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RADON ALPHA-TRACK SURVEY OF A POTENTIAL GEOTHERMAL RESOURCE AREA

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ABSTRACT

Alpha-track detectors for radon-222 were placed in the ground near and away from radioactive warm pools in Buffalo Valley, Nevada. Subsequent etching of the detectors revealed high track densities at locations near the pools and a tenfold decrease in track densities in detectors away from the pools. In the southern part of Buffalo Valley, relatively high track densities reflect the proximity of the detectors to rhyolitic tuffs which underlie valley alluvium and are the source of most of the alluvial material. With the exception of the hot springs area and a single site northwest of the springs, the contoured radon track density field is fairly featureless in the region surveyed. Uranium contents of soil samples from track-detector holes do not correlate with alpha track densities, indicating that a substantial portion of the radon measured comes from sources deeper than the soil surrounding the detectors.

Introduction

The registration of alpha particles in plastics has been applied to the search for uranium in recent years. The basic track etch concept (Fleischer et al., 1972), was modified and patented by scientists of the Terradex Corporation (Alter, 1972) and the General Electric Vallecitos Laboratory to detect alpha particles from the decay of radon-222, a gaseous daughter product of uranium-238. Inverted plastic cups with a specially treated dielectric alpha-track detector attached inside are placed, each in an approximately 0.5 m-deep hole, in arrays of varying extent. The walls of the cup are thick enough to exclude alpha particles from radon in the air surrounding the cup; the only contribution is from radon emanating from soil directly beneath the mouth of the inverted cup. After exposure of several weeks, the cups are retrieved, the detectors removed and etched, revealing track densities proportional to the emanating radon flux. Significant uranium ore bodies, not detected by more traditional gamma-ray surveys, have been discovered by this method (Gingrich, 1974). It has been shown that radon travels through several tens of meters of overburden, which otherewise conceals an ore deposit by shielding its gamma radiation.

It was noted by Wollenberg (1974) that anomalously high radon emanations were associated with some hot spring systems, especially those where calcium carbonate predominates. An array of radon alpha-track detectors near and away from a radioactive spring system might indicate fault zones along which warm, radon- and radium-enriched waters were migrating.

Procedures

A good test site was afforded by hot springs in Buffalo Valley in north-central Nevada (see location map, Fig. 1). Because of the sharply varying gamma-ray fields measured at the springs, a set of alpha-track detectors was installed in their immediate area (a map of the hot springs area, showing detector locations, comprises Fig. 2). Also, an array of detectors, covering a much larger area, was installed in the valley surrounding the hot springs; detector locations and track density contours are shown in Fig. 3. The track etch detectors, mounted in plastic cups, were generously provided and processed by the Terradex Corporation (a track etch service corporation affiliate of General Electric).

Uranium and Radon

Comparison of track densities and uranium content of surficial material provides a qualitative indicator of the effect, if any, of soil uranium on the observed track densities. Therefore, to determine the uranium content of the soil directly beneath and surrounding the cups, samples of soil from the cup holes were collected and later analyzed for natural radioelement contents by gamma spectrometry at Lawrence Berkeley Laboratory. Examination of tabulated radioelement and track-density data (Table 1) indicates no apparent correlation between near-surface uranium content and track density. Frequency distributions of U and track densities are shown as histograms in Fig. 4. The ranges of U content are not nearly so broad as the range in track densities.

Radon Emanation in the Vicinity of the Hot Springs

Inspection of the sketch map (Fig. 2) shows that the small pools and mounds at Buffalo Valley Hot Springs, from which radon emanates, are associated with high track densities (several hundred to several thousand tracks/mm^2) in detectors placed nearby. However, at some locations only a few tens of meters away from the mounds and pools, well within the springs area, track densities are "normal" (tens of tracks/mm^2), while at other locations, roughly equidistant from the radioactive pools, densities are appreciably greater than normal. Therefore, radon emanations vary sharply within the springs area, though a general north-south-trending "high" is indicated on Fig. 2.

At sample locations in the hot springs area, total gamma radioactivity was measured by a 3-inch-diameter by 3-inch-thick Na I(Tℓ) detector, on the surface and within the approximately 15 cm-diameter holes dug for the radon detectors. The contribution of emanating radon to the observed gamma radioactivity was estimated by subtracting the count rate calculated from the U, Th, and K contents of soil samples, from the total observed count rate. (Calculations were based on concentration-to-exposure rate conversion factors in Beck et al. (1968), and the exposure rate-to-count rate calibration for the field gamma-ray detector.) Background count rates for the in-hole configuration were estimated by scaling up calculated surface background count rates proportionately to the ratios of radioactivities measured in-hole and on the surface. Results are listed on Table 2, and indicate that high measured count rates (>500 c/sec) were predominantly from radon, while lower rates were mainly from U, Th and K in near-surface soil.

Radon Emanation in the Valley Away from the Springs

With the exception of one location, #54, the track density contour pattern is explained by the lithology of the valley-fill and sub-alluvial material in Buffalo Valley. Relatively high track densities on the east and southeast sides of the valley reflect the relatively thin veneer of alluvium covering rhyolitic ash flow tuffs, whose uranium contents range from 10 to 15 ppm and thorium from 30 to 50 ppm (unpublished data). These tuffs were deposited by volcanism associated with an active caldera 20 to 25 million years ago (McKee, 1970). A large proportion of the Tertiary and Quaternary sediments in the east and southeast sections of Buffalo Valley is tuffaceous material derived from the Fish Creek Mountains. The radioelement contents of near-surface soil samples in this area are similar to those in other areas of the valley, indicating that the high track densities observed are from radon emanating from deeper alluvial material, or from the tuffs themselves. The basalt cinder cones and flows bordering the east side of Buffalo Valley, of considerably lower radioactivity than the tuffs, are more limited in extent, and are considerably younger (age about 3 million years), than the tuffs. The basalt, therefore, has not contributed as much material to the deeper alluvium. Relatively low track densities in the rest of the area covered reflect the deep alluvial material, where debris predominates from Paleozoic and Mesozoic sedimentary terranes in the Tobin Range and northern Fish Creek Mountains.

The relatively high track density at location #54, 79 tracks/mm^2, surrounded by locations where track densities are "normal", cannot be explained now. There is an old drill hole nearby, of unknown depth in playa sediments, which may have had an effect on radon emanation in this area. Obviously, more locations, closer to the drill hole and location #54, are necessary to substantiate this anomaly.

Conclusion

Radon alpha-track detectors, presently used successfully to delineate concealed uranium deposits, are also sensitive to radon emanated from radioactive geothermal systems. The spotty nature of radon emanated in the Buffalo Valley Hot Springs area was evidenced by detectors near and away from radioactive pools and mounds. Within the valley away from the springs, a single high-track-density location perturbs an otherwise relatively uniform radon field, reflecting the composition of alluvial and sub-alluvial materials. The association of high track density at location #54 with subsurface geothermal activity can only be confirmed by a tighter array of track detectors surrounding the location, and subsequent heat-flow drilling.

Acknowledgments

I thank Daniel Lovett of G. E. Vallecitos and H. W. Alter and J. E. Gingrich of Terradex Corporation for preparation and processing of alpha-track detectors. Most of the detectors were emplaced and retrieved, and soil samples obtained, by R. Solbau of the LBL geothermal studies group. A. R. Smith of LBL performed most of the gamma ray spectrometric analyses of soil samples.

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Table 1. Field, Track Density, and Gamma-Spectrometric Results of Buffalo Valley Radon Array.

	GE Ser. No.	Tracks/mm^2	Equiv. U (ppm)	Th (ppm)	K (%)
Buffalo Hot Springs Area[a]					
	9542	2598	65.7	6.20	0.35
	9549		21.7	5.08	1.18
	9548	27	5.57	5.18	1.61
	9547	355	27.7	5.73	1.05
	9535	429	52.0	4.31	0.44
	9545	30	3.29	10.25	3.00
	9541	286			
	9540	112	2.47	6.65	1.98
	9539	332	2.58	8.64	1.73
	9538	225	1.43	2.86	0.94
	9537	25			
	9536	30			
Buffalo Valley Array[b]					
Location					
7	9544	42			
8	9543	56	4.17	14.36	2.77
39	9534	55	4.96	15.35	2.72
A	9533	59	4.86	17.32	3.08
49	9532	41	4.19	13.85	2.88
48	9531	55	4.53	14.09	2.77
46	9570	58	5.16	15.14	2.57
35	9569	37	3.79	13.73	2.69
28	9568	31	3.82	12.39	2.82
87	9567	28	3.86	9.83	2.94
1	9566	41	4.16	12.56	3.07
85	9565	18	4.21	11.38	3.25

Location	GE Ser. No.	Tracks/mm^2 (30 day exp.)	Equiv. U (ppm)	Th (ppm)	K (%)
12	9564	29	4.04	11.04	2.33
2	9563	38	3.49	9.50	2.13
4	9562	22	3.59	10.34	2.17
36	9561	27	3.36	9.41	2.23
43	9560	23	2.85	8.40	1.86
45	9559	28	3.42	10.65	2.08
B	9558	31	4.26	14.80	3.16
90	9557	37			
86	9556	40	3.95	11.20	2.50
83	9555	28	3.86	12.70	2.70
80	9554	21	2.92	6.99	1.70
156x	9553	33	4.41	13.42	2.63
157	9552	19	4.52	10.37	2.51
155	9551	10	2.83	8.04	2.40
53	9580	27	3.47	10.27	1.98
54	9579	79	3.12	7.86	1.88
50	9578	21	3.82	8.03	1.64
25	9577	Lost	3.05	8.59	2.13
52	9576	7	3.18	6.91	1.56
29	9575	28	3.09	8.57	2.42
26	9574	38	3.10	8.11	1.60
32	9573	16	3.84	9.14	2.20
60	9572	36	2.73	7.60	2.22
34	9571	13	3.64	11.37	2.05
	Mean	32.5	3.76	10.88	2.39
Standard deviation		15.5	0.64	2.73	0.47

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[a] Location by track density, as shown on Figure 2.

[b] Location numbers shown on Figure 3.

Table 2. Observed, Background and Net Gamma Radioactivities from ^{222}Rn in Counts Per Second, in Buffalo Hot Springs Area.

Tracks/mm^2	Observed		Background from U, Th, K in soil		Net, from Rn	
	surface	in-hole	surface	in-hole	surface	in-hole
2598	2000	3500	210	368	1890	3132
--	750	1700	240	544	510	1156
27	400	575	335	481	65	94
355	1200	2100	242	423	958	1677
429	1200	2900	186	450	1014	2450
30	500	750	417	625	83	125
56	575	750	490	639	85	111
112	320	430	283	380	37	50
332	420	550	300	392	120	158
225	300	300	137	137	163	163

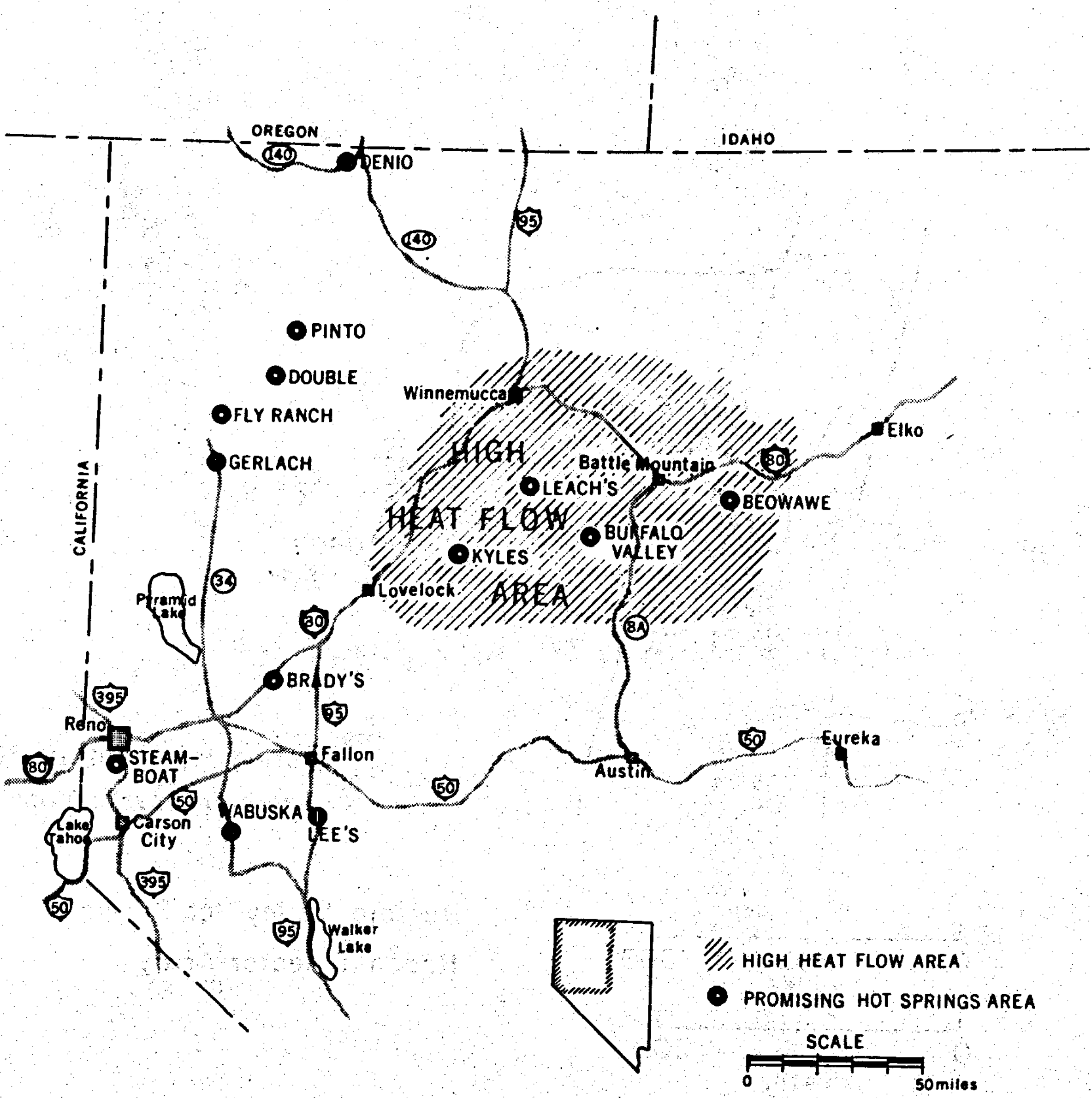
Figure Captions

1. Location map, northwestern Nevada, showing Buffalo Valley and other prominent thermal spring areas within and outside of the Battle Mountain high heat flow region.

2. Sketch map of Buffalo Valley Hot Springs area, showing locations of some of the warm pools, temperatures, and normalized track densities.

3. Contours of radon alpha-track density (in tracks/mm, normalized to a 30-day exposure) in Buffalo Valley. Dotted numbers: locations corresponding to those on Table 1.

4. Frequency distribution of track densities normalized to a 30 day exposure (a), and (b), uranium contents of soils from track detector holes in Buffalo Valley.



Hot Springs in Northwestern Nevada

XBL 735 676

Fig. 1.

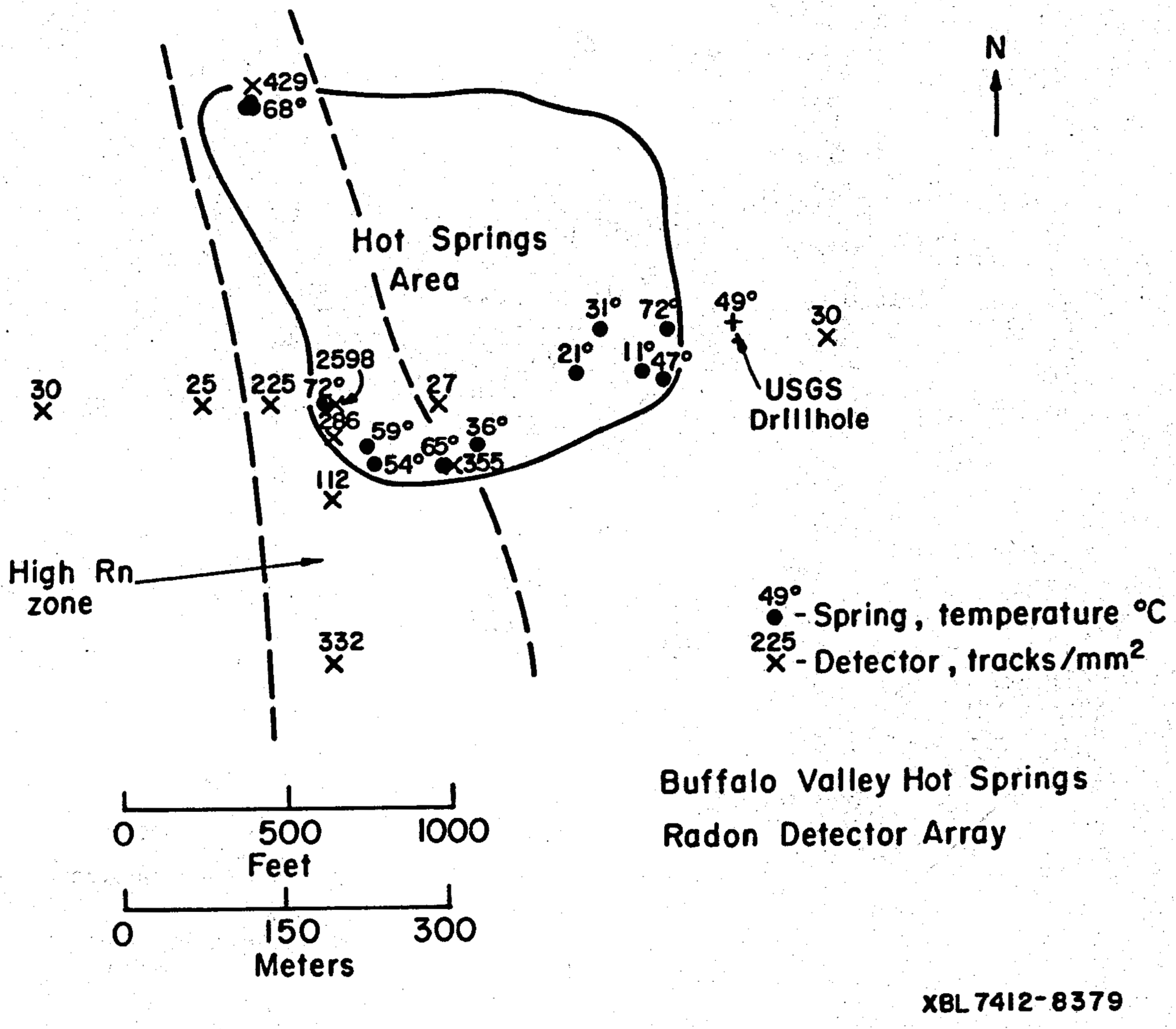

N
429
68°
Hot Springs
Area
31°
72°
49°
30
21°
11°
47°
USGS
Drillhole
30
25
225
2598
72°
27
286
59°
36°
65°
54°
355
112
High Rn
zone
49°
- Spring, temperature °C
225
- Detector, tracks/mm²
332
0
500
1000
Feet
0
150
300
Meters
Buffalo Valley Hot Springs
Radon Detector Array
XBL 7412-8379

Fig. 2.

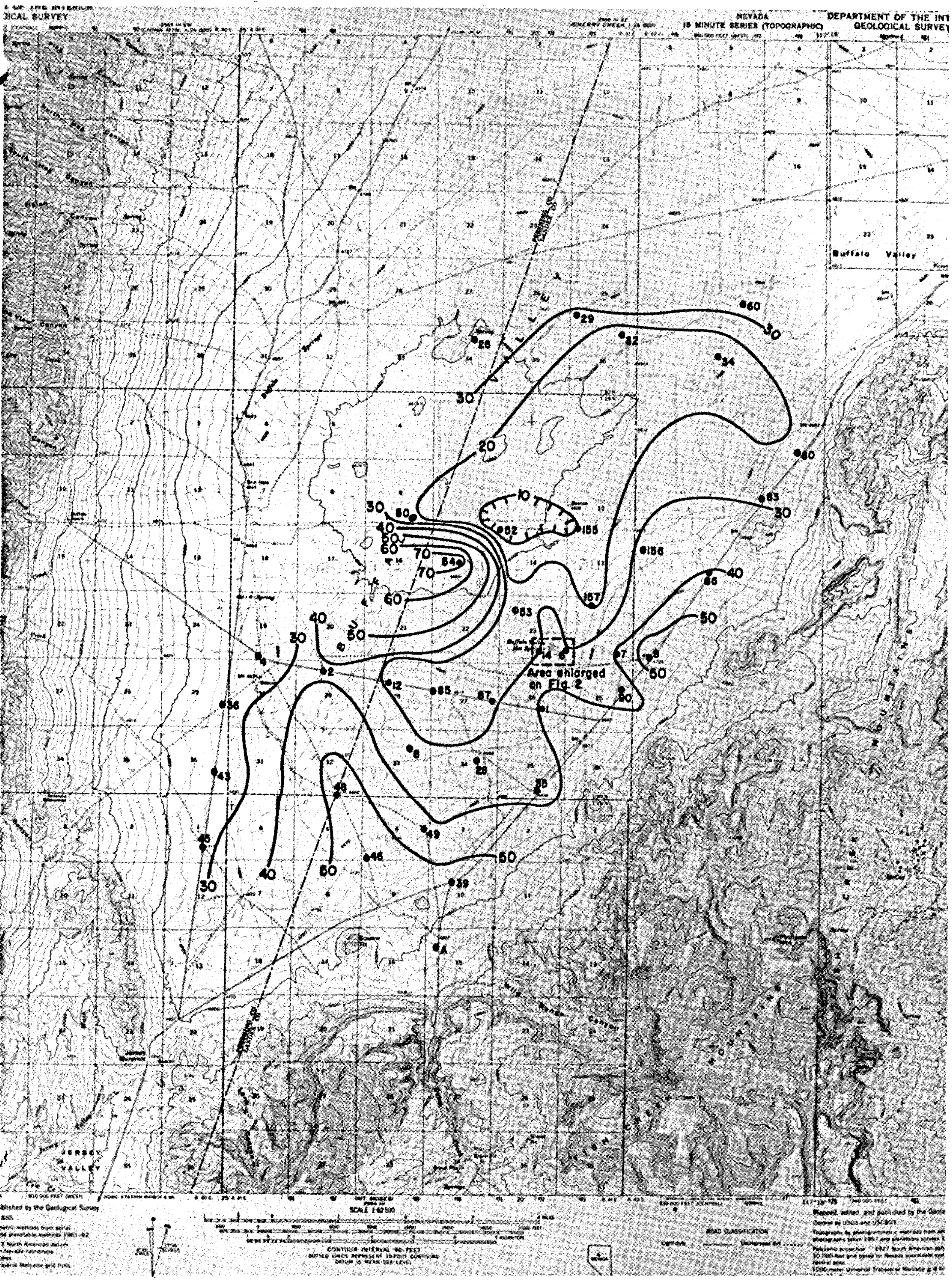
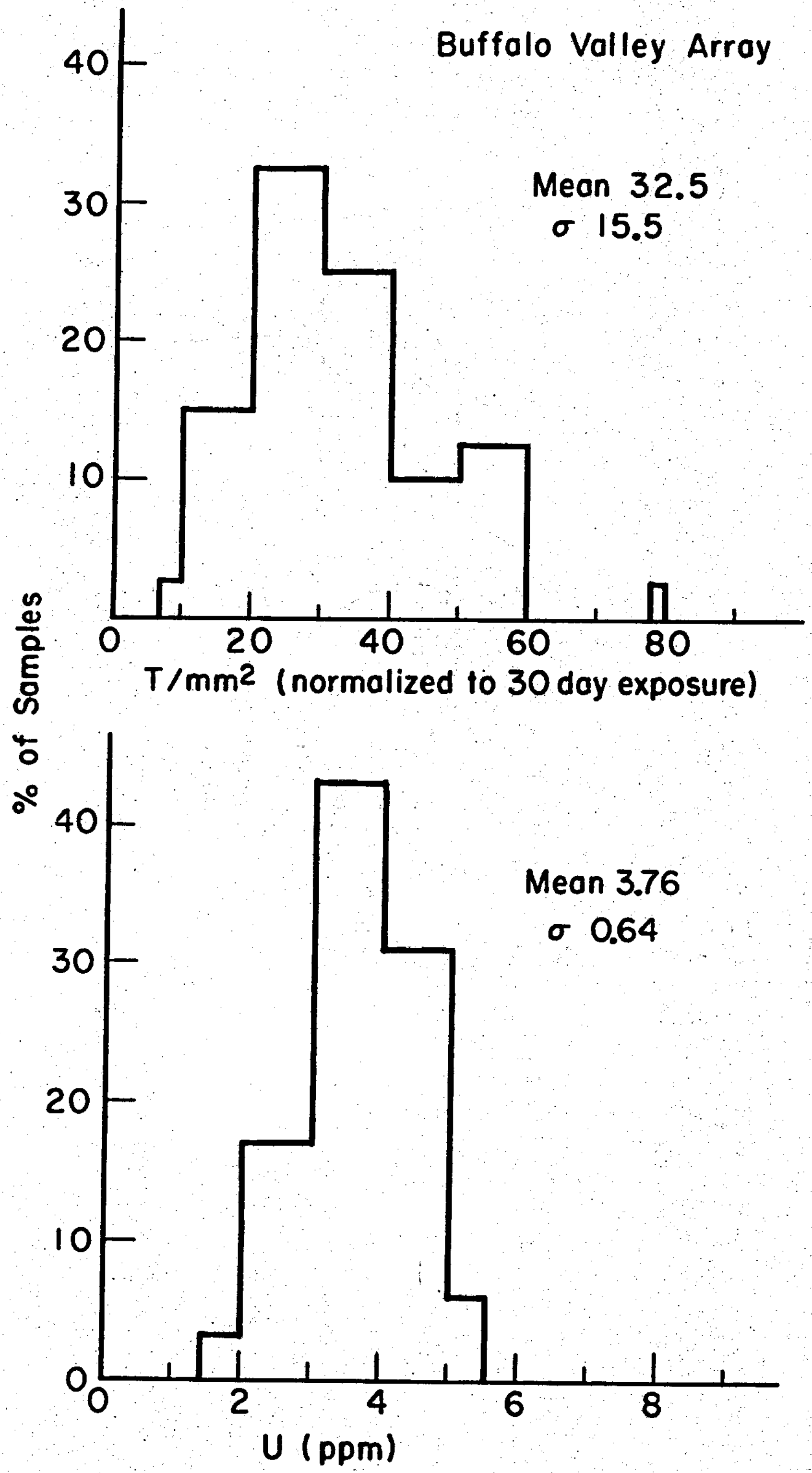

DEPARTMENT OF THE INT
GEOLOGICAL SURVEY
NEVADA
15 MINUTE SERIES (TOPOGRAPHIC)
Buffalo Valley
JERSEY
VALLEY
Area enlarged on Fig. 2
10
20
30
40
50
60
70
29
60
32
34
26
80
63
155
156
152
64
86
157
53
14
7
8
12
85
87
1
90
2
36
43
8
28
25
48
49
46
39
A
SCALE 1:62500
CONTOUR INTERVAL 80 FEET
DOTTED LINES REPRESENT 40-FOOT CONTOURS
DATUM IS MEAN SEA LEVEL
ROAD CLASSIFICATION

Fig. 3.



XBL7412-8380

Fig. 4.