VARIATIONS IN RADON CONTENT IN SOIL AND DWELLINGS IN THE KINSARVIK AREA, NORWAY, ARE STRONGLY DEPENDENT ON AIR TEMPERATURE

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SUMMARY

The area of Huse in Kinsarvik, Norway was defined as a problem area regarding Radon in 1994 – 96 when several Radon measurements in residences showed very high concentrations (yearly averages of up to 60 000 Bq/m^3)(1621 pCi/l). However, the concentrations varied much, from almost nothing to more than 100 000 Bq/m^3. Geological investigations revealed normal to high concentrations of Uranium in the bedrock, very coarse sediment in the ground and an extensive vadose zone (above the water table). To understand the high amplitude of changes in Radon concentration, we performed a simple test with C-39 alpha track detectors in the ground. This revealed a process of temperature driven seasonal transport of Radon. To further explore the process, we have now mounted two data loggers that are measuring water content, temperature, pressure differences and Radon continuously in the soil as well as climatic parameters. The rapid changes in Radon concentration appear to be highly dependent on air temperature.

INTRODUCTION

Huse is a small residential area situated in Ullensvang County in Norway (Figure 1 & 2). It is approximately 0.2km^2 and has a slight inclination towards the Hardanger fjord.

Geology

The bedrock in the area is made up of early- to middle proterozoic metaigneous rocks and include rock types as fine- to medium grained metagranites, foliated coarse-grained granites, meta-andesites and meta-dacites. At the research site, the fine-to medium grained meta-granites dominate. East and south of the Kinsarvik area, phyllites of mainly Ordovician age are found. (Figure 1) (Sigmond *et al.* 1984).

Routine measurements of uranium content of the different rock types in the area showed concentrations of uranium from 2-17 ppm for a total of 28 different samples (Maaloe, 1997). The highest values were recorded in granites with an average value of 7.7 ppm and a maximum value of 17 ppm.

The valley is a typical glacial valley with steep sides. During the deglaciation of the area a substantial thickness of coarse material was deposited. The main part of the deposit is an extensive coarse marginal moraine, which was generated at the end of last glacial (Holtedahl, 1975). Since the land was pressed down due to the heavy load of ice, the sea level was much higher than today and reached almost the top of the moraine at 110 metres above sea level. This produced a capping of finer sediments above the much coarser moraine material. Since the coarse moraine is highly permeable, the groundwater level is more than 20 m below the surface (vadose zone) (Valen *et al.* 1997, 1999).

Temperature driven flow of air – "Chimney effect"

To understand how Radon was transported in the ground in this 0.2 km^2 (approx.) area, we used C-39 alpha track detectors buried in 23 different localities. The detectors were sealed inside thin plastic bags to prevent immediate overexposure and were exposed for up to 3 days. This was repeated five times in different seasons and at different air temperatures.

The results show distinct seasonal variability, implying a profound soil air movement in the coarse moraine. There is a movement of relatively warm soil air towards the higher areas during winter giving rise to a high Radon content in the ground of the topographical elevated areas, while the lower areas are aerated. In the summertime the process is reversed, giving rise to a high Radon content in the lower parts of the area. This transport of air in the ground entails a more extensive range from where Radon can be transported to dwellings.

Results from a comprehensive study of Radon in dwellings in the same area show the same seasonal variability (Jensen, 1997). The buildings in the lower part of this moraine ridge show higher Radon values during summer than winter. The buildings in the elevated parts of the area show the opposite. However, different building types and construction methods make the variability less pronounced.

Dataloggers

To further explore the process, we mounted two data loggers that measure moisture, temperature, pressure differences and Radon continuously in the soil. In the higher station we also measure climatic parameters. Based on the early studies with alpha track detectors, we placed the dataloggers in areas showing major seasonal variation in Radon concentrations (Figure 2). The input to the Radon sensors is at one meter depth in both stations.

The dataloggers were constructed and set up by OCEANOR ASA in Norway in the end of January 2000. Instruments for measuring temperature and precipitation are delivered by Aanderaa (Air temperature sensor 2775, Rainfall sensor 2890) and the Radon devices are two SARAD 2000-2.

RESULTS AND DISCUSSION

In the period from February to August the dataloggers show changes in temperature from -8 to 23 °C with a mean temperature of 7.7 °C. The precipitation maximum is 9.2 mm per hour and the total for the period is 820 mm. Radon concentration in the topographically highest station has varied from below detection limit to ca. 252 000 Bq/m^3 with a mean of 33 700 Bq/m^3. The lower station has varied from below detection limit to ca. 180 000 Bq/m^3 with a mean of 65 600 Bq/m^3.

A nearby weather station has an average typical annual temperature of 6.2 °C and annual precipitation of 1570 mm (period 1961 – 90)(Førland, 1993, Aune, 1993).

Seasonal changes

Changes in temperature are the main reason for changes in Radon concentrations. In Figure 3 the moving average of Radon in both stations and air temperature are plotted. The moving average was used to remove short-term changes. The results show a clear seasonal shift from winter to summer conditions. This change is the result of a reversing airflow, which is temperature driven. In summer the soil air is cooler than the air temperature and the airflow in the soil is flowing from the topographical high areas to low areas (Figure 5). In winter this airflow is reversed because the soil air temperature now is higher than the air temperature.

Daily changes

Figure 4 shows daily changes in Radon concentration controlled by daily changes in temperature. We see clearly that the amplitude of change in temperature governs the response in Radon concentration. When the temperature is close to the annual mean temperature, there is a high amplitude change in Radon concentration. The concentration becomes more stable when temperature rises well above the annual mean. There is a delay from changes in air temperature to the response in Radon concentration, which is dependent on whether the concentration is rising or sinking. A change of airflow, so that the flow is from the surface and down towards the sensors, aerates the site fast. However, a change of airflow so that the flow is from the ground towards the sensor will build up the Radon concentration in the area that was aerated from before.

General changes

Sudden changes in temperature, which become close to or below the annual mean, result in changes of Radon concentration as shown above under "Daily changes" (Figure 4). However, it seems that in general the amplitude of change in Radon concentrations becomes higher close to the reversing point. The highest Radon concentrations in general are found when the temperature is close to the soil temperature. The change in soil temperature in 1.50 m is from ca. 0 °C in winter to 10 °C in summer. The change, however, will be less deep in the soil.

When temperature in general is rising from the annual mean towards the summer maximums (Period May – Aug.), the Radon concentration at the topographical lower station decreases (Figure 3). There is a negative correlation between temperature and Radon concentration in the topographical lower area (Stat. 2). In general, we could expect an increase in airflow through the ground with increasing difference between soil air temperature and air temperature. This area is highly permeable, and we believe that an increasing airflow velocity in the ground, to a certain degree will aerate also the "high-Radon area", thus decreasing Radon concentration. This is emphasised by the positive correlation in winter measurements between Radon concentration in the topographical higher area and temperature.

Further work

The stations will stay at the site until January next year, and we will study further the correlation between temperature and Radon. Comparisons between Radon and all the other parameters, measured at the sites, will also be made.

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FIGURES

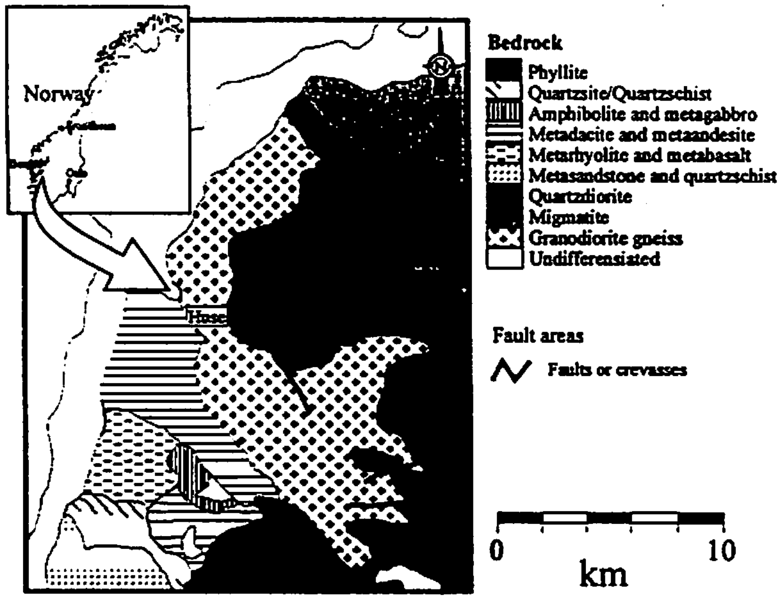

Figure 1: The Area of Huse is situated in the western part of Norway in Ullensvang County. The bedrock geology map of the area around Kinsarvik is based on Sigmond *et al.* (1984).

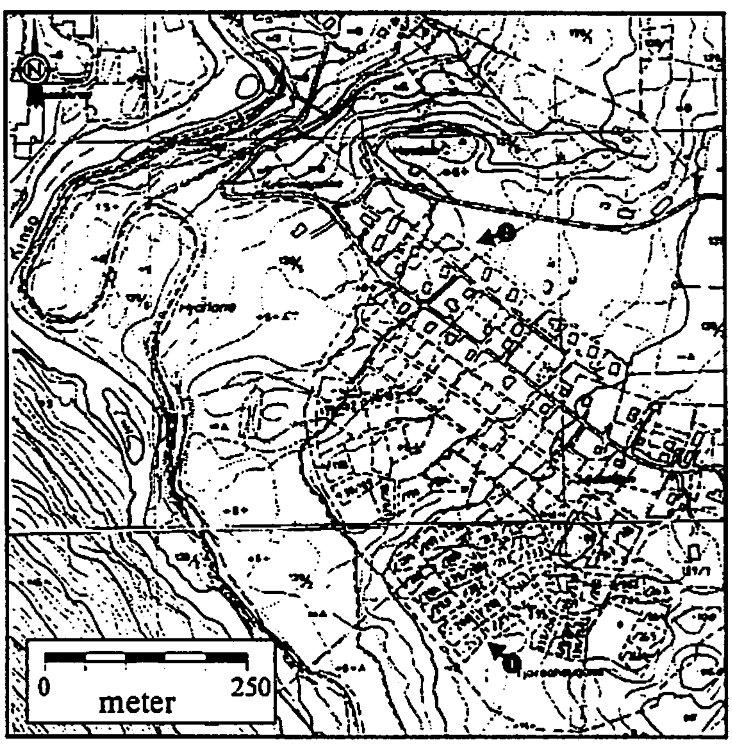

Figure 2: Topographical map of the area of Huse in Kinsarvik. The sites, where the dataloggers were mounted are shown. Number one is in the topographical highest area and number two is in the lower part. The selection of these localities was based on previous measurements with alpha track detectors.

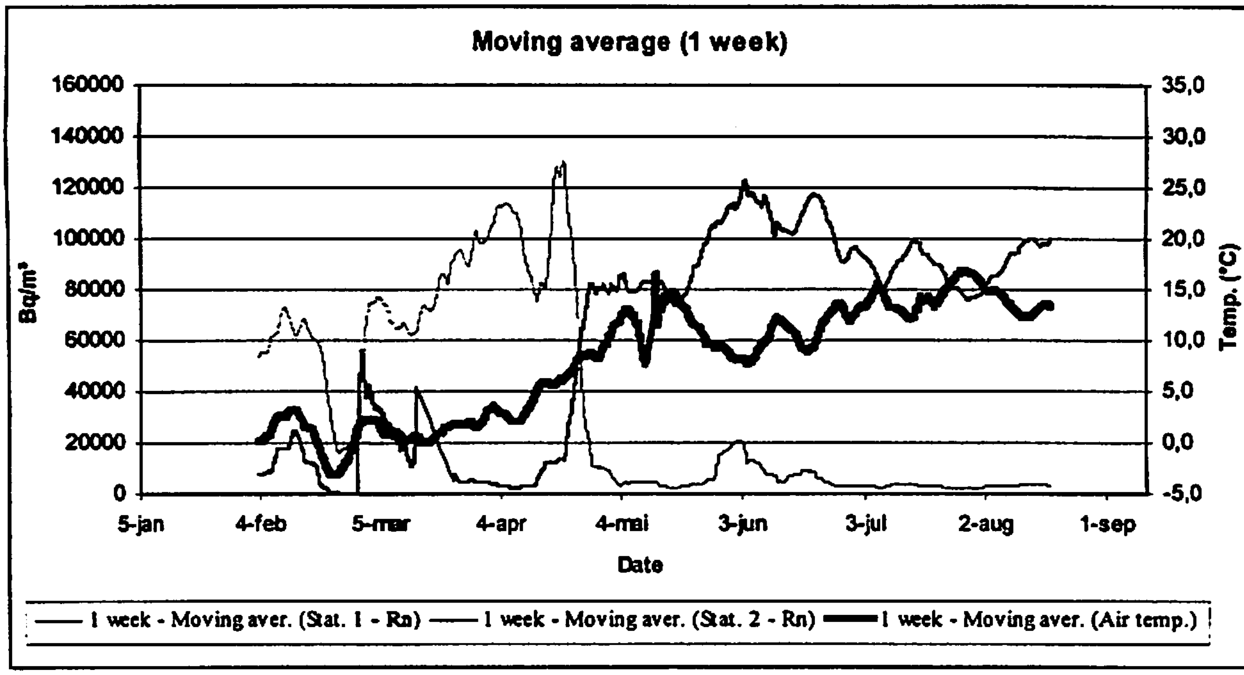

Figure 3: Moving average (1 week) for Radon concentration in both stations and air temperature.

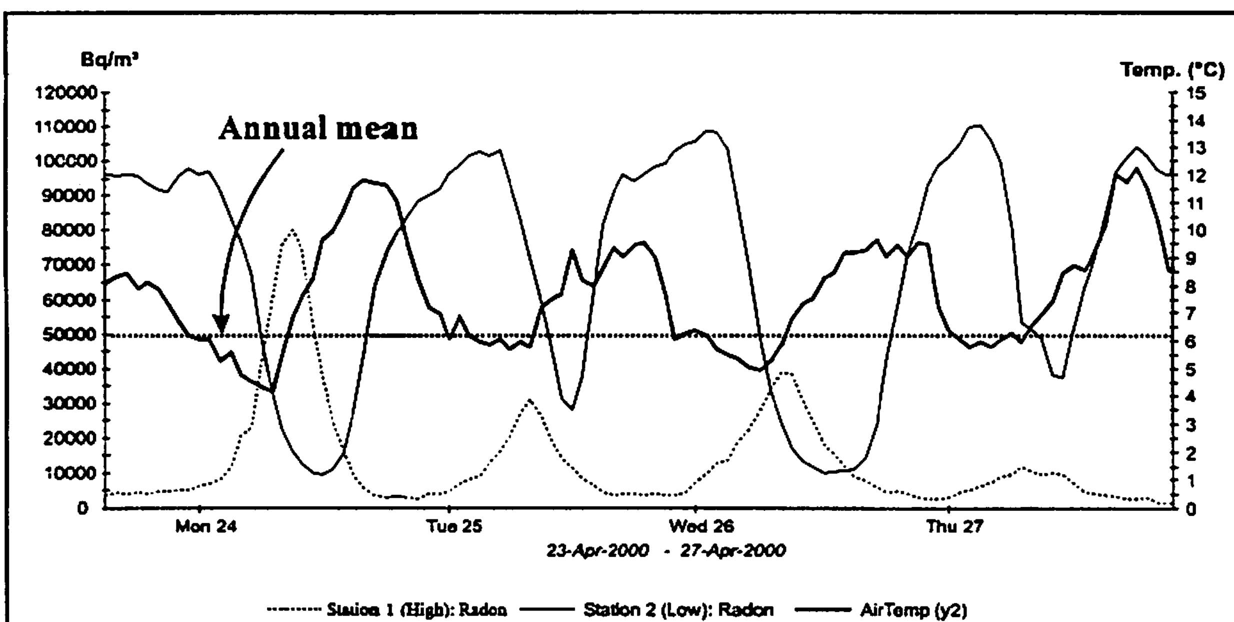

Figure 4: Daily changes in Radon concentrations and temperature in the period 23 – 27 Apr. 2000. This period is few days after the seasonal shift.

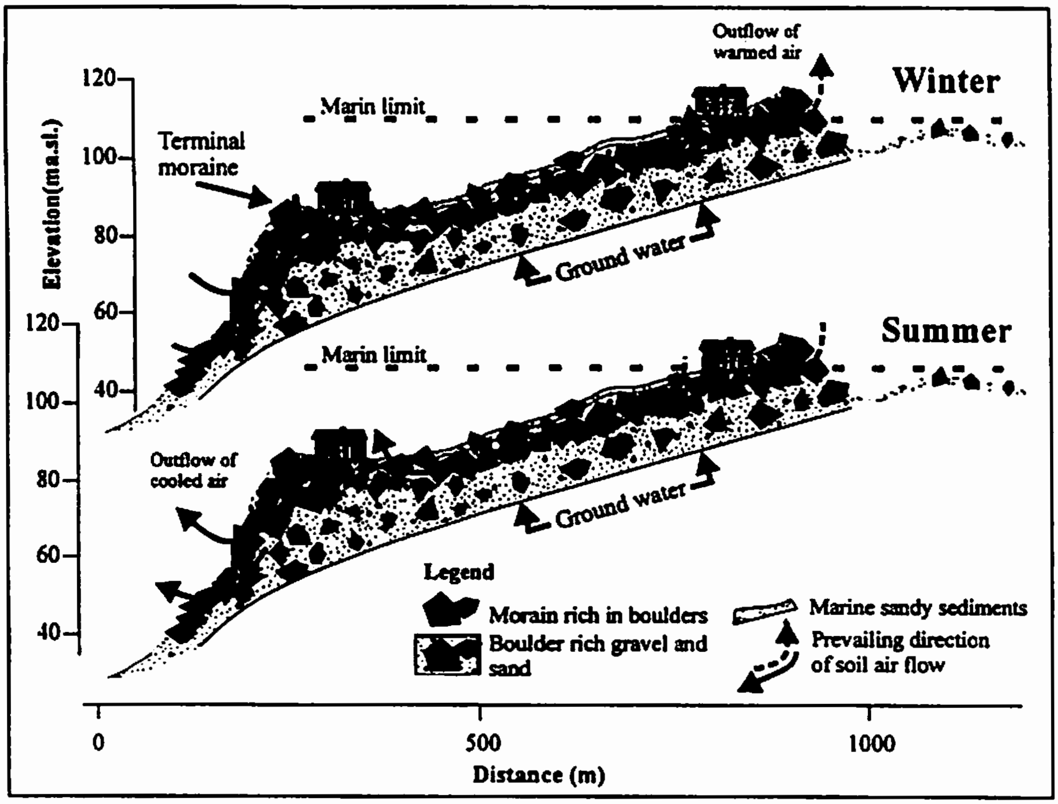

Figure 5: Radon content in the soil is clearly dependent on the seasons in this area. Due to the less permeable cover of sand and a soil horizon over highly permeable gravel, there is a prominent air movement in the ground. The air movement is controlled by temperature/pressure differences. In winter the warm and relatively light soil air is pushed towards the topographical higher parts and the lower parts are ventilated. In summer the soil air is cold and relatively heavy, and is pushed towards the topographical lower parts. This process ventilates the higher areas with air low in Radon.