Supporting Online Material for

Flow of Mantle Fluids Through the Ductile Lower Crust: Helium Isotope Trends

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Sampling methods and analytical procedures

Sample selection and locations

In an attempt to be as comprehensive as possible we targeted thermal features (springs, fumaroles, wells) throughout the Basin and Range Province (B&R), western North America and surrounding areas without making any predeterminations based on available geochemical data. Locations of the sampled features where obtained from several data bases:

http://www.osti.gov/geothermal/servlets/purl/6737326-YY5cwq/6737326.pdf

http://www.ngdc.noaa.gov/seg/geotherm.shtml

http://hotspringchem.wr.usgs.gov/)

http://www.unr.edu/Geothermal/index.html

Sampling protocols

Samples of non-condensable gas or water were collected from wells, springs and fumaroles. Three types of wells were sampled: (1) high temperature geothermal production wells in which boiling and phase separation occurs within in the well bore; (2) low to moderate temperature wells in which a separate gas phase forms upon decompression as the fluid flows up the well bore, and (3) low to moderate temperature wells that produce a single liquid phase. In sampling Type 1 wells, the wellhead vapor phase was passed sequentially through water and ice-bath condensers. The cooled fluid flows through an inverted "Y-shaped" tube separating the condensate and gas phases, allowing for collection of the non-condensable gases at ambient conditions. When sampling Type 2 wells, the water and ice-bath condensers were bypassed and the two phase well head fluid was passed directly through the inverted "Y-shaped" separator isolating a sample of the free gas phase for collection. In both cases, the entire sampling apparatus was initially filled with either the well head liquid or the liquid condensate; the separated gas phase was captured using a water displacement technique. The single phase liquid flowing from Type 3 wells was sampled directly for analysis of the dissolved gases.

Springs that were either non-boiling or without a free gas phase were sampled in much the same way as the Type 3 wells. A tube was submerged in the spring, as close to the spring inlet as possible, and water was pulled through the sampling apparatus using a peristaltic hand pump. After several volumes of water had passed through the system a sample of the liquid was collected for analysis of the dissolved gases. When sampling boiling springs or springs with a free gas phase, the vapor/gas phase was captured and forced through the water-filled sampling apparatus using an inverted funnel submerged in the spring. The non-condensable gas phase was separated and collected from the liquid phase using the "Y-shaped" separator. Water displacement was used to capture the gas phase in the sample container, in the same manner as that used for well Types 1 and 2. Fumarole gases were captured and forced through the sampling apparatus using an inverted funnel sealed around the funnel-ground contact. The gas and vapor are allowed to flow through the sampling apparatus in order to adequately purge the sampling lines of air before collecting a sample.

Analytical method

In all cases, a 9.8 cc sample of gas or liquid was collected at ambient conditions in a Cu-tube cold-welded at each end using bolt driven clamps. To insure sample integrity, the clamps remained in place until the sample was ready for analysis and attached to the sample preparation vacuum line which is in series with the noble gas mass spectrometer. Sample preparation and the noble gas analyses were conducted in the RARGA (Roving Automated Rare Gas Analysis) laboratory at the Lawrence Berkeley National Laboratory. Sample preparation, analytical techniques and the instrumentation employed in the RARGA laboratory, are identical to those described in (*S1*). The Cu-tube is opened by re-rounding the cold weld and the sample gas is allowed to expand into the sample preparation line for processing. First, water vapor is condensed in a flow through trap cooled externally using a methanol-liquid N_2 slurry. The line pressure is then measured to estimate the amount of non-condensable gases in the sample. Then CO_2 and other reactive gases (N_2, H_2, CO, etc.) are chemically removed by exposure to a stream of evaporating Ti-metal. After removal of the reactive gases, an aliquot of the remaining

purified noble gas fraction is isolated for determination of absolute and relative abundances. The rest of the noble gas fraction (~95%) is trapped on activated coconut charcoal cooled to ~35 ^{o}K, from which each noble gas can be thermally separated and analyzed individually for its isotopic composition. The sample preparation line and mass spectrometer performance are calibrated using aliquots of air and a Berkeley helium standard with an isotopic composition of 2.4 Ra (where Ra is the $^{3}He/^{4}He$ ratio in air: 1.4×10^{-6}).

Estimation of $CO_2/^{3}He$ ratio in the Dixie Valley Geothermal System

The $CO_2/^{3}He$ ratio ($\sim 40 \times 10^{9}$) discussed in the text was not measured directly because (1) our sampling method is designed for noble gas measurements in fluids not bulk gas chemistry and (2) we do not presently have the analytical capability to make the measurement on a routine basis. Therefore the quoted value for the Dixie Valley Geothermal Field is an estimate derived from literature data.

The estimate uses the following relationship:

$$(CO_2/^{3}He) = (\langle CO_2 \rangle / \langle Ar \rangle) * (^{40}Ar/^{36}Ar)_{air} * \{1.0/[(\langle F(^{4}He) \rangle * (^{4}He/^{36}Ar)_{air} * (\langle R/Ra \rangle) * Ra]\}$$

Where <i> denotes an average value for the Dixie Valley geothermal wells and we have assumed that the total average <Ar> is equivalent to the average $^{40}Ar/^{36}Ar$ ratio which for the Dixie Valley geothermal wells is indistinguishable from the atmospheric ratio of $(^{40}Ar/^{36}Ar)_{air} = 295.5$ (*S1*).

The average CO_2 and Ar concentrations are from (*S2*, see Table 8) and were calculated from production well samples collected as part of multi-year (1995-1999) monitoring program. The average $F(^{4}He)$ and R/Ra values are from (*S1*) and were calculated from production well samples as part of the same multi-year monitoring program.

The following values were used (concentrations are mole % dry gas):

$<CO_2>$	96%
<Ar>	3.0%
$<F(^4He)>$	154.0
<R/Ra>	0.7

Based on the range in the CO_2 and argon concentrations and helium isotope compositions reported for the geothermal production fluids during the monitoring period, we estimate an uncertainty in the $CO_2/^3He$ ratio is ~20-30%.

Table S1: Basin and Range fluid samples, sample location, relative noble gas abundances, and helium isotope compositions.

Sample ID	Location Name	Type G = Gas W= Water	Discharge T °C	$F(^4He)^1$	σ^2	$F(^{22}Ne)$	σ	$F(^{84}Kr)$	σ	$F(^{132}Xe)$	σ	$^{40}Ar/^{36}Ar$	σ	Rm/Ra^3	X^4	Rc/Ra^5	σ	Lat. NAD83/WGS84 °N	Long. °E
CASCADES																			
CA03LHS1	Little Hot Springs	G	76	97.69	0.75	0.3624	0.0024	1.5216	0.0113	2.0501	0.0341	299.22	0.59	1.92	269.59	1.92	0.04	41.2309	121.4040
CA03BBHS	Big Bend Hot Springs (well)	G	82	218.50	1.70	0.3471	0.0040	1.7596	0.0163	2.6680	0.0469	304.74	1.18	2.66	629.44	2.67	0.04	41.0224	121.9201
CA03LKLW	Lower Klamath Lake Well	W	70	14.69	0.12	0.2866	0.0033	1.9763	0.0140	3.6862	0.0563	297.51	0.56	3.67	51.26	3.72	0.08	41.9229	121.6083
Medicine Lake Volcano:																			
CA97ML02	Medicine Lake Geothermal Well #87-13 S02	G	-	280.51	2.97	0.4408	0.0091	1.7795	0.0154	3.2639	0.0614	301.35	0.64	7.43	636.41	7.44	0.15	41.5638	238.4339
Mt. Shasta:																			
CA04MSAS	Mount Shasta Acid Spring S1	G	70	345.18	2.94	0.6635	0.0108	1.5414	0.0159	2.6238	0.0587	315.82	0.88	5.49	520.26	5.50	0.10	41.4091	237.8038
CA04MSAS	Mount Shasta Acid Spring S2	G	70	365.98	2.79	0.7819	0.0108	1.4809	0.0132	2.6029	0.1067	317.95	0.94	5.09	468.09	5.09	0.09	41.4091	237.8038
Mt. Lassen:																			
LAS8801	Bumpass Hell - Big Boiler	G	160	1.77	0.02	0.9410	0.0320	1.0530	0.0090					3.87	1.88	7.13	0.34	40.4579	238.4985
LAS8802	Bumpass Hell - Map Spr. #12	G	90	86.60	1.21	0.3250	0.0270	1.9320	0.0200	4.0500	0.2400	310		7.26	266.46	7.28	0.25	40.4579	238.4968
LAS8803	Growler Hot Spr.	G	93	3.50	0.05	0.4650	0.0290	1.9800	0.0180	5.4900	0.3100	295		5.31	7.53	5.97	0.23	40.3928	238.4936
LAS8804	Little Hot Spr. Valley - Map Spr. #5(L)	G	144.1	480.82	6.44	0.3160	0.0270	1.8780	0.0170	3.6100	0.2700	313		6.49	1521.58	6.49	0.29	40.4612	238.4779
LAS8805	Little Hot Spr. Valley - Map Spr. #?(L)	G	112	499.80	6.71	0.3690	0.0300	1.8990	0.0170	3.9100	0.2400	311		5.74	1354.47	5.74	0.33	40.4562	238.4820
LAS8806	Little Hot Spr. Valley - Travertine Depositing - Map Spr. #129b(U)	G	70	9.93	0.13	0.5410	0.0200	1.6520	0.0140	3.4700	0.2000	305		7.00	18.35	7.35	0.31	40.4521	238.4834
LAS8807	Devil's Kitchen - Map Spr. #242	G	100	84.00	1.12	0.2940	0.0460	1.9230	0.0200	3.7500	0.2200	313		4.73	285.71	4.74	0.21	40.4413	238.5660
LAS8808	Devil's Kitchen - Frying Pan - Map Spr. #290	G	96	49.99	0.67	0.4240	0.0190	1.7140	0.0140	3.0200	0.1700	295		6.15	117.90	6.19	0.29	40.4412	238.5686
Newberry Caldera:																			
OR03NB03	Newberry Caldera - Paulina Hot Spring	G	54.8	14.09	0.20	0.2775	0.0079	1.9274	0.0150	3.8884	0.2040	294.90	1.89	7.24	50.79	7.36	0.15	43.7318	238.7388
OR04NB03	Newberry Caldera - Paulina Hot Spring	G	54.8	11.52	0.09	0.3071	0.0035	1.9474	0.0125	3.7504	0.0617	296.43	0.70	7.06	37.51	7.23	0.15	43.7318	238.7388
OR03NB01	Newberry Caldera - Obsidian Flow Seep	G	14.6	77.52	0.90	0.2848	0.0072	1.8541	0.0125	3.5526	0.1991	295.36	1.88	6.74	272.19	6.76	0.14	43.7030	238.7655
OR03NB02	Newberry Caldera - East Lake Hot Spring	G	29	46.62	0.54	0.3315	0.0066	1.7825	0.0129	3.2453	0.1839	300.45	1.98	6.31	140.61	6.35	0.10	43.7198	238.7996
BASIN AND RANGE																			
Long Valley: Representative data from the USS-LBNL monitoring program - published data in (*S6, S7*)																			
LV01BAL	Big Alkali Lake	G	57	64.53	0.30	0.5951	0.0056	1.2308	0.0084	1.5840	0.0333	296.60	1.28	5.14	108.44	5.18	0.09	37.7000	241.2180
LV02RD08	RD 08 Well	G	-	325.60	37.77	0.2894	0.0239	1.8747	0.0206	3.5908	0.2091	308.66	2.17	4.39	1125.01	4.39	0.09	37.6586	241.0480
LV02LHCS	Little Hot Creek Valley	G	89	83.80	0.64	0.3908	0.0056	2.0102	0.0217	4.2451	0.1091	302.11	1.07	5.04	214.41	5.06	0.12	37.6907	241.1560
LV02HCV	Hot Creek Valley	G	78	58.64	0.45	0.4646	0.0049	1.7961	0.0122	3.5775	0.0633	297.70	1.10	5.11	126.19	5.14	0.09	37.6474	241.1400
LV02HBP	Hot Bubbling Pool	G	92	27.23	0.21	0.5036	0.0052	1.6740	0.0103	2.9080	0.0570	298.89	1.10	3.49	54.06	3.54	0.08	37.6613	241.1720
LV02CDF	Casa Diablo Fumarole	G	93	49.13	0.38	0.5875	0.0042	1.7478	0.0117	3.5540	0.0567	296.63	1.11	3.95	83.64	3.98	0.10	37.6470	241.0930
LV02ASS	Artesian Soda Spring	W	-	2.02	0.02	0.5289	0.0053	1.8184	0.0167	3.1220	0.0707			3.29	3.83	4.09	0.21	37.5982	240.9340
LV02RCS	Red Creek Hot Spring	W	46	1.24	0.02	0.4776	0.0034	1.7107	0.0108	2.9874	0.0522			3.46	2.60	5.00	0.25	37.6191	240.9410
LV01MMF2	Mammoth Mountain Fumarole	G	86	1103.99	5.39	0.4550	0.0091	1.9689	0.0118	4.0741	0.0741	412.41	1.77	4.96	2426.14	4.96	0.06	37.6220	240.9710
LV90MMF	Mammoth Mountain Fumarole	G	84	3823.80	191.90	0.2900	0.2890	2.0210	0.1080	4.7900	0.3900			6.72	13185.52	6.72	1.04	37.6220	240.9710
LV99MMF	Mammoth Mountain Fumarole	G	85	2093.71	24.61			2.0426	0.0407	5.8447	0.1784	437.71	2.99			3.04	0.05	37.6220	240.9710
Well MBP3	Casa Diablo Geothermal Energy Plant	G	-	143.20	1.80	0.2580	0.0100	2.0750	0.0160	4.2600	0.1500			4.66	555.04	4.67	0.27	37.6448	241.0860
CDW#1	Casa Diablo Geothermal Energy Plant	G	-	217.50	4.50	0.2790	0.0290	2.1620	0.0440	4.8400	0.2500			4.58	779.57	4.58	0.25	37.6448	241.0850
CDW#3	Casa Diablo Geothermal Energy Plant	G	-	191.40	3.90	0.2830	0.0160	2.1080	0.0430	4.5100	0.2300			4.53	676.33	4.54	0.24	37.6467	241.0840
LV00BPHS	Bridgeport Hot Spring	G	82	6.96	0.11	0.3270	0.0020	2.4010	0.0130	7.3350	0.0740	305.52	2.08	3.75	21.28	3.89	0.37	38.2450	240.7930
COSO Geothermal Field																			
cs98-01	Well 16B-20	G	173	1009.59	50.47	0.4536	0.0434	1.4503	0.0345	2.2546	0.1349	319.98	1.01	4.38	2225.65	4.38	0.16	36.0036	242.2027
cs98-02	Well 16A-20	G	174	797.12	46.00	0.5983	0.1300	1.0266	0.0346	1.5644	0.1270	321.19	1.01	2.90	1332.22	2.90	0.15	36.0042	242.2024
cs98-03	Well 15-17RD	G	173	145.87	7.47	0.7338	0.0295	1.0075	0.0225	1.2221	0.0683	297.59	1.00	6.39	198.78	6.41	0.28	36.0195	242.2021
cs98-04	Well 63A-7	G	163	386.49	19.35	0.6350	0.0343	1.2009	0.0277	1.6391	0.0927	314.68	1.02	4.80	608.66	4.81	0.18	36.0367	242.1969
cs98-05	Well 68-6	G	168	513.88	25.72	0.6354	0.0267	1.3965	0.0414	2.3478	0.1431	312.57	1.02	6.22	808.76	6.23	0.25	36.0415	242.1957
cs98-06	Well 22-16	G	178	344.27	17.68	0.2691	0.0611	1.2283	0.0309	1.7345	0.1361	297.42	1.00	4.16	1279.17	4.16	0.24	36.0251	242.2233
cs98-07	Well 38A-9	G	176	99.85	5.24	0.6518	0.0287	1.0755	0.0248	1.2802	0.0750	301.85	0.99	4.21	153.20	4.23	0.14	36.0303	242.2248
cs98-08	Well 51A-16	G	178	66.18	3.32	0.6371	0.0296	1.0981	0.0224	1.3003	0.0698	288.55	1.00	5.05	103.87	5.08	0.21	36.0268	242.2295
cs98-09	Well 64-16	G	176	242.65	12.14	0.9266	0.0198	1.0785	0.0225	1.2052	0.0864	314.45	1.63	5.82	261.88	5.84	0.41	36.0218	242.2317
cs98-10	Well 23-19	G	178	1439.93	71.98	0.7670	0.0641	1.1036	0.0243	1.1384	0.1521	357.51	1.02	4.39	1877.40	4.40	0.23	36.0084	242.1867

Table S1: continued

Sample ID	Location Name	Type G = Gas W= Water	Discharge T °C	F(^{4}He)[1]	σ[2]	F(^{22}Ne)	σ	F(^{84}Kr)	σ	F(^{132}Xe)	σ	^{40}Ar/^{36}Ar	σ	Rm/Ra[3]	X[4]	Rc/Ra[5]	σ	Lat. NAD83/WGS84 °N	Long. °E
Basin and Range General:																			
NV02HZS1	Hazen Hot Springs Gas	G	84	80.25	0.86	0.3374	0.0087	1.7546	0.0087	2.8630	0.0429	298.77	0.81	0.60	237.81	0.60	0.02	39.6010	240.8890
NV02HZS2	Hazen Hot Springs Water	W	61	36.65	0.41	0.3331	0.0085	2.1711	0.0139	3.9912	0.0599	295.28	0.62	0.55	110.04	0.55	0.03	39.6010	240.8900
NV02SCV	Smith Creek Valley Hot Spring	G	92	35.38	0.40	0.2666	0.0055	1.9368	0.0103	3.4969	0.0490	296.01	0.62	0.52	132.69	0.52	0.03	39.3160	242.4530
NV02SHS	Spencer Hot Spring	G	72	225.59	2.63	0.3593	0.0072	1.7399	0.0162	2.7617	0.0362	299.10	0.87	0.28	627.88	0.28	0.02	39.3280	243.1420
NV02EU1	Diamond Valley Cold Spring	W	18	1.78	0.03	0.8239	0.0187	1.1593	0.0085	1.3782	0.0187	294.82	0.66	0.72	2.16	0.48	0.09	39.9610	243.9380
NV02WS1	Wells Hot Spring	G	54	830.65	9.71	0.2729	0.0107	2.3138	0.0202	5.3047	0.1360	419.66	1.84	0.27	3043.59	0.27	0.01	41.1820	245.0090
NV02CC1	Cherry Creek Hot Spring	W	62	25.82	0.29	0.8032	0.0157	1.2992	0.0077	1.8672	0.0368	296.24	0.71	0.24	32.15	0.22	0.01	39.8830	245.1070
NV02CC4	Monte Neva Hot Spring	G	80	12.61	0.14	0.4151	0.0088	1.6763	0.0118	2.8519	0.0385	296.50	0.71	0.39	30.38	0.37	0.01	39.6650	245.1930
NV02GOL1	Golgonda Hot Spring	G	66	142.83	1.50	0.5473	0.0089	1.3521	0.0095	1.7100	0.0847	293.44	2.23	0.17	260.97	0.16	0.01	40.9540	242.5120
NV02RCHS	Rock Creek Hot Spring	G	34	108.64	1.14	0.7218	0.0085	1.0954	0.0090	0.8656	0.0429	291.84	1.46	0.25	150.50	0.24	0.01	41.2790	243.3790
NV02PUM1	Pumpernickel Valley Hot Spring	G	85	112.41	1.18	0.4322	0.0061	1.5179	0.0115	2.1460	0.1049	294.90	1.72	0.15	260.12	0.15	0.01	40.7610	242.5080
NV02PUM2	Pumpernickel Valley Hot Spring	G	87	29.93	0.31	0.2320	0.0066	2.6353	0.0182	6.3487	0.3105	292.50	1.68	0.28	129.04	0.28	0.02	40.7610	242.5080
NV03EU01	Sulphur Springs Well	W	23	3.20	0.03	0.3078	0.0041	1.8469	0.0131	3.3230	0.1654	292.76	1.55	1.20	10.40	1.23	0.06	39.8360	243.9310
NV03EU02	Saddler Ranch Hot Spring	W	41	3.36	0.04	0.2953	0.0041	1.9197	0.0171	3.5340	0.1726	291.25	1.56	0.85	11.37	0.83	0.05	39.9440	243.9270
NV03EU03	Siri Ranch Hot Spring	G	35	3.42	0.04	0.5905	0.0074	1.2258	0.0097	1.4777	0.0754	294.94	1.52	0.41	5.79	0.29	0.04	39.9880	243.9560
NV03EU04	Romano Ranch Well	W	19	3.10	0.03	0.2982	0.0037	1.8664	0.0134	3.4454	0.1709	296.01	1.60	0.81	10.40	0.79	0.05	39.8770	243.9330
NV03BA01	Hot Spring Hill Hot Spring	G	42	10.56	0.11	0.6983	0.0080	1.2194	0.0092	1.4045	0.0716	295.75	1.72	0.58	15.12	0.55	0.02	39.5580	243.6400
NV03BA02	Hot Spring Creek Hot Spring	G	69	16.32	0.17	0.4181	0.0062	1.5492	0.0132	2.1539	0.1059	293.73	1.53	0.04	39.03	0.01	0.01	39.4040	243.6530
OR03EAD	Easterday Hot Spring	W	52	13.03	0.18	0.3081	0.0039	1.8932	0.0124	3.7315	0.1947			0.32	42.29	0.30	0.01	42.0810	242.2400
OR03AD01	Mickey's Hot Spring	G	86	24.76	0.29	0.6322	0.0049	1.5773	0.0112	3.0323	0.1702	295.28	1.88	1.71	39.16	1.73	0.04	42.6760	241.6560
OR03AD02	Alvord Hot Spring	G	79	456.06	5.29	0.3681	0.0302	1.8684	0.0186	4.0474	0.2556	312.21	2.11	1.81	1238.79	1.81	0.03	42.5440	241.4670
OR03AD03	Hot Lake Hot Spring	G	97	35.51	0.35	0.5932	0.0097	1.6663	0.0242	2.9765	0.1946	298.54	1.80	1.24	59.86	1.24	0.04	42.3380	241.3970
OR03OW01	Rhye Grass Hot Spring	W	50	67.23	0.94	0.2858	0.0042	1.8598	0.0123	3.5322	0.1857	298.28	1.92	1.84	235.28	1.84	0.05	43.0620	242.3100
OR03OW02	Greeley Bar Hot Spring	G	55	35.42	0.41	0.6014	0.0090	1.3266	0.0117	1.7420	0.1005	294.79	1.90	0.46	58.90	0.46	0.01	43.2080	242.4550
OR03OW03	Upper Owyhee Reservoir Hot Spring	W	47.5	23.15	0.32	0.3087	0.0041	1.8968	0.0146	3.6430	0.1940	297.22	1.92	1.07	75.00	1.07	0.03	43.3020	242.6150
NV03BRD1	Dyke Hot Spring	G	70	41.70	0.48	0.4423	0.0051	1.4532	0.0105	2.1652	0.1206	295.69	1.92	0.44	94.28	0.43	0.01	41.5670	241.4360
NV03BRD2	Pinto East Hot Spring	G	93	61.20	0.71	0.2808	0.0096	2.4832	0.0174	6.6019	0.3678	302.44	1.99	0.52	217.91	0.52	0.02	41.3630	241.2120
NV03BRD3	McFarlanes Hot Spring	G	77	60.51	0.70	0.2353	0.0162	2.8836	0.0196	8.5523	0.4758	304.73	2.04	2.01	257.18	2.02	0.10	41.0520	241.2830
NV03BRD4	Trego Hot Spring	G	86	43.73	0.51	0.3929	0.0066	1.5756	0.0109	2.4958	0.1419	292.47	2.27	0.27	111.29	0.26	0.01	40.7700	240.8870
NV03BRD5	Double Hot Spring	G	81	112.82	1.31	0.3995	0.0049	1.5448	0.0115	2.4214	0.1362	297.34	1.93	0.65	282.38	0.65	0.01	41.0510	240.9720
ID03MGHS	Maple Grove Hot Spring	G	78	166.99	2.33	0.2734	0.0087	2.1038	0.0144	4.7261	0.2483	306.58	2.06	0.12	610.85	0.12	0.01	42.3080	248.2930
ID03SHS1	Squaw Hot Spring I	G	73	940.06	13.13	0.4084	0.0105	1.8921	0.0166	3.7864	0.1984	357.46	2.78	0.12	2301.67	0.12	0.01	42.1190	248.0720
UT03UTHS	Utah Hot Spring	G	59	6506.64	90.88	0.4926	0.1853	1.5048	0.0385	2.7851	0.3558	433.32	4.05	0.12	13209.18	0.12	0.00	41.3380	247.9690
UT03BKHS	Baker Hot Spring	G	82	169.78	2.37	0.3641	0.0053	1.6286	0.0110	2.7271	0.1420	305.44	2.12	0.29	466.32	0.29	0.01	39.6130	247.2710
UT03RVF2	Roosevelt Fumarole II	G	94	1031.91	14.41	0.4102	0.0472	2.0735	0.0290	5.5812	0.2950	371.86	3.03	2.25	2515.90	2.25	0.05	38.4990	247.1440
UT03THS1	Thermo Hot Spring I	G	89.5	200.41	2.80	0.3432	0.0027	1.7636	0.0120	3.1831	0.1666	301.96	1.96	0.81	583.97	0.81	0.02	38.1830	246.8020
CA03LCW1	Lake City Geothermal Well	G	130	176.80	2.47	0.3879	0.0049	1.6510	0.0116	2.6264	0.1404	302.01	2.05	1.02	455.85	1.02	0.02	41.6720	239.7790
CA03LC24	Mud Volcano South End	G	-	45.14	0.63	0.3399	0.0044	1.7756	0.0120	3.1928	0.1674	297.53	1.95	1.19	132.81	1.20	0.03	41.6670	239.7900
CA03FBHW	Fort Bidwell Hot Well	W	54	24.81	0.35	0.7186	0.0074	1.1896	0.0093	1.8540	0.0967	290.22	1.83	2.19	34.53	2.22	0.13	41.8600	239.8420
CA03LCG6	Lake City Mud Volcano - Hat Hill	W	67.7	16.43	0.23	0.5439	0.0061	1.4762	0.0097	2.3874	0.1271	291.74	1.82	1.47	30.20	1.49	0.04	41.6750	239.7940
CA03SEHS	Seyferth Hot Spring	W	65.5	73.69	1.03	0.3223	0.0083	2.0711	0.0143	4.2896	0.2334	293.68	1.86	1.12	228.65	1.12	0.02	41.6160	239.8960
CA03LEHS	Leonards Hot Spring	W	62	76.66	1.07	0.3653	0.0073	1.8971	0.0154	3.8770	0.2056	296.37	1.94	1.14	209.84	1.14	0.03	41.6010	239.9150
CA03LC1B	Mud Volcano East End	W	-	6.35	0.09	0.4431	0.0057	1.5986	0.0111	2.7945	0.1457	294.19	1.85	0.91	14.34	0.90	0.04	41.6680	239.7920
CA03SVHS	Surprise Valley Hot Spring (Well)	G	96.4	92.83	1.30	0.2371	0.0036	2.0738	0.0153	4.2058	0.2189	301.59	1.95	0.95	391.46	0.95	0.02	41.5330	239.9220
CA03LC29	Mud Volcano Big Boiler (Center)	G	98.7	47.28	0.66	0.3238	0.0101	2.1146	0.0168	4.9697	0.2593	298.21	1.91	1.09	146.03	1.09	0.03	41.6680	239.7900
CA03LCW2	Lake City Geothermal Well	G	130	178.70	2.50	0.3827	0.0056	1.5823	0.0107	2.4267	0.1275	302.91	1.97	1.03	466.94	1.03	0.02	41.6720	239.7790
OR04OW04	Lower Birch Creek Hot Spring	W	-	25.55	0.21	0.5018	0.0034	1.6680	0.0104	2.6869	0.0470	296.12	0.48	0.84	50.91	0.84	0.03	43.2216	242.4858
ID04RR3B	Raft River Geothermal Well RR3 Headspace	G	95	157.81	1.76	0.3579	0.0041	1.7324	0.0145	2.9288	0.0560	306.55	0.92	0.15	440.88	0.15	0.01	42.1070	246.6100
CA04FB01	Fort Bidwell Hot Spring = CA03FBHW	G	43	21.99	0.30	0.5712	0.0059	1.2970	0.0114	1.7201	0.0382	298.08	1.50	2.39	38.50	2.43	0.05	41.8617	239.8405
CA04FB32	Fort Bidwell Geothermal Well FB03 S2	G	92	61.26	0.64	0.3152	0.0036	1.8779	0.0110	3.3730	0.0570	296.78	0.76	2.57	194.38	2.58	0.05	41.8574	239.8325
CA04FB1W	Fort Bidwell Geothermal Well FB01	W	47	12.19	0.13	0.2933	0.0020	1.9888	0.0125	3.9559	0.0671	295.45	1.40	2.43	41.57	2.47	0.07	41.8613	239.1644
CA04FB21	Fort Bidwell Geothermal Well FB02 A	W	30	3.96	0.04	0.3071	0.0017	1.9552	0.0111	3.7248	0.0677	294.76	0.48	2.18	12.89	2.28	0.06	41.8572	239.1235
CA04FB22	Fort Bidwell Geothermal Well FB02 B	W	38	4.30	0.05	0.2983	0.0019	1.9720	0.0106	3.7292	0.0612	295.03	1.01	2.39	14.40	2.50	0.07	41.8572	239.0322
CA04FB33	Fort Bidwell Geothermal Well FB03	G/W	92	76.84	0.81	0.3768	0.0038	1.7110	0.0107	2.7757	0.0584	296.73	0.66	2.13	203.90	2.14	0.04	41.8574	239.1325
CA04KHS	Kelly Hot Springs	G	92	158.48	1.69	0.4077	0.0035	1.5659	0.0089	2.3085	0.0434	300.91	0.58	2.25	388.70	2.25	0.05	41.4540	239.8415
CA04CHW	Canby Geothermal Well	W	94	140.59	1.49	0.2659	0.0022	1.9867	0.0123	3.8672	0.0654	301.28	1.77	2.34	528.65	2.35	0.06	41.4467	239.8390
CA04ACS1	Ambrose Cold Spring	W	18	1.12	0.01	0.2627	0.0029	2.0001	0.0113	3.8856	0.0660	295.12	0.44	2.16	4.27	2.51	0.14	41.4925	239.8390
NV05MCF2	McFarlanes Hot Spring	G	77	70.47	10.85	0.3054	0.0195	3.6159	0.0589	11.2315	0.3335	302.55	1.74	1.905	230.78	1.91	0.09	41.0509	241.2811

Table S1: continued

Sample ID	Location Name	Type G = Gas W= Water	Discharge T ˚C	F(^{4}He)[1]	σ[2]	F(^{22}Ne)	σ	F(^{84}Kr)	σ	F(^{132}Xe)	σ	^{40}Ar/^{36}Ar	σ	Rm/Ra[3]	X[4]	Rc/Ra[5]	σ	Lat. NAD83/WGS84 ˚N	Long. ˚E
NV05SM01	Soldier Meadows #1	W	58	17.57	2.71	0.3328	0.0055	1.4868	0.0242	2.0357	0.0581	291.01	1.60	0.744	52.79	0.74	0.02	41.3609	240.7756
NV05SM02	Soldier Meadows #2	G	54	54.04	8.32	0.6452	0.0070	1.2795	0.0208	1.6000	0.0468	297.73	1.78	0.674	83.76	0.67	0.02	41.3526	240.7824
NV05SM03	Soldier Meadows #3	G	56	54.20	8.34	0.6055	0.0081	1.3225	0.0213	1.6897	0.0459	294.12	1.73	0.622	89.50	0.62	0.02	41.3614	240.8137
NV05BR07	Black Rock Hot Spring	G	58	107.88	16.61	0.4663	0.0060	1.3720	0.0224	1.8104	0.0492	295.14	2.16	0.575	231.38	0.57	0.01	40.9736	240.9920
NV05BR08	Unnamed Hot Spring	G	46	200.56	30.87	0.5149	0.0063	1.3100	0.0218	1.6535	0.0537	300.24	1.83	0.903	389.50	0.90	0.02	40.9552	240.9971
NV05BR09	Casey Hot Spring	G	96	110.32	17.00	0.3212	0.0050	1.7748	0.0286	2.9878	0.0807	297.82	1.90	0.569	343.45	0.57	0.01	41.0027	240.9858
NV05GL01	Big Boiling Spring Gerlach	W	98	2.81	0.43	0.5678	0.0065	1.5096	0.0254	2.2028	0.0643	294.35	1.76	0.856	4.95	0.82	0.14	40.6613	240.6336
NV05GV01	Leach Hot Spring, Grass Valley	G	97	49.50	7.62	0.3630	0.0046	1.7110	0.0274	2.6641	0.0725	298.26	1.81	0.227	136.36	0.22	0.01	40.6039	242.3504
NV05D01	Devil's Punch Bowl	G	52	212.70	32.74	0.6263	0.0068	1.3046	0.0218	1.3111	0.0465	307.97	1.89	0.449	339.59	0.45	0.01	41.2600	244.6960
NV05D02	Unnamed Hot Spring	W	36	93.06	14.32	0.2165	0.0171	2.0415	0.0342	3.4806	0.1050	311.77	1.95	0.276	429.87	0.27	0.02	41.1921	244.7135
NV05BDS1	Bradys Hot Spring	G	98	20.83	3.21	0.4041	0.0061	2.0549	0.0340	5.0252	0.1402	292.85	1.68	0.419	51.56	0.41	0.01	39.7833	240.9852
NV05W01	Unnamed Hot Spring #1	G	54	692.72	106.65	0.4038	0.0761	2.4479	0.0482	5.9155	0.1893	436.41	4.05	0.154	1715.64	0.15	0.01	41.1820	245.0103
NV05W02	Unnamed Hot Spring #2	W	39	10.32	1.59	0.3279	0.0034	1.9343	0.0311	3.6068	0.1007	297.94	1.77	0.288	31.47	0.26	0.01	41.2428	245.0520
NV05CA01	Carling Hot Spring (drowned in river)	G	79	25.42	3.91	0.3975	0.0063	1.6717	0.0271	2.6117	0.0774	297.04	1.90	0.449	63.95	0.44	0.01	40.6994	243.8704
NV05TC01	Hot Sulphur Springs South (middle)	G	90	48.54	7.47	0.2991	0.0062	2.3035	0.0375	5.0324	0.1426	293.34	1.72	0.562	162.28	0.56	0.02	41.4677	243.8477
NV05TC03	Hot Sulphur Springs South (southernmost)	W	45	16.63	2.56	0.3054	0.0038	1.8405	0.0296	3.4768	0.0935	292.82	1.63	0.503	54.44	0.49	0.02	41.4557	243.8470
NV05AM01	Adobe Hot Springs	G	64	18.20	2.80	0.6754	0.0070	1.2876	0.0214	1.4828	0.0458	295.32	1.76	0.055	26.95	0.02	0.01	40.7665	243.9575
NV05BV01	Buffalo Valley Hot Spring	G	79	17.35	2.67	0.4134	0.0074	2.1002	0.0348	4.6076	0.1263	291.58	1.75	1.470	41.98	1.48	0.03	40.3658	242.6732
CA05MBHS	Surprise Valley Menlo Baths HS	W	57	13.20	2.03	0.3715	0.0055	1.9524	0.0323	3.8528	0.1076	293.14	1.67	0.967	35.54	0.97	0.03	41.2661	239.9176
CA05LLHS	Surprise Valley Lower Lake HS	W	43	8.84	1.36	0.3251	0.0036	1.8692	0.0300	2.9868	0.0834	295.11	1.69	0.998	27.20	1.00	0.03	41.2070	239.9469
CA05WVHS	West Valley Hot Spring	G	77	161.73	24.90	0.3302	0.0039	1.6394	0.0273	2.6171	0.0726	297.89	1.80	1.232	489.83	1.23	0.02	41.1962	239.6111
W. J. Jenkins and T. Torgersen unpublished data (1978-1981) Project funded by the US Geological Survey:																			
JT1	Crystal Hot Springs	W	-													0.15		40.4880	248.0890
JT2	Crystal Hot Springs	W	-													0.15		40.4880	248.0890
JT3	INDIAN SPRINGS	W	-													0.18		42.7250	247.1280
JT4	INDIAN SPRINGS	W	-													0.18		42.7250	247.1280
JT5	Joseph Hot Springs	G	-													0.07		38.6130	247.7980
JT6	Joseph Hot Springs	W	-													0.15		38.6130	247.7980
JT7	Joseph Hot Springs	G	-													0.10		38.6130	247.7980
JT8	Joseph Hot Springs	W	-													0.15		38.6130	247.7980
JT9	Udy Hot Springs	G	-													0.19		41.8550	247.8420
JT10	Udy Hot Springs	W	-													0.22		41.8550	247.8420
JT11	Castilla Springs	W	-													0.16		40.0380	248.4710
JT12	Castilla Springs	W	-													0.16		40.0380	248.4710
JT13	Midway Hot Springs	W	-													0.18		40.5260	248.5120
JT14	Midway Hot Springs	W	-													0.20		40.5260	248.5120
JT15	Midway Hot Springs; Well #2?	G	-													0.15		40.5250	248.5320
JT16	Midway Hot Springs; Well #2?	W	-													0.20		40.5250	248.5320
JT17	Midway Hot Springs; Well #3?	G	-													0.14		40.5170	248.5250
JT18	Midway Hot Springs; Well #3?	W	-													0.20		40.5170	248.5250
JT19	Monroe (Cooper) Hot Spring	G	-													0.16		38.6330	247.8930
JT20	OAKLEY HOT SPRING	W	-													0.14		42.1730	246.1390
JT21	OAKLEY HOT SPRING	W	-													0.14		42.1730	246.1390
JT22	Red Hill Hot Spring	G	-													0.23		38.6390	247.9020
JT23	Red Hill Hot Spring	W	-													0.21		38.6390	247.9020
JT24	SQUAW HOT SPRINGS	G	-													0.14		42.1190	248.0720
JT25	LAVA HOT SPRINGS	W	-													0.47		42.6210	247.9920
JT26	LAVA HOT SPRINGS	G	-													0.59		42.6210	247.9920
JT27	PINCOCK (GREEN CANYON) HOT SPRINGS	W	-													0.31		43.7910	248.5650
JT28	PINCOCK (GREEN CANYON) HOT SPRINGS	G	-													0.71		43.7910	248.5650
JT29	SODA SPRINGS	G	-													0.67		42.6570	248.3960
JT30	Thermo Hot Spring	W	-													0.91		38.1750	246.7960
JT31	Thermo Hot Spring	G	-													0.86		38.1750	246.7960
JT32	Thermo Hot Spring	G	-													0.86		38.1750	246.7960
JT33	HEISE HOT SPRINGS	W	-													0.78		43.6440	248.3130
JT34	HEISE HOT SPRINGS	G	-													0.66		43.6440	248.3130
JT35	BROCKMAN CREEK HOT SPRING	G	-													1.03		43.2100	248.5050

Notes:

1. F(^{i}Ng) = [^{i}Ng/^{36}Ar]sample/[^{i}Ng/^{36}Ar]air

2. All errors a 1 sigma.

3. Rm/Ra = (^{3}He/^{4}He)meas/(^{3}He/^{4}He)air

4. X = Air correction factor for measured helium isotope rates determined from the measured ^{4}He/^{22}Ne ratio. Air correction assumes all ^{22}Ne is air derived and the ^{4}He/^{22}Ne in the air component is equivalent to 10 oC air saturated water (1.29).

5. Rc/Ra = (3He/4He)air corrected/(3He/4He)air

Additional literature data not included in the data table but are part of the compilation are from the following references:

Cascades: *S3, S4, S5, S6, S7*

Basin and Range: *S1, S3, S8, S9, S10, S11, S12, S13, S14, S15.*

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