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Dan Dreyfus, Director
Office of Civilian Radioactive
Waste Management
U. S. Department of Energy
Washington, D.C. 20545

Dear Dr. Dreyfus:

The State of Nevada has reviewed the DOE Study Plan for "Characterization of Structural Features in the Site Area" (Study Plan 8.3.1.4.2.2, Rev. 2) and its cited references, and is providing its comments in this letter and attachment. The State's comments address the adequacy, completeness, and technical accuracy of the Study Plan to meet the purposes of site characterization.

The State's primary concerns regarding the subject Study Plan are summarized as follows:

1. The principal geologic map of the site area (Scott and Bonk, 1984) which has formed the basis for the Yucca Mountain project, the original ESF layout, and this Study Plan, has yet to be finalized or subject to a quality assurance review. Significant known structural and stratigraphic features which could have a major influence on the proposed repository layout are absent from the Scott and Bonk, 1984 map due to its small scale. This mapping at a scale of 1:12,000 has already been proven insufficient to provide the detail necessary for resolving the geometry of faulting at Yucca Mountain. This mapping needs to be expanded to a larger scale (1:6,000 or 1:3,000) to identify all the relevant structural features before proceeding further.

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2. The Study Plan proposal to conduct five activities in parallel is inappropriate. Detailed surface mapping at a scale of 1:6,000 or larger in conjunction with geophysical surveys (Study Plan 8.3.1.4.2.1) should be followed sequentially by pavement mapping; layout and logging of boreholes; vertical seismic profiling (VSP); and finally, the layout and excavation of the ESF.

3. The use of photogrammetry as the principal method of mapping the ESF tunnels will be inadequate to obtain all of the relevant data. Although photogrammetry has certain advantages insofar as accurately locating mapped features and providing a complete digitized database, it cannot replace crucial information that can only be obtained by conventional mapping.

4. The pavement and outcrop methods to be employed in the surface-fracture network studies will probably produce some valuable, but limited data on the fracture characteristics of the Tiva Canyon formation. Mapping of only "two or more sites in each outcropping (map) unit" will probably not yield representative results at a repository scale.

Should you have any questions, this office is available to meet with the Department and discuss the State's comments at any time.

Sincerely,

Robert R. Loux
Executive Director

ATTACHMENT
cc: R. Nelson, DOE-YMPO
J. Cantlon, NWTRB
J. Youngblood, NRC
M. Steindler, NRC-ACNW
S. Kraft, EEI
D. Weigel, GAO

ATTACHMENT

State of Nevada comments on DOE Study Plan 8.3.1.4.2.2, Rev2, "Characterization of Structural Features in the Site Area."

GENERAL COMMENTS

The Study Plan seems to represent a multi-faceted approach to understanding the three-dimensional distribution of fractures in the site area. In general, it appears that the activities described for this study will be sufficient to produce data on some aspects of the geometry, spatial distribution, and physical features of fault and fracture systems at Yucca Mountain. The approaches will provide information on location, orientation, geometry, and extent of fractures. However, it is unclear how information about chronology of structural features will be obtained. Also, no description is given on techniques to be used to determine the amount and direction of movement of faults and fractures. In addition, fracture continuity and length are not satisfactorily addressed. This is especially problematical for one-dimensional exposures of fracture traces in pavements or the ESF. To address this problem, the Study Plan needs to discuss what offset markers or piercing points will be used to determine amount of offset and what kinds of structural studies will be done to determine direction of movement? How will the fracture surfaces be revealed and what kinds of kinematic indicators will be used? Also, what are the key features of faults and fault zones to be recorded?

We also have concerns about whether the data will be representative, particularly in the case of cores. Cores provide information that is not available any other way, but it is unclear from this Study Plan exactly how much core will be available. Although the number and locations of existing and proposed drillholes are included, there is no discussion of when core (as opposed to cuttings) will be collected or how this decision will be made. The statement that looking at 10% of core should yield representative results is simplistic and, we think, statistically incorrect (even if all holes will be cored from top to bottom!).

1. **Study Plan Approach**

   Mapping at 1:12,000 scale has already proven to provide insufficient detail to resolve the geometry of faults responsible for strata tilts at Yucca Mountain (c.f. Scott and Bonk, 1984). Within the repository block and adjoining areas, surface structural mapping at scales such as 1:6,000 or 1:3,000 are suggested.

   Without access to in-house technical reports which form the basis of procedures for mapping within the ESF, we are unable to completely evaluate whether the planned techniques will be sufficient. We are aware, however, that mapping within smooth-walled tunnels with circular bores poses many special problems. For example, it is unlikely that undisturbed samples can be taken in most places without coring drills. Also, magnetic compasses cannot be used to measure orientations of features because of metal track and utility lines. The photogrammetric method described in the Study Plan may provide the capability to determine the orientation of planar, through-going features that intersect the complete circular bore of the tunnel, but it seems unlikely to provide the capability of measuring orientation of discontinuous, irregular, or poorly exposed features or those that parallel the tunnel. In addition, structurally damaged zones, which will be of critical importance to evaluation of the extent of the repository block disturbed zone, tend to require extensive rock bolting and netting, which will greatly restrict study access.

2. **Study Plan Data Collection Activities**

Surface mapping activities will provide representative data on distribution of ash flow tuffs and other lithostratigraphic units only if mapping is done at a suitably large scale. Only then can surface faults be shown in any detail. However, regardless of the scale, mapping alone will not provide sufficient information to deduce the magnitude and orientation of slip along the faults. Some faults will have to be excavated to expose the fault surfaces for more detailed kinematic study. Mapping of surface pavements suffers from the same limitation as surface mapping in regards to magnitude and orientation of slip. Fault and fracture surfaces must first be exposed by cleaning or excavating.

Insufficient information is provided in the Study Plan to make an informed judgment about the mapping plan for the ESF. Underground mapping should provide a representative sampling of structures intersected by the bore of the tunnel. What is unclear is the location and geometry of the various drifts relative to known mapped fault and fracture systems at the site. The proposed layout of drifts and ramps needs to be shown on a map of known and suspected geological and structural features to evaluate whether data to be obtained from the ESF mapping will be representative of the block as a whole.

A serious State concern is about the proposed methods and the timing constraints for mapping in the ESF. Conventional geologic mapping provides data that cannot be obtained from photogrammetry, but the Study Plan suggests that conventional mapping will not be done everywhere. The reason for this decision seems to be to avoid interfering with excavation and other ESF test schedules. The criteria for deciding when and where conventional mapping will be used are not stated. It is also not clear whether other ESF tests and/or engineering decisions (e.g., casing or grouting parts of the ESF, etc.) will eliminate the possibility of geologic mapping, field checking, etc. at a later date.

3. **Study Plan Scope**

The range of studies proposed, including mapping, pavement studies, borehole studies, underground mapping, and vertical seismic profiling, seems to provide a reasonable combination of techniques for evaluating the gross nature of structural features in the site area.

4. **Study Plan Schedule**

Figure 5.1, page F-11, is difficult to interpret. Figure 5.1 shows that ESF construction begins two years after some undefined datum and that all other activities proceed after this datum. Most activities show report deadlines four or more years following construction of the ESF. Geologic mapping, stated elsewhere in the Study Plan as complete, is shown in the schedule as not complete until one year past the start of the ESF.

The sequencing of this study seems entirely inappropriate. DOE appears to be proceeding with the excavation of the Exploratory Studies Facility (ESF), the most costly aspect of the entire Site Characterization Program, without the benefit of the results of appropriate geological and geophysical studies that should, in fact, be the basis for siting and designing the ESF. A rational sequence of activities should proceed from the least expensive, most accessible sorts of data gathering, to progressively more elaborate and expensive activities. This has the benefit of allowing the most careful planning of the most expensive activities. One logical sequence of activities could be as follows:

A. Complete all surface geologic and structural mapping. This would include mapping of pavements and uncleared outcrops. Since the 1:12,000 scale of geologic maps that have been completed has been shown to be inadequate, the key areas should be remapped at 1:6,000 or a larger scale to define critical structural features at the surface.

B. Existing boreholes should be logged, using the newest technology, televiewers, etc.

C. New boreholes should be sited on the basis of evaluation of data from 1 and 2. Estimates of costs, numbers of boreholes, and siting criteria should be provided.

D. Vertical seismic profiling should be attempted, utilizing a combination of existing and new boreholes, in order to define structural anomalies in the rock mass and obtain seismic velocities for follow on seismic surveys.

E. Geophysical seismic surveys should be conducted between the boreholes utilizing the boreholes to define stratigraphy and velocities.

F. The ESF should be planned and designed only after the results of A-E are available for review. Explicit criteria and rationales for the ESF need to be worked out on the basis of all available geologic and geophysical data before any major underground incursions are made.

5. Issues Resolution

A reasonably well thoughtout series of activities has been planned for characterization of structural features. However, the sequencing of activities appears completely inadequate (see above), and little thought has been given to making maximum use of existing and newly acquired geological information in siting and organizing the activities. Numerous questions are unanswered by the Study Plan about the process of selection of sites for stripped pavements and boreholes. How are sites chosen? What statistical tests are used? How will DOE ensure that sites are representative and that they cover the entire range of variation? It is of considerable importance to plot sites on a highly detailed topographic and geologic basemap to evaluate these questions. Furthermore, many problems of measurement and representativeness or spatial data have not been adequately addressed. Many critical scientific questions regarding the geometry, regularity, continuity, and dating of fractures and faults have not even been discussed. We consider it unlikely, therefore, that this study, as written, will

resolve the issue of the characterization of the structural features of the site area.

Based on the information available in this document, we consider it unlikely that the objective of complete characterization of the structural features will be met.

6. References

The reference base, as it relates to topical studies around Yucca Mountain seems to be fairly complete. However, references are completely lacking in most of the recent literature on fractures and joints in rocks and there are no references from the Journal of Structural Geology.

SPECIFIC COMMENTS

On page 2.1-1, Activity 8.3.1.4.2.2.1, geologic mapping of zonal features in the Paintbrush Tuff at a scale of 1:12,000 is discussed. Zonal features in tuffs can be distinctive and extensive enough to provide markers for recognizing fault offsets, however, they are planar (tabular) features, not linear features. They therefore show only an apparent offset. Kinematic indicators, or a cross-cutting planar structure that provides a piercing point, are needed to determine direction and amount of net slip.

An Open-File report by Scott and Bonk on the northeast part of the mapped area was published in 1984 as preliminary. That map, which has been the principal basis for the entire Yucca

Mountain repository program has never been subject to a quality assurance review or finalized. Also, it is our understanding that the rest of the mapping was completed, and compiled on topographic bases in FY 1987. Six years later, the remainder of the mapping has not yet been published. It is stated that 1:12000 scale is adequate to show the structural geometry necessary to construct structural and tectonic models of Yucca Mountain. This is inaccurate. Many fine-scale faults not mapped in field had to be postulated by Scott and Bonk to account for steep dips of lithostratigraphic units in the vicinity of large faults. The geometry of these small faults is critical to structural interpretations, yet was never evaluated in the field. A much larger mapping scale is clearly necessary. Local mapping at larger scales is proposed, but no details are provided.

On page 2.2-1, Section 2.2.2.1, second paragraph, states that nine pavement sites have been completed, and that a total of approximately fifty sites will be studied by this method. Figure 2.2-1, however, shows only seven completed sites and twenty-seven potential sites. These need to be plotted on a much more detailed topographic base map, preferably with 1:12,000 scale geological information superimposed, in order to assess the usefulness of the existing and proposed sites. No map of the uncleared outcrop sites is given, therefore, we cannot judge whether systematic coverage can be obtained from the surface-fracture network studies. In addition, there needs to be some discussion of sample site selection strategy, and the statistical approaches that will be used, particularly fractals.

As part of Activity 8.3.1.4.2.2.2 Surface-fracture network studies, the pavement and outcrop methods discussed under Section 2.2, page 2.2-1, complement each other and both are necessary. The Study Plan states that nine pavement sites and fifty uncleared-outcrop sites have been completed. It is difficult to evaluate the choice of the number of sites without seeing the results of those studies first. However, "two or more sites in each outcropping unit" (p. 3.2-1) sounds low, particularly if "unit" refers to map units. A single tuff cooling unit typically comprises a non-welded base, a welded central zone, and a vapor-phase altered top. Each of these would be expected to have different primary fracture characteristics, and potentially different susceptibility to later tectonically-induced fracturing. A mappable member or formation may comprise more than one cooling unit. Two study sites in such a unit will probably not yield representative results.

On page 2.2-3, Section 2.2.2.4 states that the timing of surface-fracture network studies is known to be dependent upon data from geologic mapping, yet mapping is said to have been finished in 1987. When and how will the Scott and Bonk 1984 preliminary map and the 1987 maps be finalized? What quality assurance data qualification process will be utilized?

On page 2.3-1, Section 2.3, borehole evaluation of faults and fractures is discussed. Previous studies of detailed logging of fractures and faults in the cores from UE17e on the NTS as part of other structural studies, used the existing fracture logs as a starting point. The main problems with these logs appear to be (1) the geologists did not, or could not, distinguish between faults, joints, and drilling-induced fractures; (2) the geologists did not note kinematic indicators on the faults even though some surfaces showed sense of slip and/or multiple slip direction; and (3) there was a noticeable difference in log descriptions between geologists who logged different parts of a single core. All of these problems can be alleviated in the proposed study by assuring that all geologists doing fracture logging have experience with the interpretation of small-scale structures and by duplicating enough of the logging to insure reproducibility of structural observations.

In Section 2.3.1, page 2.3-1, first paragraph; Although we understand the rationale for the three logging methods and support the use of all three, we recommend that direct observation of cores be used as much as possible. This provides the kinds of information (e.g., nature of fractures, compositions of fracture fillings, kinematics of fault surfaces) that are not available from the other methods.

In Section 2.3.1, page 2.3-1, we interpret the third paragraph to say that 10% of the total oriented core, if available, would be sufficient for measuring fracture orientations. We see several problems with this approach, primarily related to (a) how much core will be available for study, and (b) whether the available core is representative. How much of each hole will be cored? If only some of the hole is cored, how are the segments to be cored chosen? How much of this is oriented core? How and why is the decision made to collect oriented vs. unoriented core? All core collected as part of this and related studies should be oriented. Based on observations on UE17e (which was continuously cored for its entire 3000' length), there are several reasons to question the representativeness of observations on 10% of a core, First fracture density can change dramatically as a result of subtle compositional variations; second fracture density changes with proximity to faults, the location(s) of which will probably not be known when coring intervals are selected); and third, core recovery is commonly poorest in fault zones.

In Section 2.4.1, page 2.4-1, although there is an advantage in using photogrammetry for accurate location of the mapped features and for generating a complete digitized data base, virtually all other measurements should be made manually at the working face.

On page 2.4-4, Section 2.4.2, second paragraph, we strongly disagree with the statement that "through photogrammetry the geologist is able to gather critical data which would be lost by conventional mapping". We think the opposite is true. Photogrammetry can probably provide fracture location, orientation, and extent more efficiently than sketching can, but it will miss the clues provided by subtle changes in color, texture, mineralogy, etc. that allow the geologist to interpret the origin of a given fracture, recognize which are the important faults, determine the number, sense(s) and relative age(s) of motion on a fault surface, etc. In addition, as have previously noted, many critical measurements (e.g., fracture aperture, composition of fracture filling, etc.) cannot be made from a photograph.

On page 2.4-6, Section 2.4.2.2, second paragraph, hand-specimen petrographic descriptions should be done at the working face, not at the surface. Such descriptions are usually made on the basis of several samples, and are often supplemented by a look at surrounding rocks to confirm an unexpected observation, a check for how representative the hand specimen is, a look for systematic compositional variation with position in the bed, etc. None of this is possible to someone identifying a sample in a lab. The description of a simple sample under lab conditions may give more "reproducible" results, but that does not mean that they are more representative or accurate.

On page 2.4-6, Section 2.4.2.3, the second paragraph states, "Where excavations expose unusual geologic features...the geologists should be allotted sufficient time and access to avoid a loss or irretrievable data". We agree, but why does this not read "...geologists WILL be allotted sufficient time>>>"?

On page 2.4-7, under Section 2.4.3, why does there have to be a choice of methods? Photogrammetry (and the associated remote analysis of results) has some advantages, but it cannot replace the crucial observations made during conventional mapping. Crucial information such as fracture aperture, nature of fractures (joint or fault), fault kinematics, etc. can only be determined by conventional mapping methods.

On page 2.4-9, Section 2.4.3.6 states that, "The mapping will be driven by the rate of excavation progress." Does this mean that the mapping must keep up with excavation, even if some important measurements must be omitted? Who will make the progress decision, the geologist or the engineer?

On page 2.4-9, Section 2.4.3.8, the statement "Test methods selected for this activity are designed to reduce to a minimum the amount of time that geologists and associated technicians are required to spend underground..." in the concluding paragraph is an alarming example of misplaced priorities. The statement suggests that collection of site characterization data will be sacrificed for a perceived underground safety problem.

On page 3.2-3, Section 3.2.1.1 and Table 2.2-1, the list of fracture parameters to be measured does not include sense of slip. Slickenside pitch, which is listed, provides a line along which slip occurred, but not the direction along that line. Other necessary measurements which are not specified include the relative ages of mineral coatings and different fault sets, joint sets, etc. It is important to distinguish between faults and joints before making relative age determinations, because cross-cutting relationships in joints give the opposite result of the same pattern in faults. The relative age determinations must be made in the field, not in the office.

In Section 3.3.2.1, on page 3.3-2, how is the distinction between natural, coring-induced, and handling-induced fractures made? For natural fractures, how are joints distinguishable from faults?

In Section 3.3.7, page 3.3-5, we note that fracture orientation data are most useful when presented as stereograms because these display both strike and dip for each data point. For Section 3.3.8, page 3.3-5, we note again that it is very important that fracture data for all three subsurface techniques be compared and that fracture data for several complete oriented cores be included in this comparison.

On page 3.4-1, Section 3.4.1, in the second paragraph, the next to last sentence, states, "In reaches where conventional mapping is used..." This statement implies that there are places where it will not be used; how will each be chosen? How much of the ESF will not be mapped by conventional techniques?

On page 3.4-3, in Section 3.4.1.2 (b), please clarify if data will be rechecked in the field as necessary, or rechecked from the photos? If a feature does not show well on the photos, no amount of rechecking in the lab will improve interpretation. On page F-11, "Figure 5-1, Schedule for Study 8.3.1.4.2.2": Why is there no required exchange of information between these studies relatively early in the project as opposed to schedule years four or five?

On page T-18, "Table 2.4-2, Test characteristics of photogrammetric and conventional sketch methods of geologic mapping": This table omits the important consideration that the "conventional sketch" method results in data that cannot be obtained from the photogrammetric method (e.g., direction and sense of motion of faults, reactivation of fault surfaces, distinction between joints and faults, etc.).