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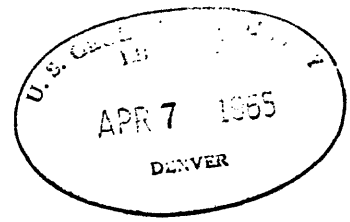
UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY



INTERIM GEOLOGICAL INVESTIGATIONS IN THE U12e.04 TUNNEL, NEVADA TEST SITE, NYE COUNTY, NEVADA*

By

W. L. Emerick, D. D. Dickey, and F. A. McKeown

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This report is preliminary and
has not been edited for conformity
with Geological Survey format.

*Prepared on behalf of the U.S. Atomic Energy Commission.

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INTERIM GEOLOGICAL INVESTIGATIONS IN THE U12e.04 TUNNEL, NEVADA TEST SITE, NYE COUNTY, NEVADA

By W. L. Emerick, D. D. Dickey, and F. A. McKeown

ABSTRACT

The U12e.04 tunnel is a part of the U12e tunnel system, which has been driven southwestward beneath Rainier Mesa in the northern part of the Nevada Test Site. The U12e.04 tunnel was driven about S. 15° W. in zeolitic tuff of subunits E and F of Tunnel Bed 4 near the top of the lower member of the Indian Trail Formation (upper Miocene or lower Pliocene). Dolomite of Paleozoic age lies about 915 feet below the end of the tunnel; vertical cover over the end of the tunnel to the surface of Rainier Mesa is about 1,390 feet.

The tuffs in the tunnel strike almost north-south and dip to the west. There are several normal northwest-trending faults with vertical to steep dips and small displacements. The predominant joint set strikes northwest and dips mostly vertically or steeply to the northeast.

Petrographically and chemically the tuffs in the U12e.04 tunnel are similar to other tuffs of the Indian Trail Formation from the Nevada Test Site.

The tuffs in the tunnel have an average porosity of 38.6 percent, dry bulk density of 1.46 g/cc (grams per cubic centimeter),

grain density of 2.38 g/cc, water content of 20.7 percent by weight, Shore hardness of 25.1, and unconfined compressive strength of 4,400 psi (pounds per square inch). Separately, the tuffs from the chamber at the end of the tunnel have an average porosity of 36.8 percent, dry bulk density of 1.51 g/cc, grain density of 2.38 g/cc, water content of 20.0 percent by weight, Shore hardness of 27.2, and unconfined compressive strength of 4,500 psi.

An NX-size cored hole was drilled from the surface of Rainier Mesa into the U12e.04 chamber.

INTRODUCTION

The U12e.04 tunnel is a part of the U12e tunnel system, which has been driven southwestward in the tunnel area beneath Rainier Mesa, a prominent topographic feature within the Whiterock Spring quadrangle in the northern part of the Nevada Test Site (figs. 1 and 2). The geologic studies in the U12e.04 tunnel were conducted by the U.S. Geological Survey on behalf of the U.S. Atomic Energy Commission, for the purpose of determining the structure and chemical and physical properties of the tuffs exposed in the tunnel.

The U12e.04 tunnel trends S. 15° W. from station 35+23 in the U12e main tunnel. The U12e.04 tunnel branches at station 6+90 to form the line of sight tunnel which strikes S. 15° W. parallel to the personnel tunnel, 70 feet to the east. The chamber at the end of the line of sight tunnel is 1,754 feet from the U12e main tunnel. Cross sections of the tunnel range from 11X12 feet to 16X16 feet. The tunnels are supported by steel sets spaced at intervals ranging from 4 to 6 feet and are lagged with heavy planking between the steel sets.

GEOLOGY

General

The U12e.04 tunnel was driven in zeolitic bedded tuffs in the upper part of Tunnel Bed 4 of the lower member of the Indian Trail Formation (upper Miocene or lower Pliocene). Tunnel Bed 4 is the youngest of the four that make up the lower member. Tunnel Beds

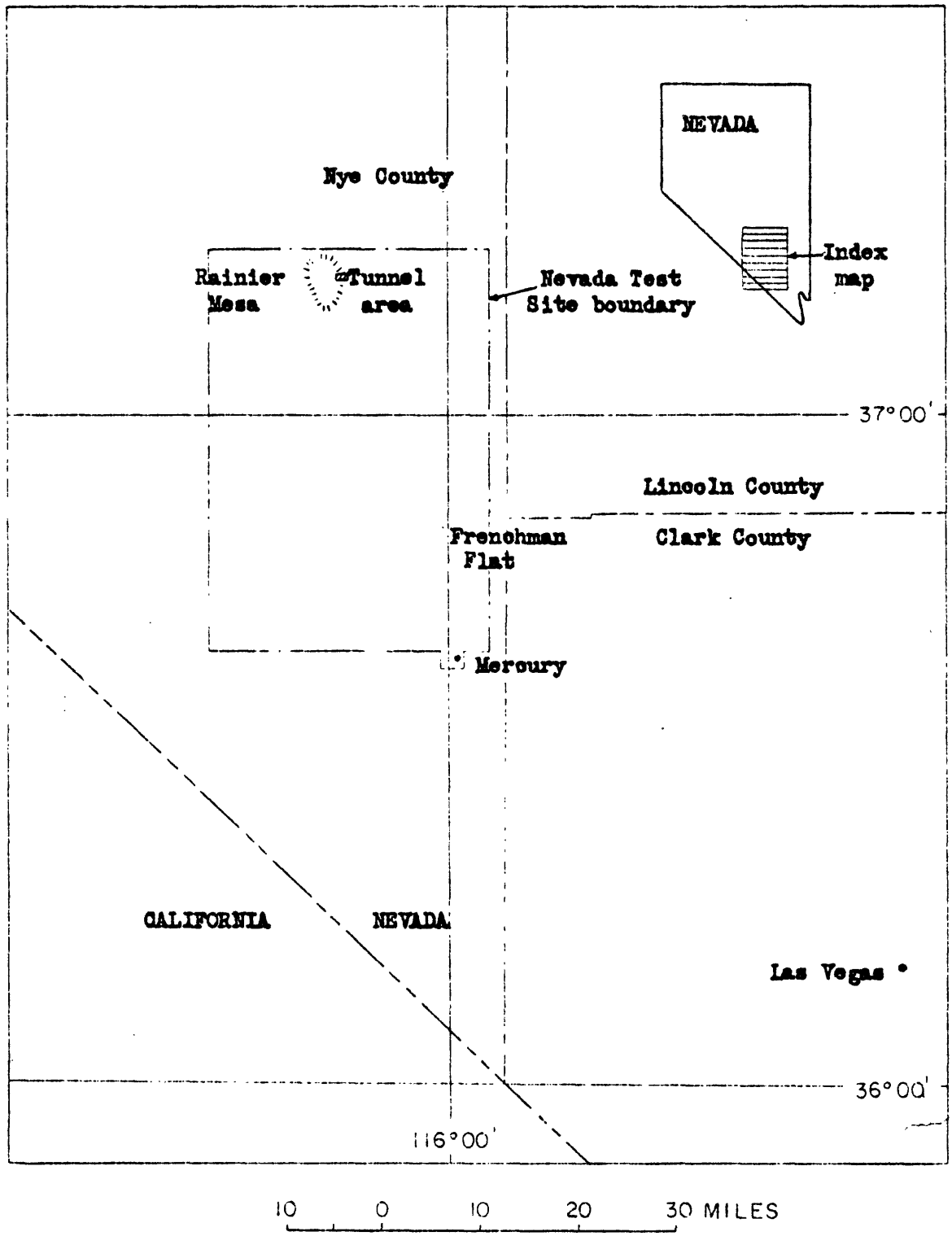

Figure 1.--Index map showing the tunnel area, Nevada Test Site, Nye County, Nevada

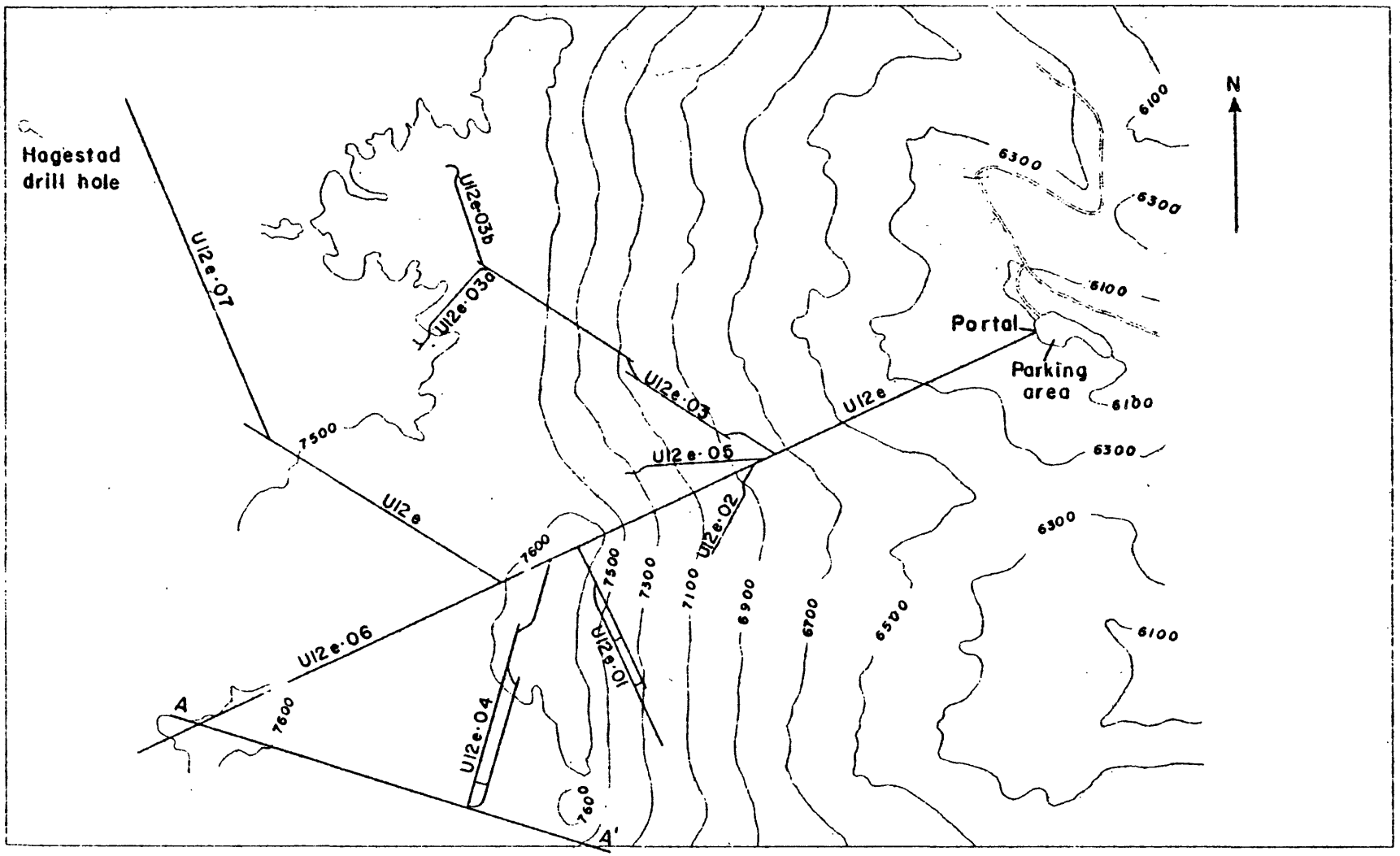

Figure 2.—Index map showing the U12e tunnel system and location of section A-A', Rainier Mesa, Nevada Test Site, Nye County, Nevada

Contour interval 200 feet, except 7600-foot contour also shown
Datum is mean sea level

1 through 4 as described by Hinrichs and Orkild (1961) are equivalent to map units Tos 1 through Tos 4 of Hansen and Lemke (1959) and Tr 1 through Tr 4 of McKeown and Dickey (1961). Mappable subunits of Tunnel Bed 4 are designated by capital letters following the unit designation. In the U12e.04 tunnel two subunits, E and F, are present.

The lower member in the U12e.04 tunnel area rests upon an erosional surface of dolomite of middle(?) Paleozoic age (fig. 3). The contact of the Paleozoic dolomite, as projected from cross sections, is about 915 feet below the U12e.04 chamber. Minimum cover above the chamber to the surface of Rainier Mesa is about 1,390 feet vertically.

The tuffaceous rocks in the U12e.04 tunnel trend north and throughout most of the tunnel dip from 4° to 12° W. In the chamber the beds trend northeast and dip 5° NW. The relatively simple structure is modified slightly by several northwest-trending normal faults of small displacement that cut through the tunnel.

Joints are common. In the tunnel, 81 percent of the joints trend northwest and 19 percent northeast. The northwest-trending joints are dominantly vertical or dip more than 60° to the northeast. The northeast-trending joints are vertical or dip either northwest or southeast at angles greater than 60°.

Rocks

The U12e.04 tunnel was driven in subunits E and F of Tunnel Bed 4 of the lower member of the Indian Trail Formation (fig. 4). The two mappable subunits are near the top of Tunnel Bed 4. They are

overlain by subunits G and H that are exposed elsewhere in the U12e tunnel system and that would be directly affected by an explosion.

Subunit E is a thick to very thick bedded, red to light-gray tuff with common coarse to lapilli altered pumice. In places it is mottled and crudely banded with red (McKeown and Dickey, 1961). All of subunit E is not exposed in this tunnel but as measured in the U12e main tunnel it is about 30 feet thick.

No samples from which mineralogy studies could be made were taken of this subunit in the U12e.04 tunnel, but the average physical properties of the subunit were obtained by F. M. Byers (1961, table 10) from a composite of eight samples taken at an earlier date in the U12e main tunnel. The average physical properties are: porosity 31.4 percent, water content 16.8 percent by weight, grain density 2.38 g/cc, and natural state bulk density 1.96 g/cc.

Subunit F is a fine to coarse, thin- to thick-bedded, white pumiceous tuff containing common red and a few white to gray porcelaneous layers. Coarse lithic fragments are conspicuous in the lower part, but in most of the tuff fine to coarse lithic fragments make up from 5 to 10 percent of the rock. A bright orange-red fine tuff bed about 2 feet thick occurs near the middle of the subunit. The subunit is incompletely exposed in the tunnel but averages about 30 feet elsewhere in the tunnel system (McKeown and Dickey, 1961).

Samples of the tuff from the subunit F were analyzed by microscopic and X-ray methods. Location of samples are shown on figure 4. The mineral constituents of the tuff were determined from examination

under a binocular microscope of slab specimens that had been etched with hydrofluoric acid and stained with cobaltinitrite. Modal analyses of tuff were made by a point-count method (table 1).

The tuff of subunit F consists of fine to lapilli pumice, sparse phenocrysts, and lithic fragments in a very fine grained zeolitized matrix. Pumice makes up from less than 1 percent to as much as 50 percent by volume of the tuff. Phenocrysts are uncommon and average 2.7 percent by volume of the rock. In order of abundance the phenocrysts are anhedral to subhedral crystals of potassium feldspar, plagioclase, quartz, and magnetite. Lithic fragments are black, fine to coarse, and are dominantly of volcanic rock. The matrix, which includes the fine and lapilli pumice, forms as much as 96.4 percent of the tuff and by X-ray analyses is shown to consist predominantly of a zeolite[1/] with trace amounts of beta-cristobalite and quartz (table 1). Hematite accounts for the red color imparted to the matrix in places. The zeolite and beta-cristobalite are alteration products of an original pumiceous material.

Chemical analyses of samples from subunit F are given in table 2, and semiquantitative spectrographic analyses in table 3. The chamber

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1/ The zeolite corresponds in X-ray pattern to heulandite but is stable above 260°C. Recent work of Shepard (1961) has shown that this thermal stability indicates that the mineral may be clinoptilolite or a heulandite-like mineral. Special heat treatment is necessary to differentiate heulandite from the heulandite-like mineral.

Table 1.--Modal analyses (in percent) of tuff from U12e.04 tunnel, Nevada Test Site

Modal analyses by W. L. Emerick; X-ray analyses by Theodore Botinelly.

Locations of samples are shown on figure 4.

Sample number codes: E, tunnel system; 4, tunnel number; 1754, footage from tunnel entrance, referred to Holmes and Narver, Inc. survey; R, right wall of tunnel; L, left wall of tunnel; F, face of tunnel; and subnumeral 1 indicates one of two samples taken from approximately the same location but at different heights above track level.

Sample Nos	E4-1754F$_1$	E4-1738R$_1$	E4-1738L$_1$	E4-1723R	E4-1723L	E4-1712R	E4-1713L	E4-1697R	Mean
Matrix 1/:									
Vesicles	1.7	3.5	2.4	1.4	13.5	12.8	4.4	4.4	5.5
Total matrix	95.5	96.4	97.1	95.9	91.7	94.1	93.8	93.5	94.7
Lithic fragments (dominantly volcanic)	0.3	0.8	1.3	1.8	4.5	3.7	3.9	4.7	2.6
Phenocrysts:									
Potassium feldspar	2.8	1.9	0.3	.0	2.0	.0	1.4	0.9	1.2
Plagioclase	0.8	0.3	1.0	1.8	0.8	0.7	.0	.0	0.7
Quartz	0.3	0.3	0.3	0.5	.0	1.5	0.9	0.9	0.6
Magnetite	<0.3	<0.3	.0	.0	< 1.0	.0	.0	.0	< 0.2
Biotite	.0	.0	.0	.0	.0	.0	.0	.0	.0
Other mafics	.0	.0	.0	.0	.0	.0	.0	.0	.0
Total	4.2	2.8	1.6	2.3	3.8	2.2	2.3	1.8	2.7
Grand total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Area measured (mm^2)	1,000	1,000	1,050	638	1,120	770	1,021	1,200	975
Zeolite	Predominant	Predominant	Predominant	Predominant	Predominant	Predominant	Predominant	Predominant	
Beta-cristobalite 2/	Trace	Trace	Trace	Trace	Trace	Trace	Trace	Trace	
Quartz 2/	Trace	Trace	Trace	Trace	Trace	Trace	Trace	Trace	

1/ The matrix includes the pumice.

2/ The amounts of zeolite, beta-cristobalite, and quartz are estimated on the intensity of the X-ray diffractometer pattern of these three minerals present in the matrix and are at best only rough approximations; predominant, 75 to 100 percent and trace, <10 percent.

Table 2.--Chemical analyses of tuff from U12e.04 tunnel, Nevada Test Site

[Analysts: P. L. D. Elmore, I. H. Barlow, and S. D. Botts. All samples taken are from subunit F. Sample number codes: E, tunnel system; 4, tunnel number; 966, footage; R, right wall of tunnel; C, chamber; a, b, and c, separate samples from the same location in tunnel]

Sample No--	E4-966Ra	E4-966Rb	E4-1673Ca	E4-1673Cb	E4-1673Cc
Laboratory No-------	154645	154646	154642	154643	154644
SiO_2	70.10	69.90	67.20	69.30	69.60
Al_2O_3	11.5	11.7	13.4	12.2	12.1
Fe_2O_3	1.2	1.2	1.2	1.0	1.1
FeO	<.1	<.1	<.1	<.1	<.1
MgO	.08	.10	.21	.10	.09
CaO	.70	.75	.70	.69	.56
Na_2O	3.4	3.3	3.3	3.4	3.4
K_2O	3.3	3.5	4.8	3.8	3.8
H_2O	9.2	8.7	8.9	9.0	8.9
TiO_2	.10	.12	.11	.09	.10
P_2O_5	.00	.00	.00	.00	.00
MnO	.01	.02	.01	.02	.03
CO_2	<.05	<.05	<.05	<.05	<.05
Sum---	100	99	100	100	100

Table 3.--Semiquantitative spectrographic analyses of tuff from U12e.04 tunnel, Nevada Test Site

Analyst: J. C. Hamilton, USGS.

All samples taken from subunit F. Sample number codes: E, tunnel system; 4, tunnel number; 996, footage; R, right wall of tunnel; C, chamber; a, b, and c, separate samples from the same location in tunnel.

0, looked for but not found. Looked for but not found: Ag, As, Au, B, Bi, Ce, Cd, Co, Dy, Er, Eu, Gd, Ge, Hf, Hg, Ho, In, Ir, Li, Lu, Nd, Ni, Os, Pd, Pr, Pt, Re, Rh, Ru, Sb, Sc, Sm, Sn, Ta, Tb, Te, Th, Tl, Tm, U, W, Zn.

Figures are reported to the nearest number in the series 7, 3, 1.5, 0.7, 0.3, 0.15, etc., in percent. These numbers represent midpoints of group data on a geometric scale. Comparisons of this type of semiquantitative result with data obtained by quantitative methods, either chemical or spectrographic, show that 60 percent of the quantitative values fall within the assigned semiquantitative groups.

Sample No--	E4-966Ra	E4-966Rb	E4-1673Ca	E4-1673Cb	E4-1673Cc	Standard spectrographic sensitivity
Laboratory No-------	273056	273057	273053	273054	273055	
Ba	0.015	0.03	0.015	0.007	0.007	0.0002
Be	.0003	.0003	.0003	.0003	.0003	.0001
Cr	.00015	.0003	.0003	0	.0007	.0001
Cu	.0003	.0003	.0007	.003	.00015	.0001
Ga	.0015	.0015	.0015	.0007	.0015	.0002
La	.003	.003	.003	0	.003	.002
Nb	.0015	.0015	.0015	.0015	.0015	.001
Pb	.0015	.0015	.003	.0015	.0015	.001
Sr	.003	.007	.007	.003	.003	.0002
Y	.0015	.0015	.0015	.003	.0015	.001
Yb	.00015	.00015	.00015	.0003	.00015	.0005
Zr	.007	.007	.007	.007	.007	.001

at the end of the line of sight tunnel (fig. 4) was extended about 65 feet southwest after the completion of the sampling represented by tables 2 and 3. Chemical and semiquantitative spectrographic analyses on eight additional samples taken in the chamber extension were not made, inasmuch as the results given in tables 2 and 3 are representative of the beds sampled in the chamber extension.

Although subunit G is not exposed in the U12e.04 tunnel it is described here because it occurs just above the chamber and certainly will be affected by an explosion of any size. The description is based on exposures in the U12e main tunnel and in the U12e.06 tunnel (Emerick, 1962).

Subunit G is a pumiceous, mottled and banded red and white, generally coarse, and commonly lapilli tuff. Bedding is indistinct, irregular, and possibly contorted. Lithic fragments make up 1 to 10 percent of the rock and a few angular cobbles of welded tuff were observed in a red bed about 1 foot thick and about 20 feet above the base of the unit.

PHYSICAL PROPERTIES

Measurements including porosity, dry bulk density, grain density, water content, hardness, and unconfined compressive strength were made on 13 of 28 samples from subunit F, and everything but water content determinations on the remaining 15 samples.

The laboratory procedure used to determine the porosity, bulk density, grain density, and water content is the same as given in previous reports (for example, Diment and others, 1959, p. 51-53). The results of these laboratory tests are given in table 4.

Hardness of the tuffs of subunit F was tested using a Shore scleroscope. In this test the height of rebound of the scleroscope points from the rock surface is read in terms of arbitrary units on a scale of 140 divisions, with the value of 100 divisions representing the rebound from hardened, pure-carbon steel (Wuerker, 1956). Results of these hardness tests on samples from subunit F are given in table 4.

Unconfined compressive strengths of the 28 samples from subunit F were made on plugs (1 inch long by 1 inch in diameter) from the rock samples. The plugs were inserted under a hydraulic jack equipped with a pressure gage. The point at which the rock fails under pressure was recorded to the nearest 500 pounds; this was recalculated to pounds per square inch for the 1-inch diameter plug tested. Results of these tests on the 28 samples are given in table 4.

An NX-size cored hole was drilled from the surface of Rainier Mesa into the U12e.04 chamber. The lithologic log of this hole is given here. Physical properties obtained on the core from this hole are given in table 5.

Table 4.--Physical properties of tuff from U12e.04 tunnel, Nevada Test Site

Analyses of porosity, dry bulk density, grain density, and water content by C. H. Roach, G. R. Johnson, and J. G. McGrath, USGS. Determination of hardness and unconfined compressive strengths by J. C. Thomas, USGS.

Each hardness value is an average of 50 readings. All samples are from subunit F.

Sample number codes: E, tunnel system; 4, tunnel number; 1668, footage; R, right wall of tunnel; L, left wall of tunnel; X, crosscut; F, face of tunnel; and 1 and 2 subnumerals indicate samples from the same location in tunnel.

Sample No.	Porosity (P) (percent)	Dry bulk density (Dbd) (g/cc)	Grain density (Dg) (g/cc)	Water content (percent by weight)	Hardness (Shore scleroscope)	Unconfined compressive strength (psi)
E4-500R	39.4	1.45	2.39	----------	25.2	3,950
E4-600R	41.9	1.43	2.46	----------	11.9	1,300
E4-700R	35.7	1.55	2.41	----------	34.7	3,950
E4-800R	34.5	1.57	2.40	----------	31.1	6,600
E4-900R	42.9	1.35	2.37	----------	7.0	3,950
E4-989R	40.7	1.42	2.40	----------	16.2	2,650
E4-1150R	33.9	1.58	2.39	----------	34.8	5,250
E4-1268R	38.3	1.46	2.37	----------	23.0	6,600
E4-1350L	47.8	1.24	2.37	----------	17.8	1,300
E4-1450L	47.6	1.24	2.38	----------	16.2	2,650
E4-1550R	44.4	1.31	2.36	----------	22.5	3,950
E4-1648R	30.8	1.61	2.32	16.5	40.3	6,600
E4-1650R	28.4	1.69	2.36	----------	42.4	9,200
E4-1060X	41.6	1.36	2.32	22.4	21.7	3,950
E4-1668R_1 1/	39.4	1.41	2.33	21.2	13.1	5,250
E4-1668R_2 2/	41.6	1.38	2.37	24.6	17.2	No core

Table 4.--Physical properties of tuff from U12e.04 tunnel, Nevada Test Site--Continued

Sample No.	Porosity (P) (percent)	Dry Bulk density (Dbd) (g/cc)	Grain density (Dg) (g/cc)	Water content (percent by weight)	Hardness (Shore scleroscope)	Unconfined compressive strength (psi)
E4-1678R	38.8	1.45	2.37	21.0	25.1	3,950
E4-1697R	45.2	1.31	2.38	24.8	20.2	2,650
E4-1712R 3/	30.8	1.69	2.41	17.3	29.7	5,250
E4-1713L 3/	40.8	1.39	2.34	23.1	28.0	5,250
E4-1723R 3/	35.5	1.54	2.39	18.5	29.0	6,600
E4-1723L 3/	41.3	1.39	2.37	22.7	18.7	2,650
E4-1738R_1 3/	35.6	1.53	2.37	18.5	32.7	5,250
E4-1738R_2 3/	36.5	1.52	2.40	----------	27.5	3,950
E4-1738L_1 3/	35.7	1.52	2.37	18.9	27.9	2,650
E4-1738L_2 3/	39.6	1.46	2.42	----------	18.6	2,650
E4-1754F_1 3/	37.2	1.50	2.38	19.3	25.8	2,650
E4-1754F_2 3/	35.4	1.55	2.39	----------	34.1	7,900
Average----	38.6	1.46	2.38	20.7	25.1	4,400
Chamber average--	36.8	1.51	2.38	20.0	27.2	4,500

1/ Sample from porcellaneous layer in tuff.
2/ Sample from softer tuff enclosing porcellaneous layer.
3/ Sample from chamber at end of tunnel.

Table 5.--Physical properties of tuff from drill hole U12e.04-1, Nevada Test Site

Nevada State coordinates: N. 884,668.47, E. 634,015.72.

[Analysis of porosity, grain density, and dry bulk density by D. R. Cunningham and John Moreland. Constants from static tests obtained by T. C. Nichols and R. A. Speirer.

All samples are from Tunnel Bed 4 of lower member of Indian Trail Formation. Sample number represents depth in feet from collar of hole]

Sample No.	Porosity (percent)	Grain density (g/cc)	Dry bulk density (g/cc)	Secant Young's modulus E (psi X 10^5)	Secant range (psi)	Poisson's ratio	Shore hardness	Unconfined compressive strength (psi) 1/
1167	34.5	2.33	1.52	7.73	600-3600	0.13	21	4,700
1185	35.1	2.43	1.57	8.33	600-1200	.23	21	3,200
1203	38.4	2.47	1.52	8.13	600-2900	.57	20	3,500
1226	34.3	2.43	1.60	5.31	300-2100	.25	40	8,300
1271	43.4	2.41	1.36	4.83	600-2700	.34	22	4,600
1237	40.9	2.49	1.47	6.45	600-3200	.45	16	3,800
1305	36.5	2.39	1.52	5.41	600-2400	.26	21	3,600
1363	37.7	2.46	1.53	8.33	1200-3500	.18	22	5,500
1399	42.3	2.38	1.37	5.51	600-3400	.09	25	7,300

1/ All elastic constants were determined on cores oven dried 105°C at least 8 hours. All strain measurements were made on 1st cycle.

LITHOLOGIC LOG OF U12e.04 VERTICAL DRILL HOLE 32

Logged by D. D. Dickey and F. N. Houser

June 28, 1961

Nevada State coordinates: N. 884,668.47, E. 634,015.72.

Ground elevation: 7,559.7 feet.

Total depth (driller's record): 1,400 feet.

Description	Thickness (feet)	Depth at bottom of unit (feet)
Piapi Canyon Formation:		
Survey Butte Member (incomplete):		
None cored----------	600	600
Tuff, sandy, and tuffaceous sandstone; light brown to dark brownish gray when wet, fine to coarse, fair sorting; about 5 percent dark lithic fragments; some white pumice. Poorly consolidated to friable. Less than 40 feet of badly broken core recovered----	50	650
Tuff, white, coarse with about 10 percent dark minerals; fairly well sorted; poorly consolidated. About 13 feet of core recovered----------	15	665
Sandstone, tuffaceous, brown, very fine grained; poorly consolidated. About 3 feet of badly broken core recovered-------	15	680
Tuff, sandy, brown, fine to very fine with some coarse tuff; coarse to lapilli white altered pumice. About 55 feet of good to fair core recovered----------	55	735
Tuff, gray to light-brown, lapilli to fine. About 35 feet of core recovered----------	35	770

Description	Thickness (feet)	Depth at bottom of unit (feet)
Piapi Canyon Formation--Continued		
Survey Butte Member (incomplete)--Continued		
Tuff, brown, fine to coarse; contains white altered pumice----------	2	772
Tuff, fine to lapilli, gray; contains white altered pumice. About 25 feet of core recovered----------	28	800
Tuff, brown, fine to coarse with abundant white altered coarse to lapilli pumice-----	10	810
Tuff, white, fine; about 2 percent fine dark lithic fragments. Much tubular structure in abundant white chalky, lapilli pumice---	2	812
Tuff, white, coarse; about 20 percent coarse phenocrysts, less than 2 percent dark lithic fragments. Core recovery poor------	7	819
Tuff, light-brown, coarse; about 5 percent dark lithic fragments, abundant at 820 and 821.5 feet; 10 to 20 percent coarse pumice----------	9	828
Tuff, white, coarse; 10 percent coarse crystals, 10 to 15 percent coarse to lapilli pumice--	1	829
Tuff, like interval 819-828----------	3	832
Tuff, white, coarse to lapilli; 60 percent pumice, 10 percent dark lithic and dark-gray obsidian fragments, some mica, moderately well laminated----------	3	835
Tuff, white, coarse to lapilli (lower one half); contains gray glass----------	2	837

Description	Thickness (feet)	Depth at bottom of unit (feet)
Piapi Canyon Formation--Continued		
Survey Butte Member (incomplete)--Continued		
Tuff like interval 819-828----------	8	845
Tuff, white to gray and light-brown, upper foot very light gray, fine to coarse but mostly fine; gritty; 5 percent dark lithic fragments----------	4	849
Tuff, dark-brown, fine to coarse, pumiceous; <20 percent crystals, <2 percent dark lithic fragments, and <20 percent pumice; 0.4-foot opalized interval at 864 feet------	15	864
Tuff, light-gray, coarse, hard; 20 percent crystals, 10 to 15 percent dark lithic fragments----------	1	865
Tuff like interval 849-864----------	3	868
Tuff like interval 864-865----------	1	869
Tuff like interval 849-864----------	7.3	876.3
Tuff, light-gray, lapilli to coarse; 5 to 10 percent lithic fragments; moderately well laminated----------	0.2	876.5
Tuff like interval 849-864, except coarse to lapilli at interval 878-881----------	4.5	881
Tuff, white to light-gray, fine to coarse, thick- and thin-bedded; top contact gradational; 0.2-foot brown opalized layer at base----------	10	891
Tuff, brown-gray, pumiceous, fine, structureless; opalized tuff at 893 feet----------	3	894

Description	Thickness (feet)	Depth at bottom of unit (feet)
Piapi Canyon Formation--Continued		
Survey Butte Member (incomplete)--Continued		
Tuff, light-brown, fine to coarse, well-bedded and laminated, dips 10°; coarse lithic tuff layer 0.3 to 0.5 foot thick at base---------	14	908
Tuff, light-gray, coarse, pumice (75 percent), structureless----------	10	918
Tuff, very light gray to white, fine to coarse; bottom contact moderately sharp----------	4	922
Tuff, brown-gray and light red-brown, fine to coarse; contains some opal nodules; bottom contact gradational----------	6.5	928.5
Tuff, chalk-white, fine to coarse; contains fine to coarse black lithic fragments; well-bedded 0.05- to 0.5-foot beds; bottom contact sharp but irregular through minimum of 0.15 foot stratigraphically----------	2	930.5
Tuff, light-gray to medium-gray, coarse with white lapilli pumice and prominent fine to coarse biotite; lower contact is gradational, 0.2-foot thick white coarse tuff layer at 931 feet----------	4	934.5
Tuff, white, coarse, pumiceous, well bedded; contains abundant lithics; upper contact gradational; possible base of subunit Z(?) of U12b tunnel system at 940.5 feet---------	6	940.5
Tuff, red-brown, fine to coarse; bottom contact gradational----------	0.5	941

Description	Thickness (feet)	Depth at bottom of unit (feet)
Piapi Canyon Formation--Continued		
Survey Butte Member (incomplete)--Continued		
Considerable core lost; white coarse tuff, probable base of subunit Y of U12b tunnel system at 944.5 feet	3.5	944.5
Considerable core lost; red-brown fine to coarse tuff, possible base of subunit X of U12b tunnel system estimated at 947.5 feet	3	947.5
Considerable core lost; white to very light gray coarse tuff, probable base of subunit W of U12b tunnel system at 949 feet	1.5	949
Tuff, red-brown, fine, structureless; bottom contact gradational	1	950
Tuff, light-brown, fine to coarse, pumiceous, structureless; lower 0.5 foot is white coarse and bedded(?)	21.5	971.5
Tuff, red-brown, pumiceous, fine to coarse, structureless (base of lower red-brown tuff of subunit V of U12b tunnel system at 978 feet)	6.5	978
Tuff, very light gray, lapilli, pumiceous, zeolitized, structureless; abundant lithic fragments, no opal; base of subunit V of U12b tunnel system at 978.5 feet	0.5	978.5
Tuff, pale-yellowish, lapilli, pumiceous, structureless; bottom contact sharp	8.5	987
Tuff, red-brown, pumiceous, fine to coarse, structureless; base of subunit U of U12b tunnel system at 988 feet	1	988

Description	Thickness (feet)	Depth at bottom of unit (feet)
Piapi Canyon Formation--Continued		
Survey Butte Member (incomplete)--Continued		
Tuff, white, lapilli pumiceous, structureless or very thick bedded; base of subunit T of U12b tunnel system at 994 feet----------	6	994
Tuff, light reddish-brown, fine to coarse, pumiceous, structureless; base of subunit S of U12b tunnel system at 1,000 feet---------	6	1,000
Tuff, pale yellow-gray, coarse to lapilli, moderately bedded----------	4	1,004
Tuff interbedded pale-yellow and tan, fine and coarse, well-bedded; beds 0.2 to 1 foot thick----------	8	1,012
Tuff, 2 feet recovered; pale-yellow, coarse to lapilli(?), intensely zeolitized; very fine hard yellow zeolitized and opalized tuff in lower 1 foot----------	16	1,028
Indian Trail Formation:		
Grouse Canyon Member; formerly designated unit Tos 5:		
Tuff, lapilli, pumiceous, vitric, nonzeolitic; <1 percent crystals, <3 percent dark lapilli lithic fragments; grades to zeolitized tuff at 1,050 feet, laminae of very fine tuff (thickness and depth in feet): 0.05 at 1,034, 0.2 at 1,035, 0.05 at 1,036, 0.08 at 1,046.5, 0.1 at 1,047, 0.1 at 1,047.5, 0.15 at 1,054, 0.1 at 1,055, 0.1 at 1,056.5, and 0.05 at 1,063----------	60	1,088

Description	Thickness (feet)	Depth at bottom of unit (feet)
Indian Trail Formation--Continued		
Grouse Cnayon Member; formerly designated unit Tos 5--Continued		
Tuff, light-tan, fine; about 3 percent fine to lapilli dark lithic fragments. Much light pumice; hard yellow silicified and zeolitized fine tuff at 1,071 to 1,072 feet; base of red to red-brown tuff, 0.5 foot thick, is gradational at 1,086 feet----------	44	1,132
Lower member; formerly designated units Tos 1 through Tos 4 (incomplete):		
Tuff, red; 40 to 50 percent light lapilli pumice; 5 to 10 percent dark lapilli to fine lithic fragments----------	5	1,137
Tuff, same as above unit but alternating buff and red in color with red predominant. More variation in size of pumice and lithic fragments with some fine and coarse pumice present. From 1,200 to 1,201 feet is greenish-yellow coarse to lapilli, zeolitized pumiceous vitric tuff similar to predominant tuff between 1,028 to 1,088 feet. Streaks of green clay mineral present at 1,173 feet, marks bottom of major red unit----------	136	1,273
Tuff, very light gray, fine; less than 5 percent fine to lapilli dark lithic fragments. Some red tuff which shows 40 to 50 percent lapilli to fine pumice----------	21	1,294
Tuff, like interval 1,137-1,270 except buff color predominates----------	6	1,400

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