Department of Energy
Washington, DC 20585

JUL 23 1991

Mr. John J. Linehan, Acting Director
Repository Licensing and Quality
Assurance Project Directorate
Division of High-Level Waste Management
Office of Nuclear Material Safety
and Safeguards
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Dear Mr. Linehan:

In a letter dated March 18, 1991 (Linehan to Shelor), the U.S. Department of Energy (DOE) received three comments from the U.S. Nuclear Regulatory Commission (NRC) on Study Plan 8.3.1.8.5.1, "Characterization of Volcanic Features." The comments were assessed by the principal investigator for their impact on the planned program and responses are enclosed.

With respect to a summary document that clearly portrays the overall volcanism program, the interrelationship of volcanism activities and other program activities is described in the Site Characterization Plan (SCP), Chapter 8, Section 8.3.1.8, "Postclosure Tectonics." SCP Figure 8.3.1.8-1 (page 8.3.1.8-2) shows how the Postclosure Tectonics program is divided into four major investigations with investigation 8.3.1.8.1, "Volcanic Activity," being the first listed. Table 8.3.1.8-1b lists studies providing information on direct releases resulting from volcanic activity and summarizes key studies or activities that supply data for this investigation. Discussion of these figures and tables are in pages 8.3.1.8-1 to 8.3.1.8-24. Further, Section 4.0 of the Study Plan explains the various applications for the data gathering during the course of the study.

Acceptance criteria for accepting or rejecting information obtained in volcanism studies are described in the Los Alamos National Laboratory (LANL) Plan LANL-YMP-QAPP, R5, which the NRC accepted via a letter to DOE dated May 29, 1991 (Linehan to Shelor). Major controlling documents include the specific detailed technical procedures listed in the Study Plan and the LANL quality procedures. Acceptance criteria are required through procedures LANL-YMP-QP-06.2 and LANL-YMP-QP-06.3. This requirement is implemented through procedures TWS-QAS-QP-3.5, "Procedure for Documenting Scientific Investigations," and TWS-QAS-QP-08.2, "Procedure for Control of Data."

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Should you have any questions, please contact Sharon Skuchko of my office at (202) 586-4590.

Sincerely,

Dwight E. Shelor
Associate Director for
Systems and Compliance
Office of Civilian Radioactive
Waste Management

Enclosure:
Responses to Comments on Study Plan 8.3.1.8.5.1, "Characterization of Volcanic Features"

cc w/Enclosure:
C. Gertz, YMPO
R. Loux, State of Nevada
K. Whipple, Lincoln County, NV
M. Baughman, Lincoln County, NV
J. Bingham, Clark County, NV
D. Bechtel, Clark County, NV
S. Bradhurst, Nye County, NV
B. Raper, Nye County, NV
P. Niedzielski-Eichner, Nye County, NV
R. Campbell, Inyo County, CA
R. Michener, Inyo County, CA
G. Derby, Lander County, NV
P. Goicoechea, Eureka, NV
C. Schank, Churchill County, NV
C. Jackson, Mineral County, NV
F. Sperry, White Pine County, NV
L. Vaughan, Esmeralda County, NV
K. Hooks, NRC
N. K. Stablein, NRC

Responses to Comments on Study Plan 8.3.1.8.5.1
"Characterization of Volcanic Features"

Activity 8.3.1.8.5.1.1 Volcanism Drill Holes

Response to Question 1

As noted on page 14 of the Study Plan ". . . magnetic polarity of the anomalies will be established by measurement of the core using a flux-gate magnetometer." Measurement of the polarity of drill core does not require oriented core, only identification of the top and bottom of the core. Los Alamos National Laboratory (Los Alamos) does plan to measure the field magnetic direction of core, which would require oriented core for the volcanism drill hole activities.

If basaltic volcanic rocks are encountered in the drill holes and the basalts are either old (> 2 Ma) and/or of small volume, these data are not expected to affect the probability calculations. In this case, drilling of a single hole with determination of only the magnetic polarity should be adequate. If the basalts are young (< 2 Ma) and/or of large volume such that probability calculations might be affected, additional drill holes will almost surely be required. One option if additional drilling is required, would be to obtain oriented core. This core could be used for paleomagnetic studies if such studies are judged to be useful. The logic for changes in planned studies resulting from a range of possible results of exploratory drilling is discussed in section 3.1.7 Study Plan.

Activity 8.3.1.8.5.1.2 Geochronology Studies

Response to Question 2

Two accessory topics in the text of the comment can be rephrased as questions; (1) does the U-Th disequilibrium method yield a crystallization age for mineral separates, and (2) is there an effect of tritium produced by nuclear testing on the ^{3}He method?

The summary paper of Pierce (1986) supplemented by Colman et al., (1987) was used as a start for selecting possible geochronology methods to augment K-Ar age estimation methods (see specifically, Table 13.2 of Pierce for a comprehensive list of Quaternary Dating Methods). Also, it is Los Alamos' opinion that the conventional K-Ar method supplemented by the $^{40}Ar/^{39}Ar$ method will provide sufficient precision and accuracy for basaltic volcanic rocks older than about 1 Ma. As Los Alamos noted on page 31 ". . . methods have been chosen from a suite of possible geochronology methods because they are judged to have the maximum chance of success for estimating the ages of the volcanic rocks in the age range of 5000 to 100,000 years."

The selection criteria were based on several lines of reasoning. First, Los Alamos wanted to apply chronology methods using different isotopic systems. The ^{14}C method cannot be used because carbon is rarely preserved in the arid desert environment. The U-Th method was chosen because it represents a different isotopic system from K-Ar and it is the most commonly used dating technique of many based on the radioactive decay series of uranium. Moreover, the U-Th method, if used with petrologic constraints from study of the rocks, can yield a crystallization age. Second, Los Alamos chose methods that are fairly well established so that major laboratory technique development is not required. Helium, and TL measurements emerged as leading candidates by this criterion. Los Alamos gained confidence that the analytical measurements required for the U-Th method using solid source mass spectrometry are feasible with only several months of laboratory work. Third, Los Alamos wanted to avoid chronology methods that would require equipment that was either extremely costly, or difficult to qualify for Quality Assurance requirements. Chronology methods requiring access to an accelerator mass spectrometer were down graded for this reason (^{36}Cl, ^{10}Be, ^{26}Al). Mass spectrometry equipment at Los Alamos was judged to be adequate to accomplish measurements for U-Th and helium studies. Fourth, Los Alamos looked for chronology methods with acceptable precision in the age range of interest (1 ka to < 500 ka). Finally, Los Alamos required that the chronology method be readily tied to volcanic events. As noted above, the U-Th method can yield a crystallization age. The helium method is used for a surface exposure age. The technique provides minimum ages that can be regarded as conservative for chronology models. Additional, the issue of variability in surface exposure age can be constrained with replicate samples. Finally, the TL method can be directly correlated with volcanic events by measuring the TL age of soils overlain and baked by lava flows. The TL method in this case dates the time of emplacement of the lava flow. Computer modeling of the thermal effects of lava flows has shown that any pre-existing TL signal is efficiently removed by the lava flow.

Using these criteria, Los Alamos consulted established chronology experts in the country, attended several special sessions on Quaternary dating methods, and utilized the expertise of the Isotope and Nuclear Chemistry Division of the Los Alamos. With this foundation, Los Alamos chose the three supplemental methods.

There is a level of subjectivity to selection of chronology methods. There are pro and cons to every chronology method and different experts have distinctive views on the choice of the best or a suite of best chronology methods. To repeat the quote from earlier in this response ". . . have been chosen from a suite of possible geochronology methods because they are judged to have the maximum chance of success for estimating the ages of the volcanic rocks in the age range of 5 to 100 ka." It is highly possible that other combinations of chronology methods could be used. However, the test of our Study Plan is whether we can successfully complete the work. Note also that we are emphasizing convergence of results not results from specific methods. We stress that the important information to recognize is not whether every conceivable chronology method has been considered, but whether a coherent and technically defendable data set can be obtained for establishing the chronology of volcanic rocks of the Yucca Mountain region. The latter is the goal of the Study Plan 8.3.1.8.5.1.

Finally, the our statement on page 17 ". . . the methods prove unsuccessful or the results inconsistent, there are a variety of other isotopic methods that may, in turn, be considered. These include but are not limited to 238U-226Ra disequilibrium measurements, other cosmogenic isotopic methods (^{36}Cl, ^{10}Be, ^{26}Al), and ^{14}C dating of rock varnish."

Question on U-Th disequilibrium Method

We are aware of the possible multistage history of phenocryst minerals in a basalt. This is acknowledged as a potential source of error in dating using the U-Th disequilibrium method. In fact this concern is an illustration of why Los Alamos is using a range of chronology methods. Each technique has different assumptions and limitations. However, careful consideration of the results of different chronology methods should provide insight into physical reasons for differences in chronology data. The test of our geochronology task is to assemble data to attempt to document a coherent and convincing case that the chronology of volcanic events is well constrained.

There are several reasons why phenocryst history is probably not a significant concern for the basalt of the Yucca Mountain region. First, the basalts are aphryic. Olivine is the major phenocryst phase with subordinate plagioclase, iron-titanium oxide and clinopyroxene. Total phenocryst contents are generally 2 to 5%. Second, the basalts are fine-grained. Petrology models for the basalt require filter-pressing to remove phenocrysts to explain the evolved compositions and the lack of phenocrysts.

U-Th References

Allegre, C.J., and Condomines, M., (1976) Fine chronology of volcanic processes using ^{238}U-^{230}Th systematics. Earth Planet. Sci. Lett. 28, 395-406.

Colman, S.M., K.L. Pierce, and R.W. Birekeland, 1987, Suggested terminology for Quaternary dating methods, Quaternary Res. v. 28, 314-319.

Condomines, M., and Allegre, C.J., (1980) Age and magmatic evolution of Stromboli Volcano from ^{230}Th-^{238}U data. Nature 288, 354-357.

Condomines, M., Tanquy, J.C., Kieffer, G., and Allegre, C.J., (1982) Magmatic evolution of a volcano studied by ^{230}Th-^{238}U disequilibria and trace element systematics: The Etna case. Geochim. Cosmochim. Acta 46, 1397-1416.

Ivanovich, M., and Harmon, R.S., eds., (1982) Uranium Series Disequilibrium: Applications to Environmental Problems. Oxford, Claredon Press. 571 pp.

Pierce, K., 1986, Dating Methods, Chapter 13 in Active Tectonics. National Academy Press, Washington, D.C. 1986.

Sources of ^{3}He

The 3He extracted from the basalt for the $^{3}He/^{4}He$ method is contained in olivine phenocrysts. Pure olivine mineral separates are used for the helium isotopic measurements. The olivines are melted under vacuum and the ^{3}He is extracted. No contamination with tritium from weapons testing is anticipated for the olivine minerals.

Activity 8.3.1.8.5.1.5 Evolutionary Cycles of Basaltic Volcanic Fields

Response to Question 3

The primary concern expressed in the background material supplied with this question is that the Crater Flat volcanic field may still be considered to be active. The question suggests that we should be examining volcanic fields on a temporal scale that exceeds the lifetime of the field. This concept was covered by the criterion on page 50 of the Study Plant that immediately follows the criterion in question.

> "Emphasis will be placed on choosing volcanic fields that exhibit evidence of being extinct (no eruptive activity for a significant period of time). This will allow us to evaluate patterns of volcanic activity associated with a waning volcanic field." (page 50).

We are in complete agreement that establishing waning patterns of activity for volcanic fields requires studying fields which are no longer active. Los Alamos believes that this was covered adequately in the selection criteria on page 50.