

EVALUATION OF He AND Rn GEOCHEMICAL URANIUM EXPLORATION TECHNIQUES IN THE "KEY" LAKE AREA, SASKATCHEWAN

Project 720067

W. Dyck, R.A. Campbell, and J.C. Pelchat
Resource Geophysics and Geochemistry Division

Abstract

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To determine the strength and extent of various geochemical signals, particularly those of He and Rn, emanating from the U deposits in the "Key" Lake, Saskatchewan area several drillhole waters, detailed lake bottom water samples, and 100 lake water samples from an 800 km² area surrounding "Key" Lake were collected, and analyzed in the field laboratory for He, Rn, O₂, Eh, pH and conductivity.

Generally the lakes are shallow (less than 10 m) and well mixed in the summer as indicated by near equilibrium O₂ values and uniform temperatures down to 7 to 10 m. Mixing has resulted in small values for the dissolved gases Rn and He and much lower values (up to a factor of 8) in the summer than in the winter under the ice.

Regional Rn and He values, determined in the field, ranged from 0 to 293 picocuries/L (pc/L) and 43 to 92 std nanolitres/litre (nL/L) respectively, with background values of about 1 pc/L for Rn and 43 nL/L for He. By comparison, waters from drillholes into the main ore zone yielded up to 300,000 pc/L Rn and 20,000 nL/L He.

The semidetalled and detailed follow-up confirmed two anomalous Rn areas, one at "Zimmer" Lake and the other at "Seahorse" Lake. On these scales of exploration both He and Rn in lake waters detected the radioactive boulder fields and the ore below several of the lakes. Concentrations were relatively low. Rn seemed more stable and gave larger contrasts than He but took longer to measure.

Introduction

The recently discovered high grade U deposits at "Key" Lake, Saskatchewan (Dahlkamp and Tan, 1977) provide excellent sites for the testing of U exploration techniques. Although drilling has already caused some disturbance of the natural environment at "Key" Lake, it is important that as many tests as possible are carried out prior to mining, for it has been the authors experience that mining activities have a profound effect on the distribution of elements in the surficial environment.

To determine the usefulness of He, Rn and U in lakes and groundwaters, in particular He for U exploration, a series of tests were designed and carried out during the 1977 field season in the "Key" Lake area. For logistic reasons the 3 man Geological Survey of Canada party joined a University of Regina team which was carrying out detailed geochemical studies in the "Key" Lake area under the direction of Dr. Parslow. The main objectives of the field tests were: (1) to see what kind of He signal could be observed in the waters over the ore deposits relative to barren country; (2) to test a semiportable He analyzer under field conditions; and (3) to compare Rn, U, and He levels obtained in the summer to those in the winter under the ice. To evaluate the effectiveness of the He method relative to the Rn and U methods of prospecting, lake waters and sediments were also collected for Rn and U analysis at selected sites. This report describes in summary form the actual field work carried out, the preliminary analytical results obtained in the field laboratory, and presents some tentative conclusions.

Field Investigations

The field investigations can be divided into 5 inter-related tests:-

1. Regional lake water and sediment survey
2. Semidetalled lake water follow-up
3. Detailed lake water follow-up
4. Seasonal comparison of lake waters
5. Drillhole water tests

1. Regional lake water and sediment survey

About 400 lake sites within an 800 km² rectangle in the southwest corner of map sheet 74 H were sampled by helicopter during the period of June 10-20, 1977. The sample area surrounded the "Key" Lake ore deposits and was bounded by U.T.M. co-ordinates 6 352 700N-442 500E; 6 352 700N-478 500E; 6 300 000N-442 500E and 6 300 000N-478 5000E. (Fig. 7.1) From each of these sites two lake sediment samples, one for the Geological Survey of Canada and one for the University of Regina, one lake surface water and one lake bottom (1 m from the bottom) water were collected. In addition two lake bottom waters were collected from every fourth site for analysis in the field laboratory. The sediment samples were collected in an Ekman dredge and contained in two 450 mL plastic bags. A Wildco acrylic water sampler was used to collect the lake bottom waters. The bottom water collected at each site was poured into a 200 mL aluminum container and the water collected at every fourth site was poured into two 300 mL glass bottles. The surface water samples were collected by hand in 220 mL plastic bottles.

To check on the sampling and analytical accuracy one blank (distilled water), one control reference (multi-trace element standard) and one duplicate were inserted in every group of 17 samples collected during the regional lake water survey.

2. Semidetalled lake water follow-up

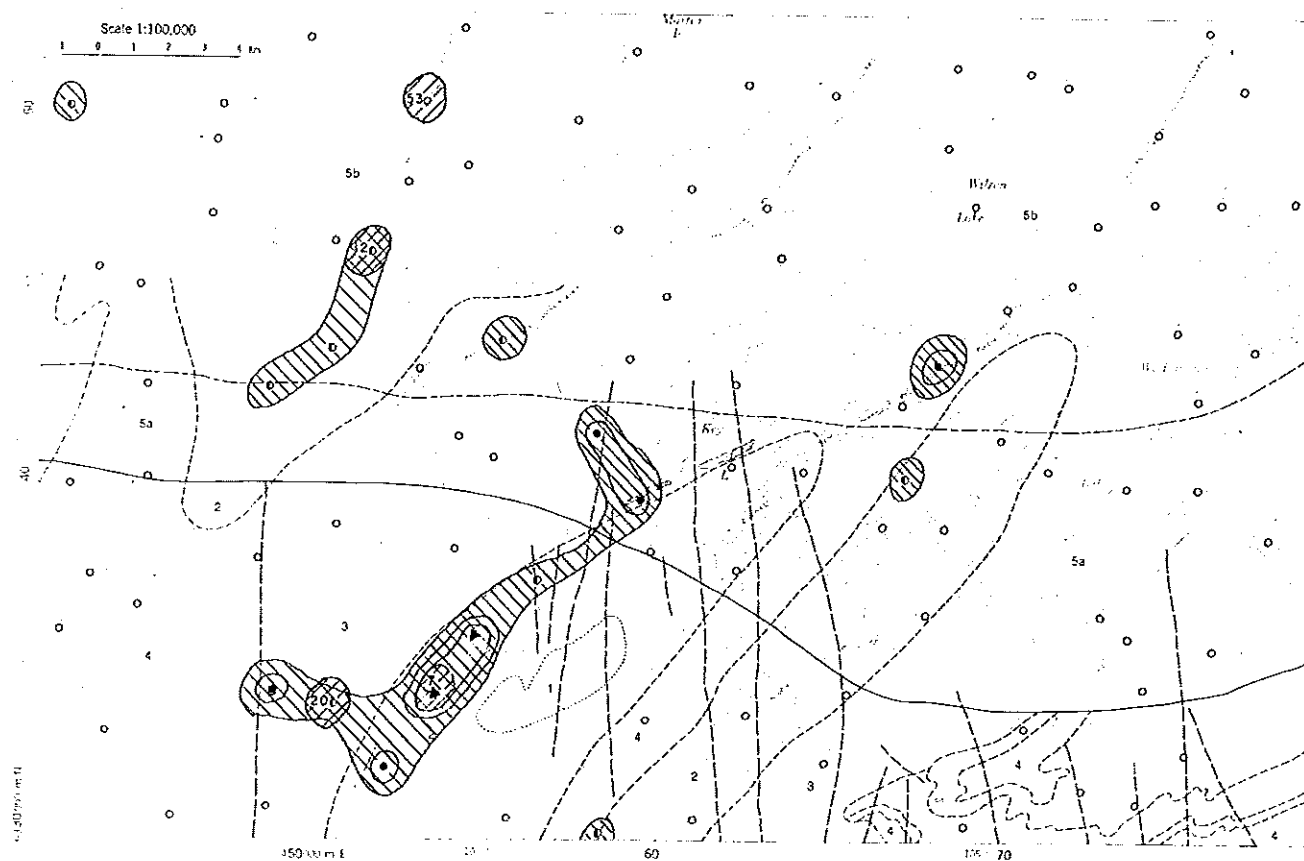
A semidetalled lake water follow-up was performed in two areas where interesting Rn results were obtained during the regional lake water and sediment survey. Altogether 57 lake water sites were sampled using helicopter and boat support between June 20 and 23, 1977. Fourteen samples were collected in a 5 km² area at "Zimmer" Lake and 33 water samples were collected in a 15 km² area at "Seahorse" Lake (Fig. 7.2). At each site a water sample was collected 1 m from the bottom using a Wildco acrylic water sampler

and two 300 mL glass bottles were filled. These samples were analyzed in the field laboratory and at the Geological Survey geochemistry laboratory in Ottawa.

3. Detailed lake water follow-up

From June 22-25, 1977, ninety-six sites were sampled in a detailed lake bottom water follow-up to the regional and semidetailed surveys. These samples were collected by boat along 13 traverses in four lakes (Fig. 7.3). These particular traverses were picked either because of their relative

position to the two orebodies (Gaertner and Deilmann) or because of interesting results obtained during the semidetailed survey. All the lines were run in a northwest direction with 3 lines (20 sites) on "Karl Ernst" Lake, 4 lines (27 sites) on "Dieter" Lake, 3 lines on "Key" Lake (37 sites) and 3 lines on "Upper Seahorse" Lake (12 sites). The lake traverses were positioned 100 m apart and the samples were collected at 30 m intervals. At each site two 300 mL glass bottles were filled with waters collected 1 m above the lake bottom by the Wildco acrylic water sampler. The samples were then analyzed in the field laboratory and in the Ottawa laboratory.



LEGEND

HELIKIAN

- 5 ATHABASKA FORMATION
 - 5a Coarse conglomerate
 - 5b Medium conglomerate and sandstone

APHEBIAN

- 4 WOLLASTON GROUP
 - Meta-arkose
- 3 WOLLASTON GROUP
 - Pelitic and semi-pelitic schists and gneisses

ARCHEAN

- 2 Biotite granite-adamellite gneiss
- 1 Charnockitic rocks

Compiled from maps produced by
Baer (1968), Ramaekers (1975) and Ray (1976)

- Rn, PC/L
 - 0 - 3 • 11 - 50
 - ◐ 4 - 10 ▲ >50
- He, NET NL/L

- Approximate edge of Athabaska Formation
- - - Size grain boundary within Athabaska Formation
- Area containing numerous outcrops
- Fault of major joints
- - - Shear with mylonite
- Location of the "Key" Lake U-Ni deposits

Figure 7.1. He and Rn in lake bottom water samples from regional survey.

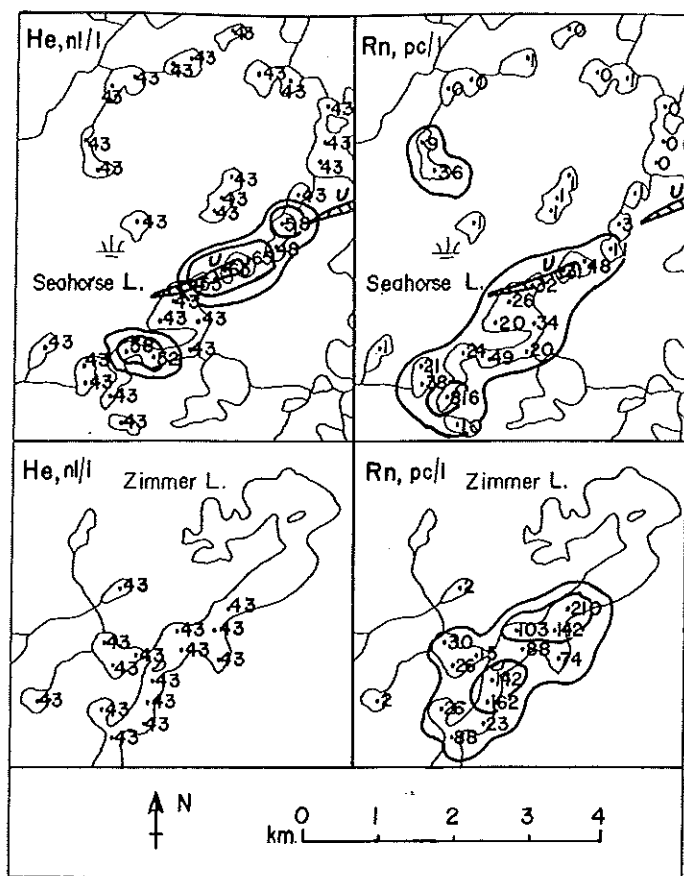


Figure 7.2. He and Rn in lake bottom water samples from semidetalled survey.

4. Seasonal comparison of lake waters

Eighty-six lake water samples from 36 sites, 4 well water samples from 2 sites and 1 stream water sample were collected between June 28-30, 1977. These sites were chosen to coincide with sites sampled in March of 1977. The 86 lake water samples were collected by boat in 8 lakes within a 16 km² area of the Uranerz camp at "Key" Lake, the stream water from a stream between "Hourglass" and "Upper Seahorse" lakes, and the well waters were collected from 2 wells located in the Uranerz camp. In the lake and stream water sampling an acrylic Wildco depth sampler was used to collect 45 samples (top, bottom, middle) from 15 sites, 40 samples (top and bottom) from 20 sites and 2 samples (bottom) from 2 sites. The top samples were collected 1 m from the surface, the bottom samples 1 m from the lake bottom and the middle samples were collected halfway between the surface and lake bottom. For each sample three, 300 mL glass bottles were filled for analysis in the field and in Ottawa.

5. Drillhole water tests

On June 27, 27 water samples were collected from 10 holes drilled for hydrological studies. On July 4, 35 samples were collected from 7 U exploration drillholes in or near U mineralization. The samples were taken at arbitrary intervals of from 15 m to 20 m. Maximum depths encountered were: 59 m for hydrological holes and 98 m for exploration holes. From each site two 300 mL glass bottles were filled for analysis in the field and in Ottawa.

Field Laboratory

The field laboratory was set up in a 25 foot trailer which was trucked into the "Key" Lake area over a winter road from La Ronge during the winter of 1976-77. The mobile laboratory was equipped with a heating system, a water supply system a radiophone and an air conditioner. Electricity was generated by two portable generators; a gasoline driven MacCulloch and a diesel driven Koeler.

In the field laboratory the water samples were analyzed for He, Rn, pH, Eh, conductivity and O₂. He was analyzed with an Alcatel ASM 10 helium leak detector while radon was determined by degassing a 120 mL aliquot into a ZnS cell and measuring the alpha particle emanation rate with a Rn counter (Dyck and Pelchat, 1977; Dyck, 1968).

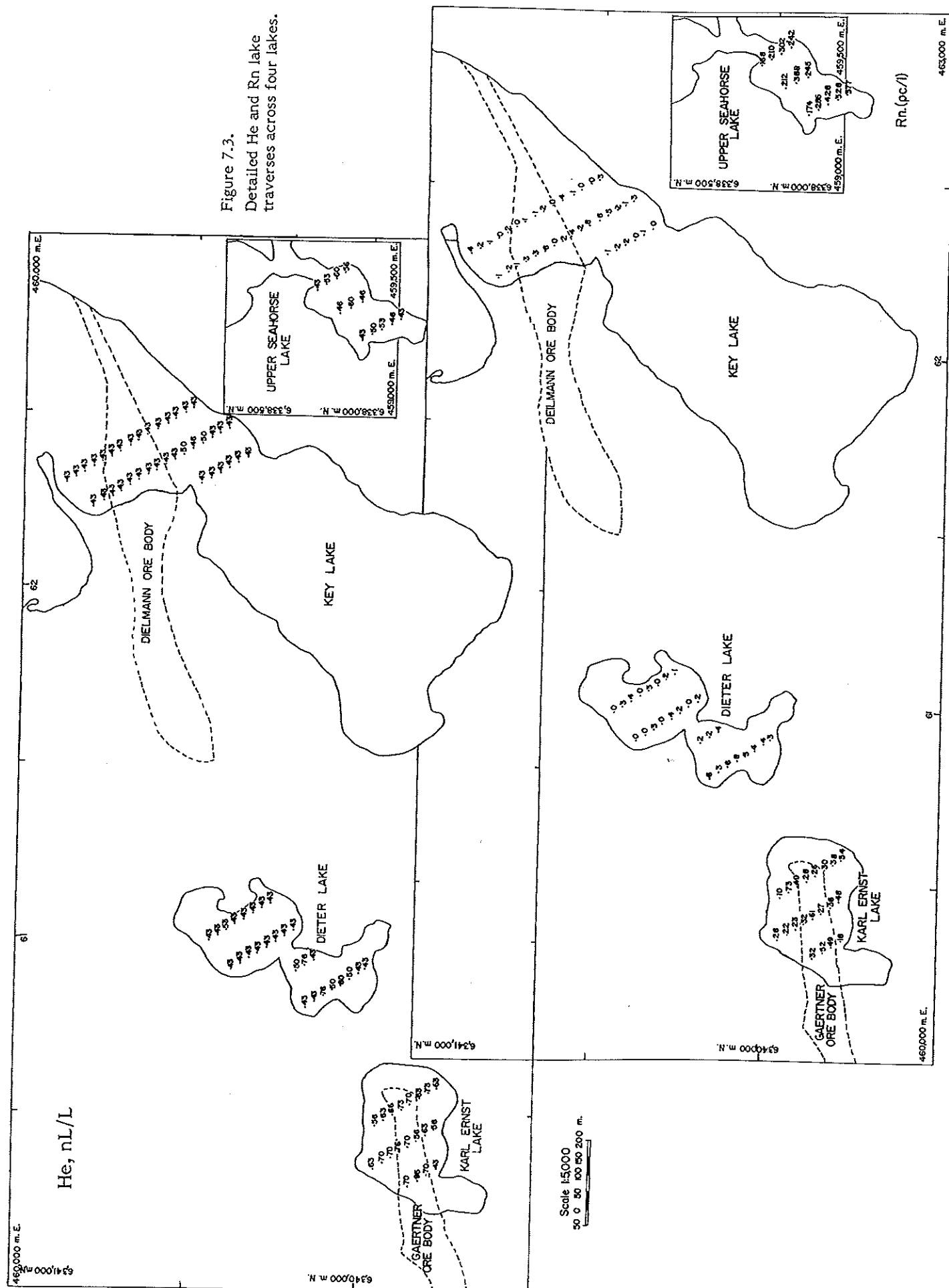
General Geology

The "Key" Lake area is at the southeastern margin of the Athabasca basin at the contact between the Athabasca Formation and the crystalline basement. In the southeastern part of the study area Aphebian metasediments (gneiss and schists) of the Wollaston Group lie unconformably on an Archean basement of foliated granitic and charnockitic rocks. In the north the Aphebian and Archean rocks are unconformably overlain by the poorly exposed Athabasca Formation consisting of sandstones, grits and conglomerates (Ramaekers, 1975). The basement rocks and those of the Athabasca Formation are almost completely covered by up to 90 m of glacial deposits (eskers, kames, outwash sands and various tills). The main structural features in the "Key" Lake area are the pre-to-post Athabasca faults. These basement faults trend northeast-southwest and one of these faults is associated with the mineralization at "Key" Lake.

To date two orebodies have been discovered at "Key" Lake; the Gaertner and Deilmann orebodies (Fig. 7.1). The Gaertner orebody is 1500 m in length, 80 m thick and ranges in width from 10 to 40 m while the Deilmann orebody has a minimum length of 800 m, a width of 10 to 100 m and a depth of 150 m. Dahlkamp and Tan (1977) report grades of up to 45% U₃O₈ and 45% Ni in the Gaertner orebody and up to 20% U₃O₈ and 25% Ni in the Deilmann orebody. The U-Ni mineralization consists of U oxides and silicates and nickel sulphides and arsenides and is found in both the Athabasca Formation and the underlying gneiss close to their unconformable contact.

Results and Discussion

As stated in the introduction, the main purpose of this study was to test the He method of prospecting for U. However, for purposes of comparison and in order to obtain as much background data as possible on what may well prove to be one of Canada's richest U deposits, the regional survey included also centre lake surface water and centre lake sediment samples. These samples as well as the He analyses of 400 lake bottom water samples await processing. But the 99 additional lake bottom water samples taken at every fourth site during the regional survey were analyzed in the field laboratory and are discussed here, as are the semidetalled and detailed lake water field data. It should be stressed here that the authors do not recommend such a wide sample density (1 site/8 km²) for routine He and Rn surveys for U exploration. The reason for this set of 99 samples was mainly to obtain a background reading from the area and test the recently assembled He analyzer (Dyck and Pelchat, 1977). Even at such wide spacing two areas with higher than background Rn values were outlined. One in the "Zimmer" Lake area where up to 292 pc/L were found relative to about 1 pc/L for background and the other in a small lake 1.5 km northwest of "Seahorse" Lake where 45 pc/L were found. The



one "Seahorse" Lake site chosen for this survey had only 12 pc/L even though there is ore some 50 m below this lake. The 45 pc/L value in the small shallow lake was confirmed in the semidetailed follow-up. It is in an area of thick overburden and sandstone cover but a preliminary geological map (Ray, 1976) shows a north-south trending fault under this lake. The semidetailed follow-up also confirmed Rn in "Zimmer" Lake and "Seahorse" Lake with the highest value of 816 pc/L in the south end of "Seahorse" Lake. It is thought that these Rn values reflect primarily the radioactive boulder train in the area.

Only four of the 99 regional sites contained higher than background He values; background in this case being the equilibrium value determined by the He content of the air and the solubility of He in water at the prevailing temperature and pressure. This value is about 45 nL/L (Weiss, 1971). For this work calibration curves for the He analyzer used in the field gave a value of 43 nL/L. Two of the high He sites were in the "Zimmer" Lake area and two in two adjacent larger lakes about 12 km northwest of "Key" Lake. Here the highest value of 96 nL/L was observed, but neither of these sites had much above background Rn values. Most likely these values reflect a structural feature with groundwater influx, for the water had also a higher than background conductivity (25 micromhos/cm vs a 10 mmh/cm background). As evident in Figure 7.2 no He readings above equilibrium were observed in "Zimmer" Lake samples taken in the semidetailed follow-up even though all the samples had anomalous Rn and two sites sampled in the regional survey had higher than background He and Rn. Perhaps a few windy days between the two sampling times had depleted the excess dissolved He but not Rn. Also Rn is able to build up quicker than He to detectable levels. However, "Seahorse", "Karl Ernst" and "Dieter" lakes gave a positive He response during the semidetailed survey.

In Figure 7.3 the detailed lake bottom traverses are shown. The traverse locations and site spacings were obtained by estimating distances from points on shore and hence are very approximate. Over the ore zone in "Karl Ernst" Lake up to 73 pc/L Rn and 95 nL/L He were observed. With all the drilling in this lake one would expect much higher values than that from contamination alone. That contamination plays only a small part is evident from the "Key" Lake He and Rn values over the ore zone; they are virtually zero even though drillholes puncture the ore zone. While the depth of lakes is believed to play a role in controlling He and Rn concentrations it does not appear to be a strong factor when a temperature gradient exists. Note the absence of both He and Rn from the two northern traverses in "Dieter" Lake in spite of the fact that some of these sites were among the deepest (up to 20 m) of all the detailed sites. These sites also indicate that nonmineralized parts of the ore bearing contact, presumed to continue from "Karl Ernst" Lake through "Dieter" Lake to "Key" Lake, do not produce He and Rn as do the drilled, mineralized parts. The higher than background He and Rn values in the southern part of "Dieter" Lake are probably produced by the ore under "Karl Ernst" Lake and groundwater moving from "Karl Ernst" Lake to "Dieter" Lake.

The detailed traverses at the south end of "Seahorse" Lake yielded up to 428 pc/L Rn and 60 nL/L He. This part of the lake reaches a depth of only 4 m so that He escape will be more pronounced. The relatively high Rn levels suggest that the source is nearby. No drilling was evident here. Most likely a concentration of radioactive boulders near the surface gives rise to this anomaly, similar to the ones in the "Zimmer" Lake area.

The winter-summer comparison tests will be described in detail elsewhere. Qualitatively speaking both Rn and He levels in the lakes were significantly lower in the summer than in the winter. For example Rn and He values in the two

"Karl Ernst" Lake bottom sites in the winter under the ice were 147 and 183 pc/L and 137 and 152 nL/L, respectively. In the summer the same sites gave 29 and 19 pc/L and 65 and 76 nL/L, respectively. The reduction in the Rn concentration at first glance appears much more drastic than the He drop but with a subtraction of the He contribution of atmospheric air of 42 to 45 nL/L one can see that the net He is reduced by a factor of 4. Three factors may explain this summer-winter contrast namely temperature, water level and flow, and wind action. Wind action, in summer was probably the most dominant factor in stirring up the water thus prohibiting the build up of a gradient. The lack of a gradient in lakes less than 7 m deep was quite evident from the constant temperature and O₂ content between surface and bottom lake samples in the summer. However, the spring run-off dilution effect of trace element concentrations may also be important. This factor should become evident when ionic species are measured. The gentle relief precludes extensive upwelling of groundwaters through faults. Regional movement is estimated to be about 3 m/year in a northeasterly direction even though the sandy overburden contains about 25% voids. Hence, groundwaters do not contribute significantly to the dissolved gas content of the lakes. This lack of communication between the groundwater and lake water regimes is also evident from the absence of U, Rn and He in "Key" Lake even though part of one orebody lies directly underneath it. Also, the mining camp wells have a conductivity of 30 micromhos/cm as compared to 10 in the lake which is about 100 metres away.

Drillhole Samples

By far the highest Rn and He values were obtained from water samples from drillholes. The results from two of these holes are shown in Figure 7.4. The highest values of about 300 000 pc/L Rn and 20 000 nL/L He were obtained at the bottom of hole 1061 which penetrates the main ore zone at about 50 m. Hole 1161 shows only a small gamma ray signal between 90 and 95 m. Contrary to expectation the Rn concentration is lower in the mineralized zone than in the sandstone above it. He behaves as expected in both holes. The lowest Rn and He values encountered in the drillholes were 300 pc/L and 43 nL/L and can be taken as typical near surface groundwater background values. None of the holes tested gave background values for Rn and He coincidentally. However, more tests, much farther from ore are needed to establish typical background values for these gases in groundwaters of the Athabasca sandstones. One interesting and clear correlation from the drillhole data emerges; low or equilibrium He values correspond to high O₂ values, indicating the strong effect atmospheric contact has on the concentration of these two gases in water. This correspondence is much less evident with Rn and O₂ resulting in poor correspondence between He and Rn in some instances. No mineralogical data were available from these holes when this report was prepared so a comparison between U in the ground and He or Rn in the water is not possible at this time. A rough comparison between the gamma ray logs and Rn or He shows a rather diffuse correspondence suggesting complex groundwater flow patterns and Ra, Rn, and He migration. Work is continuing in the hope of learning something about these patterns and establishing useful criteria and procedures for prospecting.

The high pH and conductivity values have doubtless resulted from the additives in the drilling mud which was still present in all holes as a gel when sampled. The slightly higher pH and conductivity values observed in the lakes where drilling had taken place are probably also due to these additives. The high O₂ and Eh in hole 1161 relative to that in hole 1061 may be due to the fact that hole 1161 was completed several days and hole 1061 several weeks before

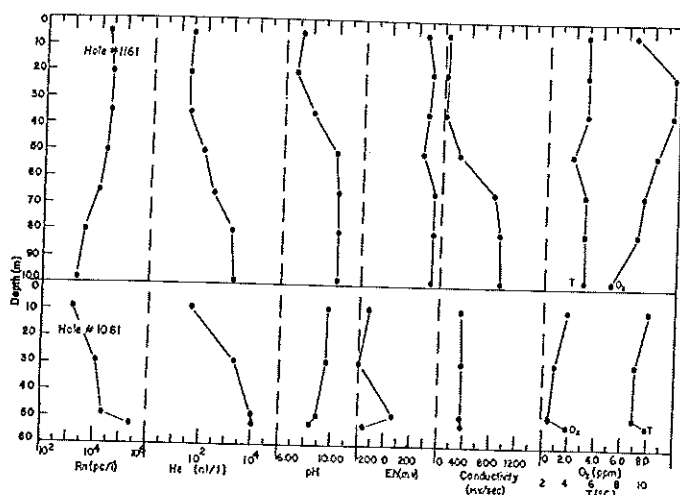


Figure 7.4. He and Rn profiles of two drillholes in mineralized ground.

sampling. The highly reducing environment in the main ore zone may also be a factor in this contrast. It is tempting to ascribe the higher temperature in hole 1061 to the nearness of the main ore zone. However, an equally likely explanation is the fact that lake water from "Seahorse" Lake moves through the ground past 1061 into "Karl Ernst" Lake. Lake waters at the time of sampling were about 17°C down to a depth of 7 to 10 m depending on the size of the lake.

Conclusions

Barring possible contamination as a result of drilling, the U ore deposits and the radioactive boulder fields in the "Key" Lake area, Saskatchewan give rise to He and Rn anomalies in lake bottom water samples, particularly when studied in detail. "Key" Lake itself, even though underlain by U ore, gives virtually zero He and Rn signals suggesting a rather tight seal between ore and lake bottom. The anomalies generally are subtle and absolute concentrations low, hence good equipment and competent operators are essential.

The He analysis facility, set up during the winter, was tested for the first time under true field conditions and found to perform well, detecting relative He concentrations of 5 nL/L and producing up to 120 analyses per man day. Although He measurements are more difficult than Rn measurements they are more quickly performed with the procedures and equipment adapted by the Geological Survey.

The presence of highly anomalous He and Rn in drillhole waters in and near U ore zones suggest that their routine measurement during exploratory drilling may indicate proximity and thereby increase the probability of detecting a deposit.

The tests as carried out during the summer revealed no obvious advantage of the He method over the Rn method for U prospecting. In fact, Rn contrasts between background and anomaly were generally higher and Rn anomalies more dispersed than He. The generally weaker He signal in lake bottom waters indicates its greater mobility and its mode of occurrence suggests that He in lakes is more suitable for detailed prospecting for U mineralization. However, in winter under the ice, lake bottom water samples from "Key" Lake itself had anomalous He but no anomalous Rn. This, plus the fact that no anomalous U is found in this lake, suggests that under the conditions prevailing at this lake He is the one tracer that is mobile enough to enter the lake and accumulate under the ice.

Acknowledgments

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