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SUMMARY

Drill core material acquired from the Parczew IG 10 exploratory borehole has provided a rich set of data from a wide range of research. The data has been used in the analysis of sedimentary basins developed at different stages of the geological evolution of the Lublin region, from Ediacaran through Cambrian, Ordovician, Silurian, Carboniferous, to Jurassic and Cretaceous times.

The full spectrum of stratigraphic research, including biostratigraphy, chronostratigraphy, lithostratigraphy, sequence stratigraphy, sedimentological and ichnological studies, micro-and macropaleontological and tectonic investigations, were performed directly on the cores and on the material taken from them. The second group of research included analytical tests, mainly geochemical studies of organic matter and igneous crystalline rocks, petrographic studies of crystalline, clastic and carbonate rocks and organic matter analysis. A full set of hydrogeological tests, wireline logs and petrophysical studies was performed in the borehole.

The total depth of the Parczew IG 10 borehole is 2355.0 m. The drilling stopped in Proterozoic crystalline rocks. Crystalline basement rocks are represented by metasomatic granitoids and biotitized and amphibolitized pyroxene rocks, with subordinate pegmatite veins. In some places, granitoids and pyroxene rocks underwent hydrothermal metamorphism, in the top part also hypergenic alterations.

The crystalline basement rocks are overlain by Ediacaran clastic deposits (depth 2181.0–2302.2 m, thickness 121.2 m). In the lowermost part of the Ediacaran succession they are represented by siliciclastic alluvial deposits of the Siemiatycze Formation passing upwards into estuarine sediments of the Lublin (Łopiennik) and Włodawa formations. The *Sabellidites-Vendotaenia* Zone was identified in the upper part of the ssuccession. A new position of the Ediacaran/Cambrian boundary in the Parczew IG 10 section was also established, coinciding with the top of the zone.

Cambrian strata occur at the depth of 1500.1–2181.0 m. This is a complex of 684.5 m thick deposits represented mainly by alternating sandstones, mudstones and claystones, forming distinctive sandstone-mudstone-claystone heteroliths deposited in a shallow marine basin in the foreshore and offshore zones. This was an open coast with strong influence of waves, and with minimal influence of tides or their absence. In the lack of trilobite fauna, the Lower Cambrian stratigraphic zonation was established using acritarchs. Individual zones were identified based on differentiation of acritarch assemblages. This allowed for clarification of the Lower Cambrian biostratigraphic scheme.

Ordovician deposits occur at the depth of 1472.2–1500.1 m, attaining a thickness of 27.9 m. The section is represented by the stages from the Tremadoc to the Ashgill. They were correlated with stages identified in the Ordovician succession of the Baltic Depression and global divisions. The Ordovician succession represents a mixed carbonate-clastic type of sedimentation. The lithological record includes mainly organodetrital and marly limestones, finely crystalline limestones, dolomitic limestones, dolomites, coquina rocks and carbonate breccias. Clastic sediments are represented by quartz sandstones, conglomerates, glauconitites, mudstones and claystones with bentonite laminae.

Silurian deposits were drilled at a depth of 1071.0–1472.2 m (driller's depth), attaining a thickness of 401.2 m. They are represented by the Llandowery, Wenlock and Ludlow. In the uppermost part of the Silurian section, lower Pridoli deposits are also likely. The Llandowery is represented by the undivided Rhuddanian, Aeronian and Telychian. The presence of the Sheinwoodian and Homerian stages was proved on the basis of Wenlock graptolites. In the Ludlow section, graptolites document the presence of the inseparable Gorstian and Ludfordian. As a model for the biostratigraphy of the Lublin sequences of the Silurian System, the stratigraphic scheme used in England and Wales was applied. The Silurian section is dominated by claystones and mudstones with limestone interbeds.

Carboniferous deposits occur at the depth of 629.0–1071.0 m, reaching a thickness of 442.05 m. The chronostratigraphic boundaries in the Carboniferous succession are established based on the correlation of depositional sequence boundaries with the marker sections and global and Western European Carboniferous subdivisions. This allowed for clarification of the stratigraphy and resulted in the revision of the boundaries. Carboniferous rocks are represented by limestones and marls, claystones, mudstones, sandstones, conglomerates, stigmarian soils, coals, bauxite and diabases. During the low relative sea level, deposition occurred in river beds and on floodplains. During the sea-level rise and the highstand, shallow-water deltaic and shallow carbonate and clay shelf environments developed. The Carboniferous section contains economic coal and bauxite deposits.

Jurassic deposits were found in the depth interval of 473.5–629.0 m and attain a thickness of 155.5 m. The Jurassic section includes the upper Middle Jurassic (Bathonian–Callovian) and lower Upper Jurassic deposits (Oxfordian). Sandy limestones were identified from well logs in the Middle Jurassic section. The Upper Jurassic section is represented only by Oxfordian deposits. Their lower portion is composed of orga-

nogenic sponge limestones, and dolomites and marly-sandy organodetrital limestones with glauconite in the lowermost part. Drill cuttings indicate that the upper part of the section is composed of organodetrital sponge limestones with sponge-coral deposits in the uppermost part. These limestones represent the Kraśnik Formation. The middle part of the section is represented by the Coral Limestone and Micrite Limestone formations. The preserved uppermost part of the section is included in the Bełżec Formation composed of white micritic and oolite limestones.

The Cretaceous succession of the Parczew IG 10 borehole occurs at the depth 26,5–447,5 m with a relatively small thickness attaining 447.0 m. The Upper Cretaceous (Cenomanian-Maastrichtian) is 421.0 m thick, whereas the Lower Cretaceous is a 26.0-m thick succession represented by upper-middle Albian shallow siliciclastic shelf deposits: sands and sandy marls with phosphorites at the top. The Cenomanian, composed of organodetrital limestones is only 7.0 m thick. The Turonian-lower Coniacian is represented by limestones with black flints. The middle-upper Coniacian, Santonian and lower Campanian succession is composed of chalk with flints. Marly chalk composes the upper Campanian, and lower and lowermost upper Maastrichtian section. The uppermost part of the upper Maastrichtian is represented by marly chalk-like limestones. The Upper Cretaceous carbonates were deposited in an epicontinental basin. They are probably overlain by a 4.0-m thick lower Paleocene series represented by carbonate-siliceous deposits. These are in turn overlain by 22.5-m Holocene sands and gravels.

The Parczew IG 10 borehole is located in the vicinity of the seismic profile TO690481, on the margin of the Kock structure, in an area where the late Carboniferous Variscan deformation is not marked. Only a small angular disconformity between the Silurian (Ludlow) and Carboniferous (Missisipian) deposits is observed in this zone, which is the result of the Bretonian tectonic phase (early Carboniferous). A very subtle angular disconformity associated with a significant erosional gap is also observed between Carboniferous and Jurrassic strata.

The basin development in the Lublin slope of the East European Craton began in late Ediacaran–early Cambrian times with a phase of rapid tectonic subsidence that continued into the Middle Cambrian. In the Lower and Middle Ordovician, the sedimentation rate was very low. The nature of the tectonic subsidence curve shows that the basin development at the Lublin slope of the East European Craton was initiated during the Ediacaran by an extensional phase. Additional confirmation of the origin of the basin is the presence of Ediacaran magmatic activity associated with rifting processes. Starting from the late Ordovician, the process of growing tectonic subsidence rate and sedimentation rate began, with the peak in the late Silurian. A model of the Caledonian orogen foreland basin was confirmed for the late Ordovician-Silurian basin. At the end of the Devonian and in the early Carboniferous (Tournaisian–early Visean) there was a strong tectonic uplift and associated erosion, leading to complete removal of Devonian sediments and partial removal of upper Silurian rocks. Uplift and simultaneous tectonic deformation, of most likely transpressional nature, can be interpreted as a result of the impact of the Variscan orogen on the foreland plate. In the Visean, the next stage of basin development began, which continued into the Westphalian. This stage is characterized by a tectonic subsidence curve illustrating a single phase of intense subsidence. Transtensional origin has been assumed for the Carboniferous depocentre, within which the Parczew IG 10 borehole lies. In the late Jurassic, a tectonic subsidence impulse is observed, which can be associated with the contemporary extensional phase in the Polish Basin. Increased tectonic subsidence occurred in the basin under the compressional tectonic regime during late Cretaceous times.

The Ediacaran and lowermost Cambrian sediments are characterized by a variable content of organic material. The amount of organic matter ranges from 0.30 to 2.85%, with a substantially higher content in the Ediacaran section. The main components of organic matter are represented by bitumen and vitrinite-like material. Organic matter contained in these sediments is of syngenetic type with some contribution of epigenetic material represented by migrating bitumen.

The degree of thermal maturity of the deposits increases with depth of burial, from the main phase of oil generation at the top of the Lower Cambrian to the main phase of gas generation at the base of the Ediacaran. The Carboniferous deposits (Namurian, Westphalian) contain considerable amounts of humic organic material composed of three main maceral groups: vitrinite, inertinite and liptinite. Their degree of alteration is not very high and corresponds to the early and main phases of oil generation. The Carboniferous rocks, excluding Visean deposits, contain a significant amount of organic carbon. Organic matter formed in the Carboniferous deposits as a result of bacterial and algal decay with a very significant participation of humic material in the Carboniferous series above the Visean deposits. The content of labile components is variable in these deposits; especially large amounts of bitumen were found in the carbonaceous intercalations. Bitumen in the Namurian sandstones is epigenetic with respect to the sediment. The degree of alteration of organic matter that occurs throughout the entire vertical Carboniferous section is low.

Few hydrocarbon shows were reported from the drill cores: oil traces in the Carboniferous section and oil in a vertical fracture in the Ordovician. Inflow of brine containing a low amount of combustible gas was observed in the Middle Cambrian–Ordovician deposits. Inflow of low-salt water containing inflammable gas was recorded in the Lower Cambrian. Inflow of brine containing low amount of natural gas was reported from the Ediacaran section.

Detailed analysis of petrophysical data enabled the precise selection of lithologic horizons characterized by at least good reservoir properties, for which the assumed porosity values are greater than 15% and permeability values exceed 5 mD. Only 21 lithologic horizons meet optimal conditions, all of which are located in the Carboniferous stratigraphic interval.

The Parczew IG 10 borehole is situated in a zone of elevated heat flow values that are likely associated with the presence of high radiogenic heat-producing rocks in the basement (gamma ray profiling failed to run within the Ediacaran and crystalline basement rocks).

Translated by Krzysztof Leszczyński