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SUMMARY

The present volume contains the results of both the earlier analyses and the latest stratigraphical, petrographical, sedimentological, tectonic and geochemical investigations based on modern research methods in accordance with the chronostratigraphic units recommended by the International Commission on Stratigraphy.

The Polskie Łąki PIG 1 borehole drilled Ordovician, Devonian, Permian, Triassic, Jurassic, Cretaceous, Palaeogene and Neogene deposits.

The oldest rocks drilled at the depth of 4427.0–4297.5 m are the Ordovician deposits represented by strongly deformed fine-grained siliciclastic rocks: claystones and mudstones with local interbeds of fine-grained sandstones. Pyroclastic rocks and lenses of limestones are subordinate. These are hemipelagic sediments and decelerating turbidity currents deposits. The suite of trace fossils, considered together with the facies features, suggests that this is a deep-water, poorly diversified and depleted assemblage. It also indicates a low-energy, suboxic or dysoxic hemipelagic environment, depleted in nutrients.

Palynological analysis allowed for a documenting of a poor and invariable taxonomic spectrum of Upper Ordovician palynomorphs. Rare graptolites of the *multidens* and *clingani* Zones indicate that these deposits can be correlated with the middle part of the British stage of Caradoc, corresponding in the chronostratigraphic scheme to the upper part of the Sandbian and the lower part of the Katian of the Ordovician, as shown in the Stratigraphic Table recommended by the International Commission on Stratigraphy.

No uppermost Ordovician, Silurian and Lower Devonian deposits have been found in the Polskie Łąki PIG 1 borehole. The Upper Ordovician rocks are directly overlain by a Devonian succession identified within the depth interval of 4297.5–3239.0 m and representing 5 lithostratigraphic units of formation rank. Palynological analysis indicates that the oldest Devonian rocks are probably represented by the uppermost Emsian or Eifelian, whereas the topmost part of the Devonian section belongs to lower Frasnian. Sedimentological and ichnofacies logging was performed for the lowermost portion of the Devonian succession, representing the ?Tuchola and ?Studnica formations. These investigations were the basis for a facies analysis of siliciclastic deposits in this interval. It has been found out that the black claystones of the ?Tuchola formation represent a lagoonal depositional system. The deposition of alternating sandstones and mudstones of the ?Studnica formation took place in washover fans, sand barriers and a tidal plain. The Givetian carbonate-siliciclastic deposits of the Miastko formation were deposited probably in the environments of tidal plain, sand barriers and within the proximal zone of a carbonate platform. It seems that the carbonate-marly sediments of the Sianów formation were deposited mostly on a carbonate platform, whereas the marly-claystone rocks of the Człuchów formation were related to the distal zone of a carbonate platform and to an open shelf.

No uppermost Givetian, upper Frasnian, Famennian, Carboniferous and Lower Permian deposits have been identified in the borehole section. The lower Frasnian is overlain by tectonically deformed Zechstein rocks (depth 3239.0–2767.0 m), represented mainly by anhydrites and rock salt of the PZ1, PZ2 and PZ3 cyclothems.

The Mesozoic deposits in the Polskie Łąki PIG 1 borehole include the Triassic, Jurassic and Cretaceous succession. In this part of the section, only 5 cored intervals have been recovered from Triassic rocks. Hence, all considerations regarding the Mesozoic are based mostly on correlations to the nearby located borehole of Korytowo 1 which provided much drill core material.

The Triassic deposits were encountered at the depth of 2767.0–1762.5 m. They are represented by the uppermost Lower Triassic belonging likely to the Olenekian, the Middle Triassic rocks of the Anisian and Ladinian, and the Upper Triassic deposits representing the Carnian, Norian and Rhaetian.

The Jurassic rocks occur at the depth of 1762.5–855.0 m. From well logs data and the correlation to the Korytowo section, it has been possible to identify the Lower, Middle and Upper Jurassic. The Lower Jurassic includes 5 lithostratigraphic units of Formation rank, assigned to the Hettangian, Sinemurian, Pliensbachian and Toarcian. The Lower/Middle Jurassic contact is of erosional nature. The gap spans part of the Toarcian, the entire Aalenian and part of the Bajocian. No lithostratigraphic scheme has been applied to the Middle Jurassic succession (represented by upper Bajocian, Bathonian and Callovian) in the region. The Upper Jurassic (Oxfordian, Kimmeridgian and Tithonian) is represented by 5 lithostratigraphic units of Formation rank and one unit of Member rank.

The Cretaceous deposits rest at the depth of 855.0–179.0 m. The Lower Cretaceous succession, spanning the Beriassian, Valanginian, Hauterivian and Barremian–Albian, is subdivided into 4 formations and 6 members, as well as 2 lithostratigraphic units defined as beds with index ammonites. No lithostratigraphic scheme is in use for the Upper Cretaceous. Well logs correlations to nearby boreholes, supported by regional macrofaunal and microfaunal data, allowed for the division of the section into individual stages from the Cenomanian through lower Maastrichtian.

The Polskie Łąki PIG 1 section is terminated by the Paleogene (depth 179.0–103.0 m), Neogene (103.0–38.5 m) and Quaternary (38.5–0.0) deposits.

The recently observed tectonic structure of the Palaeozoic and Mesozoic succession in the Polskie Łąki PIG 1 borehole was formed as a result of multiphase deformations related mainly to contractional and transpressional regime, while the impact of tectonic processes related to extensional and transtensional regime was less pronounced. The oldest episodes of deformation were associated with contractional and strike-slip tectonic activity. This led to development of bending-related macro- and mesofolds. Sediments engaged by this deformation are generally characterized by fold and thrust tectonic style and steep tectonic dipping causing significant angular unconformity with the overlying successions. These deformations could be related to the Caledonian collision of Avalonia and Baltica and to an impact of a developing orogen onto tectonic regime of its foreland. Left-lateral component of the deformation probably reflects an oblique character of the collision. The deformation developed presumably during the Early Silurian time (Llandovery). Tectonic activity at the end of Silurian-beginning of Devonian was probably of lesser importance than intra-Silurian ones (Żaba, Poprawa, 2006). The following, younger episodes of tectonic activity led to development of deformation revealing very changeable tectonic regime, from extensional and transtensional to transpressional and compressional. This generation of deformations was probably related to Variscan and post-Variscan (pre-late Permian) stage of evolution of the study area, in particular with the significant late Carboniferous-early Permian uplift and fault block tectonics. The next main stage of deformation in the Koszalin–Chojnice zone encompassed several episodes related to extensional (transtesional?) and transpressional tectonic regime. This deformation developed probably during the late Triassic to the latest Cretaceous–earliest Cainozoic. The deformation is interpreted as an expression of development of transtensional tectonic grabens in the Late Triassic–Early Jurassic and, to a lesser degree, in the Middle Jurassic and Early Cretaceous, as well as of their subsequent tectonic inversion in Late Cretaceous–earliest Cainozoic time.

The Odrovician–Triassic section is in general poor in organic matter. There are only several Zechstein, Upper Devonian and Caradoc horizons which show increased content of organic matter. The Permian and Triassic rocks contain mainly a humic (gas-forming) type of organic matter, of both authi- and allogenic origin. The Ordovician and Devonian deposits are characterized by a common occurrence of "oil-generating" organic matter derived from algae. It co-occurs with vitrinitized and fusinitized organic remains represented largely by graptolites. Thermal maturity of the Permian–Ordovician deposits increases with burial depth, ranging from the main phase of oil generation (Zechstein–Upper Devonian) to the phase of natural gas generation (Middle Devonian–Caradoc). The Upper Triassic rocks show an anomalous level of alteration. Increased values of vitrinite reflectance are most likely related to oxidizing conditions of diagenetic processes.

Detailed investigations of organic matter suggest low contents of organic carbon and labile components in the Triassic and Zechstein deposits. Bitumens found in these rocks should be considered epigenetic. A higher content of organic carbon is observed only in the Upper Devonian rocks which thus are "good" source rocks for hydrocarbon generation. Organic matter from the Upper Devonian deposits originated mostly from bacterial and algal decomposition, and as such it is a good and highly altered "oil-generating" material.

The Upper Devonian rocks contain migrating labile components. The amount of organic carbon in the Middle Devonian deposits is small.

Borehole geophysical investigations enabled the identification of both lithologies and principle petrophysical features of the rocks. Due to a wide suite of petrophysical measurements, the Polskie Łąki PIG 1 drilling is one of the key marker callibration boreholes in the central part of the Polish Lowlands.

Drill stem tests performed in the borehole show that the Main Dolomite reservoir is non-perspective. Similarly, the tests performed in the Lower Triassic horizons gave negative results. Only the Devonian rocks seem to be perspective in terms of hydrocarbon accumulation. Flow rates of <0.3 m^3/h and 5 tests with no flow suggest poor reservoir properties of the rocks. However, the high values of formation pressure gradients, ranging from 1.18 to 1.57×10^3 hPa/10 m, and little content of combustible gas (with methane concentration up to about 58% vol.) could indicate the possibility of small hydrocarbon accumulations in fracture zones and under favourable tectonic conditions. Worth noting is the increased He content in natural gas found in the Devonian rocks. If high concentrations of natural gas are confirmed, the possibility of He production should be considered.