Data Repository: Methods

Water Sampling and Analysis (Table DR1)

Springs were sampled as close to source outlets as possible. Where the outlet was not accessible, spring-fed sidestreams were sampled in stream channels under base flow conditions. Waters were clear, with no evidence of (muddy) runoff. Field temperature, pH and conductivity were measured using an Oakton pH/con 300 portable meter. Spring coordinates (latitude/longitude) were estimated from topographic maps. Water samples were preserved on ice and analyzed within 6 weeks using standard methods (American Public Health Association, 1995). Anion concentrations were analyzed on a Dionex 500X Ion Chromatograph. A Jarell-Ash S-12 and Perkin Elmer 303 were used for major cations and minor elements (Sr, Fe and Mn). Alkalinity determinations were made on a Fisher Titrimeter System. All analytes are reported as parts per million; charge balances are computed as the difference between the sum of cations and sum of anions normalized to the total (all expressed as millequivalents/L).

Gas Chemistry (Table DR2)

Gas samples were collected in two ways. Direct gas sampling (exsolved gases) was done by submerging a plastic funnel over bubbling springs/streams with gases then drawn into an evacuated 1720-glass flask or an evacuated glass bottle filled with concentrated NaOH. Water samples for gas extraction were also drawn into the evacuated and NaOH-filled containers (Giggenbach, 1993). Exsolved gases usually give $^{3}He/^{4}He$ ratios that show less air contamination that dissolved gases from the water phase (Shaw et al., 2003): therefore, it is preferred to sample the free gases where possible. Gas analysis on sample headspace volumes was performed on a gas chromatograph to determine H_2, CH_4, CO, N_2, Ar, O_2, and He. Our methods allow detection of minute quantities of trace gas by isolating the dominant gas (CO_2) into caustic solution. CO_2 and sulfur were determined by wet chemical analysis of the caustic solution (Giggenbach, 1993). Sulfur is reported for samples for which we were able to obtain free gas; however, water samples contained such significant quantities of sulfate that sulfur determinations for water-derived gas samples were unobtainable by our methods. The CO_2/N_2, N_2/He, and He/Ar ratios remain unaffected and should be used for inter-comparisons of free-gas and water-extracted gases. He isotope analysis was performed at Scripps Institution of Oceanography using procedures described in Shaw et al. (2003). Air contribution (contamination) of He isotopic measurements were corrected for using the X factor where X is the air-normalized He/Ne ratio multiplied by the ratio of the Bunsun solubility coefficient of Ne to He as described by (Hilton, 1996).

The $^{3}He/^{4}He$ ratio for continental crust ranges from 0.02 to 0.05 Ra (relative to atmosphere) (Ozima and Podosek, 2001). Addition of air increases the ratio towards 1 Ra. However, in all cases, the correction factor X is large resulting in a small change only to the measured 3He/4He value. For example, our samples range from X = 60.8 (R/Ra = 0.153) to X = 592 (R/Ra = 0.068), and the correction for the small amounts of air introduced in the samples does not lower the ratios to crustal values. The air correction changes the values to Rc/Ra = 0.140 and Rc/Ra = 0.066, respectively. Tritium contributions are considered negligible on the basis of regional groundwater ages and tritium contents (Monroe et al., 2004). Our calculations show that even in an extremely unlikely worst-case scenario, the ^{3}He contribution would not be enough to change the $^{3}He/^{4}He$ significantly. Specifically assuming we now sample a 60-year old groundwater which had a 50 TU recharge (the maximum recorded through the 1950's in the region, Monroe et al., 2004), the ^{3}He resulting from complete decay of the tritiated water is only 10% of what we measure.

Strontium Isotope Analysis (Table DR3)

$^{87}Sr/^{86}Sr$ in water and travertine was determined using a Micromass Sector 54 thermal ionizing mass spectrometer at the University of Arizona, after dissolution of carbonate with acetic acid, and cation-exchange separation.

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TABLE DR1: GRAND CANYON WATER CHEMISTRY

Label	Sample ID	River Mile	Location	T (C)	pH	Cond mS	mg/L Ca	Mg	Na	K	Sr	Cl	SO4	Alk.	%charge balance	S.I. Calcite	EQ log PCO2	Spl Date	Latitude (decimal)	Longitude (decimal)
FF	LC 02- 30.5-71	30.5*	Fence Fault	21.4	6.51	1.66	142	39.0	162	15.9	1.00	200	132	536	1.70	-0.26	-0.84	9/1/02	36.518	111.846
	LC 03- 30.5	30.5*	Fence Fault	20.9	6.67	2.25	108	42.4	202	19.5	1.31	279	176	580	-7.18	-0.21	-0.97	9/10/03	36.519	111.845
	LC 02- 32-73	32.0	Vasey's Paradise	17.0	7.88	*n.r.*	43.0	19.0	2.5	1.0	0.23	1.9	5.7	240	-3.26	0.34	-2.56	9/1/02	36.500	111.860
	LC 03-32-1	32*	Vasey's Paradise	17.8	8.58	0.36	38.1	20.1	2.3	0.8	<0.1	1.4	4.3	226	-2.13	0.93	-3.31	9/10/03	36.500	111.860
	LC-02-LCR-1A	61.4	Blue Spring	*n.r.*	***8.21***	*n.r.*	56.1	65.0	1000	6.0	10.00	1411	144	237	5.43	0.60	-2.92	4/1/02	36.116	111.693
BS	LC-02-LCR-2A	61.4*	Blue Spring	*n.r.*	***8.12***	*n.r.*	46.1	61.0	500	4.0	14.61	719	87.9	341	3.15	0.66	-2.65	4/1/02	36.116	111.693
	LC 02- 65-2	65.0	Lava Chuar	*n.r.*	*n.r.*	*n.r.*	1035	685	4850	150	5.60	5742	3057	1750	11.88	3.73	0.46	9/1/02	36.142	111.831
	LC 02- 84-2	84.0*	Clear Creek	22.6	7.03	0.66	56.0	32.0	18.0	6.0	0.30	14.2	46.5	340	-4.30	-0.22	-1.53	9/1/02	36.111	111.992
	LC 02- 84-4	84.0	Clear Creek	22.5	8.35	0.41	35.0	26.0	11.0	3.0	<0.1	9.7	13.7	220	3.19	0.73	-3.50	9/1/02	36.082	112.035
	LC 03-89-1	89*	Pipe Creek	15.4	8.58	0.47	43.7	28.0	10.8	1.6	<0.1	13.1	11.5	247	3.42	0.97	-3.29	9/15/03	36.099	112.111
	Horn Creek	90.2	Horn Creek	*n.r.*	***8.39***	*n.r.*	60.1	47.0	21.0	8.0	2.50	36.0	110	327	-3.74	1.10	-2.93	3/1/02	36.088	112.144
	Salt Creek	92.7	Salt Creek	*n.r.*	*n.r.*	*n.r.*	67.1	75.7	25.0	18.0	1.40	21.1	272	277	1.60	-0.32	-1.59	3/1/02	36.089	112.162
	LC 03-95-1	95*	Hermit Creek	24.5	8.54	0.87	36.3	30.7	54.7	5.9	0.44	83.3	22.6	230	2.15	0.92	-3.23	9/15/03	36.099	112.209
	LC 02- 95.5-2	95.5	Travertine Canyon	16.1	8.48	1.63	29.0	85.0	25.0	5.0	0.24	40.0	169	290	1.36	0.68	-3.13	9/1/02	36.097	112.221
	LC 03-96.7-1	96.7*	Boucher Creek	23.9	8.31	0.93	42.9	39.9	74.0	6.3	0.44	117	69.6	250	-0.17	0.78	-2.96	9/16/03	36.116	112.230
	LC 02- 98-1	98*	Crystal Creek	20.4	8.64	2.26	37.0	50.0	308	29.0	0.56	324	166	288	7.51	0.94	-3.29	9/1/02	36.148	112.225
	LC 02- 98-2	98.0	Crystal Creek	22.5	8.70	2.60	38.0	52.0	355	32.0	0.59	613	221	270	-7.96	1.10	-3.35	9/1/02	36.136	112.243
	LC 02- 98-3	98.0	Crystal Creek	*n.r.*	*n.r.*	*n.r.*	41.0	28.0	18.0	4.0	0.21	24.4	23.5	260	-1.88	-0.43	-1.60	9/1/02	36.169	112.203
	LC 03- 98-1	98*	Crystal Creek	30.8	8.68	1.89	28.5	42.5	275	27.8	0.44	349	157	270	0.20	0.96	-3.30	9/15/03	36.136	112.243
	LC 02- 108.6-1	108.6*	Shinumo Creek	23.8	8.44	0.28	28.0	20.0	3.0	0.5	<0.1	2.4	3.7	200	-3.57	0.71	-3.18	9/1/02	36.237	112.348
BT	LC 03- 120.1	120*	Black Tail Creek	22.1	7.97	1.98	173	112	93.8	19.5	1.75	90.8	756	289	-1.19	0.89	-2.60	9/15/03	36.240	112.472
TC	LC 02- 133.8-1	133.0	Tapeats Creek	13.1	8.44	0.28	40.0	15.0	2.4	0.2	<0.1	1.3	3.4	206	-2.11	0.73	-3.22	9/1/02	36.371	112.468
	LC 02- 136.2-1	136.0	Deer Creek	16.3	8.65	0.38	43.0	21.0	2.9	0.4	0.21	2.3	13.0	230	-1.11	1.03	-3.38	9/1/02	36.389	112.508
	LC 02- 157-1	156.8*	Havasu Creek	20.2	8.56	0.69	40.0	42.0	34.0	4.2	0.36	48.5	33.2	330	-2.92	1.06	-3.13	9/1/02	36.308	112.762
	LC-03-HAV-1	156.8	Havasu Creek	*n.r.*	***7.34***	*n.r.*	85.2	40.0	34.5	5.0	0.30	7.1	27.2	560	-4.02	0.48	-1.62	3/3/03	36.218	112.686
	LC-03-HAV-2	156.8	Havasu Creek	*n.r.*	***7.31***	*n.r.*	44.1	40.0	35.0	5.5	0.30	38.3	27.9	310	3.00	-0.04	-1.84	3/3/03	36.218	112.686
	LFA-1d	179.3	Lava Warm Springs	*n.r.*	*n.r.*	*n.r.*	151	61.5	75.0	7.5	3.30	59.1	21.9	835	1.02	0.50	-1.12	9/1/01	36.196	113.082
	LFC-1b	179.3	Lava Warm Springs	*n.r.*	*n.r.*	*n.r.*	154	59.0	77.5	7.8	<0.1	57.6	23.3	827	1.43	0.51	-1.13	9/1/01	36.197	113.083
	LFA-1a	179.3	Lava Warm Springs	*n.r.*	*n.r.*	*n.r.*	150	61.0	74.0	7.4	<0.1	75.4	37.5	817	-1.23	0.49	-1.13	9/1/01	36.196	113.082
	LFB-1a	179.3	Lava Warm Springs	*n.r.*	*n.r.*	*n.r.*	156	60.0	79.0	7.5	<0.1	61.2	26.0	756	5.42	0.48	-1.17	9/1/01	36.196	113.082
	LC 03-178-4	179.2*	Lava Warm Springs	26.3	6.50	1.44	68.9	55.4	75.9	6.6	0.44	63.1	28.3	827	-16.23	-0.30	-0.61	9/11/03	36.196	113.082
	LC 02- 178-1	179.3	Lava Warm Springs	25.8	6.48	1.54	156	55.0	80.0	6.2	0.63	71.7	30.8	820	-0.45	0.00	-0.60	9/1/02	36.196	113.082
	PS-01-1c	213.0	Pumpkin Spring	31.0	6.10	*n.r.*	237	69.0	2875	100	0.80	2879	323	1979	9.32	-0.06	0.13	9/1/01	35.915	113.334
PS	LC 02- 213-1	213*	Pumpkin Spring	25.3	6.96	14.65	236	72.0	3500	102	9.60	3115	313	2276	13.49	0.76	-0.71	9/1/02	35.915	113.334
	LC 03-213-1	213*	Pumpkin Spring	31.4	6.60	14.44	27.3	60.3	3325	92	5.26	4565	261	2256	-5.47	-0.45	-0.31	9/12/03	35.915	113.334
	LC 02- 215.5-1	215.5	Three Springs Creek	22.6	8.15	0.78	84.0	46.0	17.0	2.2	0.32	29.4	69.8	371	2.41	1.05	-2.64	9/1/02	35.886	113.308
	TR-1	229.0	Travertine Grotto	23.0	7.94	*n.r.*	29.1	16.8	414	18.3	<0.1	244	78.6	989	-7.46	0.87	-2.16	3/1/01	35.739	113.436
	TR-2	229.0	Travertine Grotto	34.0	7.86	*n.r.*	37.1	16.5	357	14.9	<0.1	199	61.3	849	-4.24	1.07	-2.16	3/1/01	35.738	113.435
	TR-3	229.0	Travertine Grotto	26.0	7.44	*n.r.*	53.1	39.2	30.0	1.6	<0.1	34.0	25.7	331	2.08	0.46	-2.20	3/1/01	35.739	113.435
	TR-4	229.0	Travertine Grotto	27.0	7.72	*n.r.*	50.1	36.7	84.0	3.7	<0.1	43.1	23.7	382	7.50	0.37	-2.15	3/1/01	35.740	113.431
	TR-6	229.0	Travertine Grotto	29.0	8.57	*n.r.*	42.1	35.4	124.0	4.6	<0.1	68.2	35.1	356	10.68	0.65	-2.41	3/1/01	35.746	113.429
	TR-7	229.0	Travertine Grotto	28.0	8.62	*n.r.*	40.1	37.4	126.0	4.5	<0.1	67.8	35.4	535	-3.40	0.77	-2.24	3/1/01	35.747	113.429
GC	TR-0302-1A	229*	Travertine Grotto Sp	23.7	7.40	0.60	50.1	36.5	29.0	2.7	0.59	36.8	29.6	285	3.96	0.05	-1.97	3/1/02	35.739	113.435
	TR-0302-2A	229.0	Travertine Grotto	29.3	7.70	1.83	37.1	16.5	415	16.0	0.52	203	209	675	1.23	0.51	-1.88	3/1/02	35.738	113.435
	TR-0302-3A	229.0	Travertine Grotto	24.3	7.70	*n.r.*	50.1	33.0	75.0	4.7	0.34	65.0	34.7	360	0.87	0.43	-2.17	3/1/02	35.739	113.435
	TR-0302-4B	229.0	Travertine Grotto	23.5	7.93	0.91	50.1	32.9	88.0	4.6	0.45	70.9	35.2	375	1.61	0.66	-2.40	3/1/02	35.739	113.434
	TR-0302-5A	229.0	Travertine Grotto	23.7	8.30	0.91	49.1	32.8	104	5.2	0.42	78.0	35.7	414	0.42	1.03	-2.74	3/1/02	35.740	113.432
GS	TR-0302-11A	229*	Travertine Grotto Sp	29.2	6.75	*n.r.*	37.6	16.5	450	15.0	0.76	201	62.8	820	6.37	-0.31	-0.84	3/1/02	35.738	113.435
	TR-0302-12B	229*	Travertine Grotto	22.4	8.05	*n.r.*	40.1	61.0	35.0	6.7	0.44	39.3	51.0	384	1.48	0.66	-2.52	3/1/02	35.743	113.429
	TR-0302-13B	229.0	Travertine Grotto	22.0	8.26	*n.r.*	34.1	32.0	110	5.1	0.53	76.6	32.1	405	-1.12	0.82	-2.71	3/1/02	35.743	113.429
	TR-0302-14B	229*	Travertine Grotto	21.7	8.37	*n.r.*	31.1	32.0	117	5.3	0.42	78.0	32.5	401	-0.10	0.87	-2.83	3/1/02	35.743	113.429

TABLE DR1: GRAND CANYON WATER CHEMISTRY

Label	Sample ID	River Mile	Location	T (C)	pH	Cond mS	mg/L Ca	Mg	Na	K	Sr	Cl	SO4	Alk.	%charge balance	S.I. Calcite	EQ log PCO2	Spl Date	Latitude (decimal)	Longitude (decimal)
	TR-0302-15A	229.0	Travertine Grotto	20.9	8.47	*n.r.*	26.1	32.8	120	5.2	0.40	86.4	34.8	355	2.07	0.83	-2.99	3/1/02	35.743	113.429
	TR-0302-16	229.0	Travertine Grotto	13.7	8.52	1.27	25.0	32.0	102	5.7	0.35	87.4	34.8	349	-2.51	0.76	-3.08	3/1/02	35.751	13.424
	LC-03-229-1	229.0	Travertine Grotto	16.9	8.54	1.06	30.1	40.0	140	6.0	0.39	83.4	40.5	390	7.05	0.92	-3.05	3/3/03	35.743	113.429
	LC-03-229-2	229.0	Travertine Grotto	16.6	8.75	1.07	27.1	39.0	140	5.7	0.29	81.3	39.3	378	7.47	1.04	-3.29	3/3/03	35.743	113.429
	LC-03-229-2a	229.0	Travertine Grotto	17.4	8.19	1.03	25.0	41.0	138	5.5	0.34	83.4	39.8	398	5.26	0.54	-2.67	3/3/03	35.743	113.429
	LC-03-229-3	229.0	Travertine Grotto	16.5	8.73	0.99	30.1	37.0	138	5.9	0.36	81.1	38.8	385	6.46	1.09	-3.25	3/3/03	35.743	113.429
	LC-03-229-5	229.0	Travertine Grotto	15.5	8.74	1.06	27.1	36.0	135	5.9	0.32	79.9	38.3	378	5.62	1.03	-3.28	3/3/03	35.743	113.429
	LC-03-229-6	229.0	Travertine Grotto	18.1	8.59	1.04	30.1	37.0	132	5.5	0.30	80.1	38.4	403	3.87	1.00	-3.08	3/3/03	35.743	113.429
	LC-03-229-7	229.0	Travertine Grotto	20.8	8.49	1.03	32.1	36.0	130	5.5	0.32	78.4	37.9	410	3.20	0.98	-2.95	3/3/03	35.743	113.429
	LC-03-229-8	229.0	Travertine Grotto	22.1	8.08	0.94	49.6	37.0	99.0	4.5	0.29	60.0	30.7	400	5.62	0.80	-2.53	3/3/03	35.743	113.429
	LC-03-229-9	229.0	Travertine Grotto	*n.r.*	***8.44***	*n.r.*	50.1	38.0	84.0	4.0	0.49	54.0	30.7	370	6.61	1.14	-2.93	3/3/03	35.743	113.429
	LC-03-229.8-1	229.0	Travertine Grotto	*n.r.*	***9.00***	*n.r.*	20.0	32.0	277.0	11.0	0.40	146.8	55.5	565	4.63	1.30	-3.36	3/3/03	35.743	113.429
	LC-03-229-50	229*	Travertine Grotto	22.4	8.76	1.21	23.0	32.0	135.0	5.0	0.20	94.9	37.0	342	3.90	1.02	-3.31	6/1/03	35.749	113.427
	LC-03-229-54	229.0	Travertine Grotto	27.8	8.50	1.25	30.1	34.0	130.0	6.0	0.45	94.2	36.5	364	3.74	1.00	-2.98	6/1/03	35.741	113.430
	LC-02-230-1	230.0	Travertine Drips	*n.r.*	*n.r.*	*n.r.*	10.0	33.0	700	20.0	0.29	487	118	1094	0.05	-0.64	-1.01	3/1/02	35.751	113.426
	LC-02-230.6-1	230.6*	Travertine Falls	19.7	7.64	1.88	38.1	25.9	247	10.4	0.55	164	41.2	595	-0.59	0.36	-1.93	3/1/02	35.754	113.449
	LC-02-230.6-2	230.6*	Travertine Falls	20.5	8.33	*n.r.*	20.0	25.9	260	10.4	0.75	166	42.2	570	-0.62	0.72	-2.65	3/1/02	35.755	113.448
	LC-02-230.6-3A	230.6	Travertine Falls	17.3	8.08	*n.r.*	30.1	26.5	290	11.1	0.47	183	45.7	648	-0.45	0.67	-2.35	3/1/02	35.756	113.447
	LC-03-TF-1	230.6	Travertine Falls	*n.r.*	***8.27***	*n.r.*	48.1	27.0	227	10.0	0.39	106	43.1	623	2.27	1.14	-2.52	3/3/03	35.752	113.449
	LC-03-231-1	231.0	231 Mile Canyon	12.8	8.66	0.48	25.0	17.5	35.0	5.0	0.23	15.0	37.4	150	8.55	0.58	-3.59	3/3/03	35.605	113.451
	LC-03-234-1	234.0	234 mile Canyon	24.3	8.78	1.22	30.1	77.0	73.0	6.5	0.45	90.4	42.7	442	2.27	1.23	-3.24	6/1/03	35.764	113.503
	LC-03-235-1	235*	Bridge Canyon	17.2	7.91	0.76	64.1	38.0	34.0	3.0	0.28	34.8	22.8	368	2.65	0.66	-2.42	3/3/03	35.769	113.526
	LC-03-238-1	238.0	Bridge Canyon City	13.2	8.68	0.91	27.1	60.0	54.0	8.1	0.30	78.5	109	210	5.48	0.69	-3.49	3/3/03	35.808	113.566
	LC-02-246-S1	246.0	Spencer Canyon	*n.r.*	*n.r.*	*n.r.*	58.1	52.5	25.0	5.7	0.35	37.0	24.8	428	-0.65	-0.12	-1.39	3/1/02	35.783	113.651
	LC-02-246-S2	246.0	Spencer Canyon	*n.r.*	*n.r.*	*n.r.*	57.6	51.0	22.5	3.2	0.42	31.7	21.6	432	-1.76	-0.11	-1.39	3/1/02	35.783	113.651
	LC-02-246-S3	246.0	Spencer Canyon	*n.r.*	*n.r.*	*n.r.*	57.1	52.0	23.0	3.2	0.42	32.2	22.0	400	1.82	-0.15	-1.42	3/1/02	35.783	113.651
	LC-02-246-S4	246.0	Spencer Canyon	*n.r.*	*n.r.*	*n.r.*	56.1	52.5	23.5	3.5	0.38	41.4	21.8	408	-0.43	-0.15	-1.41	3/1/02	35.783	113.651
	LC-02-246-S10	246.0	Spencer Canyon	18.8	8.12	0.92	46.1	55.0	24.5	3.3	0.41	33.4	22.1	377	2.59	0.75	-2.62	3/1/02	35.798	113.653
	LC-02-246-S11	246.0	Spencer Canyon	19.5	7.70	1.03	50.1	56.0	22.5	3.4	0.53	31.5	22.5	416	0.05	0.43	-2.14	3/1/02	35.806	113.659
	LC-02-246-S12A	246.0	Spencer Canyon	18.1	8.03	1.00	50.1	58.0	20.0	3.3	0.31	31.8	22.6	432	-1.29	0.74	-2.47	3/1/02	35.808	113.658
	LC-02-246-S13A	246.0	Spencer Canyon	15.3	8.44	0.71	36.1	56.0	25.0	3.1	0.49	32.4	23.1	383	-0.59	0.90	-2.96	3/1/02	35.824	113.649
	LC-02-246-M1	246*	Spencer,west	22.2	6.80	0.82	58.6	37.0	14.0	1.9	0.42	19.3	15.3	340	1.48	-0.42	-1.30	3/1/02	35.786	113.675
	LC-02-246-M2A	246.0	Spencer, west	24.0	7.07	0.82	57.1	36.5	14.0	2.3	0.46	19.4	15.2	336	1.23	-0.14	-1.57	3/1/02	35.786	113.675
	LC-03-260.8-1	260.2*	Quartermaster	23.6	7.12	0.79	64.1	49.0	15.0	2.0	0.23	17.4	11.7	428	1.26	0.03	-1.52	3/3/03	35.963	113.763
	LC-02-268-1	268.0	Travertine Slot	28.2	***6.87***	*n.r.*	302	112	58.5	6.8	0.50	129	694	550	-0.27	0.39	-1.17	6/1/02	36.050	113.836
	LC-02-268-2	268.0	Travertine Slot	*n.r.*	***7.78***	*n.r.*	72.6	25.4	63.0	9.2	0.30	68.6	210	197	-4.63	0.37	-2.52	6/1/02	36.050	113.836
	LC-02-268-3	268.0	Travertine Slot	28.7	***6.85***	*n.r.*	305	112	59.0	6.0	3.00	141.3	735	548	-1.93	0.38	-1.15	6/1/02	36.050	113.836
TS	LC-03-268-1	268.0	Travertine Slot	*n.r.*	6.62	*n.r.*	320	126	70.0	7.8	3.65	169	877	542	-3.66	0.09	-0.95	6/1/03	36.050	113.836
	LC-03-272-1	272.0	Rampart Springs	17.5	7.78	0.60	39.1	33.0	16.0	2.9	0.20	21.5	19.0	235	5.69	0.17	-2.47	3/3/03	36.092	113.914
	LC-03-274.5-1	274.5*	Columbine Falls	16.4	8.15	0.63	48.1	35.0	17.0	3.5	0.23	19.5	17.2	245	10.79	0.61	-2.84	3/3/03	36.088	113.921
	LC-03-276-1	276.0	Travertine Bluff	18.2	6.94	2.05	236	125	97.0	8.5	3.53	145	423	805	0.96	0.42	-1.14	3/3/03	36.126	113.926
	LC-03-276-10	276*	Travertine Bluff	17.6	7.07	2.10	219	133	105	8.2	4.53	164	304	918	1.44	0.57	-1.21	6/1/03	36.126	113.926

Notes:

n.r. = not reported.

* = gas analysis available (see Table DR2).

Bold italics indicate lab pH rather than field pH.

TABLE DR2: GRAND CANYON GAS CHEMISTRY

Water ID	Location	River mile*	Source*	Vol % (water free****) CO2	Stot	He	H2	Ar	O2	N2	CH4	CO
LC02-30.5-70	Fence Fault (riv left)	30.5	SP-w	85.2	nr	4.30E-02	2.63E-03	0.392	2.45	11.9	<1.02E-04	<1.11E-03
LC03-30.5-1	Fence Fault	30.5	SP-g	54.0	bd	1.26E-02	<4.68E-04	0.547	0.005	45.4	<1.41E-04	1.40E-04
LC03-30.5-1	Fence Fault	30.5	SP-w	nr	nr	nr	nr	nr	nr	nr	nr	nr
LC03-32-1	Vasey's Paradise	32	SP-g	21.5	20.9	4.23E-03	2.82E-03	0.559	10.6	46.4	<2.25E-04	2.24E-04
LC02-LCR-2A	Blue Spring	61.4	SP-g	56.7	42.8	8.41E-04	1.40E-04	0.002	0.071	0.323	<6.00E-06	<6.00E-06
LC02-84-1	Clear Creek	84	St-w	90.7	nr	<5.28E-05	1.31E-04	0.194	1.92	7.22	<1.46E-05	<5.32E-05
LC03-89-1	Pipe Creek	89	St-g	22.3	1.85	7.08E-03	5.85E-03	0.741	13.6	61.5	<2.59E-04	2.58E-04
LC03-95-1	Hermit Creek	95	St-g	22.3	23.6	<8.47E-04	2.50E-03	0.529	9.64	43.9	<2.04E-04	2.03E-04
LC03-96.7-1	Boucher Creek	96.7	St-g	17.0	30.7	<8.07E-04	2.35E-03	0.510	9.47	42.3	<1.95E-04	1.94E-04
LC02-98-1	Crystal Creek	98	St-g	9.87	nr	<4.52E-04	1.64E-03	0.050	15.5	74.5	<1.09E-04	<1.09E-04
LC03-98-1	Crystal Creek	98	St-g	23.9	bd	<8.78E-04	7.04E-04	0.759	12.3	63.0	2.12E-04	2.11E-04
LC02-108.6-1	Shinumo Creek	108.6	St-g	11.1	nr	<1.97E-03	6.47E-03	0.862	16.4	71.6	<4.75E-04	<4.74E-04
LC02-116.5-1***	Elves Chasm	116.5	St-g	14.6	nr	<6.98E-04	2.01E-03	0.035	15.4	70.0	<1.69E-04	<1.73E-04
LC02-117-1***	seep below Elves	117	St-w	98.8	nr	<2.96E-05	1.52E-04	0.002	0.289	0.861	<1.11E-05	<1.30E-04
LC03-120.1	Black Tail Creek	120.1	St-g	35.3	3.45	5.52E-03	3.00E-03	0.586	12.0	48.7	2.54E-04	2.54E-04
LC02-157-1	Havasu Creek	156.8	St-w	89.9	nr	1.14E-04	8.75E-04	0.303	3.28	6.51	<7.68E-05	<1.56E-03
LC03-178-4	Lava Warm Springs	179	St-g	36.2	12.3	<7.98E-04	2.05E-03	0.500	9.55	41.5	<1.93E-04	1.92E-04
LC03-213-1	Pumpkin Spring	213	SP-g	96.3	0.256	2.79E-02	1.16E-03	0.021	1.68	1.71	<8.18E-05	<8.17E-05
LC02-213-1	Pumpkin Spring	213	SP-g	97.6	nr	2.28E-02	1.73E-04	0.045	0.663	1.69	<5.86E-06	1.57E-03
TR-0302-11A	Travertine Grotto Sp	229	SP-w	59.1	40.5	1.79E-03	4.48E-05	0.003	0.064	0.305	<3.00E-06	<3.00E-06
LC03-229-50	Travertine Grotto	229	St-g	22.3	17.8	6.02E-02	1.30E+00	0.695	0.072	57.6	<2.73E-04	1.20E-01
TR-0302-1A	Travertine Grotto Sp	229	SP-w	46.6	52.2	<1.00E-06	<1.4E-05	0.009	0.232	0.887	<1.60E-05	<1.70E-05
TR-0302-14	Travertine Grotto	229	St-w	41.5	58.1	<1.00E-06	1.99E-04	0.005	0.088	0.188	<8.00E-06	<8.00E-06
TR-0302-12	Travertine Grotto	229	St-w	52.3	47.3	<1.00E-06	4.62E-05	0.004	0.086	0.173	<4.00E-06	<4.00E-06
LC02-230.6-2	Travertine Falls	230.6	St-w	49.3	49.8	<1.00E-06	<1.00E-06	0.008	0.174	0.660	<6.00E-06	<6.00E-06
LC02-230.6-1	Travertine Falls	230.6	St-w	53.9	45.7	<1.00E-06	<1.00E-06	0.003	0.092	0.169	<6.00E-06	<7.00E-06
LC03-235-1	Bridge Canyon	235	St-w	97.8	bd	1.15E-02	8.18E-02	0.057	0.002	2.05	<5.66E-05	2.08E-01
LC02-246-M1	Spencer Canyon	246	St-w	38.2	60.1	1.07E-03	3.20E-04	0.011	0.230	1.36	<8.00E-06	<8.00E-06
LC03-260.8-1	Quartermaster Spring	260.2	SP-w	34.1	64.3	7.67E-03	5.45E-02	0.038	0.075	1.30	<2.18E-05	<1.44E-04
LC03-274.5-1	Columbine Falls	274.5	St-g	28.6	11.8	8.03E-03	1.13	0.691	0.368	57.4	<3.22E-04	8.44E-02
LC03-276-10	Travertine Bluff	276	SP-g	32.5	0.737	8.11E-01	6.58E-03	0.130	0.008	5.82	60	<2.47E-04
		Air		0.036		5.24E-04		0.935	21.0	78.1		

Notes:

* river miles downstream from Lee's Ferry

** Spring (SP) versus stream (St); free gas sample (g) versus dissolved gas (water-extracted) sample (w); CO2 corrected for alkalinity contribution from water.

*** water chemistry not available

**** Vol% water free normalizations EXCEPT for samples not reporting S; these samples are water and S-free; use CO2/N2 for comparisons

Stot=Total reduced sulfur gases

4[He]c nccSTP/g H2O = air corrected He concentrations where [He]c = ([He]m x (X-1))/X

TABLE DR2: GRAND CANYON GAS CHEMISTRY (cont'd)

Water ID	CO2/N2	N2/He	He/Ar	Rc/Ra (1 sigma)	X	CO2/3He (x10^9)	[4He]c nccSTP/g H20	He media
LC02-30.5-70	7.2	277	0.110					
LC03-30.5-1	1.2	3605	0.023	0.11 +/- 0.004	263	1.42	nr	gas
LC03-30.5-1	nr	nr	nr	0.10 +/- 0.002	6440	13.4	160,000+/-2000	water
LC03-32-1	0.5	10968	0.008					
LC02-LCR-2A	175.8	383	0.483					
LC02-84-1	12.6							
LC03-89-1	0.4	8682	0.010					
LC03-95-1	0.5							
LC03-96.7-1	0.4							
LC02-98-1	0.1							
LC03-98-1	0.4							
LC02-108.6-1	0.2							
LC02-116.5-1***	0.2							
LC02-117-1***	114.9							
LC03-120.1	0.7	8819	0.009					
LC02-157-1	13.8							
LC03-178-4	0.9			0.15 +/- 0.005	103	368	6300+/-100	water
LC03-213-1	56.4	61	1.355	0.12 +/- 0.004	68.1	56.6	nr	gas
LC02-213-1	57.8	74	0.507					
TR-0302-11A	194.0	170	0.656	0.066 +/- 0.002	572	1720	874	water
LC03-229-50	0.4	958	0.087					
TR-0302-1A	52.6			0.14 +/- 0.01	59.1	14200	15.0	water
TR-0302-14	220.3							
TR-0302-12	302.8							
LC02-230.6-2	74.6							
LC02-230.6-1	319.8							
LC03-235-1	47.7	178	0.202					
LC02-246-M1	28.1	1270	0.101					
LC03-260.8-1	26.3	169	0.203					
LC03-274.5-1	0.5	7146	0.012					
LC03-276-10	5.6	7	6.235					
	0.0004	148855	0.001	1				

Notes (cont'd):

nr = not reported

bd=below detection (~0.2 for the sample suite)

Rc = measured 3He/4He corrected for air contamination; Ra = 3He/4He in air (1.4 x 10-6)

X = [(4He/20Ne)measured/(4He/20Ne)air]*(βNe/βHe); β are the Bunsen coefficients from Weiss (1970) assuming a groundwater recharge temperature of 15ºC

All errors reported to 1 sigma level

TABLE DR3. Sr ISOTOPE ANALYSIS OF WATERS AND TRAVERTINES

Sample	Location	river miles*	$^{87}Sr/^{86}Sr$ 2 sigma error
Colorado River			
CR03-02-1c	above Travertine Creek	229	0.709874 ± 17
CR03-02-2a	below Travertine Falls	233	0.709889 ± 20
LC-246-CR-4	above Spencer Canyon	246	0.709854 ± 18
LC-247-CR-5	below Spencer Canyon	247	0.709848 ± 17
LC-276-CR-6	Grand Wash Cliffs	276	0.709843 ± 16
Sidecreeks and springs			
TR-0302-3a	Travertine Grotto	229	0.717047 ± 14
TR-0302-11	Travertine Grotto Spring	229	0.734234 ± 24
LC-02-246-S1	Spencer Creek	246	0.713524 ± 22
LC-02-246-M1b	Spencer Spring	246	0.710595 ± 13
LC-02-230.6-1a	Travertine Falls Canyon	230.6	0.727754 ± 16
LF-c1-b	Lava Falls Warm Spring	180	0.710056 ± 16
PS-01-1c	Pumpkin Spring	212	0.726170 ± 16
Travertines			
LC-02-229-50	Travertine Creek, active	229	0.719563 ± 19
K00-180-PR2	Lava Falls Warm Spring, active	180	0.709987 ± 18
K00-229-4	Travertine Grotto	229	0.713080 ± 14
LC-16-60.3-4	below Kwagunt	60.3	0.710609 ± 18
Standards	**Standards Notes**		
NBS-987 std			0.710224 ± 16
NBS-987 std			0.710209 ± 17
NBS-987 std			0.710214 ± 14
Average	All analyses except LC-02-246-S1 and TR-0302-11		0.710216 ±
NBS-987 std	For LC-02-246-S1 and TR-0302-11		0.710269 ±
NBS-987 std	For LC-02-246-S1 and TR-0302-11		0.710265 ±

All samples adjusted for NBS-987 to 0.710235

* river miles below Lees Ferry.