1985

Chemical Composition of Ground Water in the Yucca Mountain Area, Nevada, 1971-84

Larry Benson

P. W. McKinley

USGS-OFR-85-484

UNITED STATES

DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

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By

L.V. Benson and P. W. McKinley

Open-File Report 85-484

Prepared in cooperation with the

Nevada Operations Office

U.S. Department of Energy

(Interagency Agreement DE-AI08-78ET44802)

Denver, Colorado

1985

UNITED STATES DEPARTMENT OF THE INTERIOR

DONALD PAUL HODEL, Secretary

GEOLOGICAL SURVEY

Dallas L. Peck, Director

For additional information
write to:

Chief, Nuclear Hydrology Program
U.S. Geological Survey
Water Resources Division
Box 25046, Mail Stop 416
Denver Federal Center
Lakewood, CO 80225

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CONVERSION TABLE

The metric units in this report may be converted to inch-pound units by use of the following conversion factors:

Multiply metric units	*By*	*To obtain inch-pound units*
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
degree Celsius (°C)	F=9/5°C + 32	degree Fahrenheit (°F)

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ABSTRACT

Fifteen test wells in the Yucca Mountain area of southern Nevada have been sampled for chemical analysis at least once during 1971-84. Samples were obtained by pumping water from the entire well bore (composite sample), and, in three instances, by pumping from one or more isolated intervals within a well bore. Sodium was the most abundant cation, and bicarbonate was the most abundant anion in all water samples. Samples from the deep carbonate aquifer penetrated by well UE-25p#1 contained higher relative concentrations of calcium and magnesium than did samples from overlying volcanic tuffs. Concentrations of the stable isotopes of oxygen and hydrogen were relatively negative (light) and had deuterium-excess values ranging from +5 to +10. The distribution of uncorrected radiocarbon ages of water from volcanic tuffs sampled within 1 kilometer of the exploratory block on Yucca Mountain ranged from 12,000 to 18,500 years before present. Variation in the concentrations of inorganic constituents and of stable and radioactive isotopes indicates a significant degree of lateral and vertical chemical inhomogeneity in ground water of the Yucca Mountain area.

INTRODUCTION

Part of Yucca Mountain, the exploratory block, in southern Nevada (fig. 1) is being investigated as a potential repository for the disposal of high-level nuclear wastes by the U.S. Department of Energy. 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 by the Federal government, the repository probably would be excavated within the unsaturated zone, 150 to 300 m above the water table. There is concern that radionuclides, once leached from the stored wastes, would eventually reach the saturated zone, where they would 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 ongoing since 1971. This report presents the chemical analyses of ground-water samples collected between 1971 and 1984, and incorporates selected data from earlier reports (Claassen, 1973; Benson and others, 1983). Drilling, sampling, and analytical procedures are those described in Benson and others (1983). The investigation is being conducted by the U.S. Geological Survey in cooperation with the U.S. Department of Energy as part of the Nevada Nuclear Waste Storage Investigations.

WATER COMPOSITION

The chemical composition of samples collected from test wells shown in figure 2 is listed in table 1. Certain data for test wells UE-25b#1, UE-29a#2, USW G-4, USW H-1, USW H-4, USW H-5, USW H-6, USW VH-1, J-12, and J-13 were reported previously (Claassen, 1973; Benson and others, 1983).

Plots of relative cation and anion concentrations in ground water (fig. 3) indicate that sodium and bicarbonate ions were the predominant cation and anion. Water from the deep carbonate aquifer penetrated by test well UE-25p#1 was more concentrated than water from tuffaceous rocks (table 1) and contained a greater relative concentration of calcium, magnesium, chloride, and sulfate. Variation in the concentrations of inorganic constituents and of stable and radioactive isotopes indicates a significant degree of lateral and vertical chemical inhomogeneity in ground water of the Yucca Mountain area. The sample collected from test well UE-25p#1 on February 19, 1983, represents a mixture of ground water from tuffaceous and carbonate rocks.

The uncorrected radiocarbon age of ground water within 1 km of the Yucca Mountain exploratory block ranged from 12,000 to 18,500 years before present (table 1, fig. 4). The oxygen ($\delta^{18}O$) and deuterium (δD) concentrations of ground water from the Yucca Mountain area were very light; oxygen concentrations ranged from -12.8 to -14.2 o/oo; deuterium concentrations ranged from -93.0 to -106 o/oo (table 1, fig. 5; VH-1 not within 1 km). Only two ground-water samples plot on or near the present-day meteoric water line. Instead, the deuterium-excess parameter (d) varies from +5 to +10 (fig. 5).

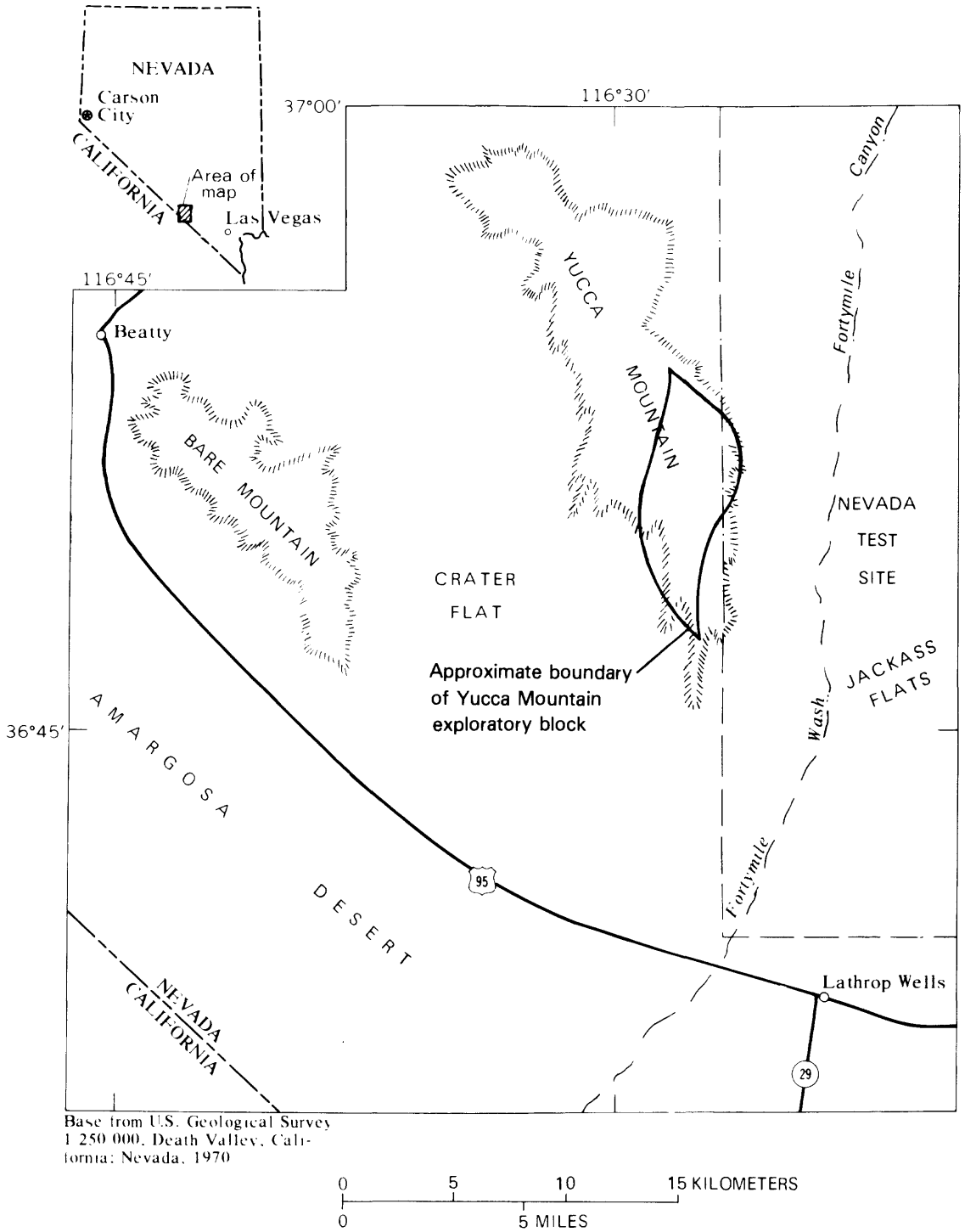

Figure 1.--Location of exploratory block on Yucca Mountain.

Table 1.--*Chemical composition of water samples obtained from test wells*

[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 SMOW; $\delta^{13}C$, del carbon-13, reported in parts per thousand, o/oo, 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), K (potassium), HCO_3 (bicarbonate), Cl (chloride), SO_4 (sulfate), SiO_2 (aqueous silica), F (fluoride), O_2 (dissolved oxygen), and dissolved solids reported in milligrams per liter, except Li (lithium) and Sr (strontium), which are reported in micrograms per liter; ---, indicates entire well bore pumped; --, indicates that no data are available for particular analysis of interest; *, certain dissolved oxygen (O_2) values taken from Ogard and Kerrisk (1984)]

Test well 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	*O_2	Specific conductance (microsiemens per centimeter at 25° C) Onsite	Specific conductance (microsiemens per centimeter at 25° C) Laboratory
J-12	953.5	347	225	---	03/26/71	-97.5	-12.8	-7.9	32.2	9,100	<220	--	285	252
J-13	1,011.3	1,063	282	---	03/26/71	-97.5	-13.0	-7.3	29.2	9,900	<220	5.7	285	252
UE-25b#1	1,200.4	1,220	470	---	08/07/81	-99.5	-13.4	-10.7	--	--	--	1.8	318	319
UE-25b#1	1,200.4	1,220	470	---	09/01/81	-101	-13.4	-10.4	16.7	14,400	<200	--	300	281
UE-25b#1	1,200.4	1,220	470	(863-875)	07/20/82	-99.5	-13.5	-8.6	18.9	13,400	2	1.6	291	297
UE-25c#1	1,131.0	914	400	---	09/30/83	-102	-13.5	-7.1	15.0	15,200	<1	--	290	310
UE-25c#2	1,132.0	913	401	---	03/13/84	-100	-13.4	-7.0	16.6	14,400	<2	--	295	303
UE-25c#3	1,132.0	913	402	---	05/09/84	-103	-13.5	-7.5	15.7	14,900	2	--	298	309
UE-25p#1	1,114.0	1,800	381	(381-1,197)	02/09/83	-106	-13.5	-4.2	3.5	26,900	<10	--	628	639
UE-25p#1	1,114.0	1,800	361	(1,297-1,805)	05/12/83	-106	-13.8	-2.3	2.3	30,300	10	1.3	1,120	1,120
UE-29a#2	1,215.1	422	29	(247-354)	01/08/82	-93.5	-12.8	-13.0	62.3	3,800	37	5.4	240	255
UE-29a#2	1,215.1	422	29	(87-213)	01/15/82	-93.0	-12.8	-13.1	60.0	4,100	37	5.6	258	317
USW G-4	1,270.0	915	541	---	12/09/82	-103	-13.8	-9.1	22.0	12,160	--	6.4	312	307
USW H-1	1,302.2	1,829	572	(572-687)	10/20/80	-103	-13.4	--	19.9	13,000	<20	--	255	258
USW H-1	1,302.2	1,829	572	(687-1,829)	12/08/80	-101	-13.5	-11.4	23.9	12,000	<20	--	247	266
USW H-3	1,483.0	1,220	--	(822-1,220)	03/14/84	-101	-13.9	-4.9	10.5	18,100	2	<0.1	523	535
USW H-4	1,249.0	1,220	519	---	05/17/82	-104	-14.0	-7.4	11.8	17,200	<10	5.8	340	381
USW H-5	1,477.8	1,220	704	---	07/03/82	-102	-13.6	-10.3	18.2	13,700	<200	6.3	275	273
USW H-5	1,477.8	1,220	704	---	07/26/82	-102	-13.6	-10.3	21.4	12,400	<200	--	278	276
USW H-6	1,302.0	1,220	526	---	10/16/82	-106	-13.8	-7.5	16.3	14,600	<10	5.9	372	--
USW H-6	1,302.0	1,220	--	(753-835)	06/20/84	-105	-14.0	-7.3	10.0	18,500	4	--	360	392
USW H-6	1,302.0	1,220	--	(608-646)	07/06/84	-107	-14.0	-7.1	12.4	16,800	1	--	402	408
USW VH-1	954.5	762	184	---	02/06/81	--	--	--	--	--	--	--	370	410
USW VH-1	954.5	762	184	---	02/08/81	--	--	--	--	--	--	--	395	397
USW VH-1	954.5	762	184	---	02/11/81	-108	-14.2	-8.5	12.2	17,000	<20	--	388	402

Table 1.--*Chemical composition of water samples obtained from test wells*--Continued

Test well designation	Onsite pH (units)	Laboratory pH (units)	Water temperature (°C)	Dissolved constituents													
				Ca	Mg	Na	K	HCO_3 (onsite)	HCO_3 (laboratory)	Cl	SO_4	SiO_2	Li	Sr	F	Dissolved solids (calculated)	Dissolved solids (180°C)
J-12	7.1	--	27.0	14	2.1	38	5.1	--	119	7.3	22	54	40	10	2.1	211	205
J-13	7.2	--	31.0	12	2.1	42	5.0	--	124	7.1	17	57	40	20	2.4	213	202
UE-25b#1	7.1	6.8	36.0	19	0.73	53	3.7	173	158	13	24	53	950	44	1.5	264	266
UE-25b#1	7.5	7.5	36.0	17	.59	46	3.5	139	134	8.5	22	52	220	38	1.6	218	225
UE-25b#1	7.1	7.7	37.2	18	.72	46	2.8	133	138	7.5	21	51	120	47	1.6	220	221
UE-25c#1	7.6	7.7	41.5	11.0	.34	56	2.0	151	140	7.4	23	56	120	30	2.1	229	--
UE-25c#2	7.7	7.8	40.5	12.0	.40	54	2.1	139	143	7.1	22	54	94	45	2.1	233	--
UE-25c#3	7.7	7.8	40.8	11.0	.40	55	1.9	137	143	7.2	22	53	110	44	2.0	229	--
UE-25p#1	6.8	7.7	44.3	37	10	92	5.6	--	282	13	38	49	230	180	3.4	418	394
UE-25p#1	6.6	7.2	56	100	39	150	12	--	569	28	160	41	590	450	4.7	812	784
UE-29a#2	7.2	7.6	25.1	10	.2	44	1.1	107	112	11	22	44	100	39	1.0	198	194
UE-29a#2	7.0	7.4	22.7	10	.3	44	1.3	107	110	8.8	21	44	110	33	.9	194	192
USW G-4	7.7	7.5	35.6	13	.2	57	2.1	139	143	5.9	19	45	67	17	2.5	215	216
USW H-1	7.7	7.8	33.0	4.5	<.1	51	2.4	--	115	5.7	18	47	40	5	1.2	--	176
USW H-1	7.5	8.0	34.7	6.2	<.1	51	1.6	--	122	5.8	19	40	40	20	1.0	--	188
USW H-3	9.2	9.0	26.5	.8	.02	120	1.1	--	274	5.5	31	43	220	1	5.5	347	--
USW H-4	7.4	7.9	34.8	17	.29	73	2.6	173	171	6.9	26	46	130	27	4.6	261	248
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	--	220
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	--	206
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 H-6	8.3	8.4	41.6	1.4	.02	88	1.3	217	183	7.2	25	47	71	3	3.9	269	--
USW H-6	8.3	8.3	37.2	4.7	.07	88	1.4	234	184	7.4	32	49	63	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	280	287
USW VH-1	7.5	7.9	35.5	10	1.5	80	1.9	165	158	10	45	50	90	70	2.7	279	274
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	275	277

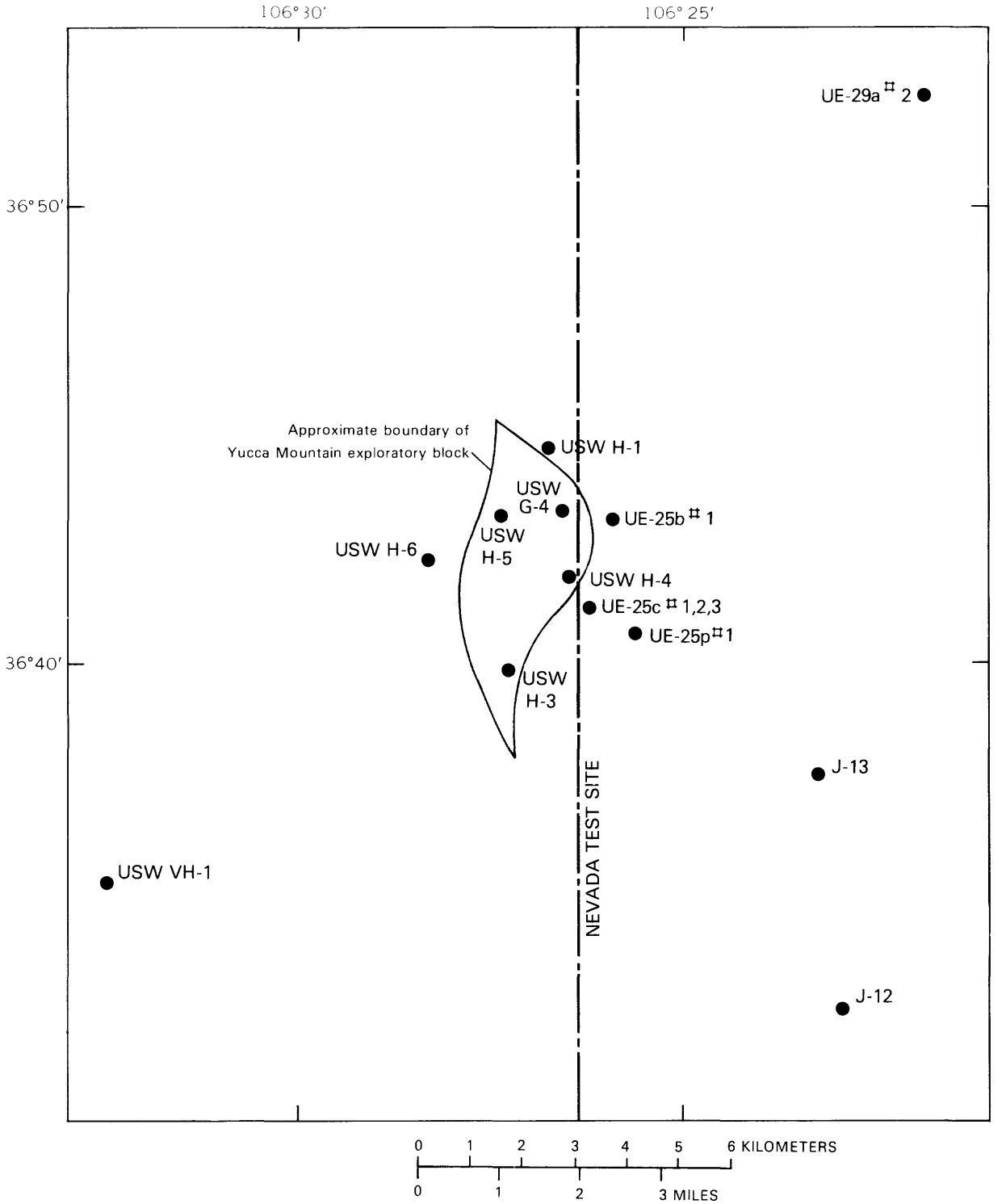

Figure 2.--Location of selected test wells in and near the exploratory block.

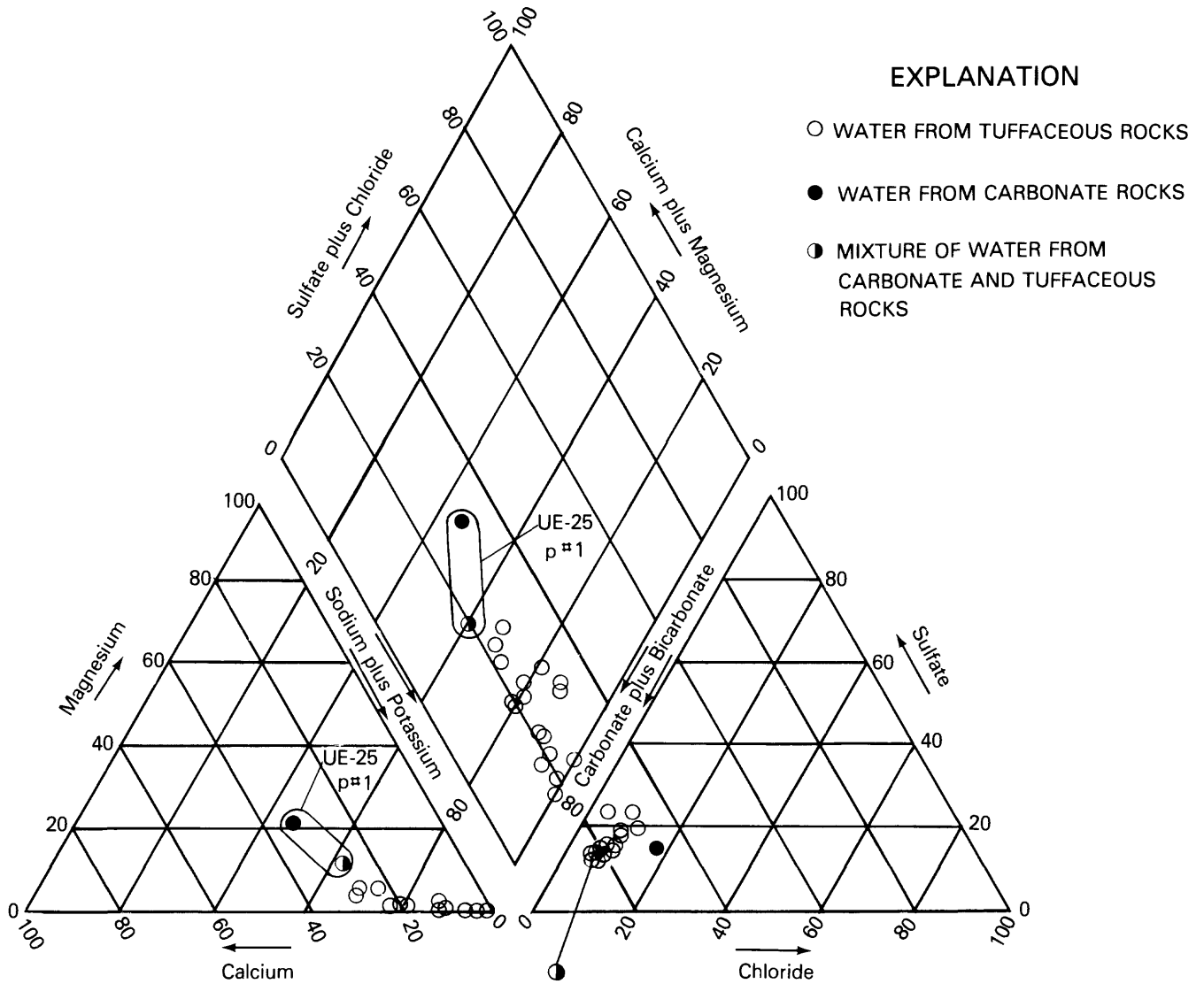

Figure 3.--Relative concentrations, in milliequivalents, of cations and anions in ground water.

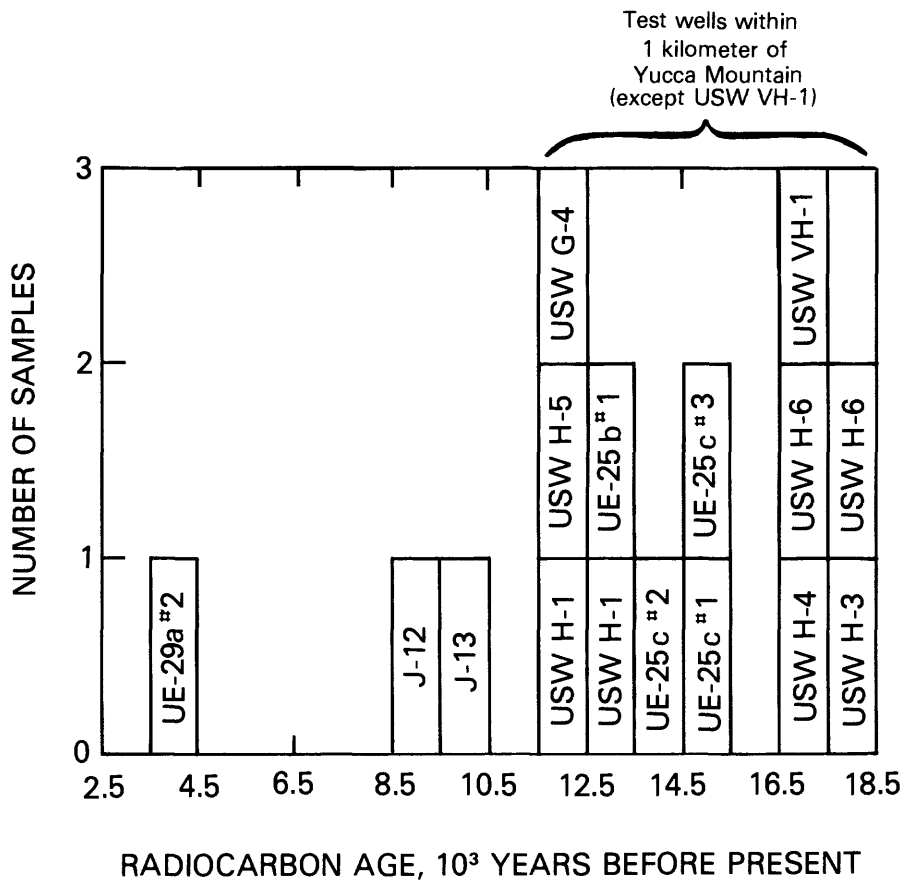

Figure 4.--Histogram of ground-water ages.

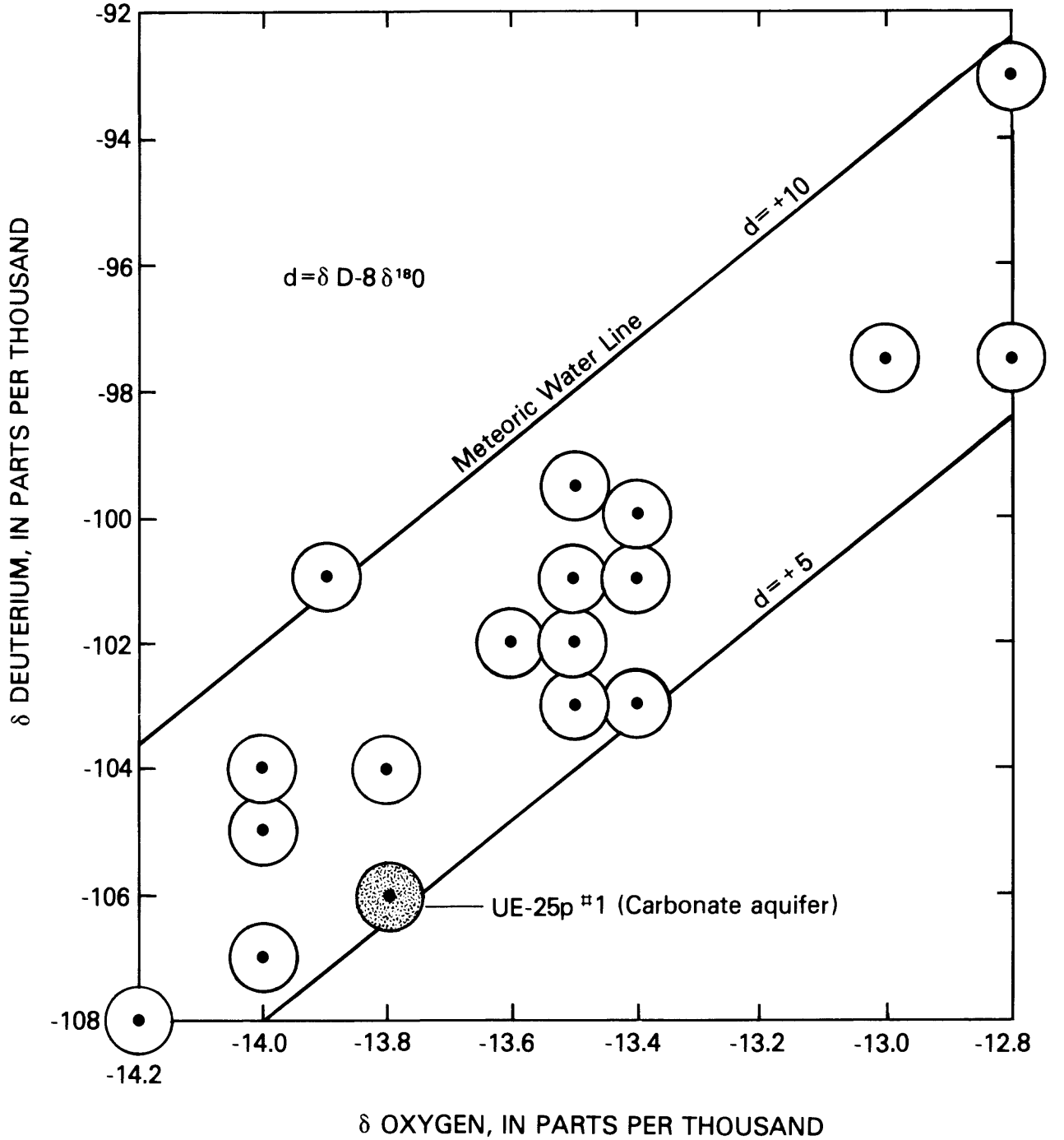

Figure 5.--Meteoric water line and relation between δ oxygen and δ deuterium concentrations.

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