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RADIOELEMENT DISTRIBUTION IN DRILL-HOLE USW-G1, YUCCA MOUNTAIN, NYE COUNTY, NEVADA

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INTRODUCTION

Drill-hole USW-G1 is one of a series of test holes drilled in the vicinity of Yucca Mountain to acquire geologic, geophysical, hydrologic, and geochemical data to determine the feasibility of using the area for long-term storage of nuclear waste. The borehole is at lat 36°52'00" N., long 116°27'29" W.; the collar elevation is 4,348.6 ft above mean sea level. The hole was drilled to 6,000 ft.

Seventy core samples ranging from 0.3-0.8 ft in length were collected at random intervals from 755.2-5,973.0 ft; some samples were selected specifically to determine the effects of welding and alteration.

The radioelement contents (radium equivalent uranium (RaeU), thorium, and potassium) of samples collected from drill hole USW-G1 were measured to characterize the geologic units penetrated by the hole, to determine the homogeneity of the units, and to ascertain where redistribution of the radioelements may have occurred. Evidence of radioelement migration is important in potential waste-disposal sites because it suggests previous fluid movement through permeable sections of the geologic units that, in turn, reflects the relative permeability and physical competence of the units. Thorium is insoluble in high-temperature fluids or groundwater, and variations in its content probably indicate variations in original magma composition or variations in the physical mechanisms of eruptive processes. In contrast, RaeU and potassium are more soluble, and variations in the concentrations of these radioelements that are independent of thorium variations probably indicate postemplacement alteration.

ANALYTICAL METHOD

RaeU (radium-equivalent uranium), thorium and potassium contents of the samples were measured by gamma-ray spectrometry. Basic operational procedures, calibration techniques, and sample preparation were described by Bunker and Bush (1966, 1967) and Bush (1981). Approximately 600 g of the material were sealed in 15-cm-diameter plastic containers. The containers were placed on a sodium iodide crystal, 12.5 cm in diameter and 10 cm thick. The gamma radiation penetrating the crystal was sorted according to energy by the associated electronic devices and the resulting spectra were stored in a 512-channel memory. The spectra were interpreted with the aid of a linear least-squares computer method that matches the spectrum from a sample to a library of radioelement standards; the computer method for determining concentrations is a modification of a program written by Schonfeld (1966). Standards used to reduce the data include the USGS standard rocks, New Brunswick Laboratories standards, and several samples for which uranium and thorium concentrations have been determined by isotope-dilution mass spectrometry or alpha spectrometry.

Uranium content was measured indirectly by measuring the ^{226}Ra daughters (^{214}Bi and ^{214}Pb) to obtain radium-equivalent uranium (RaeU) values. Radium-equivalent uranium is the amount of uranium required for secular isotopic equilibrium with the ^{226}Ra and its daughters measured in a sample. Isotopic equilibrium between these daughters and ^{226}Ra was accomplished by allowing the sealed sample containers to sit for at least 21 days prior to the analyses. All uranium concentrations measured in the drill-hole samples are radium-equivalent values.

Although thorium is also measured from daughter products (^{212}Bi, ^{212}Pb, and ^{208}Tl), isotopic disequilibrium is improbable because of the short half-lives of the daughter products measured, and the values are considered to be a direct measurement of thorium. Potassium is determined from the ^{40}K constituent that is radioactive and directly proportional to the total potassium.

All of the radioelement data reported in this report are based on replicate analyses. The coefficient of variation for the accuracy of these data, when compared to isotope-dilution and flame-photometry analyses, is about ±3 percent for RaeU and thorium and about ±1 percent for potassium. These percentages are in addition to minimum standard deviations of about 0.05 ppm for RaeU and thorium and 0.03 percent for potassium.

The radiogenic heat, that is, the heat produced by the disintegration of the radionuclides, was determined for each sample and for the averages of the rock types using the constants from Birch (1954). The heat production A, in units of 10^{-6} cal/g-yr, was calculated from

$$A = 0.73\ U + 0.20\ Th + 0.27\ K,$$

where U and Th are in parts per million and K is in percent.

RESULTS

The stratigraphy and a detailed lithologic description of the rocks penetrated by drill hole USW-G1 have been reported by Spengler and others (1981); the data are summarized in the present report where pertinent to correlations with the radioelement data. The geologic units sampled and analyzed (fig. 1 and table 1) include the lower-part of the Topopah Spring Member of the Paintbrush Tuff, the tuffaceous beds of Calico Hills, the Prow Pass, Bullfrog, and Tram Members of the Crater Flat Tuff, a flow breccia, tuff of Lithic Ridge (lithic-rich tuff in Spengler and others, 1981), and a thick sequence of older ash-flow and bedded tuffs. All the units include a basal zone that is not lithologically representative of the unit. Data from these zones have been excluded from calculations of average radioelement contents.

Topopah Spring Member, Paintbrush Tuff

Twelve samples collected from 755.2-1,399.8 ft in the Topopah Spring Member were analyzed. In this interval, the member consists of devitrified and densely welded ash-flow tuff from 755.2-1,287.0 ft vitrophyric and densely welded tuff from 1,287.0-1,342.4 ft, moderately welded at 1,342.4 ft, and nonwelded tuff at 1,394.3 ft. A basal layer from 1,394.3-1,399.9 ft is zeolitized and contains volcanic pebbles 4 to 6 cm in size that were not observed elsewhere in the member; radioelement contents from this layer are anomalous relative to the rest of the Topopah Spring and the underlying

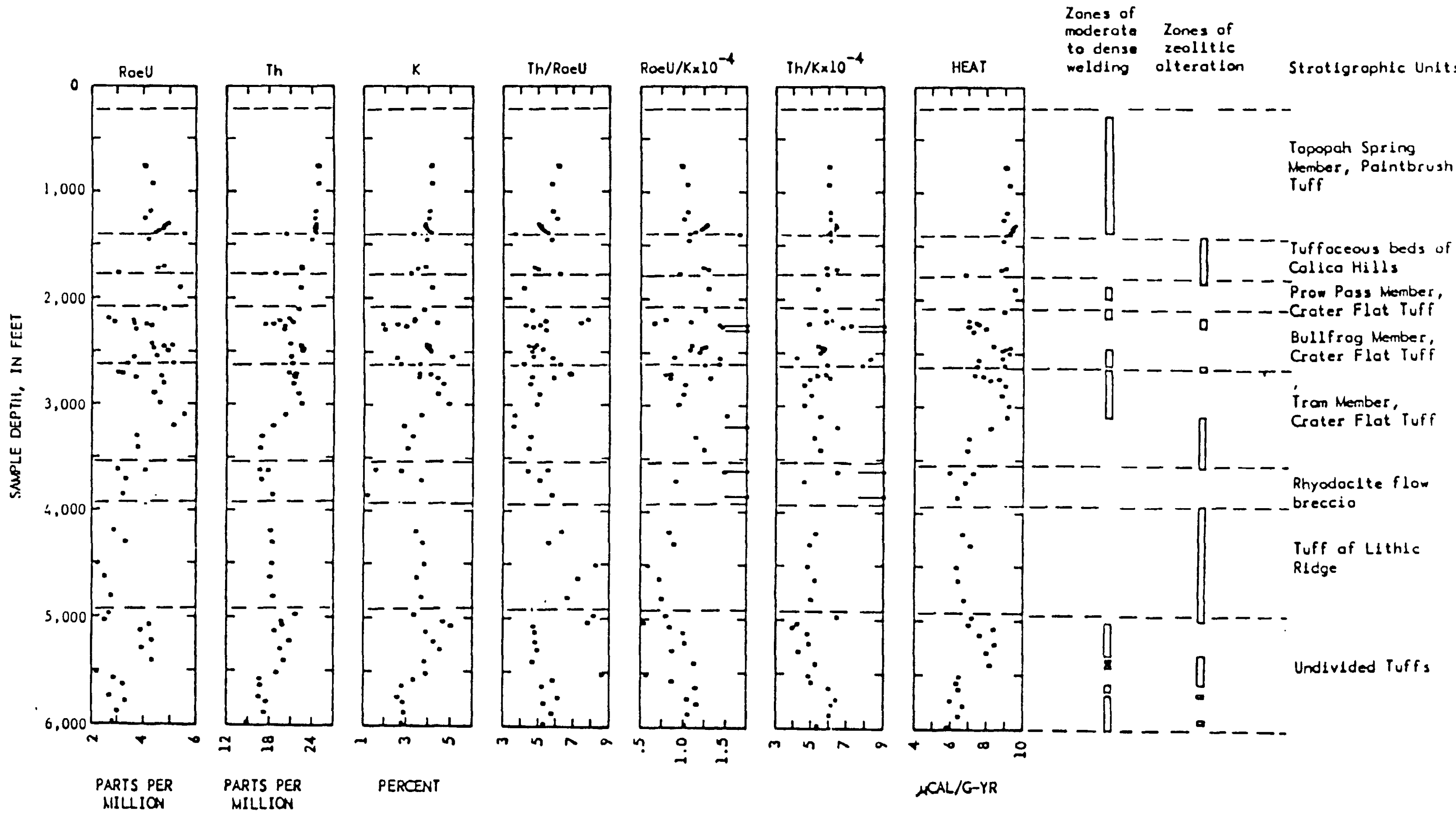

Figure 1.--Radioelement concentrations and ratios in drill hole USW-G1. Long ticks indicate points beyond scale limit.

Table 1.--Radioelement contents and ratios in core samples, drill hole USW-G1.

Sample depth (ft)	RaeU (ppm)	Th (ppm)	K (pct)	Th/ RaeU	RaeU/ Kx10^{-4}	Th/ Kx10^{-4}
Topopah Spring Member, Paintbrush Tuff						
755.2-755.6	4.0	24.7	4.13	6.14	0.97	5.98
765.6-766.2	4.1	24.9	4.12	6.15	0.98	6.04
928.0-928.8	4.3	24.8	4.14	5.74	1.04	5.99
1,184.6-1,185.0	4.2	24.4	4.03	5.78	1.05	6.05
1,252.2-1,252.6	4.0	24.3	4.00	6.04	1.01	6.08
1,302.9-1,303.3	4.9	24.5	3.85	4.99	1.28	6.36
1,321.4-1,321.9	4.8	24.5	3.81	5.14	1.25	6.43
1,335.2-1,335.8	4.8	24.2	3.87	5.09	1.23	6.25
1,348.4-1,348.8	4.7	24.5	3.91	5.18	1.21	6.27
1,369.8-1,370.3	4.6	24.2	3.99	5.32	1.14	6.07
1,389.4-1,390.1	4.4	24.5	4.12	5.53	1.08	5.95
1,399.2-1,399.8	5.5	20.3	3.32	3.66	1.67	6.11
Tuffaceous beds of Calico Hills						
1,453.8-1,454.4	4.2	23.9	3.91	5.73	1.07	6.11
1,710.3-1,710.7	4.8	22.5	3.85	4.74	1.23	5.84
1,728.5-1,729.2	4.5	22.5	3.50	4.98	1.29	6.43
1,770.5-1,771.0	3.0	18.8	3.19	6.20	0.95	5.89
Prow Pass Member, Crater Flat tuff						
1,902.0-1,902.4	5.4	22.4	4.16	4.16	1.29	5.38
2,105.6-2,106.0	4.8	22.1	3.80	4.62	1.26	5.82

Table 1.--Radioelement contents and ratios in core samples drill hole USW-G1. (Con't)

Sample depth (ft)	RaeU (ppm)	Th (ppm)	K (pct)	Th/ (RaeU)	RaeU/ Kx10^{-4}	Th/ Kx10^{-4})
Bullfrog Member, Crater Flat tuff						
2,192.2-2,192.6	2.7	20.8	3.37	7.82	0.79	6.17
2,209.2-2,209.7	3.6	19.4	3.33	5.37	1.08	5.83
2,225.0-2,225.7	2.9	21.3	4.38	7.40	0.66	4.86
2,242.6-2,243.1	3.6	18.5	2.56	5.08	1.42	7.23
2,245.3-2,245.9	4.1	17.4	1.91	4.26	2.14	9.11
2,261.5-2,262.2	4.3	20.1	2.96	4.69	1.45	6.79
2,292.9-2,293.4	3.7	20.0	1.99	5.41	1.86	10.1
2,430.2-2,430.8	4.3	20.9	3.89	4.87	1.10	5.37
2,443.2-2,443.9	5.1	22.4	4.02	4.43	1.26	5.57
2,456.1-2,456.7	4.7	22.4	3.90	4.73	1.22	5.74
2,474.0-2,474.5	4.4	22.8	4.03	5.24	1.08	5.66
2,496.5-2,497.0	4.9	22.6	4.11	4.61	1.19	5.50
2,544.2-2,544.7	4.5	21.0	5.04	4.69	0.89	4.17
2,557.0-2,557.5	3.6	21.0	2.54	5.80	1.43	8.27
2,611.0-2,611.4	5.1	21.2	3.60	4.15	1.42	5.89
2,616.4-2,617.0	3.4	21.2	2.70	6.25	1.26	7.85
Tram Member, Crater Flat tuff						
2,700.8-2,701.2	3.0	20.7	3.57	6.85	0.85	5.80
2,709.5-2,710.0	3.2	21.7	4.07	6.78	0.79	5.33
2,736.2-2,736.8	4.7	21.4	3.54	4.60	1.31	6.05
2,745.6-2,746.2	3.7	21.5	4.38	5.84	0.84	4.91

Table 1.--Radioelement contents and ratios in core samples, drill hole USW-G1. (Con't)

Sample depth (ft)	RaeU (ppm)	Th (ppm)	K (pct)	Th/ RaeU	RaeU/ $Kx10^{-4}$	Th/ $Kx10^{-4}$
Tram Member, Crater Flat tuff, Cont.						
2,800.8-2,801.1	4.7	21.3	4.65	4.50	1.02	4.58
2,895.9-2,896.3	4.4	22.0	4.40	5.03	0.99	5.00
2,991.1-2,991.6	4.6	22.5	4.89	4.89	0.94	4.60
3,097.9-3,098.3	5.5	20.2	3.66	3.65	1.51	5.52
3,199.8-3,200.2	5.1	18.5	2.85	3.60	1.80	6.49
3,298.0-3,298.4	3.7	16.9	3.27	4.52	1.14	5.17
3,408.8-3,409.2	3.8	16.7	3.03	4.43	1.24	5.51
Flow breccia						
3,613.9-3,614.4	3.0	16.6	1.56	5.53	1.92	10.6
3,620.9-3,621.5	4.1	17.8	2.74	4.40	1.48	6.50
3,708.0-3,708.3	3.3	16.9	3.67	5.08	0.91	4.60
3,852.2-3,852.7	3.2	18.4	1.18	5.75	2.71	15.6
Tuff of Lithic Ridge						
4,199.6-4,200.0	2.9	18.2	3.45	6.34	0.83	5.28
4,305.6-4,306.1	3.3	18.4	3.74	5.58	0.88	4.92
4,506.0-4,506.4	2.2	18.3	3.81	8.24	0.58	4.80
4,633.7-4,634.0	2.5	18.1	3.47	7.24	0.72	5.22
4,810.9-4,811.3	2.8	18.5	3.70	6.68	0.75	5.00

Table 1.--Radioelement contents and ratios in core samples drill hole USW-G1. (Con't)

Sample depth (ft)	RaeU (ppm)	Th (ppm)	K (pct)	Th/ RaeU	RaeU/ $Kx10^{-4}$	Th/ $Kx10^{-4}$
Undivided older tuff						
4,971.8-4,972.1	2.7	21.6	3.34	8.12	0.80	6.47
5,034.6-5,035.0	2.5	19.6	4.65	7.81	0.54	4.22
5,070.4-5,070.9	4.2	19.8	5.01	4.71	0.84	3.95
5,124.5-5,124.9	3.9	18.7	3.89	4.81	1.00	4.81
5,215.0-5,215.5	4.3	20.8	4.25	4.84	1.01	4.89
5,290.6-5,291.0	3.9	19.5	4.54	4.95	0.87	4.30
5,407.1-5,407.6	4.3	20.0	3.82	4.65	1.13	5.24
5,519.2-5,519.7	2.2	18.9	3.89	8.59	0.57	4.86
5,578.1-5,578.4	2.9	16.6	3.32	5.80	0.86	5.00
5,635.8-5,636.2	3.2	16.7	2.78	5.22	1.15	6.01
5,739.0-5,739.4	2.7	16.5	2.58	6.11	1.05	6.40
5,786.7-5,787.1	3.3	17.5	2.84	5.30	1.16	6.16
5,880.6-5,881.1	3.0	17.2	2.86	5.73	1.05	6.01
5,972.5-5,973.0	2.8	14.8	2.77	5.29	1.00	5.34

tuffaceous beds of Calico Hills, and are not included in the compositional calculation of this report. The average radioelement contents for the Topopah Spring Member are given in table 2. The thorium and potassium contents are virtually constant through the sampled interval which indicates that the Topopah Springs Member had a uniform magmatic and postmagmatic history. The devitrified layer contains slightly less RaeU than the rest of the member; this may have resulted from minor amounts of uranium or radium loss during high-temperature devitrification or subsequent alteration. Devitrified volcanics are commonly depleted in uranium relative to vitrophyres of the same flow, and the magnitude of this difference appears to increase with sample age (Zielinski, 1978).

Tuffaceous beds of Calico Hills

A sequence of highly zeolitic, lithologically homogenous nonwelded ash-flow tuff underlies the Paintbrush Tuff from 1,425.5-1,736.4 ft. For mapping purposes, a basal zone of reworked tuff, air-fall tuff, and tuffaceous sandstone below 1,736.4 ft was included in the unit, but is excluded here because of its lithologic dissimilarity and its anomalous radioelement content. The average radioelement contents in the remaining three samples of the unit are given in table 2. The limited radioelement data indicate that this unit is almost as homogenous as the Topopah Spring in spite of major zeolitic alteration. Potassium and thorium are more variable, but no evidence exists for a greater variation in RaeU abundance even though major zeolization has occurred; this is consistent with the findings of Zielinski (1980).

Crater Flat Tuff

On the basis of similar petrographic features and major-element compositions, three rhyolitic ash-flow tuff sheets found in USW-G1 have been assigned to the Crater Flat Tuff. They include, in descending order, the Prow Pass Member, the Bullfrog Member, and a lowermost ash-flow tuff, informally designated as the Tram unit.

Prow Pass Member, Crater Flat Tuff

The Prow Pass (1,801.5-2,173.0 ft) is distinguishable from the other two ash-flow tuff units of the Crater Flat Tuff by the presence of orthopyroxene relicts and an abundance of conspicuous reddish-brown mudstone lithic fragments. The member has been divided into three subunits on the basis of gross lithologic features and welding characteristics (Spengler and others, 1981). All subunits have been described as devitrified; however, partial zeolitization does occur throughout the member. The upper and lower subunits display partial to moderate welding characteristics, whereas the middle subunit (1,987.0-2,073.9 ft) is partially welded; the radioelement content of the middle subunit was not determined. Single samples from the upper and lower subunits were analyzed (table 2). More data are required to document the characteristics, homogeneity, and the importance of differences between subunits of the Prow Pass Member.

Table 2.--Summary of radioelement data, drill hole USW-G1

Stratigraphic unit[1]/	Stratigraphic interval (ft)	Interval included in averages (ft)	Number of samples	RaeU (ppm)	Th (ppm)	K (pct)	Th/ RaeU	RaeU/ $Kx10^{-4}$	Th/ $Kx10^{-4}$
Paintbrush Tuff									
Topopah Spring Member	235-1,425.5	755.2-1,390.1	11	4.4±.3	24.5± .2	4.00± .12	5.55± .44	1.11±.11	6.13± .16
Tuffaceous beds of Calico Hills	1,425.5-1,801.5	1,453.8-1,729.2	3	4.5±.3	23.0± .8	3.75± .22	5.13± .51	1.20±.12	6.13± .30
Crater Flat Tuff									
Prow Pass Member									
Upper subunit	1,801.5-1,987.0	1,902.0-1,902.4	1	5.4	22.4	4.16	4.15	1.30	5.38
Lower subunit	2,073.9-2,173.0	2,105.6-2,106.0	1	4.8	22.1	3.80	4.60	1.26	5.82
Bullfrog Member	2,173.0-2,639.4	2,192.2-2,557.5	14	4.0±.7	20.7±1.6	3.43± .93	5.30±1.03	1.26±.40	5.46±1.68
		2,430.2-2,497.0	4	4.6±.3	22.2± .9	3.98± .11	4.86± .24	1.15±.06	5.57± .17
Tram unit (informal)[2]/	2,639.4-3,558.2								
Upper subunit		2,700.8-2,991.6	7	4.0±.7	21.6± .6	4.21± .52	5.49±1.01	0.96±.18	5.18± .57
Lower subunit		3,298.0-3,409.2	2	3.8±.1	16.8± .1	3.15± .17	4.48± .13	1.19±.08	5.34± .24
Flow breccia	3,558.2-3,945.8	3,613.9-3,852.7	4	3.4±.5	17.4± .8	2.29±1.14	5.19± .62	1.76±.76	9.33±4.88
Lithic-rich tuff	3,945.8-4,940.2	4,199.6-4,811.3	5	2.7±.4	18.3± .2	3.65± .16	6.82±1.04	0.76±.12	5.04± .20
Older ash-flow and bedded tuffs									
Unit A	4,940.2-5,320.0	5,124.0-5,291.0	3	4.0±.2	19.7±1.1	4.23± .33	4.88± .11	0.96±.08	4.67± .32
Unit B	5,320.0-5,434.0	5,407.1-5,407.6	1	4.3	20.0	3.82	4.65	1.13	5.24
Unit C	5,434.0-6,000.0	5,578.1-5,973.0	6	3.0±.3	16.5±1.1	2.77± .11	5.53± .38	1.08±.07	5.98± .39

1/ Spengler and others, 1981

2/ Unit divided on basis of significant differences in radioelement contents.

Bullfrog Member, Crater Flat Tuff

The ash-flow tuff of the Bullfrog Member (2,173.0-2,629.4 ft) contains smaller and less abundant mudstone lithics and a larger amount of mafic minerals, chiefly biotite and hornblende relicts, than the Prow Pass Member. In USW-G1, the member has been described as a simple cooling unit, wherein, zones of no welding to partial welding enclose a zone of moderate to dense welding near the lower third of the ash-flow tuff from 2,447.0 to 2,547.1 ft. The base of the ash-flow tuff rests on 37.8 ft of bedded and reworked tuff. The averages and standard deviations of the radioelement contents, excluding the basal zone, are 4.0 ± 0.7 ppm RaeU, 20.8 ± 1.6 ppm thorium, and 3.43 ± 0.93 percent potassium. The Bullfrog is unique in that rocks of similar lithology contain highly variable radioelement contents. On the basis of the radioelement contents and ratios, the most homogenous zone is from about 2,430 to about 2,500 ft, which roughly corresponds to the zone of moderate to dense welding. Above about 2,246 ft, all the radioelement contents are highly variable, which, elsewhere in this drill hole, reflects reworking of the material or redeposition of the radioelements. Below 2,261.5 ft, the thorium is less variable than in the overlying zone, but except for the apparently homogenous zone, the RaeU and potassium contents are highly variable.

Tram Unit, Crater Flat Tuff

The Tram unit, from 2,639.4-3,558.2 ft, is a thick section of ash-flow tuff that is similar in color, welding, and phenocryst assemblage to the Bullfrog Member. The Tram unit contains about twice as much quartz as the Bullfrog but virtually no mudstone lithic fragments. The size and abundance of lithic fragments increase abruptly below about 3,000 ft. Above 3,100 ft, the unit is partially to moderately welded, although it is predominantly moderately welded from 2,800 to 3,100 feet. An abrupt decrease in the degree of welding and an increase in the intensity of alteration, presumably caused by hydrothermal solutions, are evident below a depth of 3,218.3 ft. The Tram is intensely altered, presumably by hydrothermal solutions, from 3,218.2-3,522.0 ft. On the basis of the thorium and potassium distribution (fig. 1) as well as lithologic characteristics, the Tram was divided into an upper zone to a depth of 3,000 ft, a gradational zone from 3,000-3,200 ft, and a lower zone below 3,200 ft. The averages and standard deviations of the radioelement contents in the upper zone are 4.0 ± 0.7 ppm RaeU, 21.6 ± 0.6 ppm thorium, and 4.21 ± 0.52 percent potassium. The averages of two samples in the lower zone are 3.8 ± 0.11 ppm RaeU, 16.8 ± 0.1 ppm thorium, and 3.15 ± 0.17 percent potassium. These statistically significant changes in radioelement concentrations occur at lithologic boundaries and they are apparently related, but the cause is uncertain. Throughout most of the Tram unit, variations in RaeU content suggests redistribution. Potassium correlates with thorium even in the hydrothermally altered zone.

Flow Breccia

The flow breccia is about 362 feet thick and consists of dacite with inclusions of large blocks of lava. Variations in the radioelement contents (table 2) indicate the relative heterogeneity of the unit. Approximately 26 ft of ash-fall, reworked, and bedded tuff underlies the flow breccia. Similar mineral constituents suggest a genetic link between these tuffs and the overlying flow breccia, and most of the upper part of the bedded interval has a volcanic texture suggesting postemplacement fusion.

Tuff of Lithic Ridge

The lithic-rich ash-flow tuff is about 975 ft thick, and remarkably uniform and homogeneous with respect to degree of welding, percentage of phenocrysts, and extent of secondary alteration. This stratigraphic unit is almost entirely partially welded and contains an appreciable amount of zeolites, dominantly analcime. The homogeneity of the unit is indicated by the narrow ranges in the radioelement contents (table 2).

Older Ash-Flow and Bedded Tuffs

A sequence of ash-flow tuffs with subordinate interbedded ash-fall and moderately reworked pumaceous sediments occupies the interval from 4,940.2-6,000 ft. The tuffs have not been mapped elsewhere in the region and reference to the sequence is informal. Three units (A,B and C) that have been identified on the basis of mineralogy occupy the intervals from 4,940.2-5,320 ft, 5,320-5,434 ft, and 5,434 ft to the bottom of the hole. Unit A consists of a thick, uniform ash-flow tuff that is partially to moderately welded, devitrified, and partially silicified. Unit B is a transitional zone between quartz-rich unit A and quartz-poor Unit C. Unit C is composed of moderately welded ash-flow tuffs separated by reworked tuffaceous sediments. One of the more conspicuous zones within Unit C occurs within the upper 148 ft where bedded tuffs are thicker and more frequent. The radioelement data (fig. 1) indicate two units separated at about 5,575 ft. RaeU contents in the upper 12 ft (2 samples) of unit A are anomalously low relative to the rest of the unit, indicating possible mobilization of RaeU. The radioelement contents in the single sample from unit B are not significantly different from those in the lower part of unit A. The radioelement data do not include a sample from the contact between units B and C, but about 145 ft below the contact (5,578 ft), coincidental with the base of the bedded tuffs, the radioelement contents become significantly lower and remain so to the bottom of the hole. The radioelement data for these units is in table 2.

Summary

The vertical distributions of the radioelement averages are shown in figure 2. The RaeU contents are similar in the units from the Topopah Spring Member through the upper subunit of the Tram; the averages gradually decrease from the lower Tram subunit through the tuff of Lithic Ridge, then increase in units A and B in the older ash-flow and bedded tuffs. The RaeU content in unit C is relatively low, similar to that in the flow breccia and the lithic-rich tuff. The thorium contents gradually decrease from the Topopah Spring Member through the upper Tram unit. The lower Tram is distinguished by a significant decrease in the thorium content relative to the upper part of the unit. The thorium content gradually increases with depth through units A and B of the older ash flow and bedded tuffs, and is significantly lower in Unit C, similar to that in the lower Tram and the flow breccia. The average potassium content is virtually constant in the stratigraphic units from the Topopah Spring through the upper Tram unit, even though the Bullfrog Member contains a wide range of potassium content. The potassium distribution pattern is similar to the thorium in that the potassium content is reduced in the lower Tram followed by a gradual increase in content through Units A and B and reduced in Unit C of the older ash flow and bedded tuffs.

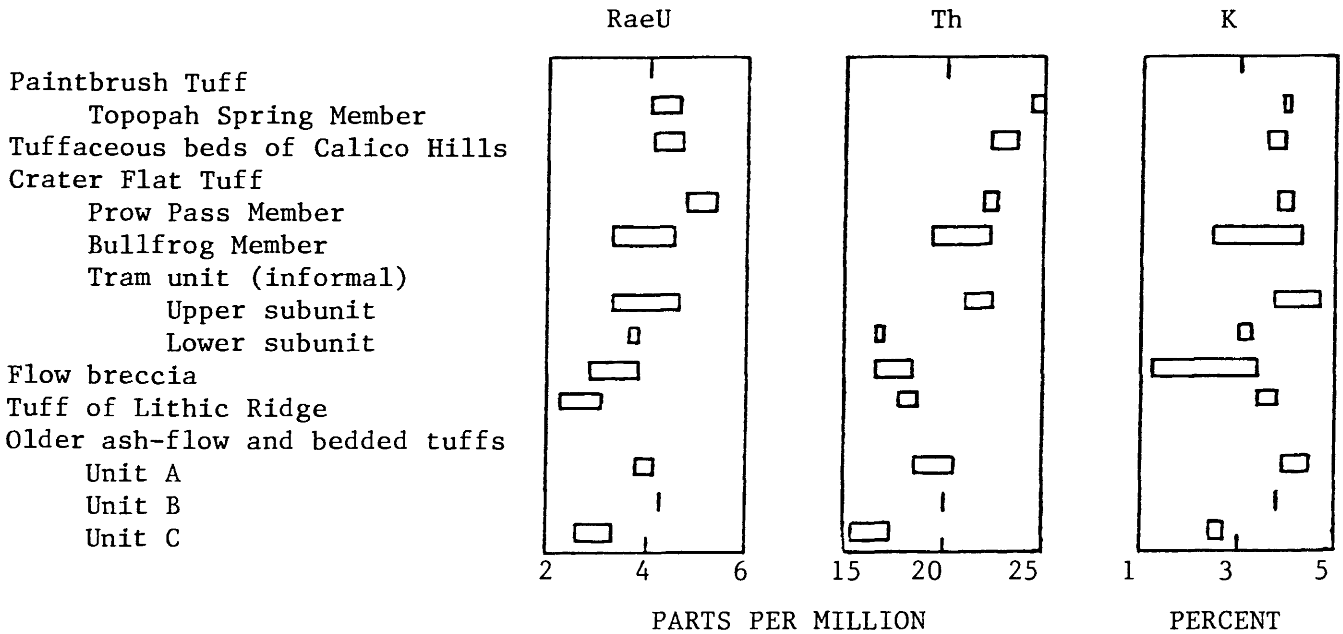

Figure 2: Distribution of average radioelement contents in stratigraphic unit penetrated by drill hole USW-G1. Bars represent contents within limits of a standard deviation from the average; averages are at midpoints of bars.

As shown in figure 1, only slight variations in radioelement concentrations and ratios occur in intervals of ash-flow tuffs described as moderately to densely welded, whereas wider variations commonly correspond to zones of no welding to partial welding, except for the Lithic Ridge Tuff, characterized as partially welded and having only minor variations in radioelement concentrations.

The distribution of the average radioelement contents (fig. 2) suggests the following sequence of events. The magma source of Unit C is apparently different than that of Units B and A of the older ash-flow and bedded tuffs.

The interval from Unit B through the lower tram exhibits a nearly linear decrease in thorium and potassium contents. The significant difference in thorium and potassium content of the lower and upper tram indicates major differences in magmatic evolution or posteruptive alteration. The thorium content in the interval from the upper tram to the more recent deposits of the Topopah Springs member gradually increases, suggesting that a consistent temporal variation in the original composition of locally erupted rhyolites that is perhaps related to differences in percent melting or to the amount of fractionation prior to eruption.

A statistically significant correlation exists between thorium and potassium for the entire sequence or any unit in which more than three samples occur except for the dacite flow breccia. RaeU does not correlate with thorium or potassium for any unit and this may indicate postmagmatic selective dissolution or precipitation of RaeU or uranium throughout the sequence sampled.

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