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UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

CHEMICAL COMPOSITION OF GROUND WATER AND THE LOCATIONS OF PERMEABLE ZONES IN THE YUCCA MOUNTAIN AREA, NEVADA

by

L. V. Benson[1], J. H. Robison[1], R. K. Blankennagel[1], and A. E. Ogard[2]

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CONVERSION TABLE

Multiply metric unit	*by*	*To obtain inch-pound unit*
millimeter (mm)	0.03937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
liter (L)	0.2642	gallon (gal)
liter per second (L/s)	15.85	gallon per minute (gal/min)

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ABSTRACT

Ten wells in the Yucca Mountain area of southern Nevada have been sampled for chemical analysis. Samples were obtained during pumping of water from the entire well bore (composite sample) and in one instance by pumping water from a single isolated interval in well UE-25b#1. Sodium is the most abundant cation and bicarbonate the most abundant anion in all water samples. Although the general chemical compositions of individual samples are similar, there are significant differences in uncorrected carbon-14 age and in inorganic and stable-isotope composition. Flow surveys of seven wells performed using iodine-131 as a tracer indicate that ground-water production is usually from one or more discrete zones of permeability.

INTRODUCTION

The Yucca Mountain site in southern Nevada (fig. 1) is being investigated as a possible repository for the disposal of high-level nuclear wastes. The site is underlain by partially altered volcanic tuffs (Caporuscio and others, 1982) that probably extend to depths greater than 3,000 m. If approved, the repository most likely will be excavated within the unsaturated zone, 150 to 300 m above the water-table surface. There is concern that radionuclides, once leached from the stored wastes, will eventually reach the saturated zone where they will be transported in the ground-water system from the repository site to the accessible environment. In order to understand the types and magnitudes of chemical processes that affect the potential movement of radionuclide species, compositional characterization of ground-water samples from the Yucca Mountain area has been initiated. This report summarizes preliminary findings to date. The authors wish to acknowledge the assistance of Charles L. Washington and William J. Oatfield, U.S. Geological Survey, who performed most of the sampling and onsite analysis procedures.

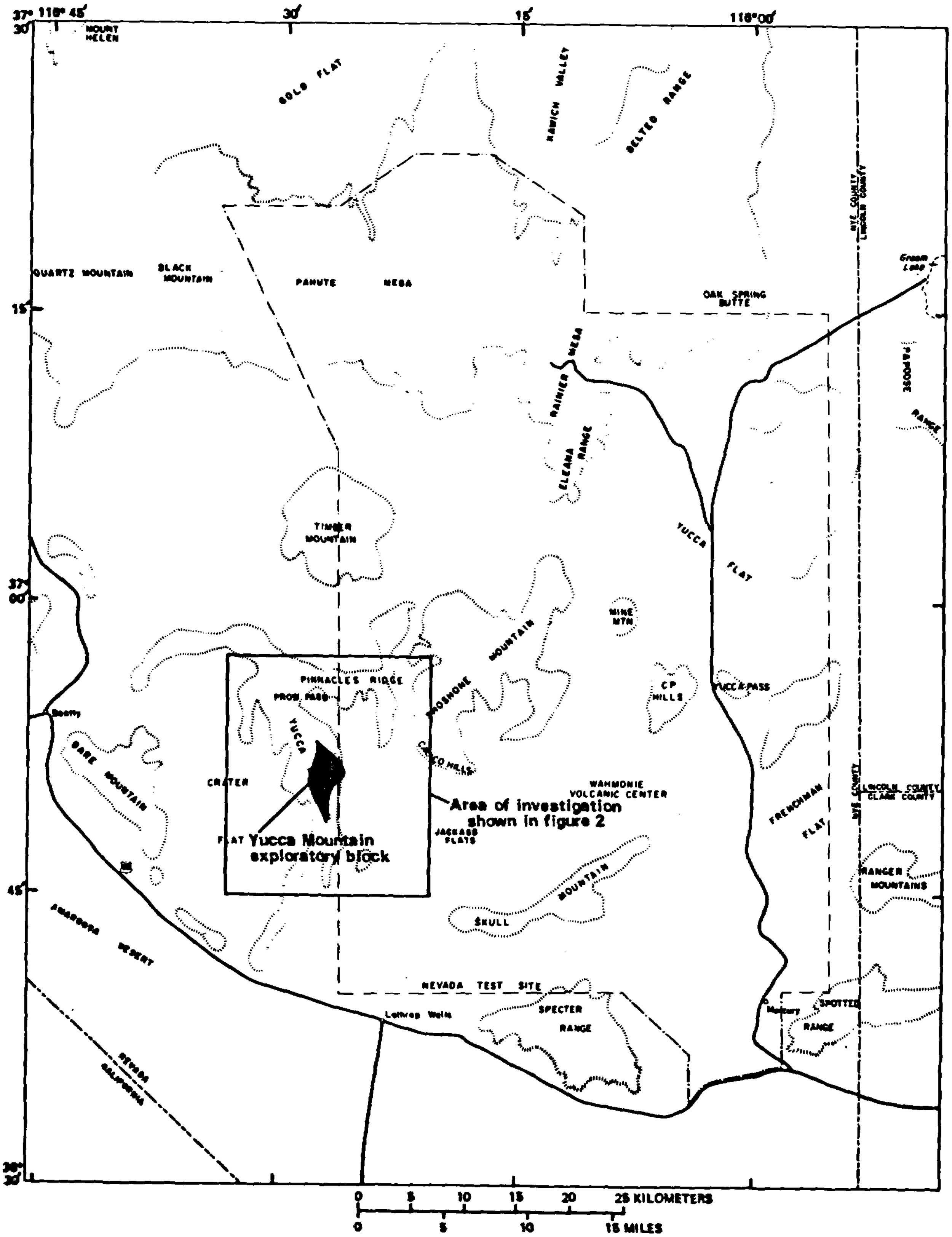


Figure 1.--Nevada Test Site and vicinity showing the area of investigation and the Yucca Mountain exploratory block.

METHODS AND PROCEDURES

Drilling fluid was composed of local ground water to which "soap" (linear olefin sulfonate or sodium benzoyl sulfonate plus isopropyl alcohol) was added. This addition generated foam that aided in removal of cuttings from the hole. For drilling of well USW H-6 (fig. 2), the source of ground water was well USW VH-1; for all other wells, the ground-water source was well J-13. A tracer consisting of about 20 mg/L (milligrams per liter) of lithium chloride was added to drilling fluid for all wells except USW H-1.

Wells were cased from the surface to depths ranging from 50 to 90 m below the water table. Casing extending from the land surface to a depth of about 100 m in the unsaturated zone was cemented to the surface. The bottom 9 m of casing penetrating the saturated zone also was cemented. That part of the saturated zone penetrated by casing was perforated. The typical well construction is shown in figure 3.

Wells were pumped for 2 to 13 days before water samples were obtained for chemical analysis. During pumping, water was monitored routinely for temperature, specific conductance, pH, and lithium concentration. An effort was made to sample after the temperature, specific conductance, and pH became relatively stable and the lithium concentration had decreased to a value near that considered typical of natural formation water [50 to 100 µg/L (micrograms per liter)]. Alkalinity usually was measured onsite. Water samples were filtered onsite using a nitrogen-pressured, stainless-steel vessel containing a 0.45 µm (micrometer) membrane. The filtered samples were collected in polyethylene bottles that previously had been washed with high-purity nitric acid and rinsed with distilled-deionized water. Samples to be analyzed for cations were acidified with high-purity nitric acid to a pH of about 1. Laboratory procedures for inorganic substances are those detailed in Brown and others (1970). Methods for collection of water samples for determination of tritium and radiocarbon are given in Thatcher and others (1977). Methods for collection of water samples for analysis of the stable isotopes of hydrogen, oxygen, and carbon were provided by R. J. Pickering (U.S. Geological Survey, written commun., 1981).

Borehole-flow surveys were conducted in all wells on or near the Yucca Mountain exploratory block (fig. 2). The surveys were done by injecting an aqueous solution of ^{131}I (iodine-131) into the borehole fluid while pumping the well. The rate of movement of the ^{131}I slug was determined using two gamma detectors positioned above the ^{131}I tracer injector. The arrival times of ^{131}I at the detectors are used with the average hole size calculated from a caliper-log survey to determine flow rates at selected depths in the borehole. A more detailed discussion of this technique is presented in Blankennagel (1967). Results of the borehole-flow surveys are depicted in figures 4 to 6 and discussed in the section "Flow Surveys."

WATER COMPOSITION

The chemical composition of samples taken from wells shown in figure 3 are listed in table 1. Data for wells J-12 and J-13 are from Claassen (1973).

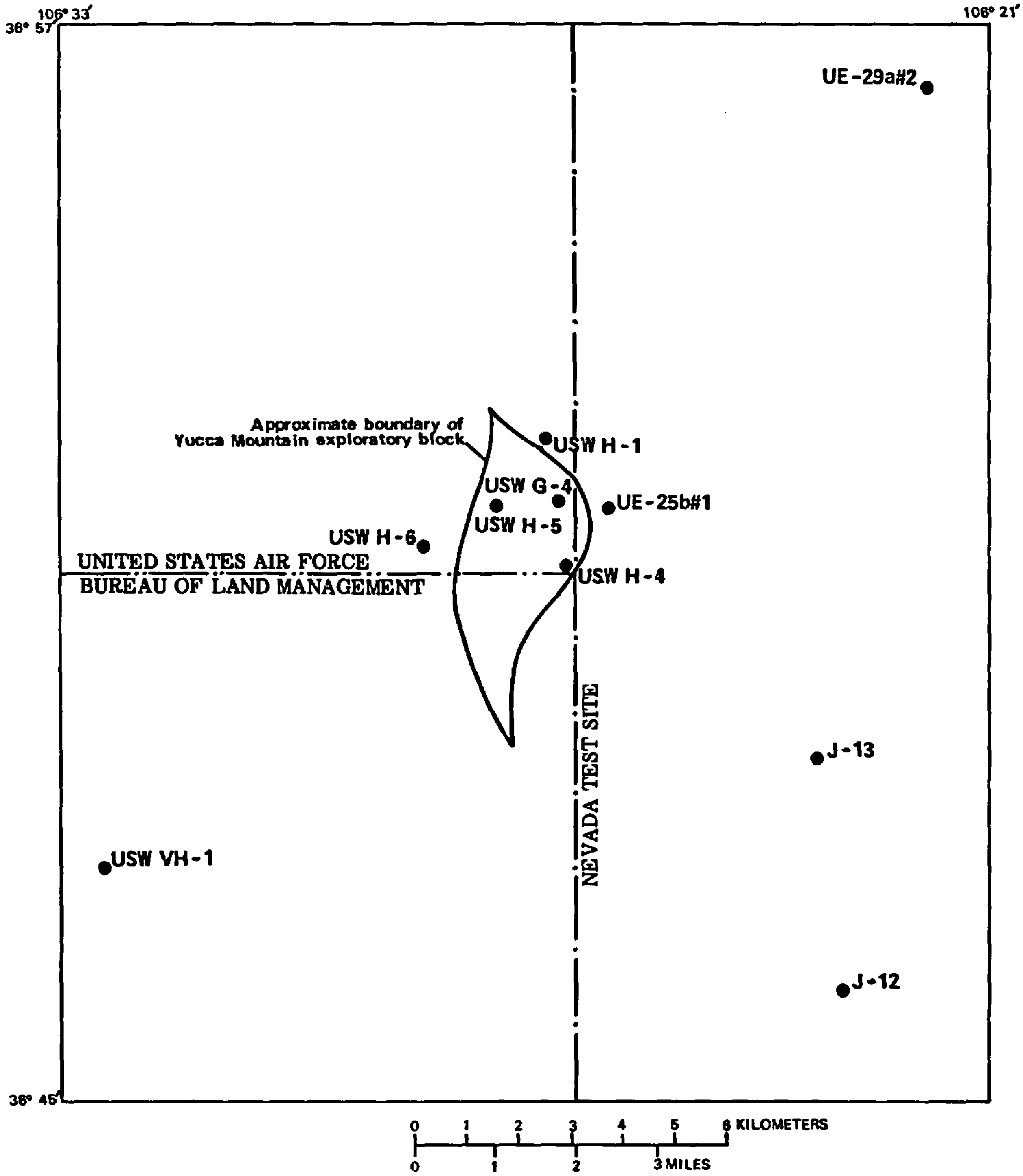


Figure 2.--Selected drill-hole locations on and near the Yucca Mountain exploratory block.

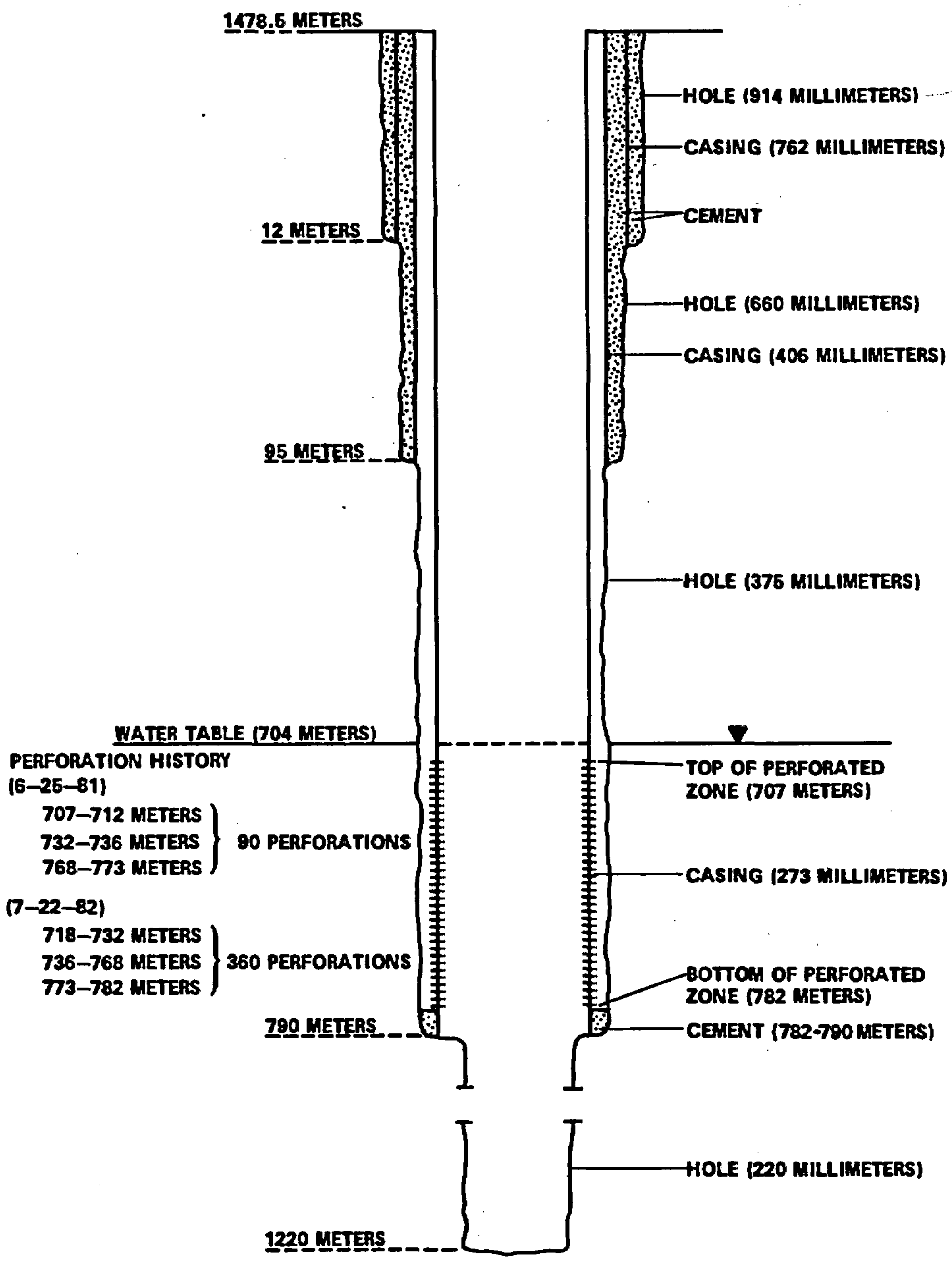


Figure 3.--A typical well construction (well USW H-5).

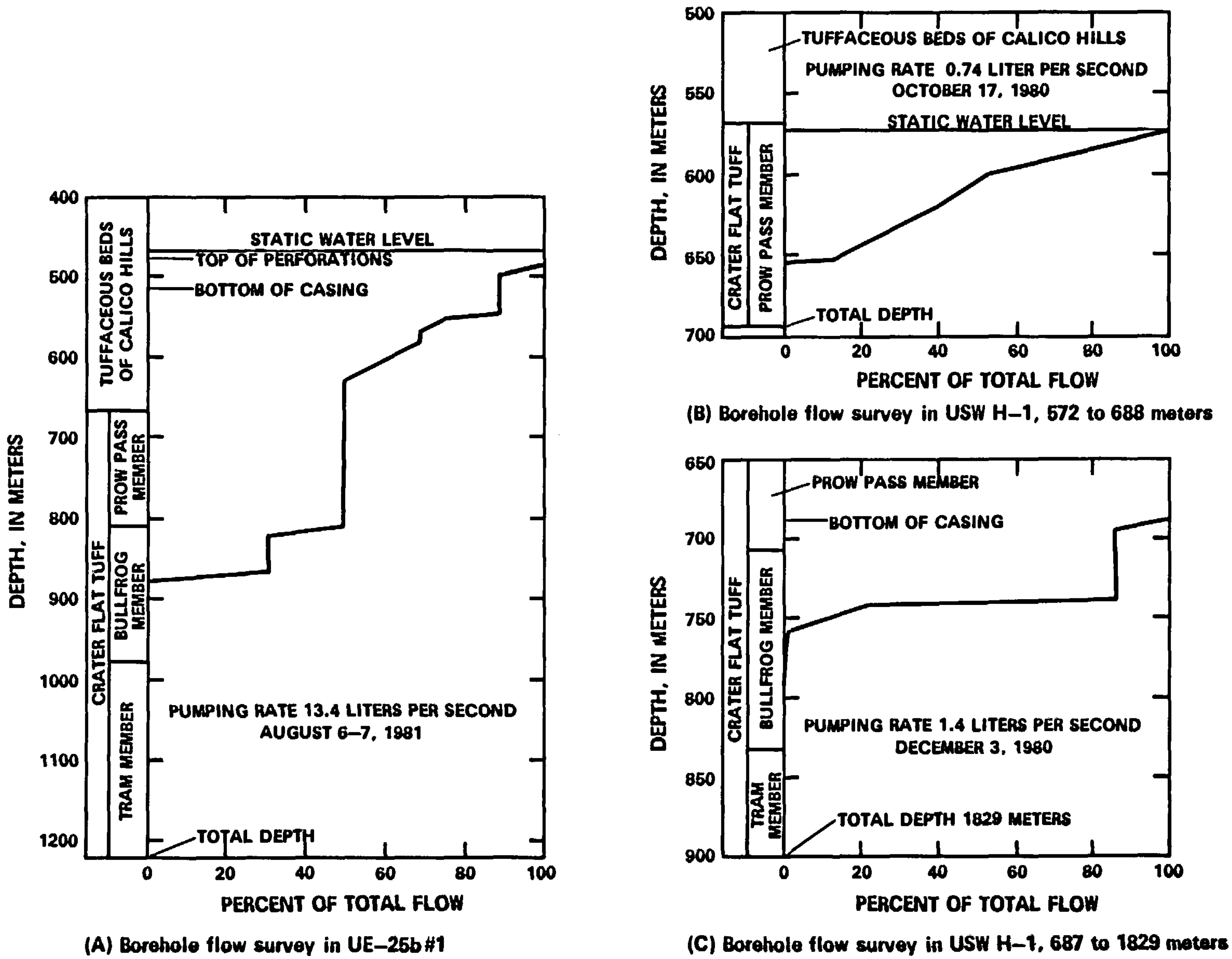
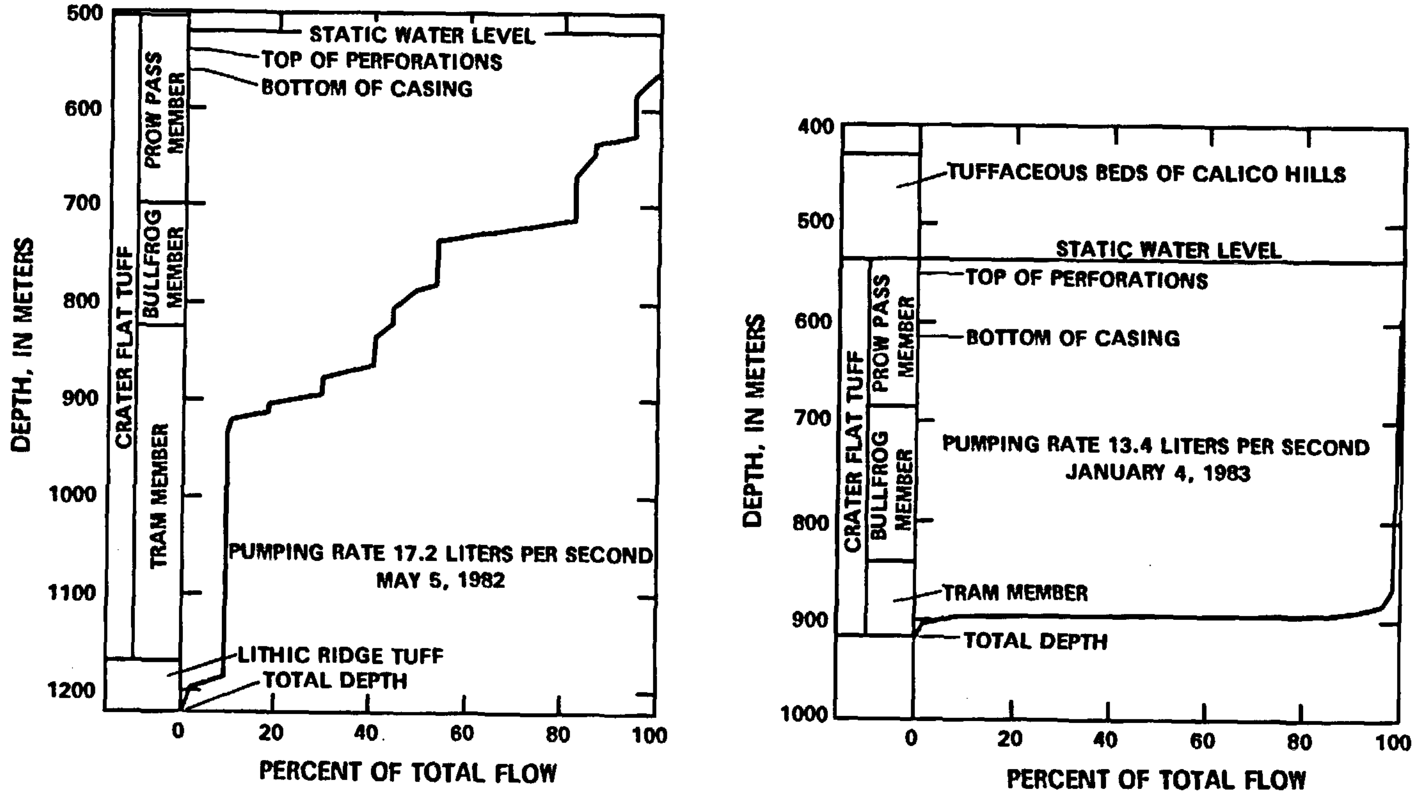


Figure 4.--Results of borehole-flow surveys in wells UE-25b#1 and USW H-1.



(A) Borehole flow survey in USW H–4

(B) Borehole flow survey in USW G–4

Figure 5.--Results of borehole-flow surveys in wells USW H-4 and USW G-4.

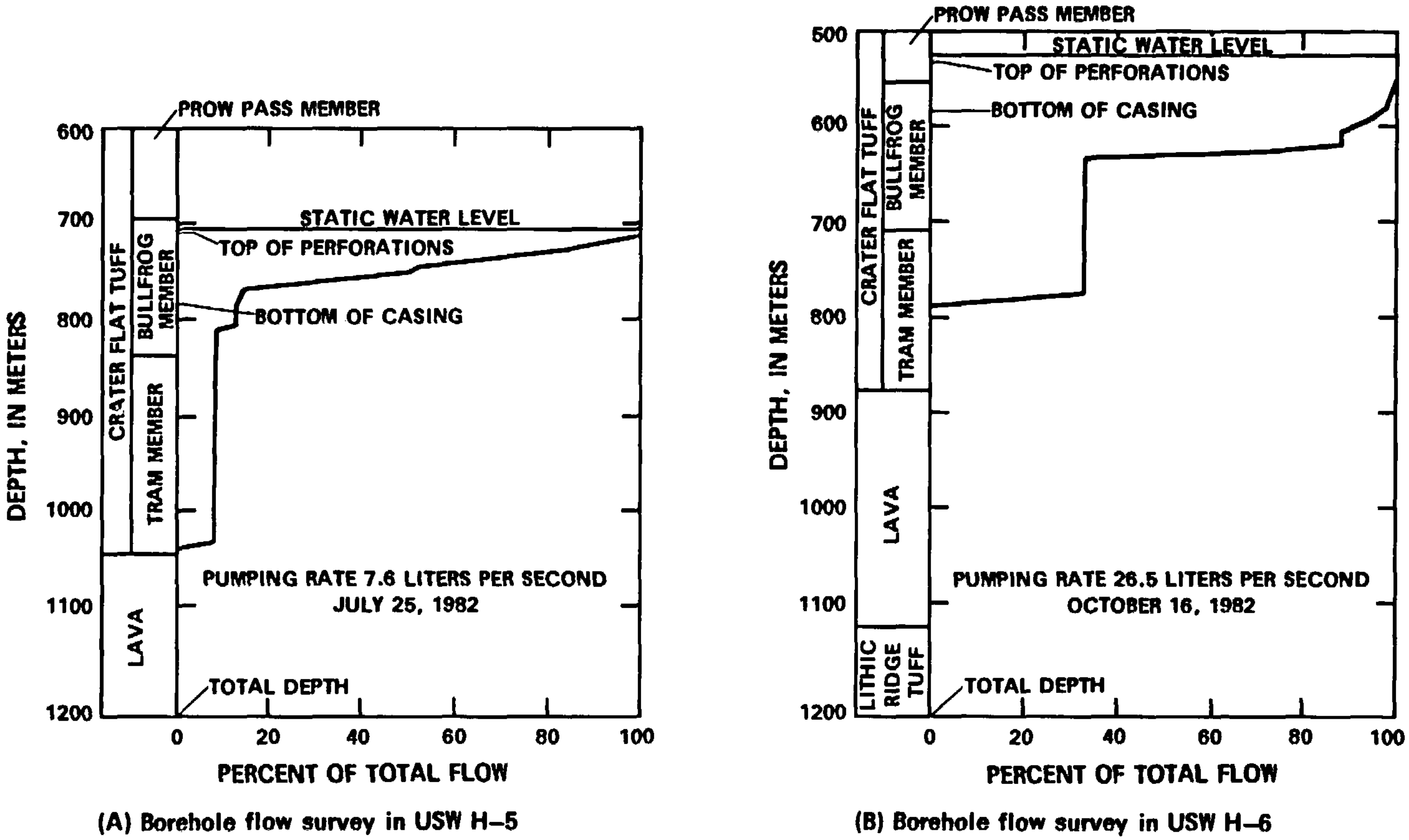


Figure 6.--Results of borehole-flow surveys in wells USW H-5 and USW H-6.

Table 1.--*Chemical composition of water samples obtained from wells in the Yucca Mountain area*

[m, meters; δD, del deuterium, reported in parts per thousand, o/oo, relative to SMOW, standard mean ocean water; $\delta^{18}O$, del oxygen-18, reported in parts per thousand, o/oo, relative to standard mean ocean water; $\delta^{13}C$, del carbon-13, reported in parts per thousand relative to PDB, Peedee belemnite; ^{14}C, carbon-14; yr B.P., years before present; HTO, tritium, reported in picocuries per liter; °C, degrees Celsius; dissolved constituents: Ca (calcium), Mg (magnesium), Na (sodium), HCO_3 (bicarbonate), Cl (chloride), SO_4 (sulfate), SiO_2 (aqueous silica), and F (fluoride) reported in milligrams per liter, excepting Li (lithium) and Sr (strontium) which are reported in micrograms per liter; - (dash) indicates entire well bore pumped in the case of column five data; otherwise, - (dash) indicates that no data are available for particular analysis of interest]

Site designation	Land-surface altitude (m)	Approximate well depth (m)	Approximate depth to water (m)	Interval sampled (m)	Collection date	δD o/oo SMOW	$\delta^{18}O$ o/oo SMOW	$\delta^{13}C$ o/oo PDB	^{14}C percent modern	^{14}C apparent age (yr B.P.)	HTO
UE-25b#1	1,200.4	1,220	470	---------	08/07/81	- 99.5	-13.4	-10.7	----	------	----
UE-25b#1				---------	09/01/81	-101	-13.4	-10.4	16.7	14,400	<200
UE-25b#1				(863- 875)	07/20/82	- 99.5	-13.5	- 8.6	18.9	13,400	2
UE-29a#2	1,215.1	422	29	---------	01/08/82	- 93.5	-12.8	-12.6	62.3	3,800	37
UE-29a#2				---------	01/15/82	- 93.0	-12.8	-13.1	60.0	4,100	37
USW G-4	1,270.0	915	541	---------	12/09/82	-103	-13.8	- 9.1	22.0	12,160	---
USW H-1	1,302.2	1,829	572	(572- 687)	10/20/80	-103	-13.4	-----	19.9	13,000	<20
USW H-1				(687-1,829)	12/08/80	-101	-13.5	-11.4	23.9	12,000	<20
USW H-4	1,249.0	1,220	519	---------	05/17/82	-104	-14.0	- 7.4	11.8	17,200	<10
USW H-5	1,477.8	1,220	704	---------	07/03/82	-102	-13.6	-10.3	18.2	13,700	<200
USW H-5				---------	07/26/82	-102	-13.6	-10.3	21.4	12,400	<200
USW H-6	1,306.1	1,220	526	---------	10/16/82	-106	-13.8	- 7.5	16.3	14,600	<10
USW VH-1	954.5	762	184	---------	02/06/81	----	-----	-----	----	------	---
USW VH-1				---------	02/08/81	----	-----	-----	----	------	---
USW VH-1				---------	02/11/81	-108	-14.2	- 8.5	12.2	17,000	<20
J-12	953.5	347	225	---------	03/26/71	- 97.5	-12.8	- 7.9	32.2	9,100	<220
J-13	1,011.3	1,063	282	---------	03/26/71	- 97.5	-13.0	- 7.3	29.2	9,900	<220

Table 1.--*Chemical composition of water samples taken from wells in the Yucca Mountain area*--Continued

Site designation	Onsite pH (units)	Laboratory pH (units)	Water temperature (°C)	Dissolved constituents											
				Ca	Mg	Na	K	HCO_3 field	HCO_3 laboratory	Cl	SO_4	SiO_2	Li	Sr	F
UE-25b#1	7.1	6.8	36.0	19	0.73	53	3.7	173	158	13	24	53	950	44	1.5
UE-25b#1	7.5	7.5	36.0	17	.59	46	3.5	139	134	8.5	22	52	220	38	1.6
UE-25b#1	7.1	7.7	37.2	18	.72	46	2.8	133	138	7.5	21	51	120	47	1.6
UE-29a#2	7.2	7.6	25.1	10	.2	44	1.1	107	112	11	22	44	100	39	1.0
UE-29a#2	7.0	7.4	22.7	10	.3	44	1.3	107	110	8.8	21	44	110	33	.9
USW H-1	7.7	7.8	33.0	4.5	<.1	51	2.4	---	115	5.7	18	47	40	5	1.2
USW G-4	7.7	7.5	35.6	13	.2	57	2.1	139	143	5.9	19	45	67	17	2.5
USW H-1	7.5	8.0	34.7	6.2	<.1	51	1.6	---	122	5.8	19	40	40	20	1.0
USW H-4	7.4	7.9	34.8	17	.29	73	2.6	173	171	6.9	26	46	130	27	4.8
USW H-5	7.8	7.8	36.5	1.9	.01	60	2.1	126	124	6.1	16	48	62	9	1.4
USW H-5	7.9	8.0	35.3	2.0	<.01	60	2.1	127	124	6.1	16	48	71	4	1.4
USW H-6	8.1	8.3	37.8	4.1	.09	86	1.3	182	188	7.6	29	48	82	8	4.7
USW VH-1	7.9	8.0	35.2	11	1.6	79	1.9	167	158	11	44	50	90	70	2.7
USW VH-1	7.5	7.9	35.5	10	1.5	80	1.9	165	158	10	45	50	90	70	2.7
USW VH-1	7.5	8.0	35.5	9.9	1.5	78	1.8	162	158	10	44	49	90	60	2.7
J-12	7.1	---	27.0	14	2.1	38	5.1	---	119	7.3	22	54	40	10	2.1
J-13	7.2	---	31.0	12	2.1	42	5.0	---	124	7.1	17	57	40	20	2.4

More than one analysis is shown for wells UE-25b#1, USW H-1, USW VH-1, and UE-29a#2. The multiple analyses permit a comparison of water compositions as a function of volume of water pumped. The sample obtained on July 20, 1982, from UE-25b#1 was collected after 28 days of pumping of an interval 863 to 875 m below the land surface (Daniels and others, 1982). This interval was isolated using inflatable packers. Well USW H-1 was first sampled on October 20, 1980, after drilling to a depth of 687 m; the hole then was cased and tack cemented from 677 to 687 m, deepened to 1,829 m, and a water sample was obtained on December 8, 1980, while pumping the interval from 687 to 1,829 m.

Plots of relative cation and anion concentrations in Yucca Mountain ground water (fig. 7) indicate that sodium and bicarbonate ions are the predominant cation and anion. However, ground water in the Yucca Mountain area is not chemically homogeneous (figs. 8 and 9). The chemical composition of ground water from well UE-29a#2 is characterized by low concentrations of sodium, potassium, bicarbonate, and fluoride and a high concentration of chloride relative to the compositions of other ground water in the Yucca Mountain area. Ground water from well UE-29a#2 is isotopically light with respect to $\delta^{18}O$ (del oxygen-18) and δD (del deuterium); its uncorrected ^{14}C (carbon-14) age is the youngest of all ground water in the area (fig. 10). Ground water from well J-12 and well J-13 have low concentrations of sodium and high concentrations of potassium, magnesium, calcium, and fluoride (figs. 8 and 9). These ground-water samples are isotopically heavy with respect to $\delta^{18}O$, δD, and $\delta^{13}C$ (del carbon-13); the uncorrected ^{14}C ages of these samples are relatively young (fig. 10). Ground water from wells USW H-4 and USW H-6 is characterized by low concentrations of sodium, bicarbonate, sulfate, and fluoride (figs. 8 and 9); ground water from these wells is isotopically light with respect to $\delta^{13}C$ and δD. The uncorrected ^{14}C age of ground water from well USW H-4 is the oldest of all ground water from the Yucca Mountain area. Ground water from well USW VH-1 has low concentrations of sodium, magnesium, bicarbonate, sulfate, chloride, and fluoride; the water is isotopically light with respect to $\delta^{18}O$ and δD, and it has the second oldest uncorrected ^{14}C age.

FLOW SURVEYS

Flow surveys were conducted in those wells near the periphery of the Yucca Mountain exploratory block. Results of these surveys indicate that fluid production usually is from a few discrete permeable intervals (figs. 4 to 6). Exceptions to this generalization are evident in the flow-survey data for well USW H-4 (fig. 5A) and well USW H-5 (fig. 6A). In well USW H-4, the majority of fluid production came from numerous zones throughout the upper one-half of the saturated interval penetrated by the borehole. In well USW H-5, fluid production in the upper one-half of the Bullfrog Member of the Crater Flat Tuff of Tertiary age also was associated with numerous zones. Borehole flow-survey data also indicate that for well UE-29a#2 production principally was from rhyolitic lavas of the Tuffaceous beds of Calico Hills of Tertiary age (R. K. Waddell, U.S. Geological Survey, written commun., 1983). Water injection tests using packers indicate that most of the production in wells J-12 and J-13 comes from the Topopah Spring Member of the Paintbrush Tuff of Tertiary age (Young, 1972; William Thordarson, U.S. Geological Survey,

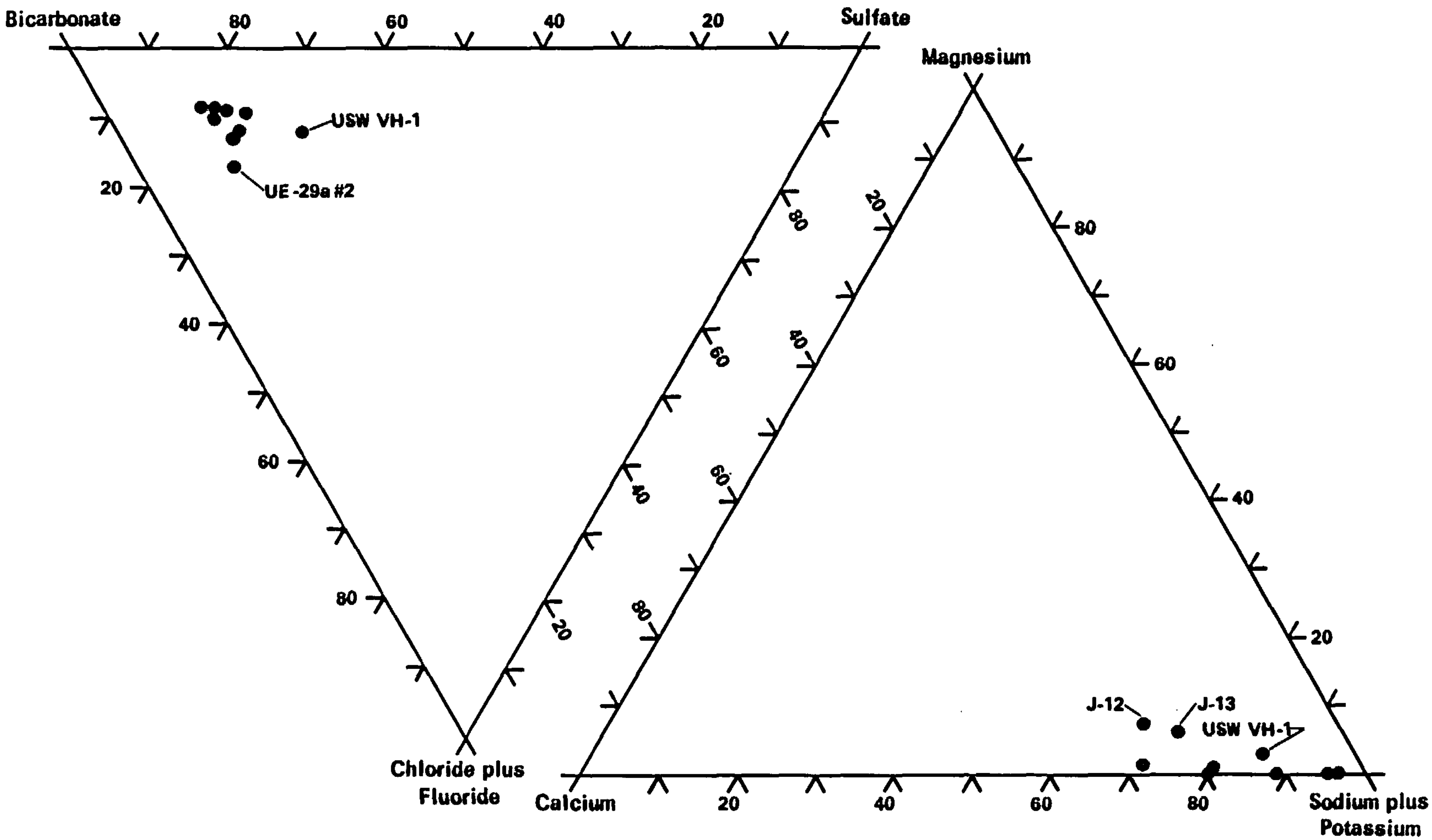


Figure 7.--Relative cation and anion concentrations (equivalent fractions) of ground water from the Yucca Mountain area.

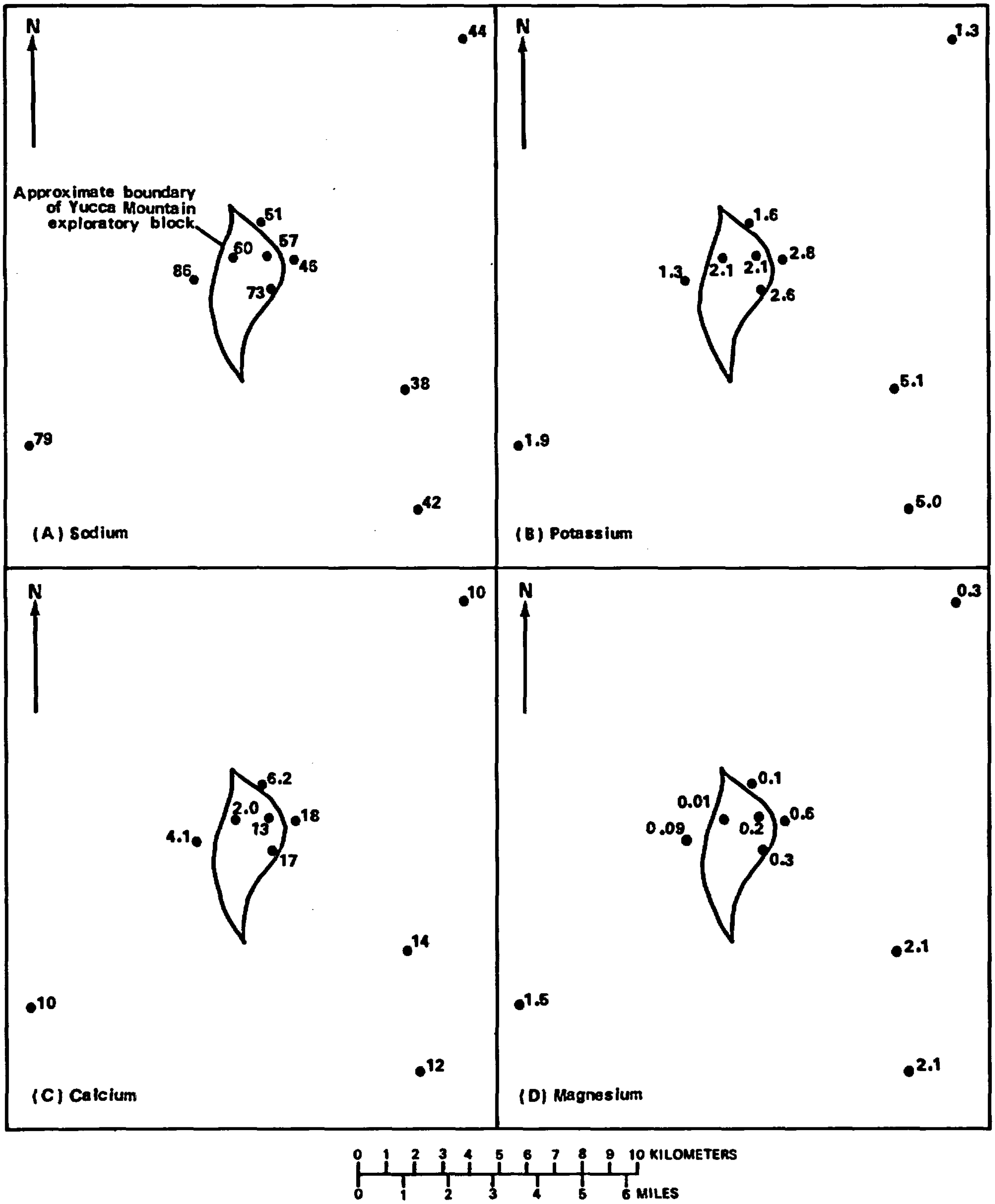


Figure 8.--Sodium, potassium, calcium, and magnesium concentrations, in milligrams per liter, in ground water from the Yucca Mountain area.

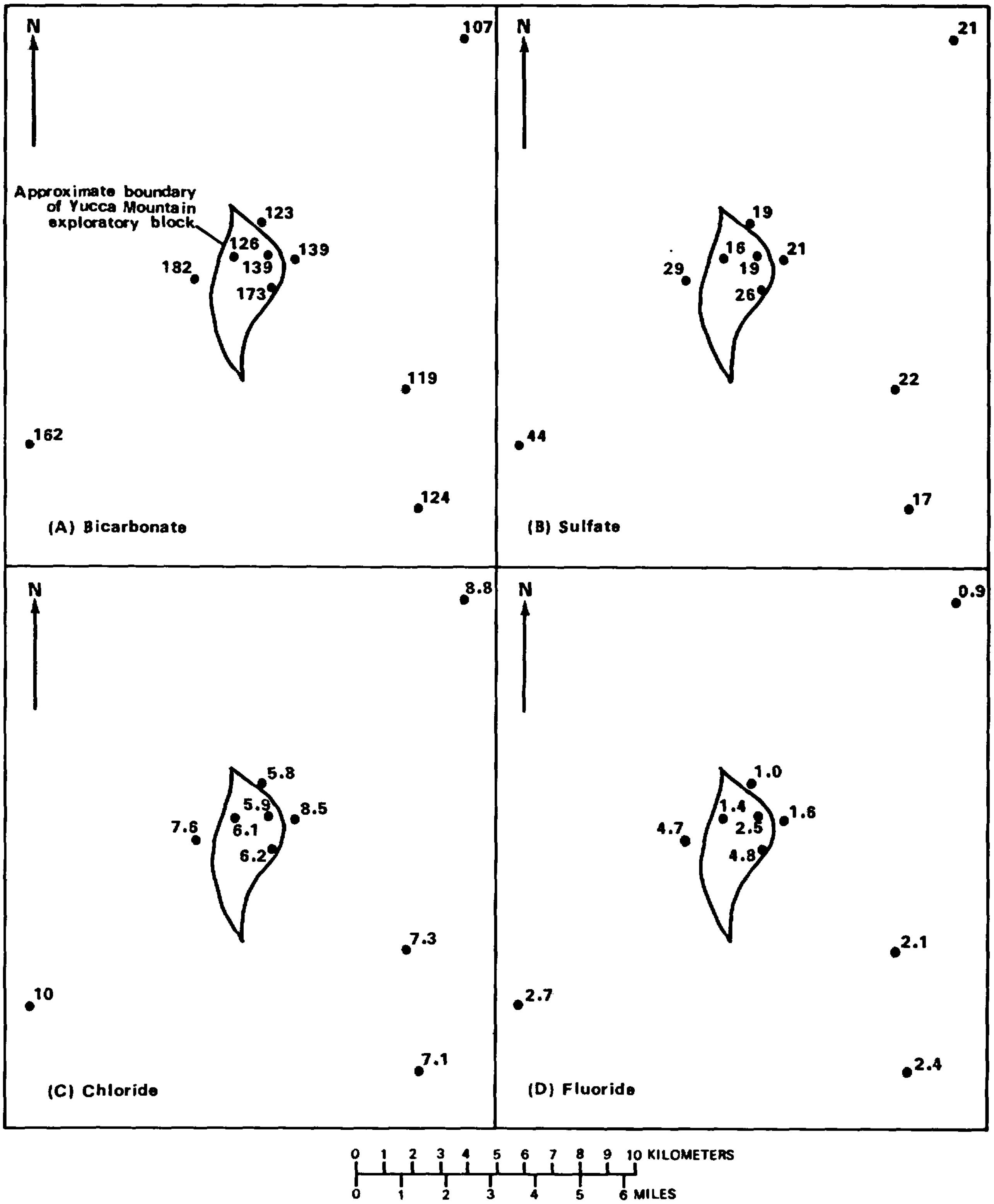


Figure 9.--Bicarbonate, sulfate, chloride, and fluoride concentrations, in milligrams per liter, in ground water from the Yucca Mountain area.

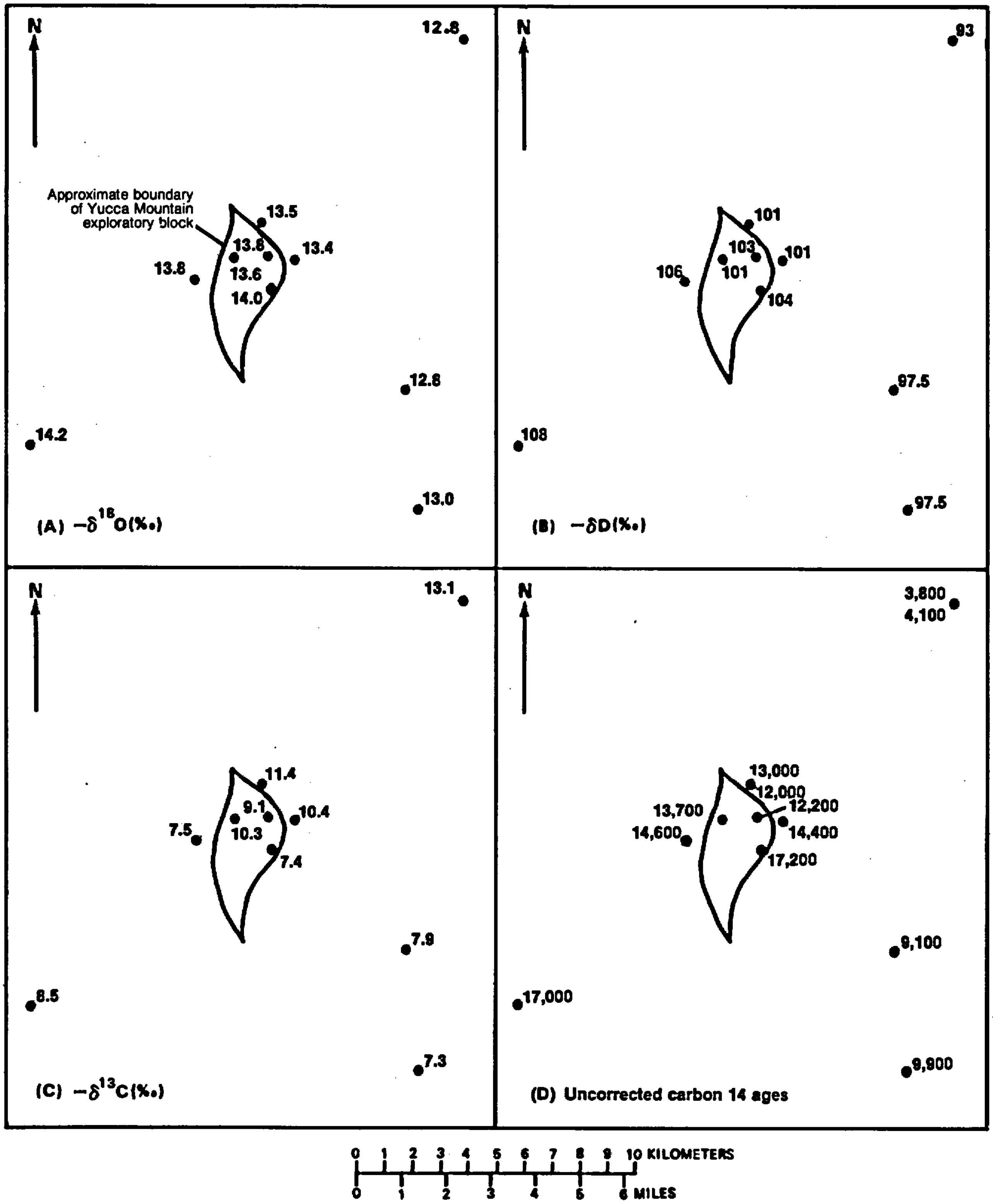


Figure 10.--Del oxygen-18 ($\delta^{18}O$), del deuterium (δD), del carbon-13 ($\delta^{13}C$), and uncorrected carbon-14 (^{14}C) ages for ground water from the Yucca Mountain area.

written commun., 1983), and that all of the production in well VH-1 comes from the Bullfrog Member of the Crater Flat Tuff of Tertiary age (Lewis Howells, U.S. Geological Survey, written commun., 1983).

A summary diagram showing the vertical distribution of permeable zones in wells in the Yucca Mountain area (fig. 11) indicates little or no well-to-well correlation of permeable zones with lithology. However, permeable intervals commonly occur near the water-table surface regardless of the geologic unit.

DISCUSSION

Representativeness of Ground-Water Samples

One criterion used to judge the representativeness of a ground-water sample is the lessening of drilling-fluid tracer concentrations to values approximating those of uncontaminated ground water. A substance chosen to be a tracer of drilling fluid needs to have the following characteristics:

1. The tracer needs to be easily detectable even when dilution processes decrease its concentration by a factor of 10^{-3};

2. Only trace concentrations of the tracer should be present in the natural ground water; and

3. The tracer should not react chemically with solids lining fluid pathways.

Lithium has the first two characteristics, but it sorbs on negatively charged mineral surfaces; however, this process probably is reversible in nature because the lithium desorbs from mineral surfaces as drilling fluid and ground water are pumped from the well. Therefore, the measured concentration of lithium in pumped waters should nearly reflect the extent of drilling-fluid contamination.

Measured lithium concentrations ranged from 40 to 950 μg/L (table 1). The percentage of drilling-fluid contamination, as a function of the lithium concentration in the formation-water and the drilling-fluid mixture, is shown in figure 12. A comparison of the lithium data of table 1 with figure 12 indicates that only the samples collected on August 7, 1981, from well UE-25b#1 had a drilling-fluid contamination in excess of 1.0 percent; the majority of samples contain less than about 0.4 percent drilling fluid. The effect of drilling-fluid contamination on measured ground-water chemical composition is minimized further by the overall similarity in chemical composition of drilling fluid and other ground water in the Yucca Mountain area.

Chemical Inhomogeneity of Yucca Mountain in Ground Water

Data presented in this report (figs. 8 to 10) indicate that ground water from wells in the Yucca Mountain area has a small degree of lateral chemical

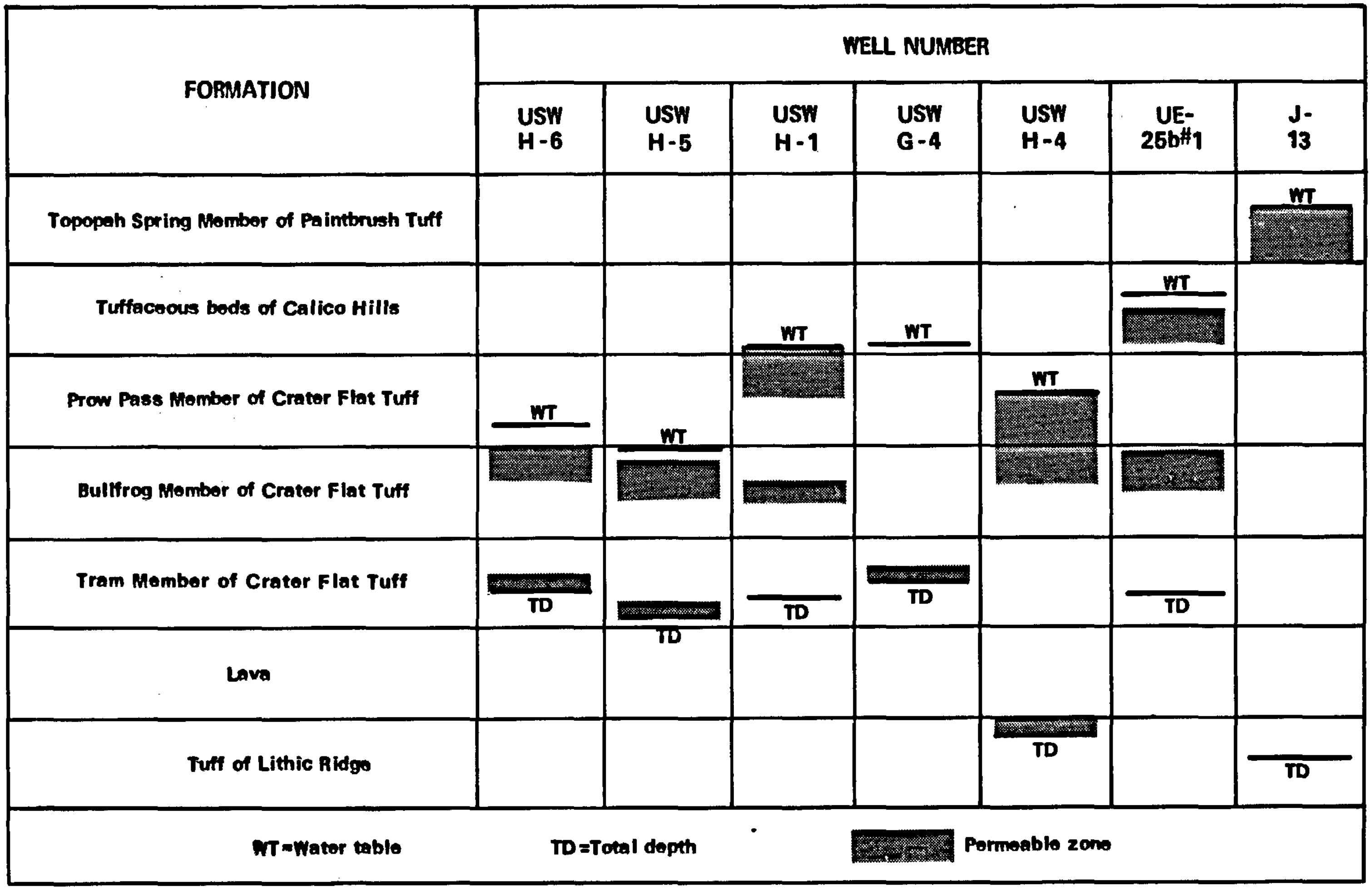


Figure 11.--Vertical distribution of permeable zones in selected wells in the Yucca Mountain area.

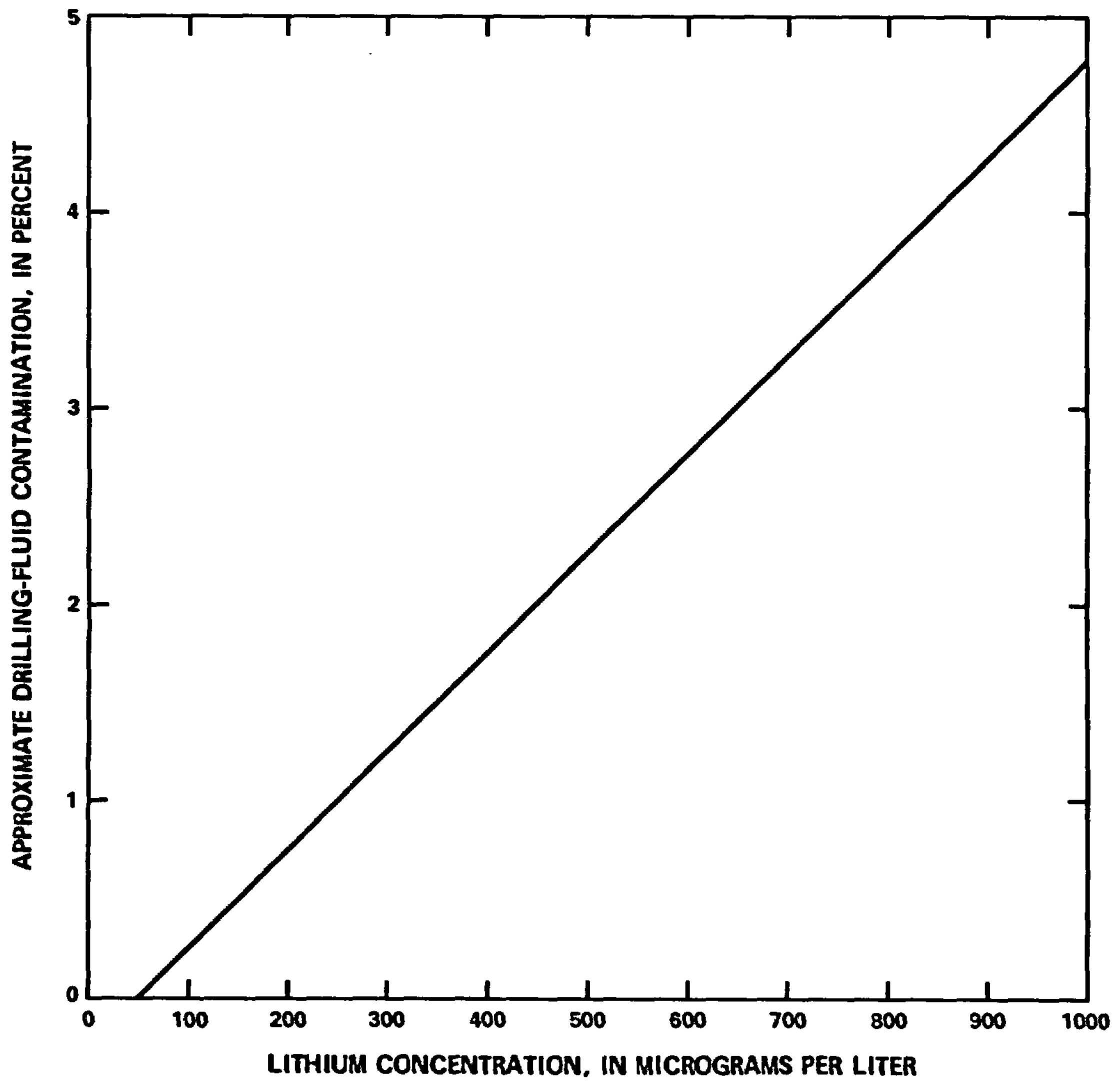


Figure 12.--Plot of drilling-fluid contamination as a function of lithium concentration.

variability. Future work is planned to test the degree of vertical chemical homogeneity of ground water from several wells located within the exploratory block.

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