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SUMMARY

The Mniszków IG 1 borehole belongs to a series of research wells drilled in the 1970s in the far north-western margin of the Holy Cross Mountains for hydrocarbons within the Mesozoic and Paleozoic complexes. Therefore, only those parts of the profile that seemed to be prospective for these raw materials were fully cored and the vast majority of the core is in the form of crumb samples. With a borehole depth of 3.028 m, the total length of the core sections is only 238.6 m, which is 7.9% of the length of the entire borehole. Coreing was not even; in intervals of 0–650 m and 1300–2300 m, coreing was performed approximately every 100 m, while in the remaining intervals – more often.

The borehole was designed to identify sediments of the Permian-Mesozoic cover up to a depth of 3,000 meters but this goal was not fully achieved because the borehole was finished in the Lower Triassic formations without reaching the Paleozoic basement.

Based on cored intervals and crumb samples lithological, facial, microfacial and sedimentological analyses were carried out as well as macro- and micropaleontological studies and tectonic observations. They were supplemented with mineralogical, petrographic, chemical and geochemical analyses. Thermal maturity of the organic matter was determined by the thermal alteration index (TAI). In addition, the sedimentation rate and burial history were analysed. Moreover, a full set of borehole geophysics measurements and hydrogeological tests were performed.

These studies resulted in development of the chrono- and detailed lithostratigraphical section of the Triassic and Jurassic deposits in the Mniszków IG 1 borehole, referring to the currently existing stratigraphic schemes, as well as in reconstruction of their depositional environments.

The oldest deposits in the Mniszków IG 1 borehole are the Lower Triassic (Olenekian) deposits occurring at a depth of 2764.0–3028.0 m, which consist of three formations – Stachura, Samsonów and Röt. The Stachura Formation (4 m thick) is built of pelitic and organodetritic limestones, originated in shallow, brackish lagoon. Presence of the *Dasycladaceae* algae may be evidence of a connection between the Polish Basin and Tethys. Overlying Samsonów Formation (128.0 m thick) consists of structureless, spotted mudstones and claystones with carbonate and gypsum nodules, deposited in alluvial plain and periodic playas. The informal Röt Formation (132.0 m thick) is more diverse and divided into several lower order units: Radoszyce Beds, Lower Gypsum Beds, Intergypsum Beds, Upper Gypsum Beds and Wilczkowice Beds. The Radoszyce Beds are represented by cherry-red, structureless mudstones with sandstones interbeds. The Lower Gypsum Beds, Intergypsum Beds are built of grey limestones passing upwards into marls with anhydrite, as well as gastropods, bivalves and ostracods fauna. The Upper Gypsum Beds consist of light-grey marly limestones, whereas the Wilczkowice Beds – of grey sandy limestones and sandstones. The Röt deposits originated in shallow, hipersaline lagoon.

The Middle Trassic (Anisian, Ladinian) is represented by the Muschelkalk, Lower Keuper and Boundary Dolomite in the Mniszków IG 1 borehole. The Lower Muschelkalk (97.1 m thick) is built of dark-grey marly limestones with brachiopods and bivalves derbis, which pass upwards into platy marls and light-grey pelitic limestones overlied by limestones with abundant bivalves and brachiopods fauna. It was deposited in shallow open marine basin. The Middle Muschelkalk (65.9 m thick) consists of dark-grey marly limestones and marls with marly dolomite interbeds in the upper part and sedimentological breccia with dolomite-anhydrite lamination at the top. These rocks, devoid of organic debris, originated in sublitoral zone and temporal sabkha. The Upper Muschelkalk (14.5 m thick) is built of grey, pelitic limestones with clayey-marly lamination in the lower part and of grey limestones and dolomites in the upper one. It was sedimented in shallow epicontinental basin.

The Lower and Middle Keuper occur in the Mniszków IG 1 borehole, whereas the Upper Keuper, comprising the Variegated Parszów Beds, that corresponds to the Rhaetian, is absent. The Middle Keuper (except the Boundary Dolomite) is correlated to Carnian and Norian of the Upper Triassic. The Lower Keuper is represented by dark-grey mudstones and marls 30.0 m thick of the Sulechów Beds. The Middle Keuper stands out among neighboring borehole profiles with its big thickness of 1073.5 m. It comprises the Boundary Dolomite, Lower Gypsum Beds, Schilfsandstein (Stuttgart Formation), Upper Gypsum Beds and Studzianna Beds. The Boundary Dolomite (17.5 m thick) consists of dark-grey dolomites and marls. The Lower Gypsum Beds (144.0 m thick) are built of olive-grey marls with claystone and anhydrite lamination in the lower part, and brown-cherry claystones and mudstones with green spots and carbonate nodules (calcretes), in the upper one. These deposits originated in hypersaline lagoon, with periodic emergence and development of calcisols. The Schilfsandstein (96.0 m thick) is clearly bipartite. The Lower Schilfsandstein consists of grey and green-grey fine-and medium-grained, polymictic sandstones with grey mudstones and claystones inserts. The Upper Schilfsandstein is built of grey, green-grey and brown-grey, fine-grained sandstones and mudstones with dark grey marly mudstones, containing flora debris, interbeds. There are also

inserts of carbonate conglomerates coming from destruction of paleosols. The Schilfsandstein was deposited in fluvial milieu, where sandstones represent the channel facies, whereas mudstones and claystones – the outside channel facies. The calcisols, which developed on the flood plain were destroyed during flood periods. The lower part of the Upper Gypsum Beds (281.0 m thick) is built of brown-cherry dolomitic claystones with numerous gypsum and anhydrites druses, which pass into brown-cherry mudstones with green spots and fine lenses and aggregates of sulphates. The middle part consists of limestone-marly deposits, whereas the upper part – of dark grey and dark brown dolomitic marls with single gypsum and anhydrite druses and crystals. The Upper Gypsum Beds originated in hypersaline playa or sabkha-like basin. The Studzianna Beds (598.0 m thick), correlated to the Jarkowo and Zbąszynek Beds of the Norian age, are tripartite. The Lower Studzianna Beds consist of variegated mudstones interbedded with brown fine-grained sandstones. The Middle Studzianna Beds are built of brown and grey structureless mudstones with carbonate nodules. There are limy conglomerates of the "Lisów breccia" type and sandstones inserts in the upper part. The Upper Studzianna Beds consist of brown-cherry and variegated claystones, mudstones and sandy mudstones interbedded with grey-green fine- and varie-grained sandstones. The Studzianna Beds were deposited on alluvial plain, periodically dry, when it came to development of calcisols (Middle Studzianna Beds).

As the Upper Studzianna Beds are covered with the Lower Jurassic Drzewica Formation, the stratigraphical gap in the Mniszków IG 1 borehole comprises Rhaetian, Hettangian, Sinemurian and early Pliensbachian. The reasons (tectonics, lack of sedimentation or erosion) for this gap have not been clearly explained yet. The Drzewica Formation (133.0 m thick) consists mainly of sandstone-mudstone-claystone heteroliths, pointing to cyclicity of sedimentation, with inserts of brown coal at the top. It originated in delta plain milieu and its upper part represents meandering rivers and swampy deposits. The Ciechocinek Formation (88.5 m thick) of early Toarcian age is bipartite, divided by a thicker sandstone layer. Its lower part consists of green-grey claystone-mudstone heteroliths and light grey fine-grained sandstones with carbonized plant detritus. The upper part is built of grey, bioturbated sandstone-mudstone heteroliths. The lower part of the formation was deposited in deltaic and lagoon environments during a transgression of brackish basin. The sandstone bed may represent barrier, delta channel or proximal shelf deposits. It is covered by regression phase deposits of lagoons, deltas and swamps. The Borucice Formation (146.5 m) begins with a thick complex of grey, fine-grained sandstones, which is overlied by grey claystones and mudstone-claystone heteroliths, locally bioturbated. They pass upwards into monotonous sandstone complex and mudstone-sandstone heteroliths, strongly bioturbated. The lower, sandstone part of the formation represents fluvial deposits, whereas mudstone-claystone heteroliths were sedimented in a lagoon, during the short time ingression of a brackish basin. The upper part of the formation originated in a deltaic and meandering river milieu. The Borucice Formation terminates the sedimentation of the Lower Jurassic in the Mniszków IG 1 profile.

Analogy with other Middle Jurassic profiles in the Holy Cross region and adjacent areas allowed for assumption of lack of the Lower Aalenian and for subdivision of the Middle Jurassic deposits in the Mniszków IG 1 section into several members, correlated to the Upper Aalenian-Callovian. Due to poor coreing the presented correlation between litho- and chronostratigraphic units is only approximate. The Sandy-Clayey Series (51.7 m thick) consists of mudstone-claystone heteroliths with reverse cyclicity. The Sandstone Series (39.1 m thick) is built of grey fine-grained sandstones. Both these members originated in the deltaic and intermediate shelf milieu, during the transgressive-regressive cycle J3-I of Feldman-Olszewska (1997b). The Lower Claystone Series (60.1 m thick) consists of claystones in the lower part, which pass gradually upwards into mudstones, sandy mudstones and sandstones at the top. It corresponds to the transgressive-regressive cycle J3-II and was deposited on a distal, intermediate and proximal shelf zones. The Lower Sub-Limestone Series (66.1 m thick) is built of light grey fine- and medium-grained sandstones with clayey siderites and sideritic dolomites, occurring in form of intraclasts, lenses and thin layers. Amount of the mudstones and sandy dolomites inserts increases upwards the section. The lower part of the Upper Sub-Limestone Series (total thickness of 14.4 m) is built of sandstones with carbonate cement and mudstones, forming the reversed cycles. The upper part consists of strongly porous and bioturbated fine- and medium-grained sandstones. Deposits of the Sub-Limestone members can be correlated with the J3-III and J3-IV sedimentary cycles. The Siliciclastic-Carbonate Complex (14.4 m thick) ends the sedimentation of the Middle Jurassic in the Mniszków IG 1 profile. It is built of dolomitic mudstones, sandy dolomites with glauconite, dolomitic sandstones and dolomites forming reversed cycles. The complex corresponds to the J4-I sedimentary cycle, that initiated the Callovian-Kimmeridgian sedimentary megasequence. Next regression of the basin, which took part at the end of the Upper Callovian, corresponds to the top of the dolomitic mudstones (866.4 m) or to the silificated dolomites in the uppermost part of the Siliciclastic-Carbonate Complex. Both Sub-Limestone Series and Siliciclastic-Carbonate Complex originated in different (distal, intermediate and proximal) zones of a silicilastic and siliciclastic-carbonate shelf.

The Upper Jurassic deposits in the Mniszków IG 1 section can be correlated to the Oxfordian and Kimmeridgian (without the uppermost Kimmeridgian). Presented lithostratigraphical units division is based mainly on geophysical measurements. The Częstochowa Sponge Limestone Formation consists of the three units: Jasna Góra Limestones Member (4.8 m thick), built of pelitic limestones, Grey Limestones Member (10.2 m thick), built of marly limestones and Morawica Limestones Member (153.0 m thick) that comprises limestones with tuberoid dots. The Pilica Formation/Siedlce Limestones Member (304.3 m thick) consists of pelitic and marly limestones and marls. Both formations originated on open carbonate shelf. They are overlied by the Kurnędz Limestones Member (125.7 m), which base can be correlated with the Oxfordian and the Lower Kimmeridgian boundary. This member comprises lithologically varied carbonate deposits, sedimented on the shallow water carbonate

platform. The Middle Marly complex (39.0 m thick), lying above, reflexes a short time deepening of the basin. The Oolite-Platy Limestones Member (35.0 m thick), built of oolitic and organodetritic limestones with marl intercalations, put an end to carbonate sedimentation on the shallow water platform, which immersed due to the sea level eustatic rise. The Stobnica Lumachelle Formation (149.0 m thick), that comprises the Lower and Upper Kimmeridgian boundary, is built of pelitic limestones and marls with locally organodetritic limestone interbeds. It originated on the siliciclastic-carbonate shelf, deepening during the sedimentation of the Pałuki Formation (11.5 m thick), which consists of marly limestones and marls. They terminate the Mesozoic section in the Mniszków IG 1 borehole.

The degree of organic matter maturity, determined on the basis of the TAI method, in the Lower Jurassic and Upper Triassic rocks is 3+ –4, what corresponds to the early stage of oil generation. Vitrinite reflectance studies have not been performed. Summarizing the results of the research of reservoir rocks in the Mniszków IG 1 borehole, it can be concluded that there are no reservoir rocks with good collector properties within the Middle and Upper Triassic formations. Tide abilities stated in the majority of the investigated horizons within the Keuper and Muschelkalk deposits, revealed that they are only isolated levels containing mainly relict waters. Moreover, there are no clearer evidences of bitumens in the Triassic and Jurassic formations, but only saturation with mineralized waters containing iodine and boron.

Studies of the burial history evidenced that the Mniszków IG 1 section is characterized by presence of several phases of higher deposition rate and higher burial rate (Triassic without Rhaetian, Middle and Late Jurassic, Late Cretaceous), separated by periods of stagnation or erosion (Late Triassic – Rhaetian, Early Jurassic, Early Cretaceous and maximum of erosion after the Late Cretaceous amounting to 1,300 m). The similar burial history can be interpreted from the Piotrków Trybunalski IG 1 section, located in the Łódź–Mogilno Basin, what indicates that Mniszków area was lowered in relation to the neighbouring Opoczno vicinity during the sedimentation of the Triassic and Jurassic deposits.

Overall, Mniszków IG 1 borehole provided important information on lithology, age and tectonics of the Triassic and Jurassic deposits as well as showed no their reservoir properties in this area of the north-western margin of the Holy Cross Mountains.