December 19, 2002

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Office of Licensing and Regulatory Compliance
U.S. Department of Energy
Office of Repository Development
P.O. Box 364629
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SUBJECT: REQUEST FOR ADDITIONAL INFORMATION - IGNEOUS ACTIVITY AGREEMENT 1.02

Dear Mr. Ziegler:

In your letter dated September 26, 2002, the U.S. Department of Energy (DOE) enclosed a report, "Interpretation of Aeromagnetic Data." This report was provided to satisfy Igneous Activity Agreement Item 1.02 in advance of documentation of the Analysis and Model Report *Characterize Framework for Igneous Activity at Yucca Mountain, Nevada.* In summary, the DOE Letter Report does not provide an adequate technical basis to evaluate the likely effects on DOE probability models from credible interpretations of new aeromagnetic and ground magnetic data. The interpretation of at least eleven additional buried basaltic volcanoes could significantly affect an independent expert's conceptual model for basaltic volcanism in the Yucca Mountain region. Different assumptions regarding the age and location of the interpreted volcanoes would likely affect expert judgment on the use of alternative conceptual models to explain possible spatial or temporal clustering. These potentially significant changes in DOE's conceptual probability models (CRWMS M&O, 1996) are not addressed in the DOE letter report. Even assuming that the conceptual basis for DOE probability models remains unchanged, some important parameter distributions in DOE models would necessarily change in response to the new aeromagnetic interpretations. The DOE Letter Report does not evaluate potential changes in parameter distributions except for small increases in recurrence rate uncertainty. In addition, the available data provide only limited confidence that all relevant subsurface basaltic features have been adequately characterized and considered in any probability model. DOE's own data, i.e. O'Leary et al. (2002), provides evidence that additional basaltic volcanoes remain present but undetected within approximately 20 km [12.4 mi] of the proposed repository site. The DOE Letter Report does not evaluate the potential effects on DOE probability models from additional basaltic volcanoes that may yet remain present but undetected in the Yucca Mountain region.

DOE will need to provide a technical basis to constrain the number and age of volcanic events which have occurred in the Yucca Mountain region, including events which may be present and undetected, and provide an analysis which considers the full range of this uncertainty, not just the limited range considered in the Letter Report. DOE also will need to provide an evaluation of how these magnetic data could change the conceptual basis used during the original elicitation to develop probability models and associated parameter distributions, including consideration of such things as event definitions, and dike and event lengths. As is stated in

NUREG-1563, acquisition and analysis of physical data should be the primary manner in which licensing information is collected, however, other considerations may preclude such collection. If expert elicitation is used and it needs to be updated, NUREG-1563 offers several choices as to how the updating could be accomplished. In all cases, however, it should be thoroughly documented to provide a transparent view of the updating process and resulting judgments. In future work, DOE also should recognize the staff does not consider that substituting the judgment of project staff for the expert judgment of the panel as an appropriate update to an existing expert elicitation.

At this time, the staff considers that Igneous Activity Agreement Item "Needs further data." The attachment to this letter provides more details on the staff's concerns. If there are any questions regarding this letter, please contact John S. Trapp at 301-415-8063 or by e-mail at jst@nrc.gov.

Sincerely,

/RA/

Janet R. Schlueter, Chief
High-Level Waste Branch
Division of Waste Management
Office of Nuclear Material Safety
and Safeguards

Attachment: NRC review of DOE letter pertaining to Igneous Activity Key Technical Agreement 1.02

NUREG-1563, acquisition and analysis of physical data should be the primary manner in which licensing information is collected, however, other considerations may preclude such collection. If expert elicitation is used and it needs to be updated, NUREG-1563 offers several choices as to how the updating could be accomplished. In all cases, however, it should be thoroughly documented to provide a transparent view of the updating process and resulting judgments. In future work, DOE also should recognize the staff does not consider that substituting the judgment of project staff for the expert judgment of the panel as an appropriate update to an existing expert elicitation.

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DATE	12/03/02	12/03/02	12/03/02	12/04/02	12/17/02	12/19/02

NRC Review of DOE Documents Pertaining to Igneous Activity
Key Technical Issue Agreement Item 1.02

The U.S. Nuclear Regulatory Commission (NRC) goal of issue resolution during this interim pre-licensing period is to assure that the U.S. Department of Energy (DOE) has assembled enough information on a given issue for NRC to accept a license application for review. Resolution by the NRC staff during pre-licensing does not prevent anyone from raising any issue for NRC consideration during the licensing proceedings. Also, and just as important, resolution by the NRC staff during pre-licensing does not prejudge what the NRC staff evaluation of that issue will be after its licensing review. Issues are resolved by the NRC staff during pre-licensing when the staff has no further questions or comments about how DOE is addressing an issue. Pertinent new information could raise new questions or comments on a previously resolved issue.

This attachment addresses one agreement between the NRC and DOE made during the Igneous Activity (IA) Technical Exchange and Management Meeting (see letter,[1] which summarized the meeting). By letter,[2] DOE submitted information to address IA Agreement 1.02. The information submitted for this agreement is discussed below.

Igneous Activity Key Technical Issue (KTI) Agreement Item 1.02

Summary

IA KTI Agreement 1.02 is for the DOE to document the effects of potential buried basaltic volcanoes on DOE probability models for volcanism. To address this agreement, DOE submitted a Letter Report entitled "Interpretation of Aeromagnetic Data." This DOE Letter Report provides a limited analysis of the effects on probability models resulting from interpretations of the new aeromagnetic data. In addition to increasing the uncertainty on the number and age of basaltic volcanoes likely buried in the Yucca Mountain region, interpretations of the new aeromagnetic data suggest that the bases for DOE probability models needs to be revised. These aeromagnetic data also provide limited assurance that all relevant basaltic igneous features have been detected and characterized in the Yucca Mountain region. Staff concludes that DOE has not provided sufficient information to adequately document the likely effects of new aeromagnetic data on DOE probability models.

Wording of the Agreement

"Examine new aeromagnetic data for potential buried igneous features (see U.S. Geological Survey, Open-File Report 00-188, Online Version 1.0), and evaluate the effect on the probability estimate. If the data survey specifications are not adequate for this use, this action is not required. DOE agreed and will document the results of the evaluation in an update to the AMR,

[1]Schlueter, J.R. "U.S. Nuclear Regulatory Commission/U.S. Department of Energy Technical Exchange and Management Meeting on Igneous Activity (August 29–31, 2000)." Letter (October 23) to S. Brocoum, DOE. Washington, DC: NRC. 2000.

[2]Ziegler, J.D. "Transmittal of Report Addressing Igneous Activity (IA) Key Technical Issue (KTI) Agreement Item 1.02." Letter (September 26) to J.R. Schlueter, NRC. Las Vegas, Nevada: DOE. 2002.

Characterize Framework for Igneous Activity at Yucca Mountain, Nevada (ANL-MGR-GS-000001), expected to be available in FY2003."

Review

DOE Probabilistic Volcanic Hazards Assessment was conducted in 1995 as an expert elicitation (CRWMS M&O, 1996). Most probability models developed during this elicitation used spatio-temporal patterns of past activity to calculate the likelihood of a subsurface igneous event intersecting the proposed Yucca Mountain repository site. These models were based on the number, location, and age of basaltic volcanoes identified in 1995.

Changes in the number, age, or location of buried volcanoes could change the probability models in CRWMS M&O (1996). As part of scientific investigations sponsored by Nye County, Nevada, the U.S. Geological Survey conducted an aeromagnetic survey in 1999 over the Yucca Mountain–Death Valley area (Blakely et al., 2000). Although the purpose of this aeromagnetic survey was to identify large-scale basins affecting groundwater flow models, DOE agreed to evaluate the survey data for features that might indicate the presence of buried basaltic volcanoes (IA KTI Agreement 1.02).

Interpretations of the new aeromagnetic data showed that, in addition to the seven buried volcanoes identified in 1995 (CRWMS M&O, 1996), thirteen additional volcanoes may be buried beneath the alluvium in this region. To evaluate the possible effects these newly interpreted volcanoes could have on DOE probability models, the DOE Letter Report considered two analyses. DOE considers all newly identified magnetic anomalies as representing buried basaltic volcanoes, and estimates the ages of these volcanoes based on presumed burial depths. For the first analysis, DOE assigns a weighting function to the likelihood that the newly identified magnetic anomalies represent buried basalt. The revised distribution for the number and age of volcanic events was then propagated through the numerical models produced in CRWMS M&O (1996). For the second analysis, all of the newly identified anomalies were assumed to represent buried basalt and the nonweighted distributions were propagated through the CRWMS M&O (1996) numerical models. These analyses conclude that the presence of newly interpreted volcanoes could increase DOE probabilities by up to a factor of approximately 1.4. In contrast, analyses presented in Hill and Stamatakos (2002) indicate probabilities could increase up to a factor of approximately 10 in response to the new interpretations of available magnetic data.

During the DOE elicitation, aeromagnetic and ground magnetic surveys identified seven anomalies that likely were caused by buried basaltic volcanoes (CRWMS M&O, 1996). For each of these anomalies, DOE experts assigned average likelihoods of 0.2–0.9 that each anomaly was caused by a buried basaltic volcano. As discussed in O'Leary et al. (2002) and Hill and Stamatakos (2002), additional high resolution ground magnetic and aeromagnetic surveys, coupled with numerical modeling, have increased confidence in the interpretation of buried basalt for these seven anomalies (e.g., Connor et al., 2000). An increase in confidence that these seven anomalies represent buried basalt would increase spatial and temporal recurrence rates, compared with the weighted recurrence rates used in CRWMS M&O (1996). Thus, interpretations of the new aeromagnetic data would likely affect the weights assigned by each expert in CRWMS M&O (1996) to the interpretation that the seven pre-existing magnetic anomalies represented buried basalt. The analyses presented in the DOE Letter Report do not

consider the effects of the new aeromagnetic data on the likelihoods assigned to anomalies during the CRWMS M&O (1996) elicitation.

One of the parameters elicited in CRWMS M&O (1996) was for the uncertainty in recurrence rate due to undetected events in the Yucca Mountain Region. Six of the experts interpreted this uncertainty to reflect the likelihood that basaltic dikes ascended within approximately 300 m [984 ft] of the surface and stagnated without eruption. One expert used only volcanoes younger than 1 Ma in his probability models, and did not believe any <1 Ma undetected events remained in the area. The three remaining experts considered that additional basaltic volcanoes might be buried but undetected in the region, however, these experts gave very low weights to the likelihood of such undetected volcanoes. Thus, the probability models used in CRWMS M&O (1996) only evaluate a maximum uncertainty in volcano recurrence rate of 10 percent (Hill and Stamatakos, 2002). Current interpretations of at least eleven additional buried volcanoes (e.g., O'Leary et al., 2002) show that the uncertainty estimates produced by the experts in 1995 were an underestimation. The new aeromagnetic data indicate at least eleven buried volcanic features in the area. These new data warrant reconsideration by the experts in estimating the number of volcanoes likely buried in this area. Thus, based on available information, CRWMS M&O (1996) does not provide an adequate basis for evaluating the number of basaltic volcanoes that may remain present but undetected in the Yucca Mountain region.

A key finding of the O'Leary et al. (2002) and Hill and Stamatakos (2002) reports is that some known basaltic volcanoes in the Yucca Mountain region cannot be readily identified from the aeromagnetic data (Blakely et al., 2000). This result was unexpected, and raises a concern that additional basaltic volcanoes may be buried in alluvial valleys but remain undetected by past geophysical surveys (Hill and Stamatakos, 2002). This concern is supported by the discovery of basalt during the March 2002, drilling of Nye County Early Warning Drillhole 23P[3]. This drillhole is located in an area of Fortymile Wash that lacks magnetic anomalies characteristic of buried basalt, and is outside many of the main volcanic source zones used in CRWMS M&O (1996). The DOE Letter Report defers discussion of undetected basaltic volcanoes to an unspecified update of the "Characterize Framework for Igneous Activity at Yucca Mountain, Nevada" report (CRWMS M&O, 2000). An evaluation of the potential effects from present-but-undetected volcanoes, however, is intrinsic to determining the risk significance of alternative interpretations of the aeromagnetic data. Because the current basis in CRWMS M&O (1996) underestimated the number of buried basaltic volcanoes that may remain present but undetected in the region, DOE will need to revise the technical basis used to quantify this fundamental uncertainty related to the aeromagnetic data. The resulting uncertainty in the number and age of undetected volcanoes can then be evaluated in DOE probability models.

The Case 1 analysis in the DOE Letter Report assigns qualitative likelihoods that each anomaly identified in O'Leary et al. (2002) and Hill and Stamatakos (2002) represents buried basalt. Although the authors of these reports assigned relative levels of confidence to the interpretations of buried basalt, other factors to consider in deriving a numerical likelihood or weighing function to these interpretations for analysis in the CRWMS M&O (1996) models include:

[3]Craig, R.W. "Yucca Mountain Project Branch - U.S. Geological Survey (YMPB-USGS) Progress Report, August, 2002." Letter (September 13) to V. Trebules, USGS. Denver, CO: USGS. 2002.

- Poor correlation exists between expert opinion and likelihood of buried basalt, as shown by the current high-confidence interpretations of anomalies in the Amargosa Desert (Connor et al., 2000; O'Leary et al., 2002; Hill and Stamatakos, 2002) compared with the low confidence given to many of those anomalies in the original elicitation (CRWMS M&O, 1996). Use of such opinions, rather than readily obtainable data (e.g., drilling of anomalies) or testable numerical models, will not help to reduce uncertainty or increase confidence in the probability calculations.

- Many of the medium confidence (Hill and Stamatakos, 2002) or level 3 confidence (O'Leary et al., 2002) anomalies can be successfully modeled as buried basalt (O'Leary et al., 2002). Although such models do not represent unique solutions to the magnetic anomaly data, they are credible and based on reasonable interpretations of geologic features characteristic of this region. Thus, reasonable tests were applied to the hypothesis that these anomalies represent buried basalt, and the hypothesis withstood those tests. As stated in Kotra et al. (1996), "...the use of expert elicitation [opinion] should not be considered as an acceptable substitute for traditional analyses based on adequate field or experimental data, when such data are reasonably available or obtainable." Rather than rely on opinion, similar modeling could be applied to lower confidence anomalies to test the hypothesis of buried basalt. The DOE Letter Report does not discuss how likelihoods were assigned to the Case 1 interpretations, or the level of consideration given to modeled versus nonmodeled anomalies.

- Different interpretations can be applied to these magnetic anomalies (Connor et al., 2000; O'Leary et al., 2002; Hill and Stamatakos, 2002), which clearly shows that independent experts can derive alternative interpretations to these data. The authors of the DOE Letter Report have made different interpretations of these data than might be made by the original authors of CRWMS M&O (1996). The Letter Report approach results in an inconsistent treatment of epistemic uncertainty in attributing potential buried basaltic volcanoes to an individual expert's 1995 data set. Applying the judgment of a DOE staff member to infer how an expert from the original elicitation would revise his opinion with the new information does not appear to be a transparent method for evaluating whether or not the original elicitation should be updated.

Many DOE experts used different combinations of vents, vent groupings, vent alignments, and subsurface features such as dikes, to define volcanic events (CRWMS M&O, 1996). The Case 2 analysis in the DOE Letter Report interprets each experts "tendency" to use certain features as volcanic events, and applies this tendency to the aeromagnetic interpretations. Clearly, the presence of the new information (e.g., these magnetic data) could change an independent expert's basis for defining volcanic events. For example, an expert who previously defined volcanic events as single point events could be biased toward an event definition based on vent alignments, due to the increased presence of aligned features interpreted from the magnetic data. As discussed for the Case 1 analysis, imposing DOE staff judgement into the elicitation results introduces inconsistent treatment of uncertainty into the elicitation and does not provide an effective evaluation of the effects of new uncertainties on the elicitation. The staff does not consider that the analysis in the DOE Letter Report adequately evaluates the potential effects of this new information on volcanic event definitions in CRWMS M&O (1996), which would likely change in response to the new aeromagnetic interpretations.

Many of the CRWMS M&O (1996) probability models define volcanic source zones based on the location of past volcanic events. Many of these models assign the proposed repository site to background source zones, with main volcanic source zones defined by the distribution of only Pliocene–Quaternary aged volcanoes. Thus, the probability of intersection is based primarily on extension of a subsurface intrusion from the main volcanic source zone to the proposed repository site, with a minor contribution from background-zone recurrence rates. The staff considers that interpretations of the new magnetic data would likely affect an expert's interpretation of the length and orientation of subsurface intrusions, as past patterns of volcanic activity in the region were used to develop these parameters during the original elicitation. The analysis in the DOE Letter Report does not evaluate likely changes in dike or alignment length and orientation, which would arise from alternative interpretations of the magnetic data.

Within the volcanic source zones used in CRWMS M&O (1996), each expert used a different series of assumptions to justify models for spatially homogeneous or nonhomogeneous recurrence rates. The addition of at least eleven buried volcanoes to a data set containing only eleven-to-sixteen events (e.g., DOE Letter Report) could change an independent expert's basis for distinguishing between uniform, random, or clustered event distributions within each volcanic source zone. The DOE Letter Report does not address the possible or likely effects of the interpreted basaltic volcanoes on conceptual model development in CRWMS M&O (1996), and does not provide an explanation on why such new information would not significantly affect probability calculations.

The use of average burial rates to provide ages of the interpreted basalts does not adequately address uncertainties and known variations in subsidence and sedimentation rates throughout the magnetic survey areas. For example, late Quaternary sediment deposits show large variations in age (i.e., modern to 659–730 ka) within the Crater Flat topographic basin (Peterson et al., 1995) and in the Amargosa Desert (e.g., Swadley and Carr, 1987). Complex interactions between tectonic uplift or subsidence and sedimentation rate also can occur in the magnetic survey area (e.g., Ferrill et al., 1996). Thus, deposition rates from <0.01 mm/yr [0.0004 in/yr] to on order of 0.1 mm/yr [0.004 in/yr] appear reasonable for the magnetic survey areas. Given the observed variations in subsidence rates and sediment accumulation rates, the use of average sedimentation rates appears inadequate to assign eruption ages for the interpreted basalts. In essence, a new data set with very poorly constrained ages is being introduced into an elicited data set with well-constrained ages. In contrast to the original DOE elicitation (CRWMS M&O, 1996), independent experts could choose different methods to assign ages and appropriate uncertainties for poorly characterized events, or consider the effects of alternative age hypotheses (e.g., Hill and Stamatakos, 2002). Thus, DOE has not developed an adequate basis to assign ages to the interpreted basalts. The use of an average sedimentation rate does not provide a reasonable method to date buried features throughout the magnetic survey area, and does not calculate appropriate uncertainties inherent in this dating method.

The lack of appropriate age constraints on the buried basalts creates additional uncertainties in the justification for conceptual models developed and abstracted in CRWMS M&O (1996). Many of the DOE experts considered only basalt younger than 5 Ma as relevant to probability calculations. Part of this consideration was due to the apparent hiatus in basaltic volcanic activity between approximately 5 Ma and 8 Ma. If some of the seventeen uncharacterized anomalies (i.e., six from PVHA, eleven from post-PVHA) represented eruptions between 5–8 Ma, or another period lacking recognized basaltic volcanic activity, then this information could affect how an expert interpreted the patterns of post-caldera basaltic volcanic activity.

Conceivably, probability models in CRWMS M&O (1996) might consider all basaltic volcanic activity younger than approximately 11 Ma relevant to conceptual or numerical probability model development, if some or all of the buried basalts represented additional episodes of uncharacterized activity. The DOE Letter Report does not address how the uncertainty in the ages of the interpreted buried basalts might affect conceptual model development in CRWMS M&O (1996). The DOE Letter Report has not justified the basis to use the conceptual models of the experts in CRWMS M&O (1996) without modification given the increase in epistemic uncertainty represented by the credible interpretations of at least eleven additional buried basaltic volcanoes in the Yucca Mountain region.

Large uncertainties on the likely ages of the interpreted basalts may also affect key assumptions in CRWMS M&O (1996) regarding temporal homogeneity in recurrence rates. Some probability models in the peer-reviewed literature (e.g., Ho, 1991; Ho and Smith, 1998) use temporally nonhomogeneous recurrence rates to account for past patterns of basaltic volcanic activity. One reason for not using temporally nonhomogeneous recurrence rates in CRWMS M&O (1996) was a lack of past activity to support or constrain such interpretations. Addition of at least eleven new events to the basaltic volcanic data set could affect how an independent expert interpreted past temporal patterns in igneous activity. Without adequate age constraints on the interpreted basaltic volcanoes, DOE will need to address alternative hypotheses regarding temporally nonhomogeneous recurrence rates and resulting effects on probability models. As discussed in Hill and Stamatakos (2002), the current age uncertainties support multiple alternative conceptual models regarding temporal clustering. Of greatest apparent risk significance is a 1-Myr-long episode of accelerated activity at approximately 4 Ma, which can be recognized in the existing data. The eleven buried basaltic volcanoes also may have formed during this period of peak activity, increasing recurrence rates from approximately 9 volcanoes/Myr to 20 volcanoes/Myr. The analysis presented in the DOE Letter Report, however, considers only changes in average recurrence rates from approximately 3 volcanoes/Myr to 5 volcanoes/Myr. Thus, the DOE Letter Report does not evaluate an appropriate range of uncertainty in volcanic recurrence rates based on alternative conceptual models for basaltic volcanism in the Western Great Basin. Again The DOE Letter Report has not justified the basis to use the conceptual models of the experts in CRWMS M&O (1996) without modification given the increases in uncertainty represented by alternative interpretations of the likely ages of buried basaltic volcanoes.

In summary, the DOE Letter Report does not provide an adequate technical basis to evaluate the likely effects on DOE probability models from credible interpretations of new aeromagnetic and ground magnetic data. The interpretation of at least eleven additional buried basaltic volcanoes could significantly affect an independent expert's conceptual model for basaltic volcanism in the Yucca Mountain region. Different assumptions regarding the age and location of the interpreted volcanoes would likely affect expert judgment on the use of alternative conceptual models to explain possible spatial or temporal clustering. These potentially significant changes in DOE's conceptual probability models (CRWMS M&O, 1996) are not addressed in the DOE letter report. Even assuming that the conceptual basis for DOE probability models remains unchanged, some important parameter distributions in DOE models would necessarily change in response to the new aeromagnetic interpretations. The DOE Letter Report does not evaluate potential changes in parameter distributions except for small increases in recurrence rate uncertainty. In addition, the available data provide only limited confidence that all relevant subsurface basaltic features have been adequately characterized and considered in any probability model. DOE's own data, i.e. O'Leary et al. (2002), provides evidence that additional basaltic volcanoes remain present but undetected within approximately 20 km

[12.4 mi] of the proposed repository site. The DOE Letter Report does not evaluate the potential effects on DOE probability models from additional basaltic volcanoes that may yet remain present but undetected in the Yucca Mountain region.

Status of Agreement

Staff concludes that DOE has not acceptably addressed the questions in Igneous Activity Key Technical Issue Agreement Item 1.02 regarding the effects of potential buried basaltic volcanoes on DOE probability models. Interpretations of available magnetic data greatly increase the uncertainty in the number and age of buried basaltic volcanoes in the Yucca Mountain region. Igneous Activity Agreement Item 1.02 is considered as "Needs additional data".

Additional Information Needed

DOE will need to provide a technical basis to constrain the number and age of volcanic events which have occurred in the Yucca Mountain region, including events which may be present and undetected, and provide an analysis which considers the full range this uncertainty, not just the limited range considered in the Letter Report. DOE also will need to provide an evaluation of how these magnetic data could change the conceptual basis used during the original elicitation to develop probability models and associated parameter distributions, including consideration of such things as event definitions, and dike and event lengths. As is stated in NUREG-1563, acquisition and analysis of physical data should be the primary manner in which licensing information is collected, however, other considerations may preclude such collection. If expert elicitation is used and it needs to be updated, NUREG-1563 offers several choices as to how the updating could be accomplished. In all cases, however, it should be thoroughly documented to provide a transparent view of the updating process and resulting judgements. In future work, DOE also should recognize the staff does not consider that substituting the judgement of project staff for the expert judgment of the panel as an appropriate update to an existing expert elicitation.

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