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GEOPHYSICAL RESEARCH OF THE WESTERN CARPATHIANS FAULTS – SOLOŠNICA (CASE STUDY)

GEOFYZIKÁLNY VÝSKUM ZLOMOV ZÁPADNÝCH KARPÁT – SOLOŠNICA (PRÍKLADOVÁ ŠTÚDIA)

Bibiána Brixová[1], Andrea Mosná[2], Andrej Mojzeš[3]

Abstract

The aim of this paper is to present the first part of the results of the Sološnica fault system, which is part of the project aimed at the multidisciplinary study of the Western Carpathians faults, through an example study. Measurement was in the area of Sološnica, on the eastern edge of the Vienna Basin at the western foot of the Malé Karpaty Mts. Two geophysical methods have been used - soil radon emanometry and seismic refraction tomography. The results from both methods correspond to each other. Increased soil ^{222}Rn values and decrease in spreading of P-waves velocities in the horizontal direction, in the area of 150 m, indicate the presence of a tectonic fault. Similar shows, even though less pronounced, were also on other sections of the measured profile. We will endeavour to verify and refine these data by completing electrical resistivity tomography (ERT) measurements and to perform complex geophysical measurements on other parallel profiles to determine the direction of fault system.

Abstrakt

Cieľom tohto príspevku je prostredníctvom príkladovej štúdie ukázať prvú časť výsledkov z oblasti sološnického zlomového systému, ktorý je súčasťou projektu zameraného na multidisciplinárny prieskum zlomov Západných Karpát. Meranie sa realizovalo v oblasti obce Sološnica, na východnom okraji Viedenskej panve pri západnom úpätí Malých Karpát. Z geofyzikálnych metód boli využité - pôdna radónová emanometria a seizmická refrakčná tomografia. Výsledky z oboch metód navzájom korešpondujú. Zvýšené hodnoty pôdneho ^{222}Rn a pokles rýchlostí šírenia sa P-vĺn v horizontálnom smere, v oblasti metráže 150m, naznačujú prítomnosť tektonickej poruchy. Podobné, aj keď menej výrazné prejavy, boli zaznamenané aj na ďalších úsekoch meraného profilu. Tieto údaje sa budeme snažiť

overiť a upresniť doplnením meraní elektrickej odporovej tomografie (ERT) a tiež realizovať komplexné geofyzikálne merania na ďalších paralelných profiloch pre určenie smeru priebehu zachyteného zlomu.

Keywords

Western Carpathians, Malé Karpaty Mts., tectonic fault, soil radon emanometry, seismic refraction tomography.

Kľúčové slová

Západné Karpaty, Malé Karpaty, tektonická porucha, pôdna radónová emanometria, seizmická refrakčná tomografia.

1 Introduction

An example study from Sološnica is a part of a comprehensive project focusing on the research of Western Carpathian faults-Multidisciplinary Research of Geophysical and Structural Parameters and Environmental Impacts of Faults of the Western Carpathians. Similar results, between 2007 and 2017, from the Horná Nitra Basin geophysicists published from the study of the Malá Magura fault system and from the region of the Slovenské Rudohorie Mts. from the study of the Muráň fault system. There were applied the geophysical electric survey methods; mainly vertical electrical resistivity sounding – VES, electrical resistivity tomography – ERT, dipole electromagnetic profiling - DEMP, spontaneous polarization - SP, complemented by magnetometric investigation and radon emanometry (Gajdoš et al., 2010; Vojtko et al., 2011; Putiška et al., 2012; Mojzeš et al., 2017). The project continues and this study focuses on the Sološnica fault system in the Malé Karpaty Mts. region. Its aim is to map the exact direction and orientation of this fault system using different geophysical methods and to contribute to the methodology of geophysical investigation of fault systems on basis of the measured faults from other geophysical measurements.

2 Geology of area

The village of Sološnica lies on the eastern edge of the Vienna basin at the western foot of the Malé Karpaty Mts. fig.1. The measured profile passes through Upper Pleistocene proluvial sediments in low cones that exist at the foot of the mountains. They are made of clay and sandy gravels with rock fragments passing through predominantly loamy - rocky hillsides and debris. The proluvial sediments overlap Paleogene clay stratum. The unit filled with Paleogene sediments you find superimposed on the northern part of the Malé Karpaty Mts. composed of the Mesozoic cover and nappe units (Marko et al., 2015). A regional-scale brittle shear zone described by Marko (2012) and Marko et al. (2013) cross the area as a Carpathian Shear Corridor (CSC). The CSC is an ENE–WSW-trending Cenozoic strike-slip zone rimmed by the My java and Horn morph lineaments (sensu Janků et al., 1984; Pospíšil et al., 1986), and rejuvenating steepened thrust boundaries between the Mesozoic nappe units of the Malé Karpaty Mts. as strike-slip and oblique-slip shear zones in the Neoalpine period (Marko et al., 2015). Also Gross and Köhler (1989) and Nemčok et al. (1989) mentioned tectonic fault, which broken Paleogene sediments on multiple fault blocks in this area.

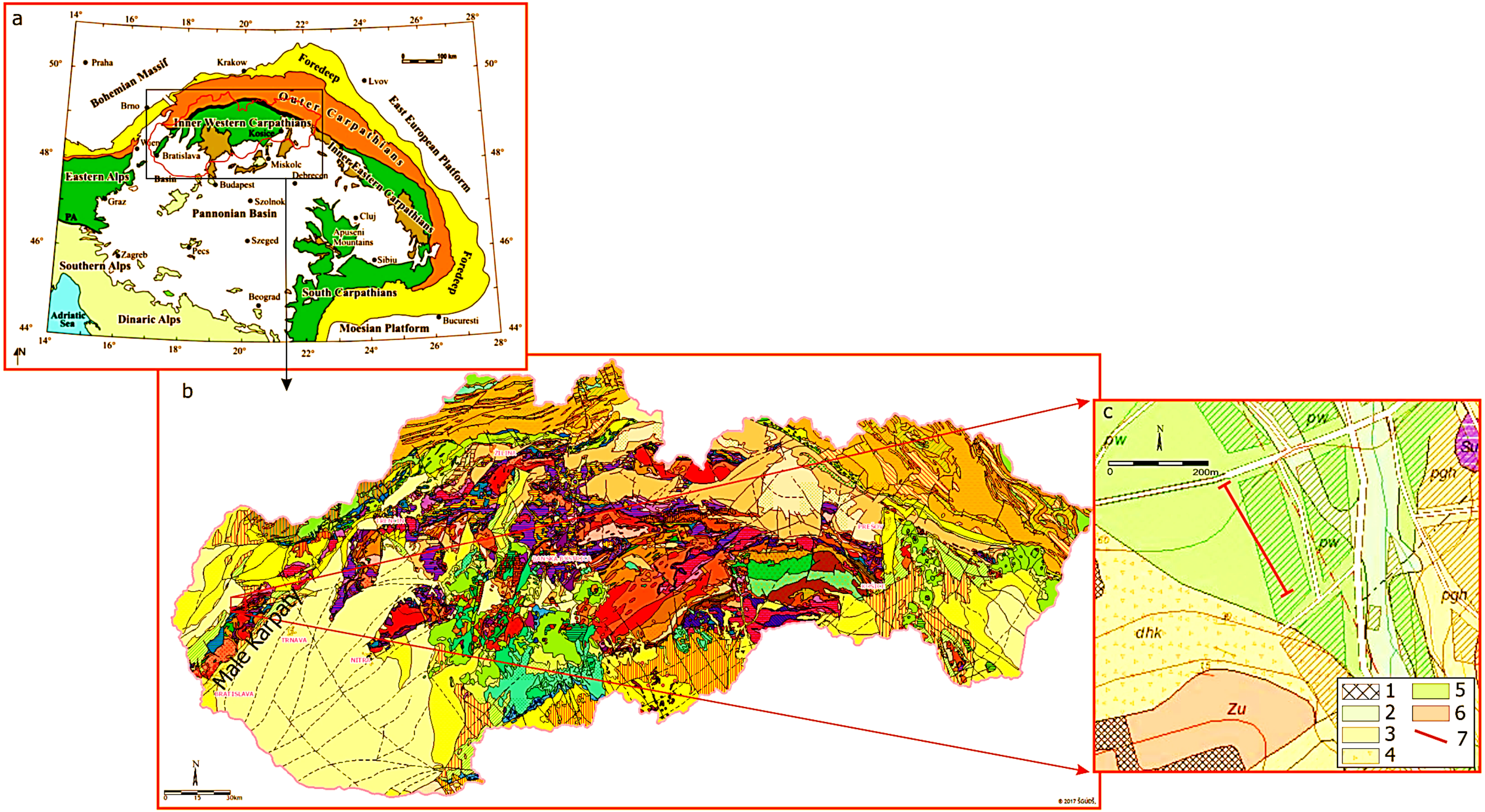

Fig.1 ***(a) Position of the Slovak Republic within the Western Carpathians, (after Bielik, 1998), (b) Geological map of the Slovak Republic, (http://mapserver.geology.sk/pgm/), showing location of the study area (c):*** *1 - anthropogeneous deposits: embankments, dumps and waste (Holocene), 2 - fluvial deposits: lithofacially undivided alluvial loams, sandy to gravel loams valley alluvial plains of rivers and streams (Holocene), 3.- deluvial –polygenetic sediments: sandy loams, deluvium (Pleistocene – Holocene), 4 - deluvial sediments: loamy-rocky debris (Pleistocene-Holocene), 5 – proluvial sediments: loamy and sandy gravels with rock fragments in low alluvial cones (Pleistocene), 6 – flysch: claystones, siltstones and sandstones (Eocene – Oligocene), 7– interpreted profile.*

They written that relatively older faults that are parallel to the axis of the Malé Karpaty Mts. – (NE–SW); the younger ones are perpendicular to the previous ones. The younger listric faults around Sološnica caused by an extension in the NW – SE direction. Consequence of this extension was a distinctive Sološnicko-Plavecká partial depression created in the area, filled with the aforementioned proluvial sediments flows.

As written in Marko et al. (2015), the study area has the advantage of good previous knowledge on local geology and tectonics gained (e.g. Marko et al., 1990; Marko and Kováč, 1997; Polák et al. 2011, 2012). In 1988, there was a unique out crop when a large map-scale fault in the CSC southern boundary fault zone exhumed approximately 150 m along its strike. This sub-vertical NE–SW-striking fault with an almost 1.5 m thick fault damage zone is named the Dúbrava fault (ca. 0.6 km southwards from our exploration area). The excavation front moved to the south accompanied by reclamation of the exploited mining areas so the Dúbrava fault is no longer exposed.

3 Methodologies

The presented results are the first phase of the Sološnica field survey focused on soil radon emanometry and seismic refraction tomography. Geophysical measurements took place at the southeaster edge of the village, at a 250 m long profile oriented to NW – SE, **fig. 1c**, with the aim of capturing the older fault of the system (NE – SW).

3.1 Refraction Seismics

Refraction seismic methods are among the geophysical methods that use artificially generated seismic waves to determine the depth of seismic interfaces below the surface and velocity of propagation of seismic waves between designated interfaces (Lilie, 1999). Seismic waves propagate from the source and the arrival of each wave detected along the geophone line. Refraction seismic uses direct wave and critically refracted waves that arise on individual interfaces. The requirement for the critically refracted wave is the increase in velocities with depth (Raynolds, 1997).

During the processing of data, the waves corresponding to the direct and critically refracted waves are marked on the seismogram. This then plots on the time of wave arrival vs. geophone distance. Velocities calculated from time-distance graph in interpreted layers and interface depths form a velocity model of the environment (Raynolds, 1997).

Seismic refraction tomography is an alternative to conventional refractive seismic interpretation methods (Sheehan et al., 2005). Tomographic methods use inverse techniques to reconstruct sub-surface velocities. They provide higher resolution and capture a change of velocity even in the horizontal direction. However, this method is suited when a good estimation of starting velocity model is available. As the complexity of the model increases, a better estimate of the starting model is required and the resultant model will be more reliant on the staring model (White, 1989).

The seismic measurement in Sološnica was carried out using 24-channel DMT equipment with 10 Hz vertical geophones and a hammer as a source. The entire profile of 235 m was measured by three overlapping lines of 120 m in length and overlapped by 12 geophones. On each of the lines, the geophone spacing was 5 m and the position of the source was shifted every 10 m, with the first shot

2.5 m before the first geophone and the last shot 2.5 m after the last geophone. At each position, the record was stacked up from 7 to 10 shots. The measured data were processed in Reflex Version 8.0 (developed by Sandmeier, 2017) by refraction seismic processing methods, which were subsequently the input model for Refraction Seismic Tomography.

Since the first soil air sample for emanometry was taken in close proximity to the busy road, the seismic profile expansion was slightly displaced. The scheme is in fig.2.

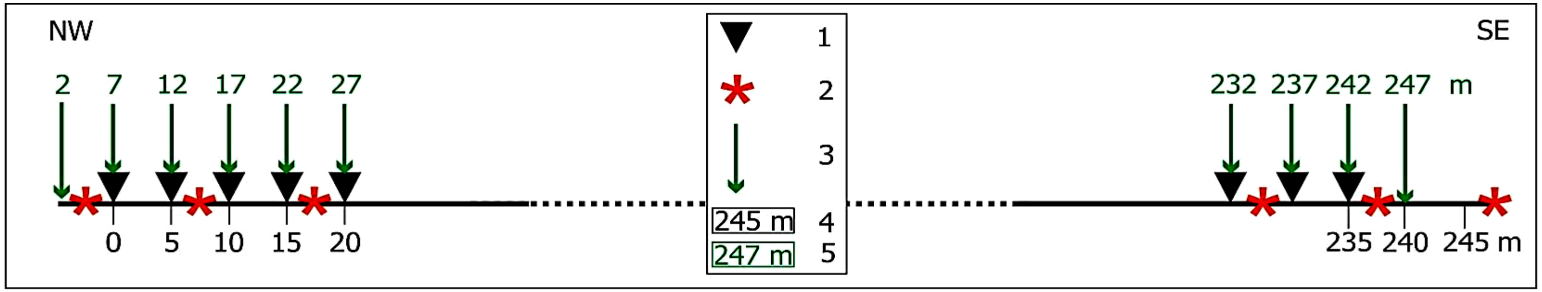

Fig.2 Sampling point distribution pattern for radon emanometry and seismic line; 1 – position of geophone, 2 – position of source, 3 – position of radon soil sample, 4 – meters distribution for refraction seismic profile, 5 – meters distribution for radon emanometry profile

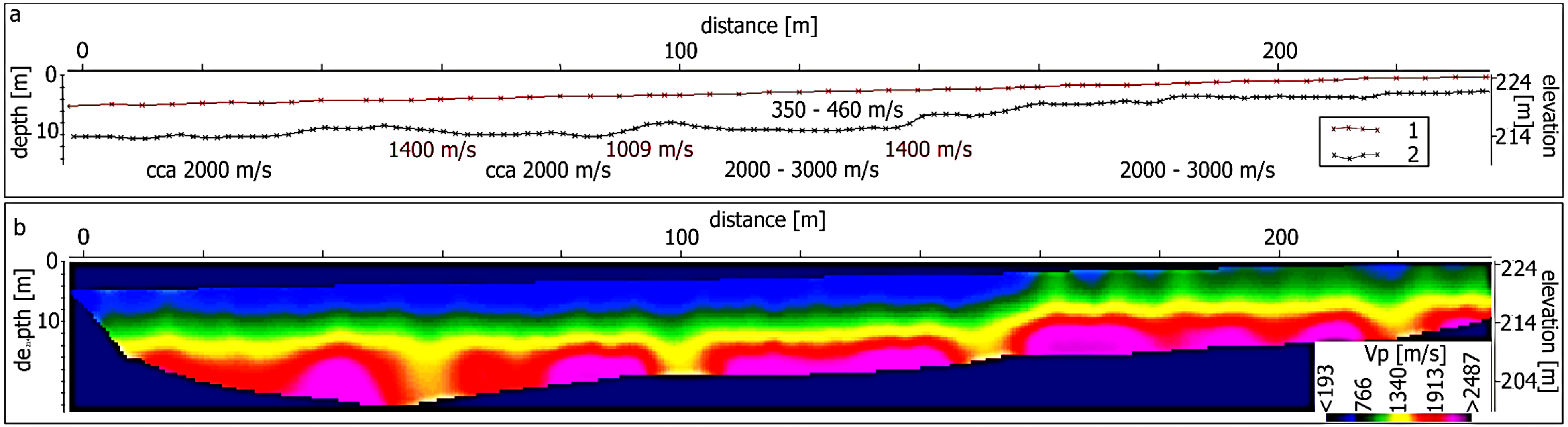

Fig.3 (a) Refraction seismic measurements – the velocity model, 1 – tomography, 2 – velocity interface; (b) Seismic refraction tomography – the velocity profile.

3.2 Radon Emanometry

Radon emanometry is among the atmospherically geochemical methods of exploration. By in-situ method, based on the analysis of the amount of alpha radiation produced in the soil air sample located in the detection chamber of the apparatus, it is possible to determine the activity concentration of radioactive gas (emanation) of ^{222}Rn in units of [kBq×m^{-3}] (kilo Becquerel per cubic meter). In general, it assumed that increased levels of radon in soil air are present in the segregated rock and soil environment in the fault zones because of better permeability and communication of deep fractures with geological structure (Singh et al., 2006). Our measurements of the activity of soil radon ^{222}Rn were realized using radon detector LUK-3R (SMM Praha, Czech Republic). At the studied 247 m long profile, 50 points were measured in 5 m spacing. Soil samples were taken from a depth of 0.8 m.

4 Results

The result of the refraction seismic measurements is the velocity model of the environment, fig.3a, and the velocity tomographic cross-section, fig.3b. In the first half of the profile, a low-velocity layer with $v_p < 500$ m / s representing the soil cover and segregated and weathered rock environment is caught up to a depth of about 3 m below the surface. Furthermore, a distinctive velocity-separating layer interface with velocities of up to about 1200 m / s from a layer with significantly higher velocities ($v_p > 1800$ m / s), interpreted as clay stratum, was interpreted on the tomographic profile. The velocity data above the interface corresponds to the alluvial and sandy gravel of the proluvial sediments. Based on the course and depth of the interpreted interface and the significant drop in velocities in the horizontal direction, a tectonic fault was identified on the 150 meter. Similar velocities are also occurring on sections in the area of 100 m and 58 m.

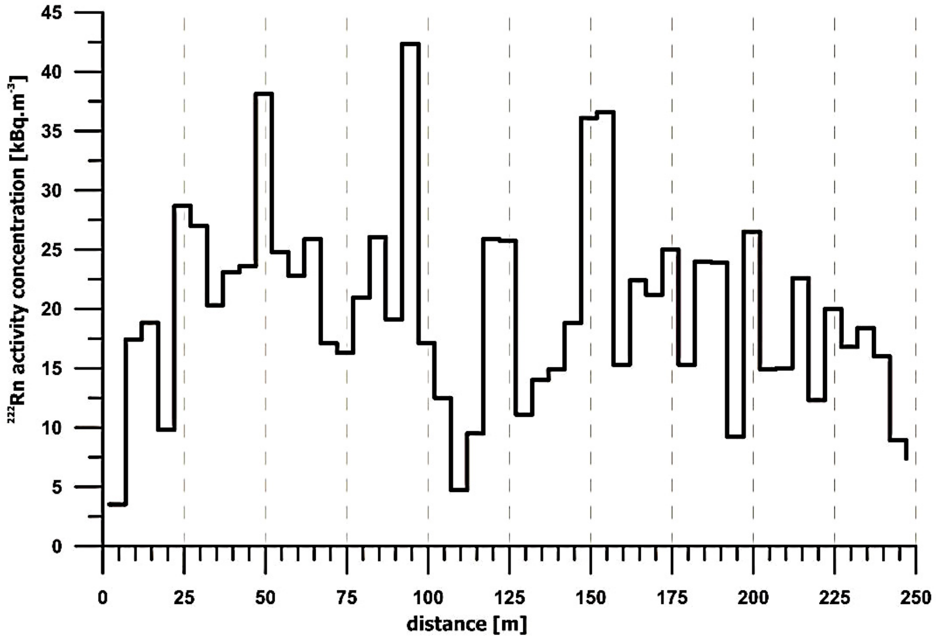

Fig.4 Soil radon emanometry

The result of radon emanometry is a graph of processed measured values corrected for uniform sampling depth and a uniform volume of sample taken, fig.4. Most of the ^{222}Rn activity concentration values in the soil air are respectively at the level of 20-kBq×m^{-3} and represents a relatively homogeneous monotonous environment. At some points the values exceed this level and could indicate the presence of fault disturbances (point 47 m with a value of about 38 kBq×m^{-3}, point 92 m approx. 42 kBq×m^{-3}, zone 145 -155 m approx. 36 kBq×m^{-3}. Of these maxima, it appears to be the most interesting zone between 145–155 meters, which (but also the other above-mentioned maxima) could actually indicate the presence of a fault. Particularly remarkable is the fact that this maximum activity concentration of soil ^{222}Rn correlates very well with the results of refraction seismic.

5 Conclusions

The results from both geophysical methods satisfactorily correspond to and confirm the presence of a tectonic fault in the 150 m area of the seismic profile (corresponding to 155m for emanometry). Similar events (elevated radon values and drop in the horizontal direction) were also recorded on other sections of the profile. We will endeavour to verify and refine these data by supplementing the ERT measurements and to perform measurements on other parallel profiles to determine the direction of the fault.

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[1]RNDr. Bibiána Brixová, Katedra aplikovanej a environmentálnej geofyziky, Prírodovedecká fakulta Univerzity Komenského, Ilkovičova 6, Bratislava, bibiana.brixova@uniba.sk

[2]Mgr. Andrea Mosná, Katedra aplikovanej a environmentálnej geofyziky, Prírodovedecká fakulta Univerzity Komenského, Ilkovičova 6, Bratislava, andrea.mosna90@gmail.com

[3]doc. RNDr. Andrej Mojzeš , PhD. Katedra aplikovanej a environmentálnej geofyziky, Prírodovedecká fakulta Univerzity Komenského, Ilkovičova 6, Bratislava, andrej.mojzes@uniba.sk