The radon anomaly of Porcheresse (Ardennes, Belgium). A case study (*)

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Summary. — From a very high radon concentration in a dwelling of the village of Porcheresse, one discusses on of the significance of the numerous radon indoor anomalies detected in the southern part of Belgium.

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1. – Introduction

Radon concentration in dwellings is higher in the southern part (mean value: 85 Bq/m^3) than in the northern part of Belgium (mean value: 48 Bq/m^3). This difference is obviously linked to the geological features: Paleozoic basement to the south, sands and clays of the Cenozoic covering the infra-Paleozoic basement to the north (fig. 1).

In the Ardennes Massif constituted by the formations of the Lower Devonian (phyllites and quartzites), the radon concentrations in the underground waters and dwellings are the most important (see fig. 2, for example). These values appear very high in a region where there is no crystalline basement or granites.

In 1983 radiometric anomalies were discovered by a carborne survey (see fig. 1). From such spot anomaly a more detailed survey in the western part of the Ardenne anticlinal lead to the discovery of uraniferous mineralisations (see fig. 4, Oizy zone). These ocurrrences are linked to fractures filled with ferric oxyhydroxide. The application of radon in springs and soils with in addition, ground gamma-ray survey have permitted the discovery of about ten U-anomalies and occurrences in an area of 3 km^2 (Charlet *et al.*, 1995). They have been attributed to ferralitic paleo-alteration during the continental post-Paleozoic evolution of the Ardennes Massif (Charlet *et al.*, 1987). Besides a radon survey in dwellings of the area shows a great percentage of houses and cottages with strong anomalies (Doremus *et al.*, 1992).

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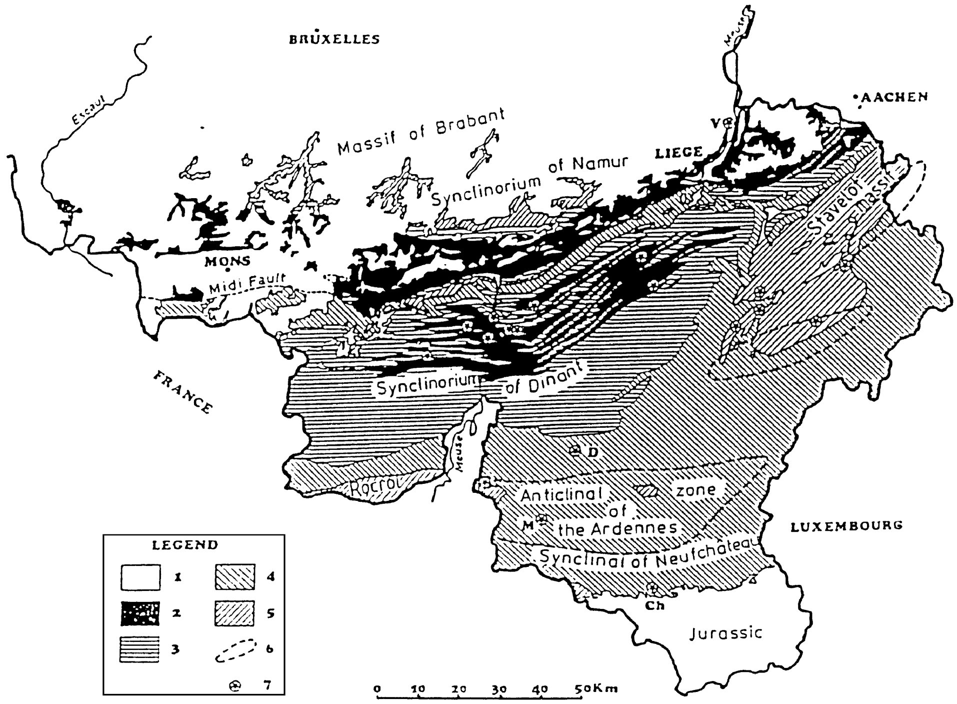

Fig. 1. – Simplified geological map. V. Visé, D: Davendisse, M: Monceau, Ch: Chiny, 1. Merocenozoic, 2. Silesian and limestone of Dinantian, 3. Middle and Upper Devonian, 4. Lower Devonian, 5. Cambrian-Ordovician and Silurian, 6. Limit of the methamorphic zones, 7. U-anomalies (after Charlet *et al.*, 1983).

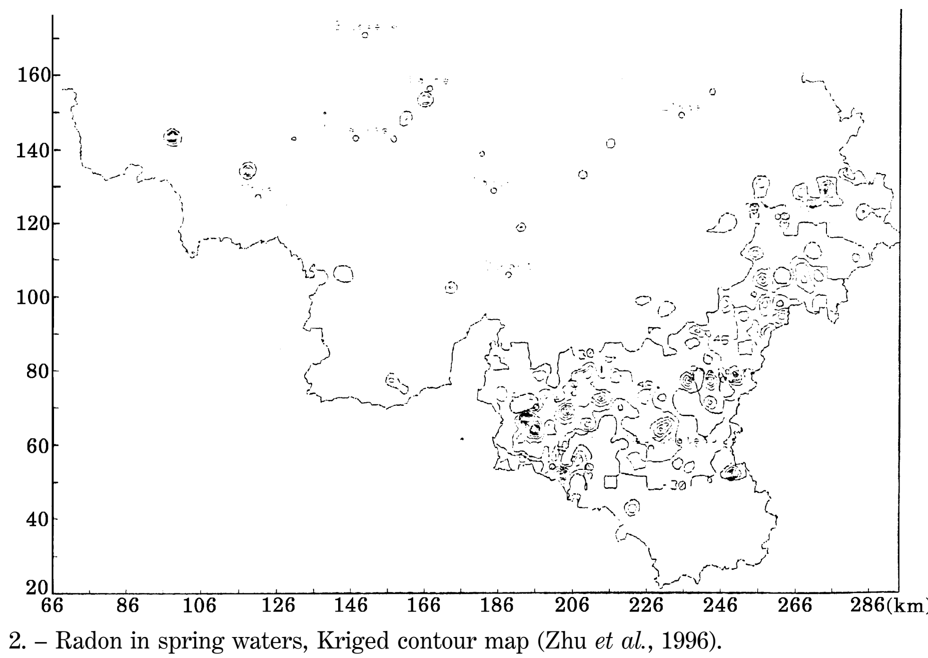

Fig. 2. – Radon in spring waters, Kriged contour map (Zhu *et al.*, 1996).

We think that other radon anomalies in the dwellings of the Ardennes Massif are in relation to similar geological context.

2. – The anomaly of Porcheresse

As part of the national measuring campaign on radon in Belgium, a house with a level of more than 4000 Bq/m^3 in the living room was detected in the village of Porcheresse (fig. 3). Detailed investigation performed afterwards did confirm this extreme value. Excepting this no such high levels were found in the neighbourhood.

Following this discovery, a field survey was undertaken. It has allowed to find some radiometric occurrences related to old iron mines (fig. 3, points 1, 2, 3 and 4). The alignment of the mining works (pits, trenchs, sotckpiled and wastes...) marks out a vein of hematite under the dwellings where radon anomalies had been detected. The iron vein is hosted by the Lower Devonian formations (phyllites, quartzites) of the paleozoic basement of the Ardenne Massif (5766). A radiometric survey of the stockpiled of iron ores allowed to find samples with a high grade of uranium (5757) with low concentration in Th and K.

Sample no.	eU (ppm)	Th (ppm)	K20 (%)
5757	113.5	0	0.05
5766	4.3	9.7	2.45

Note: about 6 km far from the Porcheresse iron mine an uraniferous occurrence had been discovered in 1982 by the Mons Laboratory (Dejonghe *et al.*, 1982). Various U-minerals have been found in a fractured zone with hematite (uraninite-U phosphates,...).

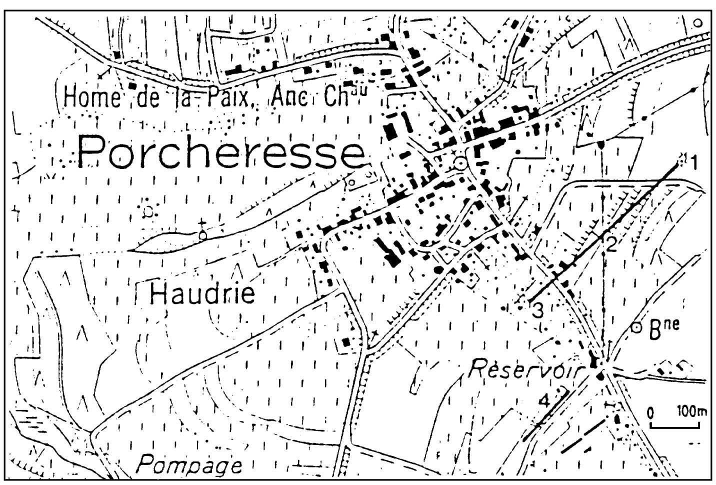

Fig. 3. – Porcheresse environment.

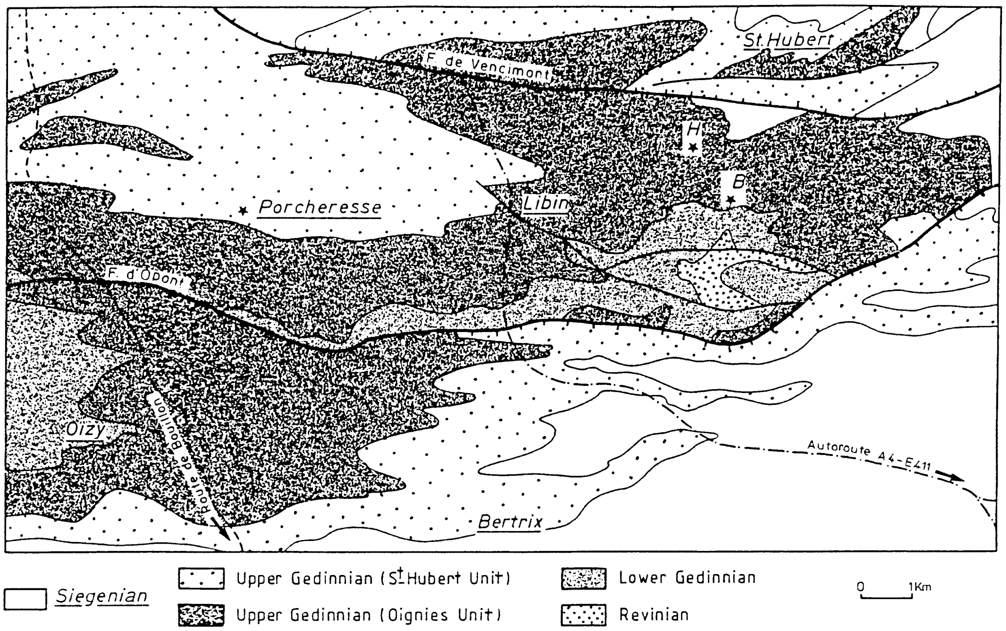

Fig. 4. – Geological context of the regional radiometric study (Ardennes massif).

3. – Radiometric anomalies on a regional scale (fig. 4)

On a regional scale, filling fractures have been studied in some quarries. They show an enrichment in U and sometimes in Th compared with the quartz phyllites of the Gedinnian (see for example 5780).

Sample no.	eU (ppm)	Th (ppm)	K20 (%)
5780	3.25	9.35	1.76
5782a	28.2	15.6	1.88
5782b	13.0	9.79	1.85
Bras 1	16.2	34	—

5782a: filling of fractures in the quarry of the Hatrival station (pt H see fig. 4 with ferric oxides and hydroxides and
5782b: hosted rocks of the fractures with strong alteration (note the decreasing of the U and Th enrichment);
Bras 1: carpeting of ferric oxide in fracture of the Bras quarry (very strong enrichment in Th).

4. – Geochemical investigations of the filling of the fractures (figs. 5, 6)

To understand a process of radioelement concentration in the fractured zones a geochemical study of REE (rare-earth elements) and trace elements has been performed.

All the REE and trace elements were determined by ICP-MS (Inductively Coupled Plasma-Mass Spectrometry) at the Royal Museum for Central Africa (Tervuren, Belgium). They have been normalized to the Post-Archean Australian Shales (PAAS).

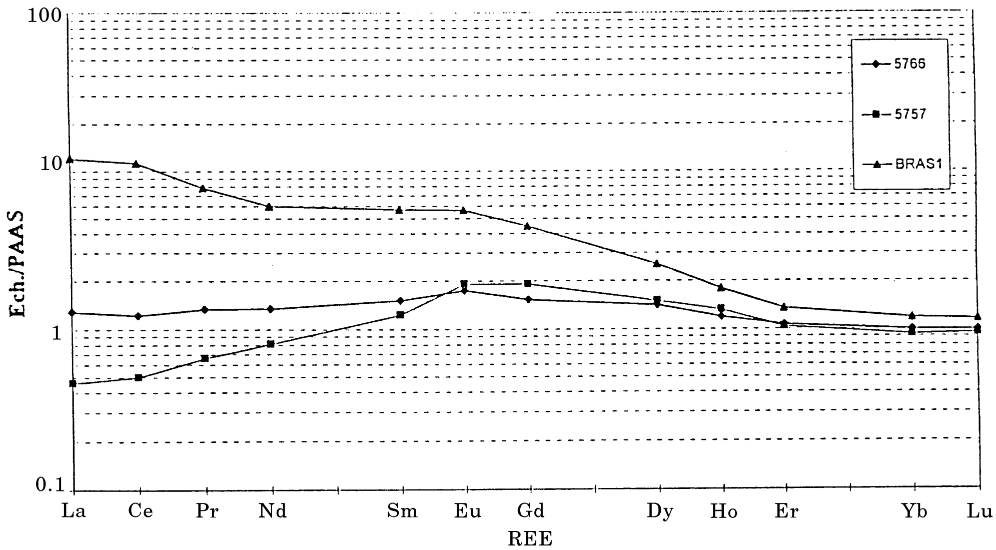

Fig. 5. – Traces elements distribution.

The iron ore 5757 shows a strong enrichment in U and Pb (Pb radiogenic) and a depletion in the other trace elements compared with the host rock (5766). The ferric oxide of the Bras Quarry shows an enrichment in U, Th and low REE.

Both these two behaviours are typical characteristics of the evolution of a ferralitic environment (residual phases with Th-REE and reconcentration of U trapped on high-surfaced iron phases possibly a gossan).

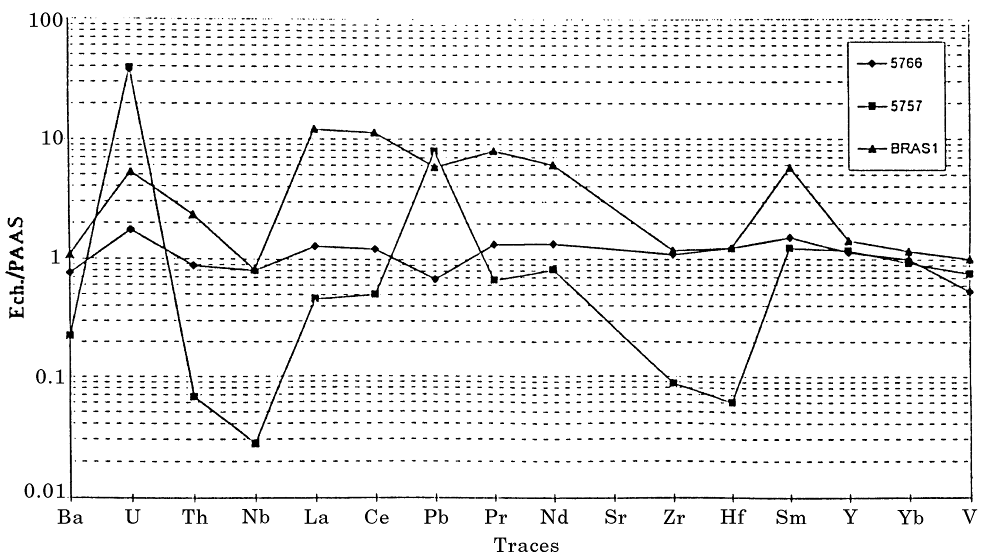

Fig. 6. – REE distribution.

5. – Conclusion

The geological history of the Ardennes Massif leads to a favourable context for the development of radon concentrations in underground waters and dwellings:

– A detrital sedimentation during the Paleozoic (phyllites, quartzites) with sometimes stratiform U-anomalies linked to the local black shales formations of the Siegenian (see fig. 1 Ch-Chiny).

– During the hercynian movement the Paleozoic series are folded and faulted: opened fractures appeared in the competent formations (quartzites, quartz phyllites, metamorphised rocks).

– During the post-Hercynian period the geomorphological and climate evolution of the Ardenne Massif leads to the development of ferralitic alteration. The tropical and subtropical climates lead to supergene processes for which the intensity is demonstrated by the great thickness of kaolin deposits or other alterites. In certain zones, these can actually reach several decameters of thickness and it may be assumed that they have covered all the Ardenne massif.

The fillings of opened fractures or microfractures by a loose material of high permeability constituted by ferric-oxyhydroxide, quartz and clays lead to the trapping of uranium by the high specific surface of these mineral phases.

So the local source of radon could be explained by

– the structural evolution of the hercynian massif

– the paleoclimatological evolution of post-Hercynian.

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