Application of In-mine Geoelectric Methods for Detecting Tectonic Disturbances of the Coal Seam Structure.

[1]Gyulai Ákos, [1]Ormos Tamás, [1,2]Dobróka Mihály, [1,2]Somogyiné Molnár Judit
[1]University of Miskolc
[2]MTA-ME Geoengineering Research Group

Summary
In-mine geoelectric methods – the geoelectric seam-sounding and geoelectric transillumination – were applied for detection of fault zones in a coal mine. To determine the model parameters of the coal seam structure seam- and drift-sounding measurement were carried out along the boundary of the coal layer (roof sounding) and that of the floor (floor sounding). From the measured apparent resistivities the model parameters of the structure were determined using a joint inversion procedure (Dobróka et al., 1991).The measured data were interpreted using geoelectric tomography procedure. Good 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 dipole array is lower than it would be in its undisturbed position. This decrease in apparent resistance allows one to detect the tectonic disturbances. The principle of the methods is shown in Fig. 1**. :**

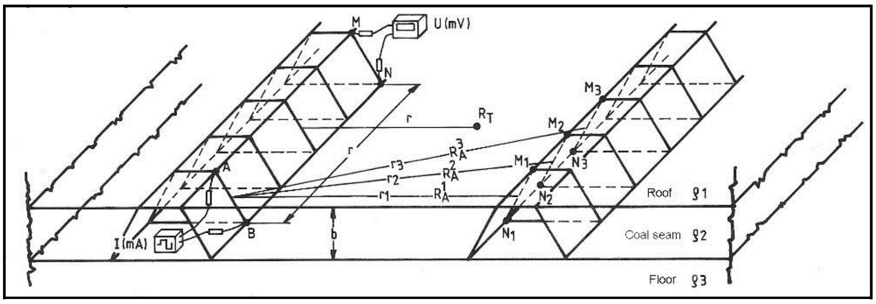

Figure 1. *Measurement arrays of the geoelectric seam-soundings and transillumination methods.*

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 dipole array. For *seam-sounding* the dipoles are placed in the same drift. The distance ***r*** between the dipoles is gradually expanded during sounding. If two drifts are accessible in the investigated area, we can use geoelectric *seam-transillumination*. 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 coal series can be calculated by means of the formulae given in Csókás et al. (1986).

The in-mine geoelectric tomography algorithm
Using the geoelectric transillumination method the apparent resistance can be measured. Its variations are determined by the inhomogeneities of the medium. In order to determine the distribution of these

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inhomogeneities we have developed an in-mine geoelectric tomography method. Usually the resistivity of the coal deposit is much higher than that of the adjacent layers. Consequently, 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.

Application

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. The well-planned mining operations requires the knowledge of tectonic zones. The seismic velocities of the seam and that of the embedding layers exclude the use of in-seam seismic methods (Sasvári et. al. 2006.). Because of this reason it was decided by the staff of the mine to ask in-mine tomographic investigations.

The location of the measurement area 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 boundary. 21 vertical dipoles were used for the measurement equidistantly, the distance between them was 10 m. The reference points of the seam soundings are depicted on the figure (blue points in the coal seam).

In-seam geoelectric (tomographic) transillumination measurement were made between the "171 127-00", "171 127-10","71-248-0", and the "177 675-0" drifts (Fig 2.). The current and measurement dipoles were again placed in vertical drill holes (reaching the coal-bedrock boundary). 43 vertical dipoles (for current (AB) or measurement (MN) purposes) were manufactured along the drifts. The drift signed "177 675-0" was closed unfortunately, so the measurement system was not optimal for tomography.

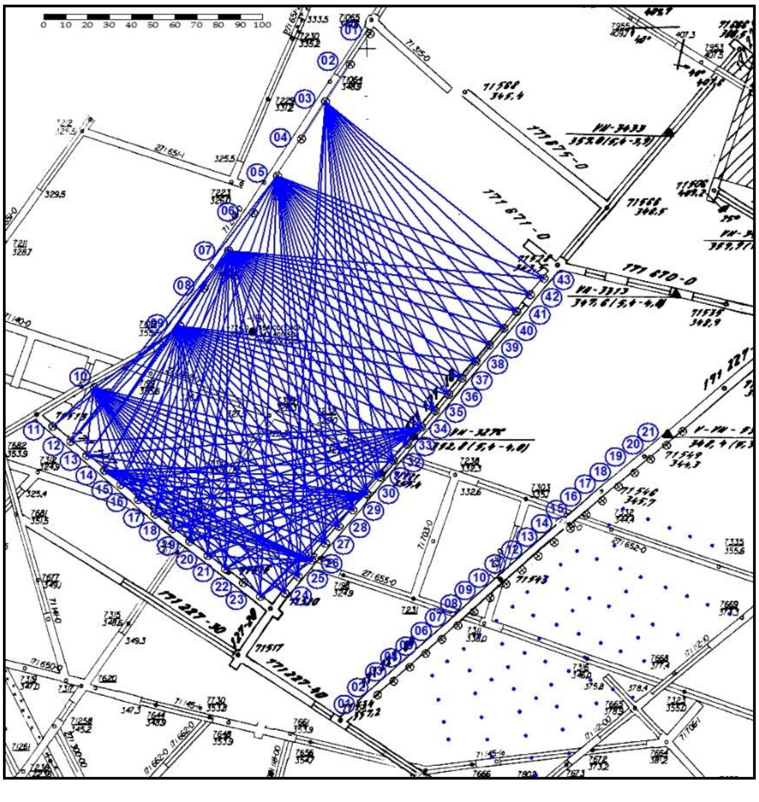

Figure 2. *Map of the geoelectric seam-soundings and tomographic measurement system.*

Measurements and results

In order to interpret the in-mine geoelectric measurements it is necessary to have the apparent resistance of the non-disturbed coal seam structure. The apparent resistance master curves can be calculated in the knowledge of the geoelectric model parameters (Csókás et al., 1986). To determine these parameters we performed seam sounding measurement along the boundary of the coal and the roof (roof sounding) and that of the floor (floor sounding). From the measured apparent resistivities the model parameters of the structure were determined using a joint inversion procedure (Dobróka et al., 1991). It was realized, that our measurements in Cigel mine can be interpreted by assuming a six layered geological model with the parameters shown in Table 1. Using these model the apparent resistance master curve shown in Fig. 3a. can be computed. This master curve was used in calculating the seam sounding deviation map (Fig. 4.) and in the tomographic reconstruction map (Fig. 5.). Fig. 3b. shows also the apparent resistivity master curve.

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

Table 1. *Parameter of the model in mine Cigel.*

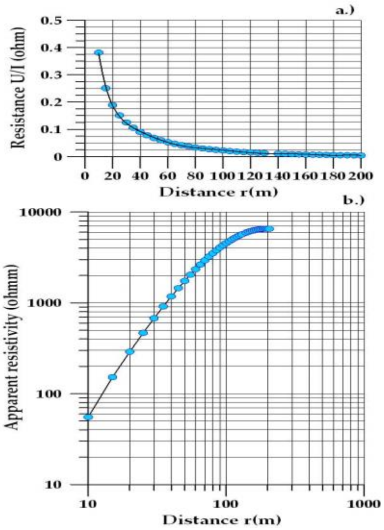

Figure 3*. Master curves for seam sounding. a) apparent resistance; b) apparent resistivity*

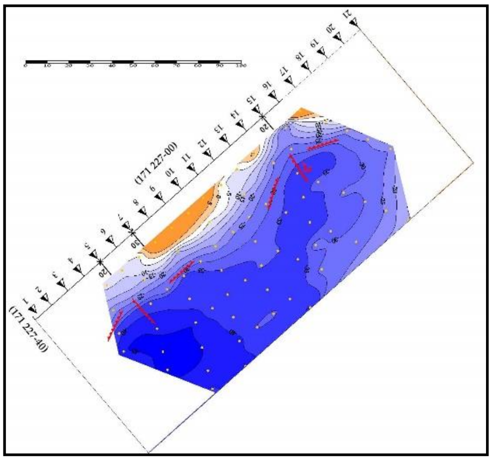

Figure 4. *Apparent resistance deviation map from seam soundings, with interpreted faults (isolines in %)*

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%). Similarly there are high (negative) resistivity deviation zones in the in-mine geoelectric tomography map (Fig. 5.) which are interpreted as tectonic zones (red lines).

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. 6). The tectonic zones observed during the mining extraction are depicted by blue colour. So it is possible to compare the predicted in Fig. 4. and Fig. 5. (red coloured lines) and the observed fault zones in Fig. 6. This comparison shows, that all the main observed tectonic faults were predicted in the interpretation of seam sounding and in-mine geoelectric tomographic measurements. There are some less accurate predictions in the tomography map near the closed drift "177 675-0".

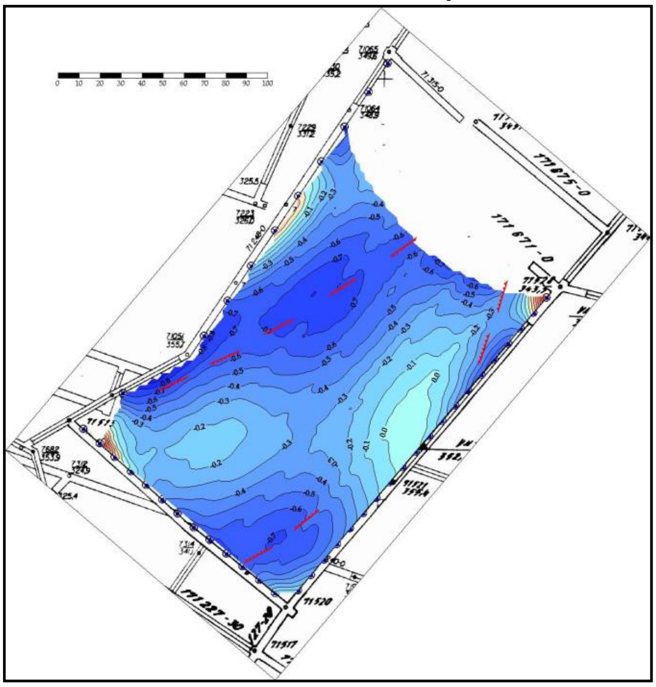

Figure 5. *Apparent resistivity deviation map from geoelectric tomography with interpreted faults.*

As is well-known the full tomographic coverage can appreciably increases the accuracy and reliabilty 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 mine (Slovakia). The interpretation of our in-mine geoelectric seam-sounding and 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 shows that the applied geoelectric methods are quick, accurate and economic under mine conditions. Due to the low current measurement equipments the safety of the operations was also ensured.

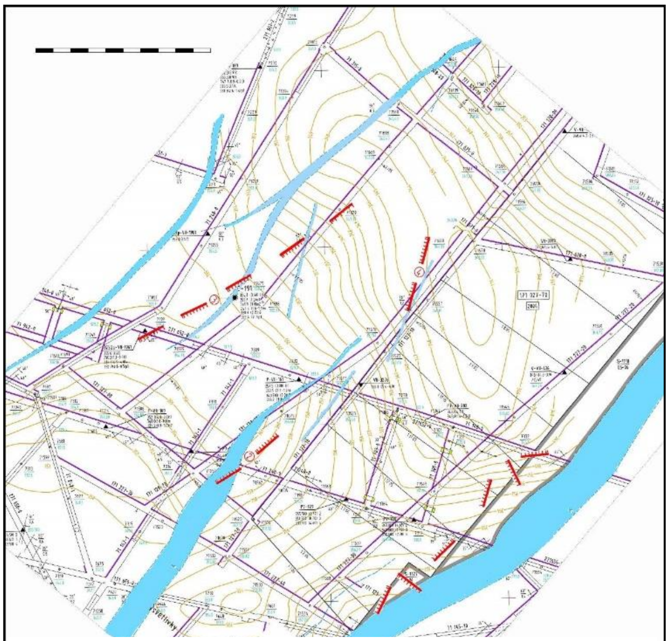

Figure 6. *Comparison between the faults predicted in the interpretation of geoelectric measurements (red colour) and observed in the mining extraction (blue colour).*

Acknowledgements

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