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Helium exploration survey for the Animas Valley, Colorado

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Figure 1. Animas Valley, Colorado orientation map.

Introduction

Recent studies have shown soil helium surveys to be useful in approximating the areal extent of geothermal resources. This method is often preferable to others since it can be time saving, economical, and used in an urban environment (McCarthy and others, 1982b). In order to further evaluate the reliability of the method in low temperature systems, a soil and water helium survey was conducted in the Animas Valley, Colorado. The results compared favorably with previous interpretations derived from other exploration techniques. In some areas, more definitive results were obtained. However, as with all exploration methods, some limitations are inherent, and should be considered.

Geologic Setting

Several thermal wells and springs occur along the western side of the Animas Valley, 10 to 15 miles (16 to 24 Km) north of Durango, in southwestern Colorado (Figure 1). A summary of spring and well characteristics is shown in Table 1.

The Animas River is a primary southerly drainage of the San Juan Mountains, which are erosional

Table 1. Animas Valley thermal water characteristics.
(adapted from Barrett and Pearl, 1976)

	Discharge (GPM)	Discharge (1/s)	TDS (Mg/1)	Temperature (C)	Temperature (F)
Pinkerton H.S.					
Little Mound S.	2	.1	3800	26	79
Mound S.	5	.3	3840	29	84
Academy S.	10	.6	3700	30	86
Well A	50	3.2	3770	32	90
Well B	20	1.3	3800	33	91
Stratten S.	10	.6	1300	28	82
Tripp S.	1	.1	3240	44	111
Trimble S.	1	.1	3340	43	110
Warm Spring N.	-	-	-	29	84
Warm Spring S.	-	-	-	27	80

remnants of an extensive Tertiary volcanic plateau. Two small late-stage uplifts within the San Juan region, now the La Plata and Needle Mountains, bound the study area on the west and north, respectively (Figure 1). The Needle Mountains are the only extensive exposure of Precambrian rocks in southwestern Colorado, and the La Plata Mountains are an eroded laccolithic dome. The San Juan structural basin bounds the valley on the south. The glaciated valley is composed largely of sedimentary rocks totaling over 15,000 ft (4573m) (McCarthy and others, 1982a).

Warm water at Pinkerton issues from the upper Mississippian Leadville Limestone (Madison Fm. equivalent), which is an important aquifer regionally. The springs further south emerge from the Honaker Trail Formation of the Hermosa Group, which is composed of alternating limestone, sandstone, and ruddy shale. Geology of the study area is shown in Figure 2.

Previous Study

Using a variety of geothermometers, Pearl (1979) estimated subsurface temperatures at Pinkerton (212°F, 100°C), and Trimble (140°F, 60°C). In 1980, the Colorado Geological Survey, under contract to the Department of Energy, conducted an electrical resistivity survey at Pinkerton, and a limited soil mercury survey at Trimble. The results of the geophysical work were used along with air photo interpretation to map faults which probably control the northern springs (shown in Figure 2). Of 14 soil mercury samples taken at Trimble, two sites were anomalous; one near a previously mapped fault, and one near the spring. A larger survey may have produced more conclusive results. Based upon this work, and supplemental geologic and historical information, McCarthy and others, (1982a) drew the following conclusions about the geothermal resource: (1) Faults transverse to the valley convey the thermal water to near surface, but the fluid is largely

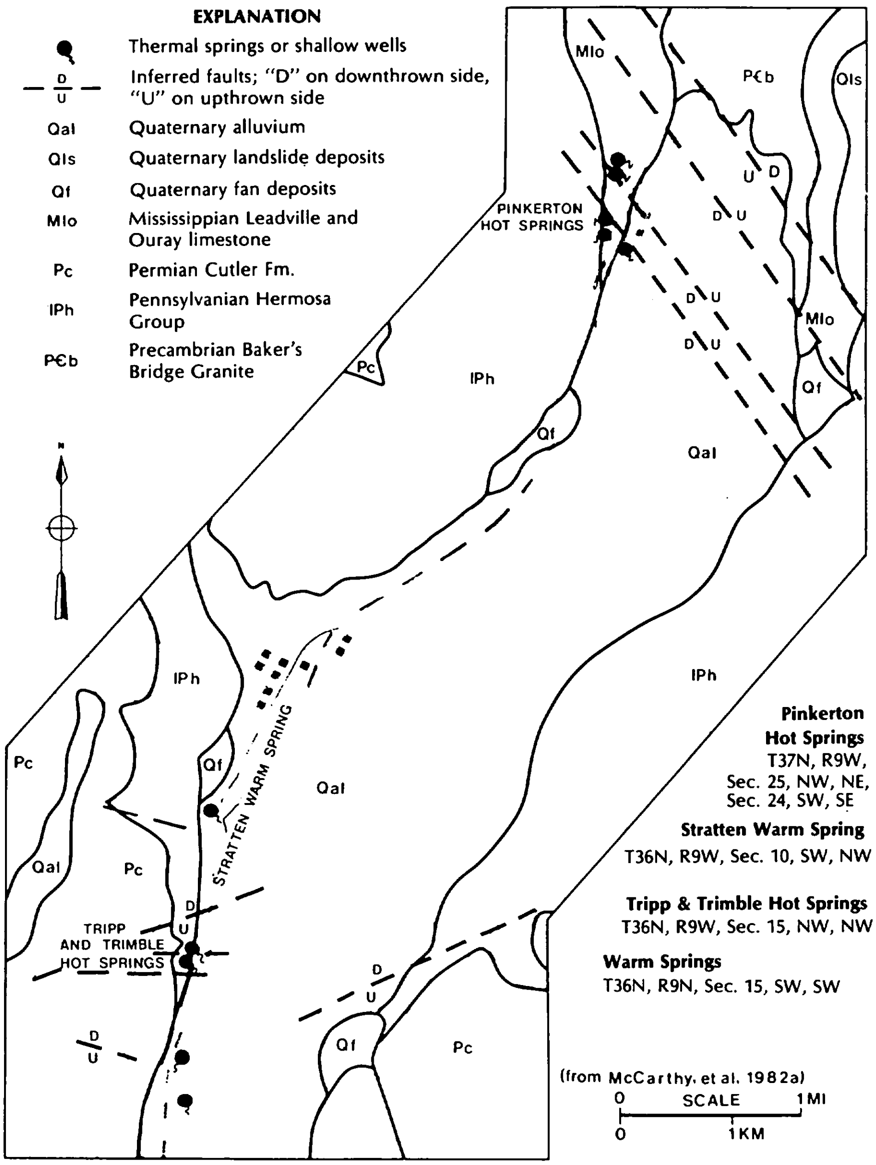

Figure 2. Geology and thermal springs in the Animas Valley, Colorado.

dispersed in the thick valley alluvium. (2) The La Plata Mountains are the primary recharge area. Relatively young intrusions, convection along deep faults, or oxidizing hydrothermal sulfide deposits in these mountains may also be providing heat. (3) The two systems (Pinkerton and Trimble area) are probably not directly connected at shallow depth under the valley floor, although the hot waters may have the same origin. (4) The water has probably moved some distance laterally from the west along faults in the Leadville Limestone.

Current well and spring conditions probably do not fully reflect the possible magnitude of the resource. For example, in the 1880's, Trimble Spring had a discharge of about 200 gallons per minute (12.8 l/s) and a temperature of about 130°F (54°C) (Peale, 1886). The deterioration of the spring may be attributed to irrigation pumping and/or tufa build-up, which increased subsurface dispersion and heat loss. It is unlikely that the heat source has cooled rapidly within the past 100 years.

Helium

Helium-4, a product of radioactive decay in basement rocks (Kahler, 1981), is concentrated in pressurized hot water at depth, and released as temperature and pressure fall. Helium is highly mobile due to its size and atomic structure, and will preferentially migrate to the surface along faults and minute fractures (Bergquist, 1979). Soil-gas and water helium anomalies occur at geothermal sites throughout the world as reported by Denton (1977), Mazor (1974), Roberts and others (1975), Roberts (1975), and Westcott (1980), among others. Helium analysis has not only proven to be useful in determining the areal extent of helium-laden hot water near the surface, but also in pinpointing faults which serve as conduits for thermal fluids. The inert gas cannot be contaminated.

Diurnal flux, hydraulic gradient, and unusual concentrations of other gases may affect soil or water helium values. The measured diurnal fluctuations (noon-midnight) of soil or water helium values generally has not exceeded 50 ppb (M. Reimer, pers. comm., 1982). This is insignificant considering the fact that the values at geothermal sites are often 1000 times this value, and the affect will usually fall within the range of analytical error. Since helium may be transported by groundwater, anomalous concentrations may be shifted along hydraulic gradient. This may be compensated for by determining vectors of groundwater motion, and analyzing other data. This factor has not been found to be significant at most sites. Finally, in some areas where large amounts of carbon dioxide or other gases are generated, the helium may be purged or diluted. Where unexpectedly low values occur, steps may be taken to quantify the other gases.

Methodology

Water samples were taken by partially filling a container with groundwater, then capping and shaking it to allow the helium in the solution to escape into the air space. The resulting gaseous mixture was then drawn off with a syringe, and injected into a leak-proof container for later analysis. The soil samples were taken by driving a 2.8 ft (.85 meter) hollow probe into the ground, and again drawing off a small soil gas sample, which was temporarily stored in a leak-proof container. For further description of the sampling procedure, see Kahler (1981), and Natural Resources Laboratory, Inc. (1983). Field materials were provided by NRL, Inc.

A precise soil-gas sampling grid was not attainable due to patchwork land ownership in the study area, and rocky or saturated soil at some sites. A transect survey was conducted, and samples were usually taken within a road right-of-way. Soil-gas samples were initially taken at 0.5 mile (0.3 Km) intervals to further define anomalies. Coverage was considered adequate, except in the northeastern portion of the study area. Figure 3

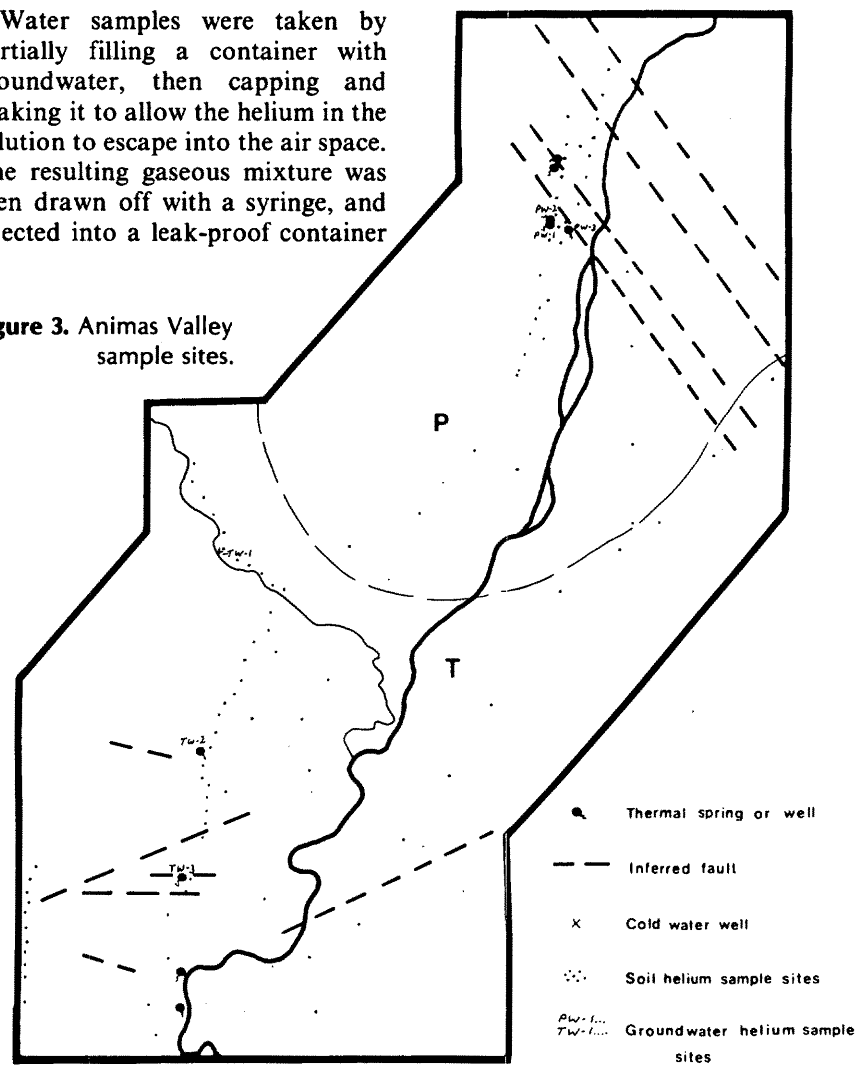

Figure 3. Animas Valley sample sites.

shows soil and water sample locations.

The samples were analyzed with a highly modified helium-leak detector mass spectrometer by Natural Resources Laboratory, Inc., Golden, Colorado. Instrument sensitivity has been determined to be better than ± 10 ppb, and the air reference used (5145 ppb) was averaged from several field samples.

The survey area was approximately 10 square miles (16 sq Km). Cost of the survey, including use of sampling equipment, was $2500, or $25 per sample. In water-saturated areas, the soil itself can be collected, carefully sealed, and sent to the laboratory, where the escaping gas is collected for analysis. Since this procedure is more expensive ($35 per sample), and more time consuming, it was not used in the study.

Results and Discussion

Table 2 shows helium values for the various sites. T sites are along Hermosa Creek, east and south, while P sites are in the northern portion of the study area (see Fig. 3). The higher T values could be explained by the fact that temperature and discharge have historically been greater at Trimble. The negative water helium values at Pinkerton, however, suggest that carbon dioxide evolving at the surface limestone outcrop may be purging the noble gas. The carbon dioxide was apparent when the Pinkerton water samples were taken, as the gas created pressure in the sample container. George (1920) reported nearly three times the excess carbon dioxide at Pinkerton than at Trimble. The extent to which dilution of helium occurs in the Pinkerton soil gas samples is unknown. It is quite possible that, although soil helium values at Pinkerton are high, the magnitude of anomalies may have been reduced due to the great volume of heavier gas escaping.

The water helium values are probably not as reliable as the soil helium values, since temperature and discharge rate of the spring or well greatly effect the rate at which helium is lost to the atmosphere (A. Roberts, written comm., 1982). These values also may not be directly comparable to water helium data published elsewhere due to various other sampling methods employed. This data, then, may only have meaning as a general comparison between the various thermal water sources in the Animas Valley, or as "order of magnitude" approximations. The soil helium results are considered very accurate, however.

The anomalous soil helium data are contoured in Figure 4. Generally, the results indicate: (1) that the two sub-systems in the study area are rather distinct, (2) that the western portion of the valley has much greater geothermal potential, and (3) that faulting plays a large role in the occurrence of spring vents. High values were detected at anomaly A near the Pinkerton Springs, despite the great volume of carbon dioxide present. Anomaly B was totally "blind", with no apparent surface indication of near-surface hot water, and was not detected during previous investigation. The highest Pinkerton value, in fact, lies within this area, but this may only be attributable to the fact that the limestone aquifer is buried here, so that less carbon

Table 2. Animas Valley helium values
(in ppb - 5145)
Air standard ; 5145 ppb

Water Helium

TW-1 (cold water well)	37	PW-1 (Well B)	-2407
TW-2 (Stratten Spring)	241,889	PW-2 (Well A)	-2387
TW-3 (Trimble Spring)	30,289	PW-3 (Academy S.)	-2329

Soil Helium

T-1	20	T-26	-63	T-51	14	P-11	154
T-2	16	T-27	-71	T-52	67	P-12	95
T-3	51	T-28	14	T-53	54	P-13	109
T-4	5	T-29	95	T-54	51	P-14	51
T-5	25	T-30	38	T-55	48	P-15	32
T-6	40	T-31	64	T-56	48	P-16	32
T-7	43	T-32	64	T-57	10	P-17	-47
T-8	48	T-33	-39	T-58	506	P-18	47
T-9	69	T-34	29	T-59	6	P-19	19
T-10	50	T-35	44	T-60	91	P-20	101
T-11	24	T-36	29	T-61	33	P-21	49
T-12	68	T-37	67	T-62	35	P-22	53
T-13	34	T-38	33	T-63	-16	P-23	71
T-14	9	T-39	64	T-64	4	P-24	55
T-15	57	T-40	78	T-65	19	P-25	393
T-16	41	T-41	44	P-1	61	P-26	-5
T-17	10	T-42	29	P-2	81	P-27	5831
T-18	26	T-43	40	P-3	73	P-28	75
T-19	25	T-44	58	P-4	87	P-29	29
T-20	2,015	T-45	71	P-5	73	P-30	46
T-21	46,441	T-46	46	P-6	216	P-31	45
T-22	642	T-47	41	P-7	271	P-32	10
T-23	364	T-48	17	P-8	128	P-33	149
T-24	error	T-49	26	P-9	85	P-34	106
T-25	78	T-50	47	P-10	489	P-35	35

dioxide is produced, in contrast to the springs just to the north. The moderate anomalies at C may indicate residual activity in what once may have been a hotter area. Extensive travertine occurs in the contoured area furthest to the west. Negative values, which lie between the small anomalies at C, again suggest that dilution may be occuring here. Helium values at anomaly D drop off rapidly to the north and south, indicating strong fault control, and perhaps less dispersion of the thermal water in the alluvium at this site. The water helium value here (Stratten Spring) was the highest analyzed. The highest soil helium values in the valley were near Trimble Spring, at anomaly E. Lower values west of Trimble may be explained by the fact that those sites are about 1000 ft (305 m) higher than the sample sites on the valley floor near the spring, and are probably that far above the subsurface hot water, also.

No significant correlation existed between rock type, hydraulic gradient, diurnal flux, and the results of the survey. Carbon dioxide in soil or water was not quantified in this study. The supposition that helium values have been affected by this gas, although apparently reasonable, is speculative. The faulting at Pinkerton was not substantiated by the results, due to inadequate coverage in the northeast.

Summary and Conclusions

The helium survey at the Animas Valley geothermal site in Colorado proved to be cost effective in further defining the system. Major conclusions of previous work were supported by the helium data, and at least one new anomaly was discovered. Diurnal flux and hydraulic gradient were apparently insignificant. Carbon dioxide produced from a carbonate aquifer may have reduced some soil helium values, and effectively purged helium in some spring water. Further surveys in carbonate terrane may be supplemented by analysis of this gas to more accurately determine the magnitude of anomalies.

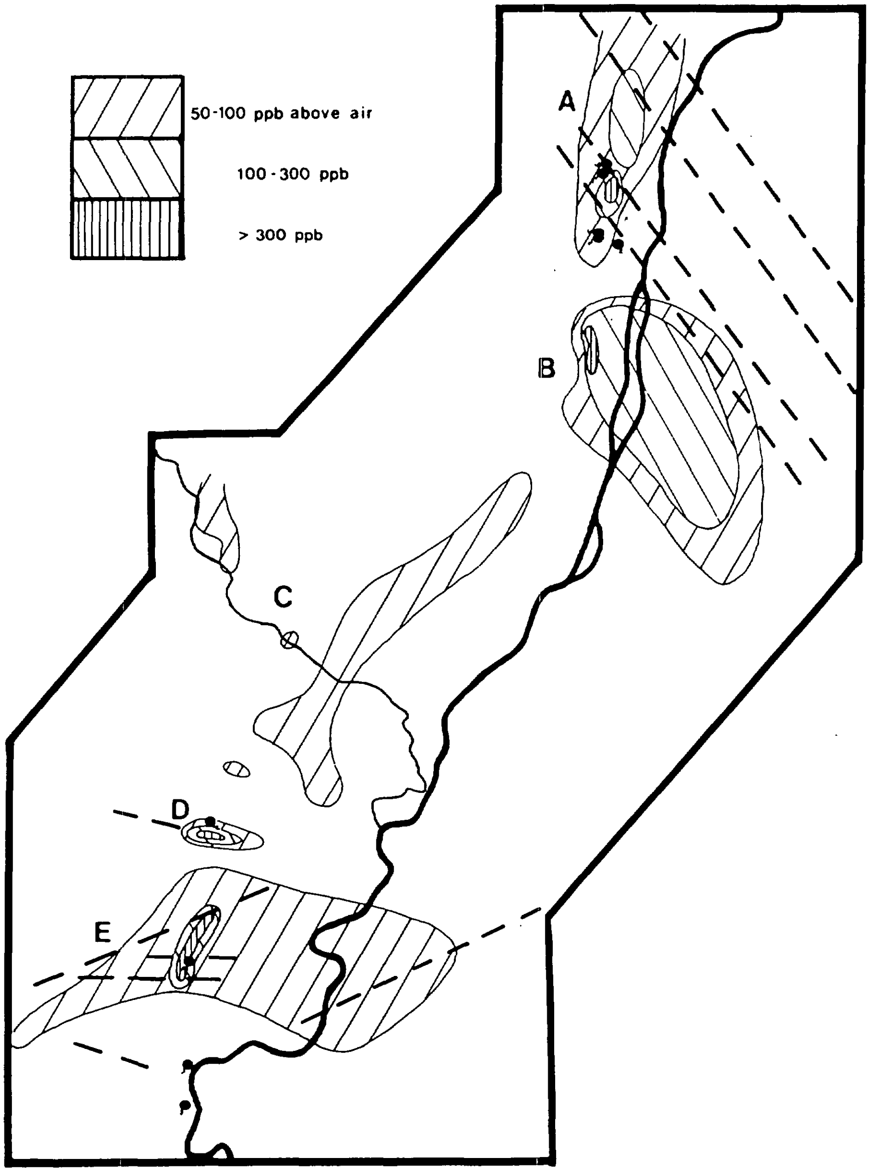

Figure 4. Contoured soil-gas-helium data—Animas Valley.

Regarding soil-gas helium as an exploration tool for low-temperature geothermal resources, the technique is apparently reliable, speedy, and economical. However, the method cannot be used in exceedingly rocky soil. Diurnal flux, hydraulic gradient, and the presence of large amounts of heavier gas may effect the results. These factors, however, usually have no greater affect on the results than those associated with other methods, and the technique will be extremely reliable if all aspects are considered. ☐

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