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HELIUM SOIL-GAS SURVEY OF THE AURORA URANIUM DEPOSIT, McDERMITT CALDERA COMPLEX, OREGON

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Abstract. Two soil gas helium surveys were carried out in a section of the McDermitt caldera complex of mineralized volcanic rocks in Oregon. A regional helium anomaly was found and is thought to be associated with uranium-rich tuffaceous fill of the caldera and the Aurora uranium deposit, which occurs near the northeastern rim of the caldera. Local hydrology may have an effect on the displacement of the helium anomaly from the uranium deposit and be a carrier of helium from sources at depth. This study suggests that helium surveys may be useful in a volcanic environment by helping to select areas for exploratory drilling for uranium deposits.

Introduction

Helium is a product of the uranium and thorium radioactive decay series. Higher concentrations of helium can be expected and are known to be associated with uranium deposits in different geologic environments [Dyck, 1976; Reimer et al., 1979], but no studies had been made in a caldera complex.

The McDermitt caldera is located along the Nevada-Oregon border and is bounded on the north by the Trout Creek Mountains, on the south by the Double-H Mountains, and on the west and east by Kings River Valley and Quinn River Valley, respectively (Figure 1a). The caldera is a Miocene collapse structure that has collected in a lacustrine environment tuffaceous sediments derived from the alteration of peralkaline ash flows [Glanzman and Rytuba, 1979]. Significant occurrences of mercury, lithium, and uranium are found within the caldera, all most probably derived from the eruptive volcanic rocks that preceded formation of the caldera. Rytuba and Glanzman [1978] report that the tuffaceous sediments in the caldera average 0.29 ppm Hg, 22 ppm U, and 236 ppm Li. One area of shallow uranium mineralization, known as the Aurora deposit, occurs in the eastern part of the McDermitt caldera and is located about 1 km southwest of the Bretz mercury mine (Figure 1b). This deposit has been described by M. W. Roper and A. B. Wallace, (unpublished report, 1980).

The area of most concentrated uranium mineralization is at 70- to 100-m depth and is disseminated throughout an area about 450 m wide by 1500 m long and about 100 m thick. The deposit is estimated to contain 17 million tons of 0.05% U_3O_8 ore. Its emplacement has been postulated as being controlled by hydrothermal activity and possibly by supergene remobilization [Roper and Wallace, 1980]. A horizon, several meters thick, containing 100-300 ppm U is located immediately above the zone containing the Aurora deposit (J. Rytuba, written communication, 1981).

Two helium soil gas surveys were conducted in a portion of the McDermitt caldera complex. The first survey, carried out in October 1980, was designed to look specifically at the distribution of helium in close proximity to the Aurora uranium deposit. The second survey, carried out in April 1981, was for the purpose of evaluating the helium distribution across the caldera rim.

Sampling and Analytical Procedure

Sample locations were along existing roads, trails, or drainage gulleys. Sample spacing was variable, but averaged 0.2 km for the October 1980 survey and 0.5 km for the April 1981 survey. The soil-gas samples were collected by pounding a hollow steel probe into the ground to a depth of 0.75 m and extracting a 10-cm^3 sample with a plastic hypodermic syringe. The syringe was then capped and stored for analysis later in the day. Analyses were performed using the U.S. Geological Survey's mobile helium analyzer [Reimer et al., 1979], which has a sensitivity of about 10 ppb for helium. The analytical equipment is mounted in a four-door pick-up truck and is self contained. The unit consists of a leak-detector mass spectrometer for which an inlet system has been developed to accept samples collected in syringes. A single analysis can be performed in about 3 min. at the field location. Data are reported in parts per billion of helium referenced to helium in air considered to be 5240 ppb. The spectrometer is calibrated by analyzing two reference gases, one, atmospheric air, and the other, a 5900 ppb standard. Calibration is performed every 10 samples to monitor and correct for changes in the instrument sensitivity.

Data

For the October 1980 survey, 106 samples were collected. Most of these samples were taken from within the inner rim of the caldera. Figure 2a is a map of the helium concentrations in relation to the Aurora uranium deposit for the first survey. The average helium concentration was found to be about 50 ppb above the helium concentration found in ambient air. By way of comparison, 838 samples collected in a reconnaissance survey of the Powder River Basin in Wyoming and Montana averaged 0 ppb with respect to the air value [Reimer et al., 1980]. The highest concentrations, greater than 80 ppb, occur to the west and to the south of the deposit. Although fewer samples were collected in the northern section than in the rest of the survey area, the distribution of helium suggested a general decrease closer to and outside of the

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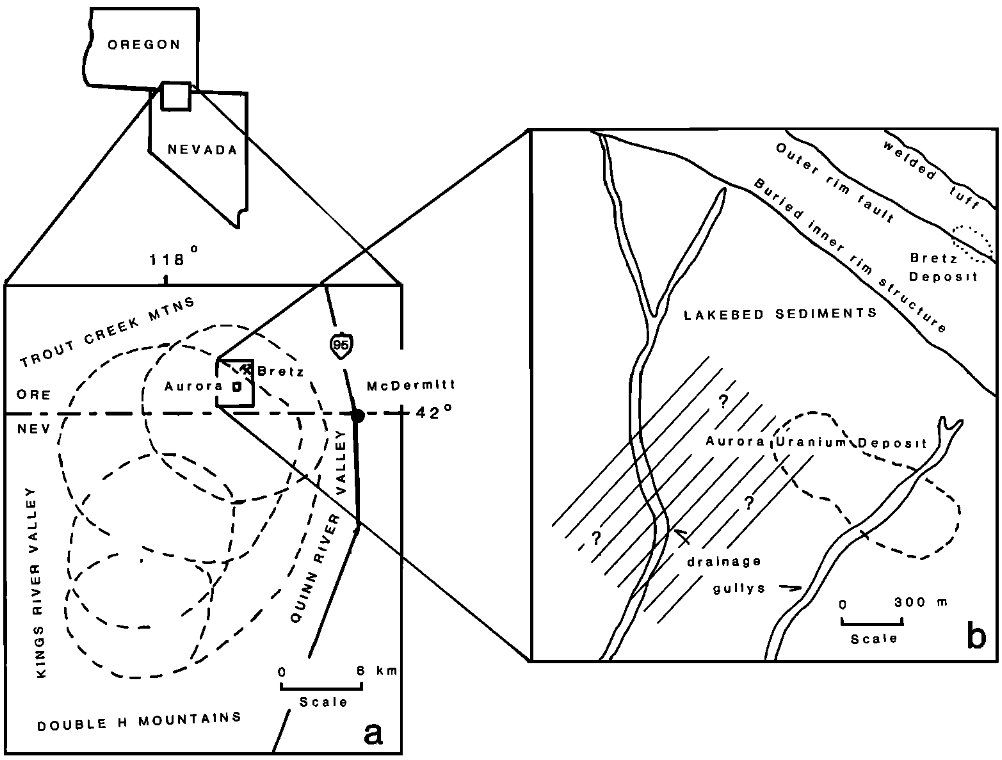

Fig. 1. (a) Location of the McDermitt caldera complex in Oregon and Nevada. The dashed circular lines represent the outlines of the major calderas that have been identified as comprising the complex [after Rytuba and Glanzman, 1978]. (b) Area of the Aurora uranium deposit (dashed line) showing relationship to the caldera rim structure. The higher background uranium concentration is within the lake bed sediments. The hatched area is the region identified by drilling that contains perched aquifers and warm water, but the full extent of the area is not known.

caldera rim. To confirm this trend, another survey was performed in April 1981. A total of 86 samples were collected, 42 of which were to the east, outside the buried inner rim structure of the caldera. The remaining samples were collected within the caldera in the vicinity of the Aurora deposit and continuing on a 6-km traverse westward, still within the caldera. The results of the April survey are shown in Figure 2b. They reveal distinct differences in the concentrations of soil-gas helium between the two areas. The average helium concentration for samples outside the caldera was 25 ppb, whereas inside, the average was 45 ppb above the ambient air reference. Because fewer samples were collected near the Aurora uranium deposit in the second survey, resolution of the deposit is not as distinct as in the first survey.

Discussion

The data from the two helium soil gas surveys in this area may not be directly comparable because of a seasonal effect on the helium concentration. Typically, concentrations tend to be higher when soil moisture is greater; moisture restricts the flux of helium into the atmosphere [Reimer, 1985]. No soil moisture determinations were performed for these studies. Although a seasonal effect may be minor, there does appear to be a difference in the two surveys of about 20 ppb helium for samples collected within the caldera, with the October 1980 survey having the higher concentrations. However, two observations are relevant. First, there is a distinct difference between the helium concentrations found inside and outside the caldera. Second, the helium concentration considered as background, that is, those samples taken a few kilometers away from the uranium deposit, seemed quite high for this type of climate and soil condition. Higher background helium concentrations of about 50 ppb above the concentration in air are normally found in tight, clayey soil, in areas of moderate vegetation, or in wet soil, as just after precipitation [Reimer, 1980]. Because those conditions were nonexistent near the Aurora deposit at the time of the survey, the high background helium concentration probably results from the high uranium concentration of the tuffaceous sediments in the caldera. The location of the helium anomalies to the south and west of the Aurora deposit probably is controlled by the local hydrologic and structural conditions. Groundwater movement generally should be from north to south following the topography. To the west of the Aurora deposit, there is a complex groundwater system, revealed by drilling, that consists of perched aquifers and circulating warm waters (M. W. Roper, oral communication, 1981). Higher helium concentrations could be likely in the perched aquifers, particularly with a nearby source of uranium and

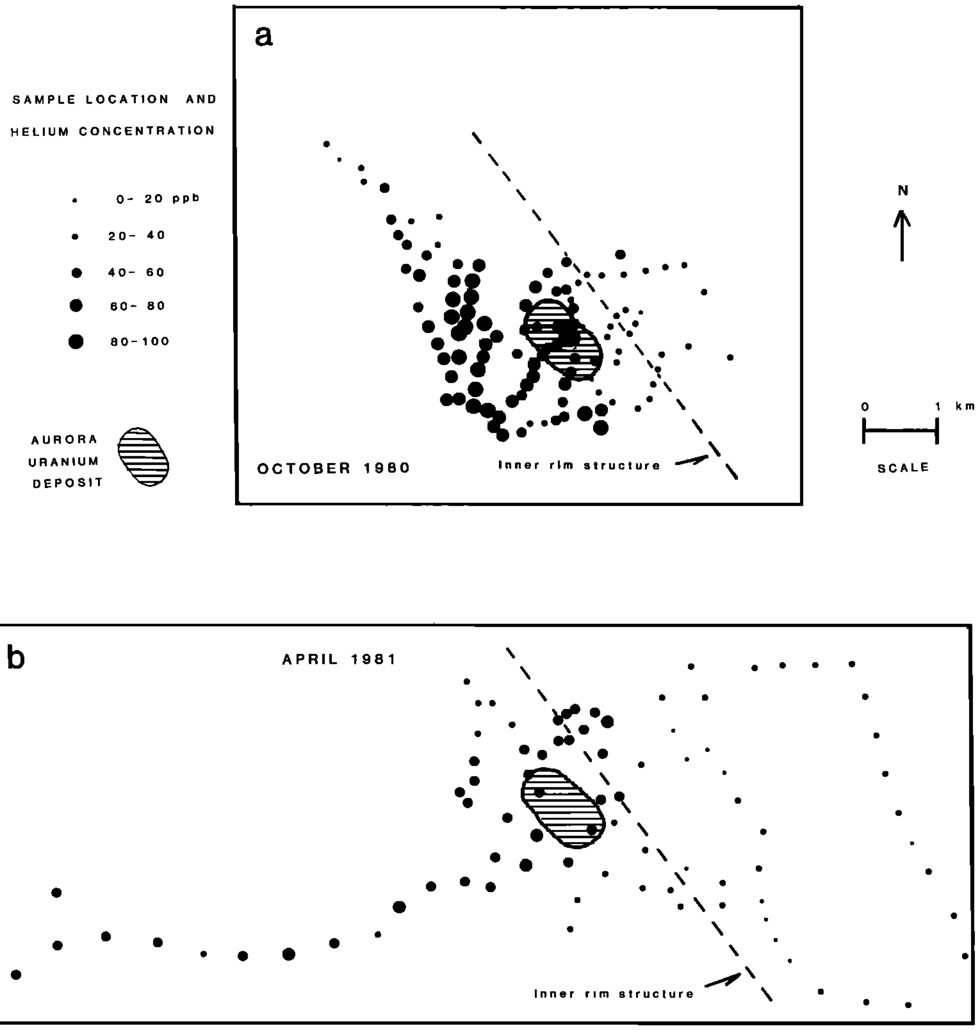

Fig. 2. Sample locations and helium concentrations for the (a) October 1980 and (b) April 1981 surveys.

daughter products. The soil-gas concentration therefore could be a reflection of the local equilibrium conditions that exist between the aquifer and the soil gas. Roberts et al. [1975] have found, for example, more than 1000 ppm helium in soil gas near a warm (40°C) spring. An alternative source of the helium could be from depth with a transport mechanism provided by the warm, circulating waters. Probable pathways would be faults and joints created by the caldera collapse.

However, if the primary source of helium were from a great depth, it is felt that there would be greater dispersion of gas than revealed by the soil-gas survey. Nonetheless, a very discrete or restricted structural pathway could create a localized anomaly.

Conclusion

The soil-gas helium surveys conducted in the McDermitt caldera revealed higher helium concentrations in the vicinity of the Aurora uranium deposit and the McDermitt caldera in general. The high uranium concentration of the tuffaceous fill is believed to be responsible for the anomalous helium concentration, although particularly in a volcanic setting, a deeper source of supply of helium cannot be discounted. Perched aquifers and circulating warm waters may be responsible for the location of specific anomalies and act as a carrier of helium from the deeper sources if they exist. In the structural setting of the caldera, helium could be used as a reconnaissance technique to locate promising areas for economic uranium occurrences.

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