.

NR˜, Letter from Joseph J. Holonich (NRC) to John P. Roberts (DOE) subject: "U.S. Nuclear Regulatory Commission Staff Review of Study Plan for Probability of Magmatic Disruption of the Repository," July 10, 1992.

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

COMMENT 5

It is unclear how the model that assumes northwest trending structures provide deep-seated control on magma pathways will be tested.

BASIS

Crowe et al., 1993, state that basalts of the Younger Post-caldera Basalt (YPB) are part of the Crater Flat Volcanic Zone (CFVZ), that NW-trending structures provided deep-seated structural control on magma pathways, and that NE-trending structures provided shallow control on location of basaltic vents in response to the maximum principal compressive stress direction of the shallow stress field. These assumptions are based on the model of Crowe and Perry (1989).

Smith et al. (1990) have proposed a model incorporating the area of most recent volcanism (AMRV), which has NE-trending structures as the regional and local control for volcanism. It is not clear in the study plan how this alternative model will be evaluated through site characterization activities.

The northeast alignment of cones in Crater Flat is interpreted to result from "secondary" structural control by the shallow stress field (Crowe et al., 1993). What structural interpretation would explain the control of vents by northwest structures — a situation noted at Lathrop Wells and other locations? This observation may indicate there are more complex structural controls on location of vents near Yucca Mountain that are not completely understood at present and that require further investigation.

It appears that current repository disruption scenarios will not eliminate the concept of NE-trending structural control on location of igneous features. This means both dike intrusion through a repository and formation of a vent at the location of the repository cannot be discounted, even if probabilities are low.

RECOMMENDATION

Provide a methodology which will allow the various alternative tectonic models to be tested and evaluated.

REFERENCES

Crowe, B.M., and F.V. Perry. 1989. Volcanic probability calculations for the Yucca Mountain site: Estimation of volcanic rates. *Proceedings for Focus '89, Nuclear Waste Isolation in the Unsaturated Zone*. La Grange Park, IL: American Nuclear Society: 326-334.

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Smith, E.I., D.L. Feuerbach, T.R. Naumann, and J.E. Faulds. 1990. The area of most recent volcanism near Yucca Mountain, Nevada: Implications for volcanic risk assessment. *Proceedings for International Topical Meeting, High-level Radioactive Waste Management*. La Grange Park, IL. American Nuclear Society: 1: 81-90

COMMENT 6

There is no discussion in the study plan of the xenolith content of the Lathrop Wells cinder cone or other cinder cones in the region, or how xenolith abundances will be studied to better characterize volcanism and constrain consequence models.

BASIS

Xenolith abundances directly reflect the ability of the fragmented magma to transport brecciated wall rock to the surface. Consequence models of potential volcanic eruptions through the Yucca Mountain repository horizon will need to constrain the ability of a basaltic dike to fragment and transport to the surface both wall rock and waste canisters. The abundances, origins, and size distributions of shallow (i.e., <1 km) crustal xenoliths are therefore critical to developing realistic consequence models.

Xenolith data for Lathrop Wells have been reported by Crowe et al. (1983) and Crowe et al. (1986). However, these data are inadequate to accurately characterize the process leading to xenolith formation and transport during this eruption. The only reference to the size of the xenoliths at Lathrop Wells is that they have a median diameter of 4 mm (Crowe et al., 1983).

Field examination of the Lathrop Wells cinder cone by NRC staff suggests that tuffaceous xenoliths much greater than 4 mm are extremely common, and tuffaceous xenoliths in the centimeter to decimeter range occur in unusual abundance relative to other Basin and Range cinder cones. This relationship at other Basin and Range volcanos is part of a program of ongoing NRC research.

The only granulometric data that identify clast composition in the Lathrop Wells cone is in Crowe et al. (1986). However, these data are only for clasts <0.7 mm, and xenolith composition is generally described as undifferentiated with only occasional identification of tuff or limestone clasts (Crowe et al., 1986, Appendix F).

It is not clear how submillimeter, sparsely phyric tuff or undifferentiated xenoliths were uniquely assigned to the Tiva Canyon Member of the Paintbrush Tuff by Crowe et al. (1983). In addition, the occurrence of limestone xenoliths in the Lathrop Wells scoria (Crowe et al., 1983) clearly indicates that pre-tuff limestone units were entrained during the eruption.

RECOMMENDATION

Describe what studies of the abundance, size distribution, morphology, and composition of xenoliths in the Lathrop Wells ejecta will be performed in order to construct models of fragmentation and transport of subsurface material.

REFERENCES

Crowe, B.M., S. Self, D. Vaniman, R. Amos, and F.V. Perry. 1983. Aspects of potential magmatic disruption of a high-level nuclear waste repository in southern Nevada. *Journal of Geology* 91: 259-276.

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

U.S. Department of Energy. 1988. *Site Characterization Plan*. DOE/RW-0160. Washington, DC: U.S. Department of Energy: I, Chapter 1.

COMMENT 7

It is unclear how the research discussed in this study plan will resolve alternative petrogenic models.

BASIS

Current models considered by DOE of temporal and spatial variations in parental basalt composition in the Yucca Mountain Region (YMR) focus on changes in depth of the source, and do not consider widely recognized compositional changes in the mantle (Crowe et al., 1993). These models have been used to conclude that the Crater Flat system is waning. However, regional geochemical trends suggest that the Western Great Basin (WGB) system, which includes the YMR, may continue to be active for several million years, whereas contemporaneous non-WGB systems, such as those of the Basin and Range (BR), may be waning in activity.

Isotopic and trace element studies (e.g., Perry et al., 1987; Farmer et al., 1989; Fitton et al., 1991; Kempton et al., 1991) have shown that asthenospherically derived melts in the BR have had variable amounts of interaction with metasomatized lithospheric mantle. The observed transition to more undersaturated compositions in the BR at about 5 Ma occurs with large geochemical and isotopic changes that clearly show different parental mantle compositions (i.e., less lithospheric character for <5 Ma basalts).

Similar transitions from lithospheric to non-lithospheric character are less clearly developed for volcanic systems around the Colorado Plateau, such as the Springerville volcanic field (Fitton et al., 1991). Although Condit et al. (1989) hypothesize that smaller amounts of partial melting occurred during the late, alkalic stage of Springerville magmatism, they clearly state that this transition is accompanied by a shift from a lithospheric to an asthenospheric source for the magmas. Isotopic studies by Cooper and Hart (1990) also show a complex transition between lithospheric and asthenospheric mantle signatures in the Springerville system. Thus, even when a transition to more undersaturated compositions is observed, the mantle source changes from metasomatized lithosphere to oceanic island basalt-type asthenosphere.

In contrast to the BR system, these temporal shifts to more undersaturated compositions at about 5 Ma are not observed in the WGB. Volcanic fields such as Crater Flat, Coso, Big Pine, Death Valley, and Mono Lake show a lithospheric source for both pre- and post-5 Ma rocks (Fitton et al., 1991; Farmer et al., 1989).

The study plan and Crowe et al. (1993) combine the WGB with the main BR system, and make interpretations regarding compositional shifts with time. This temporal relationship is important because the contention that alkaline magmatism in the WGB field indicates a waning system is not consistent with observed temporal trends throughout the central BR and Colorado Plateau margin systems.

The WGB systems have not evolved from a lithospheric to an asthenospheric phase of activity. Cima and the Lunar Crater volcanic fields are non-WGB magma systems that show a transition from lithospheric Pliocene alkaline basalt to compositionally distinct asthenospheric Quaternary alkaline basalt (Crowe et al., 1986; Wilshire et al., 1991; Foland and Bergman, 1992; Crowe et al., 1993). Thus, even when there has been a change to asthenospheric from lithospheric derived magma, this relationship shows that magmatic activity can continue for millions of years. The Crater Flat system has not reached an asthenospheric stage of magmatism (Vaniman et al., 1982; Farmer et al., 1989) and, therefore, cannot be considered a waning magma system on the basis of regional petrogenetic trends.

The regional petrogenetic trends could also be explained by modification of WGB and other allied BR systems by crustal contamination. Glazner et al. (1991) presented data for the Amboy-Pisgah volcanic centers that support contamination by mafic crust as a means for producing some of the geochemical variability in the magma system. The hypothesis that crustal contamination could control some of the geochemical variation observed in the Crater Flat system has not been examined in detail, and the geochemical variation does not require a waning volcanic system.

Changes in source composition need to be incorporated into regional petrogenetic models. Regional interpretations of waning magmatism need to be supported by comparison to analogous systems in the WGB. Alternative hypotheses besides waning magmatism may be viable for WGB systems.

RECOMMENDATION

The study plan should describe the methodology which will be used to differentiate between the various alternative petrogenetic models.

REFERENCES

Condit, C.D., L.S. Crumpler, J.C. Aubele, and W.E. Elston. 1989. Patterns of volcanism along the southern margin of the Colorado Plateau: the Springerville field. *Journal of Geophysical Research* 94: 7975-7986.

Cooper, J.L., and W.K. Hart, 1990. Mantle sources in the Arizona transition zone and global mantle heterogeneity. *Geology* 18: 1146-1149

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

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Fitton, J.D., D. James, and W.P. Leeman. 1991. Basic magmatism associated with late Cenozoic extension in the western United States: compositional variations in space and time. *Journal of Geophysical Research* 96: 13,693-13,711.

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Glazner, A.F., G.L. Farmer, W.T. Hughes, J.L. Wooden, and W. Pickthorn. 1991. Contamination of basaltic magma by mafic crust at Amboy and Pisgah Craters, Mojave Desert, California. *Journal of Geophysical Research* 96: 13,673-13,691.

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Perry, F.V., W.S. Baldridge, and D.J. DePaolo. 1987. Role of asthenosphere and lithosphere in the genesis of late Cenozoic basaltic rocks from the Rio Grande rift and adjacent regions of the southwestern United States. *Journal of Geophysical Research* 92: 9,193-9,219.

Vaniman, D.T., B.M. Crowe, and E.S. Gladney. 1982. Petrology and geochemistry of Hawaiite lavas from Crater Flat, Nevada. *Contributions in Mineralogy and Petrology* 80: 341-357.

Wilshire, H.G., A.V. McGuire, J.S. Noller, and B.D. Turrin. 1991. Petrology of lower crustal and upper mantle xenoliths from the Cima volcanic field, California. *Journal of Petrology* 32: 169-200.

QUESTION 1

What methods for the determination of all important rock magnetic properties have been considered?

BASIS

Section 2.1.1 states that a fluxgate magnetometer will be used to determine magnetic polarities.

A fluxgate magnetometer alone cannot distinguish virtual remnant magnetization (VRM) from other, more relevant magnetic components. This determination can only be done after alternating frequency demagnetization. This cleaning is sometimes needed because a VRM overprint can give spurious results.

Determination of susceptibility and thermo-remnant magnetization is important to models based on interpretation of aeromagnetic and ground magnetic data, and these properties are best determined using standard rock magnetic techniques.

The study plan does not appear to list a specific procedure for conducting these type of analyses.

RECOMMENDATION

Consider analyzing the samples in a rock magnetics laboratory so that the VRM component can be removed prior to estimation of polarity.

QUESTION 2

How were the paleomagnetic directions sampled for the Crater Flat System?

BASIS

The Crater Flat volcanoes are described as paleomagnetically reversed, but the methods used to determine direction, and the resultant data, are not described. These data are critical in determining if these units formed in the Matuyama reversed magnetic polarity epoch rather than the 0.92 to 1.01 Ma Jaramillo normal-polarity event (Spell and McDougall, 1992).

The study plan does not list a specific procedure for conducting this type of analysis.

RECOMMENDATION

The procedure used to determine paleomagnetic polarities (e.g., field flux-gate magnetometer) should be presented and discussed, along with the sampling procedure used (e.g., the number of samples per flow, the location in the flow of the sample, the number of sites per unit).

REFERENCE

Spell, T.L., and I. McDougal, 1992. Revisions to the Age of the Brunhes-Matuyama boundary and the Pleistocene geomagnetic polarity timescale, *Journal of Geophysical Research 19:* 1,181-1,184

QUESTION 3

How are the intrusion geometries associated with the development of the Crater Flat alignment to be characterized?

BASIS

Section 5 of Crowe et al. (1993) states that it may be important to characterize intrusion geometries associated with the development of the Little Cones-Northern Cone alignment. No mention is made in the Study Plan of methods of how this is to be accomplished.

In section 5 of Crowe et al. (1993), it is indicated that the Crater Flat cinder cone alignment might be related to a single set of dikes. For example, bladed dikes might extend outward from the Red Cone - Black Cone pair in NE and SW directions, feeding other, smaller cinder cones (Crowe et al., 1993). Although this idea may not be consistent with geochronological and geochemical data, it has important implications for probability models.

Geophysical methods, such as ground magnetic or electrical surveys might be suitable to test the hypothesis that bladed dikes occur along the entire length of the cinder cone alignment. Electrical methods that might be suitable include the mise-a-la-masse method (e.g., Beasley and Ward, 1986), which is used extensively in the mining industry to track the lateral extent of ore veins.

Aeromagnetic surveys may not be successful at delineating the proposed dikes, due to topographic effects associated with magnetized basaltic cones and the small amplitude of the magnetic anomaly that would be associated with the proposed dikes.

RECOMMENDATION

Describe the field investigation program, including geophysics, which will be conducted to better describe the intrusion geometries in the area of Crater Flat. If anomalies can be identified from these geophysical investigations, directional drilling should be considered as a method of sampling the anomalies.

REFERENCES

Beasley, C.W., and S.H. Ward. 1986. Three-dimensional mise-a-la-masse modeling applied to mapping fracture zones. *Geophysics* 51: 98-113.

Crowe, B.M., F.V. Perry, and G.A. Valentine. 1993. *Preliminary Draft: Status of Volcanic Hazard Studies for the Yucca Mountain Site Characterization Project.* Los Alamos National Laboratory Report: Los Alamos, NM: Los Alamos National Laboratory: 326 pp.

QUESTION 4

How will seismic tomographic data be integrated into volcanological site characterization as the project continues?

BASIS

Seismic tomographic surveys are a geophysical method that could provide extensive information on volcanism issues related to the persistence of potential magmatic features, the region, and the likelihood of future magmatic activity. Numerous studies have demonstrated the utility of detailed active and passive seismic tomographic surveys in volcanic areas (e.g., Sanders et al., 1989; Achauer et al., 1986; Iyer, 1984; Nercessian et al., 1984), and lower resolution surveys have indicated the presence of low-velocity zones in the Yucca Mountain Region (Evans and Smith, 1992).

RECOMMENDATION

Specifically address how seismic tomographic data will be incorporated into site characterization of volcanic features.

REFERENCES

Achauer, U., L. Greene, J.R. Evans, and H.M. Iyer. 1986. Nature of the magma chamber underlying the Mono Craters area, eastern California, as determined from teleseismic traveltime residuals. *Journal of Geophysical Research* 91: 13,873-13,891.

Evans, J.R., and M. Smith III. 1992. Teleseismic tomography of the Yucca Mountain Region: volcanism and tectonism. *Proceedings of the Third International Conference of High-Level Radioactive Waste Management.* La Grange Park, IL: American Nuclear Society: 2: 2,371-2,380.

Iyer, H.M. 1984. Geophysical evidence for the location, shapes and sizes, and internal structures of magma chambers beneath regions of Quaternary volcanism. *Philosophical Transactions of the Royal Society, London* A 310: 473-510.

Nercessian, Al., Al. Hirn, and Al. Tarantola. 1984. Three-dimensional seismic transmission prospecting of the Monte Dore volcano, France. *Geophysical Journal of the Royal Astronomical Society* 76: 307-315.

Sanders, C.O., P. Ho-Liu, and D. Rinn. 1989. Anomalous shear wave attenuation in the shallow crust beneath the Coso volcanic region, California. *Journal of Geophysical Research* 93: 3,321-3,338.

QUESTION 5

If the theory of polycyclic volcanism is correct for the volcanoes in the region of Yucca Mountain, how will it be assured that age determinations accurately represent the age of the various cones?

BASIS

It is unclear from the study plan what geochronological work has been done, or remains to be completed for the volcanic centers in the Yucca Mountain Region (YMR). The staff knows of only 2 published dates for both Northern Cone and Black Cone, and only one date for Little Cone. In addition, although there are a total of 23 dates reported for Red Cone, the range of dates is from 0.95±0.08 to 1.9±0.2 Ma, suggesting a poorly constrained data set.

The study plan estimates that 5 to 15 age determinations will be needed at each volcanic center. Normally 5 to 15 samples would be considered more than enough to estimate the age of volcanic activity at cinder cones. However, there are two unique problems to age determination in the YMR:

(i) these volcanoes may have a complex eruptive history; and

(ii) different groups have collected multiple suites of rocks for age determinations already, which has led to varying reports of accuracy and precision.

Given the current controversy, a more systematic and detailed sampling program may be needed for individual cinder cones.

It may be necessary to adopt a sampling method similar to that used to determine outcroo polarity in detailed paleomagnetic investigations, that is, establish sampling sites at individual outcrops within the same cooling unit and make multiple determinations. This process would then be repeated at other stratigraphic levels and outcrops. This approach may be necessary to distinguish age variations due to analytical imprecision from age variation due to polycyclic activity.

Hodges (1992) suggested collecting even more samples at a given volcano in order to employ Monte Carlo statistics to determine precision.

RECOMMENDATION

Present a sampling scheme that will be used to resolve the concerns with age determinations of potential polycyclic features.

REFERENCE

Hodges, K. 1992. Comments on volcanic issues at Yucca Mountain. *Meeting Notes* United States Nuclear Waste Technical Review Board, Panel on Structural Geology and Geoengineering, Meeting on Volcanism. September 14-16, Las Vegas, NV.

QUESTION 6

How will geodetic data be incorporated into volcanological site characterization?

BASIS

Crowe et al. (1993, p. 104) states that strain rates have decreased since Miocene. This inference is based on an apparent decrease in average slip rates on the Yucca Mountain faults. Regional strains may still be significant, but slip may be localized on faults such as Death Valley-Furnace Creek and Bare Mountain, etc.

If Crater Flat is interpreted as a pull-apart feature, intrusion or eruption processes may be directly influenced by the strain rate. The Crater Flat pull-apart could still be experiencing extension that could localize magmatism.

The Little Skull Mountain earthquake is an indication that the area is still tectonically active, and may still be extending.

RECOMMENDATION

Describe how measurements of contemporary strain will be factored into development of volcanological models.

REFERENCE

Crowe, B.M., F.V. Perry, and G.A. Valentine. 1993. *Preliminary Draft: Status of Volcanic Hazard Studies for the Yucca Mountain Site Characterization Project.* Los Alamos National Laboratory Report: Los Alamos, NM: Los Alamos National Laboratory: 326 pp.

QUESTION 7

How will data on degassing and hydrothermal alteration be gathered for incorporation into probability and consequence models?

BASIS

Volatile concentration in magmas and interaction with shallow groundwater are important parameters that govern eruption mechanics.

Direct effects of volcano degassing include the movement of gas through the repository block itself. This activity may result in accelerated rates of container corrosion and deterioration of the waste package, and change the geochemistry of the repository and surrounding rock.

Direct effects of volcano degassing would likely accompany direct magmatic disruption of the repository, but also could occur if magma intruded rocks near the repository, without actually intersecting the repository. Therefore, the probability of this type of activity occurring is higher than the probability of direct magmatic disruption.

Volcanic degassing is capable of influencing an area much greater than is disrupted by eruptive activity. This area of influence is important because most probability models for volcanic activity are area dependent.

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

Changes in movement of groundwater and gas phases in the geologic environment, and changes in the mechanical properties of the rock, also may result from degassing and thermal loading of rock by conductive and convective heat transfer.

Volcanic degassing is a long-term process. Preliminary data from Parícutin, Tolbachik, and Cerro Negro indicate that cinder cones generally cool and degas over long periods of time. Vigorous, high-temperature degassing persists at some cinder cones for decades. Low-temperature and less vigorous degassing may continue for more than 100 years.

Because of these possible effects, it is important to attempt to constrain the areas affected by diffuse degassing in the Yucca Mountain Region through mapping of alteration zones within cinder cone edifices and around cinder cones.

RECOMMENDATION

Provide information on the methodology for mapping and evaluating the zones of alteration around Lathrop Wells and other cinder cones in the Yucca Mountain Region to better understand and constrain the effects of degassing.

QUESTION 8

How will the volumetric relationships from the different volcanic systems in western North America be used to develop specific time-dependent, volume-predictable models for the Crater Flat system?

BASIS

Many of the volcanic fields listed in Section 2.5.1 as possible analogs do not appear to be representative analogs for the volcanic fields of the Yucca Mountain Region (YMR).

Crowe and Perry (1989) use a decrease in magma volume with time at the Springerville Volcanic Field to support the hypothesis that the Crater Flat Volcanic Zone (CFVZ) is a waning system. However, large petrogenetic changes and two orders-of-magnitude more basalt are present in the Springerville system which indicates this system may not be truly analogous to the CFVZ.

The gradual change to smaller eruptive volumes in Springerville at about 1 Ma is accompanied by a change in magma composition from tholeiitic to alkalic (Condit et al., 1989; Cooper and Hart, 1990). This trend is thought to represent a shift from lithospheric to more asthenospheric mantle sources. Similar compositional trends are not observed in the CFVZ within the last 4 Ma (Crowe et al., 1993).

The Springerville field erupted around 300 km^3 of mafic rock, but less than 1 km^3 has been erupted in the CFVZ since about 3.7 Ma (Crowe and Perry, 1989). The dynamics of magma generation, ascent, and eruption may be extraordinarily different for volcanic fields with such different magma fluxes.

Magma systems along the Colorado Plateau transition area certainly have higher eruption rates than Western Great Basin (WGB) systems, and it is not clear how analogous these two areas are. They have very different tectonic environments and histories, along with distinct petrogenetic trends (e.g., Fitton et al., 1991).

Crater Flat is a small volume system, yet there are numerous other late Cenozoic, small-volume Basin and Range-WGB systems such as the Death Valley, Mono Lake, Seven Troughs, Winnemucca, Battle Mountain, Table Mountain, Monarch Divide, Candellaria, Kern, Greenwater, Fallon, Tahoe, and Saline Range (Smith and Luedke, 1984) that may be more analogous to the YMR than fields such as Springerville.

Although volumetric data are not readily available for most of these areas, this lack of data does not mean that these areas should be excluded from consideration. Although the Crater Flat system is small relative to Colorado Plateau transition systems, it may not be anomalously small relative to other WGB systems.

RECOMMENDATION

Provide more information regarding the basis for selection of volcanic fields thought to be analogous to those near the Yucca Mountain site.

REFERENCES

Condit, C.D., L.S. Crumpler, J.C. Aubele, and W.E. Elston. 1989. Patterns of Volcanism Along the southers Margin of the Colorado Plateau: The Springerville Field. *Journal of Geophysical Research*. 94: 7,975-7,986.

Cooper, J.L., and W.K. Hart, 1990. Mantle sources in the Arizona transition zone and global mantle heterogeneity. *Geology* 18: 1,146-1,149.

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Smith, R.L., and Luedke, R.G. 1984. Potentially active volcanic lineaments and loci in the western conterminous United States. *Reviews in Geophysics*. Washington, DC. National Academy Press: 47-66.

QUESTION 9

How will phenocryst mineralogy be characterized in sparsely phyric rocks?

BASIS

The examination of thin-sections alone is inadequate to characterize the presence or absence of low-abundance minerals in volcanic scoria (e.g., Chayes, 1956). Additional mineralogical analyses are not listed in the study plan, with the exception of thin-section petrography. Unless detailed heavy-mineral separations are performed on these units, the presence of amphibole in some or all of the Quaternary basalts cannot be discounted. This determination will be important in constraining consequence models, as water content may be constrained using phenocryst assemblages and because phenocryst size and abundance will influence magma viscosity.

Phenocrysts of amphibole occur in the Little Cone scoria (Vaniman and Crowe, 1981) and the Sleeping Butte cones (Crowe et al., 1983), and some Red Cone units may contain groundmass amphibole and biotite (Vaniman and Crowe, 1981; Ho et al., 1991). The only detailed petrographic data reported for 4 Ma and younger basalts is by Vaniman and Crowe (1981). The available data does not appear sufficient to evaluate the mineralogy and phase relationships of these units. Petrographic data are presented without any description of the methods used to determine mineral abundances, nor are uncertainties in mineral abundances described.

Detailed petrographic data have not been presented for Buckboard Mesa flows.

Lathrop Wells petrographic data are reported as vesicle-free abundances, yet vesicle abundances are not listed (Vaniman and Crowe, 1981). Data presented in Zreda et al. (1993) and Crowe et al., (1993) indicate that plagioclase is a phenocryst in Lathrop Wells unit Ql_6 and perhaps unit Ql_4, but plagioclase is not reported in Vaniman and Crowe (1981). The presence of plagioclase phenocrysts is critical to the arguments for increasing source depth with time in the Crater Flat magma system.

RECOMMENDATION

Describe how the phenocryst assemblage will be characterized.

REFERENCES

Chayes, F. 1956. *Petrographic modal analysis.* New York, NY: John Wiley & Sons.

Crowe, B.M., F.V. Perry, and G.A. Valentine. 1993. *Preliminary Draft: Status of Volcanic Hazard Studies for the Yucca Mountain Site Characterization Project.* Los Alamos National Laboratory Report: Los Alamos, NM: Los Alamos National Laboratory: 326 pp.

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Ho, C. H., E.I. Smith, D.L. Feuerbach, and T.R. Naumann. 1991. Eruptive probability calculation for the Yucca Mountain site, USA: Statistical estimation of recurrence rates. *Bulletin of Volcanology* 54: 50–56.

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

Zreda, M.G., F.M. Phillips, P.W. Kubik, P. Sharma, and D. Elmore. 1993. Cosmogenic ^{36}Cl dating of a young basaltic eruption complex, Lathrop Wells, Nevada. *Geology* 21: 57-60.

U.S. NUCLEAR REGULATORY COMMISSION STAFF EVALUATION OF THE U.S. DEPARTMENT OF ENERGY RESPONSES TO QUESTIONS ON REVISION 0 OF THE STUDY PLAN FOR THE "CHARACTERIZATION OF VOLCANIC FEATURES"
Study Plan 8.3.1.8.5.1

Activity 8.3.1.8.5.1.1: Volcanic Drill Holes

Question 1

Why does the plan exclude collecting oriented core from drill holes?

Evaluation of DOE Response

If basaltic volcanic rocks are encountered in the drill holes and the basalts are either old (greater or equal 2 Ma) and/or of small volume, these data are not expected to affect the probability calculations. Drilling of a single hole in which magnetic polarity is measured would be adequate. Determination of magnetic polarity does not require oriented core.

If the basalts are young (less or equal to 2 Ma) and/or of large volume such that the probability calculations might be affected, additional drill holes will be required. One option, if additional drilling is required, would be to obtain oriented core for determining field magnetic direction.

The NRC staff considers this question to be resolved.

Activity 8.3.1.8.5.1.2: Geochronology Studies

Question 2

What constituted the suite of geochronology methods from which uranium-series disequilibrium, helium ratio, and thermoluminescence were chosen, and how was the selection made?

Evaluation of DOE Response

In addition to the geochronology methods listed in the question, the suite of geochronology methods include Cl-36, Be-10, and Al-26.

The selection criteria were based on several lines of reasoning:

- Los Alamos plans to apply chronology methods using different isotopic systems.
- The C-14 method was not chosen because carbon is rarely preserved in the arid environment.
- The U-Th method was chosen because it is different for K-Ar and is the most commonly used dating technique. With petrologic Constraints, U-series disequilibrium can yield crystallization ages.
- Los Alamos chose methods that are reasonably well established so that major laboratory development is not required. Helium ration and thermoluminescence met this criterion best. Also, the U-Th method using solid source mass spectrometry is feasible with several months effort.
- Chronology methods were chosen which DOE considers have acceptable precision in the age range of interest (1 ka to greater than 500 ka).
- The chronologic method should be tied to volcanic events. The U-Th method can yield a crystallization age, although the helium-ration method can yield a surface exposure age. The TL method can be directly correlated with volcanic events by measuring the TL age of soils overlain and baked by lava flows.
- With these criteria, Los Alamos consulted established chronology experts in the country, attended special sessions on Quaternary dating methods, and utilized the expertise of the isotope and Nuclear Chemistry Division of Los Alamos in arrive at the selection of the three supplemental dating methods.

The NRC staff considers that the question is resolved.

Activity 8.3.1.8.5.1.5: Evolutionary Cycles of Basaltic Volcanic Fields

Question 3

Have additional "analog" studies, aside from those presented in this activity, been considered by the DOE?

Evaluation of DOE Response

The DOE states that the primary concern expressed in the background material supplied with this question is that the Crater Flat volcanic field may still be considered active. The NRC staff does not know to what the term "background material" refers.

The NRC staff considers that the statement "emphasis will be placed on choosing volcanic fields that exhibit evidence of being extinct" makes an assumption about the area of Yucca Mountain which has not been justified.

The NRC staff considers that the assumption on "waning patterns" is presently unjustified.

The NRC staff is uncertain about what analog studies are being considered or the criteria used to select those studies.

The NRC staff considers this question to remain open.

subject study plan, DOE noted that the subject study plan had been revised in direct response to NRC staff comments on Study Plan 8.3.1.8.1.1. As a result of reviewing both study plans and the draft status report together, the staff became aware of new areas of concern not identified in its earlier review (letter from Holonich to Shelor, dated March 18, 1991).

In its review of Revision 0 of the subject study plan, the staff identified three questions. Enclosure 2 contains the staff's evaluation of DOE's responses to those questions.

If you have any questions concerning this letter or the enclosures, please contact Michael P. Lee, of my staff, at (301) 415-6677.

Sincerely,

Original signed by:
Joseph J. Holonich, Chief
High-Level Waste and Uranium
Recovery Projects Branch
Division of Waste Management
Office of Nuclear Material Safety
and Safeguards

Enclosure (2): As stated

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