RADON MONITORING IN A GEOTHERMAL ICE CAVE OF MT EREBUS, ANTARCTICA

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Summary

Uranium (^{238}U) is ubiquitous, though at highly variable concentrations, in every rock making up the earth crust. Through radioactive decay, it yields radium (^{226}Ra) which, similarly, produces an inert but radioactive gas, namely radon (^{222}Rn). Rocks, soil, endogenous fluids, ground water and even building material are an inexhaustible source of radon.
Radon ends up in the atmosphere where, due to a radioactive half life of 3.82 days, its residence time is less than one week, and its concentration is low. On the other hand, in enclosed environments (mines, underground natural or man-made cavities, and buildings), radon and its decay products may reach levels potentially dangerous for health.
In underground cavities, radon volumic activity is a function of the radium content of the wall rock, but it depends also on the ventilation, either naturally or mechanically driven. Speleologists are accustomed to the air streams that flow along the passageways, and often reverse in spring and autumn, when the outdoor temperature equals the average local temperature (*ca.* the cave temperature). Despite their natural ventilation, caves are always much more radon-rich than the outdoor atmosphere, rocketing, for example, up to an unprecedented 155 000 Bq/m^3 during the summer in the limestone Giant's Hole in Derbyshire, UK (Bown, 1992).
Due to the high permeability of volcanic piles, caves (mainly, lava tubes or collapse cavities) in volcanoes are energetically ventilated. This thermally and wind driven ventilation generally conceal the geothermal gas seeping through the ground from the volcano interior —a convective gas flow of potential use for volcano monitoring and eruption forecasting. Gases making up this volcanic emanation are, among others, CO_2, He and Rn, the latter being by far the most easily amenable to continuous monitoring (Baubron *et al.*, 1991). Any attempt to monitor this flow in a volcanic cave would, in most cases, be hindered by the ventilation of the cave and the meteorological disturbances.
At high latitudes, however, a volcano may present underground cavities with a steady ventilation, driven by a strong heat flow sustaining, throughout the year in the cavity, a temperature above the outdoor temperature. Such is the case of Mt Erebus (77°34' S), Antarctica, the summit area of which accommodates numerous sub-glacial caves, unveiled by conspicuous ice towers, up to ten meters high. These towers are no more than genuine chimneys, made up of congealed steam originating from the melting of glacier ice in contact with the warm volcanic soil.
One of these caves (3700 m a.s.l.) was discovered in 1972 by New Zealander volcanologists (Lyon and Giggenbach, 1974), and mapped two years later (Giggenbach, 1976; see Fig. 1).

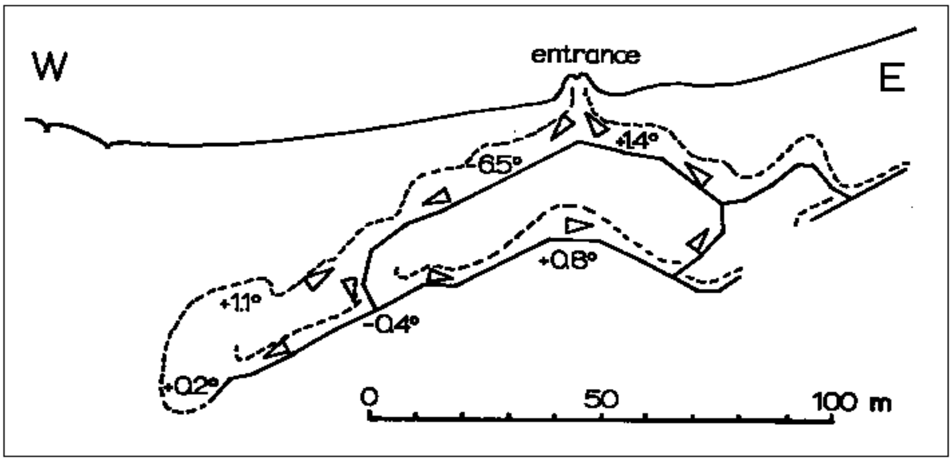

Fig. 1 - Side view of cave from south, with the air flow pattern (arrows). After Giggenbach (1976).

It consists of a 400-meter-long system of branching passages, connecting larger caverns (Fig. 2), with glacier or firn ice at the ceiling, and volcanic ash or lava making up the floor. Cave air temperature, regulated by ice melting, is consistently around the freezing point of water (up to 1.4°C).

Fig. 2 - The large ice cavern below the cave entrance (*Photo*: J.C. Sabroux).

The cave atmospheric radon was sampled for the first time in December 1974, during an international (France, New Zealand and the USA) expedition, leaded by the late H. Tazieff. Scintillating gas flasks, internally coated with zinc sulphide (Pradel and Billard, 1959), were used for both sampling and measurement. Table I displays the mean radon volumic activity of each sample. The values are the expression of the uranium content of the Mt Erebus lava (phonolytic trachyte), of the cave ventilation and, last but not least, of the volcanic heat flow: 11.3 W/m^2, according to Giggenbach (1976), two hundred times the mean geothermal heat flow on the continents.

TABLE I.

SAMPLE	Radon (Bq/m^3)
D107	16 300 ± 960
B81	11 600 ± 780
H81	12 200 ± 810

Table I - Radon volumic activity (in becquerels per cubic meter of filtered air at the sampling altitude), as sampled in a Mt Erebus ice cave on December 15th, 1974. The values (pressure corrected) are the result of several 6 minute-counts of the scintillating flasks by a photomultiplier.

Twenty years later, on the occasion of the 1994-95 cruise of the polar vessel *Antarctica*, commanded by Dr J.L. Etienne, the Mt Erebus ice cave was again visited, and its atmospheric

radon monitored for a few days by means of two automatic probes BARASOL (*Algade*, France), incorporating a silicon detector, a counting unit, and a data storage capability. Such probes are widely used as radon monitors in soil gases, in dwelling basements, or in underground cavities (Trique *et al.*, 1999), all settings in which the radon volumic activity is well above the "normal" outdoor atmospheric radon level (typically, between 5 and 50 Bq/m^3).
The mean radon volumic activity in the Mt Erebus ice cave (see Figure 3) is significantly lower than the level measured twenty years earlier, but at a different location in the cave.

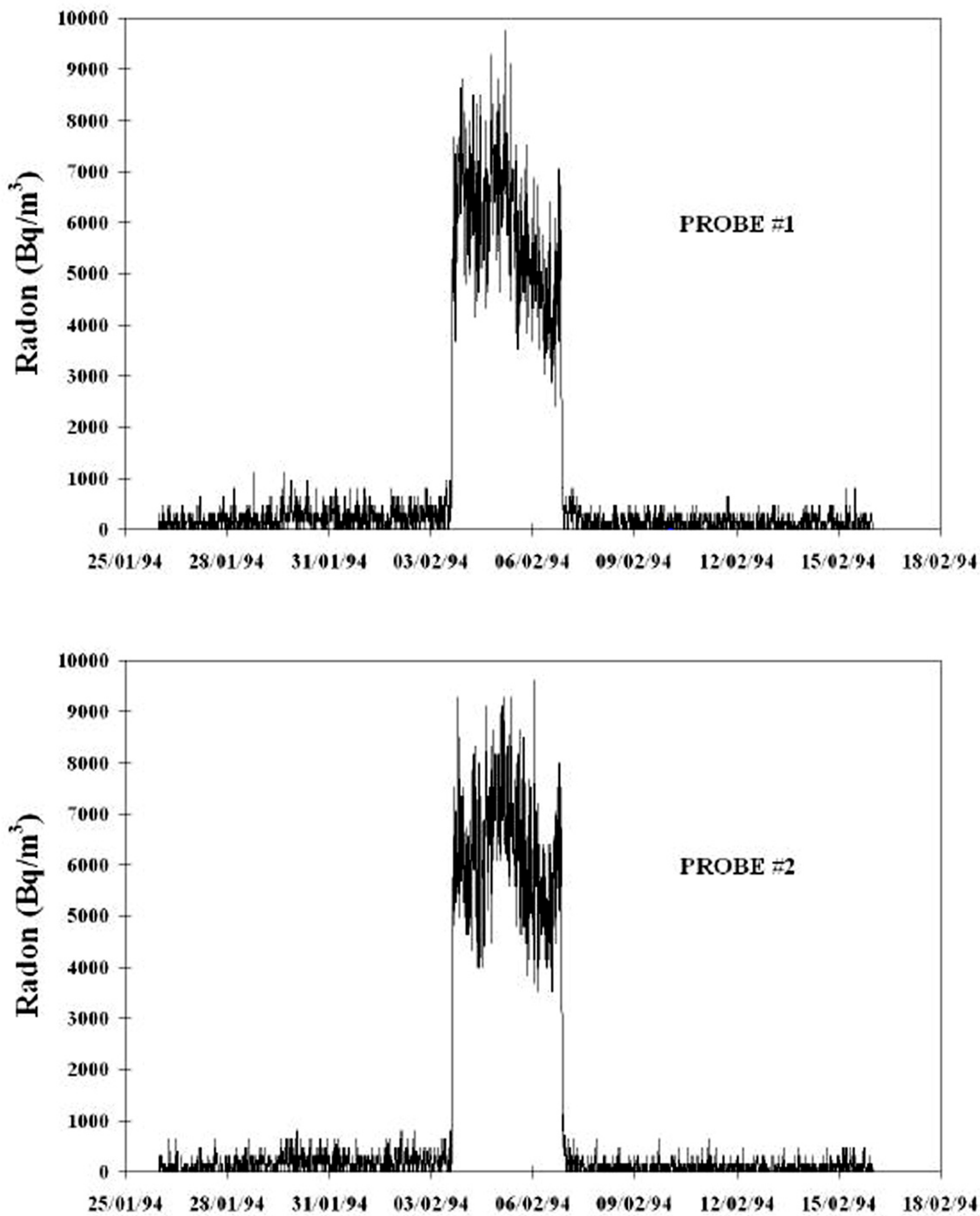

Fig. 3 - Radon measurement in the ice cave of Mt Erebus, Ross Island, Antarctica. The continuously operating probes were installed on February 3rd 1994, and withdrawn three days later. Outside this interval, the probes output is clipped at its background noise (outdoor atmosphere).

The 1994 experiment was too short to allow any correlation between the observed radon level fluctuation and the geophysical activity (not to mention the always possible influence of meteorological variations); yet, it paves the way towards a continuous radon monitoring of the Mt Erebus ice cave atmosphere. The monitoring station would, at least, incorporate several BARASOL probes and an ARGOS radio link. Taking advantage of the high rate of passes of polar orbiting satellites at high latitudes, a battery powered station would be autonomous for the compulsory ten-month or so time interval due to the remoteness of the southernmost active volcano of the world, visited only once during each Antarctic summer.

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