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UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

Mail Stop 954, Federal Center, Box 25046
Denver, Colorado 80225

GEOLOGY OF THE U12n.02 (MIDI MIST) DRIFT, AND POSTSHOT
OBSERVATIONS, RAINIER MESA, AREA 12, NEVADA TEST SITE

USGS-474-229

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By

John R. Ege, Walter Danilchik, and C. T. Feazel

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ABSTRACT

Mining of the U12n.02 drift for the Midi Mist event started on December 31, 1965, in Rainier Mesa, Nevada Test Site, and was completed on December 30, 1966. The drift was mined along a bearing of S. 65° W. at an altitude of 1,850.2 m (6,070.2 ft) to a total length of 643 m (2,109 ft). The drift lies in tunnel bed 4 and penetrates stratigraphically up the section through sub-units 4AB, 4CD, 4E, 4F, 4G, 4H, and 4J, all of Tertiary age. Two faults mapped at the surface of the mesa were identified as having cut the complex at drift level. No engineering construction or support problems greater than minor rock slabbing, ravelly ground, or water inflow along fractures were encountered. Visual inspection showed that shot-induced effects in the rock medium at drift level extended for 237.7 m (780 ft) from the working point in the form of fractures and small shear displacements along bedding planes.

INTRODUCTION

Mining of the U12n.02 (Midi Mist) drift in Rainier Mesa, Area 12, Nevada Test Site (figs. 1, 2) started on December 31, 1965, and was completed on December 30, 1966. The drift was portaled at 975.1 m (CS 31+99 ft) in the U12n extension and was driven S. 65° W. to a total length of 642.8 m (2,109 ft) along a 0.5-percent upward grade (figs. 2, 3). The coordinates of the WP (working point) are N. 892,868.89, E. 633,629.84 (Nevada State central) and the altitude is 1,849.0 m (6,066.2 ft) above sea level.

The U12n.02 reentry drift intersects the U12n.02 main drift at 320.0 m (CS 10+50 ft) and parallels the main drift (S. 65° W.), with a centerline to centerline separation of 15.2 m (50 ft) and a pillar width of 11.9 m (39 ft). The length of the reentry drift is 321.6 m (1,055 ft) (fig. 2).

ACKNOWLEDGMENTS

D. L. Healey, C. H. Miller, and F. E. Currey provided the gravity data used to construct the pre-Tertiary-surface structural contour map. F. M. Byers, Jr., and R. P. Snyder mapped the surface geologic structures on Rainier Mesa.

Figure 2.--Map of Rainier Mesa, showing location of the UI2n.02 drift.

Figure 3.--Geologic cross section along UI2n.02 (Midi Mist) drift.

GEOLOGY

The U12n.02 drift lies in tunnel bed 4. The portal was constructed in tunnel bed subunit 4AB and penetrated stratigraphically up the section through subunits 4AB, 4CD, 4E, 4F, 4G, 4H, and 4J, all of Tertiary age (figs. 3, 4; table 1). Tunnel bed 4 comprises zeolitized massive- to thin-bedded calc-alkaline and peralkaline ash-fall tuff, reworked ash-fall tuff, and tuffaceous sandstone. The WP is in subunit 4J, a moderate-reddish-brown dominantly calc-alkaline ash-fall tuff that contains characteristically large (2 cm) white pumice fragments. This unit has an earthy texture caused by argillization or alteration to clay minerals of certain of its mineral constituents.

The drift traverses, at a low angle, the southeast limb of a southwest-trending syncline. The drift neither crosses nor enters the axis of the syncline at tunnel level.

The first 305 m (1,000 ft) of drift cuts a zone of northwest-trending Class-A and Class-B faults that extends for hundreds of meters (table 1). Many of the faults produced small amounts of water, indicating that there was storage of free water along faults and joints in this zone.

Four faults that pass over the U12n.02 drift have been mapped on the surface of Rainier Mesa (fig. 5, in pocket). Two of these surface faults have been recognized at drift level and have been correlated with the faults that cut the drift at 188.4 and 234.7 m (CS 6+18 and 7+70 ft).

The U12n.02 drift passes over a pre-Tertiary buried valley that lies at a depth greater than 305 m (1,000 ft) below the WP (fig. 6, in pocket). The trace of a thrust fault (CP thrust) trends directly beneath the WP.

ENGINEERING GEOLOGY

The average spacing between faults having vertical displacements greater than 1.5 m (5 ft), and which cut the drift between 0 and 304.8 m (CS 0+00 and CS 10+00 ft), is about 20 m (65 ft). This region of closely spaced faults caused slabbing and some raveling of the rock during mining. Water seepage along fault and joint planes was more of a nuisance than a problem and was adequately handled by drainage ditches in the invert. The stratigraphic subunits, 4AB through 4F, which were affected by the faulting in the drift, had not extensively altered to clay minerals, so neither serious swelling nor squeezing ground was encountered throughout any significant lengths of drift. The major ground-support problem in fault zones was to restrain the rock from slabbing and plastically moving into the drift.

Two intervals in the drift seemed to present the greatest engineering and support difficulties. The interval between 30.5 and 91.4 m (CS 1+00 and CS 3+00 ft) had a large amount of rock slabbing that can be related to the faults and, in particular, to the narrow pillar that separates the U12n.02 and U12n.04 drifts. The thin pillar in this area had to support very high stresses, which were greater than the strength of the tuff, and, consequently, the rock failed and relieved into the drift. The interval lying between 152.4 and 243.8 m (CS 5+00 and CS 8+00 ft) had considerable rock slabbing and some raveling. These conditions were caused by faulting accompanied by closely spaced joints that fragmented the rock. Water seeps were present in this interval and enhanced raveling of the rock. The remainder of the drift from 243.8 to 642.8 m (CS 8+00 to CS 21+09 ft) presented no serious construction or support problems.

Table 1.--Fault classification

Class	Description
A	<p>"A" in text. May have any or all of following characteristics:</p> <ol style="list-style-type: none"> 1. Extends to surface. 2. Connects two tunnels (bypass tunnels are not included as a second tunnel). 3. Displacement more than 3 m (10 ft). 4. Fracture zone is 0.6 m (2 ft) wide or more at fault.
B	<p>"B" in text. May be changed to Class A with more information or mining. May have one or more of following characteristics:</p> <ol style="list-style-type: none"> 1. Displacement less than 3 m (10 ft). 2. Probable or known fault length of 61 m (200 ft) or more. 3. Faults bounding or believed to influence drainage of beds, that is, faults related or apparently related to greater than 3 percent void space in tuff, indicating drainage from tuffs to pre-Tertiary rocks below and possibly comparable distances to other Tertiary rocks horizontally and upward. 4. Fracture zone is 0.6 m (2 ft) wide or less and is not healed or tightly filled.
C	<p>"C" in text. May be changed to Class A or B with more information. Must have all of following characteristics:</p> <ol style="list-style-type: none"> 1. Less than 1.5 m (5 ft) of displacement. 2. Probable or known fault length of 61 m (200 ft) or less. 3. No associated fracturing. 4. Fault healed or tightly filled.

POSTSHOT EFFECTS

Surface

Surface effects of the Midi Mist event are shown on figures 7 and 8. Figure 7 shows the linear arrangement of fractures, mapped in the alluvium and colluvium, that locally mantle the welded tuff caprock of Rainier Mesa. Most of the fractures trend about N. 25° W. The fractures are discontinuous but traceable at least as far as shown on the map. Undoubtedly there are many unmapped explosion-induced fractures in the much jointed and faulted welded tuff caprock. Figure 8, a large-scale map of the ground zero area, shows that in the pad above the WP the dominant trend of the fractures is also northwest. Other trends, probably caused by differential compaction and settling of the pad fill, are also evident.

We believe that the linear arrangement of the fractures reflects control by joints or faults in the underlying bedrock. No vertical or lateral displacements were observed along any of the fractures. Most of the fractures were no more than 1.9-2.5 cm (3/4-1 in.) wide but some were 7.6 cm (3 in.) wide. As shown on figure 7, some fractures were found as far as 296.2 m (1,300 ft) from ground zero.

Underground

In the U12n.02 drift rock spalling from the back of the drift began at about 388.6 m (CS 12+75 ft) and continues faceward from that point (fig. 9). Figure 10 is a photograph that shows a rockfall at 403.9 m (CS 13+25 ft, or 765 ft from WP). It should be noted that the rock slabs are tabular and blocky and are bounded by relatively smooth flat surfaces. The surfaces represent bedding and joint planes.

Figure 11 is a photograph of the back of the drift at 403.9 m (CS 13+25 ft) that shows the face from which rock fell. The spall zone is domal in shape and extends up into the back about 1.5 m (5 ft). Here again, slabbing occurred along bedding and joint planes, and this is made apparent by the tabular nature of the overbreak.

A detailed lithologic description and Schmidt hammer readings converted into estimated unconfined compressive-strength values demonstrate the nonhomogeneous and anisotropic nature of the tuff at 403.9 m (CS 13+25 ft) (fig. 12) (Ege and others, 1970).

Examination of the steel sets and lagging in U12n.02 at about 426.7 m (CS 14+00 ft) revealed that the sets had been displaced about 1.2 m (4 ft) towards the portal between the spring line and the crown. Between the spring line and the base, the sets were relatively undisturbed. The lagging in the upper half of the sets was broken; the separated pieces pointed into the drift forming a V. At 403.9 m (CS 13+25 ft) the steel sets exhibited little or no displacement; however, the lagging in the crown was broken. The lagging portalward from 381.0 m (CS 12+50 ft) was not broken.

In the U12n.03 drift rock spalling occurred mainly between 0 and 213.4 m (CS 0+00 and CS 7+00 ft (fig. 9)). The tuff separated along bedding, joint, and fault planes and fell as tabular blocks. The spalling was minor and there was no resulting damage to the drift. Movement along most mapped faults either did not occur or was imperceptible to the eye; however, a fault in the right rib at about 144.8 m (CS 4+75 ft) seems to have moved a few centimeters (fig. 13).

DESCRIPTION OF MAP UNITS	
TUNNEL BEDS	
UNIT 4	
Tt4J	TUNNEL BED 4J--Calc-alkaline ash-fall tuff with some peralkaline ash-fall tuff, zeolitized, thick-bedded to massive
Tt4H	TUNNEL BED 4H--Calc-alkaline ash-fall tuff with some peralkaline ash-fall tuff, reworked in part, zeolitized, thin- to thick-bedded
Tt4G	TUNNEL BED 4G--Peralkaline ash-fall tuff, zeolitized, thin- to thick-bedded
Tt4F	TUNNEL BED 4F--Calc-alkaline ash-fall tuff, reworked in part, zeolitized, thin-bedded to very thin bedded
Tt4E	TUNNEL BED 4E--Calc-alkaline ash-fall tuff, zeolitized, massive
Tt4CD	TUNNEL BED 4CD--Ash-fall tuff, reworked in part; some peralkaline ash-fall tuff and tuffaceous sandstone; zeolitized, thin- to thick-bedded
Tt4AB	TUNNEL BED 4AB--Calc-alkaline ash-fall tuff, reworked in part, some peralkaline ash-fall and tuffaceous sandstone; zeolitized, thin- to thick-bedded
UNIT 3	
Tt3D	TUNNEL BED 3D--Calc-alkaline ash-fall tuff, zeolitized, massive
EXPLANATION	
Tt4G	CONTACT--Dashed where approximately located. Tick shows direction of dip
A 70 18	FAULT--Dashed where approximately located. Arrow shows direction of dip. Bar and ball on downthrown side; displacement in feet. Letter designates fault classification. (See table 1.)
12	VERTICAL FAULT
75	STRIKE AND DIP OF BEDS--Tick shows direction of dip
75	JOINT--Showing dip
75	DRILL HOLE--Total depth (TD) as shown
75	VERTICAL DRILL HOLE
CROSS SECTION	
Tt4G	CONTACT--Dashed where approximately located
A 70 18	FAULT--Dashed where approximately located. Arrows show direction of relative displacement
75	DRILL HOLE--Total depth (TD) as shown

Figure 4.--Geologic map of the UI2n.02 (Midi Mist) drift.

EXPLANATION

- FAULT--Bar and ball on downthrown side, dashed where concealed, dotted where inferred. Displacement in feet, queried where uncertain
- AXIS OF THE AQUEDUCT DRAINAGE--Arrow shows downstream direction
- HORIZONTAL DRILL HOLE

Figure 5.--Surface faults over the UI2n.02 (Midi Mist) drift. All drifts projected to surface.

EXPLANATION

THRUST FAULT--Teeth on upper plate

STRUCTURE CONTOUR--Above mean sea level, in feet. Number in parentheses is distance to surface below WP, in feet

AXIS OF BURIED VALLEY--Arrow shows downstream direction

HORIZONTAL DRILL HOLE

CONSTRUCTION STATION

Figure 6.--Pre-Tertiary surface below the UI2n.02 (Midi Mist) drift.
All drifts projected.

Figure 7.--Surface effects from the Midi Mist event near the pad at ground zero.

Figure 8.--Surface effects from the Midi Mist event in the pad ground zero.

Figure 9.--Plan of UI2n.02 and UI2n.03 drifts, showing areas of rock spalling.

Figure 10.--Postshot rockfall at 403.9 m (CS 13+25 ft),
U12n.02 (Midi Mist) drift.

Figure 11.--Postshot rock spall (looking up) in back of drift
at 403.9 m (CS 13+25 ft), U12n.02 (Midi Mist)
drift.

Thickness (meters) (feet)		Description of tuff beds	Schmidt hammer rebound number	Estimated compressive strength bars (lb/in ²)
1.0	3.3	Pale-brown; contains coarse pumice (12 mm) and sparse lithic fragments	30	158.6 (2,300)
0.79	2.6	Silicified layer, fine textured	37	227.6 (3,300)
.73	2.4	Grayish-yellow, fine- textured; contains very sparse lithic fragments (2 mm)	38	241.4 (3,500)
.43	1.4	Pale-brown; contains coarse pumice (12 mm) and sparse lithic fragments	31	172.4 (2,500)
.30	1.0	Yellowish-gray mottled with pink; contains abundant fine lithic fragments (3-4 mm)	30	158.6 (2,300)
0	0

Figure 12.--Detailed description of tuff beds within tunnel bed 4F
at 403.9 m (CS 13+25) in the U12n.02 (Midi Mist) drift.

Figure 13.--Postshot fault movement at 144.8 m (CS 4+75 ft),
U12n.02 (Midi Mist) drift.

Figure 14.--Distribution of spalling areas, rockfalls, and telltales in the U12n.03 drift, post-Midi Mist observations.

EXPLANATION

- Tt4G
Tt4F
- CONTACT--Dashed where approximately located, tick shows directions of dip
- A 70 18
- FAULT--Showing dip. Dashed where approximately located. Bar and ball on downthrown side. Displacement in feet. Letter designates fault classification. (See table 1.)
- 12
- STRIKE AND DIP OF BEDS--Tick shows direction of dip
- ♦
- VERTICAL DRILL HOLE

Figure 15.--Postshot effects in the UI2n.02 (Midi Mist) reentry drift.

The condition of plaster-of-paris telltales, which had been spread across many faults and joints along the walls of U12n.03 in order to detect movement, is shown on figure 14.

Postshot mapping in the U12n.02 reentry drift concentrated on discriminating between pre-shot joints and postshot fractures, bedding-plane shears, and extent of shot-induced effects. Bedding-plane shears along which strata slipped or were thrust in the course of cavity formation are in planes parallel to tuff beds. The most obvious slippage planes are usually at the contact between relatively harder and softer layers. The observed extent of strongly fractured rock, weakly fractured rock, and shear along bedding planes is shown on figure 15. The terms "strongly" and "weakly" fractured rock are subjective and relate to impressions of "more closely" spaced fractures versus "less closely" spaced fractures.

PHYSICAL PROPERTIES

Physical properties of tuff grab samples taken from the U12n.02 drift are listed in table 2. The property tests were made by the Pittsburg Testing Laboratory, Salt Lake City, Utah. The samples were not preserved in natural-state condition and, consequently, were resaturated in the laboratory for the density and compressive-strength tests. The properties are representative of resaturated tunnel bed subunits 4CD and 4H. A lithologic description of the core from the U12n.02 WP-1 drill hole collared at the WP is given in table 3.

Table 2.--Physical properties of resaturated grab samples from the Midi Mist (U12n.02) main drift

[Tests conducted by Pittsburgh Testing Laboratory, Salt Lake, City, Utah. Leaders

(---) indicate no data; R indicates right rib; L, left rib; T, back of drift]

Sample locality (meters) (feet)	Rock unit	Dry-bulk density (Mg/m ³)	Saturated- bulk density (Mg/m ³)	Porosity (percent)	Unconfined compressive strength (bars) (lb/in ²)	
15.24R 0+50R	4CD	1.51	1.89	40	---	---
15.24L 0+50L	4CD	1.60	1.96	35	---	---
15.24T 0+50T	4CD	1.71	2.02	31	73.78	1,070
30.48R 1+00R	4CD	1.53	1.89	36	91.70	1,330
30.48T 1+00T	4CD	1.73	2.06	32	60.95	884
45.72R 1+50R	4CD	1.52	1.89	37	---	---
45.72T 1+50T	4CD	1.75	2.06	31	70.33	1,020
60.96R 2+00R	4CD	1.68	2.00	32	---	---
60.96R 2+00R	4CD	1.43	1.84	42	---	---
60.96L 2+00L	4CD	1.43	1.83	40	151.69	2,200
60.96L 2+00L	4CD	1.71	2.02	32	52.40	760
76.20R 2+50R	4CD	1.52	1.86	34	89.64	1,300
76.20L 2+50L	4CD	1.39	1.81	42	100.67	1,460
76.20T 2+50T	4CD	1.64	1.97	33	---	---
91.44L 3+00L	4CD	1.51	1.86	36	---	---
91.44T 3+00T	4CD	1.75	2.06	31	75.84	1,100
106.68R 3+50R	4CD	1.46	1.86	40	---	---
106.68L 3+50L	4CD	1.47	1.86	38	---	---
106.68T 3+50T	4CD	1.69	2.00	31	50.33	730
481.58R 15+80R	4H	---	---	---	175.13	2,540
481.58R 15+80R	4H	---	---	---	253.05	3,670
481.58R 15+80R	4H	---	---	---	212.37	3,080
481.58L 15+80L	4H	---	---	---	467.48	6,780
481.58T 15+80T	4H	---	---	---	123.42	1,790

Table 3.--Lithologic log of the U12n.02 WP-1 drill hole

Description	Thickness meters (feet)	Depth to base meters (feet)
Tunnel beds, unit 4		
Subunit 4J		
Tuff, calc-alkaline ash-fall, grayish-orange, zeolitized; contains abundant 3- to 15-mm pumice fragments-----	3.4 (11)	3.4 (11)
Tuff, peralkaline ash-fall, yellowish-gray, zeolitized; contains conspicuous 1-cm lithic fragments, very sparse pumice fragments-----	3.0 (10)	6.4 (21)
Tuff, calc-alkaline ash-fall, grayish-orange, zeolitized; contains abundant 3- to 15-mm pumice fragments-----	9.4 (31)	15.8 (52)
Tuff, calc-alkaline ash-fall, moderate- reddish-brown, zeolitized; contains abundant very light gray pumice fragments (3-15 mm)-----	8.8 (29)	24.6 (81)
Total depth-----		24.6 (81)

REFERENCE CITED

Ege, J. R., Miller, D. R., and Danilchik, Walter, 1970, Schmidt hammer test method for field determination of physical properties of zeolitized tuff: U.S. Geological Survey Open-File Report, 37 p.

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Resident Manager, Mercury, NV

Engineering Decision Analysis Co., Irvine, CA:

R. P. Kennedy

Pacifica Technology, Del Mar, CA:

G. I. Kent

R & D Associates, Marina del Rey, CA:

John Lewis

SAI, Inc., La Jolla, CA:

Russell Duff

Terra Tek, Inc., Salt Lake City, UT:

Scott Butters

U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, MS:

Library
J. M. Scanlon, Jr.
William Steinriede, Jr.

Natural Resources Library, U.S. Department of Interior, Washington, DC: (2)

U.S. Geological Survey:

Geologic Data Center, Mercury, NV (15)
Library, Denver, CO (2)
Library, Flagstaff, AZ
Library, Menlo Park, CA (2)

U.S. Geological Survey, Reston, VA:

Chief Hydrologist, WRD (Attn: Radiohydrology Section)
Library (2)
Military Geology Unit
J. C. Reed, Jr.