SUMMARY

Ryszard HABRYN, Jolanta PACZEŚNA, Artur TEODORSKI

Within a period of merely five years after completion of the Bibiela PIG 1 borehole, drill core materials, and measurement and analytical data provided abundant information obtained as a result of wide spectrum of research.

The Bibiela PIG 1 borehole was an exploratory well designed to explore the geological structure of the north-eastern part of the Upper Silesian Block, especially the previously poorly studied early Paleozoic formations.

The location area of the Bibiela PIG 1 borehole is part of the tectonically complex, uplifted Brudzowice structure of Variscan age. Against the background of tectonic units underlying the Permian-Mesozoic and Cenozoic covers, the borehole is located within the Upper Silesian (Dębnik-Siewierz) fold zone.

Four structural units, separated by sedimentary and erosional discontinuities, manifested by angular discordances, have been identified in the Bibiela PIG 1 borehole. These are, in the stratigraphic order, the Neoproterozoic structural unit, represented by Ediacaran deposits, the epi-Cadomian structural unit, comprising Ordovician deposits, the Variscan structural unit of the Upper Silesian Block, which includes Devonian formations, and the epi-Variscan (Permian-Mesozoic) structural unit, represented in the Bibiela PIG 1 only by Triassic deposits.

Highly tectonically deformed and slightly diagenetically altered Ediacaran deposits, 939.05 m thick, were drilled in a depth interval of ?710.95–1650.0 m. They are represented mainly by siltstone-claystone-mudstone lithofacies. Sandstone and breccia lithofacies account for a smaller percentage in the lithologic spectrum. The Ediacaran deposits provide an association of microfossils showing low generic and special diversity. These are mainly simple spherical forms of acritarchs of the genus *Leiosphaeridia*, and fragments of filamentous *Cyanobacteria*. The Ediacaran deposits accumulated in deep-water environments and represent distal flysch sediments. The lower part of the Ediacaran section is composed of deposits of turbidity currents, outer zones of submarine fans, and the abyssal plain. Deposits of the upper part of the Ediacaran section accumulated probably in lower zones of the continental slope. Petrographic studies of the Ediacaran rocks show that they do not exhibit signs of anchimetamorphic conditions.

The Ediacaran deposits are overlain by Ordovician rocks drilled in a depth interval of 287.00–?710.95 m (423.95 m thick). The Ordovician succession includes several intervals that show varied lithological records. The upper part of the succession is dominated by grey-green claystones with interbeds of quartzitic sandstones and dolomitic claystones. Below, there is a complex of light grey-green claystones, regularly laminated with dark grey claystones. The third lithological interval consists of grey claystones interbedded with fine-grained sandstones. The lowermost interval of the Ordovician succession is characterized by the presence of intraclastic and polymictic sedimentary breccias attaining a thickness of 34 m. The above-mentioned deposits bear features of seismites and were deposited in a sedimentary basin affected by strong seismic activity of the seabed in the lower part of the continental slope. Petrographic studies of the Ordovician rocks show the presence of various rock associations represented by arenites and quartz wackes, siltstones, lithic wackes, sandy mudstones, claystones and siliceous claystones, phosphorites, tuffitic claystones, siliceous rocks, mainly cherts, and breccias. Inorganic geochemistry analyses indicate that the Ordovician section provides a record of distinct climate changes over time. The CIA index of approximately 85 for claystones is indicative of very intense chemical weathering in source areas with hot and humid climates. Towards the top of the Ordovician section, there is a systematic change in physicochemical parameters. Initially, the CIA index in the range of 68–70 is indicative of a relatively cool and dry climate, which was subsequently getting warmer and the humidity was increasing (CIA from 68 to 77).

The Ordovician deposits are separated from the overlying Devonian rocks, drilled in a depth interval of 178.3–287.0 m, by a tectonic boundary. The Devonian sequence is composed of alternating strata of clastic rocks (represented mainly by dolomite-cemented quartzitic sandstones, with minor claystones and mudstones) and carbonates, among which highly silicified micrite and sparite dolomites predominate. Also present in the section are horizontally finely laminated sandstone-mudstone-claystone heteroliths, forming sets of tidal rhythmites. The Devonian deposits accumulated in a transgressive tidal estuary.

The Devonian formations are overlain by Triassic deposits, 154.3 m in thickness, which occur in a depth interval of 24.0–178.3 m. The Triassic complex is composed mainly of carbonates occurring in the upper part of the succession, while the lower part is represented by dominant claystones and sandstones.

The lithological-stratigraphic section of the Bibiela PIG 1 borehole is terminated by Quaternary formations drilled in a depth interval of 0–24.0 m and represented by sands and tills of the South Polish Glaciation (Sanian Glaciation), muds of the Middle Polish Glaciation (Odra Glaciation) and quartz sands of the North Polish Glaciation (Vistula Glaciation).

Detrital material from the Bibiela PIG 1 borehole was examined for age determination using U-Pb analysis of detrital zircons derived from clastic rocks, and volcanogenic zircons taken from tuffite layers. Based on the dates, it has been possi-

ble to confirm the time of deposition of the Ediacaran rocks. Samples from this period were dated to 553 ± 4.9 Ma and 545.9 ± 4.8 Ma. Three further detrital zircon samples yielded ages of 539.6 ± 9 Ma, 428 ± 12 Ma and 480 ± 13 Ma. These dates do not correlate with the adopted stratigraphic scheme, and are characterized by a high uncertainty related to a change in the nature of the sedimentary basin. Analysis of a cumulative sample of tuffites indicates a large age range of deposition between 479 ± 4 Ma and 446 ± 12 Ma,. In Ediacaran time, the north eastern part of the Upper Silesian Block was fed mainly by detritus derived from eroded Neoproterozoic rocks, mainly from the Cadomian orogen that was active at that time.

The Triassic deposits contain elevated amounts of Pb, Ag, As, SO_3, Zn, Cd and Tl, indicating the presence of traces of Pb-Zn mineralization. The Paleozoic and Neoproterozoic rocks are poorly mineralized. They are characterized by low contents of ore-forming elements. The Ordovician and Ediacaran low-temperature polymetallic mineralization is associated with the effect of Variscan acidic magmatism on the Ediacaran-Paleozoic clastic rocks. The rocks are cut by numerous minor veins composed mainly of carbonates and occasionally of quartz. The Ordovician clastic rocks contain pyrite, melnicovite, markasite, chalcopyrite, galena and sphalerite. The maximum Cu content is 0.14%, and there are also elevated contents of Fe_2O_3, P_2O_5, MnO, SO_3, As, Mo, Ni, Te, Th and Zn. The highest elemental contents are recorded near magmatic rocks. The mineralization level of the Ediacaran samples is lower than of the Ordovician ones. The age succession of individual associations is difficult to determine. The highest values of Hg are found in zones of metallized rocks. No Hg anomaly has been observed so far in Paleozoic and Neoproterozoic formations of the Kraków–Lubliniec region.

Magmatic rocks in the Bibiela PIG 1 borehole are highly altered, which makes their petrographic identification difficult. They have undergone intense dolomitization, kaolinization and chloritization. It is likely that the uppermost magmatic rock was originally a lamprophyre, and the other rocks may have been finely crystalline andesites. In addition to the minerals found in the clastic rocks, the magmatic rocks also contain titanium oxides, titanite and tennantite. They are characterized by maximum contents of K_2O, TiO_2, P_2O_5, Ce, Cr, Nb, Sn, V and Zr. The contents of As, Ba, Cs, La, Mo, Ni, Sr and Th are higher than in the clastic rocks. The origin of ore mineralization in the magmatic rocks is probably different than that observed in crystalline rocks.

On the basis of palaeomagnetic studies, two components of magnetization have been determined for the Ediacaran and Ordovician rocks under study: A and B. The low-stability component A is not suitable for geological interpretations. The high-stability component B is characterized by secondary, syntectonic magnetization. In the Ediacaran rocks, it was acquired most likely during folding at the transition from the Ediacaran to the Cambrian, or in the Devonian – Early Carboniferous. In the Ordovician rocks, component B may have been acquired in Devonian–Early Carboniferous times. However, the age of remagnetization requires further research. Based on magnetic lineations, it can be concluded that the probable direction of tectonic compression could be SSW–NNE or SE–NW for the Ediacaran, and SSE–NNW for the Ordovician.

The magnetic susceptibility in the rocks from the borehole is low or very low, also negative. Rapid increases in susceptibility are recorded in magmatic rocks, suggesting the "cold" nature of contact with the surrounding rocks, and therefore the lack of wider zones of thermal contact alterations. Rapid increases in magnetic susceptibility have been recorded at the base of Röt limestones and upper Middle Triassic dolomites. These zones can be the places of flow of solutions generating a new magnetic fraction.

The Ediacaran deposits are non-source rocks for hydrocarbon generation, and they commonly contain faint amounts of thermally highly mature organic matter. Their original generative potential has been exhausted. It is also probable that these rocks originally did not have the potential to generate significant amounts of hydrocarbons.

Tectonic profiling has revealed a rich set of tectonic structures that developed as a result of multi-phase and long-term tectonic activity. It took place in several stages. Structural complexes have been identified in the Ediacaran, Ordovician, Devonian and Triassic rocks. The rocks show structures associated with the processes of extension and compression, as evidenced by the fold-block tectonics and the presence of seismites, and thrust, strike-slip, dip-slip and reverse faults. All tectonic structures found in the analysed borehole section are probably related to the activity of the most important tectonic structure in the study area, i.e. the Kraków–Lubliniec (Kraków–Hamburg) Fault.

Thicknesses of the stratigraphic units were the basis for determination of sediment deposition rate. It is variable and depends on the intensity of the subsidence process. The deposition rate varies from about 5 m/million years in the Early Ordovician to about 30 m/million years at the turn of the Ordovician and Silurian. The Ordovician/Silurian transition also saw the most rapid phase of burial. The next phase of burial occurred during early Devonian– early Permian times. Uplift events are recorded in this area at the Silurian/Devonian transition (removal of Ordovician deposits) and in the Triassic (erosion of Middle–Upper Devonian, Carboniferous and Permian deposits).

Analysis of well logs made it possible to refine the interpretation of lithologies and ore mineralization in the Bibiela PIG 1 borehole. Distinct anomalies of the potassium, uranium and thorium contents in the Ordovician correspond to horizons of occurrence of intrusive magmatic rocks. No prospective horizons for hydrocarbon accumulations have been distinguished in the borehole section.

Hydrogeological studies enabled to distinguish three groundwater aquifers: in Middle–Lower Triassic limestones and dolomites, in Lower Devonian sandstones and dolomites, and in Ordovician sandstones. The aquifers contain freshwater of infiltration origin, whose mineralization increases with depth.

Pilot studies performed on the basis of high-resolution optical scanning of drill cores allowed identifying a broad spectrum of sedimentary and tectonic structures. The detailed survey material obtained can be used for thorough geotechnical, sedimentological and tectonic analyses.