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Reconstruction of the Miocene depositional architecture of the Carpathian Foredeep basin based on geophysical data

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The Carpathian Foredeep in Poland is divided into two parts, eastern and western, with different tectonic frameworks and conditions of the Neogene sedimentary fill. The boundary is the so-called Krakow Ridge associated with the contact of two regional tectonic units: Upper Silesian and Malopolska blocks. The width of the Foredeep varies regionally and significantly differs in the western and eastern parts. It was developed within the epi-Variscan platform. Two zones can be distinguished in the Foredeep: the inner (older) zone and the outer zone. The subject of the presented work is the eastern part of the outer zone of Foredeep located in front of the head of the Carpathian thrust and filled mainly by autochthonous Miocene formations. The meridional width of this zone of the basin varies from about 10 km in the vicinity of Krakow to nearly 100 km in the central part. Its tectonic framework is defined from the south and south-west by marginal structures of the Carpathian overthrust and tectonic units of the folded Miocene. From the north-east and north-west, the border is marked by a system of faults in the foreground of Roztocze Upland and the Holy Cross Mountains. In the Sub-Cenozoic basement, a set of large faults of NW-SE length, with different times of formation and activity, is marked. These faults locally define horst structures and tectonic grabens. Some of the faults continue under the Carpathians, under which there is also a system of transversal faults in relation to the main axis of the orogeny. The influence of the tectonic structures of the basement is noticeable within the Miocene cover by faults disappearing towards the surface and continuous deformations of the adaptive type.

The outer foreland basin is filled with marine molasse type deposits of the unfolded autochthonous Middle Miocene with a thickness of up to approx. 3.500 m. The complex of Miocene formations is formed, in the lower, south-western and central part, by strongly differentiated submarine fan deposits accompanied by basin plain formations and gravitational flow deposits, including turbidite deposits characteristic of flysch sedimentation. The outer part of the fans smoothly transitions into the zone of fine-clastic sedimentation of the basin plain. Above the complex of submarine fan sediments, there are thick complexes of sediments of deltaic origin, which are also intensively variable facies, creating a set of channel (coarse-grained) and extra-channel (fine-grained) facies. The highest, relatively thin part of the sediments is formed by shallow coastal shelf formations. Submarine fans and river deltas developed mainly in the zone of the south-western and southern coasts of the Miocene reservoir, surrounded by river mouths providing an abundant supply of material from the rising and eroded Carpathians. In the north-eastern and locally even in the middle part of the basin, sediments may appear, for which the feeding area was located in the hinterland of the northern and north-eastern coast of the Miocene Sea.

The limited scope of extraction of drill cores resulting from the exploratory and exploitation nature of drilling makes it necessary to use borehole and surface geophysical data to reconstruct the depositional architecture. Processing and interpretation of geophysical data for a complex of Miocene sediments with such characteristics are problematic and ambiguous. Numerous sources of sedimentary material supply in the form of river mouths and submarine channels cause a significant diversification of the depositional architecture of the Miocene basin, making it difficult to trace uniform stratigraphic and lithological and facies boundaries. Sedimentary conditions cause, on the one hand, a certain monotony of the sediments, dominated by clastic formations, enriched by evaporate sediments horizons, and on the other hand, great lateral and depth facies differentiation. Geophysical well-logging data allows to recognize the lithological and facies variability of sediments and to determine the sequence of changes along the borehole trajectory. Seismic reflection data was used to track lateral variability. For the seismic reflective method, the reflective boundaries, characterized by a significant, abrupt change in acoustic impedance, are of primary importance. Within the Miocene basin, numerous reflective boundaries with high lateral variability and non-obvious stratigraphic identification are observed. In a complex of siliciclastic deposits, seismic wave reflections are recorded from the boundaries separating fine-grained lithofacies and medium- and coarse-grained facies. Due to the dominance of deltaic sediments and submarine fans in the depositional architecture of the Miocene complex, the regional continuity of such boundaries is problematic, and their unambiguous stratigraphic identification is practically impossible. To sum up, intense lithological and facies variability of clastic deposits, both lateral and vertical, should be expected within the Miocene complex. The sediments of individual fragments of submarine fans and deltas overlap each other, and there may also be overlaps with the sediments of neighboring fans. Such characteristics of the complex translate into a variable seismic pattern with numerous reflective boundaries and intense lateral variability of the seismic signal characteristics.

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