UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

Helium concentrations in soil gas of the Ely and Delta 1^{o} x 2^{o} quadrangles, Basin and Range Province

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Helium concentrations in soil gas of the Ely and Delta $1^o \times 2^o$ quadrangles, Basin and Range province

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ABSTRACT

A reconnaissance soil-gas helium survey was made of the Ely, Nevada and Delta, Utah $1^o \times 2^o$ quadrangles in the Basin and Range Province. Helium concentrations in 510 samples ranged from -147 to 441 ppb He with respect to ambient air. The median helium value for the study area was 36 ppb. Concentrations of more than 100 ppb He, and less than -20 ppb He, occur more commonly in the Ely Quadrangle and are especially numerous in the western one-half of this quadrangle. The data are presented both in figures and tables, and some of the geologic factors that may affect the helium distribution are discussed.

INTRODUCTION

This report contains data from a reconnaissance survey of helium in soil gas from the Ely, Nevada and Delta, Utah $1^o \times 2^o$ quadrangles of the Basin and Range Province (fig. 1). The survey consisted of 503 samples collected at approximately 5-mile spacings along roads and trails during the last week of June 1981. The sample total represents 228 and 282 samples taken from the Ely and Delta Quadrangles, respectively. Samples were obtained using soil probes driven into the ground to a 0.75-meter depth. The samples were analyzed on the day of collection using the U.S. Geological Survey's mobile helium analyzer (Reimer, 1976; Reimer and Denton, 1978). Data presented in table 1 of the Appendix, and figure 2, plate 1 and plate 2 record the helium concentration in soil-gas at the time of sampling. The level of helium concentration in the soil-fluctuates as a result of meteorologic conditions associated with weather fronts and with the diurnal cycle (Reimer, 1980). The helium concentrations are reported in parts per billion (ppb) with respect to the concentration of helium in air at 5,240 ppb helium; a negative value means that the sample contained less helium than air and probably indicates the presence of significant quantities of other gases such as CO_2 and CH_4.

ACKNOWLEDGEMENTS

The assistance of Josh Been, Don Murrey, Harry Day, Kim Green, and Pam Rotilie in collecting samples is gratefully acknowledged. Their cooperation enabled the study to be completed in a short time, so any influence of seasonal effects on the soil-gas concentrations was avoided.

GEOLOGIC SETTING

The helium study area consists of the Delta and Ely $1^o \times 2^o$ quadrangles located respectively in western Utah and eastern Nevada. The study area, bounded by latitudes 39^o and 40^o N. and longitudes 112^o and 116^o W., forms a

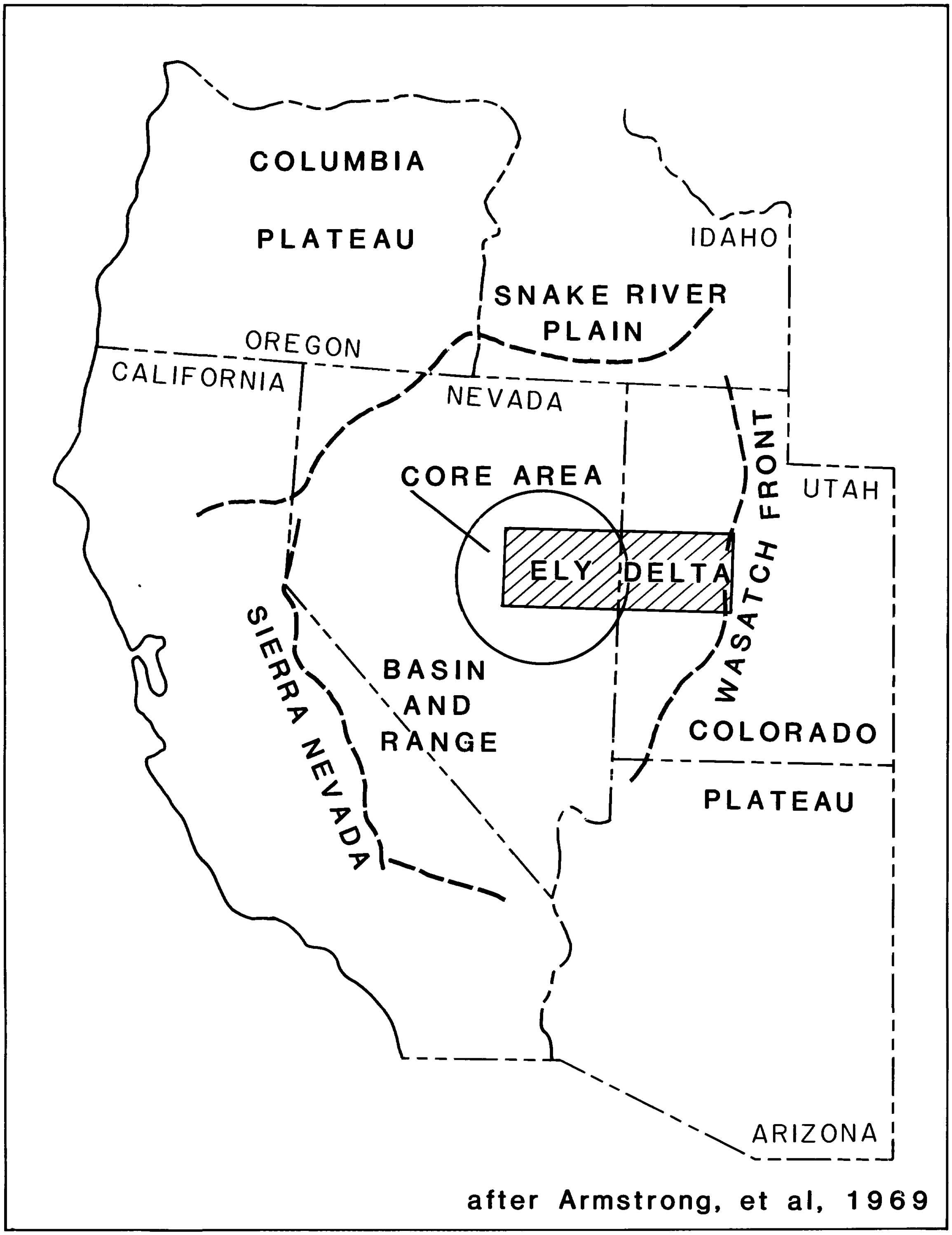

Figure 1.--Index map showing location of the Ely and Delta 1°x 2° quadrangles and the core area of mid-Cenozoic Silicic volcanism in the Basin and Range Province.

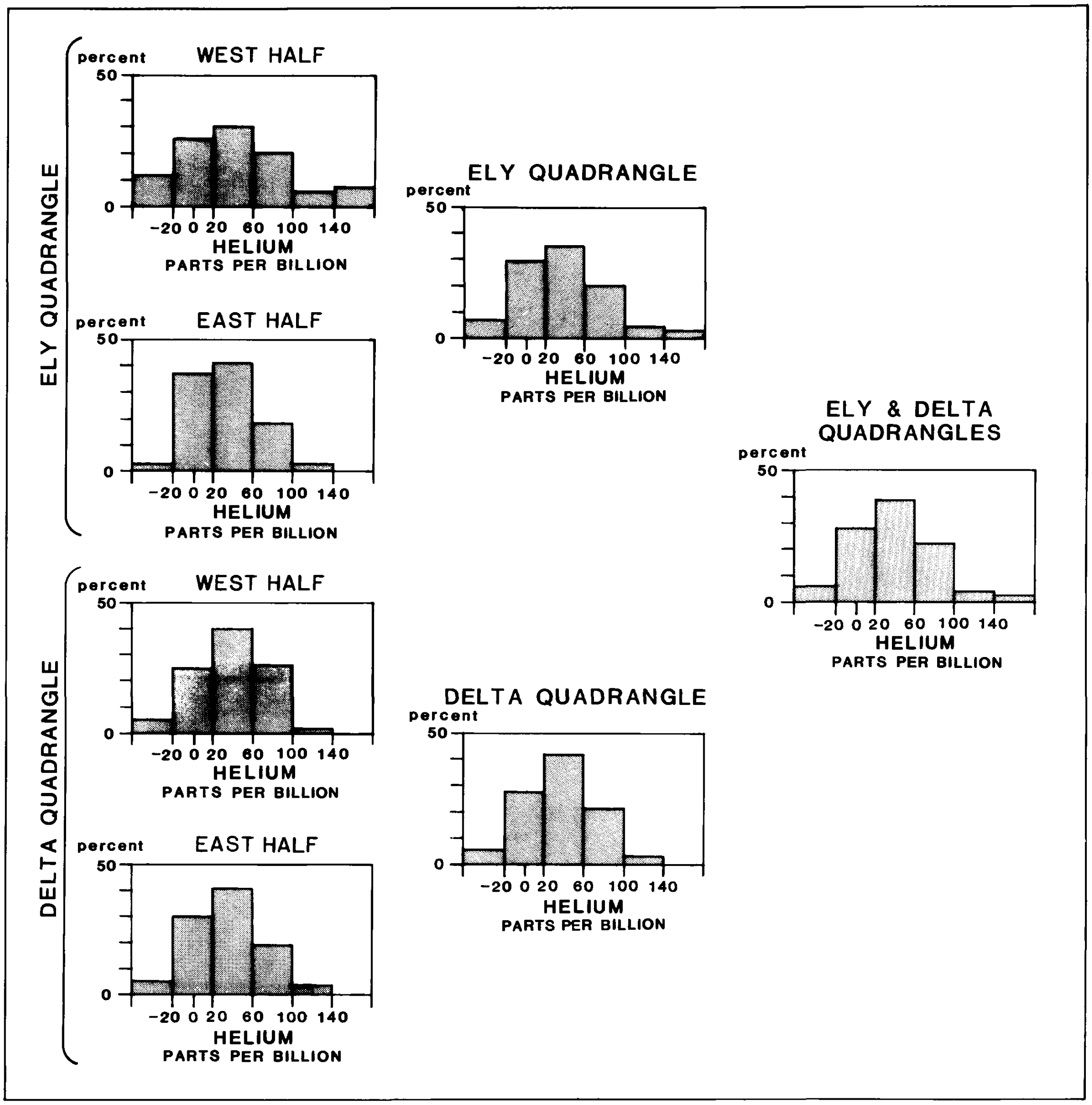

Figure 2.--Histograms of helium content in soil-gas samples from the Ely and Delta 1°x 2° quadrangles. Helium reported as parts per billion with respect to ambient air.

west-trending zone from the eastern edge to the center of the Basin and Range Province. The basin and range physiographic features of the study area, like those elsewhere in the province, are dominated not by the enormous thrusts of Laramide age, but by the grand scale of normal faulting that began during the late Miocene. The intense faulting has resulted in complex geology as shown by the 1:500,000 scale maps of Nevada (Stewart and Carlson, 1978) and Utah (Hose and Blake, 1970) to which the reader is referred. Inasmuch as the low density of soil-gas samples does not support a direct comparison of data with specific geologic features, the following discussion is limited to the geologic setting.

The ranges are oriented generally north-south and occupy 30 to 40 percent of the study area (pl. 1 and 2). The remaining area is characterized by interior drainage and closed basins that contain flat deserts; however, the desert for 100 square miles around the town to Delta, Utah is modified by irrigation from the Sevier River to support agriculture. Much of the eastern part of the study area was occupied during the Pleistocene by Lake Bonneville which withdrew northward to form the ancestral Great Salt Lake. The withdrawal left isolated remnants of Lake Bonneville in some of the basins. Sevier Lake, one of these remnants, withdrew southward leaving only 25 square miles within the study area. As the remnant lakes dried up, they were reduced to small lakes, marshes, mudflats and playas. Similar depositional environments in the basins were present intermittantly throughout the last half of the Cenozoic Era.

As much as 8,000 feet of sedimentary and igneous rocks were deposited in the structural basins during Tertiary and Quaternary time. These rocks include clastics deposits derived from the erosion of sedimentary and igneous rocks from the adjacent ranges, fresh-water limestones and gypsum that precipitated in shallow lakes, and igneous flows, and tuffs and local intrusive bodies.

The ranges contain faulted sequences of Precambrian-, Paleozoic-, and Mesozoic-age rocks and abundant acidic igneous rocks of both volcanic and intrusive origin. The earliest sedimentary rocks consist of marine siliceous clastic deposits of late Precambrian age. Siliceous clastic rocks of Early Cambrian age grade upward into marine limestones and dolomites of Middle Cambrian to Devonian age. These strata were deposited in the north-trending Cordilleran Miogeosyncline. Overlying the marine carbonate rocks are a sequence of westward-thickening deposits composed of locally-derived marine siliceous and carbonate detritus, that was laid down in rapidly subsiding local basins during Early Mississippian to Early Triassic time. These clastic units include carbonate rocks, shales, sandstones, and conglomerates. During Middle Triassic through Cretaceous time erosion of the uplifted western half of the study area supplied sediments to the eastern half. Igneous rocks in the study area include intrusive rocks of Jurassic, Cretaceous, and Cenozoic age, but the volcanic rocks of mid-to-late Cenozoic age comprise the bulk of all igneous rocks that crop out in the study area. These volcanic rocks consist of tuffs and flows, which are predominantly of silicic composition.

Cenozoic silicic volcanism in the Basin and Range Province first occurred in a core area (Armstrong and others, 1969) that includes the western half of the helium study area; the western one-half of the Ely Quadrangle lies at the center of this core area (fig. 1). Silicic volcanic activity moved away from the center of the core area, and this systematic migration of the volcanism continued to the west. To the east of the volcanic core area, there appears to be neither a systematic outward shift of the silicic eruptions nor a pattern to their termination.

The granitic and silicic volcanic rocks in the study area have characteristically high levels of uranium and thorium as indicated by radiometric data from airborne gamma-ray spectrometer surveys (High Life Helicopters, Inc., 1980; and Texas Instruments, Inc., 1979). These radiometric surveys recorded mean levels of radiation from uranium and thorium as high as 15 ppm eU and 60 ppm eTh for silicic volcanic rock units. Uranium- and thorium-bearing detritus derived from these rocks has been incorporated in the Cenozoic- to Holocene-age sediments deposited in the basins, and uranium leached from these rocks has been carried to the basins as complex ions in the surface and ground waters (Cadigan and Ketner, 1981).

Uranium occurrences related to alkali rhyolitic volcanism are present in the Thomas Range in the northcentral part of the Delta Quadrangle. These occurrences include: (1) those in fluorspar pipes in Paleozoic rocks; (2) beryllium deposits in stratified tuff and tuffaceous breccia; (3) tuffaceous sandstone and conglomerate; and (4) veinlets of opaline silica in volcanic rocks (Butz, and others, 1980). In addition, vein-type uranium occurrences are present within, and adjacent to, a granitic stock at the south flank of the Sheeprock Mountains in the northeast part of the quadrangle, and alluvial-lacustrine placer deposits occur on the east-central flank of the Deep Creek Range in the northwest corner of the Delta Quadrangle (Cadigan and Ketner, 1981). Many springs sampled in the Delta Quadrangle during the National Uranium Resource Evaluation (NURE) program had high concentrations of dissolved radon and a few had a high radium content, but uranium was not anomalous except for one spring sampled in the Thomas Range (Cadigan and Ketner, 1981).

HELIUM DISTRIBUTION

Soil-gas helium concentrations in the study area ranged from -147 to 441 ppb with respect to ambient air (Appendix table 1). The median value for helium in samples collected throughout the entire study area was about 36 ppb. The helium values of samples collected from the Ely Quadrangle exhibit a greater dispersion from the composite median than do the samples from the Delta Quadrangle. The greatest dispersion from the median value occurs in the western half of the Ely Quadrangle where both the maximum and minimum helium values were obtained.

High concentrations of soil-gas helium, i.e., concentrations greater than 100 ppb He above air, were detected in 5 percent of the sample population from the helium study area. High concentrations of helium were detected more commonly in the western half of the study area, and were most abundant in the western quarter of the area (fig. 2). This high level of soil-gas helium was present in only 3 percent of the samples taken from the Delta Quadrangle as compared to 8 percent of the samples from Ely Quadrangle (fig. 2).

Furthermore, high concentrations were detected in nearly 13 percent of the samples collected from the western half of the Ely Quadrangle.

A similar distribution pattern exists for the very low concentrations of soil-gas helium, i.e., the samples that contain less than -20 ppb He with respect to ambient air. Very low helium concentrations were present in more than 6 percent of the samples from the entire study area. Within this area the low helium concentrations were present in less than 6 percent of the samples from the Delta Quadrangle; whereas more than 7 percent of the samples from the Ely Quadrangle and almost 12 percent of the samples from the western half of the Ely Quadrangle contained a very low level of helium in the soil gas.

DISCUSSION

Both positive and negative soil-gas helium values with respect to ambient air are significant, whereas a value approaching that of atmospheric helium may only signify that the soil-gas sample contains a large volume of air. The negative helium value indicates the presence of one or more other gases that dilute and displace from the soil both atmospheric gases and terrestrially-generated helium and may be generated in the soil zone, or below. For example, organic-rich environments may generate large quantities of methane (CH_4) and carbon dioxide (CO_2), and where sulfate-bearing solutions are present, hydrogen sulfide (H_2S) may be formed. In addition, oxidation processes may yield sulfur dioxide (SO_2) or carbon dioxide. Ground-water circulation may transport and release these terrestrial gases far from their site of generation. Identification of the sources of terrestrial gases often is difficult without extensive investigation; however, it is not unusual to find both high levels of helium and high levels of other terrestrial gases, such as CH_4, CO_2, H_2S, and SO_2, occurring within a uranium district (Dyck, 1980). In fact, a direct or indirect genetic relationship locally exists between the uranium mineralization and the evolution of these gases. Therefore, the similar regional distribution pattern for the high and very low concentrations of helium with respect to ambient air is of interest.

Possible helium sources include the direct emission of helium from granitic or silicic volcanic rocks and from volcanic detritus in uranium-thorium placers, or the emission of helium from deposits formed by the mobilization and later reprecipitation of uranium along the flow path of meteoric ground waters. Faults and fractures at the margins of the basins may permit an escape to the surface of helium generated in deeply buried igneous rocks. Another potential source for helium is the fault and fracture system itself which may have been mineralized by hydrothermal waters during igneous activity.

High concentrations of soil-gas helium are less common in the eastern half of the study area which comprises the Delta Quadrangle. Within the Delta Quadrangle (pl. 2), the higher concentrations of helium occur more commonly in basins adjacent to the Drum and Keg Mountains. Silicic volcanism in these ranges is believed to have provided uraniferous source rocks; however, vein-type deposits, similar to those of the Thomas Range may also have formed during volcanism.

The regional distribution pattern for the soil-gas helium data in the study area is discordant with respect to the pattern for other data used to determine uranium favorability. As discussed previously all of the uranium production and most of the reported uranium occurrences are located in the Delta Quadrangle. Furthermore, the aerial radiometric data indicate that the exposed silicic volcanic rocks in the Delta Quadrangle are more uraniferous. Despite these relationships, the samples with high helium are most numerous in the western half of the study area.

The more common occurrence of high levels of soil-gas helium in the Ely Quadrangle possibly can be explained by the volcanic history of the Basin and Range Province. In the western half of the Ely Quadrangle silicic volcanic rocks, which represent the earliest silicic eruptions during the Cenozoic development of the basins and ranges, are dated at 35-40 m.y.b.p. Continued structural development of the basins after termination of silicic volcanism in the eruptive core area has buried mid-Cenozoic-age sedimentary deposits. If uranium deposits were formed in the basins during this period of initial silicic volcanism, then these deposits are likely to be deeply buried, whereas the younger uraniferous volcanic rocks and associated uranium deposits in the eastern parts of the study area are more likely to be present close to the surface. A larger helium signal from the more deeply buried uranium deposits could occur where structures, including faults and fractures, permit deeper ground waters to ascend and, because of reduced hydraulic pressure, to degas significant amounts of helium. This interpretation is highly conjectural and does not reflect the possible influence of meteorologic conditions upon the data. Only detailed geologic investigations and drill hole sampling can determine the significance of the high concentrations of helium in individual soil-gas samples and the significance of the regional distribution patterns for the high concentrations of helium and other terrestrial gases.

The regional distribution of helium concentrations in the Basin and Range study area is also dissimilar to that for 838 samples collected in 4, $1^{o} \times 2^{o}$ quadrangles during a study of the Powder River Basin (Reimer and others, 1980). In the Powder River Basin higher soil-gas helium concentrations generally occur east of the axis of the basin where abnormally high geothermal gradients in Pennsylvanian-age aquifers suggest that deep eastward-flowing ground water migrates up dip and into overlying aquifers. In this case, decreased hydraulic pressure permits degassing. Leakage of this free-gas helium to the surface may account for the regional distribution pattern for soil-gas helium in the Powder River Basin.

The size, structure, and hydrology of the basins in the two studies differ greatly, and, whereas distinct trends related to the regional structure of the Powder River Basin were recognizable, no similar trends were recognizable in the smaller fault basins of the Basin and Range Province. A greater density of samples in the smaller fault basins might reveal structurally-controlled areas of anomously high helium that mark the locations of potential energy sources which occur only in more localized regions.

SUMMARY

High soil-gas helium concentrations were present in 27 samples from the Delta-Ely study area. These high helium concentrations may be attributed to several sources including: 1) silicic uraniferous volcanic rocks; 2) sediments derived from these silicic rocks or from vein-type or sedimentary stratiform uranium occurrences; 3) more deeply buried crustal rocks. The possibility that soil-gas helium may be derived, at least in part, from crustal rocks fragmented during a continuing extension of the substratum is suggested by the existence of interior drainages and marshes or playas in Newark, Long, Jakes, Butte, and Antelope Valleys. These features and seismic activity in the Basin and Range Province suggest that crustal extension and down-dropping of graben blocks has continued into Quaternary and Holocene time, thereby providing open fracture systems that permit leakage of helium gas to the surface.

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Appendix

Table 1.--Helium concentrations in soil-gas samples from the Ely, Nevada and Delta, Utah $1^{\circ} \times 2^{\circ}$ quadrangles. Helium values are uncorrected data reported as parts per billion with respect to ambient air.

Ely, Nevada $1^{o} \times 2^{o}$ Quadrangle

Sample number	Date June 1981	Time of collection	Helium (parts per billion with respect to ambient air)
100	24	07:57	37
101	24	08:10	56
102	24	08:21	9
103	24	08:32	74
104	24	09:28	74
105	24	09:40	56
106	24	09:52	28
107	24	10:05	74
108	24	10:19	37
109	24	10:34	37
110	24	10:50	83
111	24	11:01	92
112	24	11:12	83
113	24	11:25	0
114	24	11:40	36
115	24	11:55	90
116	24	12:10	72
117	25	07:16	40
118	25	07:27	60
119	25	07:40	140
120	25	07:50	40
121	25	09:12	70
122	25	09:31	40
123	25	09:47	0
124	25	10:01	0
125	25	10:25	40
126	25	10:36	60
127	25	10:49	20
128	25	11:00	20
129	25	11:11	10
130	25	11:22	0
131	25	11:47	60
201	24	07:00	49
202	24	07:20	37
203	24	07:30	0
204	24	07:40	49
205	24	07:55	0

Ely, Nevada 1^o x 2^o Quadrangle--continued

Sample number	Date June 1981	Time of collection	Helium (parts per billion with respect to ambient air)
206	24	08:05	269
207	24	08:20	49
208	24	08:35	37
209	24	08:45	184
210	24	08:55	87
211	24	09:10	147
212	24	09:15	25
213	24	09:30	49
214	24	09:40	0
215	24	09:50	74
216	24	10:02	-49
217	25	07:05	30
218	25	07:18	44
219	25	07:28	88
220	25	07:35	88
221	25	-	118
222	25	-	15
223	25	-	30
224	25	-	87
225	25	-	58
226	25	-	29
227	25	-	30
228	25	-	44
229	25	-	14
230	25	-	0
231	25	-	58
301	24	07:05	120
302	24	07:30	25
303	24	07:45	-50
304	24	08:00	75
305	24	08:15	112
306	24	08:35	-50
307	24	09:00	100
308	24	09:25	0
309	24	10:00	72
310	24	10:30	175

Ely, Nevada $1^o \times 2^o$ Quadrangle--continued

Sample number	Date June 1981	Time of collection	Helium (parts per billion with respect to ambient air)
311	24	11:15	0
312	24	11:20	-37
313	24	11:35	98
314	24	12:00	98
315	24	12:15	-147
316	24	12:35	122
317	24	13:15	-74
318	24	13:30	441
319	24	13:50	0
320	24	14:05	48
321	24	14:30	-72
322	25	06:55	21
323	25	07:25	32
324	25	08:00	94
325	25	08:15	63
326	25	08:50	42
327	25	09:00	126
328	25	09:45	42
329	25	10:10	105
330	25	10:55	52
331	25	12:00	21
332	25	12:30	-63
333	25	13:00	10
334	25	13:40	0
335	25	14:30	-42
336	25	14:50	0
337	25	15:30	42
338	25	16:00	12
339	25	16:20	0
340	25	16:30	23
341	25	16:55	34
342	25	18:20	12
343	25	18:30	46
344	25	18:45	23
345	25	18:50	23

Ely, Nevada 1^{o} x 2^{o} Quadrangle--continued

Sample number	Date June 1981	Time of collection	Helium (parts per billion with respect to ambient air)
401	24	07:45	18
402	24	08:20	72
403	24	08:40	72
404	24	08:55	0
405	24	09:07	18
406	24	09:40	54
407	24	10:20	54
408	24	11:30	36
409	24	11:50	27
410	24	12:30	72
411	24	13:05	0
412	24	13:35	36
413	24	14:00	329
415	24	14:40	0
416	24	14:50	-24
417	24	16:40	188
418	24	17:20	47
419	24	17:45	-118
420	25	08:40	61
421	25	09:05	84
422	25	09:20	94
423	25	09:30	94
424	25	09:40	42
425	25	09:50	84
426	25	10:00	10
428	25	10:40	63
433	25	--	-42
434	25	--	0
435	25	15:45	22
436	25	15:55	11
437	25	16:05	0
438	25	16:20	0
439	25	16:45	11
440	25	17:00	68
441	25	17:15	34
442	25	17:30	90
443	25	18:00	45

Ely, Nevada 1^o x 2^o Quadrangle--continued

Sample number	Date June 1981	Time of collection	Helium (parts per billion with respect to ambient air)
501	24	06:13	0
502	24	06:26	37
503	24	07:07	74
504	24	07:22	0
505	24	07:42	24
506	24	08:02	37
507	24	08:26	98
508	24	08:49	12
509	24	09:10	-98
510	24	09:39	0
511	24	10:05	74
512	24	10:25	37
513	24	10:47	24
514	24	11:17	49
515	24	11:38	-122
516	24	12:14	0
517	24	12:40	24
518	24	13:03	122
519	24	13:22	0
520	24	14:00	196
521	24	14:30	122
522	24	15:06	98
523	24	15:27	-74
524	24	17:29	48
525	24	17:49	0
526	25	06:35	45
527	25	06:46	120
528	25	07:15	45
529	25	07:40	120
530	25	07:57	0
531	25	08:11	60
532	25	08:30	60
533	25	08:49	20
534	25	09:29	0
535	25	10:45	50

Ely, Nevada $1^o \times 2^o$ Quadrangle--continued

Sample number	Date June 1981	Time of collection	Helium (parts per billion with respect to ambient air)
536	25	11:43	50
537	25	12:00	0
538	25	12:17	0
539	25	12:46	-10
540	25	13:17	-40
541	25	13:58	0
542	25	14:22	0
543	25	14:44	20
544	25	15:59	0
545	25	16:11	-80
546	25	16:26	10
547	26	09:34	0
548	26	10:28	0
600	24	07:21	70
601	24	07:40	70
602	24	08:05	35
603	24	08:45	18
604	24	09:20	26
605	24	09:45	61
606	24	10:00	61
607	24	10:20	61
608	24	10:40	18
609	24	10:50	96
610	24	11:15	52
611	24	11:45	70
612	24	12:15	61
613	24	12:30	9
614	24	12:45	9
615	25	08:00	10
616	25	08:15	39
617	25	08:25	78
618	25	09:10	58
619	25	09:21	49

Ely, Nevada 1^{o} x 2^{o} Quadrangle--continued

Sample number	Date June 1981	Time of collection	Helium (parts per billion with respect to ambient air)
620	25	09:35	39
621	25	10:15	20
622	25	--	39
623	25	--	49
624	25	--	29
625	25	--	49
626	25	--	29
627	25	14:00	11
628	25	14:10	0
629	25	14:30	0
630	25	15:00	0
631	25	15:30	0
632	25	15:45	11
633	25	16:00	0
634	25	16:15	32

Delta, Utah 1^{o} x 2^{o} Quadrangle

Sample number	Date June 1981	Time of collection	Helium (parts per billion with respect to ambient air)
100	26	11:55	32
102	26	12:05	43
103	26	12:15	32
104	26	12:25	11
105	26	12:35	11
106	26	12:46	0
107	26	12:52	0
108	26	13:08	0
109	26	13:17	0
110	27	06:37	34
111	27	06:55	0
112	27	07:13	45
113	27	07:29	135
114	27	07:43	90
115	27	08:22	113
116	27	11:45	45
117	27	12:01	34
118	27	12:13	34
119	27	12:21	68
120	27	12:30	23
121	27	12:41	24
122	27	12:50	47
123	27	12:57	59
124	27	13:12	71
125	27	13:23	71
126	27	13:34	71
127	27	13:57	24
128	27	14:06	71
129	27	14:14	12
130	27	14:22	35
131	27	14:31	35
132	27	14:40	24
133	27	14:52	12
134	28	11:20	52
135	28	11:40	52

Sample number	Date June 1981	Time of collection	Helium (parts per billion with respect to ambient air)
136	28	12:53	78
137	28	13:06	52
138	28	13:45	26
139	28	16:15	52
141	28	16:42	26
201	26	11:40	42
202	26	11:55	21
203	26	12:15	32
204	26	12:24	11
205	26	12:32	0
206	26	12:46	11
207	26	12:55	11
208	26	13:10	0
209	26	14:55	0
210	26	15:05	23
211	26	15:17	23
212	26	15:40	23
213	26	15:51	0
214	26	16:01	0
215	26	16:12	0
216	26	16:23	0
217	26	16:34	0
218	26	16:46	-90
219	26	16:58	0
220	26	17:23	23
221	26	17:36	23
222	27	07:03	26
223	27	07:58	39
224	27	08:23	26
225	27	08:34	77
226	27	08:45	51
227	27	08:54	51
228	27	09:45	76
229	27	09:55	51
230	27	10:02	38

Delta, Utah 1^{o} x 2^{o} Quadrangle--continued

Sample number	Date June 1981	Time of collection	Helium (parts per billion with respect to ambient air)
231	27	10:08	25
232	27	10:35	38
233	27	10:48	51
234	27	11:00	51
235	27	11:12	63
236	27	11:25	25
237	27	11:38	0
238	27	11:50	51
239	27	12:00	51
240	27	12:08	0
241	28	10:00	0
242	28	10:30	46
243	28	10:55	34
244	28	11:05	23
245	28	11:25	11
246	28	12:00	23
247	28	--	46
248	28	--	-23
249	28	--	0
250	28	--	0
251	28	12:40	0
252	28	12:50	0
301	26	12:10	0
302	26	12:35	0
303	26	12:50	22
304	26	13:05	44
305	26	13:20	22
306	26	13:30	0
307	26	13:45	0
308	26	14:00	11
309	27	07:20	94
310	27	07:30	73
311	27	08:30	63
312	27	08:45	84
313	27	09:05	84
314	27	09:45	105
315	27	10:00	84

Sample number	Date June 1981	Time of collection	Helium (parts per billion with respect to ambient air)
316	27	10:15	63
317	27	10:40	84
318	27	11:00	63
319	27	11:30	84
320	27	11:45	31
321	27	11:55	73
322	27	12:05	52
323	27	12:15	63
324	27	12:45	63
325	27	13:20	52
326	27	13:35	42
327	27	14:00	42
328	27	14:10	42
329	27	14:45	44
330	27	15:45	77
331	27	16:00	44
332	27	16:10	33
333	27	16:20	22
334	27	16:40	66
335	27	17:00	22
336	27	17:12	44
337	27	17:35	66
401	26	12:20	-22
402	26	12:35	44
403	26	12:45	55
404	26	13:05	33
405	26	13:25	22
406	26	13:50	0
407	26	14:00	22
408	26	14:10	-78
409	26	14:35	-66
410	27	06:55	20
411	27	07:15	59
412	27	08:00	0
413	27	08:10	39
414	27	08:20	137
415	27	08:40	78

Delta, Utah $1^o \times 2^o$ Quadrangle--continued

Sample number	Date June 1981	Time of collection	Helium (parts per billion with respect to ambient air)
416	27	09:00	59
417	27	09:45	117
418	27	10:05	49
419	27	11:10	20
420	27	11:35	78
421	27	11:40	78
422	27	11:45	68
423	27	12:30	68
424	27	13:10	39
425	27	13:20	59
426	27	13:50	59
427	27	14:00	20
428	27	14:10	59
429	27	14:20	78
430	27	14:30	68
431	27	14:40	78
432	27	14:50	78
433	27	--	68
434	27	--	78
435	27	15:30	29
436	27	15:55	0
437	27	--	39
438	28	07:30	12
439	28	08:05	50
440	28	08:30	12
441	28	08:45	12
442	28	09:05	74
443	28	11:00	0
444	28	12:00	0
445	28	12:45	25
446	28	13:10	0
447	28	13:45	-25
448	28	14:00	0
449	28	--	0
450	28	14:35	0

Delta, Utah 1^{o} x 2^{o} Quadrangle--continued

Sample number	Date June 1981	Time of collection	Helium (parts per billion with respect to ambient air)
451	28	15:05	-12
452	28	15:15	-25
453	28	--	0
501	26	14:00	0
502	26	14:15	45
503	26	14:26	-23
504	26	14:40	0
505	26	14:54	-45
506	26	15:08	-23
507	26	15:20	0
508	26	15:33	0
509	26	15:45	-45
510	26	16:13	-45
511	26	16:24	-113
512	27	06:38	77
513	27	07:15	68
514	27	07:44	39
515	27	08:23	68
516	27	08:47	68
517	27	09:17	48
518	27	10:03	81
519	27	10:19	41
520	27	10:33	30
521	27	10:48	41
522	27	11:21	101
523	27	11:54	20
524	27	12:30	61
525	27	12:47	61
526	27	13:33	71
527	27	14:02	51
528	27	14:25	30
529	27	14:50	41
530	27	15:23	41
531	27	16:16	41
532	28	07:08	52
533	28	07:28	78
534	28	07:49	52
535	28	09:02	13

Sample number	Date June 1981	Time of collection	Helium (parts per billion with respect to ambient air)
536	28	--	0
537	28	10:40	26
538	28	11:37	0
539	28	11:52	26
540	28	12:17	52
541	28	13:04	52
542	28	13:25	13
543	28	14:13	26
544	28	14:27	0
545	28	15:27	0
546	28	16:04	-26
547	29	14:52	114
548	29	16:34	88
549	29	16:54	58
550	29	17:44	58
551	29	17:57	0
552	29	18:37	0
553	29	19:07	44
554	30	07:51	0
600	26	09:30	43
601	26	09:45	65
602	26	10:00	108
603	26	10:15	11
604	26	10:35	33
605	26	10:55	43
606	26	11:05	43
607	26	11:25	33
608	26	15:40	23
609	26	16:30	79
610	26	16:50	0
611	27	07:45	44
612	27	08:15	66
613	27	08:45	66
614	27	09:05	44

Delta, Utah 1^{o} x 2^{o} Quadrangle--continued

Sample number	Date June 1981	Time of collection	Helium (parts per billion with respect to ambient air)
615	27	09:20	88
617	27	09:55	88
619	27	10:15	78
620	27	10:35	66
621	27	11:00	0
622	27	12:00	78
623	27	--	44
624	28	11:10	0
625	28	11:30	33
626	28	12:20	66
627	28	12:40	66
628	28	13:00	78
629	28	13:20	33
630	29	09:45	0
631	29	10:00	0
632	29	10:30	86
633	29	10:40	0
634	29	11:25	0
635	29	11:35	37
636	29	13:45	0
637	29	14:00	0
638	29	15:30	0
639	29	15:55	12
640	29	16:05	37
641	29	16:35	49
642	29	17:00	24
643	29	17:10	0
644	29	18:45	73
645	29	19:10	-24
646	29	19:25	-24
648	29	20:00	24