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SUMMARY

The Sucha Beskidzka IG 1 exploratory borehole was drilled between December 1974 and March 1976. The final depth, accounting for the deepening of the borehole, was 3850 m. The drilling aimed to determine the deep geological structure and recognise the resource potential of the western part of the Outer Carpathians and its basement, which constitutes the southern border of the Upper Silesian Coal Basin. The key goal of the drilling was to determine the southern range of productive Carboniferous formations, which were explored for hard coal content and natural gas saturation. The other goals of the borehole were to determine the range and development of Miocene formations west of the Skawa fault zone and to assess the possibility of hydrocarbon accumulation in those formations. Additionally, the lithological and facial development of the formations that belong to the Silesian and Magura series of the Outer Carpathians should be recognised in great detail.

One of the key difficulties during the analysis of the archival data of the Sucha Beskidzka IG 1 borehole was the state of preservation of the drill cores. The Central Geological Archive stores currently 141 core boxes of the original 676 taken from the Sucha Beskidzka IG 1 borehole. Cores that documented poligenetic breccias (Miocene age), the mudstone series, the paralic series, and the Zalasie Beds (Carboniferous in age) are missing, as well as almost all cores that represented the Devonian–Carboniferous carbonate series. We attempted to systemise and update the descriptions of drill cores for this volume.

The lithostratigraphic profile of the Sucha Beskidzka IG 1 borehole presented in this study has undergone several modifications compared to previously published materials. This was the result of in–depth analyses performed on available core materials and archival literature data, as well as of additional studies performed more recently. The studies focused on micropaleontological markers, sedimentological and structural analyses.

To clarify the stratigraphy of the Devonian formations in the Sucha Beskidzka IG 1 borehole, we attempted to correlate the Devonian–Carboniferous carbonate series between the neighbouring, benchmark profiles of the boreholes: Goczałkowice IG 1, Potrójna IG 1, Lachowice 1, Lachowice 2, and Jachówka 2K. Analyses of geophysical measurements revealed strong similarity between gamma logs of individual boreholes. The lack of sufficient core material made impossible to verify the log-correlation with biostratigraphic data. Nevertheless, it seems that despite a lack of unambiguous evidence, the Sucha Beskidzka IG 1 well reached older formations than previously thought.

We present a more detailed lithostratigraphic division of the Carboniferous succession, based on the recent lithostratigraphic schema of this system of the Upper Silesian Coal Basin. Additionally, the Mississippian–Pensylvanian boundary was established, as well as the Devonian–Carboniferous boundary, located in the Devonian–Carboniferous carbonate series. This boundary, at a depth of 3614.0 m, was already suggested by Tomaś and Zając (1996a, b).

In the final report of the Sucha Beskidzka IG 1 borehole (see Ślączka, 1976), the deposits from the depth interval of 3145.0–3168.0 m (23 m in thickness) were classified as lower Miocene. However, Moryc (2014) indicated a terrestrial origin of the succession and dated it as Triassic. The same approach was used in this work accounting discussed deposits to the Buntsandstein.

Detailed structural, lithological, and microfaunistic analysis of the Miocene deposits allowed to distinguish the deposits of the Skawina Formation and the Dębowiec Formation in both the autochthonous and allochthonous Miocene profiles. Moreover, it was possible to specify the age of the z Sucha and Stryszawa Formation as Carpathian (lower Miocene), based on micropaleontological analyses performed recently.

In the final report of the Sucha Beskidzka IG 1 borehole (Ślączka, 1976), in the depth interval of 2055.0–2214.5 m (159.5 m in thickness), the formations of the Silesian and Sub-Silesian series were distinguished, which are represented by tectonic breccias. Analysis and reinterpretation of lithological and micropalaeontological descriptions allowed to define them as olistostrome within the Silesian Series. Its formation likely occurred in the Miocene. The presence of these form should therefore be associated with synorogenic phenomena in the foreland basin, which could have occurred during the Carpathian fold-and-thrust belt development.

The analysis of drill cores and the reinterpretation of geophysical measurements indicate that the upper part of the Inoceramian Beds, laying at the depth of 970.5–1766.5 m (796 m in thickness), is dominated by sandstones. This might suggest that this part of the profile could be the equivalent of the Mutne Sandstones. However, due to the lack of other unambiguous evidence for the presence of that formation in the borehole profile, authors decided not to separate it. Moreover, we attempted to confront the data we had obtained with the views on the presence of the Oligo-

cene succession of the Dukla Series in the analysed borehole section (Ryłko, Paul, 2013, 2014). This concerns the depth interval 1766.5–2055.0 m (288.5 m in thickness), where the Krosno Beds were documented originally. Due to the lithostratigraphic and facies features of the Krosno Beds, which do not enable an unambiguous decision on their affiliation to the Silesian or Dukla series, we continued with the classification of discusssed formation to the Silesian Series.

Based on facies analysis and micropaleontological data, we proposed distinguishing the Wątkowa Sandstones in the interval of 3.9–791.5 m (787.6 m) in the Magura Beds. The Submagura Beds and Hieroglyphic Beds, in the interval of 791.5–956.0 m depth (164.5 m in thickness), were not separated, because of the lack of facial differentiation.

In addition, we prepared a genetic interpretation of the depositional systems of subsequent lithostratigraphic units of the Outer Carpathians, based on the integrated analysis of core material and gamma (GR) and neutron–gamma (NEGR) logs. Based on geophysical well-logs, we interpreted the elements of the depositional systems of the Inoceramian and Krosno beds.

The Miocene formations of the Carpathian Foredeep should be subjected to a more detailed and comprehensive analysis. It should allow to better link the regional events such as successive stages of the overthrusting of the Outer Carpathian accretionary prism, with the development of the sedimentary filling of the western part of the Carpathian Foredeep (cf. Moryc, 2005). These relationships should be considered in the context of the current models of the development of sedimentary megasequences of foreland basins. An example of such a megasequence controlled by tectonic factors is the succession of the Sucha Formation (olistostrome complex) – the Stachorówka Conglomerates Member (Stryszawa Formation) – the Bielsko Member (Stryszawa Formation), which reaches a total thickness of 570.0 m in the Sucha Beskidzka IG 1 borehole. The thicknesses of this megasequence is even greater in the surrounding boreholes (e.g. Zawoja 1 or Lachowice 2).

The topmost 3.9 m of the borehole succession is built of the Quaternary deposits of the flood terrace of the Stryszawka Stream.

The petrographic characteristics of the formations is exclusively based on archival descriptions of petrographic thin sections, included in the final report of the Sucha Beskidzka IG 1 borehole (Ślączka, 1976). The descriptions were updated, using current terminology.

The structural development of the formations drilled through by the Sucha Beskidzka IG 1 well was described in detail within this volume. The tectonic structures preserved in the available core material were considered. The results are involved into a geological cross-section (fig. 25). The tectonic analyses included reinterpretation of the geological map of the area around the Sucha Beskidzka IG 1 well, considering new lithostratigraphic divisions and the interpretation of the LIDAR Digital Terrain Model. The analysis allowed to distinguish a new structural element, the Pykowica Scale, which is visible in both the surface and the deep images. The interpretation of the seismic data was also used for the tectonic investigations, which enabled the indication of probable discontinuities in the folded Carpathian formations as well as in their substratum.

A comprehensive verification and correction of geophysical profiling were conducted. This improved the quality of the data markedly and enabled its reliable use in further geological and deposit analyses. Our goals were to rescale the geophysical data to the applicable units of measurement, and to ensure depth and lithological consistency. The processing of inclinometric data into digital data enabled precise reconstruction of the trajectory of the Sucha Beskidzka IG 1 well, the total departure of which reached 166.6 m at an azimuth of 305°. Based on available temperature measurements in a steady state of thermal equilibrium, we determined an average geothermal gradient of 2.4°C/100 m. This information provided valuable guidance in our assessment of the region's geothermal potential.

The depth–linking of laboratory data bulk density with well logs (RHOB) enabled precise lithological and stratigraphic interpretation of the drilled formations; these analyses, in turn, enabled the identification of a larger number of hard coal inserts in the Carboniferous formations. We determined clay content throughout the borehole profile based on improved and rescaled natural gamma radioactivity profiling. The incomplete set of well logs, however, limited porosity interpretation to intervals in which acoustic profiling was performed.

The measurements of the average velocities taken in the Sucha Beskidzka IG 1 borehole enabled us to determine several velocity complexes, and to link them to the appropriate lithostratigraphic levels and structural units of the Outer Carpathians. The analysis of smoothed velocity curves, interval velocities and, above all, the values of the average complex velocity enabled us to locate changes in the value of that parameter in relation to the lithological variability of stratigraphic units in the Magura and Silesian series, allochthonous Miocene, and the platform basement of the Carpathians. We noted the highest velocity contrasts at the boundary of the Paleocene and Upper Cretaceous (Inoceramian Beds of the Magura Series), Silesian Series (Krosno Beds), allochthonous Miocene (poligenetic breccia), and between the basic conglomerates and mudstones of the Stryszawa Formation of the platform basement of the Carpathians.

Magnetotelluric surveys conducted in the 1980s and 1990s in the immediate vicinity of the Sucha Beskidzka IG 1 borehole allowed for the identification of two main geoelectric complexes: an upper, low-resistance complex with high resistance variability, reaching a depth of approx. 5 km, and a lower, high–resistance complex. On the basis of these studies, three tectonic zones were identified, with relatively shallow Miocene substratum, as well as the surfaces of the top of the Devonian (a block with a resistivity of 350 Ωm) and the top of the Precambrian (blocks with a resistivity of 75 Ωm).

The area around the borehole is well recognized gravimetrically. The Sucha Beskidzka IG 1 borehole is located on the southern edge of the gravimetric high associated

with the Upper Silesian Block, approx. 20 km north of the border of the Carpathian gravimetric low. Local, minor forms of residual gravity anomalies show a close relationship with divers flysh formations.

Analysis of the seismic section measured less than 90 m from the borehole allowed us to identify the Triassic formations wedging out in the vicinity of the Sucha Beskidzka and to trace the main thrusts of the Silesian and Magura units, as well as a number of smaller thrusts within the Magura Unit itself. It was also possible to trace the horizons associated with the lithostratigraphic units identified in the borehole.

Despite numerous oil and gas indications in the borehole, we obtained no compelling hydrocarbon flows after performing numerous reservoir tests in selected intervals: we obtained flows only of reservoir waters—and they were very rarely gasified. A summary of the hydrogeological conditions in the borehole and its surroundings, based on archival and literature data, indicates that the horizons have very poor reservoir properties. Water samples from the borehole are characterised by the Cl–Na or HCO_3–Na type with mineralisation of 16.8 to 3.4 g/dm^3; this classifies them as salt waters, but not brines.

Sucha Beskidzka IG 1 well documented the possibility of thermal waters occurrence in the region. No other economically valuable minerals were identified.