Clastic interbeddings and ash within lignite mined in the Konin vicinity, central Poland (PhD thesis)

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Abstract

My PhD thesis, submitted to the Scientific Council of the study of the Earth and the environment in fulfilment of the requirements for the degree of Doctor of Philosophy in the Faculty of Geographic and Geological Sciences (Adam Mickiewicz University), consists of four selected publications. My participation in their preparation is in the range of 35–100%, which was confirmed by the co-authors (statements of the co-authors). Two publications (the first and the second) are devoted to clastic sediments that form interbeds in the lignite seam. On the other hand, two subsequent publications (the third and the fourth) include studies of ash present within lignite. It just so happens that in the vicinity of Konin, only the first Mid-Polish lignite seam is currently exploited (2015–2021, research period). It is mined from three opencasts: Jóźwin IIB, Drzewce and Tomisławice. An important part of the research was fieldwork, including sedimentological studies. Moreover, numerous samples were taken from each opencast, both from clastic sediments and from the lignite seam. They were used for the following laboratory tests: grain-size analysis, ash content within lignite and determination of the chemical composition of the ash, that is, its elemental and oxide composition.

As a result of mining activity of the Konin Lignite Mine (KWB Konin) in 2015–2016, between two lignite benches, siliciclastic sediments were uncovered in the Tomisławice opencast. They were lens-shaped, about 500 m long and up to 1.8 m thick, with a lignite layer up to 20 cm in the northern part of the exposure. They consisted mainly of fine-grained and well-sorted sands, with the exception of sediments in the top and basal parts, which were enriched with organic matter. Based on the sedimentological analysis of these clastic sediments (i.e., their architecture and textural and structural features), a model of their formation was proposed. These sediments were formed, most probably as a result of two floods, in the floodplain area of a meandering or anastomosing river in the Middle Miocene. After the natural levee breaching by flood waters, sandy sediments, originating mainly from the river bed and levees, were deposited in the mire area in the form of crevasse splays. In effect, in the lignite seam from the Tomisławice opencast there are clastic interbeds, which made it impossible to use its significant part for electricity production – too much ash. It is also worth noting that the

above-mentioned clastic sediments are the first to be described from the Miocene of Poland (first publication).

In the years 2018–2000, in the lignite seam in the same opencast (Tomisławice), an extensive (>1.5 km^2) and thick (up to 0.8 m) layer of clay was exposed. Most likely, these fine-grained sediments were formed as a result of long-term deposition in the lake, which existed in the area of the mid-Miocene mire. The presence of these clays in the lignite seam significantly reduces the quality of the raw material used for electricity production, as currently lignite in the Tomisławice opencast is mined together with the clays. In the extreme case, when the maximum thickness of the clay layer is up to 0.8 m, the ash content in the entire lignite seam may increase even twice. This is very harmful to the environment. Therefore, selective extraction of lignite, i.e. without clay, would be recommended. Unfortunately, this is not practiced for technological and financial reasons (second publication).

In addition to macroscopically visible clastic layers, the lignite seam also contains a mineral matter in the form of ash, which is formed as a result of lignite combustion. Ash is harmful both to the environment and reduces the calorific value of lignite. Therefore, ash content was tested for 266 lignite samples mined in the opencasts: Drzewce, Tomisławice and Jóźwin IIB. The analyses were carried out in accordance with international standards (ISO 1171). First, the samples were burnt at the temperature of 850 °C, and then the ash content on the dry basis was determined (A^d). The examined first Mid-Polish lignite seam is characterized by a variable ash distribution both in the selected vertical profiles and along the lignite walls, and also between the above-mentioned three opencasts. The ash content in individual samples ranges from 6.5 to 69.8 wt.%, while its average value for individual opencasts is from 9.7 to 17.6 wt.%. Significant enrichment in ash of some parts of the lignite seam was interpreted as a consequence of floods occurring in the middle Miocene mire or the effect of chemical precipitation (e.g., calcium carbonate). A good diagnosis of the mineral substance (ash) spatial distribution in lignite would allow its selective exploitation, and thus better protection of the environment. Simply put, less ash in coal means less pollution to the atmosphere and less ash in landfills (third publication).

Not only the quantity, but also the quality of the ash contained in the combusted lignite is important for the environment, as mentioned above. Hence, the averaged samples from three vertical lignite seam profiles, coming from the currently operating opencasts managed by Konin Lignite Mine, were subjected to chemical tests at the Central Measuring and Research Laboratory in Jastrzębie-Zdrój (Poland). Their chemical composition (oxides and trace elements) was tested according to the ASTM D6349-13 standard. The dominant oxides in the

tested ashes are SiO2 and CaO, and among the trace elements in the predominant amounts they are Ba, Sr, Cu. The most important harmful element that appears in the analyzed ashes is Pb. Only a few elements, such as Ba, Cu, Pb and Sb, have higher than average values of the clarks in the tested ashes. The obtained results prove that the analyzed ash is as hazardous to the natural environment as waste from other lignite coals used for the production of electricity. Despite some differences between the lignite opencasts, their ashes have a similar chemical composition for oxides and concentrations of individual elements. These ashes can be described as carbonate ones due to increased content CaO. On the other hand, this high $CaCO_3$ content (~30 wt.%) is a positive component as it participates in the so-called natural desulfurization (fourth publication).