The precursor effects in the mineral spring "Radonquelle", Bad Brambach prior to the January 14-19, 1997 earthquake swarm near Novy Kostel (NW Bohemia) (*)

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(ricevuto il 9 Giugno 1998; approvato il 18 Dicembre 1998)

Summary. — The main result of the 7 years' continuous radon recording at the mineral spring "Radonquelle", Bad Brambach was the identification of a "sensitive" epicentral area 12 km E of the measuring site (Heinicke *et al.*, 1995a, b; Koch and Heinicke, 1996). The derived model conception is based upon a fluidal connection (water, mantle-originated gases) between the hypocenters and the observed spring, and a spreading of seismotectonically induced pressure pulse within the fluidal system. From January 6 to January 20, 1997 a radon anomaly with a maximum on January 12 was recorded at the "Radonquelle". About 55 hours after that maximum an earthquake swarm with more than 100 single events occurred. The epicenter was located again within the above-mentioned sensitive region near Novy Kostel (Czech Republic). An increased gas flow in the spring capture was proved to be responsible for the generation of that anomaly, and confirmed the significance of the pressure pulse model.

PACS 91.30.Px – Phenomena related to earthquake prediction.
PACS 92.40.Kf – Groundwater.
PACS 01.30.Cc – Conference proceedings.

1. – Introduction

Since 1989, radiometric, geochemical and hydrological parameters are investigated in the Vogtland-NW Bohemian swarmquake region with regard to their suitability for earthquake prediction purposes. The epicenters of these swarmquakes are located on intersections of the Marianske Lazne Fault Zone (MFZ, NW-SE) which crosses the Eger Rift (WSW-ENE) as the other main tectonic element (Bormann, 1989; Procházková, 1988).

(*) Paper presented at the "Fourth International Conference on Rare Gas Geochemistry", Rome, October 8-10, 1997.
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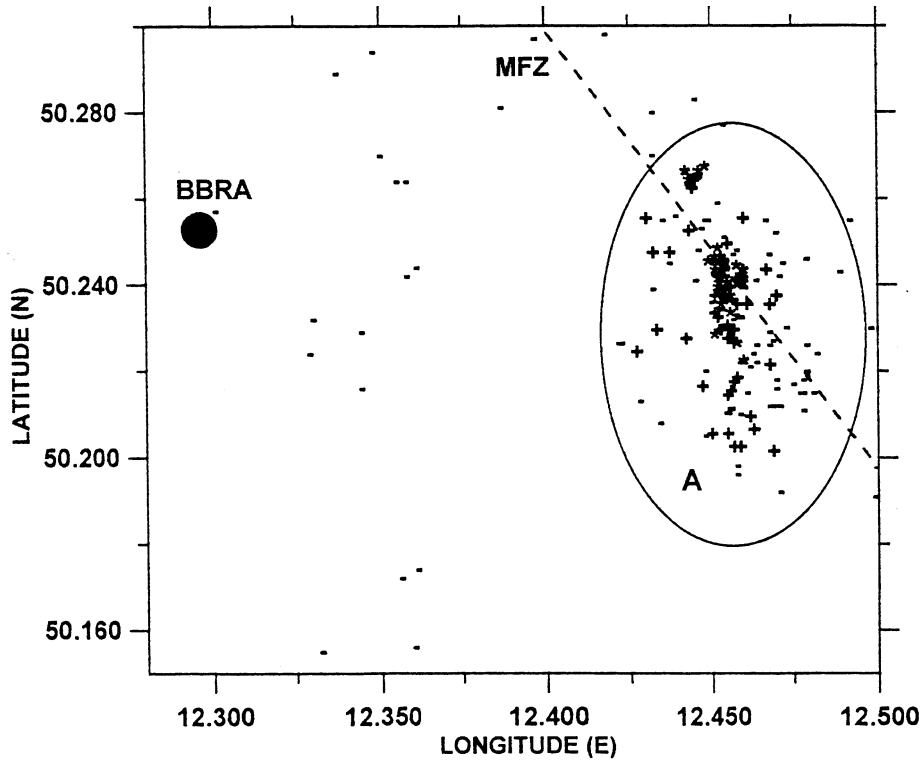

Fig. 1. – The "sensitive area A" 12 km E of Bad Brambach. The epicenters of the seismic events connected with a radon anomaly in the spring "Radonquelle" during the periods 1989-1992 and 1993/94 are marked by (+) and (★), respectively. Note the clustering within area "A" where about 35 anomaly-accompanied events occurred in 1993/94. (–) characterizes epicenters of the earthquakes without anomalies.

The local magnitudes are < 4 and the hypocenters between 3 and 12 km depth. Single events have focal depths of 8 to 20 km (Neunhöfer and Güth, 1988). The most frequent epicentre is located near Novy Kostel (50.190–50.240 N; 12.420–12.460 E) (fig. 1). The seismic network consists of 24 Czech and German stations with a regular data exchange. The area is characterized by numerous springs and mofettes with high CO_2 concentrations (a few g/l). The isotopic composition of the gases indicates a crust/upper mantle genesis (Weinlich *et al.*, 1993).

During the last 7 years the Bad Brambach mineral spring "Radonquelle" (^{222}Rn: 25 kBq/l, CO_2: 2.5 g/l) became the main location for geochemical precursor studies of earthquakes in the region. The hitherto investigations demonstrated the existence of a fluidal connection in the ground between the Novy Kostel hypocentres and the spring. Details and model conception are described by Heinicke *et al.* (1995a, b) and Koch and Heinicke (1996).

2. – Measurements

Table I gives an overview about the several parameters recorded continuously at the spring "Radonquelle" (see also fig. 2). Furthermore, similar supporting

TABLE I. – *Parameters measured continuously at the mineral spring "Radonquelle".*

Parameter	Measuring principle	Measured since	Temporal resolution
Radon in spring water (upper probe)	total γ-equivalent of Rn daughter ^{214}Bi	11/1989	40 min
Radon in spring water (lower probe)	γ-spectrometry of Rn daughters ^{214}Pb, ^{214}Bi	2/1995	15 min
Radon de-emanated from the water	Rn-α-activity of the gas	2/1992	15 min
CO_2 degassed from the water	gas concentration (relative units, mV)	6/1993	15 min
Radon in spring capture atmosphere	α-counting (calibrated device, Bq/m^3)	1/1996	30 min
Hydrostatic pressure at the spring bottom	relative units (mV)	1/1996	15 min (possible 10 s)

measurements at the springs "Eisenquelle" (gas flow rate, CO_2, radon), "Wiesenquelle" (radon in soil air), as well as climatic (air and soil temperature, atmospheric pressure, precipitation) and hydrological registrations (spring discharge, water temperature) are accomplished.

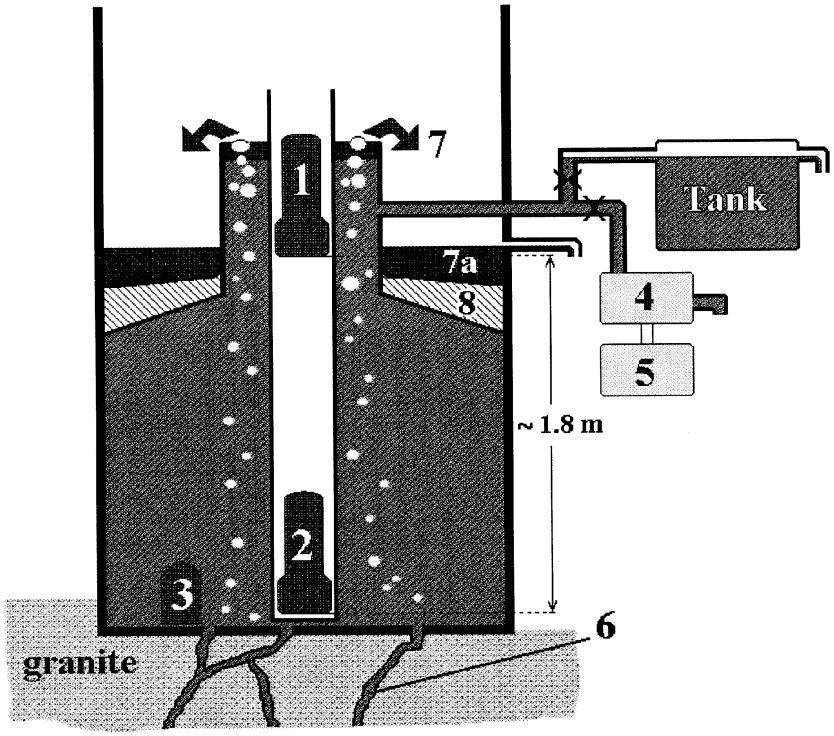

Fig. 2. – The overfoaming (7) of the "Radonquelle" spring capture prior to the January 1997 swarm-quake formed an additional water volume (7a) around probe 1 which recorded a γ-anomaly. The γ-spectrometer probe (2) did not show an anomalous behaviour. 3: pressure sensor, 4: degassing unit, 5: Rn- and CO_2-sensors, 6: fissures with mineral water, Rn and CO_2, 8: concrete.

Up to now, the most interesting results were achieved by means of the γ-probe installed in the upper part of the spring capture (No. 1 in fig. 2). The extremely stable long-term background and the comprehensive experience about possible anthropogenic influences (*e.g.* water storing for therapeutic purposes) permit the identification of very small anomalies.

3. – Results and discussion

From January 6, 1997 the γ-activity at the upper probe of the spring capture of the "Radonquelle" increased continuously up to values of 42% above the background (fig. 3). When it reached its maximum on January 12 the Institute of Geosciences of the University of Jena (Germany) and the Institute of Earth's Physics Brno (Czech Republic) were informed about that fact. About 48-60 hours after the γ-maximum, a swarm of more than 100 earthquakes occurred from January 14-19, 1997. The epicentres were located between 50.232–50.235 N and 12.454–12.458 E, again within the "sensitive" area around Novy Kostel. The maximum earthquake frequency was registered about 75 hours, the strongest event ($M_L = 2.6$) about 140 hours after the

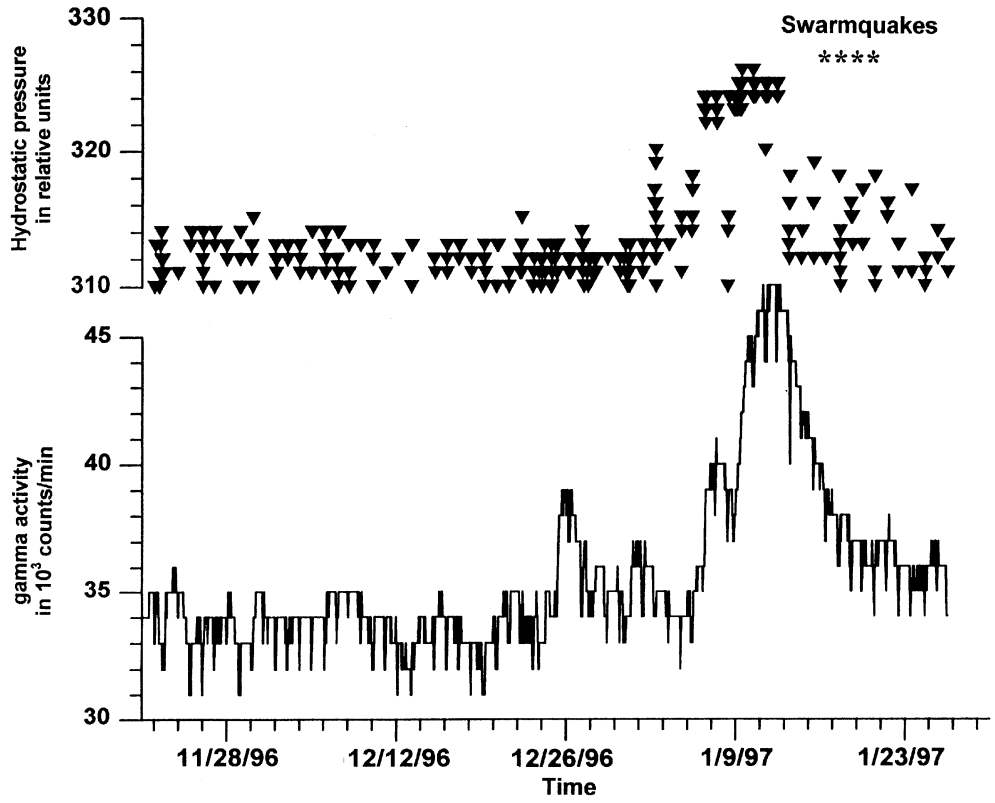

Fig. 3. – Anomalies of radon and hydrostatic pressure in the "Radonquelle" spring capture 5 to 6 days before the January 1997 earthquake swarm near Novy Kostel. Note the increased pressure in the water. The overflow of the capture starts at a pressure value of 324 units.

anomaly maximum. Thus, this radon anomaly became the first internal (unintentional) trial of an "earthquake prediction" in the Vogtland-NW Bohemian region.

At first sight, it was surprising that the other components recorded at the spring (table I) did not show any significant anomalous behaviour with the exception of the hydrostatic pressure (fig. 3) and the CO_2 degassed from the liquid phase. The pressure curve shows that the vertical capture tube had been overflowed for some days before the earthquake swarm. This process begins at a pressure value of 324 units. In spite of that, the spring discharge did not increase during that period. Obviously, lots of additional free CO_2 bubbles caused an overfoaming of the water, which was collected in the drainage ring around the capture tube (fig. 2). This ring is almost on the same level as the detecting area of probe 1, where a respective excess of γ-activity could be registered. The long and relatively shallow shape of the anomaly could be formed due to the duration of the additional water discharge out of the drainage ring, and due to the radioactive decay of radon of that water volume as well.

After all, the "radon" anomaly before the January 1997 Vogtland-NW Bohemian swarmquake was primarily a pressure and/or CO_2 anomaly. The assumption of an excess free CO_2 volume is also confirmed by the slightly increased values of dissolved CO_2 degassed from the liquid phase indicating an oversaturation of the water.

4. – Conclusions

The radon anomaly at the spring "Radonquelle" in January 1997 is a further indication to the existence of connection between the Novy Kostel hypocentres at the MFZ and the Bad Brambach mineral aquifer by upstreaming fluids. The fissure and crack systems with respective permeabilities up to > 10 km depth being necessary for such transport processes could be demonstrated by deep drilling programs and have been discussed comprehensively (KTB Report, 1993; Person and Baumgartner, 1995; Roeloffs, 1996; Zatsepin and Crampin, 1995). Radon anomalies appear to be the indirect result of a disturbed transport process of deep fluids, whereas the radon itself acts as a tracer near the surface. Obviously, the anomalous degassing phenomena are caused by generation of pressure pulses in the fluid-filled weak zone as a reaction of expanded rupture zones. Therefore, the pressure pulse (wave) model (Koch and Heinioke, 1996; Häfner *et al.*, 1985) offers a suitable explanation for the relatively fast information transmission (some hours up to some days) from the hypocentre to the surface over a distance of a few kilometres.

Further investigations are necessary to explain the reason for the different shapes of radon anomalies in the spring water, particularly the spike-like one.

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