Pergamon

Phys. Chem. Earth, Vol. 23, No. 9–10, pp. 949–952, 1998

0079-1946/98/$—see front matter

PII: S0079-1946(98)00125-6

Radon Monitoring in a Cave of North-Eastern Italy

M. Garavaglia, C. Braitenberg and M. Zadro

Department of Earth Sciences, University of Trieste, via Weiss, 1, 34127 Trieste, Italy

Received 25 April 1997; accepted 22 December 1998

Abstract

The measurement of Radon emanation from soil in seismic areas has given promising results in the research of seismic precursors. An important aspect in the precursory research is to have as complete knowledge as possible of the normal behaviour of the time variation of the concentration measured, in order to clean the data from all the known sources causing a non-seismic signal.
Since October 1994, a station for the joint monitoring of the horizontal deformation, tilt variations and Radon emanation from the soil operates in a natural cave located in a highly seismic area in NE-Italy.
The final goal of the research is to find possible correlations between Radon data in cave soil air with local seismicity and crustal deformations. In this work the results of the preliminary analysis of Radon data are shown. Disturbances of various causes on Radon data are found. First of all, we have found an apparent influence of the atmospheric pressure on Radon data. We shall proceed to remove the effect due to pressure and rainfall by means of a linear regression method.

1 Introduction

The measurement of spatio-temporal variation of Radon in soil (e.g. Csige I. et al., 1990; Hunyadi et al., 1991; Hakl et al., 1995; Kies et al., 1997) or water has given evidence that the emanation of this gas can be put in relation to tectonic stress-strain variations in the crust (e.g. King, 1993). In principle this is explained by the fact that gas fluxes along active faults or through microfractures influence the transport of Radon from its origin to the surface (Facchini et al, 1993). It has been proposed that Radon concentration is sensitive to crustal stress/strain variations, and could reveal earthquake preparatory mechanisms (e.g. reviews by Teng, 1980; King, 1986; Singh et al., 1991). A great problem in studies interested in detecting Radon signals tied to tectonic effects is the quantification of hydrologic and thermoelastic factors, which also influence the Radon concentration (Nazaroff and Nero, 1988; Chen et al., 1995; Pinault J.L. et al., 1996).
In this study we present the Radon measurements made in soil in the seismic Friuli (NE-Italy) area, and give a characterisation of the influence of barometric pressure and rainfall on the measurements.
In contrast to the more frequently used passive Radon detectors, which measure the Radon average concentration over several days, our apparatus is an active Radon detector and furnishes real time Radon variations (Braitenberg et al., 1997).

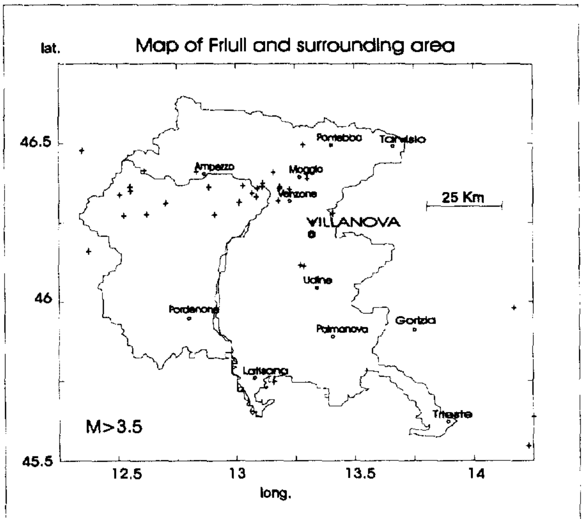

Fig. 1 - Map of the Friuli with local seismicity (M >3.5), 1977-95

2 The measuring site

The Villanova test site is located in the eastern part of the Southern Alps, in NE-Italy. The area is one of the most seismic of the Alps and has suffered in 1976 its most recent disastrous earthquake. The seismicity is attributed to the relative motion of the European plate and the Adriatic microplate. Presently seismic events are limited to the upper 15 km of depth (Slejko et al., 1987). In Fig. 1 a map of the area is shown, together with the seismic events characterized by M> 3.5 recorded by the OGS (Osservatorio Geofisico Sperimentale, Trieste) seismic network.
The test site is housed in a natural cave in a slab of limestone overthrusted into Eocene Flysch. The cave is located 60 m below the surface and has an annual temperature excursion of about 1.5°C. The ambient temperature and the barometric pressure are continuously recorded in the cave. The atmospheric and hydrologic parameters are measured moreover in a great number of stations throughout the region (ERSA, the Regione Friuli Venezia Giulia, Ufficio Idrografico e Mareografico di

Venezia and Climatology Laboratory of Earth Sciences Department, Trieste University).

3 Continuous Radon Monitoring Station

To measure the Radon exhalation we have used a device built at the I.F.G.A. (Institute of Applied General Physics) of Milan (Facchini, 1991); this is an α-meter (a scintillation counter of α particles) coupled with a measuring box. The detector consists of a transparent Plexiglas disk 2 mm thick, with a diameter of 350 mm. One of the faces of the disk is covered with a powdery, luminescent zinc sulphide sheet, protected by a mylar film. The sensitive face of the disk is directly exposed to the air in the measuring box; on the disk an aluminium paraboloid, with a specular surface, is placed. In the focus of the paraboloid a photomultiplier converts scintillation pulses to electric pulses. The photomultiplier is connected to an electronic chain (TESYS GPC-1) suitable for storing the pulses due to α radiation. The device works continuously, giving us the integrated data of α disintegrations every half hour. From both the efficiency and the background we can estimate that the α-meter is able to measure Radon concentration above 2-4 Bq/m^3; these concentrations are very small compared with common ground concentrations (1000 Bq/m^3 or more).

Air is pumped from the ground to the measuring box with a flux of 2 l/min. We choose a forced air suction in order to avoid stratification effects, very common for Radon, due to its elevated weight.

The variation in Radon concentration is given in Counts/hour. Conversion to the unit Bq/m^3 is presently not necessary as our interest relies on the measurement of relative variation. The Villanova station started measurements in October 1994. During a test period, starting July 1995 until June 1996, a second identical Radon station was installed in a separate branch of the cave. The distance between the two stations is about 20 m. The Radon concentration recorded in air at the two stations is almost identical, a part a small shift (Fig. 2).

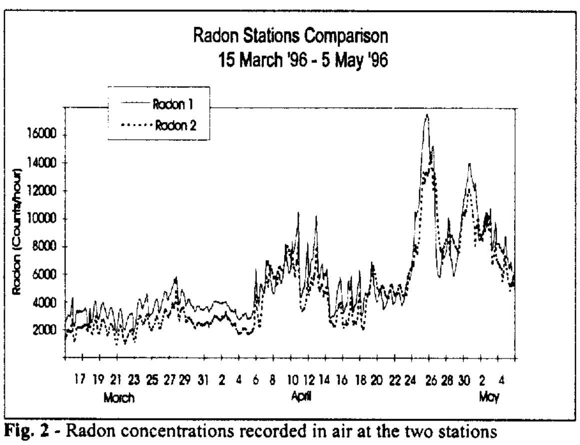

Fig. 2 - Radon concentrations recorded in air at the two stations

4 Data Analysis

Data presentation: in Fig. 3 Radon data are displayed (station1), from the time of installation (October 1994) of the station to the present. Unfortunately the electronic data acquisition system gave serious problems due to the high humidity in the cave, which lead to a considerable lack of data. The sampling is hourly. A seasonal component in the variation is observable, with generally low values for the months from November to February. An increase in the mean value, as well as in the amplitude of oscillation is observed when passing to the summer months. In the zoomed portion (Fig. 4) the near to daily regular variation is observed.

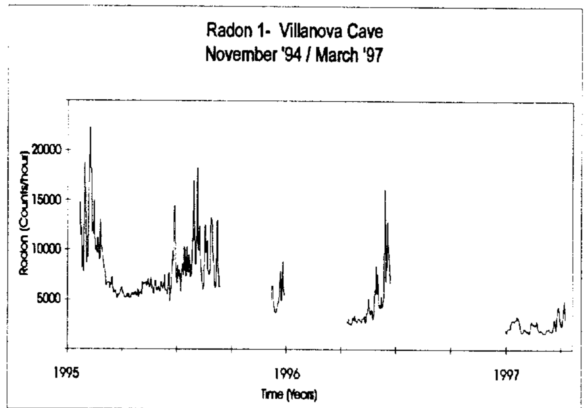

Fig. 3 - All Radon data at our disposal for the station1

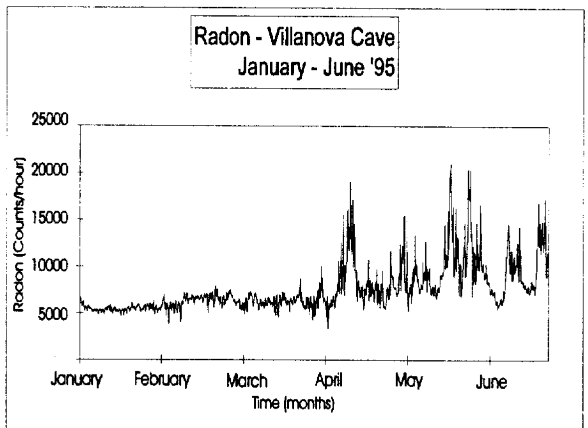

Fig. 4 - Radon concentration at Villanova cave - January/June '95

Local seismicity was low, not exceeding M=4.2 during the period of observation. In Fig. 5 Radon and seismicity are shown in the time window limited by the two conditions of data availability and occurrence of seismic events. Due to the variability of Radon (daily, monthly, seasonal) a conclusive opinion on the correlation with seismicity is difficult to take, if the influence of atmospheric factors is not quantified. Magnitudes and distances of the events from the Villanova station are given in table 1.

Table 1 - Local seismicity: magnitudes and distances of the events from the Villanova station - I.N.G. (National Institute of Geophysics) Rome

Local Seismicity
December '96 - March '97

year	Mon	day	hour GMT	Latitude	Longitude	Depth (km)	Magnitude	Ep. Dist. (km)
1996	12	22	01.30	46.4	12.9	10	2.5	40
1996	12	22	03.50	46.4	13.4	5	3.2	31
1996	12	23	00.40	46.4	13.1	7	2.5	25
1997	1	18	18.20	46.4	13.2	8.5	3.0	23
1997	1	18	19.47	46.4	13.2	5	3.2	23
1997	1	27	00.46	45.0	15.2		4.2	210
1997	2	15	13.20	46.4	12.9	10	2.9	40
1997	3	17	22.40	46.4	13.0		2.9	35

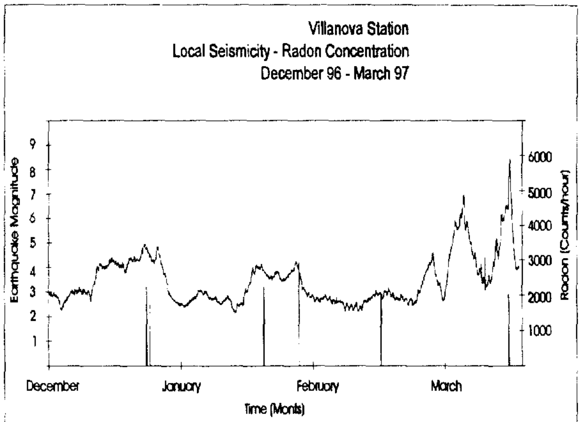

Fig. 5 - Local seismicity and Radon concentration from December '96 to March '97.

Spectral analysis: spectral analysis was performed in order to investigate the nature of the daily variation of Radon concentration. Data were preliminarily filtered (band pass 0.8 cpd-5 cpd) and analyzed on time segments limited by availability. In Table 2 the amplitudes and phases of the 24 h period are given for different segments. In Fig. 6 the spectrum of the time segment 1/11/94 to 30/6/95 is graphed. The peak value is found at a 24 h period.

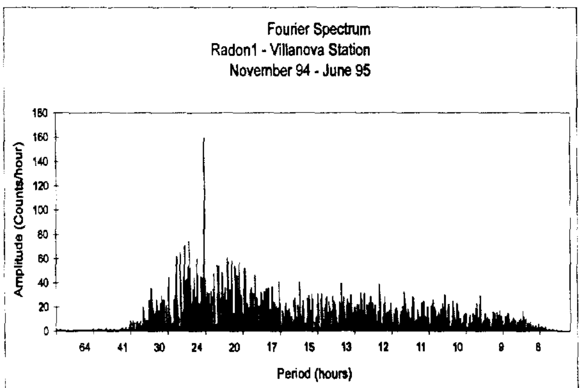

Fig. 6 - Spectrum of the time segment 1/11/94 to 30/6/95. The peak value is found at a 24 h period

Table 2 - Radon Spectral Analysis: Amplitude and phase of the 24 h wave. Radon data are pass-band filtered (0.8cpd-5 cpd).

Amplitude and Phase 24 hour Wave

Time Interval FROM	Time Interval TO	Amplitude (Counts/hour)	Phase (degree)
Radon1			
01.11.94	28.02.95	114	-107
01.03.95	30.06.95	185	-121
01.11.94	30.06.95	149	-116
01.03.96	30.04.96	113	-173
01.12.96	31.03.97	16	-160
Radon2			
01.07.95	31.08.95	234	-124

Pressure variation and Radon: a comparison of the pressure variation and Radon gave differing results, depending on the season. During the winter months the two quantities seem independent, as shown in Fig. 7 (correlation coefficient 0.03). During the summer months the influence of pressure on Radon increases (Fig. 8). We have found that the correlation is greater for the time derivative of pressure (correlation coefficient 0.4) , than the pressure alone (correlation coefficient 0.1).

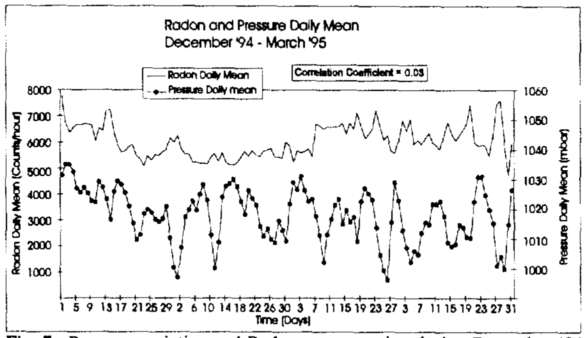

Fig. 7 - Pressure variation and Radon concentration during December '94-March '95 (daily mean).

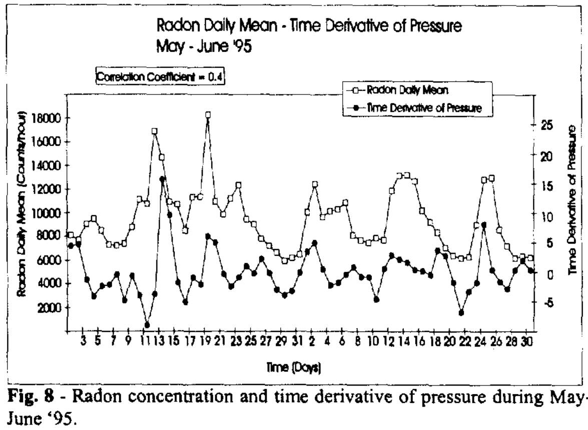

Fig. 8 - Radon concentration and time derivative of pressure during May-June '95.

Rainfall and Radon: Fig. 9 compares the rainfall measured close to Villanova (distance to Villanova 5 km) with the Radon variation during the period April '95-June '95. It is seen that strong rainfalls correspond to fast increases in Radon, followed by a slow decrease. The scatterplot of the Radon daily mean values and the daily rainfalls showed that the two quantities are quite independent for low rainfalls, whereas they are correlated for rainfalls greater than about 30 mm/day. Regression analysis for years 1995 and 1996 gave a linear coefficient of 191 (±75) (counts/hour) / (mm/day) and 159 (±28) (counts/hour) / (mm/day) for the Radon concentration increase in relation to rainfall (Fig. 10). Likewise, the correlation of areal deformation data, obtained with horizontal strainmeter, with the rainfall shows the prresence of a threshold of 40 mm/day.

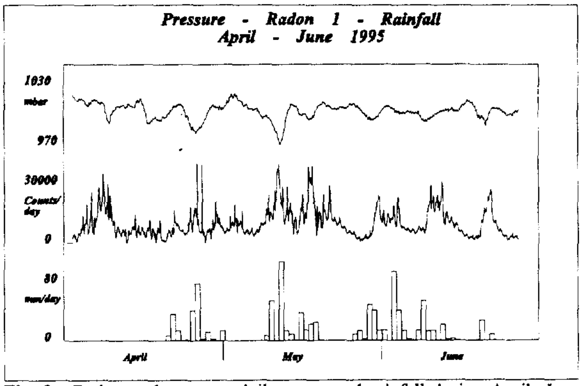

Fig. 9 - Radon and pressure daily mean and rainfall during April- June '95

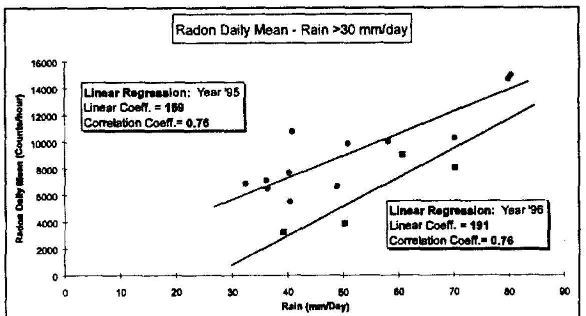

Fig. 10 - Scatterplot of Radon and rain >30mm/day

5 Conclusion

The influence of both pressure and rainfall cannot be neglected in studies seeking to detect Radon concentration increases due to tectonic movements. For our test site the pressure variations influence the Radon variation specially in the summer months. The time derivative of pressure has been shown to better correlate with Radon variations. Strong rainfalls (more than 30 mm/day) are shown to lead to an abrupt increase, with following decrease of Radon concentration. Nonetheless correction of the Radon data for the atmospheric factors remains problematic for the following main reasons. First, the strong seasonal variability in Radon variation, characterized by low amplitude in winter, and greater amplitude in summer. Second, the non-linearity of Radon response to the pressure variation and rainfall and third, the presence of limited time periods in which the response of Radon to the atmospheric factors is seemingly vanished.

Acknowledgements: This research as been supported by E.C. contract INCO-COPERNICUS ERB 15CT960205

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