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Radon Monitoring in the Soil Air with Nuclear Track Detectors –Uranium Exploration Method

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INTRODUCTION

The nuclear track detector uranium exploration method was presented and its limitations due to the effect of the moisture content in material that covers uranium mineralization as well as the thickness and uranium concentration of that overburden were considered. The radon survey was carried out over uranium anomalies that were confirmed by drilling. The radon results were used to optimize targets for future exploration drilling programs.

METHODOLOGY DESCRIPTION

Radon in U-orebodies and their overburden
Radium 226 of the uranium decay series generates the inert radioactive gas radon (222Rn) that has a half-life of 3.8 days. Radon can "migrate"relatively long distances towards the ground surface from uranium mineralization and/or a uranium anomaly. The principal mode of radon transport in soil/sediment that covers any uranium mineralization is diffusion. A less common but very important mode of radon transport is flow through geological cracks and voids. The radon gas diffusion process in any porous media can be almost inhibited by water saturation.

The radon activity concentration in air, RnAC(Bq/m3), that is contained in the uranium ore intergranular space can be calculated as follows [1]:

$$\mathrm{RnAC(Bq/m3)} = a(\mathrm{226Ra})\rho E$$

where a(226Ra) is the specific radium activity of the ore, ρ(kg/m3) is the bulk density of uranium ore and E is the radon emanation coefficient. After the following values were substituted for a(226Ra) = 12,400 Bq/kg (the equilibrium specific activity of 226Ra of the 0.1% U-ore is 12,400 Bq/kg), ρ=1,500 kg/m3 and E = 0.2 the equilibrium radon activity concentration in air of approximately 3,700,000 Bq/m3 was calculated for the uranium orebody.

The radon air activity concentration profile, RnAC(X), for a thick layer of porous non-radium bearing material can be approximately described by the following formula:

$$\mathrm{RnAC}(X) = \mathrm{RnAC}(0)\exp(-\lambda 222\mathrm{Rn}/D \,.\, X)$$

where X is the distance from the surface of the uranium mineralization, RnAC(0) is the radon activity concentration at the orebody/cover layer boundary, D (m2 s-1) is the radon diffusion coefficient and λ222Rn (2.1 10-6 s-1) is the radon decay constant [2].

The effect of the moisture content on the radon activity concentration in uranium ore intergranular pores and in its covering material is well known and is mainly governed by the diffusion constant changes with the relative water content [3]. For example if a 5 m wide uranium mineralization with 0.1% uranium ore grade is overlayed by a 5 m thick earth material layer with relative moisture content of 4%, 11%, 15%, 16% and 18% respectively, the long-term average radon activity concentration at 0.1 m below the surface of that layer could be calculate as 35,000 Bq/m3, 24,000 Bq/m3, 21,000 Bq/m3, 1.9 Bq/m3, and 0.01 Bq/m3 respectively [2].

Since the overburden of a uranium source also contains some uranium and radium, the measured radon activity concentration below the surface of the overlaying material includes its radon activity concentration in addition to an incremental radon activity concentration caused by the radon diffusion from the mineralization. The radon air activity concentration in the 5 m thick porous overburden layer with 1 ppm U can be calculated by the following formula [2]:

$RnAC(X) = 12.4\ \rho\ E\ [1 - [\cosh(\lambda 222Rn/D\ X)/(\cosh(\lambda 222Rn/D\ XL)]$

where 12.4 Bq kg-1 is the equilibrium specific activity of 226Ra of overlay material layer and XL(m) = 5 m is the thickness of the layer. The radon air activity concentrations of 220 Bq m-3, 330 Bq m-3, 370 Bq m-3, 950 Bq m-3, and 2,700 Bq m-3 respectively were calculated considering the relative moisture content of 4%, 11%, 15%, 16% and 18% respectively.

RADON MONITORING BY NUCLEAR TRACK DETECTORS

The short-term radon air activity concentration near the surface of the material cover of uranium orebodies is affected by wind, ground temperature, rain water, etc. In order to minimize these short-term effects on the measured radon air activity concentration it is necessary to use a radon monitoring technique that measures the long-term average radon activity concentration and be able to measure the radon activity concentration within a range of about 50 –1,000,000 Bq m-3.

The most appropriate and "robust"radon monitor suitable for large scale field application is a nuclear track detector. In the seventies and eighties this method was used for uranium exploration [4]. However, it is not known if the method with its nuclear track detector arrangement was instrumental in any new uranium deposit discovery.

In 1980 the first author developed the nuclear track detection method for radon monitoring in the soil air and in water [5], [6], [7]. Based on the previously published work the Nuclear Track Uranium Ore Exploration Tool (NTUOET) was developed. The NTUOET includes the nuclear track detector Kodak LR-115(type 2) that is situated inside a plastic "cavity badge"(the Passive Radon Monitor, PRM). A moisture protector is used also prevents the entry of Thoron to the PRM. The PRM is inserted into a 17 cm long plastic conduit with its top opening sealed with a plastic cap (The PRM is held inside the plastic cap with a piece of foam. The NTUOET is inserted into a 20 cm deep hole with the top of the plastic cap at the surface. It is required to slightly compact dirt around the conduit.

This robust design enables a large number of NTUOET units to be deployed during one day. The units are then collected after an exposure time of 2 –3 weeks. As this method is relatively inexpensive an exploration manager can use a number of units to obtain a more detailed radon activity concentration contour plan of the site that can be used to optimize the drilling program and thus to carry out uranium exploration more cost-effectively.

DevEx RESOURCES LIMITED URANIUM EXPLORATION AT NABARLEK

The history of the Nabarlek uranium mine

The deposit was delineated by diamond drilling in 1970 and 1971. Open cut mining took place between June and October 1979 with the ore stockpiled for milling. 546,437 t of ore were mined at an average grade of 1.84% U3O8. The mill commenced operation in June 1980 and ran until 1988, during which time 11,084 t U3O8 were produced. The site was rehabilitated by 1995 (Lally, J. & Bajwah, Z. (2006). As the geology around the old Nabarlek uranium deposit includes a number of outcrops with elevated uranium DevEx Resources Limited (the Company) acquired exploration leases that include the old Nabarlek mining leases.

The Nabarlek uranium exploration program

The Company carried out several exploration/drilling campaigns since acquiring the Nabarlek Project. This presentation summarises the most recent results of a radon survey that was carried out by the Company in 2016. In order to improve the accuracy of radon monitoring a scintillometer was also used to take a gamma count reading at radon sampling locations showing elevated radon.

The radon survey was carried out over three areas with NTUOET units positioned over a 100m (west-east) by 200m (north-south) grid. The first area served to test a largely unexplored region within a valley defined by sandstone escarpments located 12 km southeast of the Nabarlek mine site. The second area was to test a line of drilling from 2015 comprising four reverse circulation (RC) drillholes at the GC11 prospect. The third area was situated about 2 km west of the GC11 prospect to test for radon leakage over a ground gravity anomaly.

NTUOET units placed within the sandstone valley showed a distinct elevated radon anomaly trending southeast along a potential fault delineated by radon readings ranging 3,018 - 53,444 Bq m-3 within a background range of 95 –2000 Bq m-3. Radon stations to the north and south of this trend are at background levels and sharply constrain the anomaly. This anomaly represents a strong exploration target and is recommended for drill testing.

Two RC drill holes at the GC11 prospect intersected elevated uranium concentrations within dolerite, with the best results including 2m @ 2,354ppm U3O8 from 135m downhole in drillhole NAR7537; and 5m @ 1,065ppm U3O8 from 169m downhole in drillhole NAR7535. Following this drilling program it was decided to place a number of NTUOET units within and near the area where the drill holes were situated. The radon air activity concentrations that were measured within the 50 m radius of each drill hole were within a range of 2,041 –4,043 Bq m-3 with a background range of 282 –1,339 Bq m-3. We compared the radon measurements with results of the exploration drilling program and confirmed a relationship between elevated radon and anomalous subsurface uranium concentrations.

The NTUOET readings west of the GC11 prospect showed elevated radon towards the east of the survey line within the range of 2,955 –7,121 Bq m-3 with a background range of 282 –1,960 Bq m-3. These elevated readings are situated around a region of interpreted structural complexity based on ground gravity data and may represent a migration pathway for radon gas.

DISCUSSION AND CONCLUSSIONS

Northern Australia where the DevEx Resources Limited Nabarlek exploration leases are situated has a sub-tropical climate with the majority of rainfall occurring during the 'wet season'i.e. between November and April. Therefore, the radon survey was carried out during September –October 2016 i.e. at the end of the 'dry season'when the ground is more likely "dry". Although some moisture content was detected inside of some NTUOET units, the trends of measured radon air activity concentrations did not indicate that soil moisture content affected the survey outcomes. Scintillometer readings taken over radon stations of interest showed counts per second (CPS) measurements that were less than the defined upper background limit of 200 CPS. These results indicate the source of radon is not near-surface and could represent a uranium source at depth.

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Country or International Organization

Australia

Primary author: Dr KVASNICKA, Jiri (Radiation Detection Systems)

Co-author: Mr STEEGER, Henry (Chalice Gold Mines Ltd.)

Presenter: Dr KVASNICKA, Jiri (Radiation Detection Systems)

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