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**RADON EMANOMETRY AS A GEOTHERMAL
EXPLORATION TECHNIQUE; THEORY AND AN EXAMPLE
FROM ROOSEVELT HOT SPRINGS KGRA, UTAH**

Dennis L. Nielson

**EARTH SCIENCE LABORATORY
UNIVERSITY OF UTAH RESEARCH INSTITUTE
391-A Chipeta Way
Salt Lake City, Utah 84108**

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ABSTRACT

Rn^{222} is the longest lived radon isotope and has commonly been used as a geologic tracer. This isotope is a product of the U^{238} decay series and is present in some amount in all geologic systems. From published literature, radon flux in geothermal systems is evaluated in terms of: 1) the formation of radon by disintegration of parent material and the release of radon from the crystalline structure, and 2) the movement of radon through diffusion and transport processes. Rn^{222} originates from the decay of Ra^{226} which emits an alpha particle. The recoil energy of the newly formed Rn^{222} is sufficient to transport the atom 0.03-0.04 μm in rocks. This is the principal method of release of Rn from the rock matrix. It has been found that the amount of radon contributed to geofluids is inversely proportional to the particle size and the flux is thus increased in areas of fracturing.

Because of the short half-life of Rn^{222} and slow rates of diffusion, a transport mechanism must predominate if radon is to migrate appreciable distances. In the near-surface environment, transport processes are dependent on atmospheric variables including barometric pressure, wind velocities, and precipitation. These factors are very difficult to quantify but they can be compensated for by integrating the radon flux over time.

Four radon survey lines were established over the geothermal field of Roosevelt Hot Springs KGRA. The radon flux was determined using the Westinghouse Alpha 2 system which measures the flux at each station over a period of 30 days using an alpha-sensitive dosimeter. The method was very successful in locating mapped fault systems that communicate with the

structurally controlled geothermal reservoir. It is concluded that this method, coupled with a structural analysis, can be useful as a site-specific exploration tool, particularly in locating exploration holes in known geothermal areas.

INTRODUCTION

Numerous studies have demonstrated the use of radon as a naturally occurring radioactive tracer of geologic processes. These studies include mapping faults (Israel and Bjornsson, 1966), exploring for uranium deposits (Smith and others, 1976), and indicating geothermal processes (Belin, 1959; Wollenberg, 1976). The objective of this paper is to analyze the use of radon measurements as a site-specific method for locating covered faults in areas of known geothermal potential. Knowledge of the locations and geometries of faults can be used to locate drill holes to explore structurally controlled reservoirs. A limited radon survey has been established over portions of the geothermal reservoir at Roosevelt Hot Springs Known Geothermal Resource Area (KGRA) in order to test this method.

The Roosevelt Hot Springs KGRA is located in Beaver County, Utah (Fig. 1) on the western margin of the Mineral Mountains. The geology of the area has been described in detail by Nielson and others (1978), and the geology, geochemistry, and geophysics has been summarized by Ward and others (1978). In general, the Roosevelt Hot Springs resource is a hot water-dominated system occurring in structurally controlled reservoirs in crystalline rocks (Lenzer and others, 1976). Plate I is a generalized geologic map of the area showing some of the important structural features. The known producing field is bounded on the east by the Mineral Mountains block. On the west, the field is bounded by the Opal Mound Fault which is the site of deposition of siliceous sinter. To the south the field is truncated between wells Utah State 72-16 and 52-2 by a structure which is not recognized in outcrop but which shows up

UTAH

Figure I.- Index Map
Showing Location of
Roosevelt Hot Springs KGRA

as an abrupt closure of heat flow values as well as a change in electrical resistivity. An east-west structural zone along Negro Mag Wash cuts but probably does not terminate the geothermal field to the north.

In order to develop an understanding of the problems and benefits which may arise through the use of radon emanometry as a site-specific exploration aid, a summary of the origin and behavior of radon in geothermal systems is presented in the following section. A parallel study evaluating the importance of soil mercury geochemistry at the Roosevelt Hot Springs KGRA has been completed and is reported elsewhere (Capuano and Bamford, 1978).

ORIGIN AND BEHAVIOR OF RADON IN GEOTHERMAL SYSTEMS

Radon is a noble gas which is nearly inert, forming bonds with only fluorine and oxygen (Cotton and Wilkinson, 1972). With a boiling point of -61.8°C , all radon occurs as a gas in the natural environment. All isotopes of the gas are radioactive with Rn^{222} , Rn^{220} , and Rn^{219} formed from the U^{238} , Th^{232} , and U^{235} decay series respectively. The half-life of Rn^{222} is 3.825 days, that of Rn^{220} is 54.5 seconds, and that of Rn^{219} is 3.92 seconds. Rn^{220} is often known as thoron, and Rn^{219} is often called actinon.

As a result of its abundance, relatively long half-life, and mobility in the natural environment, Rn^{222} has been often studied as a geologic tracer both in geothermal systems (Belin, 1959; Stoker and Kruger, 1975; Kruger and others, 1977) and in the search for uranium ore bodies (Smith and others, 1976). The abundance of Rn^{222} stems from the abundance of its parent element U^{238} which occurs 137 times more often than U^{235} . The half-life of 3.825 days allows the gas to move relatively short distances from the source of its generation by transport and diffusion processes so that radon anomalies will mark the proximity of the radon source. The mobility of radon is a result of its gaseous state and inert chemical properties which allow it to move either as a gas or dissolved in geofluids. If transported in geofluids, radon is liberated as a gas and follows the non-condensable gas phase as the hydrostatic pressure decreases.

Measurements of radon in the natural environment have shown anomalous concentrations associated with faults geothermal systems, and uranium concentrations. Israel and Bjornsson (1966) measured the Rn^{222} and thoron

content of soil gas over known faults. Over some faults, no radon enrichment was found. Over others, two types of anomalies were present: radon anomalies without an accompanying thoron anomaly, and combined radon and thoron anomalies. They attributed the first anomaly type to the migration of radon along a fault. This was attractive since this anomaly type was found only where the soil was dry and permeable. However, they did caution that the anomaly may have resulted from the enrichment of the parent nuclides of Rn^{222} over those of Rn^{220} in the soil. Because of the short half-life of thoron, the second type of anomaly was attributed to the enrichment of the parent nuclides of radon and thoron in the soil above the faults rather than to migration along the faults. In addition, radon anomalies without accompanying thoron anomalies were found in association with siliceous sinter.

Radon measurements have been used in uranium prospecting with some success (Smith and others, 1976). The method assumes that anomalous concentrations of radon detected at the surface reflect buried anomalous concentrations of the parent nuclide U^{238} . The radon produced by a buried uranium ore body will obviously be affected by the same processes which control the distribution of radon in geothermal systems.

Numerous measurements have been made of radon in hot springs and pools (Kuroda, 1944; Wollenberg, 1974) and in geothermal systems (Belin, 1959; Stoker and Kruger, 1975; and Kruger and others, 1977). These measurements have shown a great deal of variability in radon emanation both within geothermal systems and at individual sample sites through time. The variabilities result from numerous factors including rates of fluid flow,

equilibrium within the U^{238} decay series, climatic conditions, production from the reservoir, water chemistry, and lithologies present in the geothermal area. If these variables are understood, radon measurements in geothermal areas may be of value in defining exploration targets.

The generation of radon in a geothermal system will be considered in terms of two sets of processes: first, the formation of the radon by disintegration of the parent material and the release of the newly formed radon from the crystalline structure; and second, the movement of the radon to the sampling point through diffusion and transport processes. Problems relating to the solubility and transport of the parent material will also be discussed. The discussions will concern radon in general and be generally applicable to the processes effecting gases within the geothermal environment. However, the differences in half-life of the three principal isotopes of radon and the relationships these have to the distance of transport should be kept in mind. The decay of the principal radon isotopes is graphically displayed in Figure 2 and, as will be made apparent in the following discussion, only Rn^{222} is long-lived enough to be of much use in defining buried structures which are related to geothermal systems.

The mechanics of the release of radon from rock matrices has been reviewed by Andrews and Wood (1972). When radon is formed from the spontaneous decay of radium, energy is given off in the form of an alpha particle and the recoil of the radon nucleus. The recoil energy of Rn^{222} is 85 KeV which generally results in transport of the atom 0.03 to 0.04 μm in rocks (Stoker and Kruger, 1975). Measurements show that the recoil process is the

Figure 2. — Percent decay as a function of time for the principal radon isotopes.

most efficient mechanism of release of radon from the crystalline matrix. Andrews and Wood (1972) indicate that diffusion within crystalline material is a slow process relative to the half-life of radon and is thus responsible for only a small percentage of radon release. Inhomogeneities within crystals, grain boundaries, fractures, and porous cementing material will clearly increase the diffusion rates, but the recoil process is still thought to account for the major portion of radon release.

The emanating power (E) of a rock is defined as the percent of radon released from the rock matrix relative to the radon produced by the decay of radium in the rock. The emanation power is found to vary between 1 and 30 percent (Tokarev and Shcherbakov, 1956; Barretto, 1975). This low efficiency reflects the fact that the only radon to escape from the rock matrix is that produced in an outer zone of a particle which is equivalent to the recoil range of the atom. The emanating power is thus inversely proportional to the particle size, and indeed, Andrews and Wood (1972) have shown that radon release is proportional to $1/\sqrt{d}$ where d (in μm) is the particle diameter while the emanating power is $4.9/d$. It is also found that emanating power is relatively low in fresh rock and is increased in weathered and altered samples (Starik and Melikova, 1957; Hayase and Tsutsumi, 1958). Stoker and Kruger (1975) have shown that the radon in geofluids is a function of the porosity and fracture distribution in the geothermal reservoir.

Following release from the crystalline matrix into the geofluid, the radon moves through the processes of diffusion and transport. Tanner (1964) has summarized the mathematical modeling of the movement of radioactive gas in

porous media. The diffusion of the gas follows the equation:

$$C = C_0 \exp(-\sqrt{\lambda/D} z) \quad (1)$$

C = concentration at a distance, z, from a plane source

C₀ = initial concentration

D = diffusion coefficient

λ = decay constant

This model pictures the radioactive gas as diffusing in the z direction through an infinite porous media. If a component of transport (v) is also considered, the equation becomes:

$$C = C_0 \exp\left[\left(\frac{v}{2D} - \sqrt{\frac{v^2}{4D^2} + \frac{\lambda}{D}}\right)z\right] \quad (2)$$

For the straight diffusion model and $D = 5 \times 10^{-2} \text{ cm}^2/\text{sec}$, a 100-fold decrease of radon concentration will take place over distances of 730 cm (Rn²²²) and 9 cm (Rn²²⁰) (Tanner, 1964). The value of D given above is for dry sand.

Soonawala and Telford (1975) have found $D = 4 \times 10^{-2} \text{ cm}^2/\text{sec}$ for soils. An increase in the moisture content will decrease the diffusion rate. Baranova and Novitskaya (1949) report, however, that D is doubled with an increase in temperature of 10-20°C.

From a thorough review of migration processes, Tanner (1964) has concluded:

If radon isotopes in liquid saturated rock or soil are to migrate distances significant in environmental radioactivity studies or in prospecting, the transport mechanism must predominate.

Transport includes movement with geofluids and near-surface gas migration

produced by atmospheric variables. Together these factors result in the component of transport (v) in equation 2. The transport processes are also the most unpredictable and most variable mechanisms effecting the flux of radon measured at the surface.

Kraner and others (1964) have described the effects of atmospheric conditions on the flux of Rn^{222} . The principal variables are changes in barometric pressure, precipitation, and winds. As might be expected, the atmospheric effects are most pronounced in the upper layers of the soil. Figure 3 is reproduced from Kraner and others (1964) and demonstrates the standard deviation of Rn^{222} concentration as a function of depth. The samples were taken on the same day and each data point represents at least 40 determinations. Measurements of radon concentration as a function of depth during periods of rising and falling barometric pressure (Kraner and others, 1964) indicate that the entire concentration curve is affected down to the maximum measured depth of 96 inches and that radon flux is inversely proportional to barometric pressure.

Precipitation will reduce the porosity of the surface layers and thus depress the flux of Rn^{222} . The areas principally effected are again near the surface. In addition, Kraner and others (1964) report that six inches of frozen ground will reduce the radon flux by 40 percent.

High winds have been found to deplete Rn^{222} in the upper layers of the soil. This depletion was most prominent at depths of 70 inches and less. Kraner and others (1964) feel that the winds set up limited convective cells in the soils by creating small oscillations in the barometric pressure.

Figure 3.— Fractional standard deviation of Radon-222 concentration as a function of depth. (Kraner and others, 1964).

To summarize, the dependence of emanating power on particle size and the actual tracing of faults by radon surveys indicate that the method is of use in defining structures. However, the numerous independent variables that affect the radon flux show that survey results cannot be modeled in a quantitative sense. In addition, the effects of atmospheric variables are important enough that surveys done at different times require standard reference lines to be comparable. Alpha sensitive film which can be placed in the ground for an extended period of time is successful in integrating the radon flux over a period of time. This is useful in eliminating the problem of short-term variations due to atmospheric conditions.

RADON SURVEY AT ROOSEVELT HOT SPRINGS KGRA

Radon in the natural environment is commonly measured by devices sensitive to alpha particles. Numerous analytical techniques are commercially available and will not be reviewed here.

To test the exploration applications of radon measurements, a survey was established over a geothermal field located in the Roosevelt Hot Springs KGRA. To minimize the effects of atmospheric variables, a Westinghouse Alpha 2 detection system was used. This system consists of an alpha-sensitive dosimeter located in a plastic cup. In the standard survey procedure, the cup is placed in a hole about two feet beneath the ground level. The hole is covered and the detectors are left in place for approximately 30 days. At the end of the exposure time, the cups are recovered and returned to the marketing company for analysis. The exposure of the detectors is determined and standardized with respect to time in the ground. These standardized numbers are then reported to the surveyor.

A survey utilizing 100 Alpha 2 radon detectors was laid out along four traverses. These lines were designed to intersect known structures and areas where successful production wells have been drilled. Plate I shows the survey traverses superimposed on the geology of the Roosevelt area (Nielson and others, 1978). The results are shown diagrammatically on Figures 6 through 9. The survey results are tabulated in the Appendix and are characterized by the histogram of Figure 4. The mean for the entire survey is 408 counts and the median, 315 counts. Because of the limited number of detectors available, this survey was largely confined to the area of known geothermal activity.

Figure 4.—Histogram of Alpha 2 results for
traverses A-A', B-B', C-C', and D-D'.

Since it is the conclusion of this study that faults and fracture zones in geothermal areas transport anomalous amounts of radon, the present survey does not provide sufficient data for the calculation of regional background values. Inspection of Figures 6 through 9 indicates that the two northern traverses (A-A' and B-B') show consistently higher values than the two southern traverses (C-C' and D-D'). Therefore it was felt that the data from traverses C-C' and D-D' would provide the most realistic background, although it is probable that the values are still high. The results from C-C' and D-D' are plotted on the cumulative frequency plot of Figure 5. The median value of 252 counts is considered background (Levinson, 1974). Values greater than the 95th percentile are those over 600 counts. These values for background and 95th percentile are plotted for reference in Figures 6 through 9.

Figure 6 shows the results from traverse A-A' which is approximately parallel to the Negro Mag Fault zone and slightly south of three geothermal production wells. The intersection of the Opal Mound Fault with the survey line as well as two zones of <10 ohm-m resistivity (Ward and Sill, 1976) are shown in Figure 6. The radon flux near the Opal Mound Fault is over background but is one of the lower of the entire traverse. The relatively low response over the Opal Mound Fault reflects the sealing of that fault zone by the precipitation of silica or clays formed during hydrothermal alteration. However, an area of cemented alluvium just west of the Opal Mound Fault which is also a zone of <10 ohm-m resistivity shows very anomalous readings, perhaps reflecting incomplete sealing of that fault zone or re-opening of a previously sealed zone by recent faulting.

Figure 5.—Cumulative frequency diagram of Alpha 2 survey results for traverses C-C' and D-D'.

Figure 6.— Radon traverse A-A' Zone of $<10 \Omega m$ resistivity from 100 m dipole-dipole survey of Ward and Sill (1976)

The high activity east of the Opal Mound Fault along A-A' may reflect leakage from faults parallel to the Opal Mound Fault. Alternatively, the flux in the eastern portion of the traverse may result from leakage around the casing of production holes a short distance to the north. Without a more detailed survey in this area, it is difficult to assign a source for the radon flux with a high degree of certainty.

Traverse B-B' (Fig. 7) was designed to intersect the fault zones which have been mapped along Negro Mag Wash. This traverse contains the highest counts of the entire survey with the most anomalous values present along the projection of two individual faults which were mapped in the field. This high response is interpreted to be due to a communication of these faults with the geothermal reservoir as demonstrated both by production wells along the trend and by recent siliceous sinter deposits and presently active fumaroles along Negro Mag Wash.

Traverse C-C' (Fig. 8) was established south of Thermal Power Co. well Utah State 72-16, and it crosses the Opal Mound Fault in an area of opaline and older chalcedonic sinter deposition. There is a reading over background at #1438 which is along the trace of a probable range front fault. The area just south of Utah State 72-16 is greater than background with an anomalous zone between Utah State 72-16 and the Opal Mound Fault. This zone is probably due to a fault which is parallel to the Opal Mound system. The anomaly at detector #1415 marks the western edge of a <3 ohm-m resistivity anomaly defined by Ward and Sill (1976). As was the case in traverse A-A', the Opal Mound Fault is slightly over background but the trace of the fault and the

Figure 7.—Radon traverse B-B'. Faults are projected on the basis of geologic mapping (Nielson and others, 1978).

Figure 8.—Radon traverse C-C'. Mapped faults from Nielson and others (1978). Resistivity anomalies based on 100 m dipole-dipole survey by Ward and Sill (1976).

associated sinter deposits show a well-defined radon signature. Again, the relatively low values probably result from sealing of the fault by clay alteration and the precipitation of silica. Traverse C-C' does cross the traces of two additional faults which offset alluvium in the western portion of the traverse. The zones are above background, but both are located between sample points and thus the radon response from the faults probably is reduced.

There is an apparent termination of the geothermal field between Utah State 72-16 and 52-21 (Nielson and others, 1978). Between these two holes, thermal gradient contours show rapid closure with lower values to the south (Sill and Bodell, 1977; Ward and others, 1978). In addition, there is a break between a northern area of low resistivity and a southern area of high resistivity which is plotted on Figure 9 (Ward and Sill, 1976). Ward and Sill (1976) also show two fault zones beneath gravel based on interpretations of geologic, photographic, and resistivity data. The approximate intersections of these proposed faults with section D-D' are shown on Figure 9. The radon anomalies present suggest two faults of the approximate separation shown by Ward and Sill (1976), but the zones are offset to the south approximately 130 m.

Figure 9.—Radon traverse D-D'. Fault locations based on resistivity interpretations; areas of high and low resistivity taken from Ward and Sill (1976)

SUMMARY

Radon measurements at Roosevelt Hot Springs KGRA demonstrate anomalous radon values associated with mapped faults and with resistivity anomalies. In contrast to resistivity surveys which delineate zones of alteration and brine saturated rocks, radon anomalies may define the position of faults which are open and communicating with the geothermal reservoir. The precipitation of silica and the formation of clays by alteration does retard the radon flux. Although this particular study was done over a high-temperature hydrothermal system, the method is thought to be equally valid over vapor-dominated systems as well as intermediate- to low-temperature hydrothermal systems. Indeed, it can be very effective in locating faults in non-thermal areas.

It must be stressed that this method is best suited for the definition of fault zones and should be used in conjunction with a structural analysis to define drilling sites. Figure 10 depicts an idealized cross-section of the presumed structural controls of the Roosevelt geothermal field. Here, reservoir potential is developed where older silicified fault zones are intersected by younger faults (Nielson and others, 1978). The faults involved have been defined by geologic mapping, thus their relative ages and angular relationships are known. High radon flux can be correlated to the communication of the faults with geothermal reservoir. Knowledge of the geometry of fault intersections can then be used to site an exploration well to penetrate the geothermal reservoir at the most desirable depth.

It should also be emphasized that quantitative modeling of radon surveys is not practical with the amount of information which is normally available in

Figure 10.—Idealized cross section of the presumed structural controls of the hydrothermal reservoir at Roosevelt Hot Springs KGRA showing relative radon flux.

the early stages of exploration programs. As suggested in the discussion on the behavior of radon, data such as depth to bedrock and ground water flow within the alluvium are essential for a quantitative interpretation. In addition, it would be advisable to use a gamma-ray spectrometer analysis of the sample location for uranium to correct the radon data for locally high concentrations of uranium-bearing minerals in alluvium which may produce anomalies unrelated to fracture systems.

The price for the Alpha 2 detectors used in this survey was \$14.00/detector when purchased in quantities less than 500. The unit cost decreases with orders of more than 500. The detectors can be emplaced by a technician and one laborer. For this particular survey, additional expenses including salaries, per diem, supplies, and transportation added approximately another \$6.00/detector to the survey costs. These costs suggest measurement of radon may be a cost-effective technique for mapping fault traces when alluvial cover obscures the bedrock hosting a geothermal reservoir at depth.

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REFERENCES

- Andrews, J.N., and Wood, D.F., 1972, Mechanism of radon release in rock matrices and entry into groundwaters: Inst. Mining and Metallurgy Trans./Section B., v. 81, no. 792.
- Baranova, V.I., and Novitskaya, A.P., 1949, Diffusion of radon in natural muds (in Russian): Akad Nauk SSSR Biogeochem. Lab. Trudy, no. 9, p. 161-171.
- Barretto, P.M.C., 1975, Radon-222 emanation characteristics of rocks and minerals; in Radon in Uranium mining, International Atomic Energy Agency, Vienna, p. 129-150.
- Belin, R.E., 1959, Radon in New Zealand geothermal regions: Geochem. et Cosmochim. Acta, v. 16, p. 181-191.
- Capuano, R.M., and Bamford, R.W., 1978, Initial investigation of soil mercury geochemistry as an aid to drill site selection in geothermal systems: Univ. of Utah Res. Inst., Earth Science Laboratory Rept. no. 13, DOE/DGE contract EG-78-C-07-1701, Salt Lake City.
- Cotton, F.A., and Wilkinson, G., 1972, Advanced inorganic chemistry: Interscience, New York, 1145 p.
- Hayase, I., and Tsutsumi, T., 1958, On the emanating power of powdered rocks: Kyoto Univ. Coll. Sci. Mem., Ser. B, v. 24, p. 319-23.
- Israel, H., and Bjornsson, S., 1966, Radon (Rn^{222}) and thoron (Rn^{220}) in soil air over faults: Zeitschrift. Geophys., v. 33, p. 48-64.
- Kraner, H.W., Schroeder, G.L., and Evans, R.D., 1964, Measurements of the effects of atmospheric variables on radon-222 flux and soil-gas concentration, in Adams, J.A.S. and Lowder, W.M. (eds.), The natural radiation environment: University of Chicago Press, p. 191-215.
- Kruger, P., Stoker, A., and Umana, A., 1977, Radon in geothermal reservoir engineering: Geothermics, v. 5, p. 13-19.
- Kuroda, K., 1944, Radioactive springs discovered in Masutomi: Bull. Chem. Soc. Japan, v. 19, no. 3, p. 33-83.
- Lenzer, R.C., Crosby, G.W., and Berge, C.W., 1976, Geothermal exploration of Roosevelt KGRA, Utah: 17th U.S. Symposium on rock mechanics (abs.).
- Levinson, A.A., 1974, Introduction to exploration geochemistry: Calgary, Applied Publishing Ltd., 612 p.
- Nielson, D.L., Sibbett, B.S., McKinney, D.B., Hulen, J.B., Moore, J.N., and Samberg, S.M., 1978, Geology of Roosevelt Hot Springs KGRA, Beaver

- County, Utah: Univ. of Utah Res. Inst., Earth Science Laboratory Rept. no. 12, DOE/DGE contract EG-78-C-07-1701, Salt Lake City, 121 p.
- Soonawala, N.M., and Telford, W.M., 1975, Diffusion of radon-222, and interpretation techniques for emanometer data: Society of Exploration Geophysicists, 45th meeting, Denver.
- Sill, W.R., and Bodell, J., 1977, Thermal gradients and heat flow at Roosevelt Hot Springs: Dept. of Geology and Geophysics, Univ. of Utah, Technical Report 77-3, ERDA Contract EY-76-S-07-1601, 46 p.
- Smith, A.Y., Barretto, P.M.C., Pournis, S., 1976, Radon methods in uranium exploration, in Exploration for Uranium ore deposits: International Atomic Energy Agency, Vienna, p. 185-211.
- Starik, I.Te., and Melikova, O.S., 1957, Emanating power of minerals: Radiyevyy Institut imeni V.G. Khlopina Trudy, v. 5, p. 184-202. (Engl. trans.) USAEC Rept., AEC-tr-4498, p. 206-226.
- Stoker, A.K., and Kruger, P., 1975, Radon in Geothermal reservoirs, in Second United Nations symposium on the development and use of geothermal resources., San Francisco, p. 1797-1803.
- Tanner, A.B., 1964, Radon migration in the ground: A review, in Adams, J.A.S., and Lowder, W.M., eds., The natural radiation environment: Chicago, Univ. of Chicago Press, p. 161-190.
- Tokarev, A.N., and Shcherbakov, A.V., 1956, Radiohydrology: Moscow. USAEC Rept. AEC-tr-4100 (1960).
- Ward, S.H., Parry, W.T., Nash, W.P., Sill, W.R., and Cook, K.L., Smith, R.B., Chapman, D.S., Brown, F.H., Whelan, J.A., Bowman, J.R., 1978, A summary of the geology, geochemistry and geophysics of the Roosevelt Hot Springs thermal area, Utah: Geophysics v. 43, no. 7, p. 1515-1542.
- Ward, S.H., and Sill, W.R., 1976, Dipole-dipole resistivity surveys, Roosevelt Hot Springs KGRA: Dept. of Geology and Geophysics, Univ. of Utah, NSF final report v. 2, contract GI-43741, 29 p.
- Wollenberg, H.A., 1974, Radon alpha-track survey of a potential geothermal resource area: Berkeley, Lawrence Berkeley Lab. Rept. LBL-3225.
- Wollenberg, H.A., 1976, Radioactivity of geothermal system, in Proceedings: Second United Nations symposium on the development and use of geothermal resources, San Francisco, p. 1282-1292.

APPENDIX
Data from Alpha 2 Survey

<u>Detector Number</u>	<u>Exposure (Counts)</u>	<u>Detector Number</u>	<u>Exposure (Counts)</u>	<u>Detector Number</u>	<u>Exposure (Counts)</u>
1411	329	1446	213	1481	401
1412	406	1447	246	1482	620
1413	451	1448	184	1483	744
1414	389	1449	289	1484	307
1415	608	1450	626	1485	247
1416	108	1451	626	1486	50
1417	291	1452	707	1487	150
1418	319	1453	630	1488	450
1419	295	1454	383	1489	192
1420	253	1455	446	1490	495
1421	226	1456	920	1491	141
1422	210	1457	291	1492	228
1423	117	1458	216	1493	452
1424	145	1459	238	1494	816
1425	129	1460	196	1495	732
1426	234	1461	316	1496	419
1427	189	1462	495	1497	427
1428	314	1463	165	1498	331
1429	131	1464	274	1499	560
1430	123	1465	326	1500	1003
1431	388	1466	324	1501	1068
1432	236	1467	276	1502	479
1433	144	1468	750	1503	219
1434	276	1469	454	1504	1086
1435	401	1470	373	1505	1468
1436	205	1471	570	1506	1117
1437	211	1472	606	1507	672
1438	407	1473	439	1508	578
1439	308	1474	223	1509	545
1440	294	1475	468	1510	434
1441	321	1476	767		
1442	396	1477	266		
1443	288	1478	274		
1444	331	1479	604		
1445	331	1480	417		

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EXPLANATION

- Qs Opaline and Chalcedonic sinter
- Qcal Silica-cemented alluvium
- Qh Hematite-cemented alluvium
- Qm Manganese-oxide cemented alluvium
- Qal Alluvium
- Qra Pyroclastics
- Qrf Rhyolite Flow
- Trd Rhyolite Dikes
- Tds Diabase Dikes
- Tmd Microdiorite Dikes
- Tgr Granite Dikes
- Tg Granite
- Ts Syenite
- Tpg Porphyritic Granite

- Tqm Quartz Monzonite
- PCgn Hornblende Gneiss
- PCn Biotite Gneiss
- PCbg Banded Gneiss
- Contact dashed where approximate
- Fault, intruded by dike
- Fault, dashed where inferred, dotted where covered
- Fault, mapped from linears on air photos
- 40 Joints
- 80 Foliation
- 40 70 Foliation with plunge of linear
- 60 Dip of dike
- ▲ Steam seep, active
- Geothermal well

From: Nielson, D.L., Sibbett, B.S., McKinney, D.B., Hulen, J.B., Moore, J.N., & Samberg, S.M., 1978, Geology of Roosevelt Hot Springs KGRA, Beaver County, Utah: University of Utah Research Institute, Earth Science Laboratory Report, Department of Energy Contract Number EG-78-C-07-1701

PLATE I

Geology of a portion of
Roosevelt Hot Springs KGRA
Showing the location of
Radon Sample Lines