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PRESHOT GEOLOGIC AND ENGINEERING PROPERTIES INVESTIGATIONS

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

by

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Vicksburg, Mississippi

April 1969

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PNE-322

PROJECT BUGGY

PRESHOT GEOLOGIC AND ENGINEERING
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April 1969

ABSTRACT

The site for the Buggy row charge cratering event is located on Chukar Mesa, NTS, in dry basalt. Topography is relatively flat over an approximately square area about 3,000 feet across. The site consists of about 330 feet of horizontal basalt flows resting on tuff breccia, other basalt flows, and a thick vitrophyric flow.

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Unconfined compressive strengths tend to decrease with increasing porosity from 33,000 psi for dense basalt to 6,200 psi for vesicular basalt with 20 to 30 percent vesicles. Tensile splitting and unconfined and triaxial compression tests on dense basalt indicate a failure envelope with ϕ of 50 degrees at normal stresses of 0 to 5,000 psi and ϕ of 30 degrees at normal stresses of 15,000 to 20,000 psi. Cohesion is about 5,000 psi. The Poisson's ratio for basalt ranges from 0.17 to 0.30 and is apparently not related to vesicularity.

The weighted lineal joint intercept spacing for near-surface basalt averages about 0.3 foot and that at depth averages about 0.9 foot.

Interlayered clinker zones apparently reduce the average seismic velocity of the medium by more than 50 percent. 13 references.

(auth)

PREFACE

Preshot geological and engineering investigations at the Buggy site were conducted during the period August 1967 through January 1968 by the U. S. Army Engineer Waterways Experiment Station (WES), Vicksburg, Mississippi, under the sponsorship of the U. S. Army Engineer Nuclear Cratering Group (NCG), Livermore, California.

The core drilling program was under the direction of Mr. A. L. Mathews, Embankment and Foundation Branch, Soils Division, WES.

Geological field work and the logging of cores were performed largely by Mr. R. W. Hunt, Geology Branch, Soils Division, WES. Mr. R. E. Rowland prepared Chapter 3 using test data obtained by Messrs. K. L. Saucier and A. D. Buck of the Concrete Division, WES. The remainder of the report was written by Dr. R. J. Lutton, Geology Branch, Soils Division, WES.

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Directors of the WES were COL John R. Oswalt, Jr., CE, and COL Levi A. Brown, CE. Technical Directors of the WES were Mr. J. B. Tiffany and Mr. F. R. Brown.

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CHAPTER 1

INTRODUCTION

Project Buggy was the first nuclear row cratering detonation executed as part of the Plowshare Program for development of nuclear excavation techniques. Five nuclear explosives, each with a yield of 1.1 kt, were detonated simultaneously at 0904:00.111 PST, 12 March 1968. The depths of burst were at 135 feet, and the spacing between explosives was 150 feet. The experiment took place on Chukar Mesa, Area 30, Nevada Test Site (see Figure 1.1), in a dry, complex basalt formation. Surface ground zero coordinates of the end emplacement holes designated as U-30-A and U-30-E were:

	U-30-A	U-30-E
NTS Grid Coordinates	N821,828.24 E586,630.95	N822,039.76 E586,069.54
Latitude	N37°0'26.9695"	N37°0'29.0784"
Longitude	W116°22'11.8817"	W116°22'18.7955"

The line of charges was on a bearing of N69°21'05"W. Ground elevations at each hole were as follows:

	Hole U-30-				
	A	B	C	D	E
Elevation (msl) (feet)	5,208.3	5,210.0	5,210.4	5,209.4	5,208.6

The principal objectives of the experiment were to: (1) determine nuclear row crater parameters through level terrain in a hard, dry rock; and (2) determine the fraction of radioactivity which escapes the immediate cratered area.

Apparent crater dimensions which describe the excavation are:

Apparent crater width, average (W_a)	254.0 feet
Apparent crater depth, maximum (D_a)	69.8 feet
Lip crest width, average (W_{al})	355.0 feet
Apparent crater length (L_a)	865.0 feet
Apparent lip height, average (H_{al}), sides	41.0 feet
Apparent lip height, average (H_{al}), ends	14.0 feet
Apparent crater volume	262,456.0 yd ³
Apparent lip volume	422,205.0 yd ³

1.1 PURPOSE

This report presents the findings of the investigations of pre-shot geologic and engineering properties conditions at the Project Buggy site on Chukar Mesa.

1.2 SCOPE

This report is largely limited to results of investigations conducted in the interval August 1967 through January 1968 prior to the event. Pertinent information gathered in the site selection phase of the project has been included also.

1.3 PREVIOUS WORK

The Chukar Mesa site was first visited in connection with Project Buggy in January 1966. It was subsequently selected as the most suitable location for the cratering experiment, and three borings (66-3, -4, and -5) were put down to confirm its suitability. A report of the site selection activities has been published (Reference 1).

1.4 FIELD AND LABORATORY INVESTIGATIONS

Preshot investigations at Chukar Mesa were based on 15 additional borings along and at right angles to the line of row charges (Figure 1.2). The deepest of these borings (Table 1.1) was 327 feet and the shallowest about 58 feet. The walls of all borings were photographed with the borehole camera. NX cores recovered continuously from the borings were logged and photographed for record purposes. Boring logs prepared in the field are incorporated in summary logs in Appendix A. Two borings were inclined at 60 degrees to the horizontal in order to provide a better picture of the orientation of fractures.

Tests conducted on the cores were as follows: petrographic examination, bulk specific gravity, specific gravity of solids, tensile splitting, unconfined compression, sliding friction, and triaxial compression.

TABLE 1.1 SUMMARY OF PRESHOT SUBSURFACE INVESTIGATIONS OF THE BUGGY SITE, 1967-1968

NX Core Boring Number	Location ^a		Surface Elevation	Total Depth	Angle of Boring	Total Core Recovery	Borehole Camera Log
			feet, msl	feet		percent	interval, feet
67-1	N822,036.23	E586,390.70	5,206.2	327.2	Vertical	64	8.0 to 320.0
67-2	N822,137.53	E586,426.27	5,202.2	327.4	Vertical	91	5.0 to 54.0 166.0 to 315.0
67-3	N822,139.07	E586,427.04	5,202.2	201.6	60 degrees ^b	80	7.0 to 80.0
67-4	N822,139.69	E586,427.61	5,202.2	200.9	60 degrees ^c	69	2.8 to 51.5
67-5	N822,238.38	E586,464.22	5,197.7	219.9	Vertical	79	10.0 to 175.0
67-6	N822,338.07	E586,502.75	5,194.3	219.3	Vertical	81	10.0 to 203.8
67-7	N822,540.43	E586,578.97	5,187.8	150.0	Vertical	72	5.0 to 147.0
67-8	N822,077.80	E585,966.36	5,208.2	326.2	Vertical	76	5.0 to 304.0
67-9	N822,117.41	E585,863.71	5,208.5	220.0	Vertical	57	10.0 to 212.0
67-10	N822,191.38	E585,667.24	5,211.0	150.0	Vertical	68	10.0 to 135.0
67-11	N822,340.67	E585,498.31	5,194.3	58.3	Vertical	65	5.0 to 55.0
67-12	N822,439.80	E586,540.55	5,191.6	60.5	Vertical	48	5.0 to 59.0
67-13	N822,536.28	E586,583.52	5,188.1	60.0	Vertical	78	5.0 to 58.0
67-14	N822,640.31	E586,616.59	5,184.6	60.7	Vertical	41	5.0 to 55.0
67-15	N821,854.65	E586,560.91	5,209.1	150.0	Vertical	70	5.0 to 146.0

^a Nevada state coordinate system.

^b Boring 67-3 is inclined down at an azimuth of S20°W.

^c Boring 67-4 is inclined down at an azimuth of N70°E.

Figure 1.1 Location of Buggy (Chukar Mesa) site on NTS.

Figure 1.2 Arrangement of borings (solid circles) and emplacements (open circles) at Buggy site.

CHAPTER 2

GEOLOGY OF PROJECT BUGGY SITE

The site is located in a sequence of basalt flows on Chukar Mesa, adjacent to Fortymile Canyon. It is approximately 12 miles south of Buckboard Mesa and offers somewhat similar site conditions.

2.1 GENERAL GEOLOGY AND PHYSIOGRAPHY

The site occupies a topographic flat at about 5,200 feet msl. well up on the flank of Fortymile Canyon. It is about 2 miles northeast of Dome Mountain across Chukar Canyon, a tributary to the west of Fortymile Canyon. The mesalike flat terminates on all sides except the northwest in precipitous rimrock eroded in flat-lying basalt flows (Figure 2.1).

The mesa top measures about 3,000 by 3,000 feet, but the area usable for tests is reduced by reentrants (Figure 2.2). Relief at the site is very low. Along the line of the emplacement holes (Figure 1.2), the surface does not vary in elevation by more than about 10 feet in a distance of 1,300 feet, and laterally for 800 feet, the variation in elevation does not exceed 30 feet.

At the mesa edge, the steep side slopes descend 1,000 feet to the bottom of Fortymile Canyon, less than 1 mile to the southeast, and reveal locally as many as 10 lava flows or tongues in the bedrock.

These flows are some of many that are partially exposed over an area of about 20 square miles adjacent to Fortymile Canyon. Scattered basalt outcrops are found to the north. Lavas interbedded with pyroclastic formations underlying the main basalt at Buckboard Mesa are believed to correlate with those at Chukar Mesa. These lavas are Pliocene in age and range in composition from basalt to latite (Reference 2). However, in the past, they have generally been called basalt. For the sake of simplicity and clarity, this report will continue this usage.

One source of the lavas is believed to have been a vent at Dome Mountain (Reference 2). However, the present studies have revealed indications of another source to the northwest of the Buggy site (see Section 2.3.2). Cumulative thickness of flows in Chukar Canyon between Dome Mountain and the Buggy site is more than 900 feet. The total thickness of the basalt flows is about 400 feet at the Buggy site, and it continues to decrease northward.

The ground water table was not encountered in drilling at the site.

2.2 STRATIGRAPHY OF SITE MEDIA

Basalt flows and lesser amounts of soil, tuff, rhyolite, and breccia are interlayered and form the site media. On the basis of one deep core boring (Reference 1), the basalts were divided into

a thick upper unit of several flows and a lower unit of two thin flows (Figures 2.3 and 2.4). The lower unit lies below 4,850 feet msl and has not been penetrated in site documentation borings because it is well below the area of interest. Tentatively, it appears that the upper unit correlates with the upper and middle flows of the Fortymile Canyon basalt (proposed previously in Reference 2 on the basis of chemistry).

2.2.1 Soil. Borings indicated from 4.5 to 10 feet of soil overlying bedrock. The soil consists of tan sandy to clayey silt enclosing fragments of the underlying basalt that range up to a foot or more in diameter. The presence of fragments of tuff indicates that the soil is at least partly alluvial in origin. It is possible that the soil is actually only an erosional remnant of the thick, poorly consolidated alluvial volcanic gravel that overlies the basalt to the west.

2.2.2 Upper Basalt. The uppermost bedrock consists of a series of about 7 discontinuous lava flows or flow units with total thickness of about 330 feet. No interbeds of tuff or alluvium were recognized, and only thin zones of clinkers separate individual flows. The individual flows range in thickness from about 15 to 100 feet and characteristically consist of a relatively dense lower half with less than 5 percent vesicles grading upward to a vesicular upper half with as much as 40 percent vesicles by volume.

A 1- to 2-foot vesicular zone commonly forms the base of each flow.

Vesicles are present in most of the basalt, but only that containing more than about 2 percent vesicles is classified as vesicular basalt in logs of borings. The vesicular basalt types, along with the dense basalt, have been visually classified into groups on the basis of vesicularity, which is essentially equivalent to porosity (Table 2.1). Each group is subdivided into three fabrics (structural textures): isotropic and homogeneous, anisotropic and homogeneous, and anisotropic and layered. Fabric in Chukar Mesa basalt is almost entirely in the form of the easily seen vesicles, the exception being some faint color banding in the lower basalt (Reference 1). The scale considered is that of a core segment. If the scale is decreased to the microscopic or increased to that appropriate for the whole site, the fabric would be different. The mesoscopic (intermediate) scale was chosen so that basalt types classified in this manner could be related to laboratory test results for core samples. According to the classification, all basalts are either isotropic (I) or anisotropic (A), i.e., properties are statistically either the same or different in different directions, respectively. Isotropic basalt usually consists of dense basalt or vesicular basalt with spherical to irregularly shaped vesicles dispersed uniformly. Within the anisotropic group, homogeneous and layered varieties can be distinguished according to whether the

anisotropy is homogeneous (H) or heterogeneous from point to point within the sample. In the Chukar Mesa basalt, heterogeneity takes the form of layers (L) with abundant vesicles alternating with layers with fewer vesicles.

This classification is an extension and refinement of that used at other cratering experiments in basalt (e.g. References 5 and 7), and the relation between the 5 previous types and the 15 possible types in the new classification is shown in Table 2.2. It can be seen that the types used previously do not adequately cover the common types at the Chukar Mesa site. The new classification is also intended to permit a more direct application of laboratory data to corresponding rock types logged in the field as far as the completeness of these data allows.

Beds of clinkers separate the individual flows. These are particularly porous zones composed largely of fragments averaging about 0.5 foot in diameter. The basalt in these zones is commonly oxidized to a dull black or maroon color, and this color continues downward, gradually fading to the gray of the normal basalt. The clinker zones are generally about 2 feet thick. As a consequence of the high porosity, the clinker zones can be expected to emphasize the otherwise faint horizontal stratification in the upper basalt unit. Evidence that sediment-bearing ground water has

circulated through the clinker zones is found in the presence of silty and clayey deposits in cavities and fissures.

The clayey fissure filling is light brownish tan. In its natural moist state, it is firm but has a soapy feel. Examination by X-ray diffractometer revealed the fine material to consist largely of poorly crystalline clay of the montmorillonite group.

2.2.3 Basaltic Breccia. A coarse breccia was encountered in the depth interval 330 to 352 feet below the surface in Site Selection Boring 66-4 (Reference 1). Apparent partial welding of fragments, however, suggests that the breccia is volcanic in origin. Fragments appear to average about 0.5 foot in diameter, and there is a paucity of basalt fragments finer than 0.1 foot. Much of the space between fragments is occupied by the secondary clayey deposits described in Section 2.2.2 so that the original high porosity is somewhat reduced. The breccia may constitute the top of the underlying flow.

2.2.4 Lower Basaltic Unit. A single basalt flow measuring about 20 feet in thickness immediately underlies the basalt breccia with gradational contact. The basalt is megascopically indistinguishable from others at the site. A bed of tuff breccia about 12 feet in thickness underlies the basalt. The medium hard, sandy matrix encloses scattered small fragments of white pumice. Also present are angular to subangular fragments of vesicular basalt

constituting about 25 percent of the volume. The tuff breccia extends downward, filling fissures in the underlying basalt, at least an additional 6 feet.

The lowest basalt flow was encountered at 384 feet in Site Selection Boring 66-4 (Reference 1). It is 23 feet thick and composed entirely of highly vesicular basalt. A cursory inspection of exposures in the cliffs nearby (Figure 2.1a) indicated that the two basalt flows of the Lower Basaltic Unit are more continuous, extensive, and uniform in thickness than those above. However, according to Reference 3, the lowest flow is absent in exposures southeast of the site and a single thick tuff breccia occupies this stratigraphic position.

2.2.5 Bedded Tuff Breccia. A medium hard tuff breccia occurs at a depth of 407 to 411 feet. The sandy matrix encloses scattered small fragments of pumice, basalt, and vitrophyre. The unit is bedded.

2.2.6 Vitrophyre. A conspicuously flow-layered vitrophyre forms the base of the strata explored at the site. Site Selection Boring 66-4 (Reference 1) bottomed in vitrophyre at 517.5 feet below the surface after passing through 106 feet of the same material. The flow structure consists of alternating white and gray to brown layers that appear to extend laterally for many feet without appreciably changing in thickness or composition. Thickness

of the individual layers ranges from 1/16 to 3 inches, and dips change from steeply inclined in the top 40 feet to subhorizontal below.

The rock is largely glass, and most of the groundmass exhibits a perlitic structure. Lithophysae up to several inches across are scattered through the rock with a tendency to lie in groups along flow layers. Accidental lithic inclusions of basic lava presumably are related to basaltic andesite that is known to predate the Dome Mountain basalts (Reference 2). The vitrophyre is a portion of the rhyolite flow complex that has been described in Reference 4.

A significant amount of white clayey material occurs along permeable zones such as those adjacent to fractures. This material appears to grade into intact rock, and is suspected of being comminuted and altered glass along zones that were crushed or sheared as the lava passed from molten flow to brittle state.

2.3 STRUCTURE OF SITE MEDIA

The gently dipping volcanic strata at the site have experienced mild fault deformation in the relatively short interval since deposition. The basalts were extensively jointed as they cooled.

2.3.1 Bedding. The primary bedding at the site is largely subhorizontal. According to the geologic map in Figure 2.2, the top of the vitrophyre lies at about 4,600 feet msl in exposures

4,000 feet southeast of the site. This is roughly 200 feet below the position of the same surface at the Buggy site, so it appears that the surface descends at about 3 degrees to the southeast.

Near the top of the mesa, the basalts are nearly horizontal. However, there is some indication in aerial photographs that the upper basalt has been tilted to a southeastward dip of a few degrees.

2.3.2 Primary Flow Structure and Fabric of Intact Rock. Approximately 42 percent of the upper basalt unit exhibits a planar flow structure. This is mostly due to viscous flattening of vesicles in a preferred orientation. Most of the flattened vesicles are dispersed; and thus, the rock has an anisotropy due to flattening, but it is essentially homogeneous. Layered or heterogeneous rocks are represented by those with vesicles concentrated in thin zones. All basalt has been classified visually according to fabric and porosity (see Section 2.2.2 and Table 2.1) to facilitate extrapolation of laboratory data to field core logs.

Most flow structures tend to be subhorizontal. However, steep flow layers occur locally.

Borings 67-2, -5, and -6 intersected a mass of dense basalt at a depth of about 110 to 170 feet (Figure 2.3). This is apparently a major lava flow channel in the basalt similar to those at Buckboard Mesa (Reference 5).

This channel must extend in the direction of lava flowage and

thereby constitutes a heterogeneity within the site media. Flow-layer orientations were measured where visible in this mass and found to indicate that the sense of flowage and trend of this mass are $S40^{\circ}E$. This is compatible with the orientation of flow channels observed in the field along the mesa rimrock (Figure 2.2), if a branching of flows is taken into consideration. A further complication is that the channels observed in the rimrock may represent several superimposed flows that may have come from different sources. The concept of Dome Mountain as the source of the lavas of Chukar Mesa and vicinity is now considered to be too simple. A large vent to the northwest is also indicated.

2.3.3 Faults and Major Fracture Zones. Faint linears appearing in aerial photographs apparently represent fracture zones through the basalt. One of these passing about 500 feet west of the Buggy site strikes $N15^{\circ}W$ and thus parallels a set of faults that cuts the basalt (Figure 2.2). In aerial photographs and at the south rim of the mesa, the east side appears to have been lowered along this zone.

A second fault may possibly strike about $N75^{\circ}E$ about 1,000 feet southeast of the site. At the eastern side of the mesa, the upper flow appears in aerial photographs to be higher on the south side. No support for this was found in the field, but on the preliminary geologic map (Reference 6), two faults striking northeast are shown

crossing a ridge on the flank of Fortymile Canyon about 2 miles to the northeast of the site.

The inferred regional pattern appears to be an orthogonal system of steep fractures striking north-northwest and east-northeast.

2.3.4 Joints and Incipient Fractures. The basalt, tuff breccia, and vitrophyre at the site are moderately to extensively jointed (Figure 2.1).

The basalt was the material most pertinent to the preshot evaluation study. Lineal joint intercept spacings between joints in the basalts and interlayered clinkers were tabulated from the logs of photographs of three boreholes (67-2, -5, and -8) believed to sufficiently represent fracturing in general. Considerable interpretation was necessary in intervals where grout partly obscured the walls. Weighted spacings (essentially in situ block size) have been presented in the form of cumulative frequency curves (Figure 2.5). The percentage for each spacing is based on that portion of the total interval which has the given spacing between joint intercepts. For example, if 102 spacings of 0.1 foot were recorded in an interval of 80.0 feet, the 0.1-foot spacing would constitute 10.2 feet or 13 percent of the sample.

Figure 2.5 shows the data divided into groups according to depths above or below 40 feet. Spacings for near-surface basalt (average 0.3 foot) are conspicuously less than those below (average

0.9 foot). This difference in spacing at depth is a gross characteristic and apparently not very amenable to detailed refinement such as in depth versus spacing plots. A gross difference in material properties with depth is also evident in effective porosity (Section 2.4). An increased spacing is also evident in intervals through the dense basalt mass intersected in Borings 67-2, -5, and -6 (Appendix A). Otherwise the basalt below 40 feet seems to have about the same joint spacing around the site.

The spacing data should be considered cautiously with an understanding of their meaning. They are not the joint spacings in the true sense, but instead are the lineal joint intercept spacings, i.e., the intervals along a line between intercepts of joints of any orientation. These complicated conditions have been pointed out in previous reports (for example, Reference 7). The curves shown in Figure 2.5 have value as empirical representations of in situ material that can be used in predicting crater ejecta size.

2.4 FISSURE SPACE AND EFFECTIVE POROSITY

Effective porosity is determined by the number of rock pores interconnected by voids and fractures, i.e., excludes the voids dispersed in intact rock. It has been determined in previous studies from borehole photographs; but borings at the Buggy site required

extensive grouting during coring, and consequently, portions of the walls were obscured. It was impossible to accurately recognize open pores originally present since most had been filled with grout. Also, the common natural fissure filling at the site is silt infiltrating downward from the surface and much of this was washed out by the drilling water. With these restrictions, the fissure space, both open and filled, was computed as reviewed in Reference 8 and reduced by an arbitrary factor of 50 percent to account for natural filling material. More detailed analysis of porosity with depth was not considered justified.

The intervals selected for measurement in dense and slightly vesicular basalt (Table 2.3) have an average 1.4 percent fissure space, which, when adjusted for natural filling, gives 0.7 percent effective porosity. Intervals in vesicular basalt average 4.3 percent fissure space and thus are estimated to have 2.1 percent effective porosity. The fissure space in basalt near the surface averages about 21 percent, but silt and sand are believed to fill these fissures.

The fissure space (between fragments) of clinker and breccia zones could not be determined from the borehole photographs because of grout in the walls. It is estimated from observations of clinker zones elsewhere to be approximately 15 percent. The effective porosity between fragments is 8 percent when reduced by the

arbitrary factor of 50 percent for silt fillings. This does not include any intergranular porosity in the silt.

2.5 IN SITU PROPERTIES

Geophysical tests were conducted over Site Selection Boring 66-3 as a part of site selection studies (Reference 9) and subsequently by in-hole methods. Because of the complexity of the Upper Basalt media, only gross wave velocities are reviewed here.

2.5.1 Shear Wave Velocity. Vibration test investigations indicated shear wave velocities in the Upper Basalt ranging from 900 to 2,000 ft/sec in the highly jointed material (see Section 2.3) above a depth of 40 feet. The material below 40 feet has velocities ranging from 1,600 to 3,300 ft/sec. Several anomalous zones were located.

2.5.2 Compressional Wave Velocity. Seismic velocities determined by surface refraction techniques indicated a discontinuity at about 40 feet in one traverse. This break separates material with compressional wave velocities of 2,800 to 3,500 ft/sec above from material with velocities of 4,200 to 5,600 ft/sec below.

Up-hole seismic surveys conducted in Site Selection Borings 66-3 and 66-5 for the Lawrence Radiation Laboratory (LRL) have indicated that compressional wave velocities range from 5,700 to 11,000 ft/sec. As with surface seismic results, velocities increase

with depth. The contrast in velocities obtained by surface and up-hole techniques may result from a difference in size of samples tested.

The two sets of data, when combined, indicate that: (1) high velocities (11,000 ft/sec) are characteristic of dense basalt layers, (2) low velocities (6,000 to 9,000 ft/sec) are characteristic of vesicular basalt layers, (3) clinker zones are marked seismic discontinuities and velocities should be similar to those of soil (2,000 to 3,000 ft/sec), (4) the compressional wave velocity of the Upper Basalt taken as one medium should average about 5,000 ft/sec, and (5) if the Upper Basalt is regarded as a two-layer system, the upper 40-foot layer should have a velocity of about 3,200 ft/sec and that below should have a velocity of about 6,000 ft/sec.

2.5.3 Density. The Upper Basalt can be divided into three basic material types, dense basalt with up to 10 percent vesicles, vesicular basalt with more than 10 percent vesicles, and clinker zones (Figures 2.3 and 2.4). Bulk specific gravities for these three materials in situ are approximately 2.6 for dense basalt, 2.3 for vesicular basalt, and 1.85 for clinker zones. The figures are averages of specific gravities of core samples and specific gravities from Birdwell density logs run in Site Selection Borings 66-3, -4, and -5 for LRL.

TABLE 2.1 CLASSIFICATION OF BASALT ON BASIS OF POROSITY AND FABRIC OF INTACT ROCK

	Fabric
	Isotropic and Homogeneous	Anisotropic and Homogeneous	Anisotropic and Layered
0-2	1-IH	1-AH	1-AL
2-10	2-IH	2-AH	2-AL
10-20	3-IH	3-AH	3-AL
20-30	4-IH	4-AH	4-AL
>30	5-IH	5-AH	5-AL

TABLE 2.2 PERCENTAGE ABUNDANCE OF BASALT TYPES AT BUGGY SITE
AND RELATION OF POROSITY-FABRIC CLASSIFICATION TO PREVIOUS
CLASSIFICATION USED AT BUCKBOARD MESA

Roman numerals denote the five basalt types of previous classification.

	Fabric		
	Isotropic and Homogeneous	Anisotropic and Homogeneous	Anisotropic and Layered
0-2	I 21	0	1
2-10	9	6	II 1
10-20	IV 4	8	III 1
20-30	V 15	22	0
>30	9	3	0

TABLE 2.3 OPEN OR FILLED FISSURE SPACE IN SITE MATERIAL

Material	Hole Number	Depth	Fissure Space ^a	Weighted Average ^b
		feet	percent	percent
Dense and slightly vesicular basalts	67-5	120.0 to 163.0	0.8	1.4
	67-6	51.0 to 70.0	3.3	
	67-6	123.0 to 163.0	1.2	
	67-8	220.0 to 230.6	1.0	
Vesicular basalt	67-2	210.6 to 240.0	7.5	4.3
	67-2	292.3 to 314.7	3.3	
	67-6	81.4 to 97.9	1.8	
	67-8	84.2 to 96.8	4.0	
	67-8	165.2 to 175.8	1.7	
Clinkers or breccia				(estimated) 15
Near-surface	67-2	7.7 to 21.8	39	21
	67-5	10.0 to 24.0	6.2	
	67-6	13.0 to 23.5	8.1	
	67-14	5.1 to 15.8	23	
	67-14	21.3 to 33.0	26	

^a Fissure space, between rock walls, includes filling of silt, clay, and colloidal material.

^b Weighted according to lengths of boring intervals considered.

a. View toward southeast.

b. View toward northeast.

Figure 2.1 Basalt outcrops at edge of Chukar Mesa.

Figure 2.2 Topography and geology at Chukar Mesa site and location of sections shown in Figures 2.3 and 2.4.

Figure 2.3 Geological section of Buggy site along A-A'. See Figure 1.2 for locations of borings.

Figure 2.4 Geological section of Buggy site along B-B'. See Figure 1.2 for locations of borings.

a. Above depth of 40 feet.

b. Below depth of 40 feet.

Figure 2.5 Cumulative frequency of weighted lineal joint intercept spacing for basalt above and below depth of 40 feet.

CHAPTER 3
PHYSICAL PROPERTIES AND PETROGRAPHY
OF BEDROCK AT TEST SITE

This chapter presents results of laboratory tests on samples taken from borings at the test site, and also includes results of tests made in connection with the 1966 site selection study (Reference 1). The 12 samples that were tested in 1966 were taken from various intervals in Site Selection Borings 66-3, -4, and -5, while samples tested in 1968 were taken from 14 different intervals in Borings 67-1, -2, -5, -6, and -8. A summary of results from the petrographic analyses of dense basalt, vesicular basalt, and vitrophyre is included with the laboratory test results. The complete results of petrographic analyses and descriptions of the laboratory test methods are given in Appendixes B and C, respectively.

3.1 SAMPLE DESCRIPTIONS

Core samples of NX size (2-1/8-inch diameter) from 23 separate intervals in the basalt flows encountered in the area were tested. These samples represent most types of basalt that occur in the area and include Types 2-IH, 2-AH, 3-IH, 3-AH, 4-IH, 4-AH, and 5-IH as described in Chapter 2 of this report. The AL and IL types were not tested, since layering was not common. One sample was taken from the tuff breccia layer, and two were taken from vitrophyre. The

tested core samples give a fair representation of the spectrum of porosity and vesicularity that occurs. A slight lineation is present in the attitude and shape of the vesicles in a few of the samples. Although the effects of this fabric on strength properties were not determined, it is doubtful that they are significant.

Photographs of the core samples received for testing in 1966 are shown in Figure 3.1, and brief visual descriptions are given in Table 3.1 for all samples tested.

3.2 PETROGRAPHY

Petrographic analyses were made on samples of dense basalt (Type 1-IH), vesicular basalt (Type 5-IH), and vitrophyre. The analyses on dense basalt and vitrophyre were performed during the site selection phase of Project Buggy. The detailed results of these analyses are found in Appendix B.

3.2.1 Basalt. A sample of very fine-grained, dense, medium-gray basalt (Type 1-IH) was taken from a depth of 208 feet in Site Selection Boring 66-4. This rock contains no visible phenocrysts. Microscopic and X-ray diffraction analyses indicate that the rock is composed primarily of plagioclase feldspar (andesine) and pyroxene (augite), and it is technically classified as a pyroxene andesite. Its texture is classified as pilotaxitic, with grains of pyroxene and opaque crystallites located between subparallel laths of

plagioclase. Although some of the feldspar laths attain a length of 0.3 to 0.7 mm, most of the grains measure less than 0.1 mm in diameter.

A sample of dark-gray, highly vesicular basalt (Type 5-IH) was taken from the 65.9- to 67.6-foot interval in Boring 67-2. The vesicles comprise about 35 percent of the rock, and their long dimensions range from 1/16 to 1/2 inch and average 1/4 inch. Occasional phenocrysts of feldspar and pyroxene of up to 1.7 mm maximum dimension are set in a very fine-grained matrix of tiny, unoriented, lath-shaped plagioclase feldspar crystallites, granular pyroxene, traces of olivine, and interstitial basaltic glass. Matrix grain size is generally around 0.1 mm in diameter. Microscopic X-ray diffraction analyses indicate that the rock is composed primarily of plagioclase feldspar (labradorite) and pyroxene (augite), with small amounts of olivine, interstitial glass, and opaque minerals. The rock is classified as vesicular basalt, with a texture ranging from hyalo-ophitic to intersertal.

3.2.2 Vitrophyre. A sample of light- to dark-gray, layered volcanic glass with numerous phenocrysts of clear feldspar and brown biotite was taken from a depth of 425 feet in Site Selection Boring 66-4. Thin, grayish-orange-pink layers also occasionally occur in the sequence. The phenocrysts range in size from 1/16 to 1/4 inch and average about 1/8 inch. They consist primarily of feldspar

(mostly sanidine with lesser amounts of oligoclase), although a small amount of biotite, pyroxene, and sphene occurs. The index of refraction of the glass is near 1.50, indicating a rhyolitic composition. The glass has a well-developed perlitic structure and is rather soft, which indicates that some water is present in the composition.

3.3 PHYSICAL TESTS

The physical properties that were determined (with number of samples tested for each property in parentheses) are as follows: bulk specific gravity (19), specific gravity of solids (19), tensile splitting strength (7), unconfined compression (19), frictional resistance of sawed surfaces (4), and triaxial compressive strength (2). The data obtained from these tests are summarized in Table 3.1. More detailed information regarding the methods and calculations used are given in Appendix C.

3.3.1 Specific Gravity. The specific gravities and densities of samples are given in Table 3.1. Density values were obtained by multiplying bulk dry specific gravity, G_o , values by the unit weight of water. Variation of bulk dry specific gravity with depth is shown in Figure 3.2, and the relation between bulk dry specific gravity and compressive strength is shown in Figure 3.3.

The specific gravity of solids, G_s , is fairly uniform among the various types of basalt; values of G_s range from 2.70 to 2.86

and average 2.76. A sample from the scoriaceous clinker zone indicated a specific gravity of solids similar to that of the basalt, i.e., $G_s = 2.74$. Values determined for tuff breccia (2.44) and vitrophyre (2.35 and 2.39) are considerably less. There is no clearly defined relation between G_s and increasing vesicularity. However, G_o shows a well-defined decrease with increase in vesicularity and porosity in basalt. The average value of G_o for basalt with 0 to 2 percent vesicles is 2.68; with 2 to 10 percent vesicles, it is 2.54; with 10 to 20 percent, it is 2.29; with 20 to 30 percent, it is 2.00; and with over 30 percent, it is 1.93. Low values were also obtained for tuff breccia (1.84), vitrophyre (2.24 and 2.06), and scoriaceous clinker material (2.28).

3.3.2 Porosity. The porosity values shown in Table 3.1 were calculated from specific gravity of solids (G_s) and bulk dry specific gravity (G_o) values according to the following equation:

$$\text{Porosity (\%)} = 100 \left(1 - \frac{G_o}{G_s} \right)$$

Porosity values ranged from 2.9 percent for dense basalt to 32.6 percent for highly vesicular basalt. Porosity in percent was also determined for tuff breccia (24.6), vitrophyre (6.2 and 12.4), and scoriaceous clinker material (16.8).

3.3.3 Unconfined Compressive Strength. Nineteen samples were

subjected to static unconfined compression tests using the method described in Appendix C. These results are summarized in Table 3.1.

Values of unconfined compressive strength ranged from 33,390 psi for dense basalt to 6,230 psi for vesicular basalt. This indicates a strength range in the "strong" classification of Reference 11 and the low to high strength range of Reference 12 (Figure 3.4). The results for each sample are plotted with respect to bulk dry specific gravity and basalt vesicularity in Figures 3.3 and 3.5. The results for tuff breccia (1,130 psi) and vitrophyre (2,290 and 4,100 psi) are also plotted in Figure 3.3. These figures clearly show an increase of compressive strength with increasing bulk dry specific gravity and decreasing vesicularity. Figure 3.2 shows that the compressive strength varies erratically with depth.

3.3.4 Modulus of Elasticity. Stress-strain curves for each of the 19 unconfined compression tests are given in Figures 3.6 and 3.7. The modulus of elasticity was calculated on the basis of a straight line tangent to the stress-strain curve at a stress value one-half that of the ultimate strength. These results are given in Table 3.1.

Modulus of elasticity values calculated from the unconfined tests range from 7.74×10^6 psi to 0.24×10^6 psi. The minimum value was for tuff breccia, while the maximum value was found in dense basalt. The minimum value for basalt, found in the porous

vesicular type, was 2.62×10^6 psi. Lower values of 1.66×10^6 psi and 2.52×10^6 psi were obtained for the vitrophyre. Modulus values calculated from triaxial test data were within the range determined from unconfined tests.

3.3.5 Poisson's Ratio. Poisson's ratio values were taken as the ratio of circumferential strain to axial strain at a stress value one-half that of the ultimate strength. Data taken from 13 tests (8 unconfined compression and 5 triaxial compression tests) are summarized in Table 3.1. Results of 7 of the unconfined tests ranged from 0.17 to 0.30; most of the values calculated from the triaxial tests were within this range. A high value of 0.41 from the eighth unconfined test may have been influenced by the bonding agent on the filler used to cover the voids in the rock. If this value is eliminated, the average from the 7 remaining unconfined tests is 0.22; the average value from the 5 triaxial tests is 0.23. The values appear unrelated to basalt vesicularity or bulk dry specific gravity.

3.3.6 Tensile Splitting Strength. Tensile splitting tests were conducted on 2- to 4-inch lengths of the NX core samples (2-1/8-inch diameter), using the method described in Appendix C. The tensile splitting strength values were calculated from the formula:

$$T = \frac{2P}{\pi td}$$

where

T = tensile splitting strength, psi

P = maximum applied load indicated by the testing machine,
pounds

t = length of specimen, inches

d = diameter of specimen, inches

Values of tensile splitting strength ranged from 660 psi for the most vesicular type of basalt to 2,090 psi for dense basalt. The values for each type of basalt were Type 5-IH, 660 and 730 psi; Type 4-IH, 780 psi; Type 3-IH, 1,300 psi; Type 2-IH, 2,090 psi; and Type 1-IH, 2,090 psi.

3.3.7 Sliding Friction Tests. Four direct shear tests were made on sawed surfaces for normal stresses of 500, 1,000, and 2,000 psi. The method and equipment are described in Appendix C. Curves relating shear stress to strain are shown in Figure 3.8, and the data are summarized in Table 3.1. The plots of shear stress versus normal stress (Figure 3.9) resulted in envelopes that were convex upward when extended through the origin, with a ϕ value of approximately 30 degrees between 0- and 1,000-psi normal stress, and a ϕ of 15 degrees between 1,000 and 2,000 psi. The strength at 500-psi normal stress on basalt from a depth of 269 feet in Boring 67-2

is anomalously low. Irregularities up to $1/32$ inch high on the untested sawed surfaces may account for the initial curvature of the failure envelopes. Another manifestation of this initial roughness of the surface is the fact that under normal stresses above 1,000 psi, tangential deflection rates increase only very gradually with increasing increments of shear stress and the point at which sliding commences, i.e. the yield point, is hard to determine.

3.3.8 Triaxial Compression Tests. Two triaxial tests were performed using the method and apparatus described in Appendix C. One test was on dense basalt (Type 1-IH) and the other on vesicular basalt (Type 5-IH). Curves relating deviator stress to strain are given in Figure 3.10, and the strength results are summarized in Table 3.1. The results of the first two tests on highly vesicular basalt are questionable, since the confining fluid penetrated the rubber membrane that jacketed the specimens. Although the ultimate strength from the test at 500-psi confining pressure (9,940 psi) may approximate the correct value, the anomalously low strength at 1,250-psi confining pressure (6,350 psi) should probably be disregarded. To prevent a recurrence of rupture in the third test, the specimen was first jacketed with a copper shield before being covered with a rubber membrane. Removal of the SR-4 strain gage wires was necessary in this process, and consequently, no stress-strain data are available from the test. However, the strength measurement appears to be

satisfactory. The sample of dense basalt was tested under confining pressures twice those used for the vesicular basalt, and the resulting compressive strengths were more than three times higher.

Tensile splitting and unconfined compressive strengths for each of the two triaxial test samples were combined with the triaxial values to construct Mohr envelopes. The envelopes are sharply curved, with angle of friction decreasing with increasing normal stress (Figure 3.11). The envelope construction for vesicular basalt is only approximate, since failure was not reached at 500- and 1,250-psi confining pressures. The 1,000-psi confining pressure strength value for dense basalt was also anomalously low. For the dense basalt, ϕ ranged from about 50 degrees between 0- and 5,000-psi normal stress to about 30 degrees in the interval from 15,000 to 20,000 psi, with a cohesion of 5,000 psi. For vesicular basalt, ϕ ranged from about 50 degrees in the 0- to 1,000-psi normal stress interval to about 35 degrees in the 3,000- to 6,000-psi interval, with a cohesion of 1,150 psi.

3.3.9 Discussion of Test Results. The more vesicular and porous basalt is characterized by lower bulk specific gravity (density) and lower compressive strength or modulus of elasticity. Although a wide variation of strength and density occurs in the basalts, most of the values are higher than those obtained from the tuff breccia and vitrophyre. Since the vitrophyre consists of one

uniform rock type, the two samples that were taken are probably more representative of the overall strength than a like number of samples from the basalts. Table 3.2 compares the ranges in values of some of the properties of two rock groups.

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TABLE 3.1 SUMMARY OF LABORATORY TEST RESULTS

Boring Number	Sample Depth		Basalt Classification	Sample Description	Bulk Dry Specific Gravity	Specific Gravity of Solids	Bulk Dry Density	Porosity	Shear Strength of Precut Surfaces with Normal Stresses of			Tensile Splitting Strength	Unconfined Compression Tests			Triaxial Compression Tests			
	From	To											Compressive Strength	Young's Modulus	Poisson's Ratio	Confining Pressure	Compressive Strength	Young's Modulus	Poisson's Ratio
	feet	feet							500 psi	1,000 psi	2,000 psi		psi	10 ⁶ psi		psi	psi	10 ⁶ psi	
66-3	210.7	211.7	4-AH	Basalt, large flat vesicles $\perp$ core axis	2.07	2.80	129	26.0	--	--	--	--	6,230	2.62	--	--	--	--	--
66-4	64.6	65.7	1-IH	Basalt, dense, isotropic	2.62	2.72	164	3.7	--	--	--	--	23,090	5.23	--	--	--	--	--
66-4	105.9	107.0	4-AH	Basalt, with elongate vesicles at 45 degrees to core axis	1.98	2.75	124	28.0	--	--	--	--	8,240	4.96	--	--	--	--	--
66-4 ^b	151.1	152.1	4-IH ^a	Basalt, vesicular, isotropic	1.98	2.70	124	26.7	--	--	--	--	7,560	4.07	--	--	--	--	--
66-4 ^b	208.1	209.1	2-II ^a	Basalt, dense, isotropic	2.72	2.86	170	4.9	--	--	--	--	18,430	5.10	--	--	--	--	--
66-4 ^b	374.5	375.8	--	Tuff breccia	1.84	2.44	115	24.6	--	--	--	--	1,130	0.24	--	--	--	--	--
66-4 ^b	424.3	425.4	--	Vitrophyre, with plane at 45 degrees to core axis	2.24	2.39	140	6.2	--	--	--	--	2,290	1.66	--	--	--	--	--
66-4	482.8	483.7	--	Vitrophyre	2.06	2.35	129	12.4	--	--	--	--	4,100	2.52	--	--	--	--	--
66-4	291.9	292.8	--	Scoriaceous, crumbly basalt	1.70	2.63	106	35.4	--	--	--	--	--	--	--	--	--	--	--
66-5	109.5	110.7	3-AH ^a	Basalt, with elongate vesicles 60 degrees to core axis	2.39	2.70	149	11.5	--	--	--	--	8,680	4.59	--	--	--	--	--
66-5	115.5	116.6	2-IH ^a	Basalt, scattered vesicles	2.52	2.70	157	6.6	--	--	--	--	20,460	5.57	--	--	--	--	--
66-5	202.9	203.7	1-IH	Basalt, dense, isotropic, fine-grained	2.76	2.86	173	3.5	--	--	--	--	23,090	7.19	--	--	--	--	--
67-1	36.1	36.8	2-IH	Basalt, dark gray, medium porous, isotropic	2.47	2.75	154	10.2	--	--	--	--	--	--	--	--	--	--	--
67-2	39.3	39.8	5-IH	Basalt, medium dark gray, medium porous	--	--	--	--	332	554	775	--	--	--	--	--	--	--	--
67-2	44.1	45.0	5-II	Basalt, dark gray, very vesicular, isotropic	2.00	2.72	125	26.5	--	--	--	660	6,750	4.02	0.23	--	--	--	--
67-2 ^b	65.9	67.6	5-IH	Basalt, dark gray, very vesicular, isotropic	--	--	--	--	--	--	--	--	--	--	--	500 1,250 2,500	9,940 ^c 6,350 ^d 13,290	4.16 3.36 -- ^e	0.25 0.16 -- ^e
67-2	124.0	125.3	2-II ^a	Basalt, light gray, few vesicles, isotropic	2.46	2.74	154	10.2	324	420	554	1,700	15,240	5.63	0.23	--	--	--	--
67-2	183.3	183.4	--	Scoriaceous clinker zone	2.28	2.74	143	16.8	--	--	--	--	--	--	--	--	--	--	--
67-2	262.3	263.3	5-IH	Basalt, elongate vesicles 55 degrees to core axis	1.86	2.76	116	32.6	--	--	--	730	8,670	4.25	0.30	--	--	--	--
67-2	269.0	269.8	5-IH	Basalt, small elongate vesicles	--	--	--	--	221	554	775	--	9,400	4.15	0.19	--	--	--	--
67-5	148.3	153.0	1-IH	Basalt, very light gray, dense, isotropic	2.66	2.74	166	2.9	398	609	831	2,090	33,390	5.50	0.24	1,000 2,500 5,000	34,310 43,000 48,950	4.59 5.00 5.22	0.24 0.27 0.24
67-6	14.9	16.2	2-IH	Basalt, medium gray, scattered round vesicles	--	--	--	--	--	--	--	2,090	26,190	7.74	0.20	--	--	--	--
67-6	56.1	58.1	3-IH	Basalt, many small round vesicles	--	--	--	--	--	--	--	1,300	16,480	5.47	0.17	--	--	--	--
67-6	102.6	103.6	3-IH ^a	Basalt, with some large elongate vesicles	2.19	2.80	137	21.8	--	--	--	--	--	--	--	--	--	--	--
67-8	114.9	116.8	4-IH	Basalt, very dark gray, abundant round vesicles of irregular size	--	--	--	--	--	--	--	780	10,030	6.15	0.41	--	--	--	--
67-8	185.0	186.0	4-IH	Basalt, very dark gray, abundant round vesicles of irregular size	1.98	2.78	124	28.8	--	--	--	--	--	--	--	--	--	--	--

^a Classification of test specimen differs from that shown in log in Appendix A because it was necessary to generalize for longer core interval in log.^b Sample was examined petrographically.^c Doubtful results--membrane ruptured.^d Failure not reached--membrane ruptured^e Strain not measured--copper membrane used.

TABLE 3.2 RANGE IN VALUES OF PHYSICAL PROPERTIES OF BEDROCK

Property	Basalts (16 samples)	Tuff Breccia and Vitrophyre (3 samples)
Bulk dry specific gravity	1.70 to 2.76	1.84 to 2.24
Specific gravity of solids	2.63 to 2.86	2.35 to 2.44
Density (pcf)	106 to 173	115 to 140
Porosity (pct)	2.9 to 35.4	6.2 to 24.6
Unconfined compressive strength (psi)	6,230 to 33,390	1,130 to 4,100
Modulus of elasticity (10^6 psi)	2.62 to 7.74	0.24 to 2.52

Figure 3.1 Core samples received for testing in 1966.

Figure 3.2 Variation of physical properties of intact samples with depth.

Figure 3.3 Relation between bulk dry specific gravity and static unconfined compressive strength. Curve is approximate trend of results for 146 samples of Buckboard Mesa basalt (Reference 10).

Figure 3.4 Engineering classification for intact rock (Reference 12).

Figure 3.5 Relation between basalt type and static unconfined compressive strength.

Figure 3.6 Stress-strain curves for unconfined compression tests (1966 tests). Samples failed at upper end of curves.

Figure 3.7 Stress-strain curves for unconfined compression tests (1968 tests). Samples failed at upper end of curves.

Figure 3.8 Shear stress versus displacement for sliding friction tests. Samples failed at upper end of curves.

Figure 3.9 Shear stress versus normal stress for sliding friction tests.

VESICULAR BASALT (TYPE 5-IH) HOLE 67-2, DEPTH 66 FT.

DENSE BASALT (TYPE 1-IH) HOLE 67-5, DEPTH 150 FT.

Figure 3.10 Deviator stress versus strain for triaxial tests. Samples failed at upper end of curves.

Figure 3.11 Mohr envelopes for vesicular and dense basalts.

CHAPTER 4

SUMMARY

The Buggy site, located on Chukar Mesa, occupies a portion of the top of a small flat-topped ridge adjacent to Fortymile Canyon. The elevation is about 5,200 feet msl, some 1,000 feet above the bottom of the main canyon. Ground water was not encountered in drilling; the water table probably lies at least 1,000 feet below the surface. The cliffs that limit the mesa reveal a series of basalt flows. These flows have been explored by means of three site selection borings and 15 site documentation borings. The basalts are divisible into an upper unit measuring about 330 feet thick and a lower unit consisting of two basalt flows and interbedded tuff breccia with total thickness of about 80 feet. A thick vitrophyre lava flow underlies these units. Tests conducted on cores mostly from the Upper Basalt unit were petrographic examination, bulk specific gravity, specific gravity of solids, tensile splitting, unconfined compression, sliding friction, and triaxial compression.

The Upper Basalt unit within which the five devices were emplaced appears in cross sections to consist of seven lava flows or flow units. Typically, each unit consists of a vesicular upper half and a dense lower half bounded above and below by clinker zones. One relatively well-developed flow channel through which molten lava was

originally fed has been identified at the site. This extended cylindrical mass trends about S40°E and suggests a source to the northwest. Other flows probably issued from Dome Mountain to the south.

The basalt has been classified into 15 possible types according to porosity and structure of the intact core. Dense basalt with less than 10 percent vesicles tends to be homogeneous and to have the greatest strengths, i.e. in the range 15,240 to 33,390 psi. In contrast, highly vesicular basalt tends to have an anisotropy and to have lower strength values in the range 6,230 to 16,480 psi.

Poisson's ratios of intact core specimens range from 0.16 to 0.30 for unconfined and triaxial tests. The values appear to be unrelated to basalt vesicularity. Tensile splitting strengths range from 660 psi for vesicular basalt to 2,090 psi for dense basalt. Combining the tensile splitting, unconfined, and triaxial test results produced Mohr envelopes that are sharply curved, with angle of friction decreasing with increasing normal stress. For dense basalt, the ϕ ranged from about 50 degrees between 0- and 5,000-psi normal stress to about 30 degrees in the interval from 15,000 to 20,000 psi.

Geophysical results have revealed that although the seismic compressional wave velocities for individual layers range as high as 11,000 ft/sec for dense basalt, the interlayering of much lower velocity material reduces the overall velocity of the Upper Basalt to about 5,000 ft/sec.

The Upper Basalt may also be regarded as a two-layer system in which the upper 40-foot layer has a compressional wave velocity of about 3,200 ft/sec and the lower layer a velocity of about 6,000 ft/sec. This appears to be a result of greater fracture frequency above 40 feet. The average lineal joint intercept spacing for this near-surface material is about 0.3 foot and conspicuously less than the average spacing of 0.9 foot in the material below. The upper material also has a much higher percentage of soil-filled fissure space which undoubtedly contributes to its lower seismic velocity. The fissure space for dense and vesicular basalts below a depth of 40 feet averages from 1.5 to 4 percent of the material in contrast to an estimated 20 percent for the near-surface material. The filling of the fissure space near the surface by silt washed from the surface reduces the porosity, however. The site medium may be regarded as a horizontal system of many layers of contrasting density and seismic velocity; or it may be regarded as a one- or two-layer system with relatively intermediate properties, which vary according to the layering.

APPENDIX A

PROJECT BUGGY BORING LOGS

LEGEND FOR PRESHOT BORINGS

LITHOLOGY

SOIL

BASALT, DENSE; WITH UP TO 2% VESICLES

BASALT, VERY HIGHLY VESICULAR; WITH 30% VESICLES OR MORE

BRECCIA OR CLINKER ZONE; MOSTLY WITHIN OR BETWEEN FLOWS OF BASALT

BASALT, HIGHLY VESICULAR; WITH 20 TO 30% VESICLES

TUFF OR TUFF BRECCIA

BASALT, MODERATELY VESICULAR; WITH 10 TO 20% VESICLES

VITROPHYRE

BASALT, MODERATELY TO SLIGHTLY VESICULAR; WITH 2 TO 10% VESICLES

STRUCTURE

CLASSIFICATION OF BASALT ON BASIS OF POROSITY AND FABRIC OF INTACT CORE

1 - $\leq$ 2% POROSITY

I - ISOTROPIC FABRIC

2 - 2 TO 10% POROSITY

A - ANISOTROPIC FABRIC

3 - 10 TO 20% POROSITY

H - HOMOGENEOUS FABRIC

4 - 20 TO 30% POROSITY

L - LAYERED FABRIC

5 - 30 TO 40% POROSITY

HIGHLY FRACTURED; FRACTURES ISOLATE FRAGMENTS THAT AVERAGE 2 INCHES OR MORE IN DIAMETER

VERY HIGHLY FRACTURED; FRACTURES ISOLATE FRAGMENTS THAT AVERAGE LESS THAN 2 INCHES IN DIAMETER

MODERATELY FRACTURED; MIDPOINT OF INDIVIDUAL FRACTURES AS SHOWN

Boring No. 67 Buggy No. 1									
LOCATION NEVADA STATE COORDINATES: N25, 056.23 1556, 390.70									
BRAND:									
TYPE OF BORING: EX Diamond									
DEPTH TO WATER TABLE: Not encountered									
TOTAL DEPTH: 371.2 ft									
HOLE SPACED 2 August 1967									
HOLE COMPLETED 23 August 1967									
EL. DEPTH	LOG	DESCRIPTION	PER. CORE RECOVER	SOIL HOLE CAMERA JOINT DATA	W.C. STAINING	DP	W.C. FILLING		
PT. MBL. FT.									
5204.2	5	SOIL (0.0 to 5.0 ft), tan sandy clay with fragments and blocks of vesicular basalt	65						
		Top of Rock							
		VESICULAR BASALT (0.0 to 31.5 ft), dark gray, 20% to 30% elongate, (average 1/4 in.) and generally brown along most joints; altered some joints are filled or coated with calcite	94						
	10	11.0 to 16.0 ft, vesicles, average 1/16 in. long							
	15								
	20								
	25								
	30								
5174.7	30	Gradational	80						
		VESICULAR BASALT (31.5 to 40.0 ft) medium gray; 5 to 7% apertural vesicles, up to 3/4 in. diameter; calcite coating joints							
	35								
5166.2	40	Gradational	43						
		IRREGULAR BASALT (40.0 to 66.0 ft) dark gray; 2% to 3% apertural vesicles; calcite coating joints							
	45								
	50								
	55								
	60								
	65	Gradational	33						
		VESICULAR BASALT (66.0 to 87.5 ft) light gray; 5 to 10% elongate vesicles, averaging 1/4 to 1/2 in. long; few vesicles lined with calcite							
	70								
	75								
	80								
	85	89.8 to 87.5 ft, vesicles increase to 15 to 20% and are horizontal							
	90	87.5 ft, flow contact							
5118.7	90	VESICULAR BASALT (87.5 to 98.0 ft) medium gray; 30 to 35% apertural vesicles; calcite lining few vesicles	72						
	95								
5111.2	95	Gradational	100						
		VESICULAR BASALT (98.0 to 98.5 ft) medium gray; 20% elongate vertical vesicles, decreasing to 10% with depth							
5107.7	100	Gradational							

(continued)

Boring No. 67 Buggy No. 1 (Continued)									
LOCATION NEVADA STATE COORDINATES: N25, 056.23 1556, 390.70									
BRAND:									
TYPE OF BORING: EX Diamond									
DEPTH TO WATER TABLE: Not encountered									
TOTAL DEPTH: 371.2 ft									
HOLE SPACED 2 August 1967									
HOLE COMPLETED 23 August 1967									
EL. DEPTH	LOG	DESCRIPTION	PER. CORE RECOVER	SOIL HOLE CAMERA JOINT DATA	W.C. STAINING	DP	W.C. FILLING		
PT. MBL. FT.									
5103.2	105	VESICULAR BASALT (98.5 to 103.0 ft) dark gray; 20% to 30% elongate vesicles, decreasing from 10 to 2% with depth	100						
		Gradational							
	110								
	115								
	120	121.0 to 123.0 ft, vesicles increase to 10%							
5098.2	125	CLIMBERS (123.0 to 124.0 ft) dark gray; 20% to 30% elongate vesicles, decreasing 1/4 in. across; calcite and tan silt along joints	67						
	130								
	135								
5096.2	140	Gradational	91						
		VESICULAR BASALT (140.0 to 156.0 ft) medium gray; 15 to 20% elongate vesicles, decreasing 1/4 in. long (average 1/4 in.); iron stain and tan silt along joints							
	145								
	150								
5048.7	155	Gradational	46						
		VESICULAR BASALT (156.0 to 157.5 ft) light gray; 5% apertural vesicles; calcite coating joints							
	160								
	165								
5066.2	180	CLIMBERS (180.0 to 190.0 ft) reddish gray and dark gray some white scoriaceous basalt	100						
	175	173.0 to 180.0 ft, vesicles increase to 10% and are horizontal in places							
5016.2	190	VESICULAR BASALT (190.0 to 198.5 ft) dark to medium gray; 20% elongate vesicles, 3/8 in. long or less; filled with tan silty clay	53						
	195								
5007.7	200	Gradational	91						
		VESICULAR BASALT (198.5 to 201.5 ft) dark gray; 20% elongate vesicles, 1/2 in. thick							

(continued)

Figure A.1 Log of core Boring 67 Buggy No. 1.

PROJECT BUGGY									
BORING NO.: 67 Buggy No. 1 (Continued)									
EL FT MSL	DEPTH FT	LOG	DESCRIPTION	PER- CENT CORE RECOV	BORE HOLE CAMERA JOINT DATA				
					MID- PT	STRIKE DEG	DIP DEG	WIDTH & FILLING	
5004.7	200	1-AH	alternating with less vesicular layers at 30-deg orientation	91	NS	50E	1/16", 0		
		2-AH	Gradational		N10W	45SW	1/16", C		
		3-AH	VESICULAR BASALT (201.5 to 206.6 ft), medium gray; 5 to 10% small spheroidal vesicles	100	NS	55SW	1/8", 0		
		4-AH	Gradational		N20W	60SW	1/8", 0		
4997.2	205	5-AH	VESICULAR BASALT (206.6 to 209.0 ft), dark to medium gray; 30 to 35% elongate horizontal vesicles 1/4 in. long	53	N35W	30SW	1/4", F		
		6-AH	Gradational		N55W	70NE	1/16", F		
	210	1-AH	CLINKERS (209.0 to 214.0 ft), dark gray, highly vesicular and scoriaceous basalt	25					
		2-AH	Gradational						
		3-AH	VESICULAR BASALT (214.0 to 228.0 ft), dark to medium gray; 30 to 35% spheroidal and elongate vesicles, averaging 1/4 in. long; some vesicles are filled or coated with calcite and tan silt	94	N65W	45NE	1/8", Gf		
		4-AH	Gradational		N70W	50SW	1/2", Gf		
		5-AH	Gradational		N55W	55SE	1/8", 0		
	220	1-AH	VESICULAR BASALT (228.0 to 236.4 ft), medium to light gray; 5 to 7% spheroidal vesicles, 1/8 to 1/4 in. in diameter; many vesicles lined or filled with calcite	79					
4978.2	225	2-AH	Gradational		N80E	60SW	1/8", Fgf		
		3-AH	Gradational		N30W	65NE	1/16", 0		
		4-AH	Gradational		N55E	55SE	1/16", C		
		5-AH	Gradational		N40W	40SW	1/8", 0		
		6-AH	Gradational		N30E	8W	1/16", 0		
	230	1-AH	CLINKERS (236.4 to 242.0 ft), red and dark gray scoriaceous basalt		N5E	35SW	1/16", F		
		2-AH	Gradational		N85E	70SE	1/4", F		
4969.8	235	1-AH	CLINKERS (236.4 to 242.0 ft), red and dark gray scoriaceous basalt						
		2-AH	Gradational						
		3-AH	VESICULAR BASALT (242.0 to 248.0 ft), dark gray; 20% elongate vesicles, averaging 1/4 in. long and oriented 75 deg; colloform calcite coating many joints	62	N10E	45W	1-3/8", F		
		4-AH	Gradational		N75E	80SE	1/16", 0		
4958.2	245	5-AH	VESICULAR BASALT (248.0 to 254.0 ft), light gray; 20 to 10% elongate and spheroidal, vertically oriented vesicles, up to 1/4 in. long; iron oxide lining vesicles; vesicles are about 3% in upper foot	80	N50E	60SW	1/4", 0		
		6-AH	Gradational		N10E	60W	1/16", 0		
		7-AH	Gradational		N15W	55NE	1/4", F		
		8-AH	Gradational		N5E	60E	1/4", 0		
		9-AH	Gradational		N60E	70SW	1/8", 0		
		10-AH	Gradational		NS	50W	1/16", C		
4952.2	250	1-AH	VESICULAR BASALT (254.0 to 265.0 ft), light gray; 5 to 7% spheroidal vesicles, averaging 1/8 in. in diameter; calcite coating joints	100	N25E	70SW	1/4", 0		
		2-AH	Gradational		N5E	85E	1/8", 0		
		3-AH	Gradational		N25E	90	1/4", 0		
	255	1-AH	263.0 to 265.0 ft, vesicles increase to 10 to 15% and are oriented horizontally	84					
		2-AH	Flow Contact		N75W	90	1/8", C		
4941.2	265	1-AH	VESICULAR BASALT (265.0 to 272.5 ft), medium gray; 35% elongate vesicles, about 1/4 in. long and oriented 30 deg; coated with iron oxide		N70W	80W	1/4", F		
		2-AH	Gradational		N5E	65W	1/16", 0		
		3-AH	Gradational						
4933.7	270	4-AH	269.0 to 272.5 ft, vesicles decrease to 25% and become more elongate up to 3/4 in.		N25W	70SW	1/8", 0		
		5-AH	Gradational						
		6-AH	VESICULAR BASALT (272.5 to 279.0 ft), medium gray; 15% elongate vesicles, up to 1-1/2 in. long, oriented 15 deg	100	N45E	15SW	1/8", F		
		7-AH	Gradational		N5E	60W	1/4", 0		
		8-AH	Gradational		N15E	90	1/4", 0		
		9-AH	Gradational		N40E	65SW	1/4", 0		
		10-AH	Gradational		N50E	90	1/4", 0		
		11-AH	Gradational		N10E	20W	1/16", 0		
4928.2	280	1-AH	VESICULAR BASALT (279.0 to 282.0 ft), (as above); vesicles decrease to 8 to 5%, become spheroidal and decrease in size to 1/4 in. or less		N70W	35W	1/8", 0		
		2-AH	Gradational		N40W	65SW	1/8", 0		
		3-AH	Gradational		N40W	55SW	1/8", 0		
		4-AH	Gradational		N40W	60SW	1/4", 0		
		5-AH	Gradational		N45W	85NE	1/8", C		
	285	1-AH	VENISE BASALT (282.0 to 289.0 ft), light gray; 0 to 2% small spheroidal vesicles		N50E	70SW	1/8"		
4917.2	290	1-AH	287.0 to 289.0 ft, vesicles increase to 15%, average 1/4 in. long and are horizontal						
		2-AH	CLINKERS (289.0 to 302.0 ft), reddish brown and gray scoriaceous basalt fragments with large amount of tan silt and some calcite	49	N70E	80SW	1/4"		
		3-AH	Gradational		N40E	70SW	1/16"		
		4-AH	Gradational		N15W	75SW	1/4", 0		
		5-AH	Gradational		N30E	70SE	1/4", 0		
	295	1-AH	CLINKERS (289.0 to 302.0 ft), reddish brown and gray scoriaceous basalt fragments with large amount of tan silt and some calcite	65					
	300	1-AH	CLINKERS (289.0 to 302.0 ft), reddish brown and gray scoriaceous basalt fragments with large amount of tan silt and some calcite						

(Continued)

PROJECT BUGGY										
BORING NO. 67 Buggy No. 1 (Concluded)										
EL FT MSL	DEPTH FT	LOG	DESCRIPTION	PER- CENT CORE RECOV	BORE HOLE CAMERA JOINT DATA					
					MID- PT	STRIKE DEG	DIP DEG	WIDTH & FILLING		
4904.2	300	4-AH	CLINKERS (Continued)	63						
	305	VESICULAR BASALT (302.0 to 310.0 ft) medium gray; 25 to 20% elongate and spheroidal vesicles up to 2-1/2 in. long or more (averaging 1/8 to 1/4 in.) oriented roughly horizontal; calcite coating joints								
4896.2	310	8-AH	Gradational				N5E	45N	1/8", 0	
		VESICULAR BASALT (310.0 to 315.0 ft) light gray; vesicles gradually de- crease from 15% in top to 2% in bottom; 1/4 in. or less in length; oriented 10 to 15 deg	100				N30E	75N	1/8", 0	
4891.2	315	1-AH	Gradational					N40E	75NN	1/8", 0
		DENSE BASALT (315.0 to 325.0 ft) light gray; scattered small spher- oidal vesicles					N40E	55NN	1/4", 0	
								N35E	60NN	1/8", 0
								N55E	70NN	1/8", 0
								N50N	55NE	1/16", 0
								N85E	65NN	1/16", 0
	320	1-IH								
			324.0 to 325.0 ft, 15 to 20% elon- gate vesicles oriented 0 to 10 deg					No photographs be- low 316.1 ft		
4881.2	325	1-AH	CLINKERS (325.0 to 327.2 ft) red-brown scoriaceous basalt	57						

BOTTOM DEPTH: 327.2 ft	
BOTTOM ELEVATION: 4879.0 ft	

PROJECT BUGGY									
BORING NO.: 67 Buggy No. 2									
LOCATION (NEVADA STATE COORDINATES): N 822,137.53 E 506,426.27									
ANGLE OF BORING: Vertical									
BEARING: DRILLING AGENCY: WES									
EL TOP OF HOLE: 5202.2 ft MSL									
TOTAL DEPTH: 327.4 ft									
TOTAL CORE RECOVERY: 91.4%									
HOLE COMPLETED: 12 September 1967									
EL FT MSL	DEPTH FT	LOG	DESCRIPTION	PERCENT CORE RECOV.	BORE HOLE CAMERA JOINT DATA				
					MID- PT	STRIKE DIP	DIP DIP	WIDTH & FILLING	
5202.2	0		SOIL (0.0 to 6.1 ft) tan sandy clay with fragments and blocks of vesicular basalt						
5196.1	5		Top of Rock						
5188.0	10		VESICULAR BASALT (6.1 to 19.0 ft) medium gray; 20 to 30% or more spheroidal and elongate vesicles up to 3/4 in. long; earthy calcite in joints.	94		N25E N30E N55E	45SE 45SE 45SE	1 1/4", F 2", F 1 1/8", F	
5183.2	15		14.2 to 19.0 ft, vesicles are oriented 40 deg; vesicles in top are coated with limonite; colloform calcite in few joints.	100		N10W N65E N75E	90 50E 50SE	2", F 1 1/4", F 1", F	
	20		Gradational						
	25		VESICULAR BASALT (19.0 to 21.0 ft) medium gray; 15 to 20% spheroidal vesicles.	100		N5E N45W N55W	40E 90 90	1-1/2", F 3", F 1 1/8", F	
	30		Gradational						
	35		VESICULAR BASALT (21.0 to 31.5 ft) light gray; 5% small spheroidal vesicles.	100		N25W N75W N45E	90 60W 55SE	1 1/8", F 1 1/2", F 3/4", F	
	40		30.0 to 31.5 ft, 15% elongate vesicles; 1/8 to 3/4 in. long, horizontal	96		N15E N45W N55W	40E 90 90	1", F 1 1/2", F 1 1/8", F	
5172.2	45		CLINKERS (31.5 to 32.4 ft)	90		N65E N35E N20E	50NW 65SE 70W	3", F 3/4", F 1 1/2", F	
5170.7	50		VESICULAR BASALT (32.4 to 72.8 ft) dark gray (weathered brown along few joints); 20 to 35% spheroidal and elongate vesicles; calcite along many joints.	100					
5169.8	55		32.4 to 50.3 ft, 30 to 35% vesicles, up to 1/4 in. long.	89					
	60		50.3 to 61.2 ft, 25 to 30% vesicles, up to 1/2 in. long; oriented 90 deg.	41					
	65		61.2 to 69.2 ft, 25 to 30% elongate vesicles, up to 3/4 in. long; oriented 90 deg.	87					
5169.4	70		69.2 to 72.8 ft, 25 to 30% elongate vesicles, up to 3/4 in. long; oriented 90 deg.	100					
	75		72.8 to 82.0 ft) dark gray to black; 25% very small vesicles (1/32 in. or less.	80					
5120.2	80		SCORIAEUS CLINKERS (82.0 to 85.0 ft) dark gray and brown scoriaeous basalt and tan silt and sand.	90					
5117.2	85		VESICULAR BASALT (85.0 to 115.0 ft) medium gray; 25% mostly elongate vesicles, ranging from 1/4 in. long in top, gradually increasing in size with depth to 1 in. long; orientation of vesicles varies from 15 deg in top to 45 deg in bottom; calcite coating most joints.	88					
	90			90					
	95			100					

(Continued)

PROJECT BUGGY									
BORING NO.: 67 Buggy No. 2 (Continued)									
EL FT MSL	DEPTH FT	LOG	DESCRIPTION	PERCENT CORE RECOV.	BORE HOLE CAMERA JOINT DATA				
					MID- PT	STRIKE DIP	DIP DIP	WIDTH & FILLING	
	100		VESICULAR BASALT (as above)	100					
5091.4	105		110.9 to 112.2 ft, 3 to 5% horizontal vesicles.						
5090.0	110		112.2 to 115.0 ft, 10% vesicles						
5088.2	115		Gradational	100					
5087.2	120		VESICULAR BASALT (115.0 to 146.5 ft) light gray, vesicles are about 5% in top gradually decreasing to 2% in bottom; few vesicles up to 2-1/2 in. long or more, most are less than 1/2 in.; calcite in many vesicles.	100					
5080.2	125		115.0 to 122.0 ft, vesicles are oriented 10 to 20 deg.	100					
	130		122.0 to 146.5 ft, vesicles have no preferred orientation.	100					
	135								
	140								
	145								
5055.7	150		Gradational	100					
	155		DENSE BASALT (146.5 to 171.3 ft) light gray, 2 to 6% small vesicles.						
	160								
	165								
	170								
5030.9	175		Gradational	100					
	180		VESICULAR BASALT (171.3 to 182.0 ft) light gray; 5% vesicles increasing to 10% with depth; vesicles up to 1/4 in. long, oriented 10 to 20 deg; platy fractures common.						
	185		Basalt has a brown tint in bottom few feet.						
5020.2	190		SCORIAEUS CLINKERS (182.0 to 190.6 ft) dark gray and red-brown scoriaeous basalt; abundant colloform calcite and opal.	89					
	195			91					
5011.6	200		VESICULAR BASALT (190.6 to 199.3 ft) medium gray, 30% vesicles about 1/4 in. in size.	100					
5005.2	205		197.0 to 199.3 ft, 8% vesicles as above; many filled with calcite.	98					
5002.9	210								

(Continued)

Figure A.3 Log of core Boring 67 Buggy No. 2.

PROJECT SUMMARY									
BORING NO. 67 Bugey No. 4		5556, 147, 61							
LOCATION (NAD83 STATE COORDINATES)		N292.139.69							
ANGLE OF BORING 30°		TYPE OF BORING: IX Diamond							
BEARING: N70°E		DRILLING AGENCY: VBS							
EL. TOP OF HOLE 5002.2 ft		DEPTH TO WATER TABLE: None encountered							
TOTAL DEPTH 200.2 ft		HOLE STARTED: September 1967							
TOTAL CORE RECOVERY: 69%		HOLE COMPLETED: 6 October 1967							
EL. DEPTH FT	LOG	DESCRIPTION	PER. CORE RECOV. FT	BONE HOLE CAMERA JOINT DATA MID-STRIKE CORV. PT.	STRIKE CORV. PT.	DIP CORV. PT.	WORTH A DIP CORV. PT.		
5002.2	0	SOIL (0.0 to 6.4 ft): tan sandy clay with fragments and blocks of vesicular basalt and fragments of tuff							
5002.8	5	Top of rock							
	10	VESICULAR BASALT (6.4 to 20.0 ft): medium gray; 10 to 12% apertural vesicles; abundant earthy calcite along joints	63						
	15	16.0 to 20.0 ft: vesicles increase to 20% and become elongate up to 1 in.; oriented 70 deg; basalt becomes brown	73						
5002.8	20	CLINKERS (20.0 to 27.9 ft): brown and dark gray scoriaceous basalts with abundant tan silt and calcite	66						
	25	VESICULAR BASALT (27.9 to 30.0 ft): dark gray; 25 to 30% elongate oriented 25 deg	39						
5002.8	30	VESICULAR BASALT (30.0 to 34.2 ft): medium gray; 19% apertural vesicles up to 1/8 in. diameter							
5002.0	35	CLINKERS (34.2 to 39.7 ft): brown scoriaceous basalt							
5002.5	40	VESICULAR BASALT (39.7 to 47.7 ft): dark gray; 30 to 35% apertural vesicles averaging 1/8 in. diameter; basalt is weathered brown along joints	86						
5004.5	45	VESICULAR BASALT (47.7 to 50.0 ft): dark gray with brown tint; 25 to 30% elongate vesicles up to 1 in.; oriented 90 deg	82						
5004.2	50	VESICULAR BASALT (50.0 to 59.0 ft): dark gray and brown; 25% apertural vesicles averaging 1/8 in. diameter	100						
5004.2	55	VESICULAR BASALT (59.0 to 66.7 ft): dark gray; 25% elongate vesicles up to 3/8 in. diameter	67						
5004.7	60	VESICULAR BASALT (66.7 to 70.5 ft): light gray; vesicles are apertural; average 1/8 in. diameter	100						
5004.7	65	Gradational							
5004.7	70	VESICULAR BASALT (70.5 to 81.2 ft): up to 3/8 in. diameter vesicles (1 in.); oriented 15 deg; calcite in some vesicles	93						
5007.2	75	75.0 to 81.2 ft: vesicles have no preferred orientation and increase gradually to 30% or more	95						
5007.2	80	VESICULAR BASALT (81.2 to 89.0 ft): decrease from 10% in top to 8% at 86 ft; range up to 1 in. long; oriented 80 deg; vesicles below 86 ft average 1/8 in. diameter	100						
5007.2	85	89.0 to 89.0 ft: 25% vesicles 1/8 in. diameter							
5007.2	90	VESICULAR BASALT (89.0 to 104.0 ft): dark gray; 30 to 35% apertural vesicles from 1/8 to 1/2 in. diameter; abundant tan silt and along joints	69						
5007.2	95								
5007.2	100								

(continued)

PROJECT SUMMARY									
BORING NO. 67 Bugey No. 4 (Continued)									
EL. DEPTH FT	LOG	DESCRIPTION	PER. CORE RECOV. FT	BONE HOLE CAMERA JOINT DATA MID-STRIKE CORV. PT.	STRIKE CORV. PT.	DIP CORV. PT.	WORTH A DIP CORV. PT.		
100		VESICULAR BASALT (as above)							
5008.2	105	VESICULAR BASALT (104.0 to 113.6 ft): dark gray; 25 to 30% apertural vesicles averaging 1/16 in. diameter	49						
5008.6	110		60						
	115	SCORIEFORM CLINKERS (113.6 to 123.7 ft): basalt is red and abundant consolidated tan silt with some calcite and opal	47						
	120		38						
5008.5	125	VESICULAR BASALT (123.7 to 130.4 ft)	49						
	130	SCORIEFORM CLINKERS (130.4 to 139.4 ft) with silty clay filling interstices	48						
5009.2	135		48						
5009.8	140	VESICULAR BASALT (139.4 to 147.5 ft): light gray; 25 to 30% apertural vesicles 1/2 to 1/4 in. diameter	84						
	145		60						
5009.2	150	VESICULAR BASALT (147.5 to 156.2 ft): medium gray; 30 to 35% apertural vesicles up to 1/8 in. diameter	43						
	155		79						
5006.0	160	VESICULAR BASALT (156.2 to 161.0 ft): medium gray; 25% vesicles averaging 1/16 in. diameter	100						
	165	VESICULAR BASALT (161.0 to 169.2 ft): medium gray; 30 to 35% apertural vesicles up to 1/8 in. diameter	80						
5003.0	170	VESICULAR BASALT (169.2 to 174.8 ft): dark gray; 25 to 30% apertural vesicles up to 1/8 in. diameter; abundant columnar vesicles along joints	75						
5027.4	175	Gradational	96						
5028.2	180	VESICULAR BASALT (174.8 to 178.0 ft): medium gray; 15% vesicles decreasing to 7% with depth	65						
	185	CLINKERS (178.0 to 185.0 ft): dark gray; 15% vesicles; abundant vesicular and scoriaceous basalt	61						
5007.2	190	VESICULAR BASALT (185.0 to 200.9 ft): medium to dark gray; 25 to 30% apertural vesicles; vesicles in bottom 2 ft are 1/16 in. or less diameter; abundant tan silt in joints	30						
	195								
200									

Notes Depth: 200.2 ft
Bottom Elevation: 5001.3 ft

Figure A.6 Log of core Boring 67 Bugey No. 4.

PROJECT BUGGY										
BORING NO.: 67 Buggy No. 5										
LOCATION (NEVADA STATE COORDINATES): N 822,236.35 E 56,464.22										
ANGLE OF BORING: Vertical			TYPE OF BORING: NX - DIAMOND							
BEARING:			DRILLING AGENCY: WES							
EL TOP OF HOLE: 5197.70 ft MSL			DEPTH TO WATER TABLE: Not encountered							
TOTAL DEPTH: 219.9 ft			HOLE STARTED: 2 November 1967							
TOTAL CORE RECOVERY: 79%			HOLE COMPLETED: 11 November 1967							
EL FT MSL	DEPTH FT	LOG	DESCRIPTION	PERCENT CORE RECOV.	MID-PT	STRIKE DEG	DIP DEG	WIDTH & FILLING	BORE HOLE CAMERA JOINT DATA	
	0		SOIL (0.0 to 9.0 ft), tan sandy clay with fragments and blocks of vesicular basalt.							
	5									
5188.7			Top of Rock							
	10		VESICULAR BASALT (9.0 to 32.7 ft) dark gray; 20 to 30% spheroidal and elongate vesicles ranging up to 1-1/2 in. long (average 1/8 to 1/2 in.); earthy calcite along joints.	27		N10W	50SW 1/4", Pr			
	15			61		N25W	40SW 1/4", Pr			
5179.7			9.0 to 18.0 ft, vesicles are oriented from 0 deg in top to 30 deg in bottom.			N65E	50NW 1/2", Pr			
5177.7						N40W	50NE 1/2", O			
5175.2			20.0 to 22.5 ft, vesicles are oriented 90 deg.			N65E	70SE 3", Gr			
	25		27.6 to 29.7 ft, 30 to 35% spheroidal vesicles oriented 45 to 70 deg.	89		N95W	45N 1/8", Gr			
5170.1			29.7 to 32.7 ft, vesicles are up to 2 in. long and oriented 30 deg in top; decreasing in size to 1/16 in. long and oriented 0 deg in bottom.			N35E	45SE 1/4", Pr, C			
5168.0						N25E	60E 1/4", Pr, C			
5165.0						N95W	30N 1/4", Gr			
	30					N60W	50NE 3/8", Gr			
	35		SCORIEOUS CLINKERS (32.7 to 38.5 ft) tan and dark gray scorieous basalt.			N60E	45SE 1/4", Gr			
5159.2						N30E	50NW 1/4", Gr			
5157.7			38.5 to 46.5 ft) dark gray, 25 to 30% irregular to elongate vesicles up to 1 in. long (average 1/4 in.), decreasing to 7/8 in. in bottom foot; orientation changes from 70 deg at 40.0 ft to 40 deg in bottom; tan silt along joints.	60		N30E	80NW 1/2", Gr			
5154.7				72		N25W	60NE 1/8", Gr			
5151.2				100		N35W	59NE 1/4", Gr			
	45			38		N10W	50NE 1/8", Gr			
	50		SCORIEOUS CLINKERS (46.5 to 55.5 ft) red-brown and gray scorieous basalt.							
	55			36						
5142.2				50						
5139.9			55.5 to 82.2 ft) dark gray; 25 to 30% spheroidal and elongate vesicles, ranging from 1/16 to 2 in. long; tan silt along joints.	79		E-W	60S 1/4", Gr			
5135.8			55.5 to 57.8 ft, vesicles range from 1/8 to 1 in. long and are oriented 20 to 30 deg; brown tint in top foot.			N65E	90 1/4", Gr			
5131.5			57.8 to 61.9 ft, 30 to 35% spheroidal vesicles, averaging 1/4 in. in size.			N65E	75SE 1/4", Gr			
5126.6			61.9 to 66.2 ft, vesicles range from 1-1/2 in. long in top to 1/4 in. long in bottom and are oriented 30 to 40 deg.							
5124.5			66.2 to 71.1 ft, spheroidal vesicles averaging 1/4 in. in size.	100						
5122.7			71.1 to 73.2 ft, tear drop vesicles up to 1-1/2 in. long with a curved orientation.			N45W	55NE 1/8", Pr			
	80		75.1 to 82.2 ft, vesicles up to 2 in. long, oriented 90 deg, calcite in few vesicles.			N35E	30SE 1/8", Pr			
5115.5						N60E	50NW 1/16", Pr			
	85		SCORIEOUS CLINKERS (82.2 to 89.7 ft) brown and gray scorieous basalt.	40		N20E	65E 1/4", Pr			
5108.0				15		N70E	45SE 1/4", Pr			
5105.8			89.7 to 99.0 ft) dark gray; 25% irregular and elongate vesicles decreasing to 15 to 20% below 91.9 ft; average 1/16 to 1/4 in. long. Vesicles in top are oriented to 10 deg.	78		N45W	50NE 1/16", Pr			
	95					N10W	65SW 1/4", F			
5098.7			95.8 to 96.8 ft, fine buff to dark gray sand.	100		N45E	85SE 1/4", Pr			

(Continued)

PROJECT BUGGY										
BORING NO.: 67 Buggy No. 5 (Continued)										
EL FT MSL	DEPTH FT	LOG	DESCRIPTION	PERCENT CORE RECOV.	MID-PT	STRIKE DEG	DIP DEG	WIDTH & FILLING	BORE HOLE CAMERA JOINT DATA	
	100		VESICULAR BASALT (99.0 to 107.0 ft) medium gray with brown tint; 25% irregular and elongate vesicles, ranging up to greater than 2-1/8 in. long (majority are less than 1/4 in. long); oriented 0 to 5 deg; vesicles have oxidized coatings.						N55E	70SE 1/16", Pr
5090.7			Gradational						N30W	85SW 1/8", Pr
5087.1			107.0 to 110.6 ft) (as above) vesicles decrease to 15% and are oriented 40 to 45 deg.	100						
	110		Gradational						N25W	55SE 1/8", F
	115		VESICULAR BASALT (110.3 to 124.0 ft) (as above) vesicles gradually decreasing from 10% in top with 40 deg orientation to 2% in bottom with 70 deg orientation; core is losing brown tint.							
	120								N30E	80SE 1/16", O
5073.7			Gradational						N45W	50SE 1/8", F
	125		DENSE BASALT (124.0 to 173.5 ft) light gray; 2% spheroidal vesicles.						N55W	65SW 1/16", Pr
	130								N45W	80SW 1/8", O
	135								N25W	85SW 1/16", Pr
	140									
	145		145.0 to 173.5 ft, very few to no vesicles.						N15W	50SW 1/8", Pr
	150								N65E	50NW 1/16", Pr
	155								N15W	70NE 3/8", F
	160									
	165									
	170								N75E	45NW 1/8", O, C
5064.2									N15E	45SE 1/16", Pr
	175		SCORIEOUS CLINKERS (173.5 to 184.0 ft) red brown and gray scorieous basalt.						N50W	65SW 3/4", F
	180								N15E	50NE 1/16", O
5013.7			184.0 to 188.7 ft) dark gray with brown tint in top foot; 20 to 30% irregular and elongate vesicles ranging from 1/32 to 2 in. long.	68					N25W	45NW 1/32", F
5009.0			Gradational						N10E	35NE 1/32", O
	190		VESICULAR BASALT (188.7 to 196.0 ft) dark gray, 10% spheroidal vesicles ranging from 1/32 to 1/2 in. in size. Vesicles become elongate and horizontal in bottom foot.	80					N-S	50W 1/8", Pr
5001.7				61					N10W	60W 1/8", O
	195			27						
	200		VESICULAR BASALT (196.0 to 200.7 ft) dark gray; 30% elongate vesicles ranging from 1/32 to 1 in. long, oriented 90 deg in top to 0 deg in bottom.	69						

(Continued)

Figure A.7 Log of core Boring 67 Buggy No. 5.

PROJECT BUGGY									
BORING NO.: 67 Buggy No. 6 (Continued)									
EL FT MSL	DEPTH FT	LOG	DESCRIPTION	PERCENT CORE RECOVERED	BORE HOLE CAMERA JOINT DATA				
					MID- PT	STRIKE DEG	DIP DEG	WIDTH & FILLING	
	100		VESICULAR BASALT (99.5 to 106.8 ft) (as above); 15 to 30% spheroidal and elongate vesicles ranging up to 2 in. long (most are < 1/2 in.) and oriented 45 to 60 deg, many vesicles are lined with calcite.	100					
	105	P-AH	Gradational						
5087.4			VESICULAR BASALT (106.8 to 117.0 ft) light gray; spheroidal vesicles decrease from 10% in top to 2% in bottom, range from 1/16 to 1 in. in size and are oriented 45 deg in top to 90 deg in bottom; many vesicles are lined or filled with calcite.	100					
	110	P-AH	Gradational						
	115		DENSE BASALT (117.0 to 168.0 ft) (as above) light gray; 2% spheroidal vesicles ranging up to 1-1/2 in. in size, decreasing to 0% below 136.0 ft; many vesicles are coated with calcite.	100					
5077.2			Gradational						
	120			100					
	125								
	130			100					
	135								
	140			100					
145		1-TH							
	150			100					
	155								
	160			98					
	165								
5026.2		P-AH	168.0 to 169.9 ft, gradational change to vesicular basalt with 5 to 20% elongate vesicles up to 1 in. long oriented horizontal; vesicles average 1/16 in. in bottom foot.	94					
5024.3		P-AH							
5022.2		P-AH							
	175		SCORIALACIOUS CLINKERS (172.0 to 179.1 ft), angular fragments of black and red-brown scoriaceous basalt contained in a large amount of consolidated sandy silt.	79					
5015.1									
	180		VESICULAR BASALT (179.1 to 188.6 ft) brick red at top, gradually changing to dark gray with depth; 30% irregular and elongate vesicles gradually decreasing to 20% toward bottom; vesicles range up to 1 in. (average 1/8 to 1/4 in.)						
5009.2			185.0 to 188.6, vesicles become more elongate; oriented 90 deg in top to 0 deg in bottom.	100					
5005.6			Gradational						
	190		VESICULAR BASALT (188.6 to 192.1 ft) (as above) elongate vesicles up to 2 in. long decreasing from 20% in top to 10% in bottom; oriented 0 deg in top to 90 deg in bottom.	88					
5002.1			Gradational						
	195		VESICULAR BASALT (192.1 to 199.3 ft) (as above) light gray; 5 to 10% elongate vesicles up to 1-1/2 in. long; oriented 0 deg, scattered black frothy and glassy inclu- sions up to 1 in. in size.	86					
4994.3									
	200								

(Continued)

PROJECT BUGGY									
BORING NO.: 67 Buggy No. 6 (Continued)									
EL FT MSL	DEPTH FT	LOG	DESCRIPTION	PERCENT CORE RECOVERED	BORE HOLE CAMERA JOINT DATA				
					MID- PT	STRIKE DEG	DIP DEG	WIDTH & FILLING	
	200		SCORIALACIOUS CLINKERS (199.9 to 211.0 ft) black and red-brown scoriaceous basalt and cinders	50					
	205			50					
	210			50					
4963.2				50					
4961.6			VESICULAR BASALT (211.0 to 219.3 ft) light gray; 15% elongate vesicles in top decreasing to 3% in bottom.	100					
	215		211.0 to 212.6 ft, vesicles up to 2 in. or more long, oriented 0 to 15 deg.	89					
4974.9			212.6 to 219.3 ft, vesicles average 1/8 to 1/4 in. across.						
			BOTTOM DEPTH: 219.3 ft BOTTOM ELEVATION: 4974.9 ft						

Figure A.9 Log of core Boring 67 Buggy No. 6 (Continued).

(continued)

Figure A.10 Log of core Boring 67 Buggy No. 7.

PROJECT SUMMARY									
BORING NO. 67 Buggy No. 8									
LOCATION: NEWADA STATE COORDINATES: 1022.077, 50 59.5, 566.36									
ANGLE OF BORING: VERTICAL									
BRASS: 109221 05' N									
EL. TOP OF HOLE: 5008.2 FT. and									
TOTAL DEPTH: 366.2 FT.									
TOTAL CORE RECOVERY: 75.5%									
EL. FT.	DEPTH FT.	LOG	DESCRIPTION	PER. CORE RECOVERY	BONE HOLE CAMERA JOINT DATA	NO. OF STRIKE	DIAG.	DP.	WRT. A.
5008.2	0		SOIL (0.0 to 11.8 ft.) tan sandy clay with fragments and blocks of vesicular basalt						
5008.4	10		Top of Rock						
5008.4	15	1-H	VEGETARIAN BASALT (11.8 to 21.8 ft.) averaging 1/8 in. in size; earthy calcite along joints	91					
5008.4	20			100					
5008.4	25	1-H	VEGETARIAN BASALT (21.8 to 33.5 ft.) averaging 1/8 in. across; many vesicles lined with calcite	83					
5008.4	30	1-H	28.0 to 33.5 ft., 2 to 5% vesicles oriented 30 deg	89					
5008.4	35		Gradational						
5008.4	40		VEGETARIAN BASALT (33.5 to 60.0 ft.) light gray; 0 to 2% small spheroidal vesicles; calcite lining or filling vesicles	86					
5008.4	45	1-H		100					
5008.4	50			77					
5008.4	55			15					
5008.4	60		VEGETARIAN BASALT (60.0 to 71.0 ft.) dark gray; 20 to 30% spheroidal vesicles; 1/32 to 1/8 in. across; limonite coating vesicles in top	80					
5008.4	65			91					
5008.4	70	1-H	69.0 to 67.7 ft., 2 to 10% vesicles up to 1 in. long; oriented 0 deg in top few inches	86					
5008.4	75		SCORALACIOUS CLINKERS (71.0 to 76.0 ft.) black; many silt and colloform calcite present	37					
5008.4	80		VEGETARIAN BASALT (76.0 to 90.3 ft.) dark gray; 20 to 25% spheroidal and elongate vesicles up to 3/8 in. long (average 1/32 to 1/8 in.); parallel to many joints	100					
5008.4	85			10					
5008.4	90		Gradational						
5008.4	95		VEGETARIAN BASALT (90.3 to 97.4 ft.) medium gray; 15 to 20% elongate vesicles up to 2 in. long (most 1/8 to 1/4 in.); oriented 0 deg in top to 45 deg in bottom; calcite lining few vesicles	92					
5008.4	100		20 to 25% small vesicles in bottom	72					
5008.4	105		CLINKERS (97.4 to 99.5 ft.)						

(continued)

PROJECT SUMMARY									
BORING NO. 67 Buggy No. 8 (Continued)									
EL. FT.	DEPTH FT.	LOG	DESCRIPTION	PER. CORE RECOVERY	BONE HOLE CAMERA JOINT DATA	NO. OF STRIKE	DIAG.	DP.	WRT. A.
5008.2	100	1-H	VEGETARIAN BASALT (99.5 to 105.5 ft.) dark gray; 20 to 25% spheroidal vesicles; 1/32 to 1/8 in. long (average 1/8 in.); oriented 60 to 70 deg	86					
5008.2	105		Gradational						
5008.2	110	1-H	VEGETARIAN BASALT (105.5 to 112.0 ft.) dark gray; 20 to 25% spheroidal vesicles; 1/32 to 1/8 in. long (average 1/8 in.); oriented 60 to 70 deg	84					
5008.2	115	1-H	CLINKERS (112.0 to 113.9 ft.)	91					
5008.2	120		Gradational						
5008.2	125	1-H	VEGETARIAN BASALT (119.3 to 126.3 ft.) medium gray; 10 to 15% spheroidal vesicles up to 1 in. across	100					
5008.2	130	1-H	126.6 to 126.3 ft., 20 to 30% elongate vesicles; oriented 15 deg; calcite coating in vesicles near bottom	33					
5008.2	135	1-H	CLINKERS (126.3 to 129.0 ft.)						
5008.2	140		Gradational						
5008.2	145	1-H	VEGETARIAN BASALT (129.0 to 131.0 ft.) dark gray; 20 to 30% spheroidal vesicles; 1/32 to 1/8 in. long (average 1/8 in.); oriented 60 to 70 deg	50					
5008.2	150	1-H	VEGETARIAN BASALT (131.0 to 137.0 ft.) dark gray; 20 to 30% vesicles up to 1 in. long; orientated 45 to 60 deg	100					
5008.2	155			46					
5008.2	160	1-H		55					
5008.2	165			100					
5008.2	170			96					
5008.2	175			100					
5008.2	180			100					
5008.2	185	1-H	182.5 to 191.8 ft., 25 to 30% irregular and elongate vesicles ranging from 1/8 to 1/4 in.; oriented 90 deg in top to 50 deg in bottom; calcite lining most joints	93					
5008.2	190			100					
5008.2	195	1-H		100					
5008.2	200		CLINKERS (197.0 to 207.0 ft.) black scoriaceous basalt	33					

(continued)

Figure A.11 Log of core Boring 67 Buggy No. 8.

PROJECT BORING									
BORING NO.	67 Buggy No. 9								
LOCATION (NEVADA STATE COORDINATES)	N282.117, N4.535, 869.171								
DATE OF BORING	Vertical								
BEARING	N65°21'05"W								
EL. TOP OF HOLE	5208.5								
TOTAL DEPTH	280.0								
TOTAL CORE RECOVERY	56.0%								
		HOLE STAYED		18 November 1967					
		BORE HOLE CAMERA JONT DATA							
EL. FT.	DEPTH	LOG	DESCRIPTION	PER. CORE RECV.	BONE HOLE CAMERA JONT DATA	NO. STYNE	DP	WIDTH & FILLING	
5208.5	0		SOIL (0.0 to 11.3 ft) tan sandy clay with fragments and blocks of vesicular basalt						
5197.5	10		Top of Rock						
5192.0	15		VEGETIAR BASALT (11.3 to 16.5 ft) in thin discontinuous layers oriented 0 to 15 deg; calcite lining may vesicles						
5188.5	20		CLINKERS (16.5 to 20.0 ft) scoriaceous basalt						
5184.7	24		VEGETIAR BASALT (20.0 to 30.0 ft) dark gray; 10 to 30% spheroidal and elongate vesicles, ranging up to 1 in. long (average 1/8 to 1/4 in.); limonite coating many vesicles						
5180.0	28		Drainage						
5178.5	30		VEGETIAR BASALT (30.0 to 40.0 ft) dark gray; 20% spheroidal and elongate vesicles, gradually decreasing in size with depth; to 1 in. long (average 1/8 to 1/4 in.); limonite coating many vesicles						
5166.5	40		CLINKERS (40.0 to 42.0 ft)						
5162.5	44		VEGETIAR BASALT (42.0 to 102.0 ft) dark gray; 20% spheroidal and elongate vesicles, averaging 1/4 in. long, ranging from 1/16 in. to 1 in. long; generally increasing in size toward bottom						
5158.5	50								
5154.5	54								
5150.5	58								
5146.5	62								
5142.5	66								
5138.5	70								
5134.5	74								
5130.5	78								
5126.5	82								
5122.5	86								
5118.5	90								
5114.5	94								
5110.5	98								
5106.5	102								

(continued)

PROJECT BORING									
BORING NO.	67 Buggy No. 9 (Continued)								
EL. FT.	DEPTH LOG	DESCRIPTION	PER. CORE RECV.	BONE HOLE CAMERA JONT DATA	NO. STYNE	DP	WIDTH & FILLING		
5105.5	106	VEGETIAR BASALT (105.0 to 121.0 ft) medium gray; spheroidal vesicles gradually decrease from 10% in top to 2% in bottom; vesicles range from 1/8 to 1/4 in.; joints (average 1/8 to 1/4 in.); joints are coated with tan clay and vesicles calcite coating many vesicles							
5097.5	120	VEGETIAR BASALT (120.0 to 136.5 ft) dark gray; spheroidal and elongate vesicles range from 10% to 15% in size; calcite coating many vesicles							
5093.5	124								
5089.5	128								
5085.5	132								
5081.5	136								
5077.5	140								
5073.5	144								
5069.5	148								
5065.5	152								
5061.5	156								
5057.5	160								
5053.5	164								
5049.5	168								
5045.5	172								
5041.5	176								
5037.5	180								
5033.5	184								
5029.5	188								
5025.5	192								
5021.5	196								
5017.5	200								

(continued)

Figure A.13 Log of core Boring 67 Buggy No. 9.

BORING NO. 67 Buggy No. 10 (Continued)									
EL FT MSL	DEPTH FT	LOG	DESCRIPTION	PER- CENT CORE RECOV	BORE HOLE CAMERA JOINT DATA				
					MID- PT	STRIKE DEG	DIP DEG	WIDTH & FILLING	
	100	5-AH	VESTITAR BASALT (as above)	100	N60W	50NE	1-1/2", Gr		
				73	N65E	50NW	3/4", Gr		
5106.5			Gradational		N30E	40SE	1/2", F		
				65	N8	60W	1/8", F		
5108.8			VESTITAR BASALT (104.5 to 110.0 ft)	100	N75W	55E	1/16", F		
			medium gray; 15% vesicles in top decreasing to 2% in bottom; vesicles range up to 2 in. long oriented 90 deg in top to 40 deg in bottom		N85W	50N	1/16", O		
5101.0			Gradational	100					
			DENSE BASALT (110.0 to 118.2 ft)		N85W	70N	1/16", O		
			light gray; scattered small spheroidal vesicles	100	N35W	80SW	1/8", O		
5095.0		1-TH		86	N70E	70SE	1/4", O		
					N75E	50SE	1/16", Pgt		
5092.8			116.0 to 118.2 ft increase in vesicles to 10 to 15% up to 1 in. long and oriented 30 to 70 deg	94	N45E	60SE	1/4", C		
			SCORIALOUS CLINKERS (118.2 to 122.4 ft) black and brown scoriaeous basalt						
5088.6			VESTITAR BASALT (122.4 to 150.0 ft)	39	N10E	70W	3/4", F		
			dark gray; 25 to 30% spheroidal and elongate vesicles ranging up to 1 in. long (average 1/4 in. orientation of vesicles varies from 0 to 90 deg; many joints are coated with tan waxy clay; basalt is brown in a thin zone parallel to joints above 133.0 ft)	150					
				54					
				38					
				80					
				56	N20W	75SW	1/8", Pgt		
				100	N25E	40NW	1/4", Gr		
							Bottom of Camera Coverage		
				75					
				83					
				100					
				80					
5061.0									

Bottom Depth: 150.0 ft
Bottom Elevation: 5061.0 ft

PROJECT BUGGY									
BORING NO. 67 Buggy No. 11									
LOCATION (NEVADA STATE COORDINATES):									
ANGLE OF BORING: Vertical					TYPE OF BORING: NX - DIAMOND				
BEARING:					DRILLING AGENCY: WBS				
EL TOP OF HOLE: 5194.4 ft MSL					DEPTH TO WATER TABLE: Not encountered				
TOTAL DEPTH: 58.3 ft					HOLE STARTED: 7 December 1967				
TOTAL CORE RECOVERY: 65%					HOLE COMPLETED: 7 December 1967				
EL FT MSL	DEPTH FT	LOG	DESCRIPTION	PERCENT CORE RECOV	MID- PT	STRIKE DEG	DIP DEG	WIDTH & FILLING	
5194.4	0		SOIL (0.0 to 11.4 ft), tan sandy clay with fragments and blocks of vesicular basalt and fragments of tuff.						Interval photographed 9.5 to 55.0 ft.
	5								
	10								
5183.0			Top of Rock	100					
			VESTITAR BASALT (11.4 to 23.8 ft)	72	N75W	70SW	1/8", Pr		
			dark gray; 10 to 15% elongate vesicles, averaging 1/8 in. to 1/2 in. long with few up to 1 in. wide by 2 in. long; orientation of vesicles varies from 70 to 90 deg in top few feet to 90 deg at 15.0 ft; back to 70 to 90 deg below 15.0 ft; many vesicles and joints are lined or filled with calcite.		N50W	70NE	1/4", O, C		
					N35E	40NE	1/4", O, C		
					N55E	30E	1/8", Pr		
					N35W	70SE	1-1/2", F		
					N55E	60SE	1/2", O, C		
					N55W	40SW	1/8", Pr		
					N10E	55SE	2", O, C		
					N40W	40W	1/2", O, C		
					N55W	60SW	1", O, C		
					N75W	40W	1/2", O, C		
5170.6			Gradational	82	N55W	55SW	1/4", O, C		
					N45E	55NW	1-1/2", O, C		
5168.4		2-4H	VESTITAR BASALT (23.8 to 42.2 ft)	85	N45E	60S	1/2", O, C		
			medium gray; 5 to 7% spheroidal vesicles ranging up to 1/2 in. in size and oriented 70 deg at 23.8 ft to 30 deg at 26.0 ft; calcite coating most joints.		N55E	65NW	1/4", O, C		
					N45W	90	1/16", Pr		
					N55W	20SW	2", O, C		
					N60E	50SE	1", O, C		
					N55E	55NW	1/4", O, C		
					N50E	50SE	3/8", O, C		
					N35E	25SE	1/8", O, C		
					N25E	10NW	1", O, C		
					N45E	40NW	1/2", O, C		
					N60E	30W	3/4", O, C		
					N5E	90	1/32", F		
					N25E	55E	1/4", O, C		
					N75E	90	1/2", O, C		
					N45E	65NW	1/2", O, C		
5155.2			39.2 to 42.2 ft, 10 to 15% elongate vesicles ranging up to 1 in. long and oriented 0 to 10 deg; basalt has a brown tint; possibly clinkers in bottom 2 ft.	80	N15E	70SE	1/8", O, C		
					N30E	75NW	1/2", O, C		
					N75E	65SE	1/4", O, C		
5152.2					N25E	70E	1/4", O, C		
5151.1		2-5H	VESTITAR BASALT (42.2 to 58.3 ft)		N45E	70NW	1/4", O, C		
			dark gray; 25 to 30% spheroidal and elongate vesicles.		N35E	80NW	3/8", O		
5149.4		4-1H	42.2 to 45.0 ft, vesicles range from 1/16 in. to 3/8 in. in size (average 1/8 to 1/4 in.)	78	N25E	75SE	1/4", Pr		
					N45E	30SE	1/8", F		
					N75E	72NW	1/8", F		
					N60E	45SE	1/8", O		
					N75E	90	1/16", O		
					N55E	50SE	1/2", O, C		
					N30E	50NW	1/16", O, C		
					N55E	60NW	1/8", O, C		
					N85W	60SW	1", O, C		
					N25E	30NW	3/4", O, C		
					N45E	25W	3/4", O, C		
					N45E	50SE	1/2", O, C		
					N65W	25SW	1/2", O, C		
					N65W	25SW	1/4", O, C		
					N25E	30SE	1/4", O, C		
					N45W	45NW	1/2", F		
					N70W	60NE	2", F		
					N15E	70NW	1/8", O, C		
					N75E	70NW	1/2", Pr		
					N85W	65SW	1/4", Pr		
					N15W	75W	1/8", F		
					N40W	60NE	1/2", F		
					N5E	40SE	1/4", Pr		
					N45W	60SW	1/2", F		
					N45W	60NE	1/2", F		
					N10W	90	1", F		
					N35E	30SE	1/4", F		
					N55E	70NW	1", F		
					N45E	55NW	1/2", F		
					N45E	45SE	1/4", F		
					N70E	55SE	1/2", F		
					N10W	70NE	1/2", F		

Bottom Depth: 58.3 ft
Bottom Elevation: 5136.1 ft

Figure A.15 Log of core Boring 67 Buggy No. 10 (Continued) and 67 Buggy No. 11.

Figure A.16 Log of core Boring 67 Buggy No. 12 and 67 Buggy No. 13.

PROJECT BUGGY									
BORING NO.:	67 Buggy No. 14	PROJECT BUGGY							
LOCATION (NEVADA STATE COORDINATES):	N 882,040.31 E 596,616.99								
NAME OF BORING:	Vertical	TYPE OF BORING:	IN - DIAMOND						
BEARING:		DILLING AGENCY:	VBS						
EL TOP OF HOLE:	5180.6 ft MSL	DEPTH TO WATER TABLE:	Not encountered						
TOTAL DEPTH:	60.7 ft	HOLE STARTED:	11 December 1967						
TOTAL CORE RECOVERY:	41.4	HOLE COMPLETED:	12 December 1967						
EL. FT.	DEPTH FT.	LOG	DESCRIPTION	PERCENT RECOVERED	NO. OF STRINGS	DIAMETER IN.	WATER FILLING	BONE HOLE CAMERA JOINT DATA	
5180.6	0		ROIL (0.0 to 1.0 ft) tan sandy clay with fragments and blocks of vesicular basalt and nodules of tuff.						
5180.6	5		VESICULAR BASALT (4.0 to 14.5 ft) med. gray 10 to 20% spherulitic and elongate vesicles averaging 1/8 in. in diam. oriented 0 to 90 deg; few vesicles are lined with calcite; most joints are filled with sandy calcite. Long oriented 90 deg.	70					
5170.1	15		CLINCHER (15.0 to 21.3 ft) brown and dark gray black saccular and silty and calcite present.						
5165.3	20		VESICULAR BASALT (21.3 to 27.3 ft) dark gray 20 to 25% irregular and elongate vesicles up to 1/2 in. in diam. oriented 0 to 90 deg; few vesicles are lined with calcite.						
5157.3	25		VESICULAR BASALT (27.3 to 33.1 ft) dark gray 20 to 25% irregular and elongate vesicles up to 1/2 in. in diam. oriented 0 to 90 deg; few vesicles are lined with calcite.						
5151.5	35		CLINCHER (33.1 to 39.4 ft) brown and black saccular basalt.						
5146.2	40		VESICULAR BASALT (39.4 to 60.7 ft) dark gray 20 to 25% irregular and elongate vesicles averaging 1/8 in. in diam. oriented 0 to 90 deg; few vesicles are lined with calcite. Most joints are filled with sandy calcite. Long oriented 90 deg.						
5139.9	60								

Bottom Depth: 60.7 ft
Bottom Elevation: 5139.9 ft

PROJECT BUGGY									
BORING NO.:	67 Buggy No. 15	PROJECT BUGGY							
LOCATION (NEVADA STATE COORDINATES):	N821,041.65 E596,560.31								
NAME OF BORING:	Vertical	TYPE OF BORING:	IN - DIAMOND						
BEARING:		DILLING AGENCY:	VBS						
EL TOP OF HOLE:	5209.1 ft MSL	DEPTH TO WATER TABLE:	Not encountered						
TOTAL DEPTH:	100.0 ft	HOLE STARTED:	19 December 1967						
TOTAL CORE RECOVERY:	69.9%	HOLE COMPLETED:	30 December 1967						
EL. FT.	DEPTH FT.	LOG	DESCRIPTION	PERCENT RECOVERED	NO. OF STRINGS	DIAMETER IN.	WATER FILLING	BONE HOLE CAMERA JOINT DATA	
5209.1	0		ROIL (0.0 to 8.0 ft) tan sandy clay with fragments and blocks of vesicular basalt and fragments of tuff.						
5201.1	8		Top of Rock						
5201.1	10		VESICULAR BASALT (8.0 to 12.6 ft) light gray 10% vesicles in thin discontinuous layers spaced 1/4 to 1/2 in. apart; oriented 0 deg.	88					
5197.5	15		CLINCHER BASALT (12.6 to 22.5 ft) light gray 10% vesicles in thin discontinuous layers spaced 1/4 to 1/2 in. apart; oriented 0 deg.						
5187.9	20		CLINCHER BASALT (22.5 to 31.4 ft) light gray 10% vesicles in thin discontinuous layers spaced 1/4 to 1/2 in. apart; oriented 0 deg.						
5186.6	25		CLINCHER BASALT (31.4 to 35.2 ft) light gray 10% vesicles in thin discontinuous layers spaced 1/4 to 1/2 in. apart; oriented 0 deg.						
5183.9	30		CLINCHER BASALT (35.2 to 39.4 ft) light gray 10% vesicles in thin discontinuous layers spaced 1/4 to 1/2 in. apart; oriented 0 deg.						
5179.7	35		CLINCHER BASALT (39.4 to 43.6 ft) light gray 10% vesicles in thin discontinuous layers spaced 1/4 to 1/2 in. apart; oriented 0 deg.						
5168.1	45		CLINCHER BASALT (43.6 to 52.0 ft) light gray 10% vesicles in thin discontinuous layers spaced 1/4 to 1/2 in. apart; oriented 0 deg.						
5157.1	55		CLINCHER BASALT (52.0 to 60.7 ft) light gray 10% vesicles in thin discontinuous layers spaced 1/4 to 1/2 in. apart; oriented 0 deg.						
5146.2	65		CLINCHER BASALT (60.7 to 69.9 ft) light gray 10% vesicles in thin discontinuous layers spaced 1/4 to 1/2 in. apart; oriented 0 deg.						
5139.9	75		CLINCHER BASALT (69.9 to 79.1 ft) light gray 10% vesicles in thin discontinuous layers spaced 1/4 to 1/2 in. apart; oriented 0 deg.						
5128.1	85		CLINCHER BASALT (79.1 to 88.3 ft) light gray 10% vesicles in thin discontinuous layers spaced 1/4 to 1/2 in. apart; oriented 0 deg.						
5124.9	95		CLINCHER BASALT (88.3 to 97.5 ft) light gray 10% vesicles in thin discontinuous layers spaced 1/4 to 1/2 in. apart; oriented 0 deg.						
5121.3	99		CLINCHER BASALT (97.5 to 100.0 ft) light gray 10% vesicles in thin discontinuous layers spaced 1/4 to 1/2 in. apart; oriented 0 deg.						
5115.6	100		CLINCHER BASALT (100.0 to 100.0 ft) light gray 10% vesicles in thin discontinuous layers spaced 1/4 to 1/2 in. apart; oriented 0 deg.						

(continued)

Figure A.17 Log of core Boring 67 Buggy No. 14 and 67 Buggy No. 15.

Figure A.18 Log of core Boring 67 Buggy No. 15 (Continued).

APPENDIX B PETROGRAPHIC REPORT

B.1 SAMPLES

Samples were taken for analysis from Site Selection Boring 66-4 (old No. UE-30A-2) and Boring 67-2. The material from 66-4 consisted of short end pieces from the tops and bottoms of 4-inch-diameter cores from which cylinders for physical tests had been sawed. The material from 67-2 consisted of three segments of NX core, each about an inch long, which had been taken from a 1.7-foot interval that was sectioned for a triaxial compression test. Sample intervals were as follows:

Borehole No.	Depth feet	Length of Core Specimen		
		Top inches	Middle inches	Bottom inches
66-4	208.1 - 209.1	2	--	2
66-4	424.3 - 425.4	2	--	3-1/2
67-2	65.9 - 67.6	1	1	1

B.2 TEST PROCEDURE

The samples were examined visually and with a stereoscopic microscope on freshly broken or sawed surfaces. Thin sections were

taken from 1/4-inch-thick slices cut normal to the core axis and examined with a petrographic microscope. Photomicrographs were taken of the samples from Site Selection Boring 66-4 in order to illustrate pertinent features within the thin sections. The compositions of the glass sample and the feldspars in the two rock samples were determined from oil immersion mounts of crushed material. Samples for X-ray diffraction analysis obtained from those portions of the 1/4-inch-thick slices not used for thin sections were ground to pass a No. 325 sieve and analyzed as packed powders on an X-ray diffractometer. The secondary material that lined and partially filled some vesicles in the leached lower part of the sample from 67.6 feet in Boring 67-2 was scraped from the vesicles and analyzed on the diffractometer.

B.3 RESULTS OF EXAMINATIONS

B.3.1 Sample 4-1 (Boring 66-4, Depth 208.1 to 209.1 feet). The sample was medium-gray (N-5); dense, very fine-grained igneous rock containing occasional pinhead to 1/4-inch-diameter voids. Most voids were empty; a few contained white calcite linings. No phenocrysts were observed with the unaided eye. The bottom piece of core sample contained a steeply dipping joint plane on one side of the core. The top and bottom surfaces were probably old fracture surfaces. They contained dark bluish to brown discolorations, but no deposits or

linings were present. The rock was unweathered and moderately hard; it could be scratched with a dissecting needle.

Thin sections indicated that the groundmass of the rock had a pilotaxitic texture composed of subparallel, usually twinned plagioclase laths and stubby intergranular pyroxene and opaque mineral crystallites. Figure B.1 shows the general appearance of the rock in thin section. The pyroxene was present in various stages of alteration, most being relatively unaltered pale green augite; however, alteration to iron oxide was observed in many pyroxene crystallites, starting at the edges as brown staining and progressing inward until the entire crystallite was an opaque brown.

Most plagioclase laths measured about 300 microns or less in long dimension and about 75 microns in width. Occasional feldspar crystals up to 700 microns long were noted. The pyroxene measured about 50 to 300 microns in "diameter," mostly 50 to 75 microns. Magnetite and other opaque minerals were mostly less than 100 microns. Only a few larger feldspar and pyroxene phenocrysts were present.

Index of refraction determinations indicated that the composition of the plagioclase was andesine and that the unaltered pyroxene was augite. Olivine was not positively identified, and no quartz was detected. X-ray diffraction analysis indicated that the rock was composed primarily of plagioclase feldspar and pyroxene. Based on its composition and texture, this rock was classified as an andesite,

more specifically a pyroxene andesite.

B.3.2 Sample 4-7 (Boring 66-4, Depth 424.3 to 425.4 feet). The core samples were of a banded glassy igneous rock made up of alternating light-gray, dark-gray, and occasionally thin, grayish-orange-pink bands and containing numerous clear feldspar and brown biotite phenocrysts. The phenocrysts ranged in size from less than 1/16 to about 1/4 inch; most were slightly less than 1/8 inch. The banding in the rock dipped at 45 to 60 degrees to the horizontal. The glass itself had a vitreous luster and a perlitic structure. The perlitic structure is shown in Figures B.2 and B.3. The composition and texture of the glass rendered the rock rather soft and brittle. More or less rounded glassy balls could be easily plucked out with a fingernail. The rock was easily fractured by pressing it with a dissecting needle; phenocrysts could be plucked out of the glassy matrix with a needle. The rock also contained several grayish-red to medium-gray basaltic xenoliths measuring 1/2 to 1 inch in diameter. Figure B.4 shows a portion of a typical xenolith in contact with the glassy groundmass of the rock. The bottom piece of core contained a fracture filled with soft, yellow-white material that was identified by X-ray diffraction as very poorly crystalline montmorillonite.

Thin section studies and index of refraction measurements indicated that two feldspars were present as phenocrysts. Clear, unaltered, but usually fractured sanidine crystals up to 2 mm in long

dimension were most abundant. Other feldspar phenocrysts of similar size consisting of clusters of twinned plagioclase crystals (oligoclase) were present in fewer numbers. Occasional biotite, pyroxene, and sphene crystals were also present. Extremely small opaque grains, probably magnetite, mostly less than 5 microns, were present as inclusions in feldspar phenocrysts and in the glass groundmass. The index of refraction of the glass was near 1.50. The silica content of the glass was therefore about 72 percent based on a curve of silica content versus index of refraction for natural glasses.

The composition and texture of the glassy groundmass of the sample together with the presence of sanidine and oligoclase phenocrysts suggest that the lava flow from which this rock solidified was of rhyolitic composition. The rock was classified as porphyritic perlitic rhyolite.

B.3.3 Sample B-3 (Boring 67-2, Depth 65.9 to 67.6 feet). The samples from the top and middle of the core interval were composed of dark-gray, slightly reddish-tinged vesicular igneous rock. The vesicles were empty and had roughly elliptical shapes; some were fairly elongated and measured from about 1/16 to slightly over 1/2 inch, averaging about 1/4 inch along the major axes. The walls of most vesicles were dark-reddish-tinged, probably due to oxidation. The upper surface of the core section from the top of the interval was bounded by a joint or fracture plane, the surface of which was partially

coated with a white powdery material composed of a mixture of amorphous silica and clay.

The sample from the bottom of the core interval was similar to the two upper samples except that a portion of the core was leached to a brownish-gray color. Some vesicles in this leached zone were lined or filled with yellowish-white to light-brownish-gray silty and clayey material. The bottom surface of the core segment was a fracture or joint plane making about a 45-degree angle with the axis of the core. The vesicles and the surface itself were coated with yellowish and blue-white clay and amorphous silica. The leached zone in the bottom core segment was about 1/2 inch wide and was roughly parallel to the fracture plane just described. It graded abruptly into dark-gray unweathered rock like that in the upper samples. The secondary material coating the fracture surface and lining and filling the vesicles in the leached zone was deposited by water moving along the fracture. The leaching was undoubtedly also produced by water passing along the fracture plane.

Thin sections of all three samples were quite similar and showed that the rock was a partly glassy, vesicular igneous rock composed of tiny lath-shaped plagioclase feldspar crystallites, pyroxene, and olivine crystals with or without typical crystal outlines, together with occasional larger plagioclase and pyroxene phenocrysts and opaque minerals. The interstices between the crystals were filled with

dark-brown glass. The textural term for a rock such as this is hyalophitic to intersertal. The small plagioclase laths ranged between 80 and 350 microns in length and 30 to 50 microns in width, averaging about 100 to 200 by 30 to 40 microns. Some of the large laths were larger than 1,500 by 300 microns. Occasional large, stubby feldspar phenocrysts measured about 1,700 microns. Most of these larger feldspar crystals were highly corroded, and zoning was not uncommon. Optical measurements indicated that the smaller feldspar crystals were in the labradorite range. The iron-rich minerals, composed mostly of pyroxene (augite), generally measured from 50 to 100 microns in maximum dimension; most grains were more or less equant. A few pyroxene crystals were more than 200 microns, and one large phenocryst about 1,500 by 400 microns was noted in one thin section.

X-ray diffraction examination indicated that all three core sections had similar mineralogical compositions, principally plagioclase feldspar and a pyroxene mineral. The presence of minor amounts of olivine was suspected, but could not be confirmed by X-ray diffraction alone because of interference from plagioclase lines. A trace of mica was detected in the top core, and a small amount of poorly crystalline montmorillonitic clay was present in the sample from the bottom of the interval. The unusually high backgrounds of all three samples indicated the presence of iron minerals or natural glass, or both.

The only difference between the X-ray pattern of the bottom sample containing the leached rock and the two upper samples was the presence of montmorillonitic clay. A sample of the material lining and filling the vesicles in the leached zone was examined and found to be composed of very poorly crystalline montmorillonitic clay, a minor amount of degraded clay of kaolinite group, and probably amorphous silica. However, the leached part of the core represented a very minor part when the total interval is considered, and the secondary deposits in the vesicles constituted only a very minor part of the leached zone. Thus, the leached zone and the associated secondary minerals should not affect the physical properties of the rock as a whole.

The rock was classified as a vesicular basalt based on its mineralogical composition and texture. With the exception of the thin zone in the sample from the lowest depth bordering the fracture plane, the rock was essentially unaffected by weathering.

Plane light, X20, thin section parallel to axis of core. Note the slight lineation of the lath-shaped plagioclase crystals diagonally downward from right to left. The dark-gray and black irregularly shaped splotches are altered pyroxene and ore minerals.

Figure B.1 Boring 66-4, 208.1-209.1 feet (dense basalt).

Thin section, plane light, X20. The photomicrograph illustrates the perlitic cracking in the glassy matrix of the rock. The rounded white areas are holes from which the perlitic glass has been removed during preparation of the thin section. Feldspar phenocrysts not readily distinguishable from the glass in the above photomicrograph are more clearly seen in Figure B.3.

Figure B.2 Boring 66-4, 424.3-425.4 feet (vitrophyre).

Thin section, cross polarized light, X20. Same field as previous photomicrograph, illustrating the amorphous character of the glassy matrix. The distribution of the phenocrysts is more readily observable than in Figure B.2.

Figure B.3 Boring 66-4, 424.3-425.4 feet (vitrophyre).

Thin section, plane light, X20. Photomicrograph shows portion of basalt xenolith in rhyolitic glass host rock. The shrinkage crack running diagonally across the photomicrograph along the contact was a characteristic feature of the xenolith-host rock contacts. The large dark phenocryst in the lower left portion of the photomicrograph is biotite.

Figure B.4 Boring 66-4, 424.3-425.4 feet (vitrophyre).

APPENDIX C
DESCRIPTIONS OF PHYSICAL TESTS

C.1 BULK DRY SPECIFIC GRAVITY

Bulk dry specific gravity (G_o) calculations were made on a basis of oven-dry weight divided by weight of equivalent volume of water as follows:

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

where

W_o = weight of oven-dried sample

V_o = volume of cored material

γ_w = unit weight of water

The volume was calculated from averages of nine length measurements and nine diameter measurements (at top, middle, and bottom of core). The unit weight of water was taken as that at the temperature of the test specimen.

C.2 SPECIFIC GRAVITY OF SOLIDS

Specific gravity of solids (G_s) was calculated from the formula:

$$G_s = \frac{W_{sa}}{W_{sa} - W_{sw}}$$

where

W_{sa} = weight of dry crushed material in air

W_{sw} = weight of crushed material in distilled water (entrapped air was removed from submerged material by agitation under vacuum pressure)

C.3 STATIC UNCONFINED COMPRESSIVE STRENGTH

Static unconfined compression tests were conducted according to procedures given in CRD-C 19 of Reference 13. Samples were prepared as follows: core lengths were sawed so that the length-diameter ratio was approximately 2.0; sawed ends of the dense basalt were prepared by surface grinding; and surface voids in the vesicular basalts were filled with hydrostone filler so that the strain gages would have a 100 percent contact with the rock. A uniform loading rate of 50 psi/sec was applied to all specimens. Circumferential and axial strain measurements were made by means of diametrically opposed pairs of SR-4 electrical strain gages bonded to the specimen.

C.4 TENSILE SPLITTING TESTS

Tensile splitting tests were conducted according to the procedures given in CRD-C 77 of Reference 13. Core lengths were sawed so that the length-diameter ratio was between 1.0 and 2.0, preferably the latter.

C.5 SLIDING FRICTION TESTS

Shear strength under increasing normal stresses was measured on

presawed surfaces cut normal to the core axes. A sketch of the test apparatus is given in Figure C.1. The core sections were sealed with hydrostone into metal test blocks in which circular bores slightly larger than the core diameter had been cut. (The method of loading indicated by the sketch most likely imparted a turning moment so that higher normal stresses were put on the side of the sliding surface away from the shearing load.) Normal stress was applied by a hydraulic ram oriented parallel to the base of the machine. Shear movement was measured by a 0.0001-inch dial gage mounted between the loading head and the base of the apparatus.

C.6 TRIAXIAL COMPRESSION TEST

Triaxial compression tests were conducted according to the procedures given in CRD-C 93 of Reference 13. Sections of core were cut so that the length-diameter ratio was approximately 2.0. Two diametrically opposed circumferential and two axial SR-4 electrical strain gages were cemented to the specimens. Specimen ends were machine-ground and hand-lapped with No. 420 grid abrasive. A thin latex membrane was placed over the specimen and gages prior to application of hydraulic confining pressure. After confining pressure was applied to the specimens, the axial load was applied at a uniform rate of 50 psi/sec until failure occurred. The deviator stresses and strains were recorded and plotted graphically.

Figure C.1 Sketch of sliding shear strength test rig.

REFERENCES

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