

SUMMARY

The Zaręby IG 2 borehole, drilled in the central part of the Kielce–Łagów Synclinorium, is one of the most important boreholes located in the Palaeozoic region of the Holy Cross Mountains. Due to the fact that Palaeozoic rocks in the Holy Cross Mountains are largely exposed and available for research in natural open pits, excavations and shallow drillholes, the number of deep, costly boreholes that enable detailed observation of full rock sequences is small here, and the significance of each of them is particularly appreciable. The Zaręby IG 2 borehole, although drilled as part of a petroleum research program, provided very valuable fundamental geological data regarding structural foundations, stratigraphy, tectonics and facies development of Palaeozoic deposits. The information obtained from this borehole made the knowledge on the petroleum issues broader, and allowed a detailed recognition of the lithology of the Devonian carbonate series that are currently the subject of very intense mining. Although the borehole was drilled more than 50 years ago, it is still the only one that penetrated the Devonian succession and reached the Lower Palaeozoic basement of the Kielce–Łagów Synclinorium. Thanks to this, it was possible to demonstrate the relationship between the basement of the central synclinorium and the southerly located Chęciny–Klimontów Anticlinorium, which was fundamental to the knowledge on the geological structure of the Palaeozoic in the Holy Cross region. The great value of this borehole is its almost complete coring, and the vast majority of the core is still preserved today and available for further research.

The unique section of Cambrian rocks in the Zaręby IG 2 borehole, although generally similar to the deposits occurring in the southern part of the Holy Cross Mountains, shows some differences as compared to them. Its apparent thickness is over 150 m. Two distinct lithological complexes can be distinguished: the lower one includes strongly bioturbated and quartzitic sandstones, which can be identified as the equivalent of the Ociesęki Formation, and the upper complex of silt-clay deposits, well correlated with

the Kamieniec Formation rocks (Orłowski, 1975). However, the Cambrian rocks from the Zaręby IG 2 borehole are more tectonically deformed and have a higher degree of diagenesis in comparison with their counterparts in the southern area. This is confirmed by observations of thermal maturity of organic matter within them (Grotek, this volume; Szczepanik, this volume). They point to relatively high palaeotemperatures of the Cambrian rocks drilled in the Zaręby IG 2 borehole, clearly higher than those found nearby in the coeval Cambrian rocks from the basement of the Bardo Syncline and the Koprzywianka valley. This difference is difficult to explain only by the burial depth of the Cambrian deposits in this borehole to more than 1000 m, because the rocks in the Kowala 1 borehole, found at the same depth in the Chęciny–Klimontów Anticlinorium, do not show elevated thermal maturity. Thus, there is another reason for the differentiation of the degree of thermal maturity of the Cambrian organic matter in the Kielce–Łagów Synclinorium and the Chęciny–Klimontów Anticlinorium. This phenomenon may be related to the proximity of the Holy Cross Fault, but it may also result from the variable thickness of sedimentary rocks that, in the geological past, covered the Cambrian series in both regions.

However, the most valuable information derived from the Cambrian section drilled in Zaręby pertains to palaeontological data, especially in relation to palaeogeography and biostratigraphy. The trilobite assemblage (Bednarczyk *et al.*, 1965; Żylińska, Szczepanik, 2009; Żylińska, this volume) allows unambiguous dating of rocks from a depth interval of 1335.0–1337.0 m as the uppermost Series 2 of the Cambrian. The recent taxonomic revisions indicate links of the trilobite fauna with the areas of Gondwana and Avalonia (Żylińska, Szczepanik, 2009; Żylińska, this volume). Such observations require explanation, as the structural and tectonic data (*e.g.* Aleksandrowski, Mazur, 2017) and part of the trilobite palaeobiogeographic data about the Cambrian Series 2 in the Holy Cross region (*e.g.* Żylińska, 2013a, b) suggest the location of sedimentary basins near

Baltica. This may result from both a relatively short distance from the West Gondwana palaeocontinent and a system of sea currents, thanks to which the larval stages of Gondwana trilobites were reaching the Baltic shelf (Żylińska, 2013a, b; Nowicki, Żylińska, 2017).

Valuable data were also provided by studies of acritarch microplankton. Using this research method, it was possible, independently from trilobite determinations, to infer about the early Cambrian (upper part of the Cambrian Series 2) age of the studied series. The lack of provincialism of the Early Cambrian acritarch microfloras and the strong provincialism of the coeval trilobite assemblages make all the possibilities for correlations of faunistic and microfloristic data very valuable. All these are the unique data provided by the Cambrian section in the Zaręby IG 2 borehole.

The Devonian succession shows the greatest thickness (exceeding 1100 m) among all the systems identified in the borehole. This section, as well as those of Janczyce I and Kowala 1, is one of the «benchmark» Devonian sections in the Holy Cross Mountains. Research conducted over several decades on the borehole material has provided very valuable data, crucial for the studies of this system in the Holy Cross Mountains. Due to both the widespread occurrence of Devonian deposits in the region (almost half of the area of exposed Palaeozoic rocks) and the economic significance of the rocks of this formation in the Holy Cross region, the data from the Zaręby IG 2 borehole acquire a special value.

The borehole provides a continuous, nearly full section of Devonian rocks, characteristic of the eastern part of the Kielce region. It consists of deposits of all three Devonian series and almost all (excluding the Lochkovian) stages, which were deposited in various sedimentary environments.

The Devonian section starts with clastic rocks deposited in inland, lake-type shallow basins, which are replaced upper in the section by lithologically similar rocks that accumulated in brackish-type basins (Malec, this volume). The Old Red succession passes without a sedimentary break into Emsian shallow-marine clastic deposits (mainly sandstones). These are followed by marine carbonate sediments. After an intense transgressive stage and a short period of open-marine conditions, the sedimentation took place in the conditions of a growing carbonate platform that began to be gradually drowned in the Frasnian. In the Late Devonian and the earliest Carboniferous, the sedimentation of marly and calcareous deposits occurred on a deep shelf in an open, constantly deepening basin, passing subsequently into a clay-siliceous sedimentation in the late Early Carboniferous. The only part missing in the Zaręby section is the uppermost series of Carboniferous deep-marine deposits preserved in the Kielce–Łagów Synclinorium, namely the Viséan shales and greywackes of the Lechówek Formation (Żakowa, Migaszewski, 1995). Thus, the drill core from this borehole provides practically a complete section of the Variscan structural level, which makes it unique among all borehole drilled in the Holy Cross Mountains.

The Lower Devonian succession is represented by facies typical of the eastern part of the Kielce region, and its subdivision is given in a single lithostratigraphic scheme (Tarnowska, 1976, 1995). Thanks to the palynological research carried out in this borehole (Fijałkowska-Mader, this volume), it was possible to document the boundary between the Pragian and Emsian deposits. The guide conodont fossils, found in the Lower Devonian section (Malec, 2002, this volume), enabled documenting the Emsian – Eifelian boundary and proving the sedimentary continuity from the Lower Devonian terrigenous marine series into the carbonate complex.

Detailed petrographic and sedimentological studies of the Middle and Upper Devonian carbonates (Radlicz, Wójcik, this volume; Romanek, this volume) enabled precise recognition and description of lithologies, and reconstruction of their sedimentary conditions. By comparing this Devonian section with other carbonate sequences of this age, it became possible to reconstruct the palaeogeographic development of carbonate platform in the Holy Cross Devonian.

Palinological studies of the uppermost Devonian and the lowermost Carboniferous were conducted by Filipiak (2004, 2005, this volume). His reinterpretation (Filipiak, this volume) of the results of older studies carried out by Jachowicz (1967) provided very valuable biostratigraphic and palaeoenvironmental data. The position of the Devonian – Carboniferous boundary in the Zaręby IG 2 borehole was redefined and shifted downward into the marly-calcareous complex. Earlier, this boundary had been marked at the base of the clay-siliceous complex. These findings prove, beyond any doubt, the continuous transition from the Devonian rocks into the Carboniferous succession.

The Zaręby IG 2 borehole was drilled as part of the program of prospecting for hydrocarbon accumulation in Palaeozoic deposits of the Holy Cross Mountains. The research, carried out in the mid-1960s and based on methods available at that time, revealed the presence of various types of bitumen shows in the Givetian, Frasnian and Famennian sections (according to the present-day knowledge also of the Lower Carboniferous) in this borehole. Undoubtedly, this is the most abundant borehole in terms of the occurrences of oil, asphaltites and other bitumens in the Holy Cross Mountains and adjoining areas. Due to the lack of a regional seal, the Devonian rocks occurring on or near the surface cannot be considered as potential formations of hydrocarbon accumulation (Jurkiewicz, 1966), but the same deposits under a cover of younger sealing rocks are a promising formation for oil and gas accumulations. As an interesting region for potential exploration, the researchers who dealt with petroleum issues in this borehole in the mid-1960s suggested the area located on the western extension of the Kielce–Łagów Synclinorium axis. As the potential reservoir rocks, they indicated zones of the Devonian fractured carbonates (Jurkiewicz, 1966). This suggestion is also sustained by research teams that have been concerned with these issues in recent years (Malec *et al.*, 2010). Recent stu-

dies of organic matter from the Famennian–Tournaisian marly and claystone deposits (Więclaw, Kotarba, this volume) also provided promising data on its quantity and quality in terms of the possibility of hydrocarbon expulsion. In spite of unambiguous indications concerning potential source and reservoir rocks, and suggestions for the direction of further research, no work has been carried out for over

50 years in this area. No geophysical and drilling operations aimed at prospecting for potential oil- and gas-bearing structures have been conducted. Perhaps now, in a situation of great interest in hydrocarbon deposits, there is a good time to design and implement this type of research program.

Translated by Krzysztof Leszczyński