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Concentrations of N_2, O_2, CO_2, and He in Soil Gases Collected in the Northern San Luis Valley, Colorado

By

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ABSTRACT

Concentrations of N_2, O_2, CO_2, and He were measured in a total of 395 soil-gas samples collected in 1992 and 1993 in the northern part of the San Luis Valley, Colorado. The study was part of a multimedia geochemical and geophysical survey, funded by the U.S. Department of Energy, to seek surface evidence of possible extensions of the Valley View Hot Springs and Mineral Hot Springs Known Geothermal Resource Areas. Sampling and analysis of the soil gases are described and measurements of gas concentrations are listed.

INTRODUCTION

The San Luis Valley is an east-dipping half graben, the geomorphic expression of the Rio Grande Rift in southern Colorado. The valley lies between low foothills of the San Juan Volcanic Field to the west and the steeply rising Sangre de Cristo Range to the east. The prominent late-Tertiary age Sangre de Cristo fault is the bounding fault of the Sangre de Cristo Range; the fault runs the length of the west side of the range and cuts across several structural features. The Holocene Villa Grove fault zone trends northwesterly across the northern San Luis Valley from the vicinity of Valley View Hot Springs (Knepper, 1976; Knepper and Marrs, 1971). The western side of the valley is cut by the Kerber, Noland, and Villa Grove faults, which extend northwesterly from the vicinity of Mineral Hot Springs (Scott and others, 1978) (fig. 1).

Soil-gas surveys were made in 1992 and 1993 in the northern San Luis Valley, Colorado, as part of a multimedia geochemical study and remote-sensing study to seek surface evidence of any possible extensions of two known geothermal resource areas (KGRA's). The first KGRA, Mineral Hot Springs (spring water temperatures 32-55°C), occurs in valley fill about midway between the San Juan Volcanic Field on the west side of the valley and the Sangre de Cristo Range on the east. The second KGRA, Valley View Hot Springs (spring water temperatures 31-33°C), lies along the prominent Sangre de Cristo fault. Although the temperatures of these geothermal waters are not hot enough to indicate the presence of high-temperature geothermal systems, waters of these temperatures can be used for space heating, agriculture, and industry.

Other data releases in this multimedia study include analyses of rabbitbrush samples (Erdman and VanTrump, 1993) and results of a resistivity survey near Mineral Hot Springs (Zohdy and Bisdorf, 1993).

ACKNOWLEDGEMENTS

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SAMPLE COLLECTION AND ANALYSIS

Soil-gas samples were collected by driving a hollow probe into the ground to a depth of 0.6 to 0.7 m; the hollow probe was described by Reimer and Bowles (1979). The probe was driven into the ground by means of a sliding hammer attached to the shaft of the probe. After the probe was driven into the ground, it was fitted with an airtight cap and septum for withdrawal of the soil-gas sample.

Samples were collected from the hollow probe by inserting the needle of the syringe through the septum in the cap and withdrawing 10 mL of the soil gas. Before removal of the first sample, 10 mL of air were withdrawn from the probe to remove air introduced when the probe was emplaced in the ground. The soil-gas samples were transferred to four 5-mL evacuated blood-sampling vials for storage (two each for gas chromatographic and mass spectrometric analyses), by inserting the needle of the syringe containing the gas sample through the rubber cap of the evacuated vial and allowing the sample in the syringe to be drawn inside. The needle holes were covered with silicone glue. Soil-gas samples can be stored in these evacuated vials for as long as 2 months without leakage (Hinkle and Kilburn, 1979).

For He analysis, gas in the vials was removed by injecting 5 mL of air (equal to the volume of the vial) into the vial and removing the mixture of air and soil gas. The samples were analyzed for He using mass spectrometry (Reimer and Denton, 1978). Standard samples of air containing known concentrations of He were analyzed several times per day to ensure stability of the instrument. Concentrations of He were reported as parts per billion volume/volume; reproducibility of the measurement was ±20 ppb. The concentration of He in air is 5,220 ppb (Holland and Emerson, 1987). The tubes used for sample storage were approximately 80 percent evacuated. They contained a residual concentration of He, introduced during the manufacturing process that was the same for all the tubes in each lot produced by the manufacturer. This residual He concentration was measured and subtracted from the raw measurement of He in the soil gas.

Samples were analyzed for N_2, O_2, and CO_2 using gas chromatography; operating conditions for the gas chromatograph are shown in table 1. For gas chromatography analysis, gas in the vials was removed by injecting 5 mL of pure He (equal to the volume of the vial) into the vial and removing the mixture of He and soil gas for the chromatographic analysis. Concentrations of N_2, O_2, and CO_2 were measured compared to standard curves and are reported as volume percents. Standard samples containing known concentrations of the gases diluted with He were placed in the same vials used for sample storage and were analyzed several times per day to ensure stability of the instrument.

Soil temperature was measured at each sample site during the 1993 survey, because soil temperature can strongly affect concentrations of He and CO_2 (Hinkle, 1993). However, the soil temperatures, which ranged from 6°C to 15°C during the survey, had no effect on soil-gas concentrations. Correlation coefficients for the 275 soil temperature-gas concentration pairs were -0.07, -0.04, -0.05, and 0.07, for N_2, O_2, CO_2, and He, respectively.

Totals of 120 and 275 soil-gas samples were collected in 1992 and 1993, respectively. Twelve of the 1992 sites along county road GG were resampled in 1993 for comparative purposes; one of the 1993 sites was sampled twice. The replicate site numbers, from west to east along road GG, with their sample numbers (1992 and 1993, respectively) are: site 1—91 and 278; site 2—92 and 279; site 3—93 and 280; site 4—94 and 281; site 5—95 and 282; site 6—96, 150, and 283; site 7—97 and 284; site 8—98 and 285; site 9—99 and 286; site 10—100 and 287; site 11—106 and 395; site 12—3 and 358. Plots of the 1992 and 1993 N_2, O_2, CO_2, and He concentrations at these twelve sites are shown in figure 1.

DESCRIPTION OF THE DATA TABLES

Data from the analyses were entered into an IBM-compatible personal computer and stored on disks, using the QuattroPro program (Borland International, Inc.). The data were converted into the U.S. Geological Survey STATPAC format for statistical analyses (Grundy and Miesch, 1987), and into the U.S. Geological Survey GSMAP format for plotting (Selner and Taylor, 1992). Table 2 shows the maximum, minimum, mean, and standard deviation of the raw-data measurements for the 1992 and 1993 data sets. Table 3 lists the results of the 395 soil-gas analyses; samples numbered one through 120 were collected in 1992, samples 121 through 397 were collected in 1993. The concentrations of He listed in tables 2 and 3 are significant only to between two and three figures, and not to the four figures implied by the raw data.

A digital STATPAC-base format of the data in table 3 can be found on floppy disk in the pocket of this report, U.S. Geological Survey Open-File Report 93-584.

Plots of the combined 1992-1993 measurements of N_2, O_2, CO_2, and He in the soil-gas samples are shown in figures 2-6. Figures 2-6 were prepared by calculating concentration values for the 1992 and 1993 data sets separately, and then plotting the 1992 and 1993 concentrations of each gas on the same figure. The plots show concentration values of (1) less than mean minus one standard deviation, (2) the range of mean minus one standard deviation to mean plus one standard deviation, and (3) greater than mean plus one standard deviation. These values are equivalent to (1) less than 25th percentile, (2) 25th through approximately 85th percentile, and (3) greater than about the 85th percentile.

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Table 1. Operating conditions for the gas chromatograph

Type of gas chromatograph	Carle AGC-100
Detector	Thermistor detector
Lower limit of detection	1% N_2 or O_2, 0.03% CO_2
Reproducibility	±10%
Column	Concentric stainless steel, outer column 72 in. x 1/4 in. molecular sieve inner column 72 in. x 1/8 in. Porapak mixture (Alltech Associates, Deerfield, IL)
Carrier gas	Helium at 60 mL/minute
Temperature	Column: 60°C Detector: "low" mode

Table 2. Summary data for soil gases

Constituent	Minimum	Maximum	Mean	Standard deviation
N_2 (%)				
1992	29.1	79.2	63.2	10.4
1993	56.2	79.5	72.2	2.8
O_2 (%)				
1992	7.4	22.5	17.1	3.7
1993	14.7	21.5	19.3	0.9
CO_2 (%)				
1992	0.02	0.46	0.22	0.10
1993	0.06	2.00	0.37	0.15
He (ppb)				
1992	5,030	5,756	5,402	130
1993	4,970	5,768	5,335	109

Table 3. Analytical results for 1992-1993 soil-gas samples

Sample	Latitude	Longitude	N2(%)	O2(%)	CO2(%)	He(ppb)	Sample	Latitude	Longitude	N2(%)	O2(%)	CO2(%)	He(ppb)
1	38.183	105.824	67.4	17.1	0.26	5430	52	38.235	105.856	55.7	11.1	0.06	5510
2	38.183	105.823	64.8	18.4	0.08	5350	53	38.236	105.857	49.9	13.8	0.14	5510
3	38.185	105.822	67.0	17.1	0.12	5430	54	38.236	105.859	53.5	11.8	0.12	5510
4	38.186	105.821	57.0	16.0	0.10	5470	55	38.237	105.861	55.3	10.8	0.10	5590
5	38.187	105.819	55.8	12.9	0.06	5590	56	38.237	105.862	51.3	14.2	0.24	5310
6	38.188	105.818	64.3	18.2	0.20	5510	57	38.238	105.864	35.0	9.0	0.10	5630
7	38.189	105.816	63.8	17.9	0.18	5510	58	38.239	105.865	68.7	19.6	0.30	5430
8	38.191	105.815	54.5	14.0	0.32	5430	59	38.239	105.867	69.7	19.7	0.46	5470
9	38.192	105.814	65.9	18.6	0.32	5350	60	38.240	105.869	76.3	21.7	0.34	5390
10	38.193	105.813	69.1	19.6	0.30	5630	61	38.241	105.871	73.2	20.9	0.14	5390
11	38.187	105.840	52.2	14.6	0.12	5310	62	38.241	105.873	65.3	18.6	0.18	5590
12	38.189	105.839	67.8	17.3	0.24	5270	63	38.192	105.981	68.0	19.1	0.42	5470
13	38.190	105.837	66.5	18.8	0.34	5230	64	38.193	105.981	68.5	19.4	0.32	5630
14	38.191	105.836	67.2	17.2	0.16	5470	65	38.194	105.982	68.4	19.3	0.36	5510
15	38.192	105.834	57.9	16.3	0.12	5230	66	38.194	105.980	64.1	18.2	0.18	5510
16	38.193	105.833	53.3	14.9	0.12	5550	67	38.183	105.979	68.0	18.8	0.28	5439
17	38.194	105.832	53.5	13.7	0.14	5310	68	38.196	105.978	67.0	19.0	0.30	5462
18	38.195	105.830	53.8	14.9	0.08	5590	69	38.197	105.977	72.4	20.6	0.34	5588
19	38.196	105.829	54.3	10.5	0.04	5470	70	38.198	105.976	69.0	18.5	0.24	5462
20	38.197	105.828	32.3	8.6	0.02	5390	71	38.198	105.974	71.7	20.4	0.26	5420
21	38.197	105.827	52.2	14.5	0.12	5470	72	38.198	105.973	70.3	19.9	0.34	5504
22	38.199	105.827	53.6	14.8	0.22	5150	73	38.198	105.971	73.7	21.0	0.32	5630
23	38.200	105.826	50.8	14.1	0.10	5230	74	38.199	105.969	69.2	19.2	0.22	5378
24	38.202	105.825	55.4	12.7	0.08	5390	75	38.200	105.968	70.0	19.8	0.24	5462
25	38.203	105.823	68.9	17.7	0.20	5430	76	38.201	105.967	64.6	18.2	0.26	5462
26	38.203	105.822	54.8	11.8	0.08	5430	77	38.202	105.965	68.0	18.4	0.24	5504
27	38.204	105.820	55.3	15.5	0.20	5350	78	38.203	105.964	67.7	19.2	0.24	5420
28	38.204	105.819	52.6	13.2	0.08	5590	79	38.204	105.962	65.2	18.4	0.24	5336
29	38.204	105.817	54.3	12.2	0.18	5430	80	38.205	105.961	68.7	19.5	0.26	5588
30	38.210	105.881	52.5	13.7	0.10	5230	81	38.206	105.959	69.7	19.8	0.22	5420
31	38.210	105.878	55.3	12.6	0.12	5310	82	38.207	105.959	68.0	17.5	0.22	5462
32	38.211	105.876	31.1	8.0	0.02	5430	83	38.208	105.957	64.3	18.3	0.16	5378
33	38.212	105.875	58.0	16.4	0.10	5310	84	38.209	105.956	68.4	19.4	0.26	5462
34	38.214	105.874	33.6	8.8	0.06	5470	85	38.209	105.954	74.4	21.2	0.34	5420
35	38.215	105.872	29.1	7.4	0.06	5510	86	38.209	105.952	73.2	20.9	0.26	5504
36	38.216	105.871	55.6	14.3	0.16	5430	87	38.210	105.949	72.6	21.5	0.36	5546
37	38.218	105.869	54.2	12.0	0.10	5470	88	38.209	105.947	72.7	20.7	0.28	5252
38	38.219	105.868	55.8	14.6	0.16	5390	89	38.209	105.945	69.5	19.7	0.34	5210
39	38.220	105.867	50.7	14.0	0.14	5470	90	38.209	105.943	68.4	19.4	0.20	5378
40	38.221	105.865	55.5	10.9	0.12	5270	91	38.189	105.940	76.2	21.7	0.22	5462
41	38.222	105.864	54.2	12.1	0.12	5310	92	38.189	105.937	67.5	19.2	0.24	5462
42	38.223	105.863	56.1	11.1	0.06	5390	93	38.189	105.935	76.2	21.7	0.32	5126
43	38.224	105.862	34.3	9.0	0.06	5190	94	38.189	105.933	67.7	19.2	0.26	5378
44	38.225	105.861	54.7	13.5	0.16	5390	95	38.189	105.931	72.3	20.6	0.26	5378
45	38.226	105.860	68.4	17.5	0.10	5470	96	38.189	105.929	71.1	21.7	0.26	5378
46	38.227	105.859	66.6	16.9	0.22	5310	97	38.189	105.927	71.7	20.3	0.38	5378
47	38.228	105.857	56.2	15.7	0.16	5270	98	38.188	105.925	71.2	20.3	0.24	5588
48	38.229	105.856	55.7	12.7	0.10	5110	99	38.189	105.923	69.4	19.7	0.24	5378
49	38.230	105.855	55.4	15.3	0.18	5150	100	38.189	105.922	74.2	21.2	0.32	5588
50	38.231	105.854	66.6	16.6	0.40	5350	101	38.189	105.920	67.4	19.1	0.28	5420
51	38.235	105.854	68.4	19.3	0.34	5030	102	38.189	105.918	66.0	18.8	0.16	5462

Table 3. Analytical results for 1992-1993 soil-gas samples (continued)

Sample	Latitude	Longitude	N2(%)	O2(%)	CO2(%)	He(ppb)
103	38.189	105.910	78.3	22.4	0.32	5378
104	38.189	105.902	67.8	19.2	0.30	5462
105	38.189	105.885	67.4	17.3	0.22	5756
106	38.189	105.864	68.3	19.4	0.24	5336
107	38.189	105.851	73.1	20.8	0.34	5420
108	38.184	105.926	68.4	17.5	0.20	5252
109	38.186	105.942	65.8	18.5	0.32	5504
110	38.186	105.944	68.5	18.6	0.30	5336
111	38.187	105.946	59.3	16.7	0.18	5252
112	38.188	105.948	69.4	18.0	0.12	5252
113	38.188	105.950	70.9	20.2	0.30	5336
114	38.188	105.952	75.8	21.6	0.34	5168
115	38.188	105.954	69.6	19.7	0.30	5210
116	38.188	105.956	71.8	20.4	0.32	5252
117	38.189	105.958	78.3	22.2	0.44	5294
118	38.189	105.960	77.9	22.2	0.38	5210
119	38.190	105.961	77.6	22.1	0.40	5252
120	38.191	105.963	79.2	22.5	0.46	5168
121	38.244	105.946	71.0	19.0	0.34	5222
122	38.244	105.945	68.8	18.4	0.26	5432
123	38.243	105.943	74.9	20.3	0.29	5306
124	38.241	105.942	74.1	19.9	0.24	5096
125	38.240	105.940	72.6	19.5	0.24	5516
126	38.240	105.938	71.7	19.3	0.32	5306
127	38.238	105.936	75.5	20.4	0.27	5306
128	38.237	105.936	69.4	18.6	0.34	5348
129	38.236	105.935	73.4	19.8	0.27	5348
130	38.235	105.935	77.4	20.9	0.47	5306
131	38.234	105.934	76.1	18.8	0.32	5324
132	38.233	105.934	73.3	19.7	0.39	5228
133	38.231	105.933	77.4	19.2	0.33	5360
134	38.230	105.933	69.7	18.6	0.25	5180
135	38.229	105.933	70.3	18.9	0.34	5288
136	38.227	105.933	64.3	17.8	0.25	5264
137	38.226	105.933	74.5	20.0	0.48	5180
138	38.225	105.933	72.5	19.6	0.22	5264
139	38.222	105.933	64.8	17.1	0.29	5348
140	38.219	105.933	70.9	19.0	0.36	5306
141	38.216	105.932	70.7	19.2	0.60	5432
142	38.213	105.932	74.7	20.0	0.35	5390
143	38.210	105.932	67.1	18.0	0.14	5222
144	38.207	105.931	68.9	18.5	0.37	5474
145	38.204	105.931	71.1	19.3	0.24	5390
146	38.201	105.931	71.5	19.2	0.24	5280
147	38.199	105.931	70.6	18.9	0.37	5216
148	38.196	105.930	74.0	20.0	0.36	5252
149	38.192	105.929	71.2	19.1	0.32	5432
150	38.189	105.929	78.0	21.0	0.36	5348
151	38.187	105.929	74.5	20.0	0.45	5348
152	38.186	105.929	73.7	19.8	0.48	5432
153	38.184	105.929	68.7	18.3	0.36	5222
154	38.183	105.929	73.6	19.8	0.48	5390
155	38.181	105.928	74.5	20.1	0.39	5432
156	38.180	105.928	73.3	19.6	0.45	5390
157	38.178	105.928	70.9	19.0	0.21	5432
158	38.176	105.928	74.1	19.9	0.47	5474
159	38.175	105.927	70.2	18.8	0.27	5348
160	38.174	105.926	73.8	19.8	0.40	5516
161	38.172	105.925	70.2	18.8	0.33	5348
162	38.168	105.928	74.4	20.0	0.37	5474
163	38.167	105.930	69.0	18.5	0.33	5390
164	38.167	105.931	76.1	20.5	0.31	5390
165	38.167	105.933	69.1	18.5	0.26	5600
166	38.168	105.934	70.6	18.9	0.27	5432
167	38.168	105.936	71.7	19.2	0.42	5474
168	38.168	105.938	71.1	19.0	0.46	5600
169	38.168	105.939	73.5	19.9	0.38	5432
170	38.168	105.941	72.3	19.4	0.40	5390
171	38.169	105.944	73.0	19.6	0.31	5390
172	38.173	105.970	71.0	19.0	0.35	5390
173	38.174	105.968	72.3	19.3	0.48	5222
174	38.176	105.966	56.2	14.7	0.10	5306
175	38.177	105.963	63.8	17.1	0.10	5264
176	38.178	105.962	71.0	19.0	0.28	4970
177	38.178	105.960	66.5	17.7	0.31	5222
178	38.178	105.959	73.2	19.7	0.31	5264
179	38.177	105.958	72.8	19.4	0.47	5360
180	38.177	105.957	76.8	20.7	0.51	5480
181	38.176	105.956	71.2	19.1	0.33	5328
182	38.175	105.955	74.9	20.3	0.29	5284
183	38.174	105.953	72.1	19.3	0.29	5222
184	38.174	105.951	75.1	20.4	0.42	5222
185	38.173	105.949	71.9	19.4	0.31	5222
186	38.173	105.946	69.9	18.6	0.47	5264
187	38.172	105.945	72.9	21.3	0.38	5348
188	38.221	105.944	68.0	18.2	0.31	5264
189	38.221	105.946	70.3	18.8	0.32	5222
190	38.221	105.947	66.7	17.7	0.21	5264
191	38.221	105.949	74.0	19.8	0.42	5390
192	38.221	105.951	73.6	19.8	0.35	5390
193	38.221	105.953	72.7	19.5	0.44	5284
194	38.221	105.956	73.7	19.8	0.35	5328
195	38.221	105.957	71.6	19.3	0.27	5284
196	38.223	105.958	71.7	19.2	0.44	5348
197	38.225	105.958	76.1	20.5	0.36	5348
198	38.226	105.959	74.5	20.0	0.35	5240
199	38.227	105.960	71.2	19.2	0.41	5152
200	38.228	105.961	71.6	19.2	0.28	5372
201	38.228	105.963	73.1	19.6	0.51	5348
202	38.228	105.965	73.3	19.7	0.46	5264
203	38.227	105.967	74.9	20.2	0.44	5348
204	38.227	105.969	75.5	20.3	0.26	5432

Table 3. Analytical results for 1992-1993 soil-gas samples (continued)

Sample	Latitude	Longitude	N2(%)	O2(%)	CO2(%)	He(ppb)	Sample	Latitude	Longitude	N2(%)	O2(%)	CO2(%)	He(ppb)
205	38.228	105.971	71.9	19.3	0.28	5432	257	38.188	105.989	73.6	19.7	0.42	5306
206	38.228	105.972	70.5	19.0	0.32	5284	258	38.189	105.987	74.6	20.2	0.35	5306
207	38.228	105.974	69.9	18.8	0.43	5284	259	38.190	105.985	72.1	19.4	0.38	5474
208	38.229	105.975	74.3	19.8	0.56	5284	260	38.190	105.984	73.0	19.6	0.44	5264
209	38.229	105.977	75.3	20.1	0.51	5348	261	38.191	105.982	72.6	19.5	0.39	5264
210	38.229	105.979	72.8	19.4	0.38	5306	262	38.179	105.963	72.6	19.5	0.34	5324
211	38.228	105.980	72.0	19.3	0.27	5390	263	38.180	105.964	74.0	19.9	0.44	5216
212	38.227	105.981	79.5	21.5	0.35	5348	264	38.180	105.966	69.0	18.5	0.33	5200
213	38.226	105.982	71.0	19.0	0.24	5768	265	38.181	105.968	72.5	19.5	0.38	5432
214	38.225	105.982	74.6	20.1	0.32	5348	266	38.182	105.971	67.9	18.1	0.38	5264
215	38.224	105.982	73.0	19.6	0.33	5348	267	38.183	105.972	71.6	19.2	0.42	5324
216	38.223	105.981	72.3	19.4	0.50	5516	268	38.184	105.975	71.2	19.1	0.58	5288
217	38.221	105.981	77.3	20.9	0.43	5474	269	38.184	105.978	71.1	19.0	0.45	5144
218	38.220	105.980	76.5	20.6	0.49	5348	270	38.184	105.980	73.4	19.7	0.43	5390
219	38.219	105.980	73.9	19.7	0.48	5359	271	38.186	105.980	72.6	19.6	0.41	5642
220	38.218	105.979	72.6	19.4	0.44	5306	272	38.187	105.980	70.6	18.9	0.38	5306
221	38.216	105.979	71.4	19.1	0.38	5020	273	38.188	105.980	70.6	18.8	0.40	5096
222	38.215	105.979	72.6	19.5	0.41	5372	274	38.188	105.980	72.4	19.5	0.37	5264
223	38.214	105.980	70.9	18.9	0.32	5359	275	38.189	105.980	73.2	19.5	0.53	5516
224	38.213	105.983	71.9	19.3	0.24	5222	276	38.190	105.979	74.0	19.9	0.58	5348
225	38.212	105.985	72.0	19.4	0.34	5222	277	38.192	105.979	74.3	20.0	0.51	5432
226	38.211	105.986	70.7	18.8	0.45	5390	278	38.189	105.940	78.2	21.2	0.30	5306
227	38.209	105.988	71.0	19.0	0.45	5390	279	38.189	105.937	69.6	18.8	0.37	5348
228	38.221	105.978	72.7	19.5	0.43	5200	280	38.189	105.935	78.3	21.2	0.40	5306
229	38.221	105.976	74.4	20.1	0.32	5288	281	38.189	105.933	72.9	19.6	0.33	539C
230	38.220	105.975	71.1	18.9	0.28	5216	282	38.189	105.931	77.1	21.2	0.45	5432
231	38.220	105.973	71.8	19.2	0.36	5252	283	38.189	105.929	70.5	18.6	0.31	5264
232	38.220	105.970	70.5	19.0	0.29	5216	284	38.189	105.928	72.4	18.8	0.34	5432
233	38.219	105.968	71.1	19.1	0.29	5324	285	38.189	105.925	74.0	20.0	0.33	5390
234	38.219	105.966	72.8	19.3	0.35	5252	286	38.189	105.923	73.1	18.5	0.29	5348
235	38.220	105.963	73.0	19.7	0.24	5180	287	38.189	105.922	75.3	20.3	0.27	5390
236	38.219	105.962	70.3	19.0	0.20	5264	288	38.144	105.828	71.3	19.0	0.39	5180
237	38.220	105.960	74.1	20.0	0.40	5348	289	38.149	105.835	70.3	18.9	0.25	5390
238	38.220	105.959	69.8	18.8	0.26	5480	290	38.154	105.839	74.1	19.9	0.41	5264
239	38.221	105.959	73.8	20.0	0.38	5560	291	38.158	105.845	70.2	18.7	0.32	5264
241	38.199	105.968	72.8	19.6	0.27	5520	292	38.158	105.854	72.3	19.3	0.45	5222
242	38.198	105.966	69.4	18.5	0.33	5390	293	38.130	105.864	71.3	18.7	0.32	5348
243	38.198	105.963	73.4	19.7	0.39	5348	294	38.148	105.902	73.5	19.6	0.30	5306
244	38.198	105.962	71.7	19.3	0.29	5390	295	38.148	105.904	72.1	19.3	0.22	5348
245	38.198	105.960	72.9	19.5	0.31	5390	296	38.148	105.906	73.3	19.7	0.42	5348
246	38.198	105.958	74.3	20.0	0.31	5348	297	38.148	105.908	68.3	18.2	0.34	5390
247	38.198	105.956	70.1	18.9	0.26	5474	298	38.148	105.910	76.7	20.7	0.45	5432
248	38.198	105.954	72.8	19.4	0.44	5432	299	38.148	105.912	72.1	19.4	0.34	5390
249	38.199	105.952	71.4	19.5	0.42	5246	300	38.148	105.914	73.6	19.8	0.48	5264
250	38.198	105.950	68.9	18.5	0.40	5348	301	38.148	105.916	75.9	20.4	0.54	5432
251	38.198	105.948	73.1	19.6	0.35	5246	302	38.148	105.919	72.7	19.4	0.41	5432
252	38.198	105.947	68.5	18.3	0.22	5484	303	38.148	105.921	76.4	20.6	0.24	5432
253	38.197	105.943	70.3	18.9	0.41	5246	304	38.148	105.923	73.4	19.8	0.27	5474
254	38.196	105.942	74.0	20.0	0.27	5306	305	38.252	105.951	75.8	20.2	0.46	5390
255	38.186	105.992	70.3	18.8	0.34	5348	306	38.252	105.954	75.3	20.4	0.31	5306
256	38.188	105.991	70.1	18.8	0.45	5306	307	38.252	105.956	71.9	19.2	0.21	5348

Table 3. Analytical results for 1992-1993 soil-gas samples (continued)

Sample	Latitude	Longitude	N2(%)	O2(%)	CO2(%)	He(ppb)
308	38.251	105.958	71.3	19.1	0.21	5306
309	38.251	105.960	77.8	21.1	0.31	5012
310	38.251	105.962	64.2	17.2	0.10	5306
311	38.251	105.963	73.2	19.8	0.33	5264
312	38.250	105.965	73.8	19.9	0.39	5216
313	38.250	105.967	71.5	19.4	0.28	5252
314	38.249	105.968	71.4	19.3	0.29	5558
315	38.248	105.970	70.4	18.9	0.23	5306
316	38.247	105.971	73.2	19.7	0.41	5222
317	38.247	105.973	75.0	20.2	0.58	5288
318	38.246	105.975	73.1	19.7	0.26	5216
319	38.246	105.977	67.7	18.1	0.30	5348
320	38.245	105.978	74.4	20.1	0.32	5348
321	38.244	105.980	72.3	19.4	0.37	5390
322	38.244	105.982	72.5	19.6	0.33	5474
323	38.243	105.984	69.4	18.6	0.30	5600
324	38.243	105.986	74.5	20.2	0.35	5600
325	38.242	105.987	72.5	19.5	0.41	5390
326	38.242	105.988	70.6	18.9	0.29	5432
327	38.242	105.990	75.8	20.5	0.41	5560
328	38.241	105.992	73.0	19.7	0.28	5440
329	38.241	105.992	75.2	20.4	0.37	5600
330	38.241	105.993	72.0	19.4	0.31	5180
331	38.241	105.996	71.3	18.6	0.53	5252
332	38.240	105.998	73.8	19.8	0.39	5390
333	38.240	105.998	72.6	19.7	0.36	5390
334	38.240	105.999	69.7	18.7	0.33	5390
335	38.240	106.000	72.8	19.6	0.47	5348
336	38.240	106.002	74.1	20.0	0.24	5348
337	38.239	106.005	72.8	19.6	0.37	5348
338	38.239	106.008	73.3	19.8	0.41	5306
340	38.238	106.013	70.4	18.5	0.57	5516
341	38.237	106.014	69.5	18.7	0.33	5348
342	38.236	106.016	72.1	19.4	0.31	5264
343	38.235	106.017	71.7	19.3	0.17	5348
344	38.158	105.882	68.6	18.2	0.28	5264
345	38.159	105.864	71.9	19.2	0.45	5328
346	38.157	105.882	69.9	18.8	0.26	5196
347	38.156	105.882	69.0	18.4	0.34	5152
348	38.155	105.882	71.0	19.0	0.30	5324
349	38.153	105.882	70.0	18.8	0.25	5288
350	38.151	105.882	73.7	19.7	0.40	5432
351	38.150	105.882	69.1	18.5	0.44	5348
352	38.148	105.882	68.6	18.4	0.27	5180
353	38.147	105.882	69.0	18.4	0.33	5348
354	38.145	105.883	74.4	19.9	0.70	5264
355	38.144	105.882	71.6	19.2	0.35	5558
356	38.130	105.883	71.3	18.8	0.45	5180
357	38.129	105.828	73.5	19.8	0.46	5432
358	38.185	105.822	69.3	18.3	0.59	5516
359	38.184	105.820	72.5	19.5	0.43	5306

Sample	Latitude	Longitude	N2(%)	O2(%)	CO2(%)	He(ppb)
360	38.183	105.819	70.7	18.8	0.64	5390
361	38.182	105.818	73.3	19.6	0.84	5348
362	38.181	105.816	61.1	16.1	0.14	5180
363	38.180	105.815	68.1	18.0	0.52	5072
364	38.180	105.812	73.8	19.6	0.63	5252
365	38.179	105.812	67.6	18.1	0.44	5328
366	38.178	105.811	75.7	19.1	0.39	5240
367	38.177	105.809	74.6	20.0	0.61	5240
368	38.176	105.809	71.0	18.6	0.51	5252
369	38.174	105.809	72.6	19.5	0.44	5144
370	38.173	105.809	69.8	18.5	0.69	5348
371	38.172	105.808	73.3	18.5	0.48	5348
372	38.170	105.807	76.5	20.6	0.51	5306
373	38.169	105.807	73.8	17.7	0.08	5306
374	38.167	105.809	78.4	21.0	0.06	5306
375	38.165	105.809	73.2	19.7	0.22	5348
376	38.164	105.808	74.1	20.0	0.47	5264
377	38.163	105.808	70.7	19.0	0.47	5474
378	38.161	105.808	73.1	19.6	0.51	5432
379	38.160	105.808	73.8	19.8	0.52	5474
380	38.158	105.808	73.1	19.7	0.30	5474
381	38.157	105.808	71.7	19.2	0.74	5200
382	38.155	105.808	69.7	18.7	0.39	5280
383	38.154	105.808	73.7	19.8	0.25	5222
384	38.153	105.808	72.5	19.4	0.46	5432
385	38.151	105.808	72.1	19.3	0.40	5264
386	38.149	105.808	67.4	18.0	0.37	5264
387	38.148	105.808	72.7	19.4	0.47	5390
388	38.147	105.808	72.0	19.4	0.38	5390
389	38.146	105.810	75.2	20.3	0.39	5180
390	38.144	105.811	68.4	18.4	0.31	5320
391	38.144	105.818	71.8	19.4	2.00	5320
392	38.192	105.813	66.8	17.5	0.41	5390
393	38.189	105.845	75.9	20.5	0.51	5264
394	38.189	105.855	73.7	19.7	0.26	5306
395	38.189	105.863	73.7	19.9	0.35	5264
396	38.189	105.873	68.3	18.2	0.33	5264
397	38.189	105.883	69.1	18.5	0.26	5306

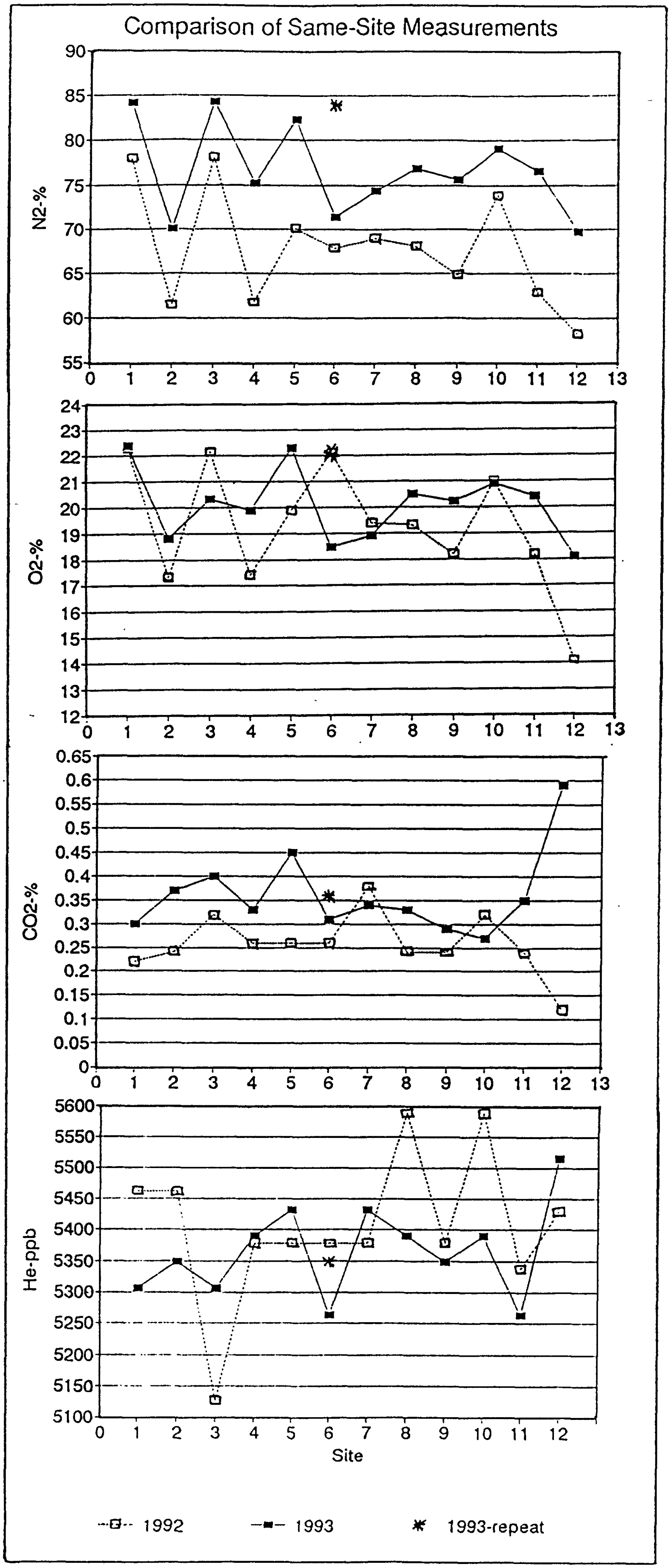

Figure 1. Comparison of same-site measurements of soil gases.

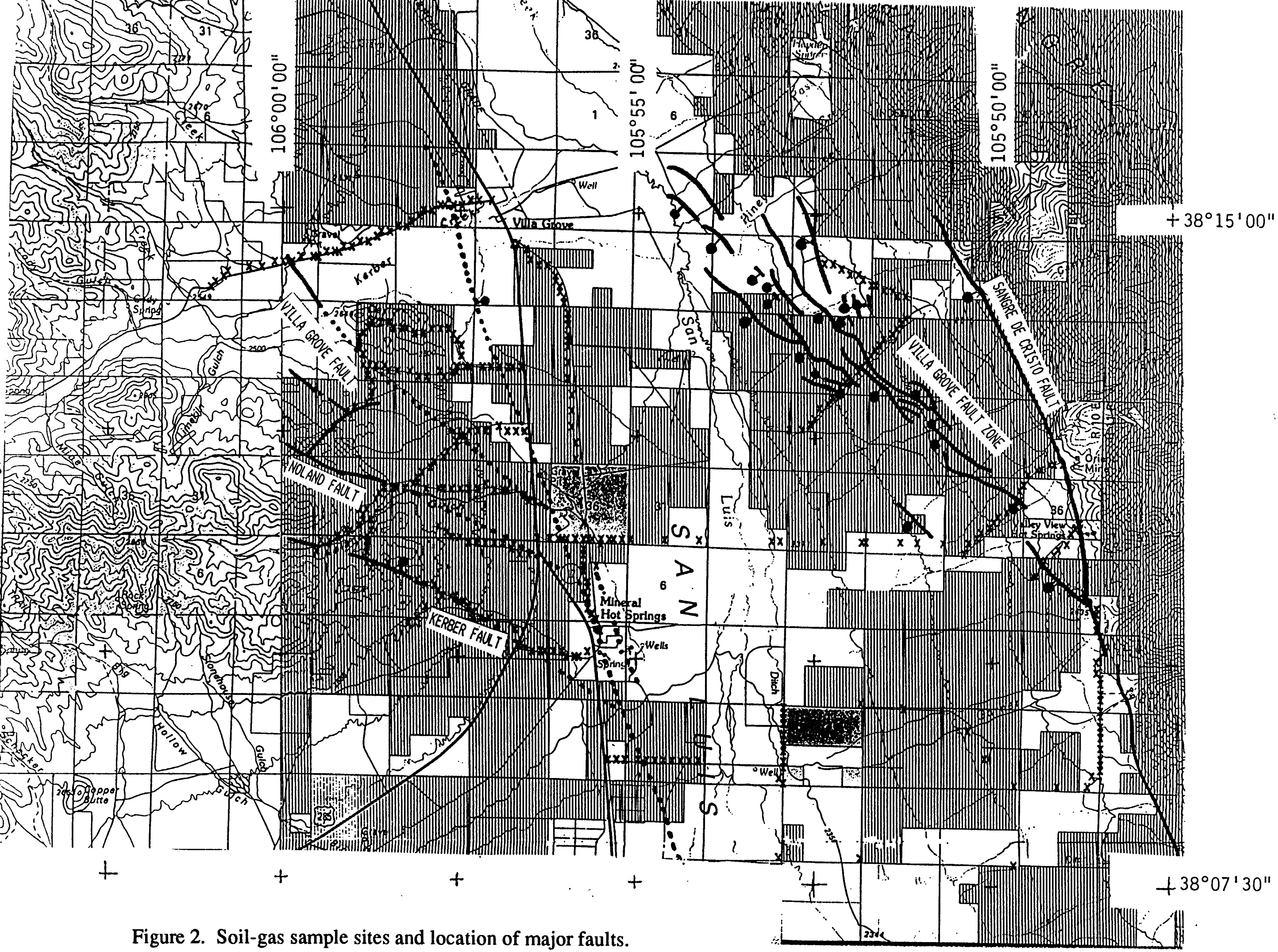

Figure 2. Soil-gas sample sites and location of major faults.

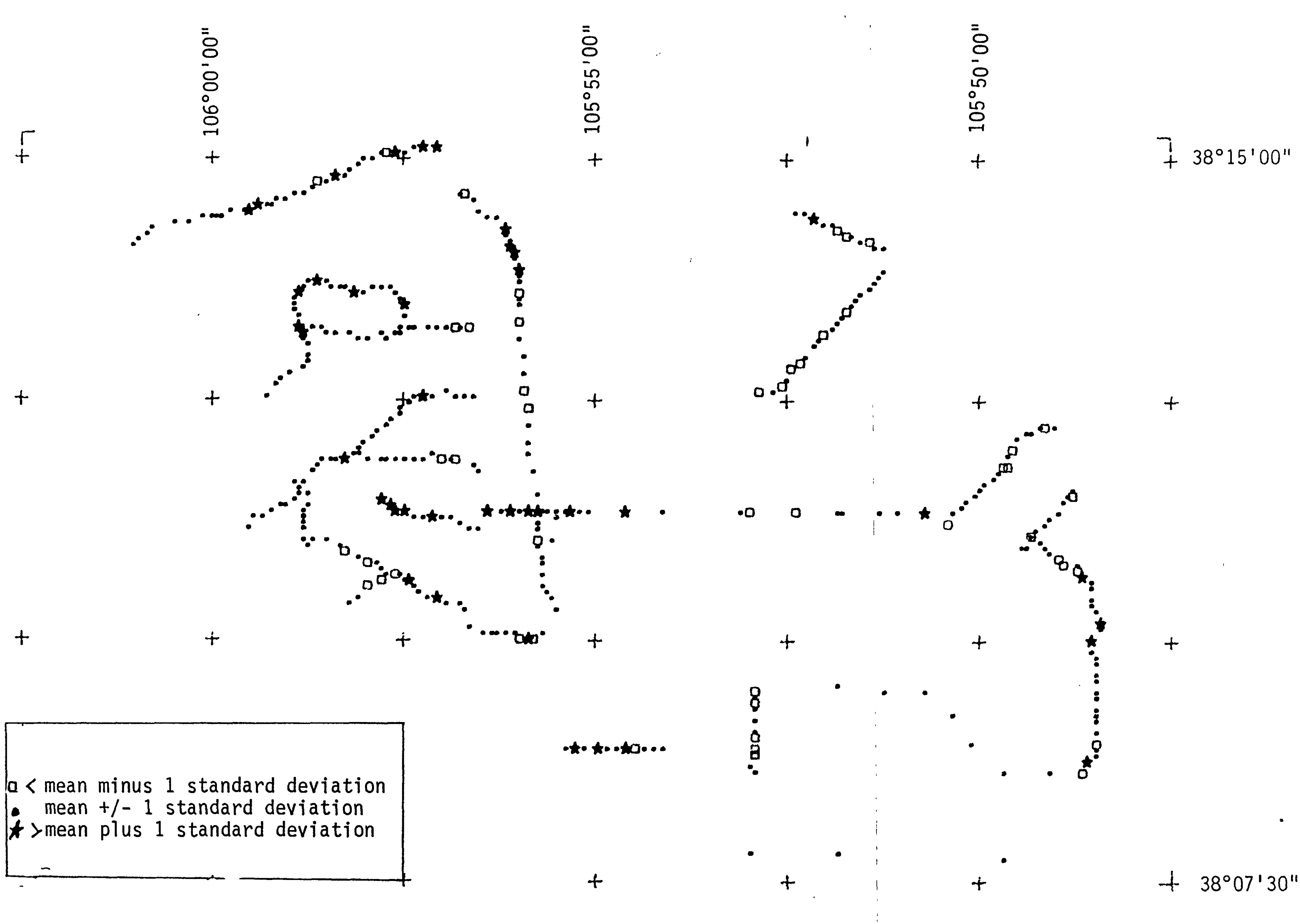

Figure 3. Concentrations of N_2 in soil gases.

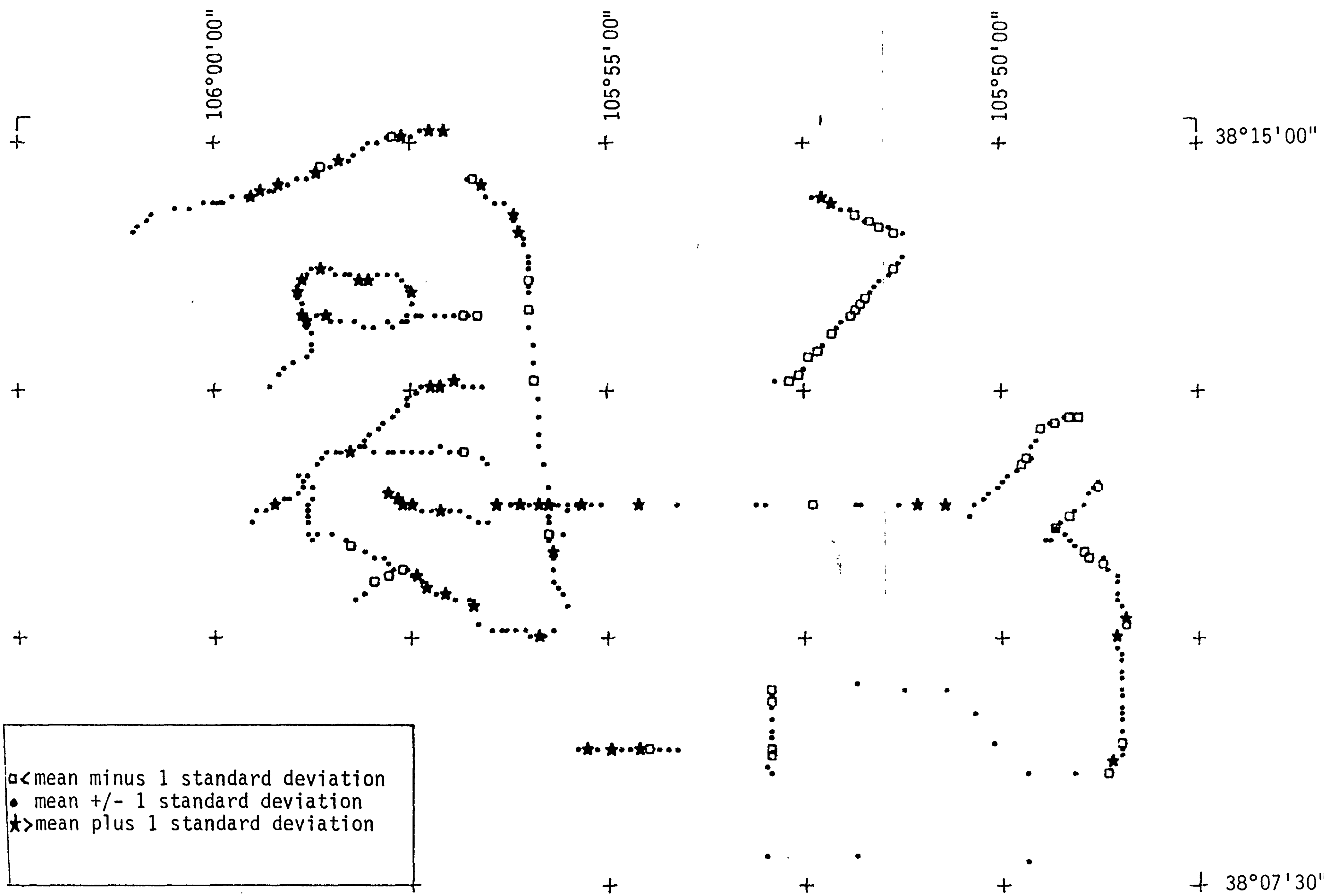

Figure 4. Concentrations of O_2 in soil gases.

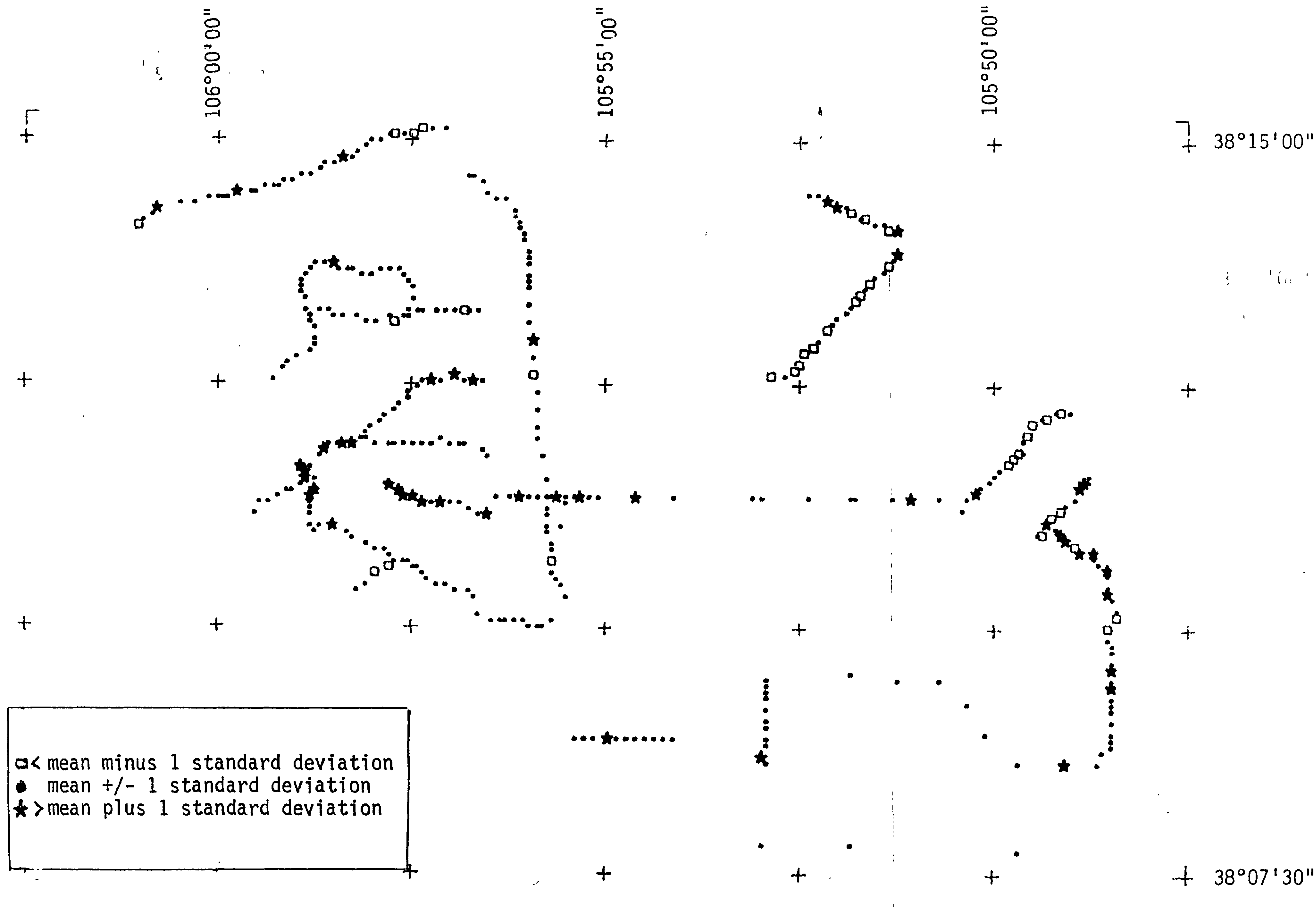

Figure 5. Concentrations of CO_2 in soil gases.

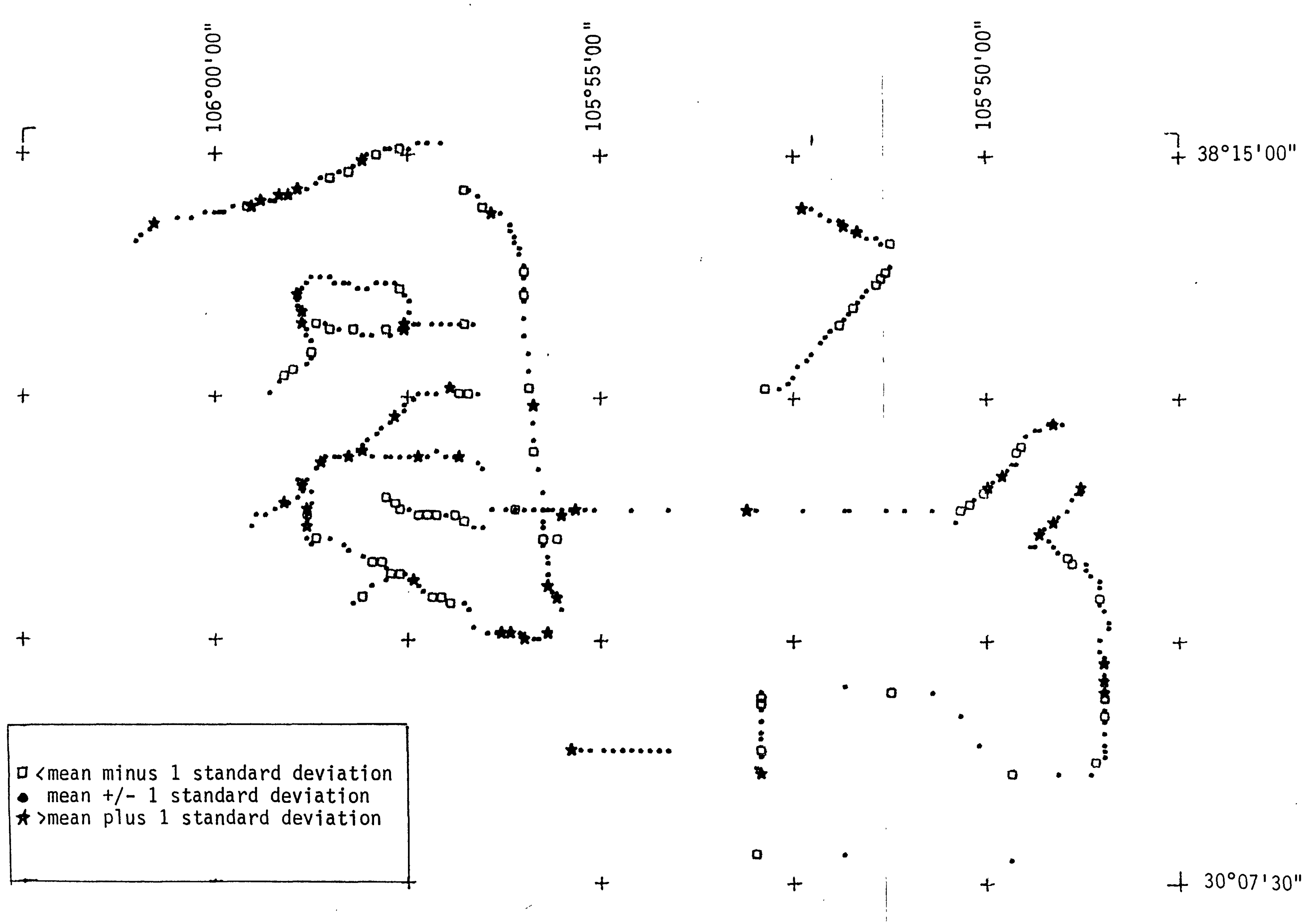

Figure 6. Concentrations of He in soil gases.