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SUMMARY

The Tuchola IG 1 borehole is located in the south-eastern part of Western Pomerania within the Pomeranian Trough, near the Permian-Mesozoic tectonic structure called the Koszalin–Chojnice Zone (comp. P. Krzywiec). The borehole penetrated Paleozoic, Mesozoic and Cenozoic deposits. This location resulted in a significant complication of the tectonic structure, the presence of a number of stratigraphic gaps, as well as variable thickness of individual lithological complexes in relation to the nearby areas.

The following Systems were encountered in the Tuchola IG 1 section: Devonian (unpierced Givetian and undefined Upper Devonian – probably Frasnian), Permian (incomplete Zechstein represented by the PZ4 and PZ3 cyclothems), Triassic, Jurassic, Cretaceous, Paleogene, Neogene and Quaternary (see Figure 3 – detailed lithological and stratigraphical log). Typical of this section are considerable gaps not only between the individual Systems (lack of the whole Carboniferous), but also within the Systems (e.g. lack of a significant part of the Upper Devonian and Permian). Most of these gaps are definitely of local extent and are not common in the whole area of Western Pomerania.

The oldest deposits drilled are carbonates and siliciclastics representing the Middle Devonian (Givetian). They are composed of three lithostratigraphical units (from the oldest): (1) Tuchola Formation represented mainly by marly claystones and stromatoporoid-coral marls and limestones, (2) Silno Formation represented mainly by low-calcareous claystones and siliciclastics (sandstones and mudstones) with occasional thin limestone interbeds, and (3) Chojnice Formation represented mainly by calcareous siliciclastics (sandstones and mudstones). The overlying marly sediments of the Człuchów Formation probably represent the Upper Devonian, possibly the Frasnian. The Devonian deposits were investigated for conodonts and miospores (H. Matyja, E. Turnau), whose usefulness for biostratigraphic studies of Pomerania has been beyond any doubt. All tested rock samples from the Silno and Tuchola formations contained palynomorphs. State of preservation of spores was different, and the majority of the identified taxa has long stratigraphic ranges and is therefore less useful for stratigraphy. Much of the analyzed rock samples from the Tuchola, Silno nad Chojnice formations contain conodonts. Biostratigraphic analysis showed that the Devonian deposits are represented by the Givetian and undefined Upper Devonian, probably the Frasnian. There are no upper Frasnian and Famennian deposits. The gap also spans the Carboniferous and lower Permian.

Middle Devonian (Givetian) clastics and their depositional environment, located between the lagoon, tidal flat and barrier, as well as trace fossil assemblage were characterized by J. Pacześna. Carbonate depositional environments of the same age were associated with small organic structures and their immediate surroundings, and with a lagoonal environment (H. Matyja).

The ?Frasnian deposits are overlain by Upper Permian and Zechstein rocks. The Zechstein section, represented mainly by saline facies, is incomplete. It includes two incomplete evaporite cyclothems PZ4 and PZ3 (R. Wagner). More detailed macroscopic and geochemical investigations of the salt sediments of both the cyclothems suggest that they were deposited within a shallow salt pan out of brines highly diluted by rain water (G. Czapowski).

The Mesozoic succession is represented the Triassic, Jurassic and Cretaceous. Triassic deposits, over 800 m thick, represent the Lower Triassic composed of Buntsandstein facies, including the Baltic Formation, Pomerania Formation (divided into the Drawsko Sandstone and Trzebiatów Member), Połczyn Formation (and the Kołobrzeg Member) and the Barwice Formation), through the Middle Triassic composed of Muschelkalk facies, up to the Upper Triassic represented by layers the Sulechów Beds and Lower Gypsiferous Beds of Keuper fasies. A total of 21 lithostratigraphic units in the rank of groups, formations, and members layers have been identified (A. Becker). In relation to the data from the borehole's final report, modifications have been made to the boundaries between some lithostratigraphic units (correcting the boundaries of the Połczyn and Pomerania formations and establishing the Baltic and Barwice formations). Based on well logs analysis, the Lower/MiddleMuschelkalk boundary has also been changed. The Upper Triassic lithostratigraphic subdivision is also critically discussed in this report.

It seems that the Jurassic section is almost fully developed in the Tuchola IG 1, including the Lower, Middle and Upper Series (A. Feldman). The Lower Jurassic section, mostly non-cored, probably includes deposits from the Hettangian through the Toarcian. Based on the correlation with nearby boreholes (Chojnice 1, 2, 4, 5, Charzykowy IG 1, Człuchów 1, Wilcze IG 1, 2 and Witkowo 1 and Zabartowo 2), five lithostratigraphic units in the rank of formation have been distinguished in the Tuchola IG 1 section (Zagaje, Łobez, Komorowo, Ciechocinek and Borucice formations). The Middle Jurassic is represented by the uppermost Bajocian, Bathonian and Callovian deposits. No lithostratigraphic scheme has been so far

established. The Upper Jurassic is represented the Łyna, Pałuki and Kcynia formations and the Corbula Limestone Member.

The Cretaceous sequence includes the Lower Cretaceous siliciclastic succession (Berriasian–Albian) followed by the Upper Cretaceous succession (Cenomanian–Maastrichtian) represented by carbonate, siliciclastic and carbonate-siliceous lithofacies. The diversified facies pattern was controlled by tectonic activity of the Koszalin–Chojnice Zone, inversion of the axial zone of the Mid-Polish Trough and the supply of clastics from the Baltic Shield.

Paleogene and/or Neogene and Quaternary sediments were drilled without coring. The Paleogene/Neogene series is represented by clays, sands and muds. The Quaternary deposits are composed of fine-grained quartz sands and clays (M. Jaskowiak-Schoeneichowa). The Paleozoic and Mesozoic deposits (Middle Devonian–Upper Jurassic) contain variable amounts of organic matter (I. Grotek). The highest concentrations of organic matter occur in the Jurassic sediments (1.2 to 4.8% and locally up to 10.2%). The Devonian, Permian and Triassic show lower values with an average of 0.2–0.4%. A slightly increased concentration of organic matter (0.5–0.7%) is observed in the Middle Devonian sediments. The Devonian organic matter is poorly diversified in terms of genetic type and form of occurrence. It is represented by vitrinite-like material, solid bitumens and zooclasts. Liptinite material occurs most often in trace amounts, reaching a maximum of 0.1% in individual levels of the Middle Devonian succession, in which a number of bituminous impregnations are commonly observed. The Permian-Jurassic deposits contain abundant humic-sapropelic material composed mainly of vitrinite and liptinite macerals with a considerable proportion of inertinite group macerals. Thermal maturity of organic matter, determined from vitrinite/vitrinite-like material reflectance ratio slightly increases downwards in the vertical section of the borehole from 0.45% R_O at a depth of 1104.0 m (Upper Jurassic) to 1.27% R_O at a depth of 4141.9 m (Middle Devonian). This corresponds to the transition from an immature stage for liquid hydrocarbon generation (Upper and Middle Jurassic), through the early stage (Lower Jurassic, 0.50% R_O) and main stage of oil generation (Lower Triassic, Upper Permian, 0.62–0.63% R_O, Upper and Middle Devonian, 0.83–0.89% R_O), to the phase of wet gas and condensate generation (Middle Devonian below 4000 m, 1.19–1.27% R_O). These values suggest the increasing maximum paleotemperature of diagenetic processes from 50 to 130°C. The only Upper Jurassic and Cretaceous deposits may be considered as „good", and the Lower Jurassic as „very good" source rocks for hydrocarbon generation (E. Klimuszko). Devonian and Permian deposits are „poor" source rocks. Generally, the amount of bitumens present in the tested deposits is not high. The Devonian deposits also contain large amounts of labile components, which are generally epigenetic in relation to the sediment. Organic matter from the Devonian rocks is of sapropelic type, containing small amounts of humic material. It is highly altered and is sourced from bacteria and marine algae. Organic matter in the Mesozoic succession is of sapropelic and humic type. In the Jurassic and Cretaceous deposits it is generally poorly altered. Only in the Upper Jurassic and Upper Cretaceous rocks, there is co-occurrence of hydrocarbons of varying degrees of alteration, suggesting a process of hydrocarbon migration.

Tectonic subsidence analysis for the Tuchola IG section included both the late Paleozoic stage of evolution (Pomeranian Basin) and the Permian-Mesozoic stage associated with the Pomeranian sector of the Polish Basin (P. Poprawa). In addition, analysis of deposition rate was performed to reconstruct the activity of source areas for detrital material. Analysis of tectonic subsidence curves for the late Paleozoic Pomeranian Basin illustrates the presence of a strong phase of Middle to Late Devonian subsidence, followed by a period of slow subsidence in the early Carboniferous. Such a subsidence history in this area was interpreted as reflecting an extensional development of a back-arc basin. Deposition rate in the Middle and Late Devonian was about 80–160 m/My. It decreased in the early Carboniferous to about 10–40 m/My. In the late Carboniferous and early Permian, an intense tectonic uplift occurred, probably associated with a compressional or transpressional tectonic regime in the forefield of the Variscan orogenic zone. The Permian-Mesozoic tectonic subsidence curve constructed for the borehole illustrates the tectonic evolution characteristic of the Polish Basin. It begins with a tectonic event of rapid subsidence in the Late Permian–Early Triassic, followed by a sustained period of gradually decreasing subsidence over the rest of Mesozoic times. The overall trend of this part of the tectonic subsidence curve is typical of rift basins. The main phase of syn-rift extension can be identified with the phase of rapid Late Permian–Early Triassic subsidence. The subsequent decrease in the subsidence rate can be interpreted as an expression of post-rift thermal subsidence. Deposition rate in the Polish Basin was the highest during the Late Permian and Early Triassic, reaching a maximum of about 230 m/My. In the Middle and Late Triassic and in the Jurassic, deposition rate was commonly from several to about 60 m/My. Lower deposition rate during the Early Cretaceous was followed by higher Late Cretaceous deposition rate of about 10–80 m/My.

This analyzed area of the Pomeranian region is characterized by the presence of two main burial stages, separated by a phase of tectonic uplift, and followed by a stagnation phase (P. Poprawa). In the first stage of basin development, from the Middle Devonian to the Early Carboniferous, extension-controlled subsidence led to the formation of a sedimentary cover attaining a thickness of about 4100–4200 m. In Late Carboniferous and Early Permian times, there was a tectonic uplift phase, leading to erosion of part of the Variscan sedimentary cover. Particularly important are the Late Permian and Early Triassic burial phases and, to a lesser extent, the Late Jurassic and Late Cretaceous phases. Thermal maturity and thermal history modelling performed for the Tuchola IG 1 were calibrated by Ro measurements made for a section approximately 3000 m thick. The origin of the formation of the thermal maturity profile, defined by Ro measurements, can be explained by assuming the Late Cretaceous and/or Paleocene thermal event. Migration of hot fluids within the Upper Cretaceous rocks is assumed as a potential mechanism for supplying additional thermal energy to these rocks.

Well logging was performed at 10 depth intervals during the drilling (J. Szewczyk). Radiometric measurements helped to assess the lithology and reservoir properties of rocks. Temperature, acoustic and electrometric and hydrogeological (formation water flow testing) measurements were also made.

Measurements of average seismic velocities and vertical seismic profiling (PPS – English VSP) were performed in the 0–3960 m interval. The data show that both the velocity contrast boundaries and reflection horizons occur at the Mesozoic/Cenozoic boundary (about 200 m depth), top of the Lower Cretaceous (about 800 m), top of the Lower Jurassic (about 1600 m), within the Lower Triassic (at depths of about 2 500, 2 800 m), between the Permian and Devonian (about 3165 m) and within the Middle Devonian (approximately 3600 m) (L. Dziewińska and W. Jóźwiak).

Hydrogeological tests were carried out at eight intervals in the Jurassic and Cretaceous aquifers during the drilling, two intervals in the Upper Devonian aquifers during the drilling, and four intervals in the Middle Devonian and Lower Jurassic after completion of drilling (L. Bojarski, A. Sokołowski and J. Sokołowski). These tests were aimed at observation of bitumen shows and at providing indirect evidence for the possibility of hydrocarbon accumulations in different strata. Testing of the Middle Devonian sandstones (Chojnice Formation) was carried out after finding oil shows within these rocks. The tests, despite the fracturing procedure applied, showed no oil flow. Negative results were probably due to almost complete lack of permeability of the rocks. Weakly metamorphosed brines were encountered in the Lower Jurassic, only.