Department of Energy
Washington, DC 20585

April 8, 1994

Mr. Joseph J. Holonich, Director
Repository Licensing & Quality
Assurance Project Directorate
Division of High-Level
Waste Management
Office of Nuclear Material
Safety and Safeguards
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Mr. Holonich:

Enclosed are the Exploratory Studies Facility starter tunnel map (enclosure 1) and analysis paper (enclosure 2), that your staff verbally requested. The map and analysis paper were previously sent to the State of Nevada on March 16, 1994.

If you have any questions, please contact Chris Einberg of my staff at (202) 586-8869.

Sincerely,

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

Enclosures:
1. Exploratory Studies
Facility Map
2. Analysis Paper

NH03 1/1
102.8
WM-11

cc w/encls:

R. Nelson, YMPO
R. Loux, State of Nevada (w/o encl)
W. Offutt, Nye County, NV
T. J. Hickey, Nevada Legislative Committee
D. Bechtel, Las Vegas, NV
Eureka County, NV
Lander County, Battle Mountain, NV
P. Niedzielski-Eichner, Nye County, NV
L. Bradshaw, Nye County, NV
C. Schank, Churchill County, NV
F. Mariani, White Pine County, NV
V. Poe, Mineral County, NV
J. Pitts, Lincoln County, NV
J. Hayes, Esmeralda County, NV
B. Mettam, Inyo County, CA

Rec'd with letter dtd
4/8/94

Yucca Mountain Project
Exploratory Studies Facility

North Ramp - Starter Tunnel

ANALYSIS PAPER: FULL-PERIPHERY GEOLOGIC MAP

Prepared for

U.S. Department of Energy

by

U.S. Geological Survey and Bureau of Reclamation

Geologic Mapping of the Exploratory Studies Facility
SCP No. 8.3.1.4.2.2.4

Principal Investigator - Steven C. Beason

102.8

ENCLOSURE 2

Yucca Mountain Project - Exploratory Studies Facility
North Ramp - Starter Tunnel

Analysis Paper:
FULL PERIPHERY GEOLOGIC MAP

Introduction

The Department of Energy is constructing the Exploratory Studies Facility (ESF) to investigate the subsurface conditions of the volcanic rock at Yucca Mountain. The facility consists of 75,000+ feet of various sizes drifts excavated by both machine and drill-blast methods. Under the tasks of "Geologic Mapping of the ESF" (SCP No. 8.3.1.4.2.2.4) the walls and crown of each excavation will be mapped in detail to determine the geology encountered by each drift. The first completed opening of the ESF is the starter tunnel of the North Ramp. The starter tunnel is a 200-foot long drill-blast modified horseshoe-shaped tunnel mined into the east side of Exile Hill, on the eastern flank of Yucca Mountain. The purpose of the starter tunnel is to prepare a launch area for an 8m diameter tunnel boring machine which will excavate the ramps and main drift of the ESF. A test alcove was excavated in the right wall of the starter tunnel at sta. 1+40. The test alcove is an 18-foot diameter modified horseshoe-shaped drift which will provide space for unsaturated-zone hydrology testing. The geologic mapping of the test alcove will be included with a later report.

How This Map Was Developed

The method for recording the locations and traces of fractures in the starter tunnel is full-periphery mapping. In this method, the entire circumference of the excavation is represented by a flat sheet. The walls of the tunnel are "unrolled" such that the centerline of the tunnel crown is located longitudinally on the center of the map area. The base of the left and right walls are located at the top and bottom of the sheet (Figure -1). The advantage of this method is that features can be located on the tunnel wall and then sketched onto the map without any compensation or projection. Strike and dip symbols are placed on the map at the location where the measurement was taken. The locations of both geologic and non-geologic features such as rock reinforcement, photogrammetry targets,

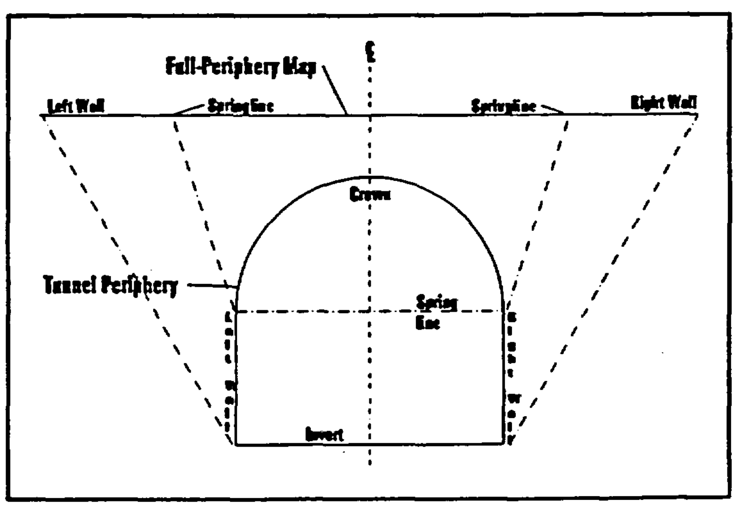

Figure 1

and samples can also be recorded on the map. The viewer should keep in mind the map is representation of the tunnel surface and not a plan view of the tunnel. The view shown here is as if the viewer were outside and above the tunnel.

The starter tunnel was excavated by the heading and bench method to maximize the amount of ground control possible during excavation. This method is common with larger openings and involves excavating smaller drifts, one at a time, stabilizing that opening, and then excavating the next portion of the drift. At the ESF starter tunnel, a pilot bore 12 ft. high X 12 ft. wide was opened first, and this heading advanced to sta. 1+00. The right and left slashes were then advanced to sta. 1+00. The pilot bore was then advanced one or two rounds (12-16 ft.) and then the slashes caught up to the face. After the heading was completed to sta. 1+96, the contractor began removing the lower bench. This bench was removed in 6 to 10-foot rounds to sta. 1+96. The tunnel was stabilized initially by the use of split-set rock anchors and 6-inch welded wire mesh. These materials were followed later with the application of shotcrete.

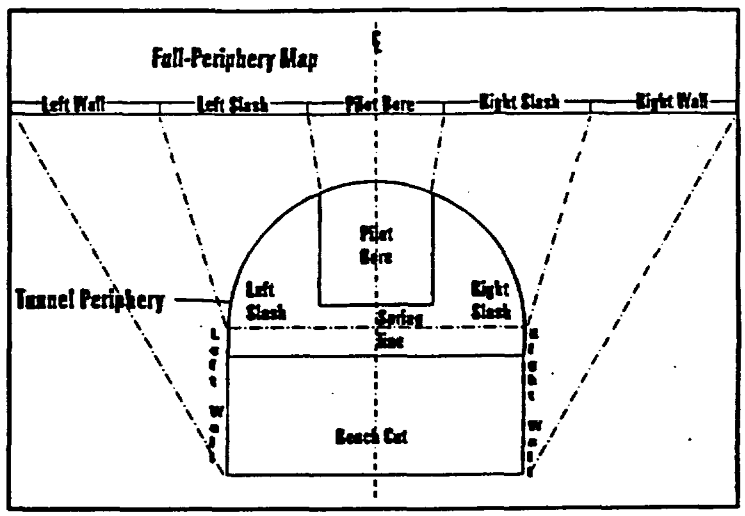

Figure 2

The mapping was performed after the installation of split sets and mesh, but before shotcrete. In the pilot bore, this usually consisted of mapping one or two blast rounds at a time (6 to 16 ft.). This offered a very limited look at the geology of the starter tunnel. Also this offered no opportunity beyond the time allotted to recheck the mapping as the shotcrete immediately followed the mapping sessions. Of the mapping done in the pilot bore, only the portion in the crown becomes part of the permanent map of the starter tunnel since the walls of the pilot bore were later removed with the slash cuts (Figure 2). The full-periphery map then is a mosaic or composite resulting from the assembling of a number of smaller field maps developed over the period from April to September, 1993.

The map was drawn by observing features on the tunnel wall or crown and then sketching the features on the map. Stationing control was established by using the photogrammetry targets (placed by the mapping team before full-periphery mapping begins). Generally, photogrammetry targets and split sets were located and sketched onto the field base map before any geology. These targets helped geologists locate both station and distance above or below a known datum line such as springline, centerline, or floor. With these in place, the geologist then noted at what station a particular geologic feature intersects a known line such as the springline, and where the fracture terminates. The strike and dip of the feature were then measured and recorded on the map. In areas where detailed line surveys (DLS) were being done, the geologist compared the map locations with locations recorded in the DLS notebook to assure that features on the map correlated with those on the line surveys. On the map, only features with trace lengths longer than 3 ft. are recorded. On the DLS, features as short as 1 ft. are recorded. Where geologists determine that some feature less than 3 feet long is of significance, they may opt to include the feature on the full-periphery map.

Fracture symbols appearing on the map represent the strike and dip taken at the point. An individual fracture may have more than one strike and dip symbol if the geologist observed that the fractures curves or angles. Please note that both the strike and dip are usually shown at each symbol. Where only the dip is shown, the strike of the fracture parallels the fracture trace at that point.

Use of English and Metric Units in Description

Because of construction stationing[1] and surveying constraints both English and metric units have been used in these descriptions. Generally, all stationing and descriptions relating to the excavation have been presented in English units. Geologic descriptions are generally described using metric units on smaller features (lithophysae size, fracture aperture, etc.). For larger features (fault offset, width of zones) both units are displayed.

Mapping Teams

Full-periphery mapping and detailed line surveys were performed by teams of Bureau of Reclamation personnel of three to six people. These teams were supervised by the principal investigator, Steven C. Beason, or the project geologist, Gary Turlington. Present for significant portions of the mapping were Michael F. Fahy, Paul A. Burger, Larry Hobbs, Rob Lung, and Derek W. Ryter. A complete list of mapping personnel is available upon request from the principal investigator.

Types of Features are Mapped

The map displays the locations and characteristics of fractures, foliation surfaces, faults, and shears. Areas of fallout, breakage to large fracture faces, and other notes which convey to the viewer the condition of the tunnel can be placed on the map.

Where the tunnel walls have broken to fracture surfaces over relatively large areas, the area of the surfaces are shown by 45° cross-hatching (solid lines). These are generally shown when surfaces are larger than 10 ft^2. Where overbreak or fallout occurs greater than 3-4 ft. outside the normal tunnel diameter, these areas are shown using a dashed hatching.

Eleven areas on the map are shown as intensely fractured. These areas are regions where the fractures are too closely spaced or are irregularly fractured with such intensity that individual

[1] **Stationing is a construction symbolism to delineate the number of feet from the start of a particular project. The designation "Station 1+25" simply represents 125 feet from the beginning of the excavation. In this case, the ESF starter tunnel begins at sta. 0+00, with the face of the excavation at sta. 1+96.**

fracture planes cannot be shown on the map.

Geology of the Starter Tunnel

Petrology

The entire starter tunnel was excavated in the upper lithophysal zone of the Tiva Canyon Member of the Paintbrush Tuff. The rock is a rhyolitic, densely welded, ash-flow tuff. It is typically brownish-gray to gray, devitrified, with light-gray, flattened pumice fragments to 5 cm in size. Lithophysae are present throughout the rock in this section of tunnel. The lithophysae vary in size and percent volume of the rock mass, having both the highest percent volume and largest size near the portal in the upper half of the tunnel.

Between stas. 0+00 and 0+50, lithophysae up to 60 cm in diameter were observed, with average size 6-10 cm. Percent by volume is estimated to be as high as 30% near sta. 0+15 in the crown and upper wall. The lithophysae in this area are typically oblate with aspect ratios of 2:1 to 3:1 (L:H). The lithophysae frequently exhibit drusy quartz or opal linings, but also commonly have red-brown smectite (only when intersected by a fracture), devitrified pumice, or occasional vapor-phase crystallization.

Between stas. 0+50 and 1+97, both the percentage and volume of the lithophysae decrease. Size of the lithophysae decrease to 2-6 cm, and at the face (1+96) comprise less than 5% of the rock volume. The lithophysae become spheroidal with increasing depth into the cooling unit (toward the tunnel heading). Aspect ratios near the face range from 1:1 to 2:1, and the shape sometimes convolute. Lithophysal fillings are similar to those near the portal, with drusy quartz and opal continuing as the most common filling, but smectite fillings were rare.

Foliation surfaces were common throughout the starter tunnel, but were rarely continuous prior to sta. 1+00. The foliations referred to here are generally parallel to, but distinct from, the flattening planes observed in the lithophysae. The foliations were not always distinct discontinuities, but frequently appeared as devitrified pumice-rich zones along which discontinuities formed. The zones were up to 5 cm thick. the foliations frequently provided failure planes along which the upper faces of wedges formed. The foliations also served as indicators of the dip of the ash-flow, and as reference markers for offset along shears and faults. Of particular note is the high percentage of fractures which terminate in the foliation surfaces, especially between stas. 1+00 and 1+97, where more than 50% of the mapped fractures terminate in foliation traces.

Structure

Only one fault with discernible offset is shown on the map. This fault intersects the crown centerline at Sta. 1+84. The fault strikes 175°, and dips 83° SW. The fault is mapped with 45 cm (1.5 ft.)dip-slip offset, down to the SW. The fault zone varies in thickness from about 1 cm to about 150 cm (~5 ft.). No slickensides were visible along the fault surface.

Numerous shear planes were observed (identified by the presence of breccia or thin gouge) in the starter tunnel, some with apparent local offset up to 30 cm (1ft.), but none with offset which extends across the tunnel. The most apparent of these shears is a zone which extends irregularly across the tunnel from stas. 0+25 at the base of the left wall to 0+16 (crown), to 0+41 at the base of the right wall. The zone is quite irregular, varying from a few centimeters in thickness at springline on the left wall to nearly 1.8 m (6 ft.) in the crown. The fillings in these shear zones are composed of both clast- and matrix-supported breccias. Where the zones widen to 30 cm (1 ft.) or more, the breccia is usually clast-supported, with the matrix composed of clay to gravel-size materials, and clast sizes to >30cm (1 ft.). Where the zones are less than 30 cm (1ft.), the shears are typically matrix-supported, with small lenticular and tabular clasts (<15 cm) in a matrix of clay to sand-size materials. Some shears display thin, usually discontinuous, fillings of gouge probably derived from the adjacent wall rock. All materials observed in the shear zones are similar in appearance to the wall rock in color and composition. The breccias are uncemented and frequently display open voids between clasts to 1cm. The shear zones are commonly bounded by distinct fracture planes.

FRACTURE FINGERPRINT DIAGRAM

Data for the fracture fingerprint diagrams (FFD) is gathered using detailed line surveys along the right wall of the slash cut in the starter tunnel (4 ft above springline). The FFD is comprised of several fracture interpretation diagrams on two sheets: a lower hemisphere stereographic equal area projection of poles to fracture planes (poles are vector normal to the fracture plane); a contour plot of pole density; a strike azimuth versus dip magnitude crossplot; a strike azimuth histogram; a dip magnitude histogram; and a continuity plot (strike azimuth versus length). A second sheet contains length, aperture, and roughness histograms.

The stereographic projections allow the recognition of distinguishing of dominant fracture sets based on orientation clustering. The strike azimuth versus dip magnitude crossplot determines whether the strike and dip are correlated. If they are not correlated, then univariate statistics may be applied to each. The continuity plot demonstrated whether there are differences in length distributions for preferred orientations.

Forty-four discontinuities were measured along the right slash cut DLS of the ESF North Ramp Starter Tunnel. A 2% count circle is appropriate for this lower hemisphere Schmidt plot analysis. Contour levels of 4% or greater have significance when compared to a uniform distribution. There are five sets identified from the contoured Schmidt plots. One set, striking 329° and dipping 25°NE, represents the foliation or parting planes observed. All other sets are steeply inclined. There are two basic families (grouping of sets) among the steeply inclined discontinuities. Distributed about a mean orientation of 175° dipping 69°SW are three sets - one primary (175°/69°), and two secondary sets (206°/74° and 152°/76°). These can be interpreted as shear fracture sets (strike differences of 206°-175°= 31° and 175°-152°= 23°) about the central fracture set (175°/69°) which can be interpreted as an extension set. In addition, there is a separate set with orientation 241° dipping 86° to NE with a strike separation of 66° from the primary set.

As displayed on the continuity plot, all sets exhibit a range of lengths except for the set

206°/74° which are short (generally less than 7.0 feet in length). All other sets exhibit lengths which range up to 20 feet with a few in excess of twenty feet. Continuity is interpreted to be extensive with respect to the opening size (that is, the sampling area).

There is no correlation between strike and dip. There may be a "blind zone" for discontinuities parallel or subparallel to the tunnel axis (299°), however, there are no measured steeply inclined discontinuities for this orientation in the slash cut data. Based on the full periphery mapping, there are few discontinuities with that orientation.

ENCLOSURE FORM

THE ENCLOSURE CAN BE LOCATED: ENCL I & II
ARE IN TYMAN'S OFFICE

THE ENCLOSURE WAS SUBMITTED TO:

THIS PAGE IS AN OVERSIZED DRAWING OR FIGURE,

THAT CAN BE VIEWED AT THE RECORD TITLED:

ESF NRTH RAMP STARTER TUNNEL:

RIGHT SLASH CUT (RSC) WITHIN THIS PACKAGE

NOTE: Because of this page's large file size, it may be more convenient to copy the file to a local drive and use the Imaging (Wang) viewer, which can be accessed from the Programs/Accessories menu.

D-1

THIS PAGE IS AN OVERSIZED DRAWING OR FIGURE,

THAT CAN BE VIEWED AT THE RECORD TITLED:

DWG. NO. 0A-46-171
YUCCA MOUNTAIN PROJECT
STARTER TUNNEL-EXPLORATORY STUDIES FACILITY FULL-PERIPHERY GEOLOGY MAP RIGHT SLASH CUT (RSC)

WITHIN THIS PACKAGE ...OR, BY SEARCHING USING THE DOCUMENT/REPORT NUMBER

DWG. NO. 0A-46-171

NOTE: Because of this page's large file size, it may be more convenient to copy the file to a local drive and use the Imaging (Wang) viewer, which can be accessed from the Programs/Accessories menu.