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TEI-832

GAMMA - RADIOACTIVITY INVESTIGATIONS
AT THE NEVADA TEST SITE,
NYE COUNTY, NEVADA

(INTERIM REPORT, FEBRUARY 1960 TO JULY 1961)

By Carl M. Bunker and Marvin D. Shutler

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

metadc502027

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Report TEI-832

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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ABSTRACT

As a part of continuous geologic and geophysical investigations at the Nevada Test Site, gamma-radioactivity measurements are being made in tunnels and drill holes to determine semiquantitatively the natural gamma radioactivity of geologic formations and the distribution of nuclear-explosion-produced radioisotopes. Tunnel walls were surveyed with portable scintillation detection equipment and drill holes were logged with Geiger-Mueller detectors. These measurements were started in 1957 and have continued to date; however, only the results of studies between February 1960 and July 1961 are reported here.

The natural gamma radioactivity was measured in tuff, alluvium, marble, dolomite, and granite. The highest natural radioactivity was measured in granite; the lowest natural radioactivity was in marble and dolomite. Gamma-ray logs of drill holes generally show (a) contacts between rock types by changes in radioactivity at contacts, (b) location of water level, and (c) location of casing. Gamma-radioactivity surveys in tunnels seldom show contacts between the types of tuff exposed in the tunnels.

Measurements of nuclear-explosion-produced radioactivity show the distribution of gamma-emitting radioisotopes around the locations of the explosions. Surveys show that explosion products are disseminated through fractures and faults; and they also show the relative efficiency of stemming in the tunnels. Inefficient stemming may permit contamination of sections of the tunnels otherwise unaffected by nuclear explosions, and the resulting contamination may partly invalidate measurements of natural gamma radioactivity.

INTRODUCTION

Geologic and geophysical investigations, including gamma-radioactivity measurements, were started in 1957 at the Nevada Test Site, Nye and Lincoln Counties, Nev. (fig. 1). Initially, the radioactivity measurements were made to aid geologic studies and to furnish information on the natural gamma radioactivity of the geologic formations underlying the Test Site. Investigations following underground tests of nuclear devices to determine the effects of nuclear explosions (Diment and others, 1959) included gamma-radioactivity measurements to determine the distribution of explosion-produced radioisotopes. The results of the gamma-radioactivity investigations made prior to February 1960 have been published (Bunker and others, 1960; Bunker, 1961).

This report includes only the results of measurements made from February 1960 to July 1961. No nuclear tests were made during this period. Post-explosion radioactivity measured during this period is in the vicinities of nuclear tests made during 1957 and 1958. Therefore, the radioactivity data do not necessarily agree quantitatively with measurements made previously because the radioisotopes have decayed during the time interval between measurements.

The objectives of the gamma-radioactivity measurements were to determine semiquantitatively the natural gamma radioactivity of the formations underlying the Nevada Test Site, especially those in which nuclear tests were made or proposed, and to determine the location and radioactivity of nuclear-explosion-produced radioisotopes. The natural gamma-radioactivity data contribute to the general

Figure 1.—Index map, Nevada Test Site and vicinity, Nye and Lincoln Counties, Nevada

knowledge of the physical properties of rock underlying the Nevada Test Site. The data will be used as a basis for determining the distribution of anomalous gamma radioactivity from radioisotopes produced by future underground nuclear explosions.

The gamma-radioactivity values obtained by tunnel surveys are probably accurate within +10 percent. Factors that contribute to the error include statistical error in meter reading during both instrument calibration and tunnel surveying, variations in geometry between the detector and the wall rock, the effect of shielding by steel sets and lagging in the tunnel, and drift in the response of the instrument during the surveys.

The areas of investigation, including tunnel surveys and drill holes logged, and the dates on which the work was done are summarized in tables 1 and 2.

Gamma-radioactivity surveys were made in the U12b (fig. 2) and U12e (fig. 3) tunnel systems; both tunnels are located in Area 12 (fig. 1).

The geologic names and symbols for the members (Hinrichs and Orkild, 1961) and for the former Oak Spring Formation (Poole and McKeown, 1962) have been changed. To minimize confusion when referring to the report on previous gamma-radioactivity investigations at the Nevada Test Site (Bunker, 1961), a correlation chart (table 3) is included.

Hand-portable survey meters and inhole-logging equipment were used to measure the gamma radioactivity in tunnels and drill holes.

Table 1.--Summary of data pertaining to tunnel surveys, Nevada Test Site

Tunnel	Stations surveyed	Distance between measurements (feet)	Date surveyed
U12b (main drift)-----	0+12 to 25+00	20	1/23/61
U12b.01-----	0+20 to 3+00	20	1/25/61
U12b.02-----	0+00 to 1+20	20	1/23/61
U12b.03-----	0+20 to 4+80	20	1/25/61
U12b.07-----	0+10 to 10+30	20	10/20/60
	0+20 to 5+80	20	1/23/61
U12b.09-----	1+30 to 4+60	20	10/20/60
L.O.S.-----	0+40 to 4+00	20	1/23/61
Personnel-----	0+40 to 6+83	20	10/20/60
U12b Rainier exploratory			
W drift-----	0+00 to 0+64.5	2.5	6/22/61
Vertical shaft-----	0+00 to 0+45	2.0	6/22/61
Upper drift-----	0+01 to 3+80	5	3/19/60
U12e (main drift)-----	0+00 to 5+00	20	1/25/61
	5+00 to 20+60	20	1/23/61
	32+00 to 56+00	20	1/23/61
U12e.01-----	0+60 to 14+80	20	1/25/61
U12e.02 (reentry drift)---	0+20 to 3+60	20	1/23/61
Reentry extension----	0+00 to 3+15	5	6/23/61
Reentry crosscut----	0+00 to 1+40	5	6/23/61
U12e.03-----	0+20 to 25+20	20	1/23/61
U12e.03a-----	0+40 to 8+00	20	1/23/61
U12e.03b-----	0+00 to 7+58	20	1/23/61
U12e.04 (L.O.S.)-----	0+40 to 17+50	20	1/23/61
U12e.05-----	0+30 to 3+00	15	6/23/61
U12e.06-----	0+40 to 20+63	20	10/20/60
U12e.07-----	0+20 to 26+00	20	10/21/60

Table 2.--Drill-hole data pertaining to holes gamma-ray logged, Nevada Test Site

Drill hole No.	Collar coordinates	Vertical angle (degrees)	Depth gamma-ray logged (feet)	Collar elevation (feet)	Depth drilled (feet)	Drill-bit size (inches)	Casing		Date logged
							Length (feet)	Size (inches)	
Granite site									
28	N. 901,925 E. 676,780	-90	323.5	5,115	950.0	6	<u>1</u> /	8	10/17/60
29	N. 901,920 E. 676,870	-90	701.0	5,115	700.0(?)	6	<u>1</u> /	6	10/17/60
32	N. 902,155 E. 677,800	-90	1,049.0	5,077	907.0(?)	8	<u>1</u> /	10	10/17/60
33	N. 901,675 E. 675,850	-90	363.5	<u>1</u> /	982.0	8	20	10	10/17/60
Buckboard Mesa									
Wagon 1	N. 860,080 E. 585,025	-90	216.0	5,469	<u>1</u> /	<u>1</u> /	None	None	10/18/60
DB-2	About N. 856,700 About E. 593,950	-90	55.0	5,309	55.0	BX	None	None	10/21/60
DB-27	About N. 852,575 About E. 592,800	-90	23.5	5,390	24.0	BX	None	None	10/21/60

1/ Unknown at present.

Figure 2.--Index map, U12b tunnel system, Area 12, Nevada Test Site

Figure 3.—Index map, U12e tunnel system, Area 12, Nevada Test Site

Table 3.--Equivalent map units for previous and present reports

Unit in previous reports	Formation	Unit in present report
Tos ₈ ----- ----- -----	Piapi Canyon	Rainier Mesa Member (Tpr).
-----		Tiva Canyon Member, upper part (Tpcu).
-----		Tiva Canyon Member, lower unit (Tpcl).
T7 ₂ -----		Topopah Spring Member (Tpt).
T7 ₁ -----		Stockade Wash Member (Tpww).
Tos ₇ -----		Survey Butte Member (Tps).
Tos ₆ -----	Indian Trail	Grouse Canyon Member, upper part (Tigu).
Tgor(?), between Tos ₄ and Tos ₅ -----		Tub Spring Member (Tits).
Tw 1-4, Tcj, Tg, Tgo and Tunnel Beds Tos ₁ through Tos ₄ -----		Lower member (Til).

All instruments were calibrated with radium-226 standard sources of radioactivity to make possible the quantitative interpretation of field data in terms of a standard gamma-radiation unit--mr/hr (milliroentgens per hour) (Bunker, 1961).

Tunnel surveys were made by placing a hand-portable survey meter against the wall of the tunnel or shaft. When possible, the meter readings were obtained with the meter on contact with the rock; however, presence of steelwork and timbering sometimes made on-contact measurements impossible. Measurements were generally made at a distance of about 4-1/2 feet above the tunnel floor.

W. A. Bradley rendered valuable assistance in obtaining and evaluating portions of the data in this report. This investigation was made on behalf of the Albuquerque Operations Office, U.S. Atomic Energy Commission.

TUNNEL SURVEYS

U12b tunnel (main drift)

Gamma-radioactivity surveys were made in parts of the U12b main drift in September 1958, in conjunction with a study of the effects of the Rainier underground nuclear explosion (Bunker, 1961). During 1959, the tunnel was widened and lengthened to about station 25+00. On January 23, 1961, a gamma-radioactivity survey was made on the right (north) wall from station 0+00 to station 25+00 (table 4).

Table 4.--Gamma-radioactivity survey data, U12b tunnel (main drift)

Survey station	Radioactivity (mr/hr)	Survey station	Radioactivity (mr/hr)	Survey station	Radioactivity (mr/hr)
0+00	0.060	7+00	0.060	14+00	0.113
20	.074	20	.112	20	.044
40	.055	40	.183	40	.046
60	.036	60	.141	60	.060
80	.070	80	.074	80	.032
1+00	.060	8+00	.074	15+00	.032
20	.074	20	.22	20	.027
40	.103	40	.22	40	.019
60	.063	60	.108	60	.016
80	.046	80	.141	80	.018
2+00	.068	9+00	.10	16+00	.017
20	.060	20	.103	20	.017
40	.030	40	.103	40	.016
60	.070	60	.27	60	.017
80	.070	80	.173	80	.017
3+00	.065	10+00	.141	17+00	.017
20	.117	20	.19	20	.018
40	.083	40	.108	40	.017
60	.087	60	.17	60	.017
80	.089	80	.24	80	.017
4+00	.072	11+00	.093	18+00	.018
20	.096	20	.131	20	.017
40	.082	40	.065	40	.020
60	.086	60	.27	60	.017
80	.091	84	.050	80	.017
5+00	.093	12+00	.046	19+00	.018
20	.078	20	.050	20	.015
40	.065	40	.084	40	.019
60	.110	60	.050	60	.017
80	.074	80	.088	80	.018
6+00	.21	13+00	.065	20+00	.019
20	.113	20	.27	20	.017
40	.103	44	.20	40	.017
60	.093	60	.046	60	.017
80	.093	80	.31	80	.017

Table 4.--Gamma-radioactivity survey data, U12b tunnel (main drift)--
Continued

Survey station	Radioactivity (mr/hr)	Survey station	Radioactivity (mr/hr)
21+00	0.017	23+00	0.018
20	.017	20	.017
40	.017	40	.018
60	.017	60	.018
80	.016	80	.019
22+00	.016	24+00	.019
20	.016	20	.017
40	.015	40	.017
60	.016	60	.018
80	.017	80	.019
		25+00	.021

The explosion-produced gamma radioactivity was in the range of 0.015 to 0.31 mr/hr. The natural gamma radioactivity in the section between stations 15+50 and 25+00, which was not contaminated by nuclear explosions, was in the range of 0.015 to 0.020 mr/hr. The slight changes in the natural gamma radioactivity do not seem to be related to geologic units or to structural features. The higher radioactivity between stations 0+00 and 15+50 was very likely caused by contamination from mining operations in the Rainier Exploratory tunnel (station 14+50) and in other reentry mining along the tunnel, plus direct contamination by radioisotopes from nuclear explosions in the tunnel system. The overall contamination obscures areas of anomalous radioactivity caused directly by the nuclear explosions and precludes conclusions on the effect of geologic features and the distribution of explosion-produced radioisotopes.

U12b.01 tunnel

The gamma radioactivity on the right (east) wall was in the range of 0.12 to 0.32 mr/hr (table 5) which was significantly greater than the natural gamma radioactivity measured in similar rock elsewhere in the U12b and U12e tunnel systems. The anomalously high gamma radioactivity was caused by nuclear tests in the vicinity of the U12b.01 tunnel, probably from a test in the adjacent U12b.02 tunnel. The highest radioactivity was measured between stations 0+20 and 1+20. A blast door is located at station 1+30. A possible

Table 5.--Gamma-radioactivity survey data, U12b.01 tunnel

Survey station	Radioactivity (mr/hr)	Survey station	Radioactivity (mr/hr)
0+20	0.17	2+00	0.16
40	.24	20	.16
60	.32	40	.12
80	.24	60	.13
		80	.19
1+00	.23		
20	.12	3+00	.22
40	.15		
60	.16		
80	.17		

explanation for the highly radioactive zone is that radioisotopes escaped from the test chamber in the U12b.02 tunnel and were forced through the U12b main drift into U12b.01 as far as the blast door where most of them were stopped or diverted into the alcove at station 1+10. The level of radioactivity in the entire tunnel is probably too high to allow post-nuclear-explosion radioactivity studies of a device detonated in the U12b.01 tunnel, until a few months following a detonation. Gamma-radioactivity anomalies in this tunnel are apparently unrelated to geologic units, fractures, or faults.

U12b.02 tunnel

Less than half of the tunnel was accessible for radiation surveys in January 1961 because of high-intensity radioactivity. The gamma radioactivity observed between stations 0+00 and 1+24 was in the range of 0.09 to 0.18 mr/hr (table 6). The variations in the radioactivity between stations 0+00 and 0+50 are unrelated to geologic features and may have been caused by the shielding effect of mine cars parked in this section of the tunnel during the survey.

U12b.03 tunnel

The gamma radioactivity on the right (east) wall of the U12b.03 tunnel was in the range of 0.086 to 0.32 mr/hr (table 7), which is significantly higher than the natural gamma radioactivity (0.015 to 0.025 mr/hr) observed elsewhere in the U12b and U12e tunnel systems.

Table 6.--Gamma-radioactivity survey data, U12b.02 tunnel

Survey station	Radioactivity (mr/hr)
0+00	0.094
10	.11
20	.15
30	.105
40	.088
50	.13
70	.16
90	.18
1+10	.16
30	.18

Table 7.--Gamma-radioactivity survey data, U12b.03 tunnel

Survey station	Radioactivity (mr/hr)	Survey station	Radioactivity (mr/hr)
0+20	0.23	3+00	0.113
40	.31	20	.152
60	.23	40	.086
80	.31	60	.162
		80	.112
1+00	.32		
20	.25	4+00	.141
40	.26	20	.141
60	.23	40	.162
85	.23	60	.152
95	.173	80	.152
2+00	.20	5+00	.22
20	.162	20	.16
40	.122	40	.13
60	.122	60	.13
80	.113	80	.12
		6+00	.14
		20	.14

The anomalously high radioactivity was caused by nuclear tests in the vicinity of the U12b.03 tunnel, probably from a nuclear test in the adjacent U12b.02 tunnel. The highest radioactivity was measured between stations 0+20 and about 2+00; station 2+00 is the location of the inner side of a blast door. A possible explanation for the zone of high gamma radioactivity is that radioisotopes escaped from the test chamber in U12b.02 and were forced through the U12b main drift into U12b.03 as far as the blast door where most of them were stopped or diverted into Alcove No. 2. Some of this radioactivity may also be caused by spillage of radioactive rock from mine cars parked in the tunnel at various times. The increases in radioactivity at stations 3+20, 3+60, and 5+00 cannot be related definitely to fractures that occur at those locations. The level of radioactivity in the tunnel is probably too high to allow post-explosion radioactivity studies of a nuclear device detonated in the U12b.03 shot chamber, until a few months following a detonation.

U12b.07 tunnel

Measurements were started at station 0+10 in the U12b.07 tunnel near the intersection with the U12b main drift and were terminated at station 10+30 (table 8). The measurements were made at intervals of 20 feet.

The gamma radioactivity observed in the tunnel is natural and is in the range of 0.017 to 0.032 mr/hr (table 8). The gamma radioactivity in the subunit Z of the lower part of Survey Butte Member is essentially constant, averaging about 0.017 mr/hr and

Table 8.--Gamma-radioactivity survey data, U12b.07 tunnel

Survey station	Radioactivity (mr/hr)	Survey station	Radioactivity (mr/hr)
0+20	0.018	6+00	0.021
40	.018	20	.021
60	.017	40	.021
80	.016	60	.022
		80	.022
1+00	.015		
20	.015	7+00	.022
40	.015	20	.022
60	.015	40	.022
80	.016	60	.023
		80	.023
2+00	.015		
20	.015	8+00	.022
40	.017	20	.021
60	.019	40	.024
80	.019	60	.022
		80	.022
3+00	.019		
20	.020	9+00	.020
40	.021	20	.020
60	.021	40	.018
80	.021	60	.020
		70	.018
4+00	.021		
20	.019	10+15	.018
40	.018	30	.018
60	.017		
80	.020		
5+00	.018		
20	.018		
40	.020		
60	.020		
80	.020		

ranging from about 0.015 to about 0.018 mr/hr. The gamma radioactivity in subunits V, W, X, and Y of the lower part of the Survey Butte Member is slightly less and ranges from about 0.015 to 0.019 mr/hr. The contact between subunits U and V of the lower part of the Survey Butte Member is indicated by an increase in radioactivity in U to an average of about 0.021 mr/hr. The radioactivity of subunits M through O of the upper part of the Grouse Canyon Member and P through T of the lower part of the Survey Butte Member is about the same as that in subunit U. The radioactivity in subunit L of the lower part of the Grouse Canyon Member is slightly higher than in subunits M through U, and increases to a maximum of about 0.024 mr/hr; however, the average is about 0.022 mr/hr. The radioactivity in the agglomerate of the upper part of the Grouse Canyon Member is considerably less than in subunit L of the lower part of the Grouse Canyon Member; it is in the range of 0.018 to 0.020 mr/hr and averages about 0.019 mr/hr. These results show that gamma-radiation measurements can be used to aid geologic studies in some parts of the tunnel system.

U12b.09 tunnel

Gamma-radioactivity measurements were made on the northwest wall between stations 0+40 and 4+60 in the L.O.S. tunnel and between stations 0+00 and 6+80 in the Personnel tunnel of the U12b.09 tunnel (table 9).

Table 9.--Gamma-radioactivity survey data, U12b.09 tunnel

Survey station	Radioactivity (mr/hr)	Survey station	Radioactivity (mr/hr)
L.O.S. tunnel			
0+40	0.017	3+00	0.019
60	.017	20	.017
80	.017	40	.019
		60	.018
1+00	.020	80	.018
20	.019		
40	.020	4+00	.018
60	.019	20	.018
80	.020	40	.018
		60	.018
2+00	.018		
20	.019		
40	.018		
60	.017		
80	.018		
Personnel tunnel			
0+40	.018	4+00	.016
60	.018	20	.016
80	.018	40	.015
		60	.016
1+00	.018	80	.016
20	.018		
40	.018	5+00	.016
60	.018	20	.016
80	.018	40	.017
		60	.017
2+00	.017	80	.017
20	.018		
50	.018	6+00	.017
60	.018	20	.017
80	.017	40	.016
		60	.016
3+00	.016	80	.017
20	.017		
40	.017		
60	.016		
80	.015		

The natural gamma radioactivity measured on the northeast walls of the tunnels is in the range of 0.015 to 0.020 mr/hr. The results of the survey are related to geologic data in a report by Dickey and others (1962).

Rainier W drift and shaft, and upper drift

The gamma-radioactivity of the W drift and shaft (fig. 4) was surveyed on June 22, 1961. The shaft intersects the U12b exploratory drift and extends downward from station 16+73. Measurements were made at intervals of 2 feet from the intersection to a depth of 45 feet; below that depth the shaft was inaccessible. Measurements were made on both walls in the W drift at intervals of 2.5 feet from the shaft to about station 0+60. The drift follows a shell of radioactive glass underlying the Rainier explosion point. The radioactivity measurements were made on contact with the outline of the visible glass shell. A detailed survey of the drift could not be made because of time limits imposed by radiation safety.

The results (fig. 4) further verify the presence of the radioactive shell described by Bunker and others (1960) and Bunker (1961). The survey shows, in part, the shell-like distribution of radioactivity caused by the Rainier explosion, especially in the vertical shaft. The most intense gamma radioactivity observed was in the vertical shaft 16 feet below the exploratory drift and was about 150 mr/hr.

Figure 4.--Gamma-radioactivity survey data, W drift and shaft,
Rainier Site, Nevada Test Site

The upper drift, which penetrates the slump zone above the Rainier explosion point, was surveyed on March 19, 1960. Measurements were made at 5-foot intervals from the raise (station 0+1) to station 3+80. The radioactivity was in the range of 0.024 to 0.034 mr/hr (table 10) which is about twice the normal background.

U12e tunnel (main drift)

Gamma-radioactivity surveys were made in the U12e tunnel (table 11) in October 1960, and January 1961.

Data obtained in January 1961 show a section of high gamma radioactivity that extends from station 19+40 to about station 20+80. The cause for this radioactivity may be attributed to a nuclear explosion in the nearby U12e.05 tunnel, but part of the radioactivity may also be attributed to reentry mining operations in the vicinity of the U12e.05 and U12e.02 tunnels.

The data obtained between stations 38+00 and 56+00 in October 1960 show no significant changes in gamma radioactivity, which averaged about 0.018 mr/hr.

U12e.01 tunnel

The gamma-radioactivity measurements were made on the west wall of the U12e.01 tunnel and were indexed to station locations surveyed by Holmes and Narver, Inc. This radioactivity ranges from 0.015 to 0.019 mr/hr (table 12). This amount of radiation is considered as

Table 10.--Gamma-radioactivity survey data, Rainier upper drift

Survey station	Radioactivity (mr/hr)	Survey station	Radioactivity (mr/hr)
0+01	0.025	2+00	0.028
05	.025	5	.027
10	.026	10	.027
15	.026	15	.028
20	.026	20	.029
25	.025	25	.038
30	.026	30	.031
35	.026	35	.029
40	.026	40	.029
45	.026	45	.029
50	.025	50	.030
55	.025	55	.029
60	.024	60	.029
65	.026	65	.030
70	.028	70	.028
75	.031	75	.027
80	.030	80	.029
85	.030	85	.028
90	.031	90	.030
95	.028	95	.029
1+00	.027	3+00	.028
5	.028	5	.033
10	.027	10	.027
15	.026	15	.026
20	.025	20	.024
25	.027	25	.025
30	.027	30	.027
35	.025	35	.027
40	.025	40	.026
45	.025	45	.027
50	.026	50	.028
55	.026	55	.034
60	.026	60	.033
65	.026	65	.034
70	.027	70	.033
75	.027	75	.033
80	.027	80	.033
85	.026		
90	.026		
95	.027		

Table 11.--Gamma-radioactivity survey data, U12e tunnel (main drift)

Survey station	Radioactivity (mr/hr)	Survey station	Radioactivity (mr/hr)
0+20	0.021	7+00	0.023
40	.024	20	.024
60	.024	40	.023
80	.027	60	.025
		80	.026
1+00	.028		
20	.028	8+00	.032
40	.027	20	.032
60	.030	40	.032
80	.029	60	.029
		80	.031
2+00	.031		
20	.030	9+00	.031
40	.030	20	.028
60	.031	40	.033
80	.036	60	.035
		80	.040
3+00	.033		
20	.031	10+00	.027
40	.023	20	.025
60	.021	40	.031
80	.019	60	.029
		80	.032
4+00	.020		
20	.020	11+00	.024
40	.021	20	.021
60	.023	40	.022
80	.021	60	.021
		80	.017
5+00	.027		
20	.028	12+00	.017
40	.027	20	.017
60	.024	40	.018
80	.023	60	.023
		80	.022
6+00	.019		
20	.019	13+00	.021
40	.021	20	.018
60	.021	40	.019
80	.024	60	.021
		80	.021

Table 11.--Gamma-radioactivity survey data, U12e tunnel (main drift)--
Continued

Survey station	Radioactivity (mr/hr)	Survey station	Radioactivity (mr/hr)
14+00	0.019	32+00	0.014
20	.020	20	.017
40	.021	40	.016
60	.021	60	.015
80	.022	80	.014
15+00	.024	33+00	.015
20	.025	20	.017
40	.031	40	.015
60	.029	60	.017
80	.029	80	.016
16+00	.028	34+00	.016
20	.035	20	.017
40	.036	40	.016
60	.023	60	.017
80	.023	80	.015
17+00	.021	35+00	.015
20	.027	20	.015
40	.023	40	.015
60	.022	60	.015
80	.018	80	.016
18+00	.024	36+00	.015
20	.021	20	.015
40	.021	40	.016
80	.027	60	.016
		80	.017
19+00	.023	37+00	.015
20	.019	20	.015
40	.024	40	.014
60	.024	60	.014
80	.017	80	.015
20+00	.023	38+00	.015
20	.023	20	.018
40	.035	40	.018
60	.018	60	.017
80	.024	80	.018

Table 11.--Gamma-radioactivity survey data, U12e tunnel (main drift)--
Continued

Survey station	Radioactivity (mr/hr)	Survey station	Radioactivity (mr/hr)
39+00	0.017	46+00	0.017
20	.018	20	.018
40	.018	40	.018
60	.018	60	.017
80	.018	80	.018
40+00	.018	47+00	.018
20	.018	20	.018
40	.019	40	.017
60	.018	60	.018
80	.018	80	.018
41+00	.018	48+00	.018
20	.018	20	.017
40	.018	40	.018
60	.018	60	.018
80	.018	80	.018
42+00	.018	49+00	.017
20	.018	20	.018
40	.018	40	.018
60	.018	60	.017
80	.018	80	.018
43+00	.018	50+00	.017
20	.018	20	.017
40	.019	40	.018
60	.018	60	.018
80	.018	80	.017
44+00	.018	51+00	.018
20	.018	20	.018
40	.018	40	.018
60	.018	60	.018
80	.018	80	.018
45+00	.018	52+00	.018
20	.018	20	.018
40	.018	40	.017
60	.017	60	.017
80	.018	80	.017

Table 11.--Gamma-radioactivity survey data, U12e tunnel (main drift)--
Continued

Survey station	Radioactivity (mr/hr)	Survey station	Radioactivity (mr/hr)
53+00	0.018	55+00	0.018
20	.018	20	.017
40	.018	40	.018
60	.018	60	.018
80	.018	80	.018
54+00	.017	56+00	.018
20	.018		
40	.018		
60	.018		
80	.018		

Table 12.--Gamma-radioactivity survey data, U12e.01 tunnel

Survey station	Radioactivity (mr/hr)	Survey station	Radioactivity (mr/hr)
0+60	0.019	8+00	0.017
80	.018	20	.015
		40	.016
1+00	.017	60	.018
20	.017	80	.017
40	.016		
60	.017	9+00	.018
80	.017	20	.017
		40	.016
2+00	.019	60	.015
20	.016	80	.017
40	.016		
60	.017	10+00	.017
80	.017	20	.017
		40	.015
3+00	.015	60	.015
20	.018	80	.017
40	.016		
60	.017	11+00	.016
80	.017	20	.017
		40	.018
4+00	.018	60	.017
20	.016	80	.015
40	.016	96	.017
60	.016		
80	.017	12+20	.017
		40	.017
5+00	.017	60	.017
20	.017	80	.016
40	.018		
60	.016	13+00	.017
80	.015	20	.017
		40	.018
6+00	.017	60	.015
20	.017	80	.017
40	.017		
60	.016	14+00	.016
80	.017	20	.017
		40	.016
7+00	.015	60	.017
20	.016	80	.017
40	.015		
60	.015		
80	.017		

natural, and is not an indication of the presence of explosion-produced radioisotopes. Slight changes in radioactivity are generally unrelated to geologic features. The radioactivity increases significantly at the contact between units Tilt₃ and Tilt₄ near station 2+00, although the radioactivity of the units themselves is of essentially the same intensity in the U12e.01 tunnel. The cause for this increase is not known.

U12e.02 tunnel

Gamma-radioactivity surveys were made in the U12e.02 tunnel (table 13) subsequent to a nuclear explosion in the chamber at the end of the original tunnel. The surveys were made between stations 0+20 and 3+60, in the reentry drift which is part of the original tunnel; in the reentry extension (stations 0+00 to 3+14) which starts at station 4+05.75 in the original tunnel; and in the reentry crosscut (station 0+05 to 1+40) which starts at station 2+41.93 in the reentry drift.

The radioactivity was in the range of 0.023 to more than 400 mr/hr. Most of the radioactivity is less than 40 mr/hr. The lowest radioactivity is in the original tunnel to about station 2+60. The higher radioactivity in the remainder of the tunnel has been caused by contamination during mining and possibly by contamination caused directly by radioisotopes transported at the time of the nuclear explosion. A shell of high gamma radioactivity, which is probably related to explosion-produced glass, is between stations 2+30 and 2+80 in the reentry extension and between stations 0+20 and 0+55 in the reentry crosscut. Explosion-produced glass was observed at station 2+55 in the reentry extension, where the radioactivity was greater than 400 mr/hr.

Table 13.--Gamma-radioactivity survey data, U12e.02 reentry tunnel

Survey station	Radioactivity (mr/hr)	Survey station	Radioactivity (mr/hr)
Reentry drift			
0+20	0.027	2+00	0.036
40	.041	20	.084
60	.033	40	.041
80	.033	60	.065
		80	.098
1+00	.027		
20	.023	3+00	.108
40	.027	20	.131
60	.033	40	.098
80	.046	60	.103
Reentry extension			
0+00	.28	1+00	0.080
05	.28	05	.080
10	.27	10	.086
15	.26	15	.086
20	.26	20	.094
25	.24	25	.094
30	.28	30	.105
35	.19	35	.12
40	.17	40	.13
45	.21	45	.13
50	.16	50	.12
55	.15	55	.13
60	.16	60	.12
65	.13	65	.125
70	.105	70	.17
75	.094	75	.18
80	.088	80	.145
85	.086	85	.27
90	.083	90	.21
95	.068	95	.21

Table 13.--Gamma-radioactivity survey data, U12e.02 reentry tunnel--
Continued

Survey station	Radioactivity (mr/hr)	Survey station	Radioactivity (mr/hr)
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Reentry extension--Continued

2+00	0.15	2+65	9.3
05	.36	70	43.0
10	.47	75	5.6
15	.47	80	2.5
20	.93	85	2.3
25	1.10	90	3.6
30	1.95	95	1.2
35	1.70		
40	7.0	3+00	.47
45	23.5	05	.36
50	28.0	10	.72
55	>400.0	14	.47
60	8.0		

Reentry crosscut

0+05	14.0	0+80	4.4
10	4.2	85	7.0
15	4.4	90	7.0
20	9.3	95	4.4
25	9.3		
30	37.5	1+00	4.4
35	33.0	05	11.0
40	26.0	10	8.0
45	4.4	15	12.5
50	16.0	20	23.5
55	30.0	25	11.0
60	12.5	30	16.0
65	7.0	35	19.5
70	3.1	40	12.5
75	8.0		

U12e.03 tunnel

A gamma-radioactivity survey of the main drift and Personnel tunnel of the U12e.03 tunnel was made on January 23, 1961. Measurements were made at 20-foot intervals between stations 0+20 and 11+30 in the main drift, and between stations 1+20 and 13+80 in the Personnel tunnel. The one exception is in the zone of anomalously high gamma radioactivity between stations 3+00 and 5+00 where measurements were made at intervals of 10 feet. The gamma-radioactivity data (table 14) were obtained on the right (north-northeast) wall of the tunnel.

The radioactivity was in the range of 0.014 to 0.86 mr/hr. Higher radioactivity (1.35 mr/hr) was measured on the left wall at station 4+60. The natural radioactivity is in the range of 0.014 to 0.017 mr/hr, and averages about 0.016 mr/hr.

Increases in radioactivity are sometimes related to fractures and faults (stations 2+20, 4+50 to 4+90, and 6+20). The highly radioactive zone between stations 4+30 and 4+90, and between 6+00 and 6+40 were caused by explosion-produced radioisotopes, probably from the Blanca test in the U12e.05 tunnel. Other zones of anomalous gamma radioactivity are probably unrelated to geologic features. For example, the increases in radioactivity at stations 3+40 and 4+00 to 4+30 may be caused by spillage of radioactive material from mine cars at the bends in the tunnel.

The low level of the radioactivity from station 7+00 to the heading will not interfere with post-nuclear-explosion studies.

Table 14.--Gamma-radioactivity survey data, U12e.03 tunnel

Survey station	Radioactivity (mr/hr)	Survey station	Radioactivity (mr/hr)
0+20	0.022	5+00	0.050
40	.021	20	.019
60	.019	40	.024
80	.017	60	.024
		80	.033
1+00	.015		
20	.015	6+00	.098
40	.017	20	.72
60	.019	40	.041
80	.019	60	.025
		80	.050
2+00	.021		
20	.029	7+00	.103
40	.020	20	.021
60	.019	40	.017
80	.018	60	.015
		80	.017
3+00	.029		
20	.024	8+00	.016
32	.079	20	.015
50	.023	40	.015
60	.021	60	.015
70	.035	80	.015
80	.055		
90	.065	9+00	.014
		20	.014
4+00	.089	40	.015
10	.103	60	.015
20	.093	80	.015
30	.098		
40	.38	10+00	.016
50	.48	20	.015
60	.75	40	.014
70	.86	60	.015
80	.58	80	.017
90	.108		
		11+00	.016
		20	.016
		12+00	.015

Table 14.--Gamma-radioactivity survey data, U12e.03 tunnel--Continued

Survey station	Radioactivity (mr/hr)	Survey station	Radioactivity (mr/hr)
Personnel tunnel			
1+20 <u>1/</u>	0.017	8+00	0.016
40	.017	20	.014
60	.015	40	.015
80	.016	60	.015
		80	.015
2+00	.015		
20	.015	9+00	.015
40	.016	20	.015
60	.015	40	.015
80	.015	60	.016
		80	.015
3+00	.016		
20	.015	10+00	.015
40	.017	20	.016
60	.017	40	.017
80	.016	60	.015
		80	.016
4+00	.015		
20	.015	11+00	.014
40	.016	20	.015
60	.014	40	.015
80	.016	60	.016
		80	.015
5+00	.016		
20	.014	12+00	.016
40	.015	20	.015
60	.016	40	.017
80	.016	60	.016
6+00	.016	13+00	.016
20	.015	20	.015
40	.016	40	.017
60	.015	60	.017
80	.015		
7+00	.015		
20	.015		
40	.015		
60	.016		
80	.015		

1/ Station 1+20 in Personnel tunnel (U12e.03) is the same as station 12+40 in main drift. Separate numbering system is used for station locations in Personnel tunnel.

U12e.03a tunnel

Gamma-radioactivity measurements were started at station 0+40 in the U12e.03a tunnel and were terminated at station 8+00 (table 15).

The natural gamma radioactivity observed in the tunnel is in the range of 0.14 to 0.18 mr/hr. No significant difference in the radioactivity in Tunnel Beds 3D and 4A of the lower member of the Indian Trail Formation was observed. Zones of anomalous radioactivity are related to a fault at station 2+65 and to sections of the tunnel where north-south fracture systems predominate; for example, from station 2+40 to 3+40 and from station 4+80 to 5+80. No data are available at present to explain these anomalies.

U12e.03b tunnel

Gamma radioactivity measured on the right (east) wall of the tunnel ranges from 0.014 to 0.017 mr/hr (table 16). This is within the range of natural gamma radioactivity measured elsewhere in the U12e tunnel system. The few small variations in gamma radioactivity observed in the tunnel are unrelated to geologic features.

U12e.04 tunnel

Gamma-radioactivity measurements were made at intervals of 20 feet between stations 0+40 and 17+30 on the right (west) wall in the L.O.S. tunnel of the U12e.04 tunnel (table 17). The walls in the section between stations 8+40 and 9+40 were inaccessible because of steel sets and lagging.

Table 15.--Gamma-radioactivity survey data, U12e.03a tunnel

Survey station	Radioactivity (mr/hr)	Survey station	Radioactivity (mr/hr)
0+40	0.015	5+00	0.017
60	.015	20	.018
80	.016	40	.017
		60	.018
1+00	.014	80	.015
20	.015		
40	.017	6+00	.016
60	.016	20	.016
80	.015	40	.015
		60	.016
2+00	.015	80	.016
20	.017		
40	.016	7+00	.015
60	.018	20	.015
80	.018	40	.015
		60	.016
3+00	.015	80	.015
20	.017		
40	.017	8+00	.017
60	.015		
80	.016		
4+00	.016		
20	.016		
40	.016		
60	.016		
80	.016		

Table 16.--Gamma-radioactivity survey data, U12e.03b tunnel

Survey station	Radioactivity (mr/hr)	Survey station	Radioactivity (mr/hr)
0+20	0.016	4+00	0.015
40	.016	20	.015
60	.015	40	.015
80	.016	60	.014
		80	.017
1+00	.015		
20	.015	5+00	.015
40	.014	20	.015
60	.014	40	.015
80	.015	60	.015
		80	.017
2+00	.015		
20	.016	6+00	.016
40	.016	20	.016
60	.015	40	.016
80	.015	60	.017
		80	.015
3+00	.016		
20	.015	7+00	.016
40	.016	20	.015
60	.017	40	.015
80	.015	58	.016

Table 17.--Gamma radioactivity survey data, U12e.04 L.O.S. tunnel

Survey station	Radioactivity (mr/hr)	Survey station	Radioactivity (mr/hr)	Survey station	Radioactivity (mr/hr)
0+00	0.016	6+00	0.015	12+00	0.015
60	.018	20	.015	20	.015
80	.017	40	.015	40	.014
		60	.016	60	.015
1+00	.023	80	.016	80	.015
20	.017				
40	.016	7+00	.015	13+00	.014
60	.015	20	.015	20	.014
80	.014	40	.015	40	.013
		60	.015	60	.015
2+00	.014	80	.015	80	.014
20	.015				
40	.015	8+00	.015	14+00	.015
60	.015	20	.017	20	.016
80	.015	40	.016	40	.015
				60	.015
3+00	.014	9+00	.014	80	.015
20	.015	60	.015		
40	.015	80	.015	15+00	.015
60	.015			20	.014
80	.015	10+00	.015	40	.014
		20	.016	60	.017
4+00	.014	40	.016	80	.014
20	.015	60	.017		
40	.015	80	.016	16+00	.015
60	.015			20	.013
80	.015	11+00	.015	40	.015
		20	.015	60	.014
5+00	.017	40	.018	80	.013
20	.015	60	.015		
40	.014	80	.015	17+00	.016
60	.015			20	.017
80	.016			40	.017
				50	.017

The radioactivity is in the range of 0.013 to 0.023 mr/hr and averages about 0.015 mr/hr. The relatively high radioactivity between stations 0+40 and 1+20 is probably caused by contamination from radioactive rock that has fallen from mine cars parked at various times in that section. Contamination of this type has also been observed in other tunnels. Excluding the section near the tunnel entrance, the radioactivity is in the range of the natural gamma radioactivity measured in other parts of the tunnel systems at the Nevada Test Site. Small variations in the gamma radioactivity measured in the U12e.04 tunnel, in some places, can be related to major faults--for example, near stations 11+40 and 15+40 and 15+40 to 16+20. Generally, however, changes in radioactivity are unrelated to geologic features.

U12e.05 reentry tunnel

The gamma-radioactivity survey of the U12e.05 reentry tunnel (table 18) into the site of a nuclear explosion indicates a radioactive shell about 155 feet (station 1+50) from the explosion site. The gamma radioactivity in the tunnel was in the range of 0.15 to 8.0 mr/hr. The highly gamma-radioactive zone that extends from about station 1+35 to about station 1+80 is probably associated with radioactive glass.

Table 18.--Gamma-radioactivity data, U12e.05 reentry tunnel

Survey station	Radioactivity (mr/hr)	Survey station	Radioactivity (mr/hr)
0+00	1.83	2+10	0.56
15	1.15	25	.70
30	1.30	40	.84
45	.24	55	.47
60	.135	70	.37
75	.15	85	.21
90	.26		
		3+00	.84
1+05	1.50		
20	1.50		
35	3.0		
50	8.0		
65	5.5		
80	.84		
95	3.15		

U12e.06 tunnel

The natural gamma radioactivity observed in the tunnel is in the range of 0.017 to 0.024 mr/hr (table 19). The radioactivity is essentially the same in subunits G, H₁, and H₂, except in the fractured and faulted zones. The observed gamma radioactivity is apparently related in a general way to the number of faults that intersect the tunnel. The radioactivity is greatest where faults are numerous, for example between stations 8+00 to 14+80, where a maximum value of 0.024 mr/hr was observed. The radioactivity in relatively unfaulted sections of the tunnel--stations 0+40 to 8+00--is roughly 0.017 to 0.020 mr/hr. In slightly faulted sections--stations 14+80 to 20+63--the radioactivity is 0.019 to 0.022 mr/hr.

The source of the anomalous gamma radioactivity in the section between 8+00 and 14+80 has not been determined. However, several water seeps were observed in this section of the tunnel and the orientation of the fractures and faults from which water is seeping does not exclude the possibility of water migration from the vicinity of the U12b tunnel. Therefore, the anomalous gamma radioactivity may be caused by waterborne radioisotopes resulting from nuclear explosions in the U12b tunnel system.

U12e.07 tunnel

Gamma-radioactivity measurements were made along the right (east) wall of the U12e.07 tunnel (table 20). The range of this radioactivity

Table 19.--Gamma-radioactivity survey data, U12e.06 tunnel

Survey station	Radioactivity (mr/hr)	Survey station	Radioactivity (mr/hr)	Survey station	Radioactivity (mr/hr)
0+40	0.017	7+00	0.019	14+00	.021
60	.019	20	.019	20	.021
80	.019	40	.021	40	.021
		60	.020	60	.021
1+00	.019	80	.020	80	.020
20	.021				
40	.020	8+00	.020	15+00	.019
60	.020	20	.019	20	.019
80	.020	40	.021	40	.019
		60	.022	60	.020
2+00	.019	80	.022	80	.020
20	.019				
40	.019	9+00	.021	16+00	.021
60	.020	20	.021	20	.019
80	.021	40	.022	40	.020
		60	.021	60	.021
3+00	.020	80	.022	80	.021
20	.019				
40	.019	10+00	.021	17+00	.021
60	.019	20	.022	20	.020
80	.021	40	.022	40	.021
		60	.022	60	.021
4+00	.020	80	.022	80	.022
20	.020				
40	.020	11+00	.022	18+00	.022
60	.020	20	.021	20	.021
80	.020	40	.021	40	.021
		60	.023	60	.021
5+00	.019	80	.023	80	.020
20	.019				
40	.020	12+00	.022	19+00	.022
60	.019	20	.022	20	.021
80	.018	40	.022	40	.021
		60	.022	60	.022
6+00	.019	80	.023	80	.022
20	.019			91	.022
40	.019	13+00	.023		
60	.018	20	.024	20+00	.022
80	.019	40	.024	20	.021
		60	.022	40	.021
		80	.022	63	.020

Table 20.--Gamma-radioactivity data, U12e.07 tunnel

Survey station	Radioactivity (mr/hr)	Survey station	Radioactivity (mr/hr)
0+20	0.017	7+00	0.020
40	.018	20	.019
60	.017	40	.018
80	.018	60	.018
		80	.017
1+00	.017		
20	.017	8+00	.017
40	.017	20	.017
60	.017	40	.017
80	.017	60	.017
		80	.017
2+00	.016		
20	.017	9+00	.017
40	.016	20	.016
60	.016	40	.017
80	.017	60	.017
		80	.017
3+00	.017		
20	.017	10+00	.017
40	.017	20	.017
60	.017	40	.017
80	.018	60	.017
		80	.017
4+00	.018		
20	.018	11+00	.017
40	.019	20	.017
60	.020	40	.016
80	.019	60	.016
		80	.016
5+00	.020		
20	.019	12+00	.017
40	.021	20	.017
60	.019	40	.017
80	.018	60	.017
		80	.017
6+00	.019		
20	.018	13+00	.017
40	.018	20	.017
60	.020	40	.017
80	.018	60	.016
		80	.016

Table 20--Gamma-radioactivity data, U12e.07 tunnel--Continued

Survey station	Radioactivity (mr/hr)	Survey station	Radioactivity (mr/hr)
14+00	0.017	20+00	0.017
20	.017	20	.017
40	.017	40	.018
60	.017	60	.017
80	.016	80	.018
15+00	.017	21+00	.017
20	.017	20	.017
40	.018	40	.017
60	.017	60	.017
80	.017	80	.017
16+00	.018	22+00	.018
20	.018	20	.017
40	.017	40	.018
60	.017	60	.018
80	.018	80	.018
17+00	.017	23+00	.018
20	.017	20	.017
40	.017	40	.017
60	.017	60	.017
80	.017	80	.018
18+00	.017	24+00	.017
20	.017	20	.017
40	.018	40	.016
60	.017	60	.018
80	.017		
19+00	.018	25+20	.017
20	.018	40	.017
40	.017	60	.017
60	.017	80	.017
80	.018	26+00	.017

is 0.016 to 0.020 mr/hr which is about within the range of natural gamma radioactivity observed elsewhere in the U12e tunnel system.

Granite tunnel

The gamma-radioactivity of the Granite tunnel located at the Granite Site in Area 15 was surveyed in October 1960. The survey was made along the right (east) wall of the tunnel from stations 0+2 to 5+80. The radioactivity is in the range of 0.019 to 0.028 mr/hr) (table 21). The natural gamma radioactivity here is higher than has been observed in other rock types at the Nevada Test Site. The higher radioactivity is probably caused by greater concentrations of radioisotopes of uranium, thorium, and potassium than is present in other rock types. The radioactivity is slightly higher in the tunnel than in drill holes in the vicinity of the tunnel; the difference may be attributable to source-to-detector geometry and mass effect.

DRILL-HOLE LOGS

Gamma-ray logs were made in exploratory drill holes to determine the intensity of the natural gamma radioactivity and to aid geologic studies. The data on the natural radioactivity are used as a basis for determining the distribution of explosion-produced gamma radioactivity in holes drilled after nuclear explosions.

Table 21.--Gamma-radioactivity data, Granite tunnel

Survey station	Radioactivity (mr/hr)	Survey station	Radioactivity (mr/hr)
0+02	0.023	3+00	0.023
10	.026	20	.023
20	.028	40	.021
30	.023	60	.022
40	.022	80	.022
50	.022		
60	.022	4+00	.021
70	.023	20	.021
80	.023	40	.022
90	.023	60	.021
		84	.021
1+00	.024		
20	.023	5+00	.021
40	.022	20	.022
60	.021	40	.021
80	.022	58	.019
		80	.020
2+00	.021		
20	.022		
40	.022		
60	.023		
80	.022		

Granite Site, Area U15

Four drill holes in the vicinity of the Granite Site (fig. 5) in Area U15, the location of an underground nuclear explosion, were gamma-ray logged prior to the explosion. The logs of holes 28, 29, 32, and 33 (figs. 6, 7, 8, and 9) indicate gamma radioactivity in the range of 0.012 to 0.045 mr/hr. No large changes in this radioactivity were observed; however, the slight variations observed on all the logs indicate that the rock may not be completely homogeneous.

Buckboard Mesa

Buckboard Mesa is located in the western part of the Nevada Test Site. The mesa is capped by basalt overlying tuff. Three holes (fig. 10) in this area were gamma-ray logged (fig. 11). Wagon drill hole 1 was drilled for geologic studies and core was recovered; holes DB-2 and DB-27 were drilled for seismic studies. The natural gamma radioactivity is about 0.01 to 0.023 mr/hr, essentially the same as that measured in tuff and alluvium. The partly saturated, weathered basalt near the top of Wagon 1 is slightly more radioactive than unweathered basalt. No significant change is observed at the basalt-tuff contact near the bottom of the hole.

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Figure 5.--Index map of drill-hole locations, Granite Site, Area U15, Nevada Test Site

Figure 6. — Gamma-ray log, drill hole 28, Granite Site, Area U15, Nevada Test Site

Drill hole 29
Collar elevation 5115 ft.

Figure 7 — Gamma-ray log, drill hole 29, Granite site, Area U15, Nevada Test Site

Logged by C.M. Bunker and M.D. Shutler, Nov. 17, 1960

Figure 9. — Gamma-ray log, drill hole 33, Granite Site, Area UI5, Nevada Test Site.

Figure 10.--Index map, drill-hole locations, Buckboard Mesa, Nevada Test Site

Figure 11.— Gamma-ray logs of drill holes, Wagon 1, DB-2, and DB-27, Buckboard Mesa, Nevada Test Site

CONCLUSIONS

The natural gamma-radioactivity of tuff penetrated by the U12b and U12e tunnel systems is generally in the range of 0.015 to 0.025 mr/hr. Higher radioactivity is attributed to contamination by nuclear-explosion-produced radioisotopes. Changes in the gamma radioactivity are not necessarily related to changes in rock type.

Explosion-produced radioactivity as great as 400 mr/hr was measured near the sites of underground nuclear explosions. Shell-like structures of anomalously high radioactivity, similar to that observed in the vicinity of the Rainier explosion (Bunker, 1961), were noted in the U12e.02 and U12e.05 tunnels. The gamma radioactivity in the shells is locally related to zones of visible explosion-produced glass. Some zones of high radioactivity are related to fractures and faults through which radioisotopes were apparently transmitted at the time of the nuclear explosions.

Gamma-ray logs of holes at Buckboard Mesa and the Granite Site show no significant changes in radioactivity, except at casing changes and at the water level.

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Figure 8. — Gamma-ray log, drill hole 32, Granite Site, Area U15, Nevada Test Site