Helium Survey, A Possible Technique For Locating Geothermal Reservoirs

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Abstract. Measurements were made of the helium concentration in the soil gases surrounding the Indian Hot Springs, Idaho Springs, Colorado. The helium concentration was shown to vary in a regular manner from the background level of 5.2 ppm to a high of more than 100 ppm near a warm (26°C) water seep, and more than 1,000 ppm near a hot (40°C) water seep. Such an association of helium in the soil gas with these hot waters near the earth's surface suggests the possible utility of helium surveys in locating hidden geothermal reservoirs.

It is becoming increasingly apparent that geothermal energy may one day be a significant contributor to our energy supply. (See for example Anderson and Axtell, 1972; Armstead, 1973; Hickel, 1972.) However, exploration capability is in the infant stage. To quote Walter Hickel, (1972, p. 22) "At the present time, the most reliable exploration technique for new geothermal reservoirs is to find areas containing hot springs, a situation similar to that in the petroleum industry in the early 1900's when petroleum exploration consisted of finding areas of surface oil seeps."

Preliminary work by Margaret Hinkle and co-workers at the U.S. Geological Survey (oral communication, 1975) has shown a high concentration of helium (>100 ppm) in the gases dissolved in the water from seven widely scattered hot springs in the western United States. These investigators also found anomalously high helium levels in the soil gases near a hot spring in Yellowstone National Park.

We attempted therefore to apply a portable helium detector that we have been developing for oil and gas exploration to the problem of locating geothermal resource areas. We present here our work on the concentration of helium in the soil gases around the Indian Hot Springs Resort, Idaho Springs, Clear Creek County, Colorado (Long. 105° 30'; Lat. 39° 45').

Sample Collection and Analysis

Measurements of helium in soil gases were made with a commercial helium leak detector mounted in a small truck. This instrument consists of a small (1 cm radius) mass spectrometer set to collect helium (mass 4) ions. These ions are distinguishable from triply-charged carbon, the only ions at nominal mass 4 that we might expect to interfere. The electron accelerating voltage can be adjusted to ionize helium without producing triply-charged carbon ions. The power to the leak detector was supplied by a propane-fueled generator which was electronically stabilized in voltage, frequency and wave form. High source pressure and high filament temperature maximized sensitivity of the mass spectrometer to helium.

The sample probes (steel tubing) were driven into the soil to a depth of about 0.5 m. Gas was slowly pumped out of the probe. A small amount of this gas was allowed to leak into the mass spectrometer source. Periodically the mass spectrometer was switched to a sample of helium in compressed air standardized chromatographically by the U.S. Bureau of Mines, Helium Division at 5.26 ± 0.05 ppm as well as to a sample containing 7.60 ± 0.05 ppm helium for calibration of sensitivity. With this comparison technique our instrumentation detects changes in helium abundance in the gas

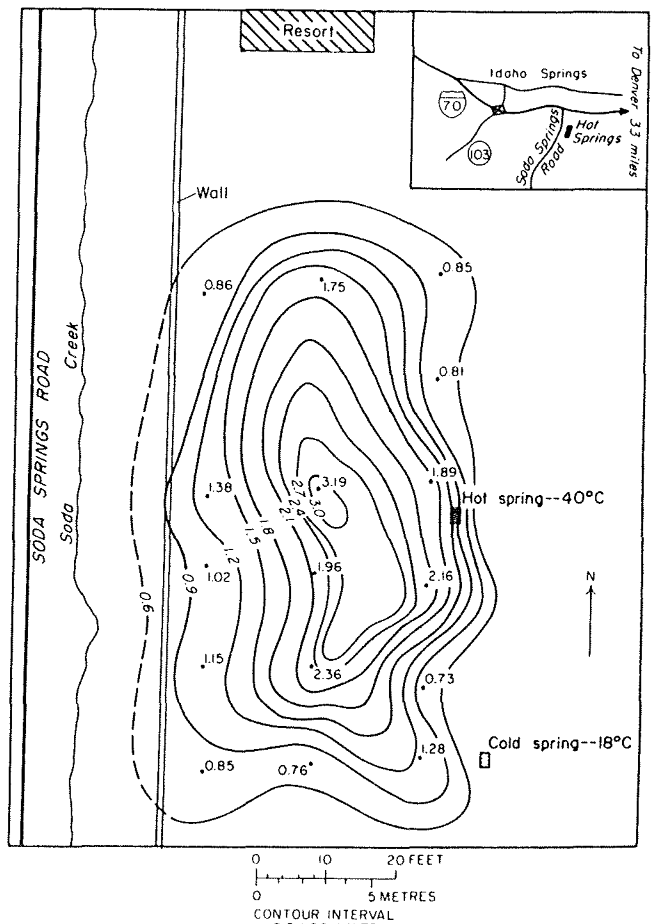

Figure 1. Map showing isopleths of the logarithm of the helium concentrations (ppm) in soil gases around a hot spring south of the Indian Hot Springs Resort, Idaho Springs, Colorado.

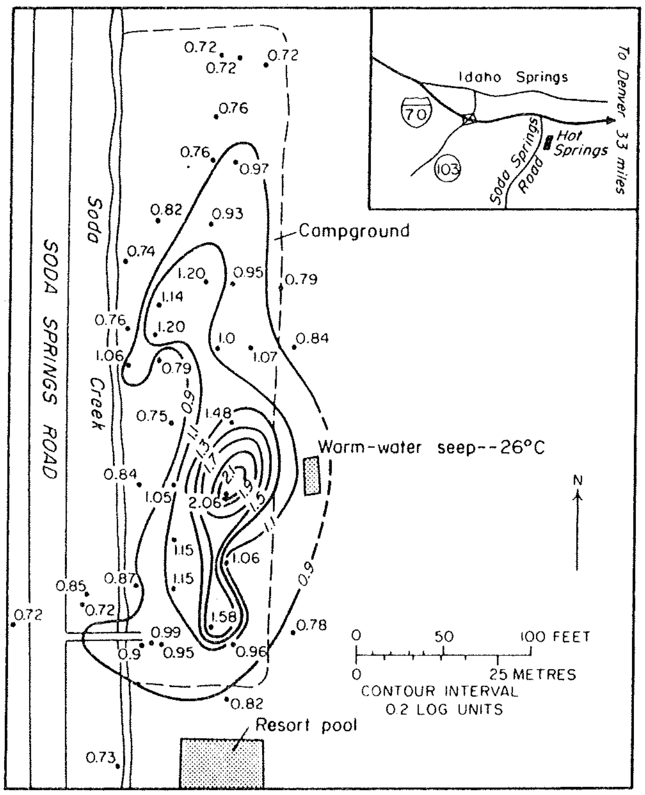

Figure 2. Map showing isopleths of the logarithm of the helium concentrations (ppm) in soil gases around a hot spring north of the Indian Hot Springs Resort, Idaho Springs, Colorado.

stream of about 0.05 ppm (50 parts per billion). A single measurement takes about 3 to 4 minutes, including the time to insert and extract the probe.

Results

The results of the helium survey involving 63 stations taken near the Indian Hot Springs Resort are shown in Figures 1 and 2. Figure 1 shows that the concentration of helium in the soil gases varies in a regular manner from a low of 5.4 ppm (0.73 log units) in front of the cold (18°C) water seep to a high of more than 1,000 ppm (3.19 log units) in front of the hot (40°C) water seep. In contrast, numerous readings taken in the surrounding few square kilometres of countryside showed only the 5.2 ppm concentration of helium that is typical of the atmosphere.

Figure 2 illustrates a similar increase in helium concentration to a peak greater than 100 ppm (2.1 log units) located near a warm (26°C) water seep about 100 metres north of the hot seep. Subsequent replicate readings taken under different weather conditions showed that temperature, wind velocity, and barometric pressure have no observable effect on the concentration of helium in soil gas at Indian Hot Springs Resort.

Discussion

The above results demonstrated dramatically a definite association of helium in soil gases with near-surface hot waters. Preliminary work done in several other hot-spring areas by us and at Yellowstone National Park by Margaret Hinkle (oral communication, 1975) suggests that this association is a common occurrence.

The solubility of helium in water is unusual in that it does not continually decrease with increasing temperature. It decreases up to 30°C and increases above that (Mazor, 1972). We believe that hot water under pressure can act as an excellent scavenger of the helium being produced from the radioactive decay of uranium and thorium in rocks and soil. As this water nears the surface it will be both cooler and under less pressure, thereby allowing the helium to excape from solution and diffuse up through the soil to the surface where it can be measured.

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