Disturbance of geothermal field of the Upper Silesian Coal Basin due to mining activity

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ABSTRACT

The thermal field of the Upper Silesian Coal Basin (USCB) is influenced by mining activity i.e. coal extraction, ventilation and dewatering of mines. Long-term mining, in some mines lasting even for hundreds of years, is the reason for essential changes in heat flow, hydrogeologic conditions and in consequence in distribution of temperature in rock massif which is manifested in pre-cooling of rocks in mines. On the basis of temperature and geological data acquired from wells, mine workings, and from geological and geothermal maps a diagram of rock temperature versus depth was composed. Geological conditions of coal extraction are varying between western and eastern parts of the coal basin, and have an influence on water content and air motion in mines in particular parts of the region; ventilation and water content in rock mass have substantial impact on the temperature distribution in mines.

KEYWORDS
Coal extraction, ventilation, dewatering, temperatures of rocks

1. Ventilation in mines

Taking into consideration the high values of geothermal gradients in mining provinces (in the Upper Silesian Coal Basin it is 3.4-3.9°C/100 m) (KARWASIECKA 1996), coal extraction would not be possible without ventilation of the mine workings. The temperature of the rock is of major importance to the climatic conditions in the workings, because 50% of the heat in mines comes from the rock mass. The intensity of heat exchange between rocks and air depends on initial rock temperature, amount of airflow in the workings, and the length of ventilation time. During air motion in the workings, cooling down of longwalls takes place and the cooling penetrates zones of a particular thickness in the rock mass; the higher the thermal conductivity of the rock, the deeper is the penetration. The greater the temperature difference between the ventilation air and the rock mass, the more intensive is the heat exchange process with rocks. For sandstones the range of cooling
is 12-25 m, for shales 8-10 m and for coal 3-5 m (FRYCZ 1970). More recent research on rock temperature and distribution of heat flow around mine galleries has been conducted by Chmura (CHMURA et al. 1988) in the Halemba mine, at a depth of 1030 m. Chmura’s research shows that the range of pre-cooling zones inside walls is quite variable; it can vary between 11 and 30 m for sandstones and 4.5 and 30 m for coal. The position of rock temperature isolines around workings is non-uniform. It depends on the lithology and also on the water content of the rock; the more water the rock contains, the higher is its thermal conductivity and the deeper is the zone of cooling.

Figure 1: Relationship between temperature and the depth of deposition
The natural-state rock temperatures measured in six mines in the north-western part of the USCB and results of temperature logging in nine selected wells from the northern part of the area are presented in Figure 1.

All the rock temperature data collected in mines and wells clearly show the relationship between rock temperatures and their depth, but Fig. 1 shows the linear increase in rock temperature with increasing depth for the temperatures measured in wells, while temperatures measured in mine workings are differentiated. In wells at a depth of 250 m (at sea level), rock temperature is 20°C, and at a depth of 1050 m (800 m b.s.l.) the temperature is about 53°C; thus, the geothermal gradient in the depth interval from 250 m (sea level) to 1050 m (800 m b.s.l.) is about 4°C/100 m. Temperatures measured in mine workings are variable at particular depths, and the increase of rock temperature with depth is non-linear. At a depth of 250 m (at sea level) the temperature is 16°C. At a depth of about 650 m (400 m b.s.l.), the temperature varies between 24 and 32°C, and at a depth of 1050 m (800 m b.s.l.) the temperature is about 32°C. Thus the temperature at this level is about 20°C lower than the temperature in the well. According to measurements in mines at the same depth interval, the geothermal gradient oscillates between 2.5°C/100 m and 3.8°C/100 m. This testifies the pre-cooling of the rock mass due to mining activity, especially ventilation (KUROWSKA 1999).

2. Water content in mines

Water content in the USCB is investigated in the context of mining activity, for which the amount of water flowing from the surrounding rocks into the workings is of great importance for safety. The amount of water flowing into the mine depends on rock structure, permeability and existence of natural water-migration paths (fissures and faults). In shallow mines inflows are greater and more dependent on precipitation than in deep mines (KORMAN 1978). In mines where coal seams are in sandstone formations, the amount of inflowing water is distinctly greater than in mines where coal is recovered from shale formations (claystones and siltstones).

The lithology and thickness of cover is another factor influencing water inflow into mines. Quaternary deposits are generally permeable. Where they are deposited directly onto sandstone Carboniferous rocks, waters have easier access to coal mines. Siltstones and claystones of Tertiary formations are impermeable; thus mines beneath have small inflows (WILK 1965). Mines in the north-western and western part of the USCB, located in Paralic Series and Siltstone Series, and where impermeable Miocene cover occurs, are considered as small-inflow mines. The largest inflows occur in mines of the eastern part, where the Upper Silesian Sandstone Series and Krakow Sandstone Series are mined, and where permeable Triassic and Quaternary cover occurs (table 1).

Mining activity is the reason of drainage of rock mass and flowing off the water from cooler, higher part of the rock massif down to the mine. During that process rocks on deeper levels are cooled and water is heated. Water inflow in mines of USCB and temperatures of rock mass is presented in table 1. The distinct decrease of temperature of rocks in eastern part of
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basin is due to low thickness and kind of the cover, intensive dewatering and higher thermal conductivity of rocks.

*Table 1: Conditions of coal mining in selected mines of the USCB (GOSZCZ & ROGOZ 1991, KNECHTEL et al. 1980, GEOLOGICAL DOCUMENTATION...*)

<table>
<thead>
<tr>
<th>Zone of the USCB</th>
<th>Western part of USCB</th>
<th>Eastern part of USCB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mine</td>
<td>Knurów</td>
<td>Jaworzno</td>
</tr>
<tr>
<td>Depth of mine [m b.t.s]</td>
<td>700</td>
<td>700</td>
</tr>
<tr>
<td>Average thickness of cover [m]</td>
<td>300</td>
<td>100</td>
</tr>
<tr>
<td>Type of cover</td>
<td>Sealing Tertiary (Miocene) claystones and siltstones, and Quaternary sediments</td>
<td>Quaternary sandstones and clays</td>
</tr>
<tr>
<td>Recovered formation</td>
<td>Siltstone Series - Orzesze beds and Upper Silesian Sandstone Series - Ruda Beds</td>
<td>Krakow Sandstone Series - Lazy Beds and Siltstone Series - Orzesze Beds</td>
</tr>
<tr>
<td>Inflows [1000 m³/24 h]</td>
<td>15-20</td>
<td>101</td>
</tr>
<tr>
<td>Temperatures of rock mass [°C] at 450 m b.t.s.</td>
<td>31-36</td>
<td>25-27</td>
</tr>
</tbody>
</table>

3. Temperatures in Staszic mine

Differences between the temperatures of rocks, temperatures measured on sidewalls, and temperatures of the air in workings were confirmed by temperature surveys performed by the author. The temperatures were measured with an electronic thermometer at a depth of approximately 720 m ± 12 m. According to the map of rock temperatures compiled for the 720 m level in the Staszic mine, the rock mass temperature oscillates between 30.5 and 33.2°C. The rock temperatures were approximately 32-33°C in the places where the measurements were taken. All temperature survey results are presented in Figure 2. The temperature of rocks on sidewalls is about 8-10°C lower than the natural rock temperature. This is the result of ventilation, which lowers the temperature in workings down to a maximum of 28°C. The temperature of air in workings at the 720 m level in the Staszic...
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mine was as expected. The temperature of water flowing out of the wall into the workings was 28.4 and it was about 3.6-4.6°C lower than the rock temperature, and higher than the temperature measured on the sidewall. This indicates that water probably comes from the cooler, higher part of the rock massif and is heated during its migration down to the mine.

Temperature of the air pumped out to the surface in Staszc mine is about 14-19°C (about 216-480 thousands m<sup>3</sup>/24 h).

![Diagram: Temperatures measured at the 720 m level in Staszc mine (central part of basin).](image)

Fig. 2: Temperatures measured at the 720 m level in Staszc mine (central part of basin).

4. Conclusions

Rock temperature increase in wells shows a linear correlation with increase of depth, while in mine workings the temperature increase is non-linear, being variable at a particular depth. This testifies the pre-cooling of the rock mass due to ventilation.

Temperatures of rocks in western part of the basin are higher than temperatures in the eastern part. One of the reason of that situation is variable amount of water percolating from the surface and from surrounding rock mass down to workings.

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With the deepening of mining and the increase of temperature of exploited rocks, more heat is pumped out with ventilation air and mine waters. This heat from deep mines is a potential source of thermal energy, ready for direct use on the surface (MALOLEPSZY 1998).

References


GEOLOGICAL DOCUMENTATION OF COAL DEPOSIT IN THE STASZIC KNUROW GLIWICE SZCZYGÓWCE SOSNICA, MAKOSZOWY & PSTROWSKI MINES. Archive materials of mines.