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SUMMARY

The Ciechocinek IG 2 borehole was located in the south-western flank of the Ciechocinek Anticline which, like the nearby Brześć Kujawski Anticline, is a kind of a salt pillow where Zechstein salt has not pierced up through the Mesozoic overburden.

The Ciechocinek IG 2 borehole reached the depth of 1981 m and drilled through Quaternary, Paleogene, Lower Cretaceous, Upper Jurassic and the Middle Jurassic deposits into the lower Aalenian. As compared to the predicted thicknesses of individual formations, those of the Upper and Middle Jurassic appeared to be greater, and the base of Middle Jurassic, initially expected to be at a depth of about 1580 m, is in fact deeper than 1981 m.

Both chronostratigraphic and lithostratigraphic schemes are applied to the Lower Cretaceous and Upper Jurassic series. The Paleogene succession is subdivided into the Adamów and Czempiń formations. The Lower Cretaceous is represented by the Rogoźno Formation. The Upper Jurassic is subdivided into the Kcynia, Pałuki, Calcareous-Marly-Coquina Formations and the Limestone Group A. Stratification of the Middle Jurassic section in this borehole is based on chronostratigraphy.

Stratigraphic and lithological investigations revealed the presence of a stratigraphic gap spanning the Valanginian through the Late Paleocene.

Sedimentological studies of the Middle Jurassic succession showed that shallow marine sedimentation in an epicontinental basin took place at that time. The Middle Jurassic sandstones were deposited above the fairweather wave-base, within the lower, middle and upper shoreface zone. Sedimentation of mudstones and heteroliths occurred primarily within a transitional zone between the fairweather and storm wave-base.

Claystones and shales represent an offshore environment with dysoxic to oxygenated conditions.

Biostratigraphic investigations of the Middle Jurassic, in particular of Bajocian and Bathonian deposits, allowed for detailed dating based on foraminifers and dinoflagellates.

Petrographical and diagenetic studies of the Middle Jurassic rocks indicate that detrital material in the sandstones is represented mostly by quartz grains with the predominance of monocrystalline grains over polycrystalline ones. Infrequent feldspar grains are represented only by potassium feldspar. Mica flakes are also observed.

Mineral composition of detrital material, and generally good or moderate sorting, indicates its origin from resedimentation of quartz-containing rocks older than Middle Jurassic.

Thin siderite interbeds are more common in sandstones than in claystones. They are represented by micritic and microsparitic clay siderites or siderite coquina layers. The main component of siderites is sideroplesite, indicating reducing conditions during early diagenesis.

The original sedimentary structures and mineral composition were highly affected by diagenetic processes: reworking of the deposit by resident organisms, mechanical compaction, less important chemical compaction (expressed only by the occurrence of intergranular concave-convex contacts), quartz and feldspar grain corrosion by alkaline solutions, and replacement of original aragonite and Mg-calcite components of bioclasts by Fe/Mn-calcite, ankerite or sideroplesite of later generation. Within some of the sandstone beds (in particular in the lower and upper Bathonian) compaction activity was limited by early calcite, dolomite and ankerite cementation of sandstones.

The Callovian deposits show effects glauconitisation of calcite bioclasts and phosphatisation of glauconite. Most of these processes operated during eodiagenesis. Mesodiagenetic processes involved mechanical and chemical compaction, and replacement of less stable components.

The Ciechocinek IG 2 borehole, due to wide range of investigations, is one of the marker calibration boreholes in the central area of the Polish Lowlands. Pronounced variations in petrophysical parameters such as bulk and specific density, total and effective porosity, and permeability are observed. There is no evident effect of compaction on bulk density and porosity.

Worth noting is relatively low variability of total and effective porosity, especially in highly porous sandstones. Very distinct variations, even within the same lithologic, are observed in specific density. In the deepest part of the borehole, thermal measurements under unstable thermal conditions were made. They enabled calculation of approximate heat flow value of 70.5 mW/m^2. This value confirms the existence of a zone of increased heat flow in the central part of the Pomeranian–Kujavian Swell.

Physical and chemical, hydrochemical and hydrodynamic studies revealed very good reservoir properties of the Middle Jurassic rocks, as evidenced by maximum formation water inflow rates = 6.51–17.2 m^3/h and permeability values k = 285–850 mD. The Upper Jurassic deposits show poor reservoir properties, as evidenced by low formation water inflows (0.51 m^3/h) and low permeability (k = 15.8 mD). The Middle Jurassic deposits occur within a zone of formation pressure slightly exceeding hydrostatic pressure values, whereas the formation pressure of the Upper Jurassic deposits is lower than

hydrostatic pressure. The Jurassic rocks are filled with brines and mineralized water showing a low degree of chemical alteration, proving the occurrence of unfavourable conditions for hydrocarbon accumulation. The hydrochemical profile of the borehole indicates an increase in water mineralization with depth (from 26.5 g/dm^3 at depth 824 m to 94.8 g/dm^3 at depth 1931 m). Within a zone ranging to a depth of 350 m, low-mineralized waters may be potential usable fresh-water aquifers. Below this depth, there is a gradual increase in mineralization. The hydrochemical indicator rNa : rCl decreases with depth. A high value of hydrochemical indicator rNa : rCl (0.89) and high mineralization of brine from the deepest aquifer (>90 g/dm^3) indicates leaching of nearby halite deposits. The shallowest, Upper Jurassic reservoir is recharged largely by infiltration waters from the ground surface. Groundwater from the Ciechocinek IG 2 borehole shows relatively lower mineralization than the average values observed in the Polish Lowlands. It may result from infiltration of waters from shallower depths towards deeper formations (descension).

Geochemical investigations indicate that the Jurassic rocks contain variable amount of organic matter. Low contents (commonly <1% Corg.) are observed in the Upper Jurassic rocks. Much higher contents, ranging from 3.4 to 11.6% Corg., were recorded in the Middle Jurassic rocks. Considering the organic matter composition, these rocks also show some variations. The main components of primary organic matter of the Upper Jurassic deposits are bacteria with a considerable contribution of algae. Humus is an additional component. The Middle Jurassic rocks contain more organic matter derived from decomposition of vascular plants.

The maturity of Jurassic organic matter is relatively low and corresponds to the early or main phases of liquid hydrocarbon generation. Average values of the reflectance coefficient (% R_o) in the Upper Jurassic deposits vary from 0.50 to 0.63% R_o. R_o calculated for the Middle Jurassic rocks shows values between 0.48 and 0.67%. These data indicate relatively low maximum palaeotemperatures of approximately 40–70°C, affecting the rocks during diagenetic processes. A slight increase of the degree of metamorphism is observed with depth. The highest maturity of organic matter was recorded in the lower part of the Middle Jurassic succession. Low coalification of organic matter in the analysed samples indicates immaturity for liquid hydrocarbon generation.

Despite large amounts of organic matter and bitumens, the contribution of hydrocarbons in bitumens from the Jurassic rocks is low, and their composition is similar along the profile. There are only few sandstone samples from both the topmost and lowermost portions of the Middle Jurassic section which revealed a higher content of hydrocarbons in bitumens.

Bitumens contain large amounts of heavy compounds (asphaltenes and resins). Also, the saturated/aromatic hydrocarbons ratio is variable.

Average seismic velocities indicate that there are a number of velocity boundaries within the Lower Cretaceous and Upper Jurassic section. Higher seismic velocities in the Lower Cretaceous are related to mudstones or Beriassian carbonates. The most pronounced boundary is associated with high seismic velocities of the topmost Oxfordian carbonates.

Complex velocities of the Middle Jurassic deposits are lower in relation to their overburden. There is a contrast boundary between the Upper Jurassic carbonates and a terrigenous series. The Middle Jurassic rocks are characterized by low variability in complex velocities due to their monotonous lithology (mudstones, claystones, sandstones). A slight increase in velocities is observed in the upper Bathonian, upper Bajocian and lower Bajocian sandstones. These research results provided information useful for both identification of reflection boundaries in seismic sections and depth-converted interpretations.

The Ciechocinek IG 2 borehole fully achieved its geological objectives.