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PRESHOT GEOLOGICAL ENGINEERING INVESTIGATIONS FOR PROJECT CABRIOLET PAHUTE MESA, NEVADA TEST SITE

by

R. W. Hunt
D. M. Bailey
L. D. Carter

October 1968

Sponsored by

U. S. Army Engineer Nuclear Cratering Group
Livermore, California

Conducted by

U. S. Army Engineer Waterways Experiment Station
CORPS OF ENGINEERS
Vicksburg, Mississippi

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CABRIOLET

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ABSTRACT

The site of the Cabriolet experiment is on Pahute Mesa, Nevada Test Site. The site media, explored by four borings, consist of porphyritic trachyte overlain by a thin soil layer. Fractured, vesicular zones in the upper portions of the borings yielded poor core recovery, while higher core recovery was obtained at depth in dense, less fractured rock. Flow layers strike approximately N35°E at the surface and impart a pronounced structural grain to the rock. At depth, most joints roughly parallel the flow layering and strike N20°E. Joint spacing ranges from less than 0.1 to greater than 10 feet.

Four high-angle faults are suspected in the vicinity of the site. Three of these strike roughly north-south and pass 200, 380, and 680 feet west of the site. The fourth inferred fault strikes approximately N63°E and passes 480 feet north of surface ground zero.

For dense, unfractured rock, the bulk density, saturated surface-dry basis, averages 158.5 pcf, while the bulk density, dry, averages 156.2 pcf. The porosity averages 4.5 percent, and the unconfined compressive strength averages 12,952 psi. The vesicular material, based on one specimen, had a bulk density, saturated surface-dry basis, of 136.1 pcf, while the bulk density, dry, was 129.1 pcf. The porosity was 21.3 percent, and the unconfined compressive strength was 7,090 psi.

PREFACE

Project Cabriolet is a planned nuclear cratering experiment to be conducted by the Lawrence Radiation Laboratory (LRL) as part of the U. S. Atomic Energy Commission's Plowshare Program. The site, located on Pahute Mesa at the Nevada Test Site, was selected by LRL.

The preshot geological and engineering properties studies were conducted by the U. S. Army Engineer Waterways Experiment Station (WES) under the direction and funding of the U. S. Army Engineer Nuclear Cratering Group (NCG) during the period November 1965 through February 1966. Borings (other than emplacement and instrumentation holes) were drilled by personnel of the Embankment and Foundation Branch, WES, under the direction of Messrs. T. B. Goode and A. L. Mathews. Boring locations were selected by NCG personnel.

Mr. R. W. Hunt and PFC L. D. Carter, Geology Branch, WES, collected and analyzed field data and with the assistance of Dr. R. J. Lutton prepared the geological portion of the report. The portion dealing with physical properties of the media was prepared by Mr. D. M. Bailey, Embankment and Foundation Branch, WES, using the results of tests performed by personnel of the Concrete Division, WES, under the direction of Mr. J. M. Polatty.

The investigations were under the general direction of Messrs. W. J. Turnbull, A. A. Maxwell, C. R. Kolb, J. R. Compton, W. B. Steinriede, Jr., and W. C. Sherman, Soils Division, WES.

Director of the NCG during the investigation and the preparation of this report was LTC W. J. Slazak, CE. Director of the WES was COL John R. Oswalt, Jr., CE. Technical Director of WES was Mr. J. B. Tiffany.

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CONVERSION FACTORS, BRITISH TO METRIC UNITS OF MEASUREMENT

British units of measurement used in this report can be converted to metric units as follows:

Multiply	By	To Obtain
inches	2.54	centimeters
feet	0.3048	meters
miles	1.609344	kilometers
pounds per square inch	0.070307	kilograms per square centimeter
pounds per cubic foot	16.0185	kilograms per cubic meter

CHAPTER 1

INTRODUCTION

1.1 PURPOSE OF PROJECT

Project Cabriolet is a planned low-yield nuclear experiment to be conducted in dry porphyritic trachyte. The lithology and topography at the site are similar to those at the Project Palanquin site some 2,500 feet[1] to the west. Project Cabriolet will provide an opportunity for additional study of the engineering properties of an explosion-produced crater in a hard, dry, rock medium.

1.2 SCOPE

This report presents the results of the preshot geologic and engineering investigations conducted for Project Cabriolet during the period November 1965 through February 1966 by the U. S. Army Engineer Waterways Experiment Station (WES) under the sponsorship of the U. S. Army Engineer Nuclear Cratering Group (NCG).

1.3 FIELD AND LABORATORY INVESTIGATIONS

The site for the Cabriolet event was selected in the fall of 1965 by the Lawrence Radiation Laboratory (LRL). Specifications and requirements for subsurface exploration were determined by NCG, and

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[1] A table of factors for converting British units of measurement to metric units is presented on page 9.

WES was assigned responsibility for the drilling. The program consisted of drilling of a centrally situated 6-inch core boring and three satellitic borings located at 120-degree radials, all to depths of about 200 feet (Table 1.1). Two of the satellite holes were NX-core borings, and the third was a 4- by 5-1/2-inch core boring. Lithologic logs were prepared from examination of the recovered cores. Photographs of the boreholes were analyzed, and the data were incorporated into the logs in Appendix A. In addition, existing maps (References 1 and 2) of surface geology of the area were modified on the basis of information gained from the project.

Three samples selected from boring Ue20L-1 as most representative of the site lithology were examined petrographically and by X-ray diffraction (Appendix B).

1.4 PREVIOUS WORK

The results of geological mapping of the Trail Ridge Quadrangle, encompassing the Cabriolet site, are to be published in the near future by the U. S. Geological Survey; a preliminary map is available on request (Reference 1).

Subsurface data collected on Pahute Mesa for the U. S. Atomic Energy Commission in connection with other projects are available as technical letters (References 2 through 8).

Preshot subsurface investigations by WES (Reference 9) at the Project Palanquin site, approximately 1/2 mile west, revealed lithologic and structural details in the same geologic formation as that at the Project Cabriolet site.

1.5 LOCATION AND ACCESS

The Cabriolet site (Figures 1.1 and 1.2) is located on Pahute Mesa within Area 20 of the Nevada Test Site (NTS). Surface ground zero (SGZ) is approximately 53 miles north-northwest of Mercury, Nevada, and approximately 1/2 mile east of the Palanquin site. Nevada State coordinates of surface ground zero are N 921,249.77 and E 544,285.63. The route from Mercury to the site extends north for 22.5 miles along the Mercury Highway to the Orange Road cutoff and then 9 miles along the Orange Road to the intersection of the Pahute Mesa Road. From this intersection the Pahute Mesa Road leads 40.5 miles northwest to the site; the last 5.6 miles are unpaved.

TABLE 1.1 SUMMARY OF SUBSURFACE INVESTIGATIONS OF THE CABRIOLET SITE

Boring	Coordinates[a]	Elevation	Total Depth	Angle of Boring	Type of Boring	Core Recovery	Borehole Camera Log	Caliper Log	Nuclear Density Log	Three-Dimensional Velocity Log
		feet msl	feet		inches	pct	interval, feet	interval, feet	interval, feet	interval, feet
U20L	N 921,249.77 E 544,285.63	6197.3	274.0	Vertical	48	--	None	5.0 to 273.0	None	10.0 to 205.0
Ue20L-1	N 921,254.83 E 544,279.22	6197.3	212.3	Vertical	6 by 7-3/4	79.7	12.0 to 124.0	0.0 to 210.0	0.0 to 204.0	130.0 to 200.0
Ue20L-2	N 921,047.14 E 544,363.44	6181.0	181.5	Vertical	4 by 5-1/2	97.8	5.0 to 175.0	None	None	None
Ue20L-3	N 921,291.53 E 544,072.72	6187.1	202.3	Vertical	NX	38.9	5.0 to 186.1	None	None	None
Ue20L-4	N 921,443.44 E 544,434.23	6202.6	201.3	Vertical	NX	43.8	3.0 to 190.0	0.0 to 196.0	0.0 to 196.0	None

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[a] Nevada State coordinates.

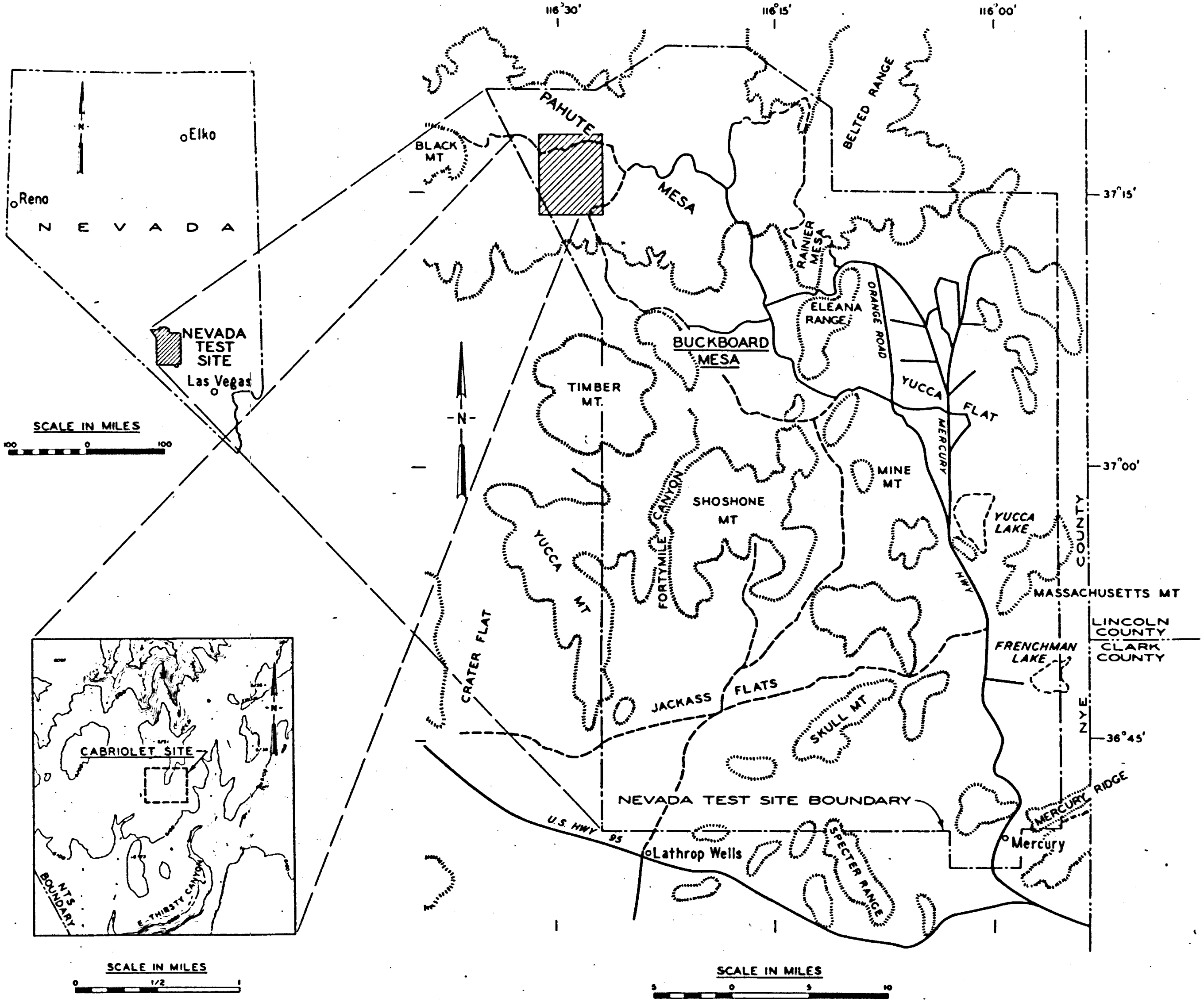

Figure 1.1 Location of Nevada Test Site and Cabriolet site.

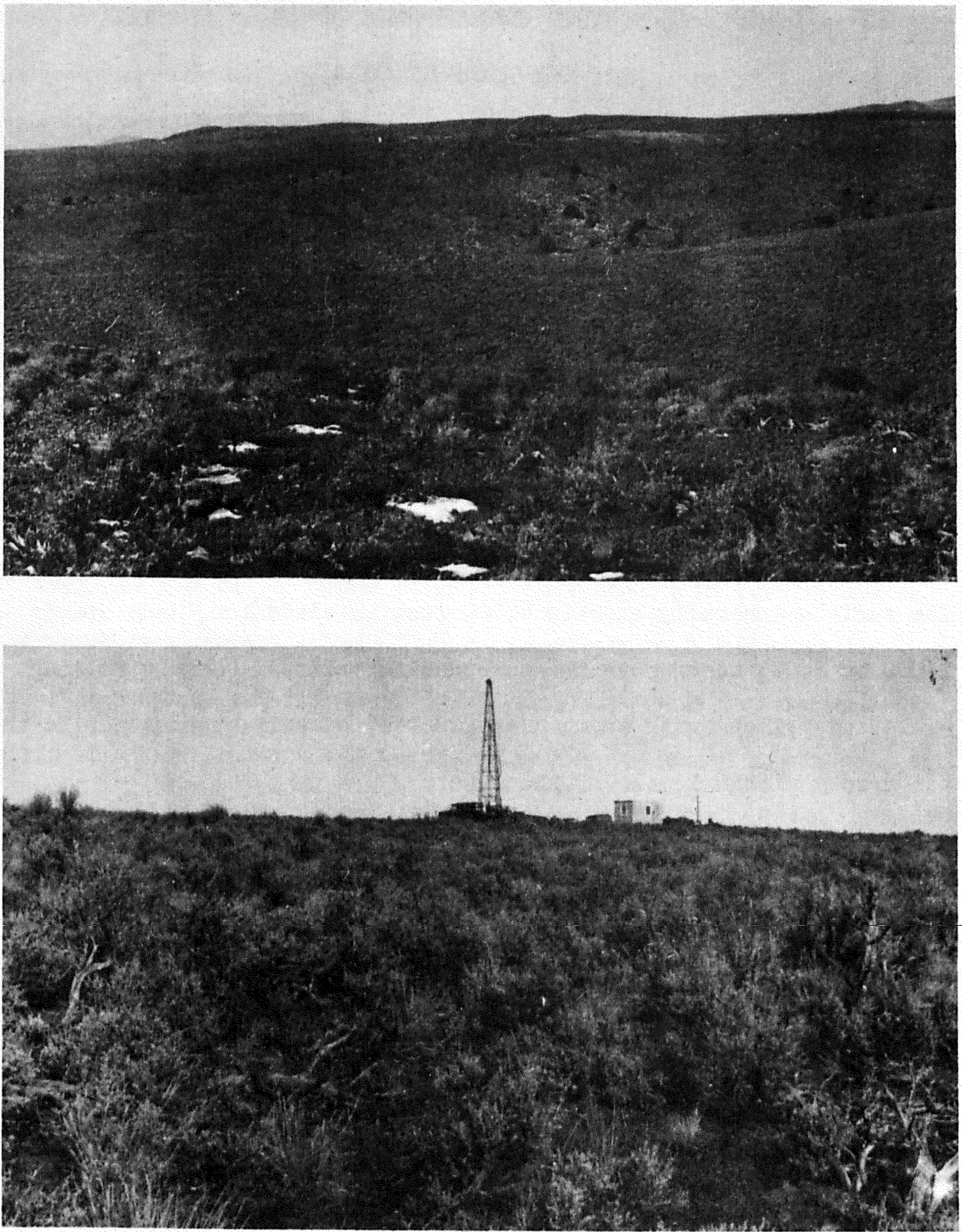

Figure 1.2 The Cabriolet site as viewed from the east (top) and from the south (bottom).

CHAPTER 2

GENERAL SETTING

2.1 PHYSIOGRAPHY

Pahute Mesa, with its long axis trending east-west, is roughly 50 miles long and 15 to 20 miles wide. Only the eastern half of the mesa lies within the NTS (Figure 1.1). The NTS in turn lies in the central portion of the Basin and Range physiographic province. This is a structural province that is characterized by north-south trending fault-block mountain ranges and intermontane basins.

Pahute Mesa is a maturely dissected mesa of Tertiary volcanics. The surface generally exceeds 6,000 feet in elevation,[1] and stands 1,000 to 2,000 feet above the surrounding valleys. Gently rolling hills and valleys with as much as 200 feet of relief characterize the topography within 1 mile of the site.

2.2 REGIONAL STRATIGRAPHY

Investigations to date have divided the rocks on Pahute Mesa into six major stratigraphic units, all Tertiary volcanics (References 4 and 5) excluding the relatively thin soils and localized alluvial and colluvial deposits. These volcanics, composed of tuffs and rhyolites, are at least 7,552 feet thick in Pahute Mesa Drill Hole (PMDH) No. 1 (Reference 3) located approximately 6 miles due

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[1] All elevations are in feet above mean sea level.

east of U20L, up to 8,380 feet thick in PMDH No. 2 (Reference 8) located approximately 5 miles northwest of U20L, and at least 13,686 feet thick in Ue20F (Reference 7) located approximately 1-1/2 miles southeast of U20L. Volcanic rocks by nature are discontinuous, and in this region formations vary considerably in thickness and physical properties in a lateral direction.

The Thirsty Canyon and Timber Mountain tuffs cap nearly all of Pahute Mesa and vary in thickness from 600 to 1,500 feet (Reference 4). The Ribbon Cliff rhyolite (locally trachytic) within which the site is located lies in the lower part of the Thirsty Canyon tuff. It overlies the older Timber Mountain tuff and is in turn overlain by the upper two members of the Thirsty Canyon tuff. These are the Spearhead member and the Trail Ridge member. These two members cap hills in the vicinity of U20L. Locally the Spearhead is absent, and the Trail Ridge rests directly on the Ribbon Cliff rhyolite. This is because of the marked topographic irregularity of the surface on which the Thirsty Canyon tuff was deposited (Reference 10).

The Ribbon Cliff rhyolite is confined in a 1- to 6-mile area centered near the site. The formation appears to represent a volcanic dome, centered west of the Palanquin site, built up by rhyolitic and trachytic flows. The fact that the Ribbon Cliff is at least 615 feet thick at U20K (Reference 2) coupled with the fact that it is either much thinner or absent in borings and outcrops at a distance of 1-1/2 to 5 miles from U20L indicates that the formation thins rapidly in every direction from its source. Flow layers first mapped for the Palanquin site (Reference 2) have been extended across the Cabriolet site by inspection of aerial photographs and verified by field measurements. The rhyolite appears to have flowed eastward.

2.3 STRUCTURE

The dominant faults crossing Pahute Mesa are near-vertical, north-south trending, normal faults with as much as 800 feet of offset (Reference 4). According to Reference 4, "Faults exposed at the surface are open, contain little or no breccia, and are only a few feet thick. The few faults cored in drill holes and inferred from geophysical logs in the older rocks range from closed with no brecciation and very thin, to very porous or healed with considerable brecciation and as much as several tens of feet thick."

Two north-south trending anticlines approximately 2 and 4 miles east of U20L, as well as a syncline approximately 1-1/2 miles west of U20L, may overlie buried topographic lows and highs.

Groundwater in the vicinity of U20L is approximately 2,000 feet below the mesa surface (Reference 6). No perched water tables were encountered during the preshot drilling.

CHAPTER 3

SITE GEOLOGY

3.1 TOPOGRAPHY

The Cabriolet site (Figure 3.1) occupies the crest of a ridge trending N30°E which reaches its maximum elevation of a little over 6,220 feet about 1,200 feet to the northeast. From this high point the ridge slopes gently southwest for 2,500 feet and gently northeast for an additional 5,500 feet, with an average width of about 1,500 feet. The average slope away from SGZ for a distance of 1,000 feet to the south, east, and west is approximately 7 percent, while from the north the slope is about 2 percent toward SGZ.

3.2 STRATIGRAPHY

Borings drilled at the Cabriolet site (Figure 3.2) revealed a relatively thin soil over at least 213 feet of porphyritic trachyte. A physically weak and porous glassy zone may mark a contact between lobes of lava. However, no attempt to show the extent of the upper lobe on the geologic map was made in view of the marked similarity among surface exposures and the lack of expression on aerial photographs.

3.2.1 Soil. Soil averaging 2 to 3 feet thick over the Cabriolet site consists of tan sandy silt containing sand- to boulder-size fragments of porphyritic trachyte and vitrophyre.

3.2.2 Ribbon Cliff Rhyolite. Petrographic and X-ray examinations on selected core samples from borings Ue20L-1 and Ue20L-3 (Appendix B) verify the trachytic composition of the medium at the site in spite of the fact that it is rhyolitic elsewhere. The rock consists mostly of devitrified, gray-brown to red-brown porphyritic trachyte, consistently containing about 20 percent of white, approximately equant, subhedral phenocrysts (averaging 1/4 inch in size) of alkali feldspar, with red-brown inclusions, bands, and flow layers common in many zones (Appendix A).

In spite of the uniform mineralogical composition of the unaltered rock, there are certain physical properties (i.e. vesiculation, denseness, degree of fracturing and jointing, flow layering) which can be distinguished (Figures 3.3 and 3.4). Several of these factors have affected core recovery, with highly fractured vesicular zones producing much less core than the dense, less fractured zones. In boring Ue20L-1, which had by far the largest percentage of core recovery, the lithology consists of (1) 15 feet of slightly to moderately vesicular, highly fractured and weathered rock, (2) 31 feet of dense, moderately to highly fractured rock, (3) 21 feet of slightly vesicular, highly fractured rock, (4) 17 feet of decomposed, crumbly, glassy rock, (5) a layer 50 feet thick that is slightly to moderately vesicular, highly fractured and altered, and (6) at least 75 feet of very dense, moderately jointed, flow-layered rock. All the borings bottomed in this lower zone which characteristically produced much higher core recovery percentages.

On the basis of stratigraphy and flow structure (see Section 3.2.3), it appears that the site media are in the upper portion of a single thick flow complex. The general decreases in vesicularity and degree of fracturing with depth are reasonable consequences of such a position. Thus a chilled, glassy crust encased a fluid interior at one point in the flow's history. Continuing movement of the hot interior until the entire unit had solidified caused intense fracturing and alteration in the hardened crust. Zones of poor core recovery, excluding that believed to be related to faulting, lie in this highly fractured and altered crust.

3.2.3 Flow Structure. Flow layers in the upper portions of the holes are widely scattered and have an average dip of about 60 degrees.

In the lower 75 feet of boring Ue20L-1, the lower 111 feet of Ue20L-3, and the lower 89 feet of Ue20L-4, flow layers are conspicuous. These layers, distinguished only by color, range from 1/2 inch to several feet in thickness. They dip at angles of about 60 degrees in the top, decreasing to 30 degrees toward the bottom and even as low as 15 degrees in the bottom of boring Ue20L-4 (Figure 3.4). Steep flow layers exposed at the surface strike about N35°E across the site and appear to establish a marked structural grain (Figure 3.5) on the upper media.

3.2.4 Joints. One hundred joint readings were taken from 15 different outcrops within 1,000 feet of the Cabriolet site. The orientations of these joints are shown in stereographic projection in Figure 3.6. Spacing between these joints ranges from 1 inch at some outcrops to about 10 feet at others. Most are tight. Where low-angle joints (ranging from 0 to 30 degrees) are present in an outcrop they are generally spaced from 3 to 12 inches and are also tight. A pronounced orientation preference is exhibited by joints measured in borehole photographs at depth (Figure 3.7). There is a very conspicuous tendency for joints to strike N20°E, roughly parallel to the flow layering (Figure 3.5).

3.2.5 Faults. Four high-angle faults are suspected of lying in the vicinity of the site (Figure 3.1) on the basis of linears visible in aerial photographs, localized breccia zones, and offset strata. Three of these pass at distances of 200, 380, and 680 feet west of SGZ and strike approximately north-south. The first two linears appear to bound a graben within which boring Ue20L-3 lies. A third linear striking approximately N63°E passes 480 feet north of SGZ.

The inferred fault along the east side of the graben appears to pass through Ue20L-3 between depths of 105 and 139 feet (Figure 3.3). The drill rods dropped under their own weight several inches in several places in this 34-foot interval. Also the core recovery in this zone was much less (34 percent) than in the same rock type in the other core borings. A fault zone extended from the surface expression through this zone would be approximately 7 feet wide and would dip about 80 degrees to the west. An offset of at least 10 feet along the graben is inferred from the fact that Trail Ridge tuff, which has been largely eroded from this portion of Pahute Mesa, is preserved in a topographic low that roughly parallels the graben. This tuff pinches out 60 to 80 feet south of boring Ue20L-3 and was not encountered in that boring.

Although the low position of Trail Ridge tuff can also be interpreted to be a result of deposition in a topographic low on the trachyte flow, a fault origin is considered more likely because of the linears visible in aerial photographs.

Indications of minor movement are manifested elsewhere in the core by thin (1 to 4 inches), steeply dipping breccia zones healed with calcite, and by striations along natural fractures. Striations on a vertical fracture between 125 and 140 feet in Ue20L-1 are dipping about 30 degrees, indicating lateral as well as vertical offset.

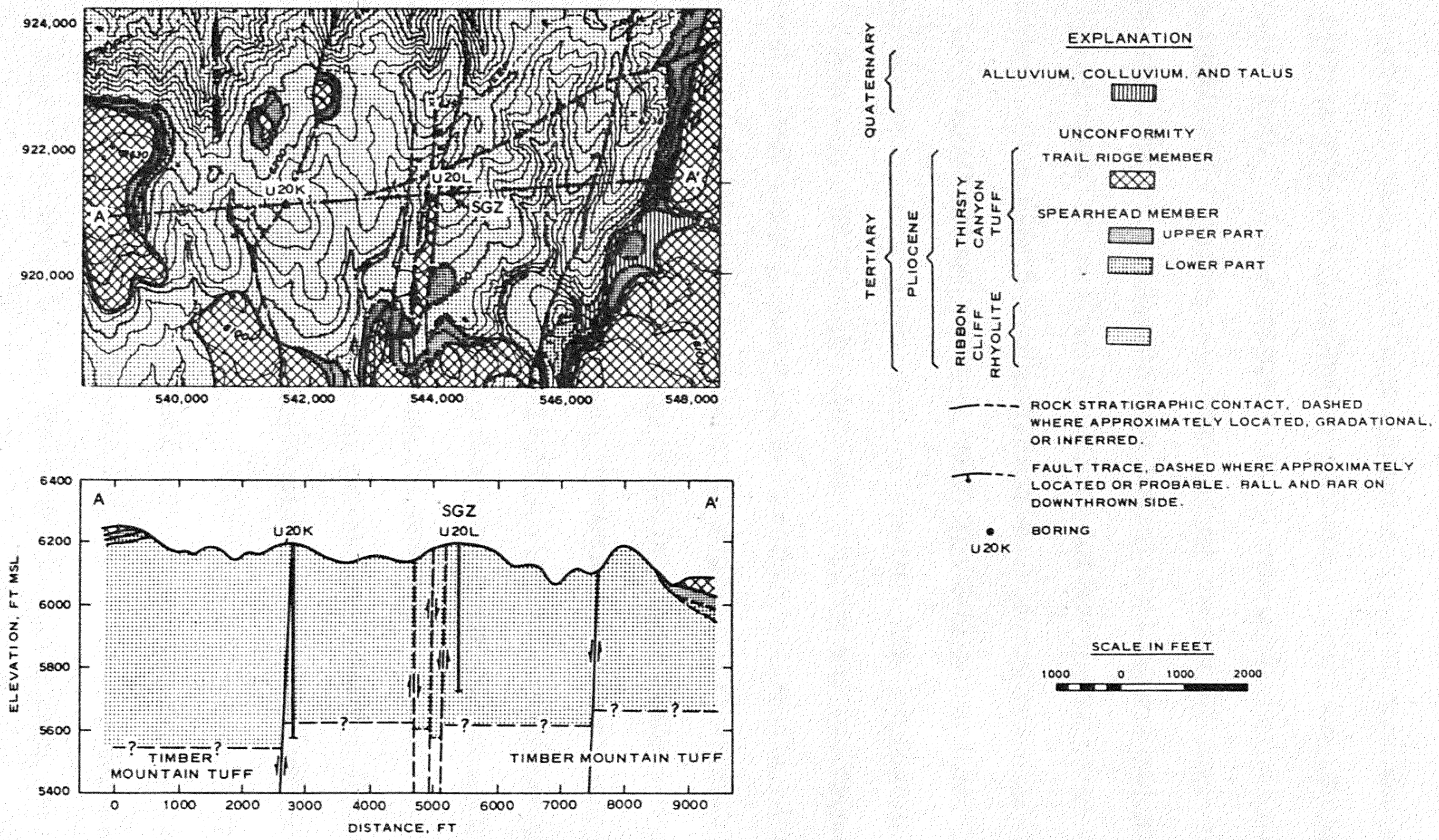

Figure 3.1 Geology and topography of Cabriolet site and vicinity.

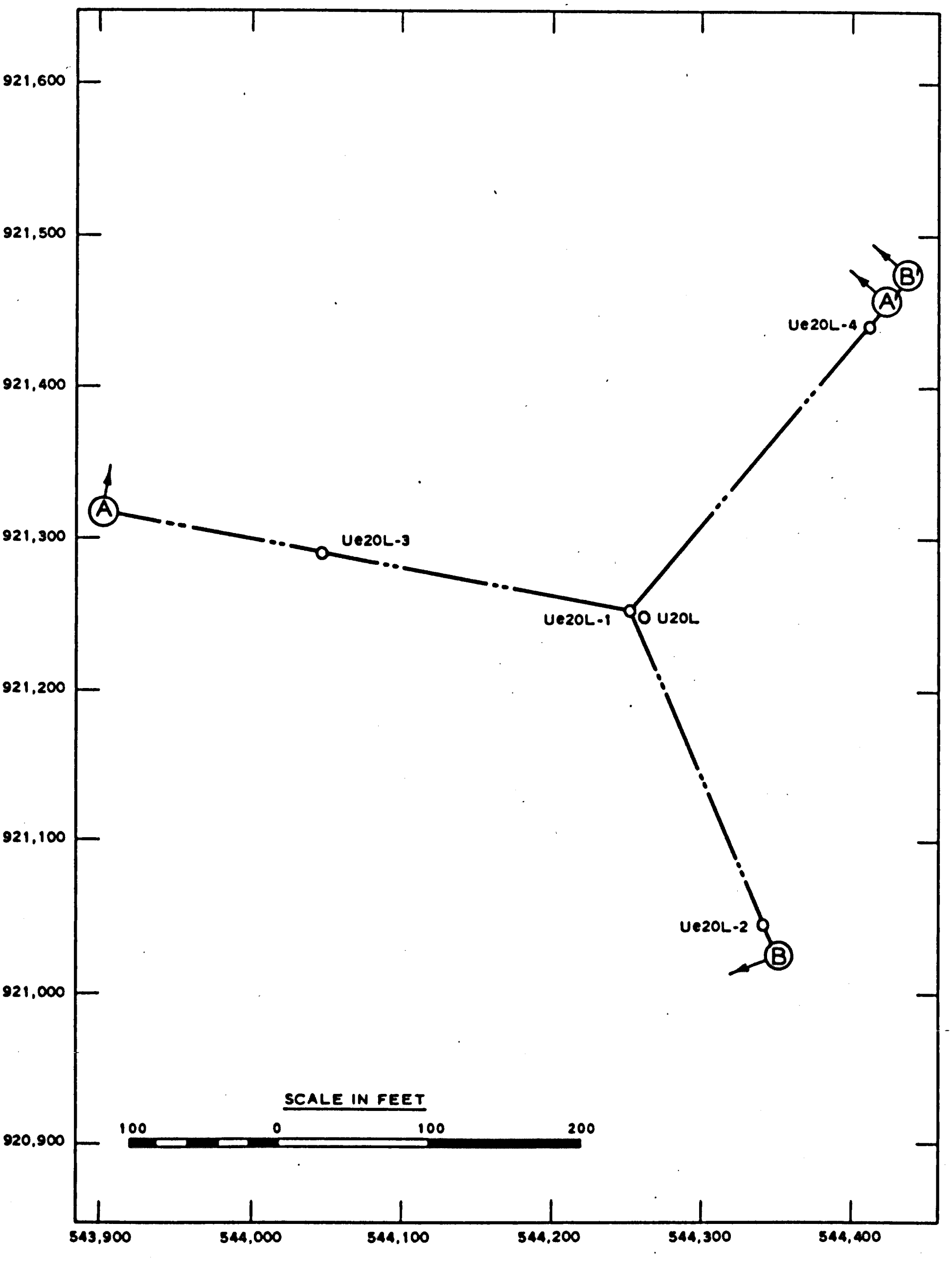

Figure 3.2 Location of borings at Cabriolet site.

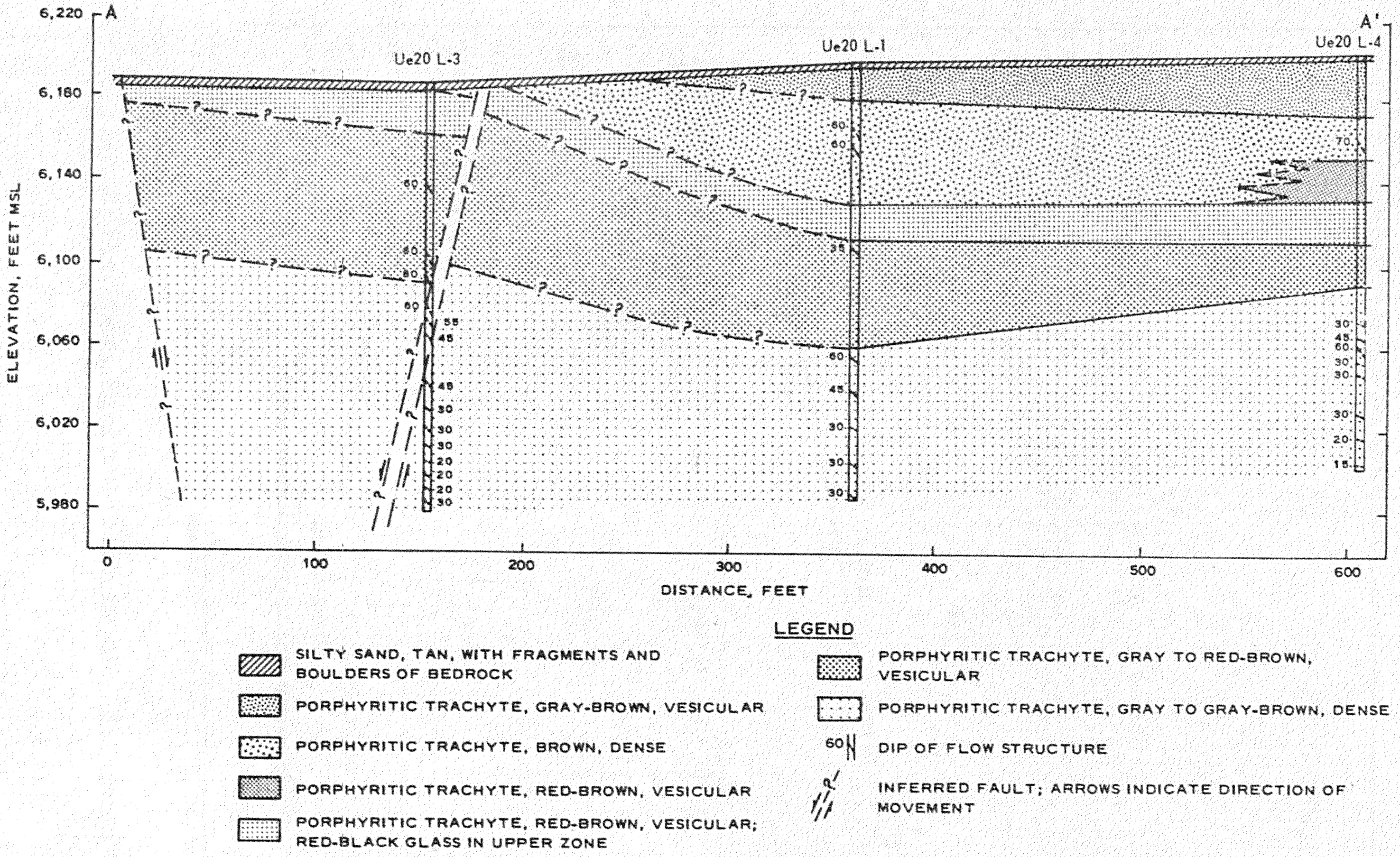

Figure 3.3 Stratigraphy between holes Ue20L-3 and Ue20L-4.

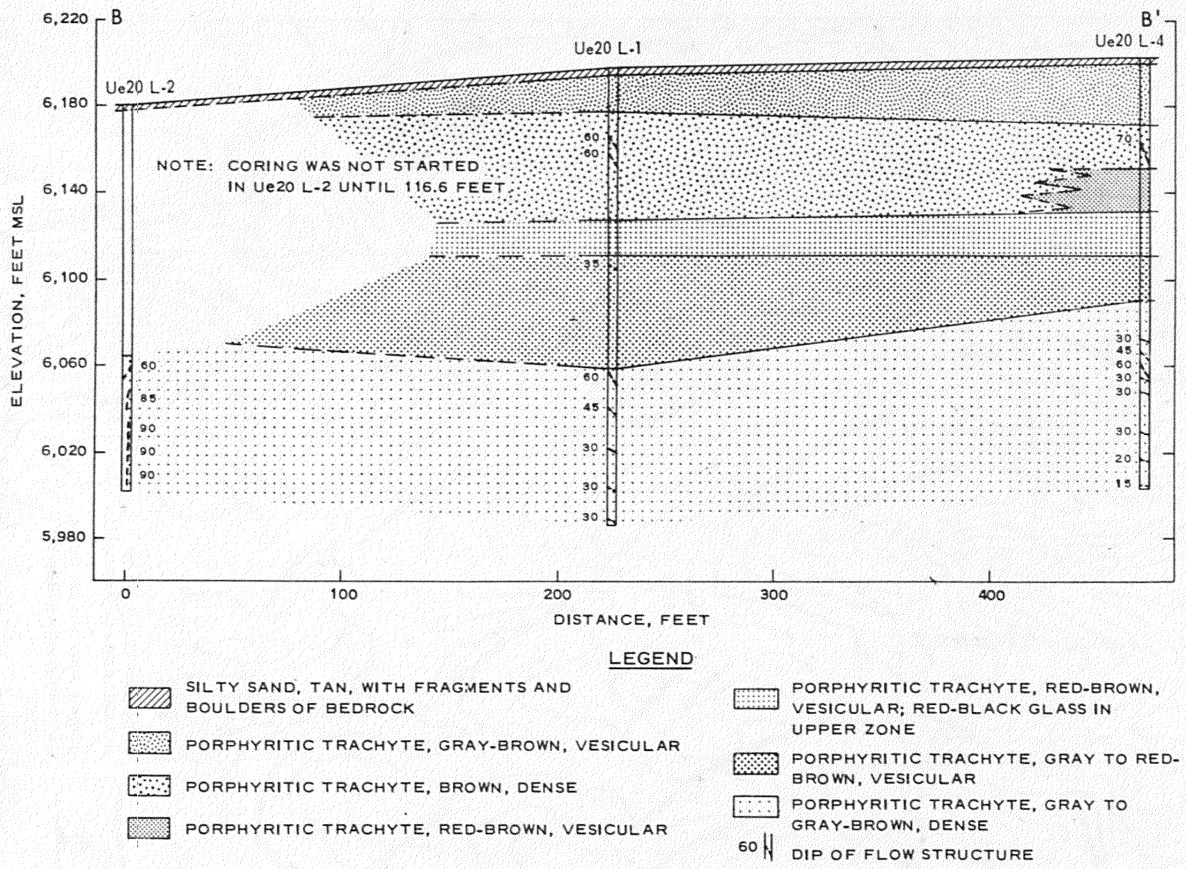

Figure 3.4 Stratigraphy between holes Ue20L-2 and Ue20L-4.

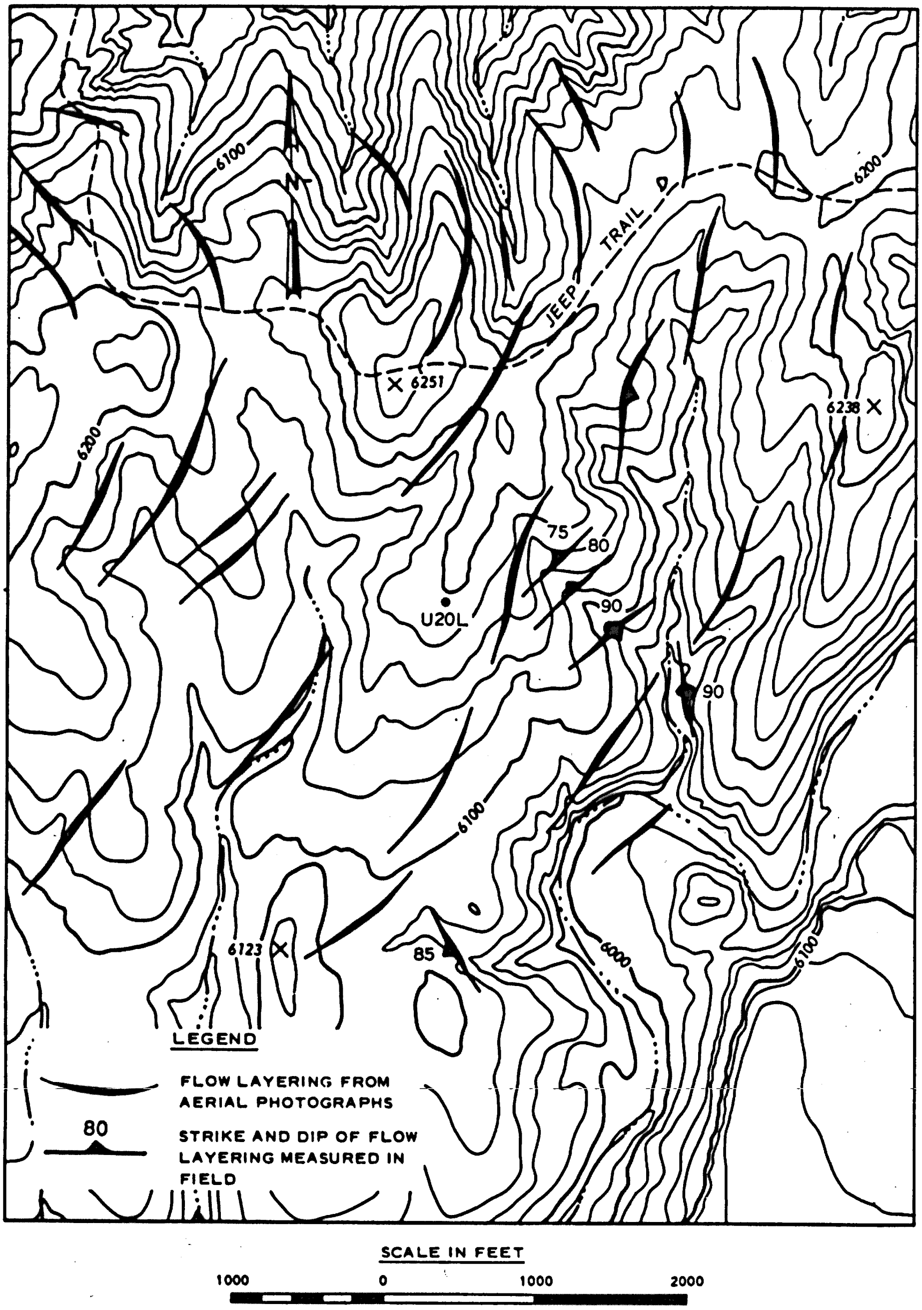

Figure 3.5 Flow structure within Ribbon Cliff rhyolite at Cabriolet site.

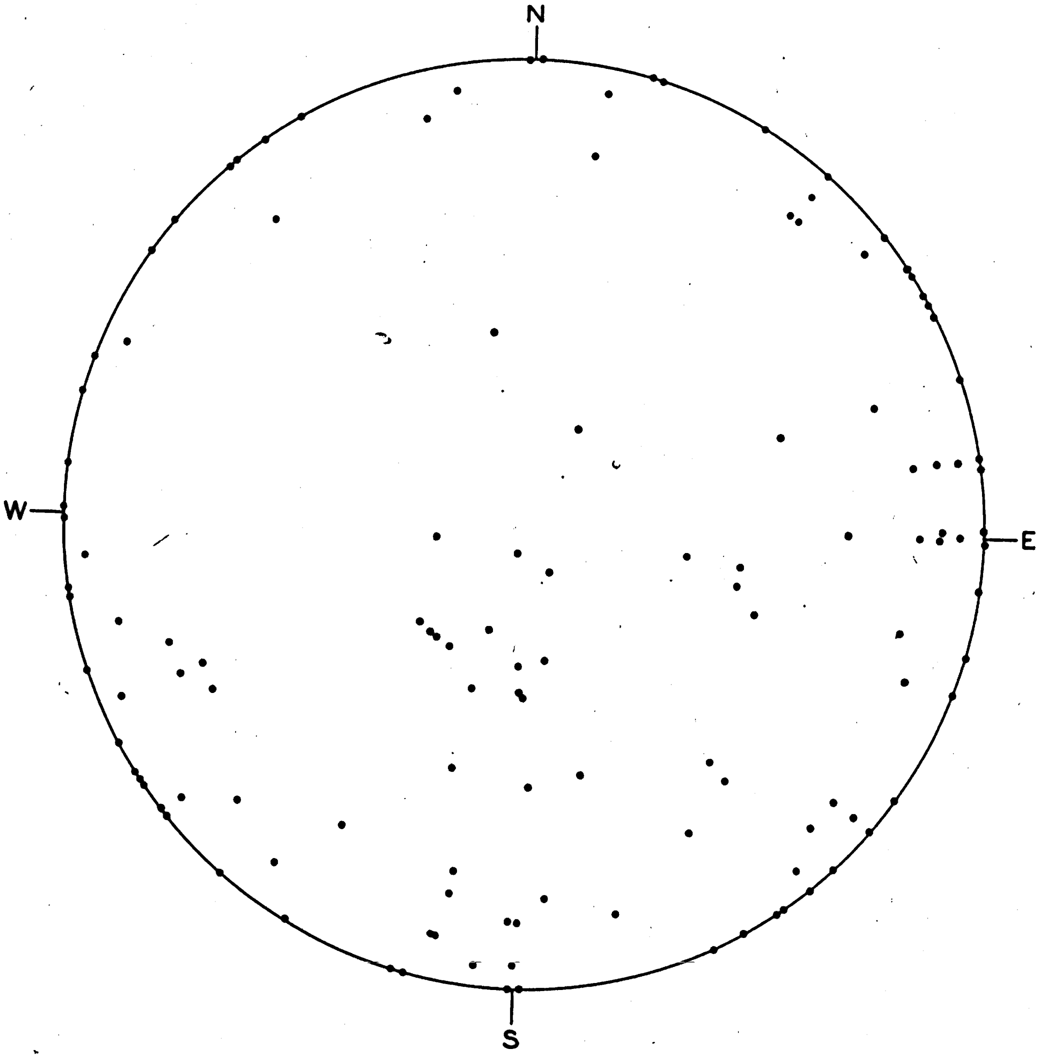

Figure 3.6 One hundred poles of joints in outcrops within 1,000 feet of Cabriolet site. Projected from lower hemisphere to equal-area net.

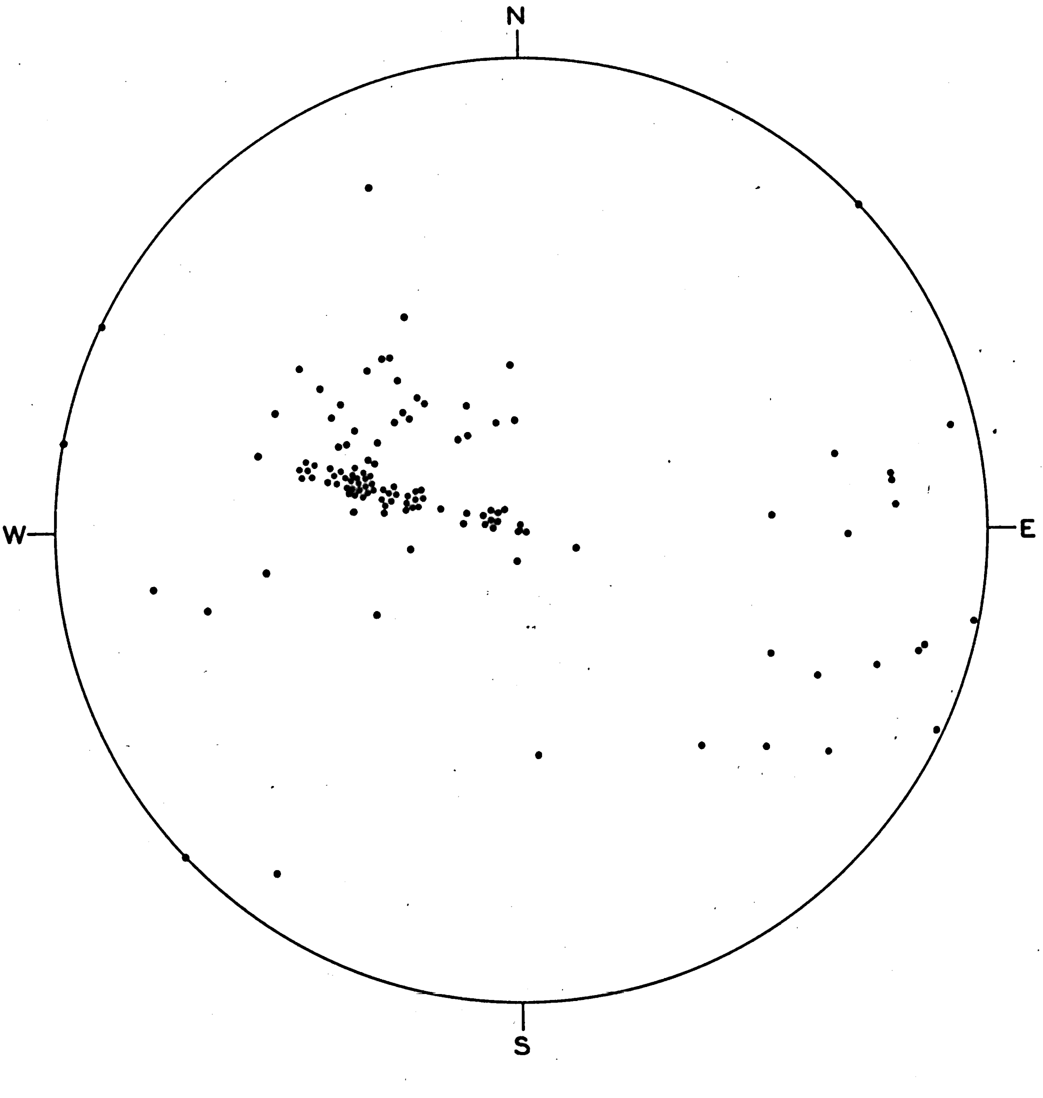

Figure 3.7 One hundred and twenty-five poles of joints occurring below a depth of 120 feet in borings Ue20L-2, Ue20L-3, and Ue20L-4. Projected from lower hemisphere to equal-area net.

CHAPTER 4

PHYSICAL PROPERTIES

Representative cores from borings Ue20L-1 and Ue20L-3 were selected for detailed visual description, petrographic examination, and physical testing. The locations of the cores are shown in Table 4.1.

4.1 SCOPE OF TESTS

The petrographic examinations resulted in classification of the rock as trachyte porphyry. (The classification of the rock as porphyritic trachyte or as trachyte porphyry is based on the relative percentage of phenocrysts and groundmass. The rock in question lies in the border zone between these two rock types, and field classifications have consistently termed the rock trachyte or porphyritic trachyte and laboratory classifications trachyte porphyry. From the standpoint of this study, this distinction is considered of no consequence, and the field classification of the rock will be used throughout the text.) The change in color with depth or between samples was found to be due to the variation in the amount of hematite and altered ferroan mineral grains in the groundmass. Representative samples of highly fractured and vesicular trachyte from boring Ue20L-1 between depths of 87.5 and 88.9 feet and from boring Ue20L-3 between depths of 76.7 and 77.7 feet were selected for testing. All other examined material was dense with little or no visible vesicularity. The petrographic examination suggested that the color variation in the dense material did not indicate properties which would appreciably affect the values from the physical testing, and this prediction was verified by the results from the physical tests. The petrographic report is presented in Appendix B.

The core recovery of vesicular trachyte was very low; hence, the material recovered probably is the strongest material as it is logical to assume that the weaker material was lost in recovery. Therefore, strength values obtained on the vesicular material should be considered as upper limit values. The dense material gave quite uniform values, and when appropriate, average values are given for this material.

Physical tests included determinations of bulk densities, specific gravity of solids, porosities, compressive strengths, tensile strengths, static and dynamic moduli of elasticity, dynamic moduli of rigidity, static and dynamic Poisson's ratios, and compression wave velocities. Detailed visual descriptions of the tested cores are given in Appendix B. Samples from boring Ue20L-1 were 6 inches in diameter; these samples were recored to NX size, approximately 2-1/8 inches in diameter, to provide more specimens and better length-to-diameter ratios for testing. Appendix C gives detailed data obtained from the physical tests and descriptions of the test procedures. This chapter presents only the principal results of the physical tests, and conclusions and observations concerning these results.

4.2 WEIGHT-VOLUME DETERMINATIONS

Table 4.1 gives values of bulk specific gravity, bulk density under saturated surface-dry (SSD) condition, bulk density under oven-dried conditions, specific gravity of solids, and porosity.

4.2.1 Specific Gravity of Solids. Six specific gravities of solids were determined. The specific gravity of the solids as shown in Table 4.1 is the ratio of the weight of a known volume of solid material to the weight of the same volume of water at 20 C. The values ranged from 2.60 to 2.66, and averaged 2.63. The specific gravity determined on a single core of vesicular material (87.5- to 88.9-foot depth, boring Ue20L-1) was 2.64. Thus it can be assumed that vesicularity does not appreciably affect specific gravity of solids.

4.2.2 Density. The dense material had bulk densities under SSD conditions ranging from 156.7 to 160.4 pcf and averaging 158.5 pcf. The SSD density of the vesicular material was determined to be 136.1 pcf or approximately 86 percent of the density of the dense material.

Oven-dried bulk densities of the dense material ranged from 154.5 to 158.5 pcf and averaged 156.2 pcf. The oven-dried bulk density for the vesicular material was 129.1 pcf or approximately 83 percent of the density of the dense material.

The oven-dried bulk densities of the dense material were, considering the averages, about 1.5 percent lower than the SSD densities, while the oven-dried bulk density of the porous or vesicular material was 5.4 percent lower than the SSD bulk density.

4.2.3 Porosity. Porosity is defined as the ratio of the volume of voids in a material to its total volume. The porosities shown in Table 4.1 were calculated from the specific gravities of the solids and the oven-dried bulk densities by means of the equation

$$n = \frac{G_s \gamma_w - \gamma_d}{G_s \gamma_w} \times 100$$

where

n = porosity, percent

G_s = specific gravity of solids

γ_w = unit weight of water

γ_d = oven-dried density

The values of porosity for the dense material ranged from 3.4 to 5.5 percent and averaged 4.5 percent. The porosity of the sample of vesicular material was 21.3 percent, which is 4 to 5 times greater than the porosity of the dense material.

4.3 STRENGTH DETERMINATIONS

4.3.1 Static Unconfined Compressive Strength. Six static unconfined compression tests were performed on representative core samples; five were conducted on dense specimens and one on a vesicular specimen from a depth of 87.5 to 88.9 feet in boring Ue20L-1. Results of these tests are shown in Table 4.2. The values for the dense material ranged from 12,250 to 13,420 psi and averaged 12,952 psi. The narrow range in which all values fell indicates the remarkable uniformity of the dense material. The unconfined compressive strength of the vesicular material was 7,090 psi, approximately 55 percent of the value for the dense material. The average values of unconfined compressive strength are in good agreement with the average values for porphyritic trachyte tested for Project Palanquin (Reference 9).

Stress-strain curves for the six unconfined compression tests are shown in Figure 4.1. Static moduli of elasticity and static Poisson's ratios were calculated for all unconfined compression tests and are discussed in subsequent sections.

4.3.2 Static Tensile Strength.

Static tensile strengths were measured by means of tensile splitting and direct tensile tests. The tensile splitting tests were conducted on six specimens, and the direct tensile tests were performed on two specimens. Results of these tests are given in Table 4.2.

Values from tensile splitting tests on five specimens of dense material ranged from 810 to 1,060 psi and averaged 904 psi. The tensile splitting test on the vesicular material gave a value of

440 psi, which is approximately 49 percent of the average strength of the dense material.

Values from the direct tensile tests on two specimens of the dense material were 350 and 410 psi and averaged 380 psi. This average is approximately 42 percent of the average value from tensile splitting tests on the same material. The low values of the direct tensile tests could possibly be the result of a slight eccentric load during testing. Microscopic horizontal cracks could have formed in the specimen during coring operations and resulted in low strengths. On the other hand, the tensile splitting test has been questioned through the years as to its ability to measure true tensile strength and is thought to give values which are on the high side of the true tensile strength. Thus, true tensile strength for the dense material could very well be bracketed by the values from these two test methods.

4.3.3 Mohr's Failure Envelopes. Three static triaxial compression tests were conducted at a confining pressure of 5,000 psi. The maximum deviator stresses are shown in Table 4.2; stress-strain curves are given in Figure 4.2. The electrical strain gages failed in one test; hence, only two stress-strain curves are available.

Results of a tensile splitting test, an unconfined compression test, and a triaxial compression test were used to construct the Mohr's failure envelopes shown for the dense material in Figures 4.3

and 4.4 and for the vesicular material in Figure 4.5. The cohesion values for the dense material were 1,700 and 1,800 psi, while the cohesion value for the vesicular material was 1,000 psi or approximately 55 percent of the cohesion values for the dense material.

4.3.4 Moduli of Elasticity and Rigidity. The static modulus of elasticity was computed for the unconfined compression tests, and the results are shown in Table 4.3. This modulus is a secant modulus obtained by dividing a measured stress by its corresponding strain. In calculating a modulus in this manner, a variation of modulus with stress is obtained. Figure 4.6 shows the variation of the secant modulus of elasticity with stress for the unconfined compression tests. Static moduli of elasticity at one-half the ultimate stress are given in Table 4.3. They ranged from a maximum of 3.62×10^6 psi for the dense material to a minimum of 2.43×10^6 psi for the vesicular material.

All values given in this paragraph were obtained from nondestructive tests. A description of the nondestructive tests can be found in Reference 11. The dynamic modulus of elasticity from two determinations on dense material averaged 2.37×10^6 psi; a single value of 0.46×10^6 psi was obtained for the vesicular material. These values were obtained by measuring the fundamental transverse frequency. Using the fundamental longitudinal frequency, an average modulus of elasticity equal to 2.62×10^6 psi was obtained for the dense material, while a single determination of 0.47×10^6 psi was obtained for the vesicular material. The dynamic modulus of rigidity averaged 1.13×10^6 psi for two tests on the dense material. A modulus of rigidity could not be obtained for the vesicular material.

4.3.5 Poisson's Ratio. Both static and dynamic Poisson's ratios were computed for the representative cores. The static values were computed from the unconfined compression test data. Dynamic ratios were obtained from results of the nondestructive tests.

The static Poisson's ratio obtained from the static unconfined compression tests was calculated by dividing the measured vertical strain into the measured horizontal strain. Each of these strains occurred at the same stress. When Poisson's ratio is calculated by this method, the ratio changes with stress. This change in Poisson's ratio with stress is shown in Figures 4.7 and 4.8. Table 4.4 gives the value of Poisson's ratio at a stress level of 3,000 psi, which is well within the elastic behavioral range for the material being tested. Values for the dense material ranged from 0.15 to 0.27 and averaged 0.22. Poisson's ratio for the vesicular material was 0.20.

The dynamic Poisson's ratio can be calculated from the dynamic values of modulus of elasticity and modulus of rigidity by the following formula:

$$\mu = \frac{E}{2G} - 1$$

where

μ = dynamic Poisson's ratio

E = dynamic modulus of elasticity

G = dynamic modulus of rigidity

This method is given in CRD-C 18 (Reference 11). Since two values of a dynamic E were determined experimentally for each specimen, two values of Poisson's ratios are also available by means of the above formula. Since the modulus of rigidity could not be determined on the vesicular material, Poisson's ratio could not be computed. Values of Poisson's ratio for the dense material as determined from the fundamental longitudinal and transverse frequencies, each in conjunction with the fundamental torsional frequency, are given in Table 4.4.

A dynamic Poisson's ratio can also be calculated by another method, as follows. The compression wave velocity is obtained from specimens by Test Method CRD-C 51 (Reference 11). The fundamental longitudinal frequency is also obtained from the specimens by Test Method CRD-C 18 of the same Reference. A velocity can be computed from the fundamental longitudinal frequency by the following formula:

$$V = 2n \ell$$

where

V = velocity

n = fundamental longitudinal frequency

ℓ = length of specimen

The dynamic Poisson's ratio can then be computed by solving the following expression:

$$\frac{(1 - \mu)}{(1 + \mu)(1 - 2\mu)} = \left(\frac{V_c}{V}\right)^2$$

where

μ = dynamic Poisson's ratio

V_c = compression wave velocity

V = velocity computed from the fundamental longitudinal frequency

The above-described method can be found in Reference 12 on page 17. Values for the dynamic Poisson's ratios computed by this method are given in Table 4.4. Two determinations were made on the dense material and one on the vesicular material. The computed values, which range from 0.33 to 0.44, appear to be on the high side and are considered suspect. Since Poisson's ratio is dependent upon other measured and calculated quantities, experimental errors in these quantities can greatly influence the values of Poisson's ratio.

4.4 COMPRESSION WAVE VELOCITY

The compression wave velocity was determined in accordance with Corps of Engineers Test Method CRD-C 51. Values of this velocity are given in Table 4.4. Two values of 11,660 and 9,930 ft/sec were obtained on two specimens of the dense rock, while a value of 7,330 ft/sec was determined on a specimen of the vesicular material.

TABLE 4.1 DENSITY, SPECIFIC GRAVITY, AND POROSITY

Boring Number	Depth	Bulk Specific Gravity G_m (SSD)	Bulk Density SSD	Bulk Density Oven-dried	Specific Gravity of Solids G_s	Porosity n
	feet		pcf	pcf		pct
Ue20L-1	21.9 to 24.0	2.51	156.7	154.5	2.60	4.6
Ue20L-1	41.7 to 43.7	2.53	157.6	155.5	2.60	4.0
Ue20L-1	87.5 to 88.9[a]	2.18	136.1	129.1	2.64	21.3
Ue20L-1	151.8 to 153.3	2.55	159.1	156.6	2.66	5.5
Ue20L-1	168.3 to 170.7	2.57	160.4	158.5	2.63	3.4
Ue20L-3	76.7 to 77.7[a]	--	--	--	--	--
Ue20L-3	106.0 to 106.8	2.54	158.7	156.1	2.63	4.8

---

[a] Vesicular material.

TABLE 4.2 STATIC STRENGTH VALUES

Boring Number	Depth	Static Unconfined Compressive Strength	Ultimate Deviator Stress from Static Triaxial Compression Test[a]	Static Tensile Splitting Strength	Direct Static Tensile Strength
	feet	psi	psi	psi	psi
Ue20L-1	21.9 to 24.0	12,250	47,750	810	350
Ue20L-1	41.7 to 43.7	12,880	--	920	--
Ue20L-1	87.5 to 88.9[b]	7,090	--	440	--
Ue20L-1	151.8 to 153.3	13,000	46,470	860	410
Ue20L-1	168.3 to 170.7	13,420	--	1,060	--
Ue20L-3	76.7 to 77.7[b]	--	37,860	--	--
Ue20L-3	106.0 to 106.8	13,210	--	870	--

---

[a] Conducted at a constant confining pressure of 5,000 psi.
[b] Vesicular material.

TABLE 4.3 MODULUS VALUES

Boring Number	Depth	Static Modulus of Elasticity[a]	Dynamic Modulus of Elasticity[b]	Dynamic Modulus of Elasticity[c]	Dynamic Modulus of Rigidity[d]
	feet	psi $\times 10^6$	psi $\times 10^6$	psi $\times 10^6$	psi $\times 10^6$
Ue20L-1	21.9 to 24.0	3.62	2.62	2.98	1.31
Ue20L-1	41.7 to 43.7	3.22	--	--	--
Ue20L-1	87.5 to 88.9[e]	2.43	0.46	0.47	--
Ue20L-1	151.8 to 153.3	2.48	2.12	2.25	0.95
Ue20L-1	168.3 to 170.7	3.50	--	--	--
Ue20L-3	76.7 to 77.7[e]	--	--	--	--
Ue20L-3	106.0 to 106.8	3.41	--	--	--

---

[a] Secant modulus of elasticity at one-half the ultimate stress determined from an unconfined compression test.

[b] Determined from the fundamental transverse frequency in accordance with Corps of Engineers Test Method CRD-C 18 (Reference 11).

[c] Determined from the fundamental longitudinal frequency in accordance with Corps of Engineers Test Method CRD-C 18 (Reference 11).

[d] Determined from the fundamental torsional frequency in accordance with Corps of Engineers Test Method CRD-C 18 (Reference 11).

[e] Vesicular material.

TABLE 4.4 POISSON'S RATIOS AND COMPRESSION WAVE VELOCITY

Boring Number	Depth	Dynamic Poisson's Ratio μ[a]	Dynamic Poisson's Ratio μ[b]	Dynamic Poisson's Ratio μ[c]	Static Poisson's Ratio μ[d]	Compression Wave Velocity V_c
	feet					ft/sec
Ue20L-1	21.9 to 24.0	0.34	0.00	0.14	0.19	11,660
Ue20L-1	41.7 to 43.7	--	--	--	0.27	--
Ue20L-1	87.5 to 88.9[e]	0.44	--	--	0.20	7,330
Ue20L-1	151.8 to 153.3	0.33	0.12	0.18	0.21	9,930
Ue20L-1	168.3 to 170.7	--	--	--	0.26	--
Ue20L-3	76.7 to 77.7[e]	--	--	--	--	--
Ue20L-3	106.0 to 106.8	--	--	--	0.15	--

---

[a] Computed from the compression wave velocity and wave velocity calculated from the fundamental longitudinal frequency.

[b] Computed from moduli of elasticity and rigidity which were calculated from the fundamental transverse and torsional frequencies.

[c] Computed from moduli of elasticity and rigidity which were calculated from the fundamental longitudinal and torsional frequencies.

[d] Determined from stress-strain curve from static unconfined compression tests at a stress of 3,000 psi.

[e] Vesicular material.

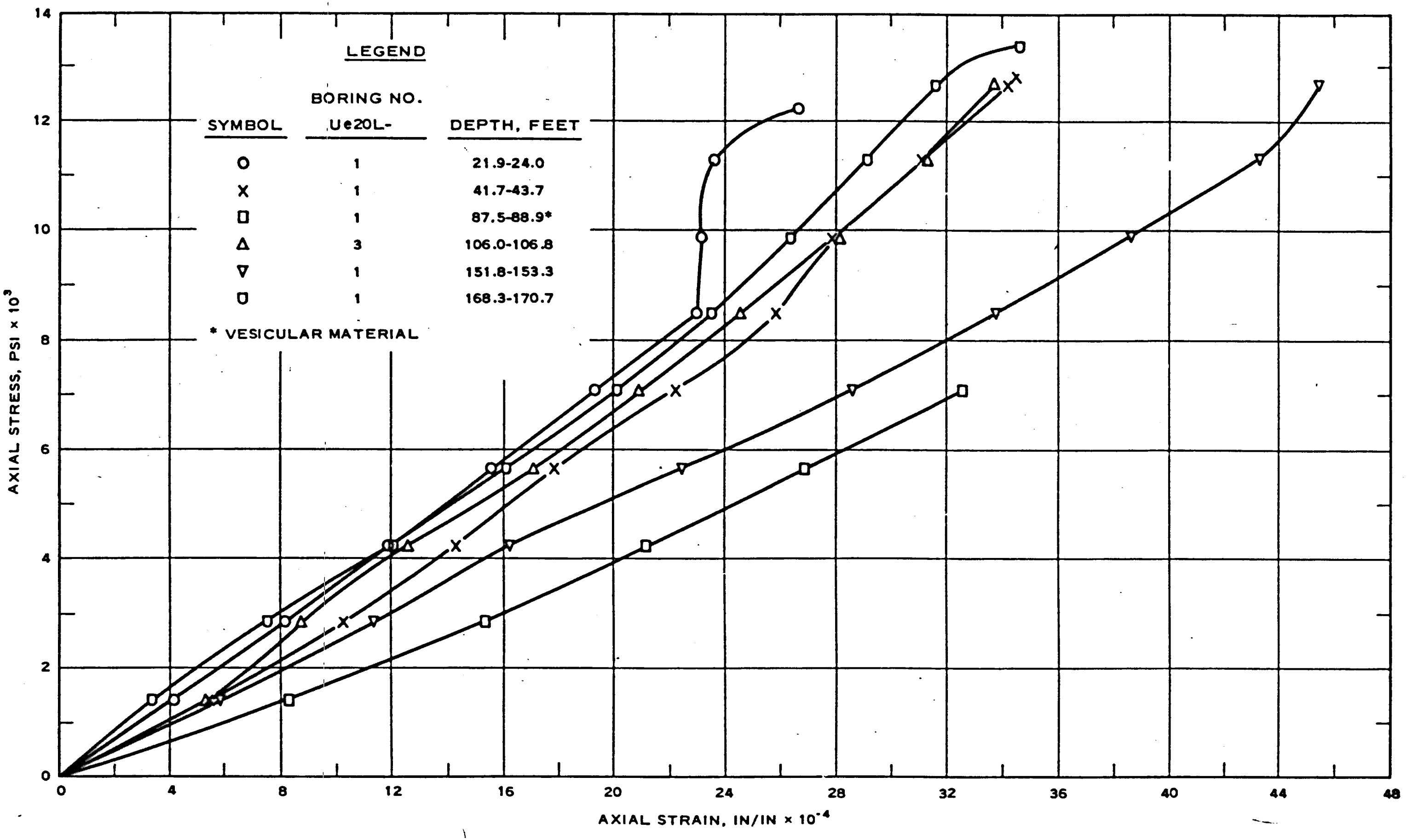

Figure 4.1 Stress-strain curves, unconfined compression tests.

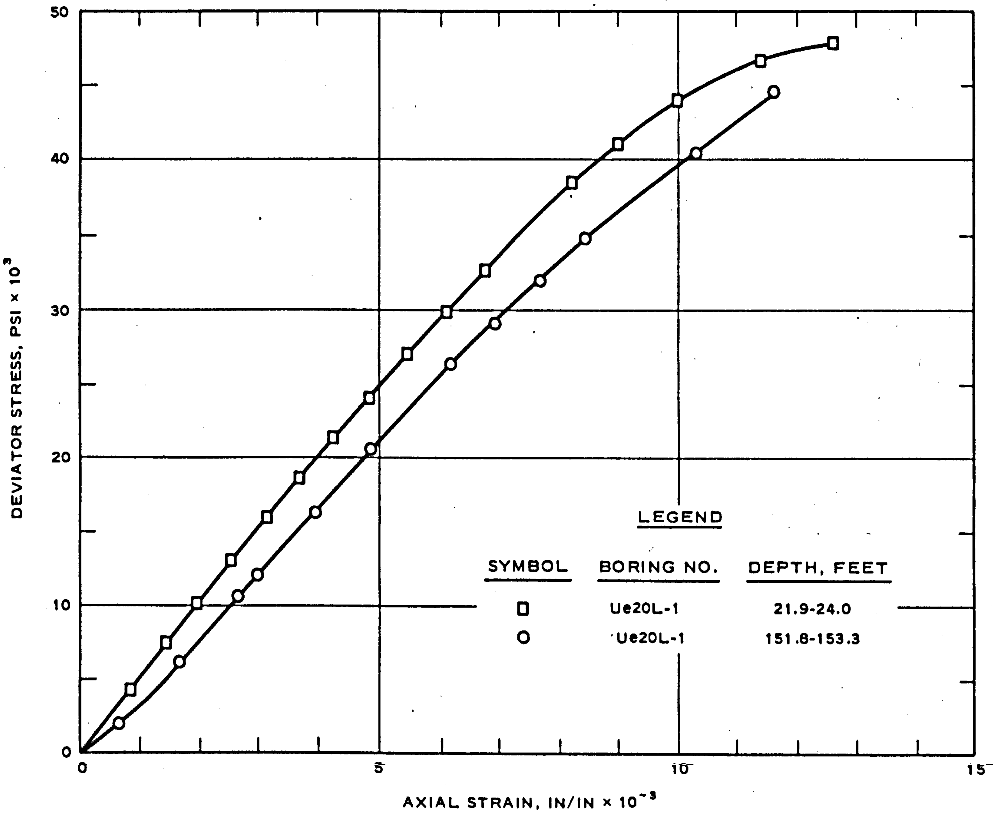

Figure 4.2 Stress-strain curves, triaxial tests.

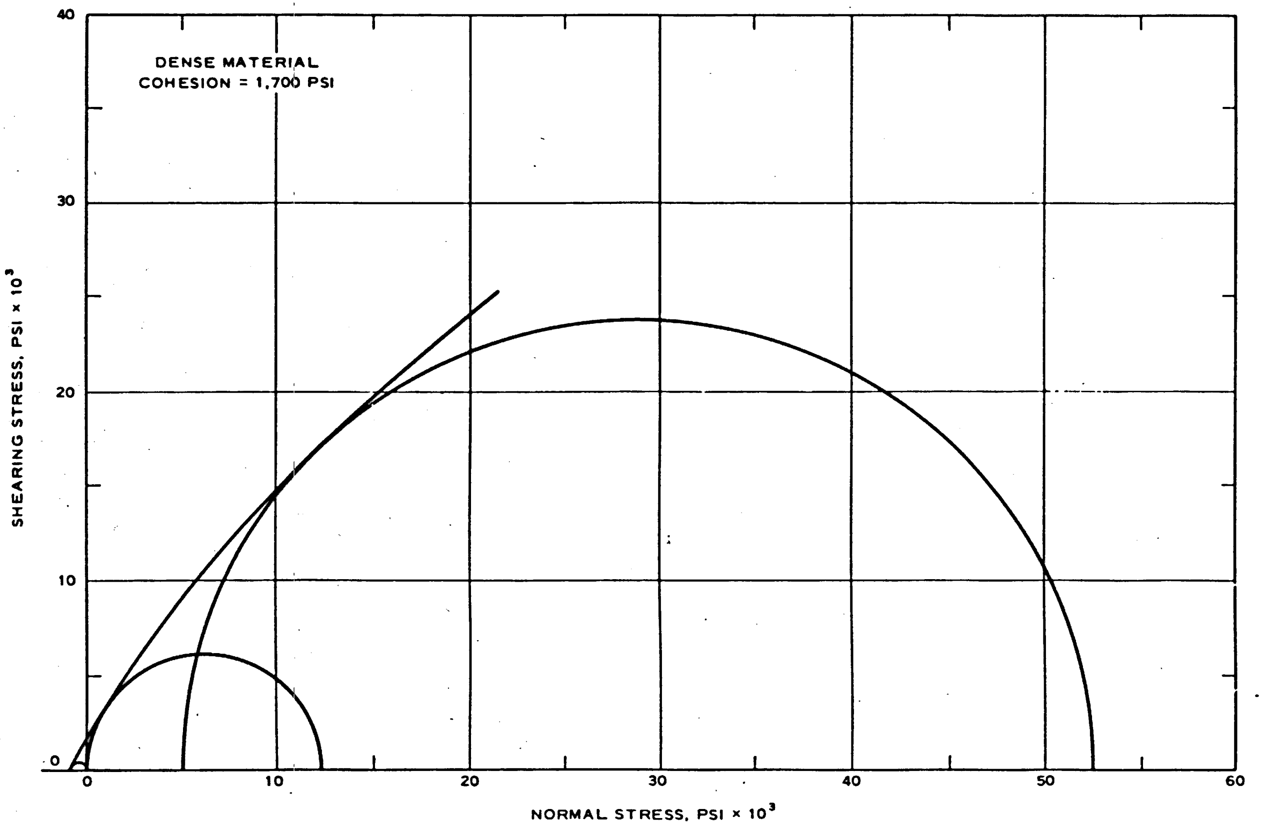

Figure 4.3 Mohr's failure envelope, boring Ue20L-1, 21.9 feet to 24.0 feet.

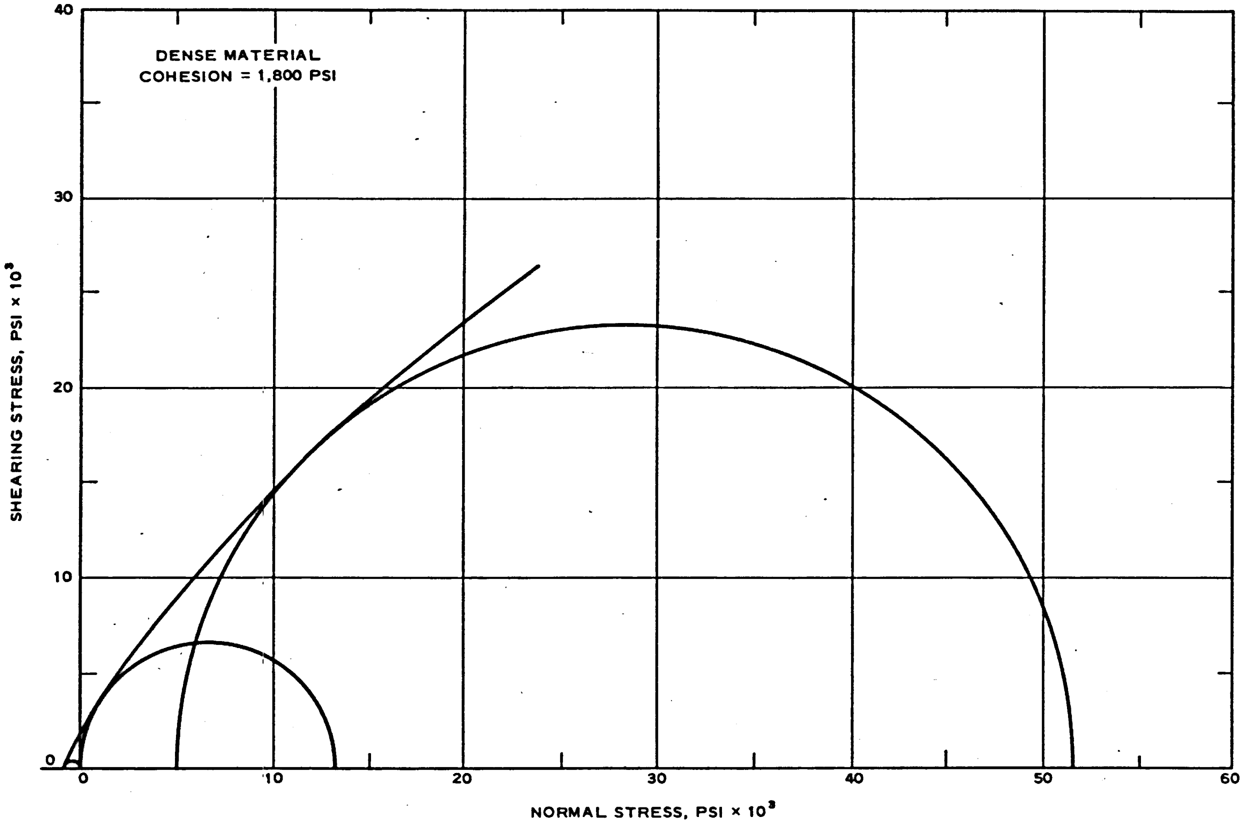

Figure 4.4 Mohr's failure envelope, boring Ue20L-1, 151.8 feet to 153.3 feet.

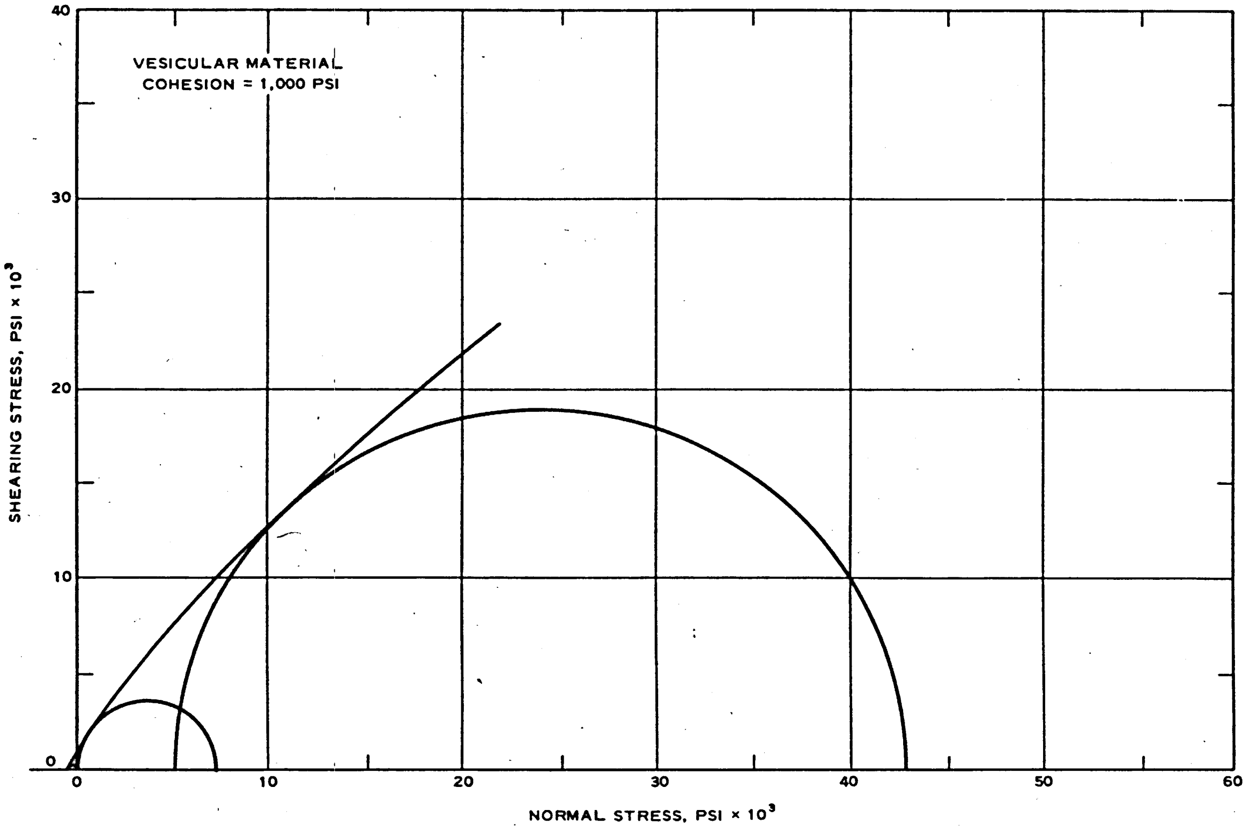

Figure 4.5 Mohr's failure envelope, borings Ue20L-1 (87.5 to 88.9 feet) and Ue20L-3 (76.7 to 77.7 feet).

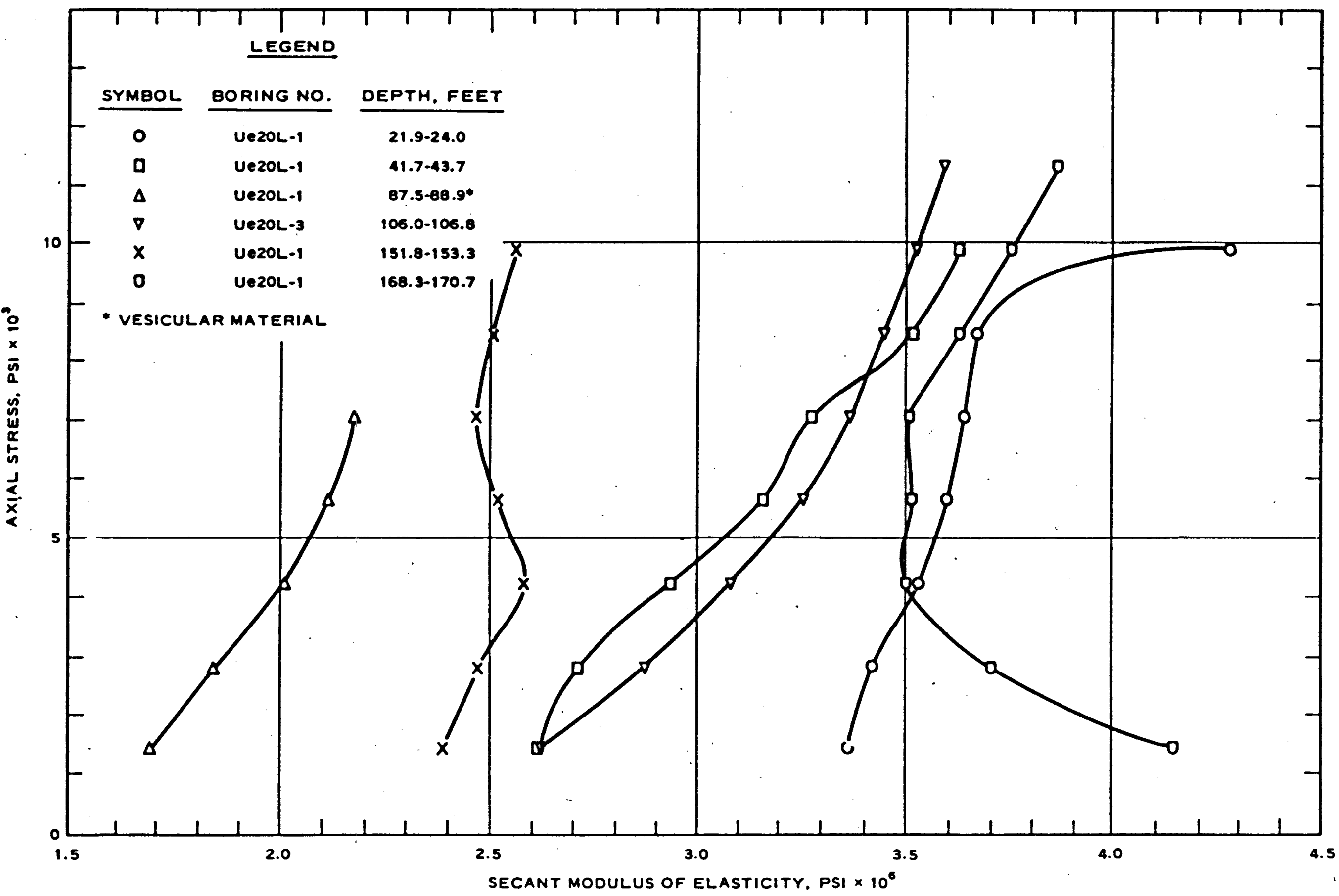

Figure 4.6 Modulus of elasticity versus stress, unconfined compression tests.

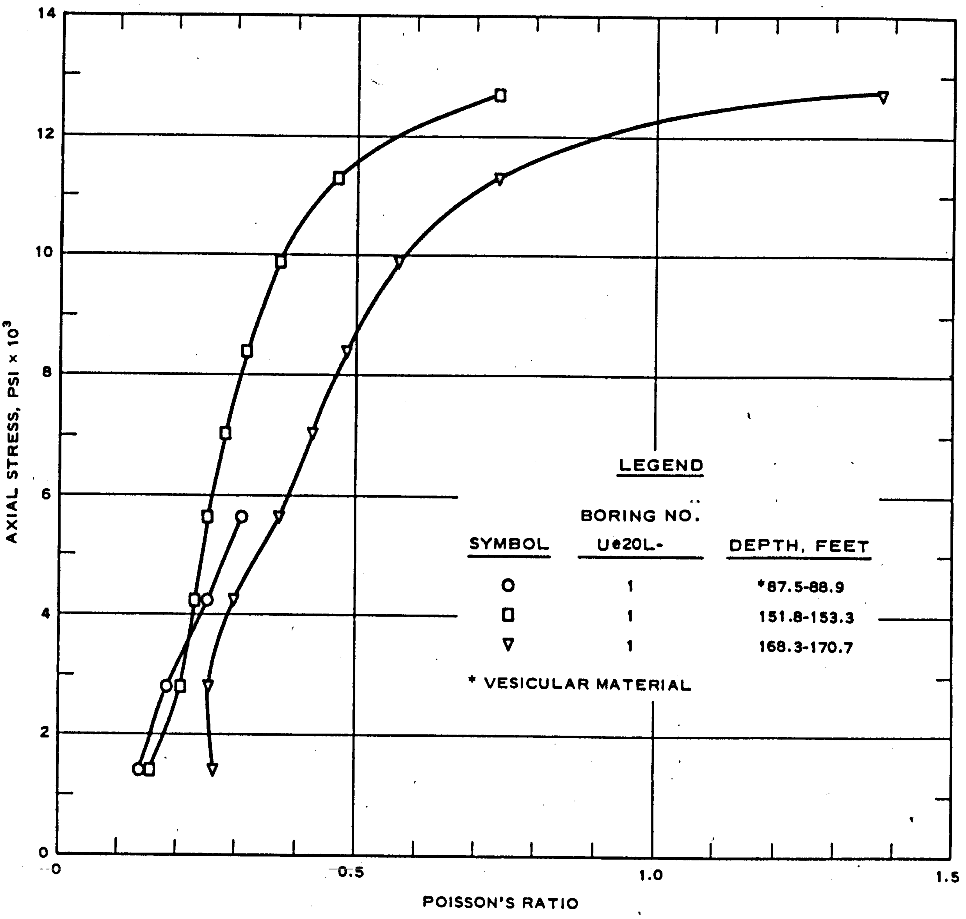

Figure 4.7 Stress versus Poisson's ratio, unconfined compression tests.

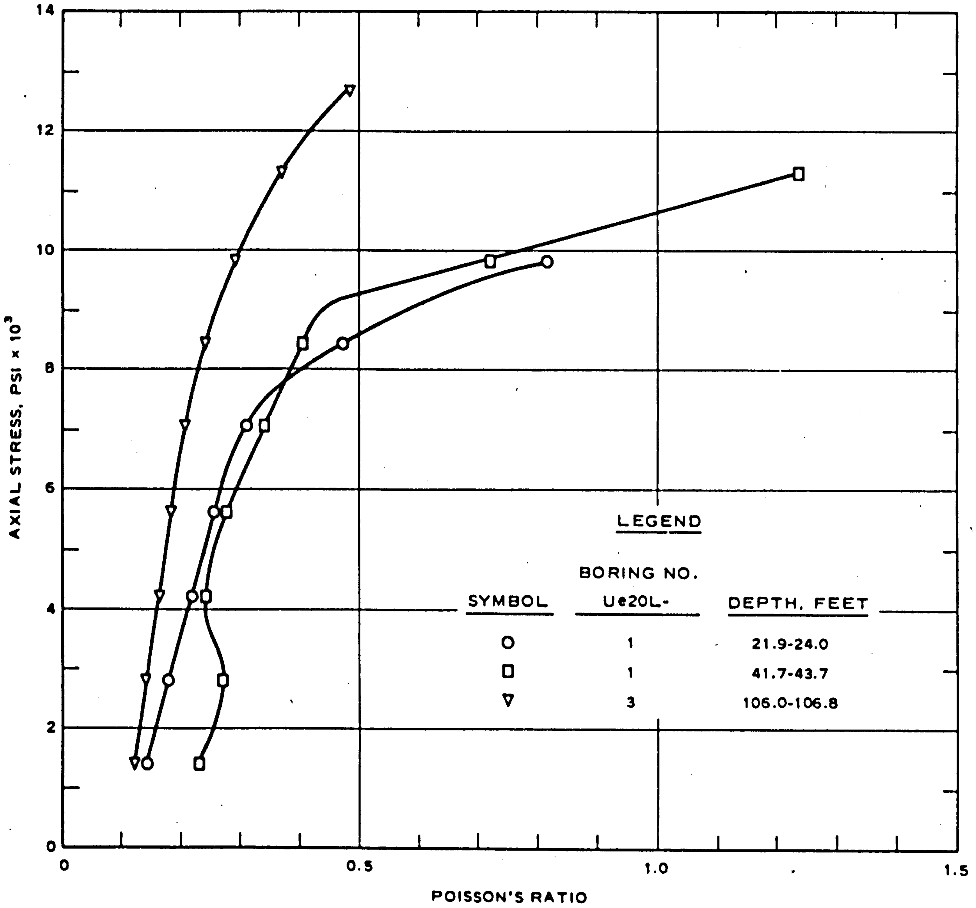

Figure 4.8 Stress versus Poisson's ratio, unconfined compression tests.

CHAPTER 5

SUMMARY OF RESULTS AND CONCLUSIONS

The Cabriolet site occupies the crest of a gently sloping ridge within Area 20 of the NTS. A thin soil layer consisting of tan sandy silt and sand- to boulder-size fragments of porphyritic trachyte and vitrophyre averages 2 to 3 feet thick. Beneath the soil lies the Ribbon Cliff rhyolite, which at the Cabriolet site consists of porphyritic trachyte at least 212 feet thick.

The rock has a uniform mineralogical composition but varies in vesicularity, degree of jointing, and flow layering. Conspicuous areas of poor core recovery occur from the surface to depths of 100 to 145 feet and are associated with fractured vesicular zones. Higher core recovery was obtained in the deeper, dense, moderately jointed, flow-layered rock.

Joint readings obtained at the surface indicate a preferred strike for steep joints of approximately N15°W, subparallel to the dominant faults of the region. The spacing of these steep joints ranges from less than 0.1 to greater than 10 feet, while the spacing of low-angle joints, when present in an outcrop, is usually between 3 and 12 inches. At depth, borehole photographs reveal a tendency for joints to strike N20°E, roughly parallel to the flow layering.

Near the surface, flow layers are scattered and steeply dipping, while at depth they are numerous and generally dip less than 45 degrees. The upper flow layers exposed at the surface strike approximately N35°E across the site, imparting a marked structural grain to the media.

Four high-angle faults are considered probable in the vicinity of the site. Three of these pass 200, 380, and 680 feet west of the site. The first two appear to bound a graben within which boring Ue20L-3 lies. On the basis of subsurface data, the suspected fault on the east side of the graben appears to be a zone 7 feet wide dipping 80 degrees to the west. The fourth inferred fault strikes approximately N63°E and passes 480 feet north of SGZ.

The average physical property values of the dense porphyritic trachyte were as follows: bulk density under saturated surface-dry conditions, 158.5 pcf; bulk density under oven-dried conditions, 156.2 pcf; specific gravity of solids, 2.63; porosity, 4.5 percent; static modulus of elasticity, 3.25×10^6 psi; static unconfined compressive strength, 12,952 psi; and static tensile splitting strength, 904 psi. The vesicular and fractured rock tested from borings Ue20L-1 and Ue20L-3 indicated lower strengths. Based on one specimen, this porous material had a bulk density, saturated surface-dry basis, of 136.1 pcf, while the bulk density, dry, was 129.1 pcf. The porosity was 21.3 percent, and the unconfined compressive strength was 7,090 psi.

It is concluded, in view of the structural anisotropy of the media, that disturbed zones resulting from the planned Project Cabriolet event may be ellipsoidal. In such case, a principal axis will probably trend between north-south (the approximate strike of inferred faults) and N35°E (the strike of flow layers). The post-shot drilling pattern should be designed with this in mind. Since no faults are known to project to the vicinity of the zero point, direct venting is not anticipated on the basis of available data.

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APPENDIX A

LITHOLOGIC LOGS FOR BORINGS DRILLED AT CABRIOLET SITE

LEGEND FOR CABRIOLET BORINGS

LITHOLOGY

▧ SANDY SILT, TAN; WITH FRAGMENTS AND BOULDERS OF PORPHYRITIC TRACHYTE AND/OR VITROPHYRE

▤ PORPHYRITIC TRACHYTE

FRACTURES

▦ HIGHLY FRACTURED: JOINTS ISOLATE FRAGMENTS AVERAGING LESS THAN 1 INCH IN DIAMETER

⊞ MODERATELY FRACTURED: JOINTS ISOLATE FRAGMENTS FROM 1 TO 5 INCHES IN DIAMETER

☰ MIDPOINTS OF INDIVIDUAL JOINTS

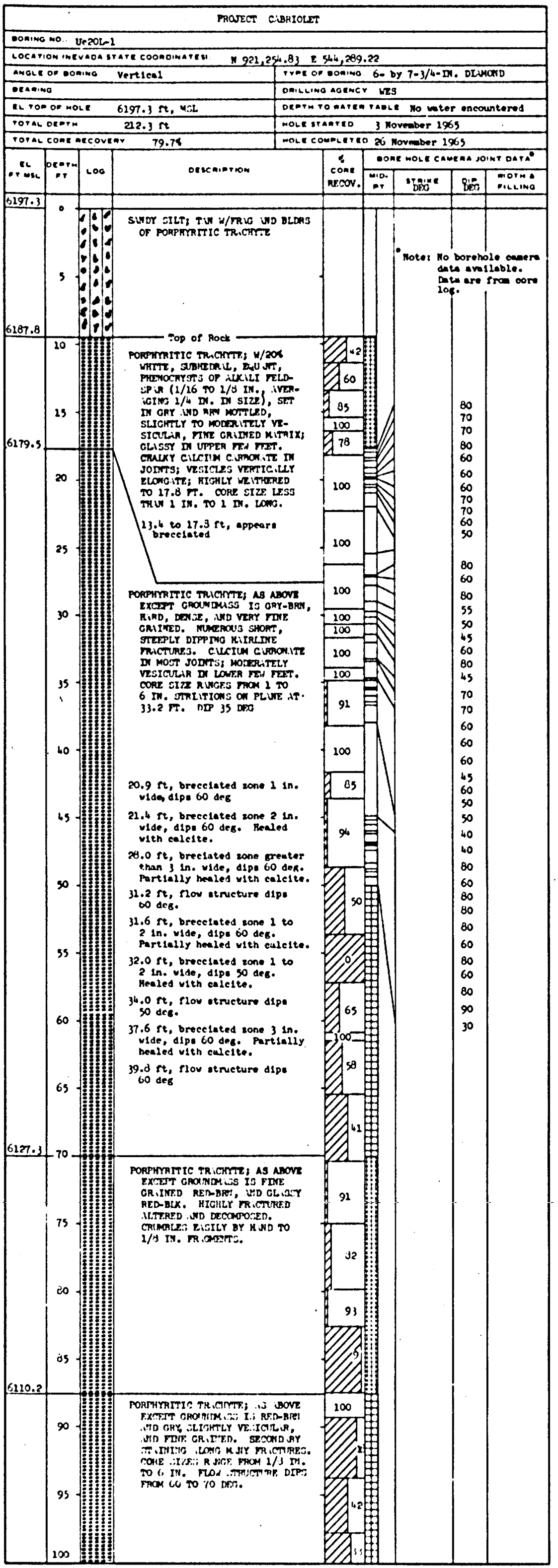
▒ GREATER THAN 50% OF PHOTOGRAPH OBSCURED BY GROUT OR OCCUPIED BY VOID SPACE

ABBREVIATIONS USED IN DESCRIPTIONS OF FRACTURES:

O	OPEN
Pf	PARTIALLY FILLED
F	FILLED
H	HAIRLINE

CORE RECOVERY

▨ 50 CORE RECOVERY IN PERCENT; CORE LOSS INDICATED GRAPHICALLY BY SHADING



PROJECT CABRIOLET

BORING NO.	Ue20L-1		
LOCATION (NEVADA STATE COORDINATES)	N 921,254.83 E 544,289.22		
ANGLE OF BORING	Vertical	TYPE OF BORING	6- by 7-3/4-IN. DIAMOND
BEARING		DRILLING AGENCY	WES
EL TOP OF HOLE	6197.3 ft, MSL	DEPTH TO WATER TABLE	No water encountered
TOTAL DEPTH	212.3 ft	HOLE STARTED	3 November 1965
TOTAL CORE RECOVERY	79.7%	HOLE COMPLETED	26 November 1965

6197.3

SANDY SILT; TAN W/FRAG AND BLDRS OF PORPHYRITIC TRACHYTE

*Note: No borehole camera data available. Data are from core log.

6187.8

Top of Rock

PORPHYRITIC TRACHYTE; W/20% WHITE, SUBHEDRAL, EQUANT, PHENOCRYSTS OF ALKALI FELDSPAR (1/16 TO 1/8 IN., AVERAGING 1/4 IN. IN SIZE), SET IN GRY AND BRN MOTTLED, SLIGHTLY TO MODERATELY VESICULAR, FINE GRAINED MATRIX; GLASSY IN UPPER FEW FEET. CHALKY CALCIUM CARBONATE IN JOINTS; VESICLES VERTICALLY ELONGATE; HIGHLY WEATHERED TO 17.8 FT. CORE SIZE LESS THAN 1 IN. TO 1 IN. LONG.

13.4 to 17.3 ft, appears brecciated

6179.5

PORPHYRITIC TRACHYTE; AS ABOVE EXCEPT GROUNDMASS IS GRY-BRN, HARD, DENSE, AND VERY FINE GRAINED. NUMEROUS SHORT, STEEPLY DIPPING HAIRLINE FRACTURES. CALCIUM CARBONATE IN MOST JOINTS; MODERATELY VESICULAR IN LOWER FEW FEET. CORE SIZE RANGES FROM 1 TO 6 IN. STRIATIONS ON PLANE AT 33.2 FT. DIP 35 DEG

20.9 ft, brecciated zone 1 in. wide, dips 60 deg

21.4 ft, brecciated zone 2 in. wide, dips 60 deg. Healed with calcite.

28.0 ft, brecciated zone greater than 3 in. wide, dips 60 deg. Partially healed with calcite.

31.2 ft, flow structure dips 60 deg.

31.6 ft, brecciated zone 1 to 2 in. wide, dips 60 deg. Partially healed with calcite.

32.0 ft, brecciated zone 1 to 2 in. wide, dips 50 deg. Healed with calcite.

34.0 ft, flow structure dips 50 deg.

37.6 ft, brecciated zone 3 in. wide, dips 60 deg. Partially healed with calcite.

39.8 ft, flow structure dips 60 deg

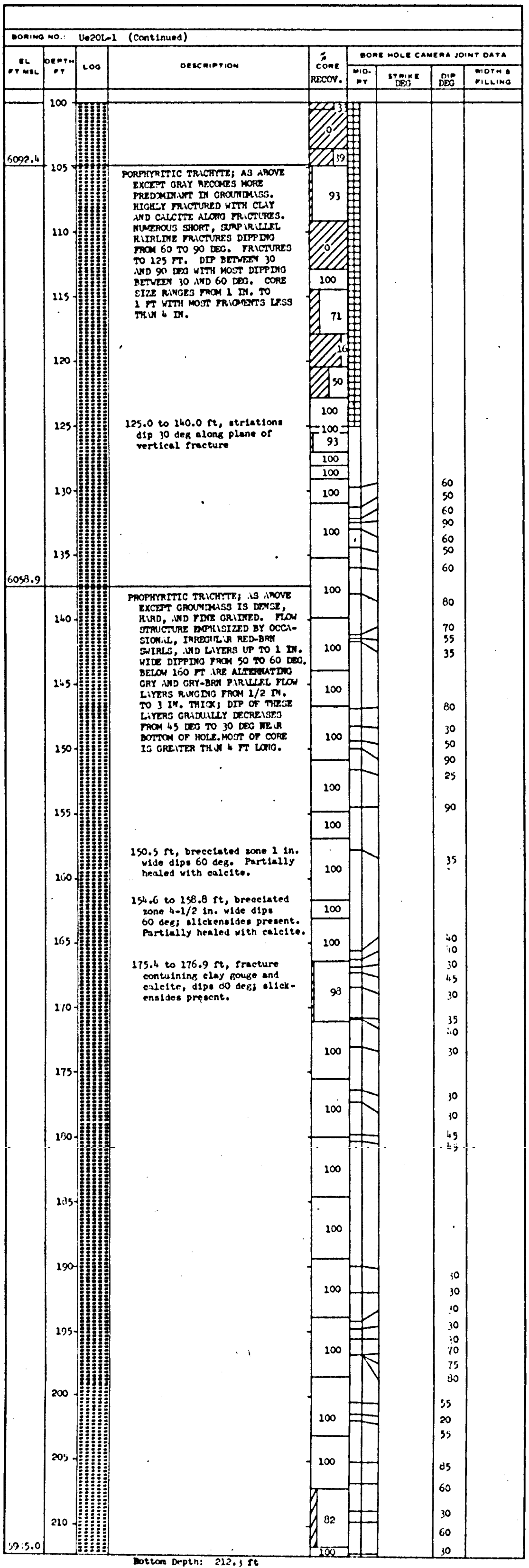
6127.3

PORPHYRITIC TRACHYTE; AS ABOVE EXCEPT GROUNDMASS IS FINE GRAINED RED-BRN, AND GLASSY RED-BLK. HIGHLY FRACTURED ALTERED AND DECOMPOSED. CRUMBLES EASILY BY HAND TO 1/8 IN. FRAGMENTS.

6110.2

PORPHYRITIC TRACHYTE; AS ABOVE EXCEPT GROUNDMASS IS RED-BRN AND GRY, SLIGHTLY VESICULAR, AND FINE GRAINED. SECONDARY STAINING ALONG MANY FRACTURES. CORE SIZES RANGE FROM 1/8 IN. TO 6 IN. FLOW STRUCTURE DIPS FROM 60 TO 70 DEG.

(Continued)



BORING NO.: Ue20L-1 (Continued)

6092.4

PORPHYRITIC TRACHYTE; AS ABOVE EXCEPT GRAY BECOMES MORE PREDOMINANT IN GROUNDMASS. HIGHLY FRACTURED WITH CLAY AND CALCITE ALONG FRACTURES. NUMEROUS SHORT, SUBPARALLEL HAIRLINE FRACTURES DIPPING FROM 60 TO 90 DEG. FRACTURES TO 125 FT. DIP BETWEEN 30 AND 90 DEG WITH MOST DIPPING BETWEEN 30 AND 60 DEG. CORE SIZE RANGES FROM 1 IN. TO 1 FT WITH MOST FRAGMENTS LESS THAN 4 IN.

125.0 to 140.0 ft, striations dip 30 deg along plane of vertical fracture

6058.9

PROPHYRITIC TRACHYTE; AS ABOVE EXCEPT GROUNDMASS IS DENSE, HARD, AND FINE GRAINED. FLOW STRUCTURE EMPHASIZED BY OCCASIONAL, IRREGULAR RED-BRN SWIRLS, AND LAYERS UP TO 1 IN. WIDE DIPPING FROM 50 TO 60 DEG. BELOW 160 FT ARE ALTERNATING GRY AND GRY-BRN PARALLEL FLOW LAYERS RANGING FROM 1/2 IN. TO 3 IN. THICK; DIP OF THESE LAYERS GRADUALLY DECREASES FROM 45 DEG TO 30 DEG NEAR BOTTOM OF HOLE. MOST OF CORE IS GREATER THAN 4 FT LONG.

150.5 ft, brecciated zone 1 in. wide dips 60 deg. Partially healed with calcite.

154.6 to 158.8 ft, brecciated zone 4-1/2 in. wide dips 60 deg; slickensides present. Partially healed with calcite.

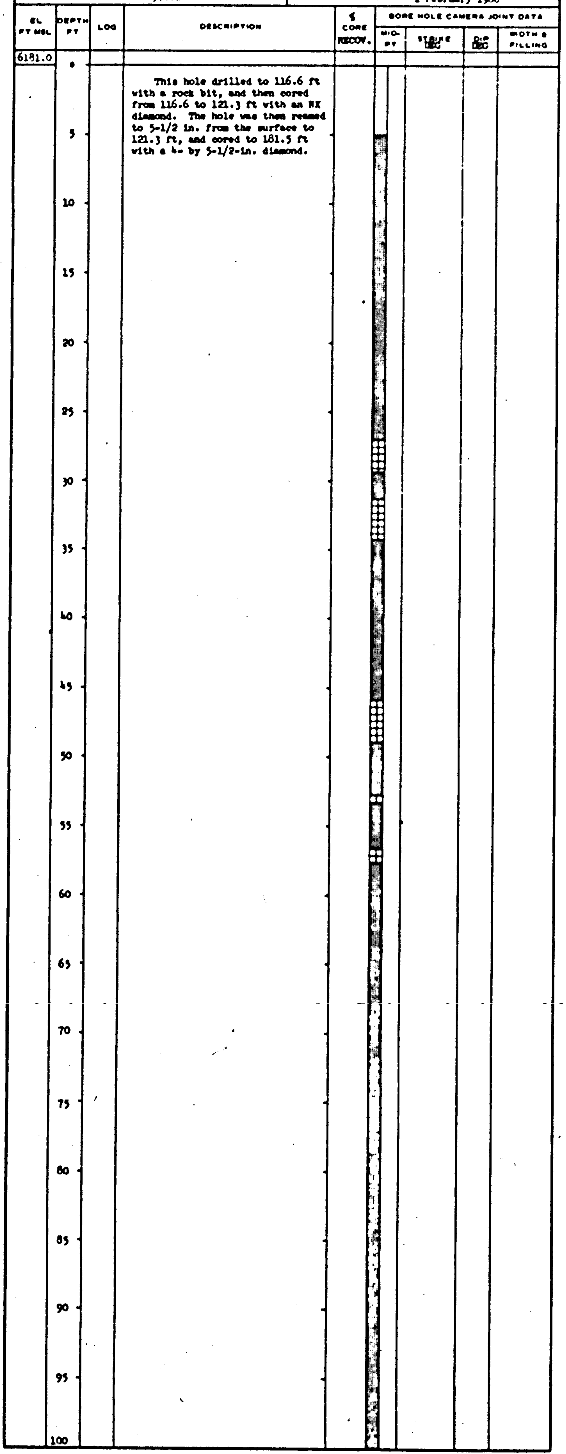
175.4 to 176.9 ft, fracture containing clay gouge and calcite, dips 60 deg; slickensides present.

5985.0

Bottom Depth: 212.3 ft
Bottom Elevation: 5985.0 ft

PROJECT CABRIOLET

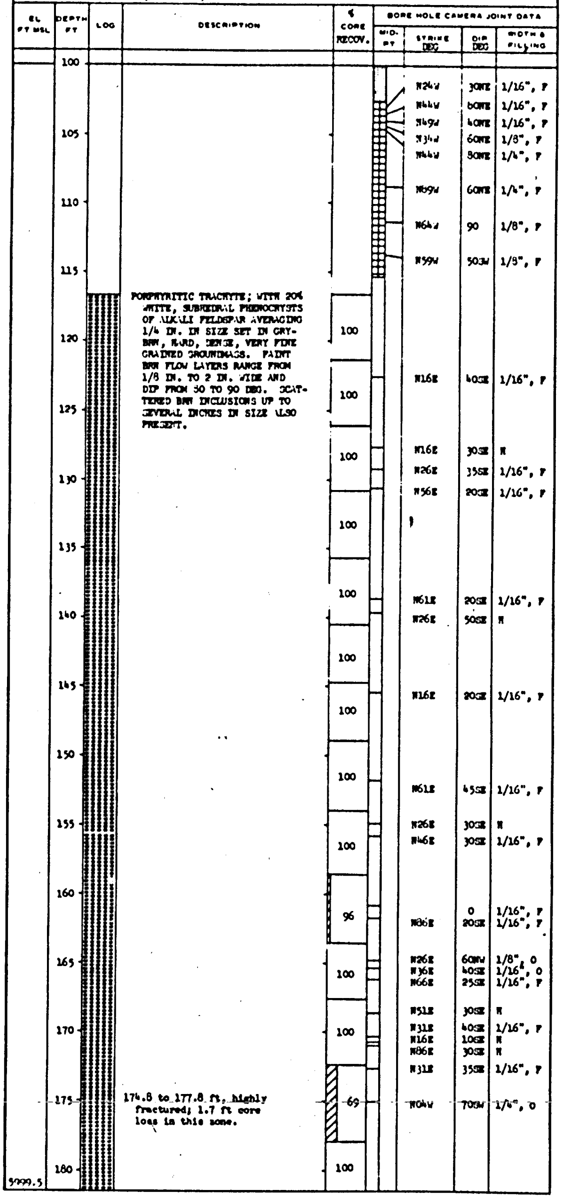
BORING NO.: Uw20L-2	
LOCATION (NEVADA STATE COORDINATES): N 921,254.83 E 544,279.22	
ANGLE OF BORING: Vertical	TYPE OF BORING: 4- by 5-1/2-IN. DIAMOND
BEARING:	DRILLING AGENCY: WES
EL TOP OF HOLE: 6181.0 ft, MSL	DEPTH TO WATER TABLE: No water encountered
TOTAL DEPTH: 181.5 ft	HOLE STARTED: 21 January 1966
TOTAL CORE RECOVERY: 97.0%	HOLE COMPLETED: 1 February 1966



This hole drilled to 116.6 ft with a rock bit, and then cored from 116.6 to 121.3 ft with an NX diamond. The hole was then reamed to 5-1/2 in. from the surface to 121.3 ft, and cored to 181.5 ft with a 4- by 5-1/2-in. diamond.

(Continued)

BORING NO.: Uw20L-2 (Continued)



PORPHYRITIC TRACHYTE; WITH 20% WHITE, SUBHEDRAL PHENOCRYSTS OF ALKALI FELDSPAR AVERAGING 1/4 IN. IN SIZE SET IN GRY-BRN, HARD, DENSE, VERY FINE GRAINED GROUNDMASS. FAINT BRN FLOW LAYERS RANGE FROM 1/8 IN. TO 2 IN. WIDE AND DIP FROM 30 TO 90 DEG. SCATTERED BRN INCLUSIONS UP TO SEVERAL INCHES IN SIZE ALSO PRESENT.

174.8 to 177.8 ft, highly fractured; 1.7 ft core loss in this zone.

% CORE RECOV.
100
100
100
100
100
100
100
100
100
96
100
100
69
100

STRIKE DEG	DIP DEG	WIDTH & FILLING
N24W	30NE	1/16", F
N44W	60NE	1/16", F
N49W	40NE	1/16", F
N34W	60NE	1/8", F
N44W	80NE	1/4", F
N69W	60NE	1/4", F
N64W	90	1/8", F
N59W	50SW	1/8", F
N16E	40SE	1/16", F
N16E	30SE	N
N26E	35SE	1/16", F
N56E	20SE	1/16", F
N61E	20SE	1/16", F
N26E	50SE	N
N16E	20SE	1/16", F
N61E	45SE	1/16", F
N26E	30SE	N
N46E	30SE	1/16", F
	0	1/16", F
N86E	20SE	1/16", F
N26E	60NW	1/8", O
N36E	40SE	1/16", O
N66E	25SE	1/16", F
N51E	30SE	N
N31E	40SE	1/16", F
N16E	10SE	N
N86E	30SE	N
N31E	35SE	1/16", F
N04W	70SW	1/4", O

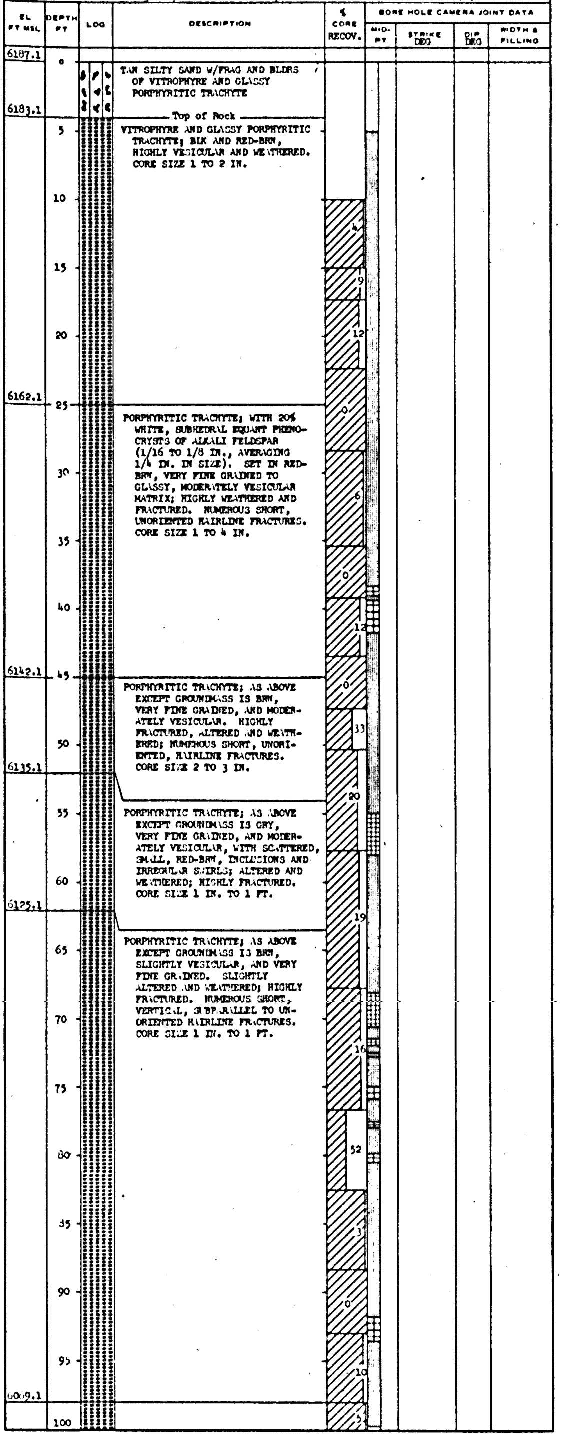
Bottom Depth: 181.5 ft
Bottom Elevation: 5999.5 ft

PROJECT CABRIOLET

BORING NO.: Ue20L-3

LOCATION (NEVADA STATE COORDINATES): N 921,047.14 E 544,363.44

ANGLE OF BORING:	Vertical	TYPE OF BORING:	NX - DIAMOND
BEARING:		DRILLING AGENCY	WES
EL TOP OF HOLE:	6187.1 ft, MSL	DEPTH TO WATER TABLE	No water encountered
TOTAL DEPTH:	202.3 ft	HOLE STARTED:	29 November 1965
TOTAL CORE RECOVERY:	38.88%	HOLE COMPLETED	11 December 1965



TAN SILTY SAND W/FRAG AND BLDRS OF VITROPHYRE AND GLASSY PORPHYRITIC TRACHYTE

Top of Rock

VITROPHYRE AND GLASSY PORPHYRITIC TRACHYTE; BLK AND RED-BRN, HIGHLY VESICULAR AND WEATHERED. CORE SIZE 1 TO 2 IN.

PORPHYRITIC TRACHYTE; WITH 20% WHITE, SUBHEDRAL EQUANT PHENOCRYSTS OF ALKALI FELDSPAR (1/16 TO 1/8 IN., AVERAGING 1/4 IN. IN SIZE). SET IN RED-BRN, VERY FINE GRAINED TO GLASSY, MODERATELY VESICULAR MATRIX; HIGHLY WEATHERED AND FRACTURED. NUMEROUS SHORT, UNORIENTED HAIRLINE FRACTURES. CORE SIZE 1 TO 4 IN.

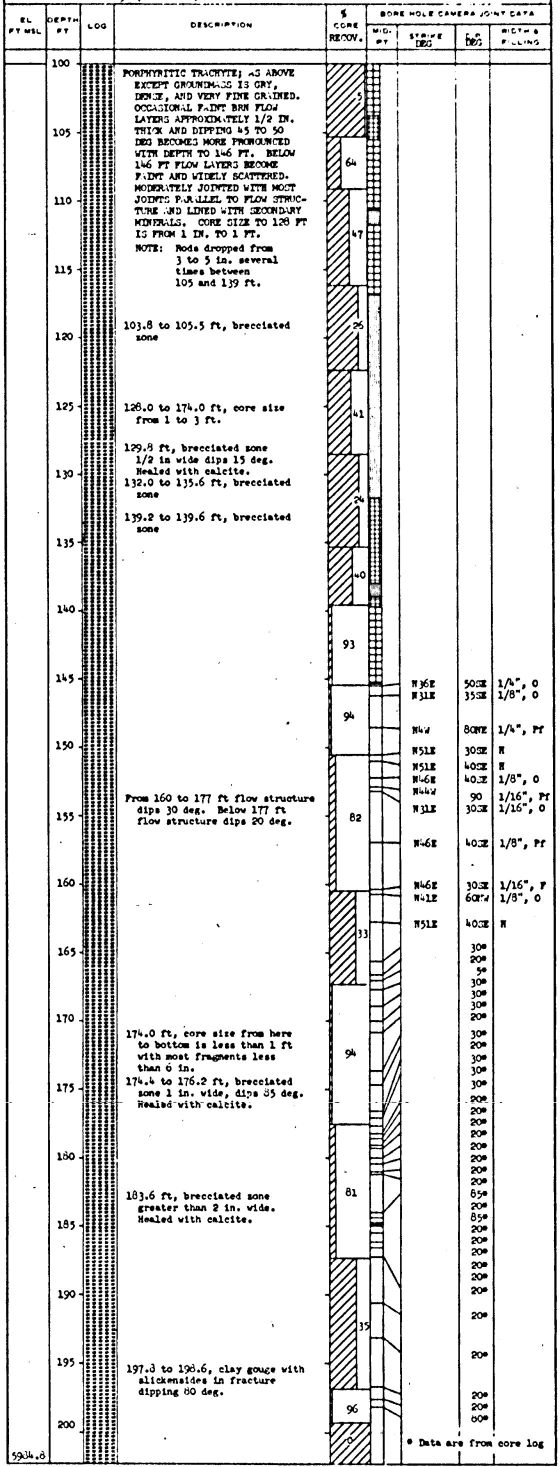
PORPHYRITIC TRACHYTE; AS ABOVE EXCEPT GROUNDMASS IS BRN, VERY FINE GRAINED, AND MODERATELY VESICULAR. HIGHLY FRACTURED, ALTERED AND WEATHERED; NUMEROUS SHORT, UNORIENTED, HAIRLINE FRACTURES. CORE SIZE 2 TO 3 IN.

PORPHYRITIC TRACHYTE; AS ABOVE EXCEPT GROUNDMASS IS GRY, VERY FINE GRAINED, AND MODERATELY VESICULAR, WITH SCATTERED, SMALL, RED-BRN, INCLUSIONS AND IRREGULAR SWIRLS; ALTERED AND WEATHERED; HIGHLY FRACTURED. CORE SIZE 1 IN. TO 1 FT.

PORPHYRITIC TRACHYTE; AS ABOVE EXCEPT GROUNDMASS IS BRN, SLIGHTLY VESICULAR, AND VERY FINE GRAINED. SLIGHTLY ALTERED AND WEATHERED; HIGHLY FRACTURED. NUMEROUS SHORT, VERTICAL, SUBPARALLEL TO UNORIENTED HAIRLINE FRACTURES. CORE SIZE 1 IN. TO 1 FT.

(Continued)

BORING NO. Ue20L-3 (Continued)



PORPHYRITIC TRACHYTE; AS ABOVE EXCEPT GROUNDMASS IS GRY, DENSE, AND VERY FINE GRAINED. OCCASIONAL FAINT BRN FLOW LAYERS APPROXIMATELY 1/2 IN. THICK AND DIPPING 45 TO 50 DEG BECOMES MORE PRONOUNCED WITH DEPTH TO 146 FT. BELOW 146 FT FLOW LAYERS BECOME FAINT AND WIDELY SCATTERED. MODERATELY JOINTED WITH MOST JOINTS PARALLEL TO FLOW STRUCTURE AND LINED WITH SECONDARY MINERALS. CORE SIZE TO 128 FT IS FROM 1 IN. TO 1 FT.

NOTE: Rods dropped from 3 to 5 in. several times between 105 and 139 ft.

103.8 to 105.5 ft, brecciated zone

128.0 to 174.0 ft, core size from 1 to 3 ft.

129.8 ft, brecciated zone 1/2 in wide dips 15 deg. Healed with calcite.

132.0 to 135.6 ft, brecciated zone

139.2 to 139.6 ft, brecciated zone

From 160 to 177 ft flow structure dips 30 deg. Below 177 ft flow structure dips 20 deg.

174.0 ft, core size from here to bottom is less than 1 ft with most fragments less than 6 in.

174.4 to 176.2 ft, brecciated zone 1 in. wide, dips 85 deg. Healed with calcite.

183.6 ft, brecciated zone greater than 2 in. wide. Healed with calcite.

197.8 to 198.6, clay gouge with slickensides in fracture dipping 80 deg.

STRIKE DEG	DIP DEG	WIDTH & FILLING
N36E	50SE	1/4", O
N31E	35SE	1/8", O
N4W	80NE	1/4", Pf
N51E	30SE	H
N51E	40SE	H
N46E	40SE	1/8", O
N44W	90	1/16", Pf
N31E	30SE	1/16", O
N46E	40SE	1/8", Pf
N46E	30SE	1/16", F
N41E	60NW	1/8", O
N51E	40SE	H
	30*	
	20*	
	5*	
	30*	
	30*	
	30*	
	20*	
	30*	
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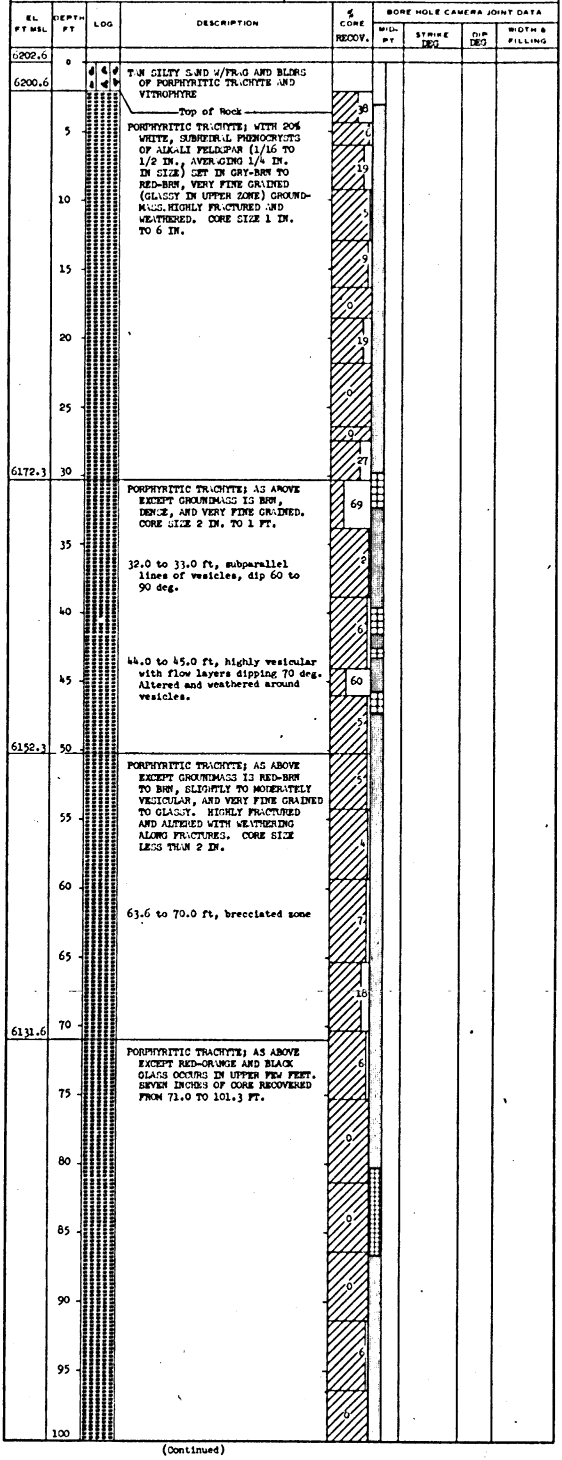
	20*	
	20*	
	20*	
	20*	
	20*	
	20*	
	60*	

* Data are from core log

Bottom Depth: 202.3 ft
Bottom Elevation: 5984.8 ft

PROJECT CABRIOLET

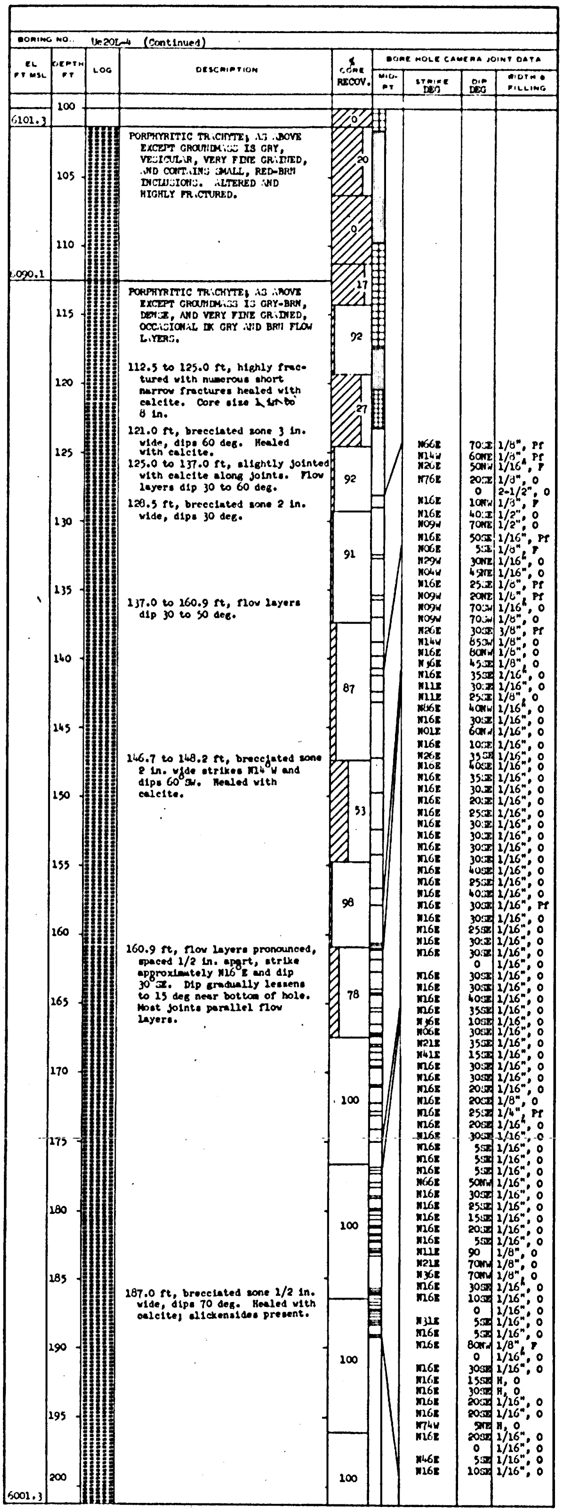
BORING NO.:	Ue20L-4		
LOCATION (NEVADA STATE COORDINATES)	N 921,443.44 E 544,434.23		
ANGLE OF BORING	Vertical	TYPE OF BORING	NX - DIAMOND
BEARING		DRILLING AGENCY	WES
EL TOP OF HOLE	6202.6 ft, MSL	DEPTH TO WATER TABLE	No water encountered
TOTAL DEPTH	201.3 ft	HOLE STARTED	16 December 1965
TOTAL CORE RECOVERY	43.8%	HOLE COMPLETED	4 January 1966



EL FT MSL	DEPTH FT	DESCRIPTION
6202.6	0	
6200.6		TAN SILTY SAND W/FRAG AND BLDRS OF PORPHYRITIC TRACHYTE AND VITROPHYRE
		Top of Rock
		PORPHYRITIC TRACHYTE; WITH 20% WHITE, SUBHEDRAL PHENOCRYSTS OF ALKALI FELDSPAR (1/16 TO 1/2 IN., AVERAGING 1/4 IN. IN SIZE) SET IN GRY-BRN TO RED-BRN, VERY FINE GRAINED (GLASSY IN UPPER ZONE) GROUNDMASS. HIGHLY FRACTURED AND WEATHERED. CORE SIZE 1 IN. TO 6 IN.
6172.3	30	PORPHYRITIC TRACHYTE; AS ABOVE EXCEPT GROUNDMASS IS BRN, DENSE, AND VERY FINE GRAINED. CORE SIZE 2 IN. TO 1 FT. 32.0 to 33.0 ft, subparallel lines of vesicles, dip 60 to 90 deg. 44.0 to 45.0 ft, highly vesicular with flow layers dipping 70 deg. Altered and weathered around vesicles.
6152.3	50	PORPHYRITIC TRACHYTE; AS ABOVE EXCEPT GROUNDMASS IS RED-BRN TO BRN, SLIGHTLY TO MODERATELY VESICULAR, AND VERY FINE GRAINED TO GLASSY. HIGHLY FRACTURED AND ALTERED WITH WEATHERING ALONG FRACTURES. CORE SIZE LESS THAN 2 IN. 63.6 to 70.0 ft, brecciated zone
6131.6	70	PORPHYRITIC TRACHYTE; AS ABOVE EXCEPT RED-ORANGE AND BLACK GLASS OCCURS IN UPPER FEW FEET. SEVEN INCHES OF CORE RECOVERED FROM 71.0 TO 101.3 FT.

(Continued)

BORING NO.: Ue20L-4 (Continued)



EL FT MSL	DEPTH FT	DESCRIPTION
	100	
6101.3		PORPHYRITIC TRACHYTE; AS ABOVE EXCEPT GROUNDMASS IS GRY, VESICULAR, VERY FINE GRAINED, AND CONTAINS SMALL, RED-BRN INCLUSIONS. ALTERED AND HIGHLY FRACTURED.
6090.1		PORPHYRITIC TRACHYTE; AS ABOVE EXCEPT GROUNDMASS IS GRY-BRN, DENSE, AND VERY FINE GRAINED, OCCASIONAL DK GRY AND BRN FLOW LAYERS. 112.5 to 125.0 ft, highly fractured with numerous short narrow fractures healed with calcite. Core size 1 in. to 8 in. 121.0 ft, brecciated zone 3 in. wide, dips 60 deg. Healed with calcite. 125.0 to 137.0 ft, slightly jointed with calcite along joints. Flow layers dip 30 to 60 deg. 128.5 ft, brecciated zone 2 in. wide, dips 30 deg. 137.0 to 160.9 ft, flow layers dip 30 to 50 deg. 146.7 to 148.2 ft, brecciated zone 2 in. wide strikes N14°W and dips 60°SW. Healed with calcite. 160.9 ft, flow layers pronounced, spaced 1/2 in. apart, strike approximately N16°E and dip 30°SE. Dip gradually lessens to 15 deg near bottom of hole. Most joints parallel flow layers. 187.0 ft, brecciated zone 1/2 in. wide, dips 70 deg. Healed with calcite; slickensides present.
6001.3		

MID-PT	STRIKE DEG	DIP DEG	WIDTH & FILLING
	N66E	70SE	1/8", Pf
	N14W	60NE	1/8", Pf
	N26E	50NW	1/16", F
	N76E	20SE	1/8", 0
		0	2-1/2", 0
	N16E	10NW	1/8", F
	N16E	40SE	1/2", 0
	N09W	70NE	1/2", 0
	N16E	50SE	1/16", Pf
	N06E	5SE	1/8", F
	N29W	30NE	1/16", 0
	N04W	45NE	1/16", 0
	N16E	25SE	1/8", Pf
	N09W	20NE	1/8", Pf
	N09W	70SW	1/16", 0
	N09W	70SW	1/8", 0
	N26E	30SE	3/8", Pf
	N14W	85SW	1/8", 0
	N16E	80NW	1/8", 0
	N36E	45SE	1/8", 0
	N16E	35SE	1/16", 0
	N11E	30SE	1/16", 0
	N11E	25SE	1/8", 0
	N06E	40NW	1/16", 0
	N16E	30SE	1/16", 0
	N01E	60NW	1/16", 0
	N16E	10SE	1/16", 0
	N26E	35SE	1/16", 0
	N16E	40SE	1/16", 0
	N16E	35SE	1/16", 0
	N16E	30SE	1/16", 0
	N16E	20SE	1/16", 0
	N16E	25SE	1/16", 0
	N16E	30SE	1/16", 0
	N16E	30SE	1/16", 0
	N16E	30SE	1/16", 0
	N16E	30SE	1/16", 0
	N16E	40SE	1/16", 0
	N16E	25SE	1/16", 0
	N16E	40SE	1/16", 0
	N16E	30SE	1/16", Pf
	N16E	30SE	1/16", 0
	N16E	25SE	1/16", 0
	N16E	30SE	1/16", 0
	N16E	30SE	1/16", 0
		0	1/16", 0
	N16E	30SE	1/16", 0
	N16E	30SE	1/16", 0
	N16E	40SE	1/16", 0
	N16E	35SE	1/16", 0
	N36E	10SE	1/16", 0
	N06E	30SE	1/16", 0
	N21E	35SE	1/16", 0
	N41E	15SE	1/16", 0
	N16E	30SE	1/16", 0
	N16E	30SE	1/16", 0
	N16E	20SE	1/16", 0
	N16E	20SE	1/8", 0
	N16E	25SE	1/4", Pf
	N16E	20SE	1/16", 0
	N16E	30SE	1/16", 0
	N16E	5SE	1/16", 0
	N16E	5SE	1/16", 0
	N16E	5SE	1/16", 0
	N66E	50NW	1/16", 0
	N16E	30SE	1/16", 0
	N16E	25SE	1/16", 0
	N16E	15SE	1/16", 0
	N16E	20SE	1/16", 0
	N16E	5SE	1/16", 0
	N11E	90	1/8", 0
	N21E	70NW	1/8", 0
	N36E	70NW	1/8", 0
	N16E	30SE	1/16", 0
	N16E	10SE	1/16", 0
		0	1/16", 0
	N31E	5SE	1/16", 0
	N16E	5SE	1/16", 0
	N16E	80NW	1/8", F
		0	1/16", 0
	N16E	30SE	1/16", 0
	N16E	15SE	H, 0
	N16E	30SE	H, 0
	N16E	20SE	1/16", 0
	N16E	20SE	1/16", 0
	N74W	5NE	H, 0
	N16E	20SE	1/16", 0
		0	1/16", 0
	N46E	5SE	1/16", 0
	N16E	10SE	1/16", 0

Bottom Depth: 201.3 ft
Bottom Elevation: 6001.3 ft

APPENDIX B

PETROGRAPHIC EXAMINATION AND SAMPLE DESCRIPTION

APPENDIX B

PETROGRAPHIC EXAMINATION AND SAMPLE DESCRIPTION

B.1 SAMPLES

Samples of the following rock cores from Project Cabriolet drill hole Ue20L-1 were received for petrographic examination. The original cores were received as 6-inch diamond-drilled cores. NX-diameter cores were drilled from the larger diameter cores in order to obtain specimens with proper length to diameter ratios for physical testing. Inspection of the cores before drilling the smaller cores indicated that there were possibly three varieties of rock present. The samples to be examined petrographically were selected on this supposition.

CD Serial No.	Field Sample No.	Depth	Description
		ft	
NTS-33 DC-1(A)	2	21.9 to 24.0	Dense, reddish porphyritic rock.
NTS-33 DC-1(C)	1	87.5 to 88.9	Vesicular, somewhat weathered, reddish porphyritic rock.
NTS-33 DC-1(D)	5	151.8 to 153.3	Dense, grayish-red porphyritic rock.

The samples examined were slices of core 1 to 2 inches long that had been trimmed from longer core lengths in the preparation of cylinders for physical testing.

B.2 TESTING PROCEDURE

The core samples were examined with a stereomicroscope on cored, freshly broken, and sawed surfaces. A thin section of each sample was prepared and examined with a petrographic microscope. Representative samples of each core were examined on the X-ray diffractometer. The indexes of refraction of the feldspar phenocrysts in the cores were determined in oil immersion mounts. The X-ray diffraction patterns and thin sections were compared with those of cores from a nearby drill hole, Ue20K-1, which had been examined earlier (see reports dated 5 March and 1 April 1965, Project: Palanquin).

B.3 DESCRIPTION OF CORES

B.3.1 Core Sample No. 2, NTS-33 DC-1(A). The sample, slightly over 1 inch long, was a dense, grayish-red (10 R 4/2)[1] porphyritic igneous rock containing clear to white anhedral to subhedral feldspar phenocrysts ranging in size from about 1/8 to 1/2 inch, and a few highly altered green ferroan mineral phenocrysts in a grayish-red, very fine-grained groundmass. Index of refraction measurements and other optical properties indicated that the composition of the feldspar phenocrysts was anorthoclase. Thin sections showed the groundmass of the rock to be composed of slightly oriented lath-shaped

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[1] The Rock Color Chart Committee, National Research Council; "The Rock Color Chart"; 1948; Washington, D. C.

feldspar microlites, extremely small greenish-yellow pyroxene grains, and reddish-brown to opaque mineral grains composed of hematite and altered ferroan minerals. The red coloration of the rock was due to these mineral grains. The feldspar phenocrysts were corroded and contained numerous inclusions, but no evidence of alteration to clay minerals was noted. The pyroxene phenocrysts were altered along edges and fractures to iron oxide. Many were almost completely altered. No quartz, mica, or clay minerals were detected either in thin section or in the X-ray diffraction pattern of the rock. The rock was classified as a trachyte porphyry on the basis of its mineralogical composition and texture.

B.3.2 Core Sample No. 5, NTS-33 DC-1(D). The groundmass of this core sample had a darker grayish-red cast (near brownish-gray (5 YR 4/1) on Rock Color Chart); otherwise it was similar in appearance to sample No. 2. The rock was a dense porphyritic igneous rock (trachyte porphyry) composed of white to clear anorthoclase feldspar and green altered pyroxene phenocrysts in a dense, very fine-grained trachytic-textured groundmass of feldspar microlites, pyroxene, hematite, and altered mineral grains. The X-ray diffraction pattern indicated that a small amount of quartz was present, although none was found by microscope. Rock represented by this core sample and sample No. 2 (NTS-33 DC-1(A)) would be expected to have very similar physical properties.

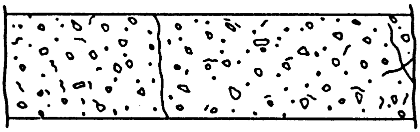
B.3.3 Core Sample No. 1, NTS-33 DC-1(C). This core sample, about 2 inches long, was composed of a somewhat weathered, vesicular, porphyritic igneous rock. The vesicles in the rock were elongated, usually less than 1/8 inch long, had clear to white linings probably composed of opal-cristobalite mixtures, and many contained small spherulites composed of cristobalite. In addition, some vesicles contained extremely small, slender, prismatic, yellow crystals similar to those found in core No. 4, a highly weathered sample from drill hole Ue20K-1, which was examined for Project Palanquin. Many of these crystals had altered to a rusty brown color. The feldspar phenocrysts were similar in size, composition, and degree of alteration to those in the other two core samples. Pyroxene phenocrysts were almost completely altered to iron oxide. Feldspar microlites in the groundmass of the rock were similar in size, composition, and orientation to those in the other samples. Almost all the small pyroxene grains in the groundmass were altered to iron oxide. The intense alteration of the ferroan minerals and the presence of tiny hematite crystals were responsible for the red coloration of the groundmass of the rock. The X-ray diffraction pattern was similar to those of the other samples. The amount of weathering and the vesicular nature of this rock should render it physically weak in comparison with the other two core samples.

B.4 COMPARISON WITH PREVIOUS SAMPLES

The three samples examined in the present study were compared with previously examined core samples from drill hole Ue20K-1, Project Palanquin (see petrographic reports dated 5 March and 1 April 1965). In general, the rock from the two drill holes was found to be similar in composition and texture, as reflected in X-ray diffraction patterns and thin sections of the core samples. All were classified as trachyte porphyry. Variations in the amount of hematite and alteration of ferroan minerals in the groundmass of the rock were responsible for the color differences in the cores. For the most part, the cores were dense and physically sound rock, but both drill holes contained weathered zones as represented by sample No. 1, 87.5 to 88.9 feet in the present drill hole, and core sample No. 4 from about 140 feet in drill hole Ue20K-1. Physical properties of the rock in the two drill holes should therefore be very similar.

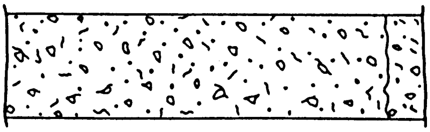
B.5 SUMMARY

Petrographic examination of the three core samples indicated that all had similar mineralogical compositions. All were soda-rich, porphyritic igneous rocks from lava flows. The cores were composed of clear to white anorthoclase (feldspar) and altered pyroxene phenocrysts in very fine-grained trachytic-textured groundmasses. Core samples No. 2 and No. 5 were dense and relatively unaffected by physical weathering and should have similar physical properties, whereas core sample No. 1 was vesicular, containing secondary deposits within the vesicles, and was physically weaker than the two dense core samples. All three samples were classified as trachyte porphyry. Minor color differences in the samples were due to variation in the amount of hematite and altered ferroan mineral grains in the groundmass, and in themselves should not affect the physical properties to any extent.



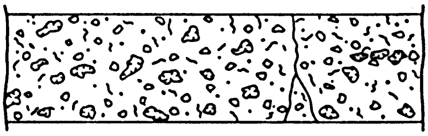
Boring No. Ue20L-1
Depth 21.9 to 24.0 feet
Core Length 11.5 inches

TRACHYTE PORPHYRY, light reddish-brown, aphanitic groundmass with small reddish crystals and large phenocrysts of soda-rich feldspar disseminated throughout the core. Phenocrysts range in size up to 1/2 inch in their longest dimension. There are numerous short narrow cracks, approximately 1/4 inch long, on the core surface, most of which are filled with iron oxide; there is no preferred orientation. There is a fresh break 4-1/2 inches from the top. Two small narrow cracks are present near the bottom of the core. This rock is very similar to the rock examined and tested for Project Palanquin.



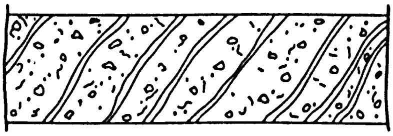
Boring No. Ue20L-1
Depth 41.7 to 43.7 feet
Core Length 11.9 inches

TRACHYTE PORPHYRY, description is the same as for specimen from 21.9 to 24.0 feet with the following exceptions: an old fracture encircles the core approximately 1 inch from the bottom of the core; a small amount of iron oxide fills the fracture.



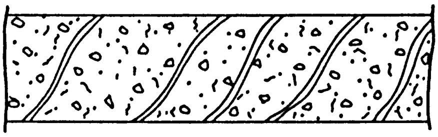
Boring No. Ue20L-1
Depth 87.5 to 88.9 feet
Core Length 11.8 inches

TRACHYTE PORPHYRY, reddish-brown, aphanitic groundmass with small reddish crystals and small and large phenocrysts of soda-rich feldspar disseminated throughout the core. Phenocrysts range in size from pinhead size to 3/8 inch in their longest dimension. The short narrow cracks as described for specimen from 21.9 to 24.0 feet are present. Numerous vesicles are present on the core surface and range from very small to 1/4 inch in their longest dimension; they have no preferred orientation. An old fracture encircles the core approximately 3 inches from the bottom. The core is badly weathered, and its physical properties should be somewhat lower than those of the other cores.



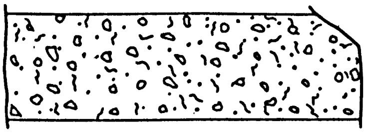
Boring No. Ue20L-1
Depth 151.8 to 153.3 feet
Core Length 10.8 inches

TRACHYTE PORPHYRY, description is the same as for specimen from 21.9 to 24.0 feet with the following exceptions: core is grayish-red with reddish-brown color bands encircling the core which dip approximately 40 degrees.



Boring No. Ue20L-1
Depth 168.3 to 170.7 feet
Core Length 12.0 inches

TRACHYTE PORPHYRY, gray with light brown color bands; aphanitic groundmass with some small reddish crystals and large phenocrysts of soda-rich feldspar disseminated throughout the core. Phenocrysts range in size up to 1/2 inch in their longest dimension. The same short narrow cracks are present as in specimen from 21.9 to 24.0 feet. Reddish-brown colorbands encircle the core and dip approximately 50 degrees.



Boring No. Ue20L-3
Depth 106.0 to 106.8 feet
Core Length 10.0 inches

TRACHYTE PORPHYRY, light brownish-gray, aphanitic groundmass with small reddish crystals and large phenocrysts of soda-rich feldspar disseminated throughout the core. Phenocrysts range in size up to 3/4 inch in their longest dimension. Numerous short narrow cracks, approximately 1/4 inch long, some filled with iron oxide, are present on the core surface. Top of core is an old fracture surface; bottom of core has an old fracture surface and a surface intersecting the fracture which appears to be a joint plane partly covered with a white noncalcareous material; the apparent joint plane dips approximately 70 degrees.

LEGEND

- ▨ FELDSPAR PHENOCRYSTS
- ▨ SHORT NARROW SURFACE CRACKS
- ▨ SMALL REDDISH CRYSTALS
- ▨ VOIDS
- ▨ COLOR BANDS

Note: These core logs were conducted on NX size cores drilled from 6-inch cores. Core ends are sawed surfaces; therefore, no description is given of the natural core ends except where so stated.

Figure B.1 Description of samples from borings Ue20L-1 and Ue20L-3.

APPENDIX C

PHYSICAL TEST DATA

TABLE C.1 UNCONFINED COMPRESSIVE STRENGTH TEST RESULTS, PROJECT CABRIOLET, 4 FEBRUARY 1966

Test method used, CRD-C 19; Specimen diameter, 2.125 inches; specimen length, 4.25 inches; rate of load, 50 psi/sec; method of sawing to length, diamond saw; method of end preparation, surface ground; testing apparatus, 440,000-pound Baldwin Universal Machine; method of strain measurement, two vertically and two horizontally opposed SR-4 strain gages, type A3-S6.

Stress	Average Strain	
	Vertical	Horizontal
psi	μin/in	μin/in
Boring Ue20L-1; Core Depth, 21.9 to 24.0 feet:		
0	0	0
1,410	420	60
2,820	825	115
4,240	1,200	260
5,650	1,570	410
7,060	1,935	595
8,470	2,305	1,095
9,890	2,310	1,895
11,300	2,355	--
12,250	2,675	--
Boring Ue20L-1; Core Depth, 41.7 to 43.7 feet:		
0	0	0
1,410	540	125
2,820	1,040	285
4,240	1,440	435
5,650	1,790	620
7,060	2,230	880
8,470	2,590	1,140
9,890	2,805	2,245
11,300	3,120	4,265
12,710	3,430	--
12,880	3,445	--
Boring Ue20L-1; Core Depth, 87.5 to 88.9 feet:		
0	0	0
1,410	840	115
2,820	1,535	285
4,240	2,115	525
5,650	2,680	825
7,060	3,260	--
7,090	--	--

Stress	Average Strain	
	Vertical	Horizontal
psi	μin/in	μin/in
Boring Ue20L-3; Core Depth, 106.0 to 106.8 feet:		
0	0	0
1,410	530	65
2,820	980	145
4,240	1,375	230
5,650	1,730	310
7,060	2,095	430
8,470	2,455	600
9,890	2,815	820
11,300	3,135	1,175
12,710	3,380	1,640
13,210	--	--
Boring Ue20L-1; Core Depth, 151.8 to 153.3 feet:		
0	0	0
1,410	590	90
2,820	1,140	235
4,240	1,635	380
5,650	2,255	570
7,060	2,865	805
8,470	3,380	1,070
9,890	3,865	1,440
11,300	4,345	2,000
12,710	4,555	3,360
13,000	--	--
Boring Ue20L-1; Core Depth, 168.3 to 170.7 feet:		
0	0	0
1,410	340	90
2,820	760	195
4,240	1,210	360
5,650	1,605	595
7,060	2,015	860
8,470	2,335	1,125
9,890	2,640	1,515
11,300	2,920	2,155
12,710	3,160	4,350
13,420	3,370	--

TABLE C.2 RESULTS OF TRIAXIAL TESTS, BORING Ue20L-1

Area of specimen, 3.54 square inches; area of loading head, 19.63 square inches; rate of load, 50 psi/sec; method of sawing to length, diamond saw; method of end preparation, surface ground; testing apparatus, 440,000-pound Baldwin Universal Machine and triaxial chamber; method of strain measurement, two vertically opposed SR-4 strain gages, type A3-S6.

Lateral Stress σ_3	Axial Load	Axial Stress	Deviator Stress σ	Axial Strain
psi	pounds	psi	psi	µin/in
Core Depth, 21.9 to 24.0 feet; Ultimate Strength, 47,749 psi; Specimen Length, 4.25 inches; Specimen Diameter, 2.125 inches; L/D Ratio, 2.00:				
0	0	0	0	0
1,000	19,000	0	0	0
2,000	37,500	0	0	0
3,000	55,500	0	0	0
4,000	75,000	0	0	0
5,000	94,500	26,700	0	0
5,000	100,000	28,250	1,550	0
5,000	110,000	31,070	4,370	825
5,000	120,000	33,900	7,200	1,420
5,000	130,000	36,720	10,020	1,965
5,000	140,000	39,550	12,840	2,555
5,000	150,000	42,370	15,670	3,125
5,000	160,000	45,200	18,490	3,685
5,000	170,000	48,020	21,320	4,265
5,000	180,000	50,850	24,140	4,875
5,000	190,000	53,670	26,970	5,480
5,000	200,000	56,500	29,790	6,115
5,000	210,000	59,320	32,620	6,785
5,000	220,000	62,150	35,440	7,475
5,000	230,000	64,970	38,270	8,235
5,000	240,000	67,800	41,090	9,070
5,000	250,000	70,620	43,920	9,985
5,000	260,000	73,450	46,750	11,445
5,000	263,500	74,440	47,749	12,625
Core Depth, 76.7 to 77.7 feet; Ultimate Strength, 37,860 psi;[a] Specimen Length, 3.75 inches; Specimen Diameter, 2.125 inches; L/D Ratio, 1.76:				
0	0	0	0	0
1,000	20,000	0	0	0
2,000	39,500	0	0	0
3,000	58,500	0	0	0
4,000	78,000	0	0	0
5,000	97,500	27,540	0	0
5,000	100,000	28,250	710	655
5,000	110,000	31,070	2,160	955
5,000	120,000	33,900	3,530	1,325
5,000	130,000	36,720	4,950	1,665[b]
5,000	130,000	36,720	4,950	
5,000	130,000	36,720	4,950	
5,000	130,000	36,720	4,950	
5,000	234,250	66,170	38,630	
Core Depth, 151.8 to 153.3 feet; Ultimate Strength, 46,470 psi; Specimen Length, 4.25 inches; Specimen Diameter, 2.125 inches; L/D Ratio, 2.00:				
0	0	0	0	0
1,000	20,000	0	0	0
2,000	40,000	0	0	0
3,000	59,000	0	0	0
4,000	78,500	0	0	0
5,000	97,500	27,540	0	0
5,000	100,000	28,250	710	10
5,000	105,000	29,700	2,160	655
5,000	110,000	31,070	3,530	925
5,000	115,000	32,490	4,950	1,340
5,000	120,000	33,900	6,360	1,640
5,000	125,000	35,310	7,770	1,915
5,000	130,000	36,720	9,180	2,255
5,000	135,000	38,140	10,600	2,625
5,000	140,000	39,550	12,010	3,000
5,000	145,000	40,960	13,420	3,265
5,000	150,000	42,370	14,830	3,595
5,000	155,000	43,790	16,250	3,975
5,000	160,000	45,200	17,660	4,275
5,000	165,000	46,610	19,070	4,565
5,000	170,000	48,020	20,480	4,895
5,000	175,000	49,440	21,900	5,235
5,000	180,000	50,850	23,310	5,585
5,000	185,000	52,260	24,720	5,895
5,000	190,000	53,670	26,130	6,240
5,000	195,000	55,090	27,550	6,695
5,000	200,000	56,500	28,960	7,005
5,000	205,000	57,910	30,370	7,430
5,000	210,000	59,320	31,780	7,765
5,000	215,000	60,730	33,190	8,140
5,000	220,000	62,150	34,610	8,485
5,000	225,000	63,560	36,020	8,900
5,000	230,000	64,970	37,430	9,400
5,000	235,000	66,380	38,840	9,915
5,000	240,000	67,800	40,260	10,335
5,000	245,000	69,210	41,670	10,765
5,000	250,000	70,620	43,080	11,305
5,000	255,000	72,030	44,490	11,665
5,000	260,000	73,450	45,910	-430
5,000	262,000	74,010	46,470	-2,070

[a] Correction of ultimate strength when L/D ratio is less than 2, CRD-C 27-63: 38,630 psi × 0.98 = 37,860 psi.

[b] Strain gage became inoperative after this reading.

TABLE C.3 RESULTS OF TENSILE STRENGTH (DIRECT) TESTS, PROJECT CABRIOLET, 4 FEBRUARY 1966

No test method has been set up to date. Specimen was cemented to steel plates which were attached to universal swivel joints and then pulled apart.

Boring Ue20L-1

Specimen diameter-- 2.125 inches

Specimen length-- 4.250 inches

Rate of load------------------ 800 lb/min or approximately 47 psi/sec

Method of sawing to length------------------------------ diamond saw

Method of end preparation-------- surface ground and Steelcote Epoxy,
binder type II, Part A-EP
(Corps of Engineers)

Testing apparatus---------------- 30,000-pound Riehle Testing Machine

Method of strain measurement------------------------------------- none

Core Depth	Direct Tensile Strength[a]
ft	psi
21.9 to 24.0	350
151.8 to 153.3	410

---

[a] Direct tensile strength = $\frac{P}{A}$.

TABLE C.4 RESULTS OF STATIC TENSILE SPLITTING TESTS, PROJECT CABRIOLET, 4 FEBRUARY 1966

Rate of load, 150 psi/sec; method of sawing to length, diamond saw; testing apparatus, 440,000-pound Baldwin Universal Machine; test method used, CRD-C 77.

Boring No.	Core Depth	Specimen		Tensile Splitting Strength[a]
		Diameter	Length	
	feet	inches	inches	psi
Ue20L-1	21.9 to 24.0	2.12	4.30	810
Ue20L-1	41.7 to 43.7	2.12	4.33	920
Ue20L-1	87.5 to 88.9	2.13	2.13	440
Ue20L-3	106.0 to 106.8	2.13	2.13	870
Ue20L-1	151.8 to 153.3	2.12	4.25	860
Ue20L-1	168.3 to 170.7	2.12	4.25	1,060

---

[a] Tensile splitting strength (T) = $\frac{2P}{\pi t d}$, where

T = tensile splitting strength, psi
P = maximum applied load, indicated by testing machine, pounds
t = length of specimen, inches
d = diameter of specimen, inches

TABLE C.5 COMPUTATIONS USED, PROJECT CABRIOLET, 4 FEBRUARY 1966

To obtain bulk density multiply specific gravity by 62.3 lb/cu ft.

Bulk Dry Specific Gravity:

$$G_o = \frac{W_o}{V_o \gamma_w}$$, where

G_o = specific gravity of the oven-dried core
W_o = weight of the oven-dried core in grams
V_o = volume of the core in milliliters
γ_w = density of water at temperature of test specimen

Saturated Surface-Dry Specific Gravity:

$$G_s = \frac{W_s}{W_s - W_w}$$, where

G_s = specific gravity of the saturated surface-dry core
W_s = weight in air of the saturated surface-dry core in grams
W_w = weight in water of the saturated surface-dry core in grams

Specific Gravity of Solids:

$$G_o = \frac{W_s K}{W_s + W_{bw} - W_{bws}}$$, where

W_s = the oven-dried weight of the powdered rock sample in grams
K = the correction factor, based on the density of water at 20 C
W_{bw} = weight of flask plus water at test temperature in grams
W_{bws} = weight of flask plus water plus solids at test temperature in grams

Figure C.1 As-received 6-inch cores.

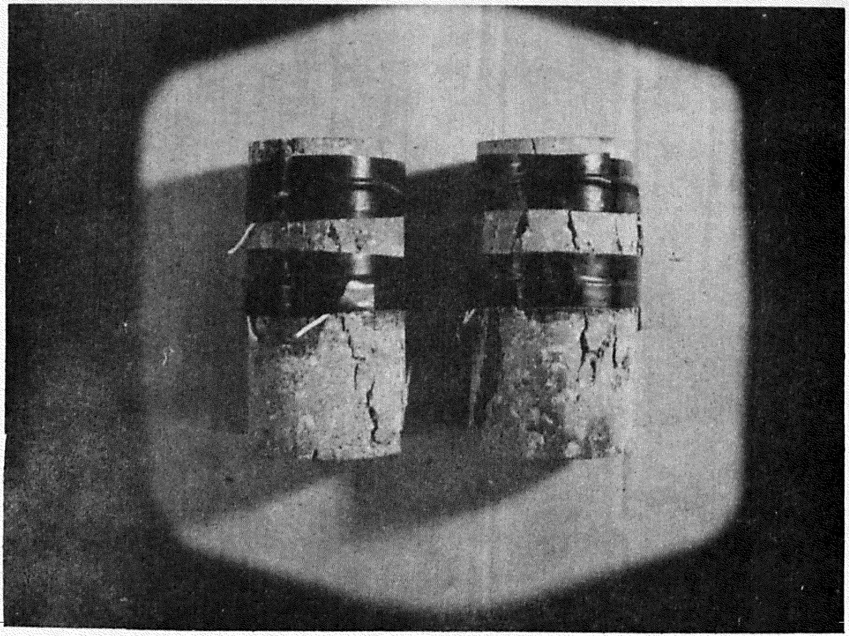


Figure C.2 Posttest photograph showing typical failure of specimens tested in unconfined compression.

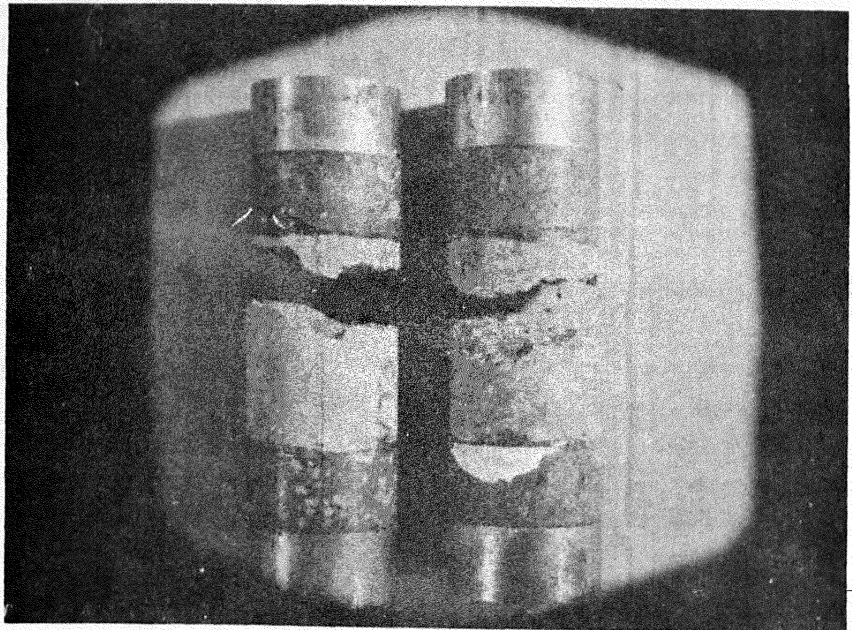


Figure C.3 Posttest photograph showing the tensile failure surfaces of specimens tested in direct tension.

PROJECT CABRIOLET REPORTS

Report	Agency	Author	Title
PNE-950	LRL		Cabriolet Summary
PNE-951	Sandia, Albu	L. Vortman	Close-In Air Blast
PNE-952	Sandia, Albu	J. Reed	Long-Range Air Blast
PNE-953	LRL	L. Ramspott	Cabriolet Pre-Shot Geology
PNE-966	WES	R. W. Hunt D. M. Bailey L. D. Carter	Preshot Geological Engineering Investigation for Project Cabriolet, Pahute Mesa, NTS

TENTATIVE REPORTS

LRL	T. Gibson	Ground Radiation Survey
LRL	R. Rohrer	Cloud and Surface Measurements
LRL	R. Marks	Subsurface Effects
NCG		Crater Topography

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13. ABSTRACT

The site of the Cabriolet experiment is on Pahute Mesa, Nevada Test Site. The site media, explored by four borings, consist of porphyritic trachyte overlain by a thin soil layer. Fractured, vesicular zones in the upper portions of the borings yielded poor core recovery, while higher core recovery was obtained at depth in dense, less fractured rock. Flow layers strike approximately N35°E at the surface and impart a pronounced structural grain to the rock. At depth, most joints roughly parallel the flow layering and strike N20°E. Joint spacing ranges from less than 0.1 to greater than 10 feet. Four high-angle faults are suspected in the vicinity of the site. Three of these strike roughly north-south and pass 200, 380, and 680 feet west of the site. The fourth inferred fault strikes approximately N63°E and passes 480 feet north of surface ground zero. For dense, unfractured rock, the bulk density, saturated surface-dry basis, averages 158.5 pcf, while the bulk density, dry, averages 156.2 pcf. The porosity averages 4.5 percent, and the unconfined compressive strength averages 12,952 psi. The vesicular material, based on one specimen, had a bulk density, saturated surface-dry basis, of 136.1 pcf, while the bulk density, dry, was 129.1 pcf. The porosity was 21.3 percent, and the unconfined compressive strength was 7,090 psi.

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Cabriolet (Project)						
Geology -- Nevada						
Nevada Proving Grounds Area						
Pahute Mesa						
Rock mechanics						
Rock -- Physical properties						
Rock -- Porosity						
Rock -- Shear stresses						