Radon in loess cover of SW Poland (*)

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Summary. — The spatial distribution of radionuclides within the loess cover was analysed by radiometric mapping and Rn soil gas measurements. Gamma spectrometric analyses (HPGe) and radon emanation measurements of samples indicate that radionuclides of the Th and U series coexist with K and their mineral system was closed long before loess sedimentation. They occur in plates of potassium mineral, biotite (with radioactive mineral inclusions) blown out from the adjacent hills. The only significant disequilibria are connected with ^{222}Rn migration into soil indicated by excess of ^{210}Pb. The Rn concentration can be explained recalculating the ^{226}Ra content of the loess.

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1. – Geological setting and methods

The loess cover of the Vistulain age of the N foreland of the Sudety Mts (SW Poland) is surrounded by hills of granites, mica schists, gabros and serpentinites, of contrasting radionuclides content.

Radiometric mapping has been done by RUM-1 radiometer with 3.2 inches NaI(Tl) scintillator. The time of measurement was 300 s and the altitude 1 m. Gamma photons of peaks: 2.62 MeV (^{208}Tl), 1.76 MeV (^{214}Bi) and 1.46 MeV (^{40}K) were recalculated in terms of the eU and eTh concentrations (see [1]). The distribution of measurement points was irregular. The results were evaluated using EXCEL and SURFER programmes. Maps of standardised values (see [2]) enabled comparison of data distribution.

HPGe gamma spectrometric analyses of ^{40}K, ^{137}Cs, ^{235}U, ^{234}Th, ^{226}Ra, ^{214}Pb, ^{214}Bi, ^{228}Ra, ^{212}Pb, ^{212}Bi have been done. The long-term average concentration of Rn was

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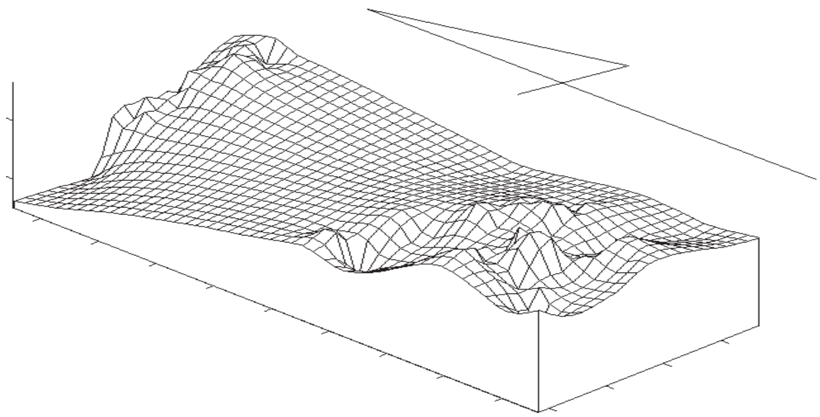

Fig. 1. – Three-dimensional view of the equivalent uranium concentration map (the arrow points North).

measured by Kodak LR115 type II. Detectors were placed in PE cups in the horizontal boreholes drilled in the vertical walls of the loess outcrops.

^{222}Rn emanation and the effective ^{226}Ra content E_{Ra} were measured by can technique [3].

The independent control of measurements was performed [4] using the gamma spectrometric results. The total amount of ^{222}Rn T_{Rn} (Bq/m^3) born in one cubic meter of the ground can be evaluated from the formula

$$T_{\mathrm{Rn}} = C_{\mathrm{Ra}} D_V V\,, \qquad (1)$$

where C_{Ra} is the ^{226}Ra concentration in Bq/kg, D_V is the volume density (kg/m^3), and V is a unit volume = 1 m^3.

The difference between the ^{226}Ra and ^{214}Pb concentrations corresponds to the ^{222}Rn

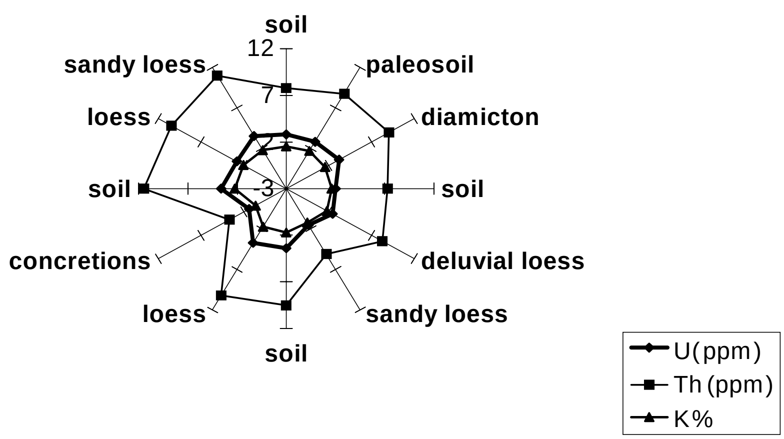

Fig. 2. – Concentration of main radionuclides in the various samples of the foresudetic loess cover.

TABLE I. – *Pearson's correlation coefficients of uranium, thorium and potassium concentrations.*

	U	K
K	0.74	
Th	0.93	0.91

emanation coefficient k_e. The product of T_{Rn} by k_e yields E_{Ra}, which should be equal in this case to the ^{222}Rn amount in soil gas of 1 m^3 of the ground. The soil gas volume V_g of 1 m^3 of the ground depends on its porosity:

$$V_g = pV . \tag{2}$$

The soil gas concentration of ^{222}Rn can be calculated using the formula

$$C_{Rn} = \frac{C_{Ra} D_V V k_e}{pV} . \tag{3}$$

^{210}Pb concentration due to its relatively long half-life time (22.3 years) reflects the average total concentration of ^{222}Rn in the ground in the last decades. The difference between the ^{226}Ra and ^{210}Pb concentrations of samples is the measure of ^{222}Rn emigration or immigration in natural ground conditions.

2. – Results

The three-dimensional view of the map of standardised eU (fig. 1) exhibits three main maxima of eU content. Similar is the distribution of the eTh and K content of the area under investigation. Variogram analysis and comparison with local geology indicates [4] that the maxima are located in the vicinity of hills of rocks with increased amount of the analysed radionuclides. Biotite is the main most radioactive common rock-forming mineral [5] and due to its occurrence as platy crystals it can be easily transported by the wind.

The radionuclides content of the typical fine-grained loess is more or less stable in vertical outcrops being lower in sandy loesses and carbonate concretions. The strong correlation of potassium, uranium and thorium content (see fig. 2, table I) indicates

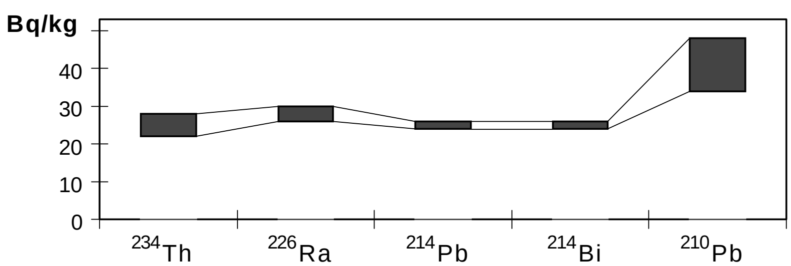

Fig. 3. – Concentration of various radionuclides of the ^{238}U decay series in the loess soil. Black squares correspond to the error bars.

TABLE II. – *Comparison of the measured soil gas radon concentration* C_{Rn}(kBq/m^3) *with the value evaluated on the basis of the gamma spectrometric results* C_{Rn}(kBq/m^3).

C_{Ra}(Bq/kg)	k_e	D_V(T/m^3)	p	evaluated C_{Rn}(kBq/m^3)	measured C_{Rn}(kBq/m^3)
30.7	0.16	1.60	0.40	19.6	21.7

that the potassium mineral biotite is the main source of radionuclides. Biotites of the Sudety Mts. often contain inclusions of zircon, monazite, uraninite and thorium bearing epidote-allanite (see [6-8]), even quartz crystals of this area may contain significant inclusions of uranium minerals [9].

The state of equilibrium between ^{234}Th and ^{226}Ra indicates that the mineral system has been closed long before dust sedimentation and no chemical migration of U, Th and Ra occurred in the loess cover (see fig. 3).

The increased ^{210}Pb concentration of the soil horizon and its local deficit in the underlying sandy loess indicates the ^{222}Rn migration. The measured C_{Rn} fits well with the C_{Rn} evaluated using gamma spectrometric data (see table II). The E_{Ra} measured by can technique varies in the range 1.7–4.2 Bq/kg.

4. – Conclusions

Radiometric mapping is a useful tool for investigation of loess dust transport. The spatial variation of the radionuclides content indicates that the Sudetic hills were their source. The main radionuclides-bearing mineral is biotite, often containing inclusions of radioactive minerals. Results of gamma spectrometric analyses and Rn concentration measurements can be combined into one model. Equilibrium within the ^{238}U series indicates that the mineral system has been closed long before dust sedimentation.

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