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In-mine Geoelectric Methods for Detection of Tectonic Disturbances of Coal Seams

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SUMMARY

In-mine geoelectric methods - the geoelectric seam-sounding and geoelectric transillumination - were applied for detection of fault zones in a coal mine. The measured data were interpreted using geoelectric tomography algorithm. Appreciable agreements were found between the location of tectonic zones predicted by the interpretation and those observed during the mining extraction.

Introduction

Efficiency and safety of coal mining necessitate that the tectonic and stratigraphic features of the coal deposits should be well known. By surface geophysics this information is generally not obtainable with sufficient accuracy. If one hits a fault, a pinch-out, or a dirt bed during coal-drawing, this would probably not only reduce the output, but could even cause a water inrush. Tectonic disturbances of coal series are traced by openings and headings, but these methods are expensive. However, there are geophysical methods for which the necessary measurements are carried out within the mine, and by which even smaller disturbances of the coal series can be detected: the in-seam seismic reflection and transmission methods (Krey, Arnetzl and Knecht 1982) and in-mine geoelectric methods (Csókás et al., 1986)

The in-mine geoelectric methods

The two in-mine geoelectric methods called "geoelectric *seam-sounding* and *transillumination*" allow the determination of tectonic and stratigraphic disturbances of coal beds. Both are based on the fact that a coal bed is a layer of high resistivity embedded in a medium of considerably lower resistivity. In the fault zones the roof and floor layers (of much lower resistivity) get connected, so that the apparent resistance of the medium measured by an equatorial vertical dipole array is lower than it would be in its undisturbed situation. This decrease in apparent resistance allows one to detect the tectonic disturbances. The principle of the methods is shown in Fig. 1**.**

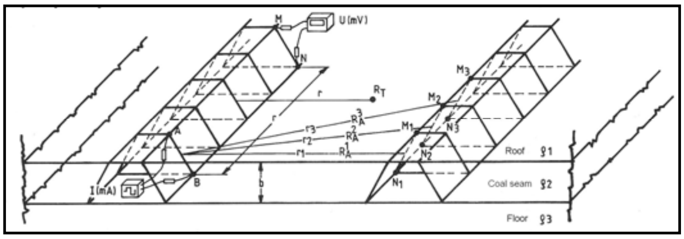

Figure 1. *The scheme of seam-soundings and seam-transillumination.*

The current electrodes ***A*** and ***B*** and the potential electrodes ***M*** and ***N*** are placed at the upper and lower boundaries of the coal seam in an equatorial vertical dipole array. For *seam-sounding* the dipoles are placed in the same drift with distance ***r*** between them. If two drifts are accessible in the investigated area, we can use geoelectric *seam-transillumination* too. In this case the current dipole is placed in one of the drifts and the potential dipole in the other. The dipole array should cover the bed in a fan-shaped form as far as possible. The apparent resistivities and the apparent resistances ***R*** of an undisturbed layered medium with coal seam can be calculated by means of the formulae given in Csókás et al. (1986).

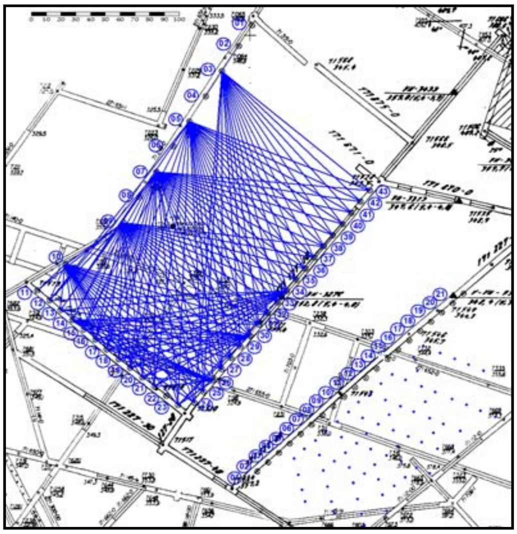

Figure 2. *Map of the geoelectric seam-soundings and transillumination measurement system.*

Area of investigation

In order to detect tectonic disturbances in-mine geoelectric measurements has been carried out in Cigel coal mine of "Hornonitrianske bane, a.s. Prievidza", Slovakia. Due to previous tectonic motions the coal seam was broken into blocks (Sasvári et. al. 2006.). The location of the geoelectric investigations and the measurement system are shown in Fig. 2. ***Seam-soundings*** were carried out in the drift "171 227-20" along with a 200 m length. The current and potential electrodes were placed in vertical drillings reaching the coal-bedrock boundaries. 21 vertical dipoles were used for the measurement equidistantly; the distance between them was 10 m. The positions of dipoles are numbered from 01 to 21 on the map. The reference points of the seam soundings are depicted on Fig. 2 too. (See blue points on the map). ***Seam-transilluminations*** were made on the area bordered by four drifts (Fig. 2.). The current and potential dipoles were placed similar with the seam-soundings. 43 vertical dipoles - numbered from 01 to 43 - were manufactured in the drifts. The drift signed “177 675-0” was closed unfortunately, so we can’t use it for measurements.

Geoelectric model of the investigated area

In order to interpret the seam-soundings and transilluminations measurements it is necessary to know the apparent resistance $\boldsymbol{R}^{(0)}$ of the non-disturbed coal seam structure. This apparent resistance master curve can be either measured on sites without disturbances, or calculated it with the knowledge of the geoelectric model parameters (Csókás et al., 1986). To determine these model parameters we performed additional drift sounding measurements along the upper (roof sounding) and lower boundaries (floor sounding) of the coal seam. From the measured apparent resistivities the model parameters of the structure (thicknesses and resistivities) were estimated using a 1D joint inversion procedure (Dobróka et al., 1991) (Table 1.). Using

11,0 Ωm	*roof*
660,0 Ωm	5,5 m, ***coal seam***
20,3 Ωm	5,8 m, *floor*
0,8 Ωm	8 m, *clay*
200,0 Ωm	2 m, *floor seam*
1,0 Ωm	*deep floor*

Table 1. *Geoelectric model parameter estimated by joint inversion*

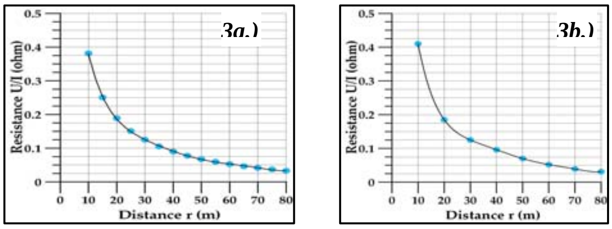

Figure 3*. Apparent resistance* $\boldsymbol{R}^{(0)}$ *master curves.* ***a)****:calculated from model parameter,* ***b)****:measured.*

these model parameters apparent resistance master curve for seam sounding were calculated (Fig. 3a). To compare these values with the measured curve, the apparent resistance curve is shown in Fig. 3b. measured in non-disturbed coal bed.

Results of seam-soundings

From the apparent resistance master values $\boldsymbol{R}^{(0)}$ and from the measured apparent resistance values $\boldsymbol{R}$ (Fig. 4.) the seam sounding deviations $\boldsymbol{E}$ were computed for k^{th} dipole-dipole position with the formulae: $E_k = \frac{R_k - R_k^{(0)}}{R_k^{(0)}}$. The computed deviations map is shown in Fig 5.

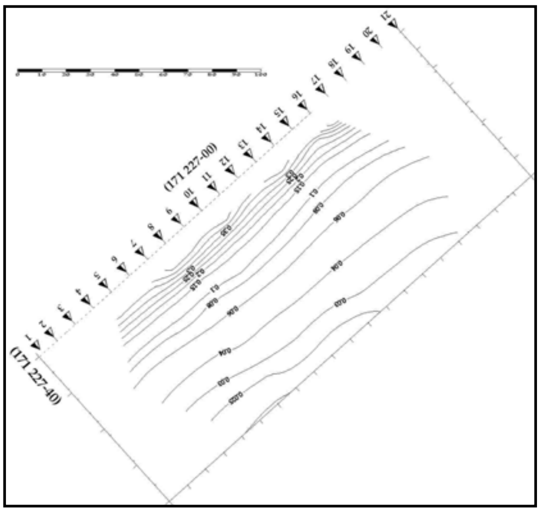

Figure 4. *Apparent resistance* ***R*** *map from seam-soundings.*

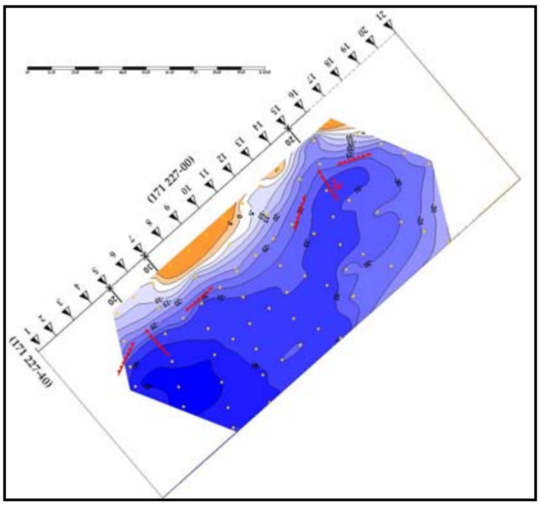

Figure 5. *Apparent resistance deviation* ***E*** *map, with interpreted faults (isolines in %).*

The apparent resistance deviation map (Fig. 4.) computed by means of the seam sounding data measured in the drift "171 227-20" shows clearly the view of tectonic zone (red lines along the 30%).

Results of seam-transilluminations

In order to determine the distribution of the inhomogeneities of coal bed we have developed an ***in-mine geoelectric tomography method***. The variations of apparent resistivity are mainly influenced by the inhomogeneities of the coal deposit. In the geoelectric tomography algorithm we relate the local relative change in apparent resistivity and the relative difference between the measured (R_k) and calculated ($R_k^{(0)}$) apparent resistances as

$$E_k = \frac{1}{A_k}\int_{L_k} e(x,y)dA_k \quad \text{with} \quad E_k = \frac{R_k - R_k^{(0)}}{R_k^{(0)}} \quad \text{and} \quad e(x,y) = \frac{\rho_a - \rho_a^{(0)}}{\rho_a^{(0)}}$$

where L_k is the surface of integration lying in the plane of the coal seam, A_k is its area. Expanding the local inhomogeneities in series by Chebishev polinomials $e(x,y) = \sum_{n=0}^{N}\sum_{m=0}^{M} B_{nm}T_n(x)T_m(y)$ an overdetermined set of inhomogeneous linear equations can be derived for the unknown B_{nm} coefficients. After solving it, the $e(x,y)$ distribution of the inhomogeneities can be calculated and plotted.

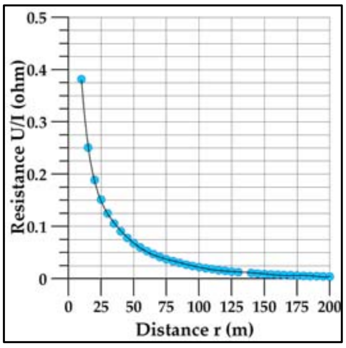

Figure 6. Apparent resistance $\boldsymbol{R^{(0)}}$ *master curve for tomography, calculated from model in Table 1.*

The high (negative) deviation zones in the in-mine geoelectric tomography map (Fig. 7.) calculated from the seam-transilluminations measurements are interpreted as tectonic zones (red lines).

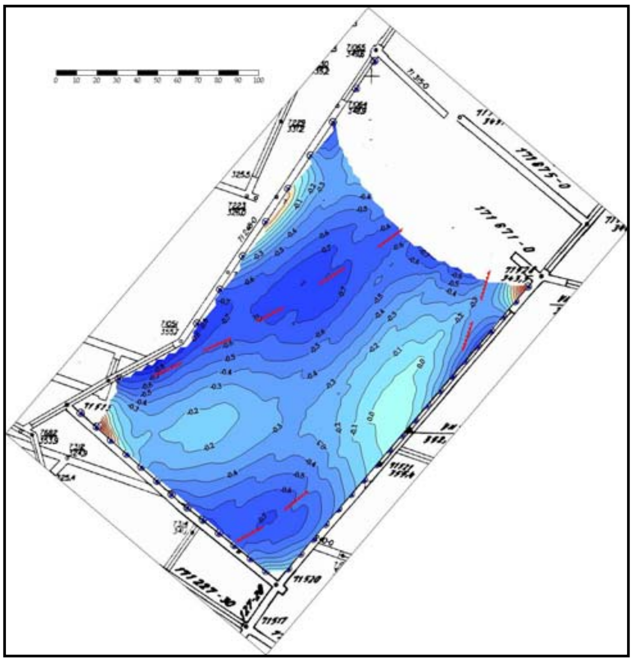

Figure 7. *Apparent resistivity deviation* ***e*** *map, from geoelectric tomography, with interpreted faults.*

Comparison of results from in-mine geoelectrics and observation by exploitation

The measurement area was extracted in the meantime and a map of the observed tectonic fault zones has been given by the colleagues at Cigel mine (Fig. 8). The tectonic zones observed during the mining extraction are depicted by blue colour. So it is possible to compare the predicted in Fig. 5. and Fig. 7. (red coloured lines) and the observed fault zones in Fig. 8. This comparison shows, that all the main observed tectonic faults were predicted in the interpretation of seam-sounding and seam-transillumination (tomographic) measurements. There are some less accurate predictions in the tomography map near the closed drift "177 675-0". As is well-known the full tomographic coverage can appreciably increases the accuracy and reliability of the tomographic reconstruction, which was not available in our measurements.

Conclusions

In order to detect tectonic disturbances two previously developed in-mine geoelectric method were used in Cigel coal mine of “Hornonitrianske bane, a.s. Prievidza“, Slovakia. The interpretation of our in-mine geoelectric seam-sounding and seam-transillumination measurements showed the existence of tectonic fault zones in the investigated coal seam structure. The measurement area was later extracted and the observed tectonic fault zones were mapped. It was found that there is a good agreement between the predicted and the observed faults. The accuracy of predictions is reduced in the zones of tomographically poor coverage.
Our experiences show that the applied geoelectric methods are quick, accurate and economic under mine conditions.

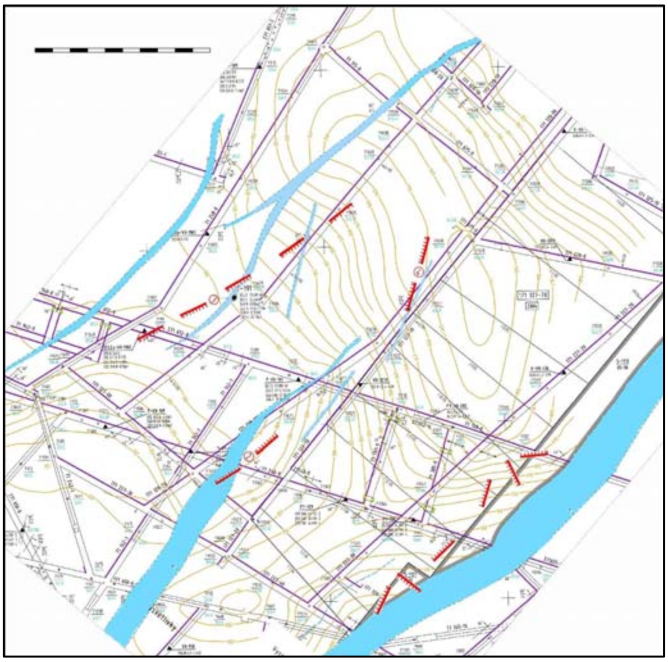

Figure 8. *Comparison between the faults predicted in the interpretation of geoelectric measurements (red colour) and observed in the mining extraction (blue colour).*

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