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SUMMARY

The Bodzanów IG 1 borehole (total depth 5854.0 m) was drilled in the period of 1979–1982 in the central part of the Płock Trough near the western border of the East European Platform, within the Teisseyre-Tornquist Zone.

The borehole has provided data that filled the significant gap existing in the 1980s regional research on the marginal zone of the East European Platform between Kutno in the SW, and Płońsk and Bieżuń in the NE.

Concerning the sub-Cenozoic structural level, the Bodzanów IG 1 borehole was drilled within the so-called Płońsk tectonic unit south-west of the Bodzanów–Dzierżanowo fault zone, bounding the Zechstein-Mesozoic Bodzanów Anticline. As regards the sub-Permian structural level, the borehole is located within an area of Variscan foredeep.

Reflection seismic data clearly reveal the occurrence of two major tectono-structural levels: (1) the Proterozoic crystalline basement of the craton and (2) its Phanerozoic sedimentary cover that, in turn, consists of four sedimentary (depositional-structural) complexes separated by tectonic disconformities: early Paleozoic (Cambrian–Silurian) complex, late Paleozoic (Carboniferous) complex, Permo–Mesozoic complex, and Cenozoic complex.

The borehole penetrated almost the entire sedimentary cover, reaching the ?Middle Cambrian succession (~Series 3).

In the sub-Zechstein Paleozoic the most striking is the lack of Upper Cambrian (~Furongian), lower stages of the Ordovician (Tremadocian, Floian and Dapingian – Tremadocian and Arenigian in the British subdivision), uppermost Silurian (Pridoli and much of the Ludlow), Devonian and Lower Carboniferous (Mississippian) deposits. They were removed during repeated events of erosion at the Cambrian/Ordovician transition, and in the Carboniferous.

The Cambrian section is represented probably by the Middle Cambrian (~Series 3). It consists of quartzitic sandstones with thin interbeds of claystones and relatively frequent intercalations of finely crystalline limestones.

The Bodzanów IG 1 borehole is among the few that penetrated the Ordovician succession (5692.5–5755.0 m) in the Płock–Warsaw Trough, attaining a thickness of 62.5 m. The Ordovician interval was well cored and the stratigraphic section is represented by the standard global stages: Darriwilian, Sandbian, Katian and Hirnantian, which correspond to a sequence of the upper Llanvirnian through Ashgillian of the British scheme. The Ordovician section is represented by limestones and marls, as well as siliciclastic rocks that are classified as mudstones, organised into three lithostratigraphic units (from base to top): the Polik Limestone Formation (0.3 m thick), Sasino Claystone Formation (46.4 m), and Prabuty Marl and Claystone Formation (12.5 m).

The Silurian section, 759.5 thick, is lithologically similar to the sections from the nearby Polik IG 1, Kamionki IG 3, Bieżuń 2 and Szczawno 1 boreholes. It is represented by three lithostratigraphic units: the Pasłęk Formation, Pelplin Formation and Kociewie Formation.

The Carboniferous section is represented by sandstones, mudstones, claystones and stigmarian soils. Its basal portion hosts sandstones showing a specific composition; they contain clasts of acidic volcanic rocks. The deposition took place during a low relative sea level in incised river valleys, riverbeds and floodplains. During a sea-level rise and a high-stand, shallow-water delta environments developed.

The Rotliegend deposits represent a sequence of alluvial fans developed at the basin margin. Their diverse petrological composition points to various sources of detrital material, thus indicating a relatively vast source area. The main components of the detrital material in the Rotliegend conglomerates are clasts of effusive rocks (rhyolites, rhyodacites, rare trachyandesites-basalts), originating probably due to erosion and denudation of crystalline and sedimentary rocks in the Masurian-Suwałki Elevation. The diagenetic processes were dominated by mechanical and chemical compaction, silicification, carbonatisation and anhydritisation, likely under the influence of infiltration of Zechstein Sea water.

The succession deposited during Late Permian and Mesozoic times indicates that the region of the Bodzanów IG 1 borehole occupied at that time an intermediate position between the stable East European Platform and the mobile Mid–Polish Trough.

The Zechstein section of the Bodzanów IG 1 borehole has closed the gap in the exploration of Zechstein deposits in the foreland of the so-called "Masurian Peninsula". The lithology of the Zechstein shows predominance of deeper-water sedimentary environments and provides a more reliable evidence for the existence of a structural depression in this area. This depression may represent a tectonic graben, partly already degraded by erosion processes.

The Zechstein succession shows highly variable mineralization, however not very abundant. The dominant minerals are chalcopyrite, sphalerite and pyrite in the Basal Conglomerate, and sphalerite, galena and pyrite (with subordinate chalcopyrite) in the Copper Shale and Zechstein Limestone.

The Triassic section is thick (1067.5 m), but the coring is poor. Based on biostratigraphic studies, only a Ladinian age of the Lower Keuper has been proved. The Buntsandstein is represented by the Baltic Formation in the lower part, the Lidzbark and Malbork formations in the middle part, and the Elbląg and Carbonate-Clastic formations in the upper part. The deposition took place in a nearshore zone of a very shallow basin, periodically even in a fluvial environment. Two transgressive pulses, documented in the Upper Bundsandstein of this area, resulted in the development of a shallow sea with later deposition of Muschelkalk facies. The Keuper section is dominated by claystones deposited in fluvial-deltaic environments, on a mudflat under more arid (which favoured precipitation of evaporites in the sediment) or more humid conditions, as well on an alluvial plain.

The Jurassic section is 1252.5 m thick and comprises the Lower, Middle and Upper Jurassic. This is a complete section with no major stratigraphic gaps. The Lower Jurassic (432.5 m) is represented by siliciclastic deposits: sandstones, heteroliths, siltstones and claystones deposited in a terrestrial environment (Zagaje Formation – Hettangian, Drzewica Formation – Upper Pliensbachian, and Borucice Formation – Upper Toarcian), shallow-marine environment (Gielniów Formation – Lower Pliensbachian), brackish bay environment (Ciechocinek Formation – Lower Toarcian) or in a mixed, terrestrial/shallow-marine environment (Ostrowiec Formation – Sinemurian). The Middle Jurassic section (195.0 m) is represented by all its stages (Aalenian, Bajocian, Bathonian and Callovian), but the thickness is reduced as compared to that from the axial zone of the sedimentary basin. The lithologies comprise marine sandstones, heteroliths, siltstones and claystones, as well as dolomitic sandstones and sandy limestones in the Callovian. The Upper Jurassic (625,0 m) is composed of Oxfordian organodetritic, micritic and oolitic limestones, Kimmeridgian marly limestones and marls and Tithonian marly limestones, marls and dolomitic limestones. A number of formations have been distinguished in this section: the Sponge, Calcareous-Marly, and Oolitic formations (Oxfordian – lowermost Kimmeridgian), the Calcareous-Marly-Coquina Formation (Lower Kimmeridgian), the Pałuki Formation (Upper Kimmeridgian, Lower Tithonian, Lower Upper Tithonian), and the Kcynia Formation with the Corbula Limestone Member (upper Upper Tithonian). These deposits accumulated in a shallow and deep carbonate ramp.

Foraminifer and ostracod fossils from the Upper Jurassic section have been revised taxonomically and biostratigraphically with respect to the currently valid stratigraphic schemes. Analysis of the micropalaeontological material has allowed identification of Oxfordian, Kimmeridgian and Tithonian deposits.

The Lower Cretaceous siliciclastic succession (220.5 m thick) was deposited in a shallow epicontinental sea and is represented by Berriasian through Albian deposits. At the Lower/Upper Berriasian boundary there is a small stratigraphic gap, with the Lower Berriasian Kcynia Formation overlain by the Upper Berriasian–Lower Valanginian Opoczki Member of the Rogoźno Formation (missing the Kajetanowo and Zakrzewo members) followed by the Bodzanowo, Włocławek and Mogilno formations. Worth noting is a high thickness of the Pagórki Member (74.0 m), which, in the area between Płock, Sierpc, Płońsk and Sochaczew, attains its maximum values in the Polish Lowlands.

The Upper Cretaceous (1200.0 m thick) is represented by all the stages from the Cenomanian through the Maastrichtian. This is the maximum Upper Cretaceous thickness determined in a borehole in this part of the Płock Trough. The dominant lithofacies are carbonate and carbonate-siliceous, but no signs of chalk deposition have been found here.

The reconstruction of burial history and thermal evolution shows that the Late Cambrian and Early Ordovician were the periods of stagnation, followed by slight deposition and subsidence continuing until end-Ordovician time. In the earliest Silurian, a continuous increase in the burial depth is observed, to more than 1600 m and to a temperature exceeding 80°C. The palaeotemperature allowed initialising organic matter maturation during the oil window phase.

During the Devonian and Early Carboniferous stage of sedimentary cover development, the sediment deposition and burial rates were lower. The maximum burial depth at the end of this stage was ca. 2100 m, and the temperature exceeded 100°C. Basinal uplift at the end of the Early Carboniferous resulted in the removal of much of the sedimentary cover, including all Devonian and (?)Lower Carboniferous deposits. The beginning of the Late Carboniferous is marked by another burial phase, terminated by an erosional event. The Early Permian was the period of stagnation. Another burial stage started in the Late Permian and continued through the Mesozoic and Quaternary. Its intensity was variable with the maxima during Late Jurassic and Late Cretaceous times. The maximum burial depth is observed currently: 5834 m, and the bottom hole temperature is approximately 160°C.

The Cambrian–Cretaceous succession in this borehole is characterised by a highly variable and generally not very abundant organic matter. Its increased concentrations are found locally in the Jurassic deposits (0.90–2.0%), in a single Carboniferous horizon – Bashkirian (1.7%), in the Silurian – Llandovery (1.0%) and in the Ordovician – Lower Katian–Sandbian (1.0–2.1%).

Thermal maturity of these rocks varies with burial depth (1285.0–5832.1m) within a very wide range from an immature phase (0.38% R_O) in the Upper Cretaceous, through the main phase of oil generation (0.52–0.96% R_O) in the Jurassic–Permian interval, and the phase of condensate and gas generation in the Carboniferous (1.15–1.48% R_O), to an „overmature" phase (4.20–4.90% R_O) in the Silurian–Cambrian rocks.

Potential source rocks for oil generation are single Upper and Lower Jurassic and Carboniferous (Bashkirian) horizons.

Geochemical studies of organic matter in the Bodzanów IG 1 borehole show that the Ordovician (Katian–Sandbian) deposits can be generally considered „good" source rocks for hydrocarbon generation. However, their thickness is small. The content of organic matter in the other intervals indicates that they are "poor" source rocks. All the rocks along the borehole section are characterised by very low or trace amounts of labile components. There is only a small percentage of bitumens that contain a high proportion of hydrocarbons. These bitumens are characterised by high values of migration coefficient, which allows concluding that they are epigenetic.

The highest hydrocarbon potential was found for deposits of two copper shale samples, which are in the oil generation stage. The remaining part of the borehole section is characterised by the low or medium hydrocarbon potential. Some Ordovician (Lower Katian–Sandbian) and Carboniferous (Pennsylvanian) rocks and single samples of Permian (Zechstein Limestone) and Jurassic (Sinemurian and Lower Kimmeridgian) rocks show features of source rocks. An important observation is that thermal maturity of organic matter increases with depth from the immature phase or the initial phase of oil generation in the Mesozoic section to the overmature phase in the entire Palaeozoic (Silurian, Ordovician and Cambrian) section. High thermal alteration resulted in the exhaustion of the current hydrocarbon potential of the Lower Katian–Sandbian rocks that contain elevated amounts of organic carbon (TOC), especially at the top, but they show low generative potential (S2) and low values of the hydrogen index (HI). The lack of saturation of these rocks with so-called free hydrocarbons (S1) results probably from their expulsion and migration during the sedimentary basin evolution.

The analysis of seismic velocity measurements in the Bodzanów IG 1 boreholes suggests that the most prominent reflections on seismic profiles should be observed, due to velocity contrasts, in the Upper Cretaceous, at the top of the Lower Cretaceous, in the Upper Jurassic and, less well pronounced, in the Middle Jurassic. Within the Triassic section, it is possible to delineate the top-Triassic and top-Muschelkalk boundaries on seismic sections. Moreover, the top- and base-Zechstein, Carboniferous and possibly Silurian boundaries complete the set of horizons selected for presenting in seismic wave images.

The Upper Carboniferous reservoir horizon is filled by brines flowing out at a low rate of ca. 1 m^3/h. They are saturated with combustible natural gas characterised by a very high He content of 0.92 vol.%. In case of a discovery of Upper Carboniferous rocks showing better reservoir properties in the region of the Bodzanów IG 1 borehole, we should expect economic occurrences of natural gas.

The Lower Triassic deposits occur in a zone of low water metamorphism and faint inflow of brines from the upper reservoir horizons, which indicate unfavourable conditions for hydrocarbon accumulations. Similar disadvantageous conditions for hydrocarbon accumulations are observed as regards the tested Middle Jurassic and Lower Cretaceous reservoir horizons that occur within a zone of active water exchange.

The Jurassic and Cretaceous waters are not suitable for balneological use. The Jurassic water concentration is more than twice of that used in bathing therapy, and the Cretaceous water concentration is too low to be used in balneotherapy. Also, these waters do not show increased concentrations of specific components of pharmacological importance.