SUMMARY

The geological goal of the Komarów IG 1 borehole, at the stage of work projecting, was to explore Carboniferous and Devonian deposits underlying a thick overburden of Mesozoic rocks, regarded as the most promising for exploration in terms of oil and natural gas in the Lublin region. During compiling of the borehole's final report, it was possible to develop only the lithological-stratigraphic profile of the borehole and to describe oil and gas shows observed during drilling, as well as the results of formation tests.

Also the exploratory goal of the borehole has been achieved by drilling a natural gas deposit. However, detailed studies of the Carboniferous and Devonian deposits took place successively over the next 47 years that have passed since the drilling operations. Particularly intense studies were conducted in the last decade under a number of research projects, among others, at the Polish Geological Institute – National Research Institute. This volume summarizes results of the latest studies carried out on drill cores and well logs.

The very high core yield from the Carboniferous and Devonian section provided research material for lithological, sedimentological, stratigraphic, petrographic, geochemical, geophysical, thermal maturity and source rock potential studies, as well as for deposition rate analysis and thermal history and burial modelling. It should be stressed that the first stratigraphic subdivision of the borehole section, currently to be found in the borehole's final report, has been updated based on the results of various litho-, bio- and palynostratigraphic studies as well as sequence stratigraphic techniques.

The oldest rocks drilled by the Komarów IG 1 borehole belong to the Devonian system and occur in a depth interval of 1933.0–2547.8 m. The chronostratigraphy of the Devonian section is based on the results of microfaunal studies of conodonts, macrofaunal investigations, and analysis of well logs with correlation to the marker borehole of Terebin IG 5.

Analysis of transgressive-regressive sequences was also performed in the borehole. The drilling pierced the Upper, Middle and Lower Devonian, however did not reach its base. The incomplete thickness of the Devonian is 614.8 m. Lower Devonian deposits occur at a depth of 2469.3–2547.8 m (driller's depth) and the undrilled thickness is 78.5 m. They are represented probably by the middle and Upper Emsian.

Within the Lower Devonian succession, the Zwoleń Formation and the Przewodów Member of the Telatyn Formation have been distinguished. The Zwoleń Formation is composed of variegated silty claystones, siltstones and sandy siltstones containing carbonate concretions, often dolomitic of *caliche* type, supposed to represent palaeosol horizons.

The claystones are interbedded with quartz sandstones (arenites), locally with quartz and quartz-mica wackes.

The Zwoleń Formation is followed by a stratigraphic gap spanning the Upper Emsian. The Przewodów Member is represented by clayey siltstones with clay pisoids, quartz sandstones (arenites) and claystones enriched with biotite and pennine. Middle Devonian deposits occur at a depth of 2301.2–2469.3 m (driller's depth) and have a thickness of 168.1 m. They probably represent the Eifelian and Givetian.

The Middle Devonian consists of five members within the Telatyn Formation. The Machnów Member is composed of dolomitic marls with pyrite concretions, dolomitic marls, and dolomites with ooids and anhydrite streaks or claystone interbeds. The Żniatyn Member consists mainly of sandstones, some of them with laminae and streaks of siltstones, which contain fragments of placoderm fish. The Pełczyn Member is represented by dolomites and limestones. The lower part of the Rachanie Member is made up of siltstones and cavernous dolomites, while its middle and upper parts are composed of various types of dolomitic claystones and clayey dolomites with anhydrite interbeds.

The Mircza Member consists of dolomites with anhydrite interlayers, pelitic dolomites and clayey and silty dolomites. In places there are also sheeted anhydrites. The Upper Devonian occurs at a depth of 1933.0–2291.8 m and its thickness is 358.8 m. It is correlated with the Frasnian and consists of the Modryń Formation subdivided into four members. The lower part of the Krzewica Member is composed of dolomites, while its upper part is represented by marls and clayey dolomites with laminae of algal mats.

The lower part of the Lipowiec Member consists of nodular limestones, locally dolomitic, containing marine fauna. Its upper part is composed of secondary dolomites, commonly cavernous, with fragments of marine fauna and algal laminites. The lower part of the Łosień Member consists mainly of dolomites, while its upper part – of limestones. The Zubowice Member is represented mainly by limestones with subordinate dolomites.

The Devonian succession is overlain by the presumed middle Visean preceded by a stratigraphic gap spanning the upper part of the Frasnian, and the Famennian, Tournaisian and Lower Visean.

Carboniferous deposits occur in a depth interval of 1057.0–1933.0, and their thickness is 876.0 m. Carbonifero-

us section of the Komarów IG 1 borehole has been interpreted mainly on the basis of lithofacies analysis of drill cores, supplemented by analysis of well-logging measurements. The chronostratigraphic boundaries have been placed based on correlations of depositional sequence boundaries with the marker section and the global and West-European Carboniferous stratigraphic divisions. It facilitated a more detailed stratigraphic subdivision and resulted in shifting existing boundaries.

The section is represented by limestones, marls, claystones, siltstones, sandstones, stigmarian soils, carbonaceous claystones and coals. In terms of thickness, the dominant lithologies are claystones and siltstones, but carbonate rocks also occur in a significant proportion. The Mississippian was found at a depth of 1185.0–1933.0 m (748.0 m in thickness), while the Pennsylvanian – at 1057.0–1185.0 m (128.0 m in thickness). The Visean section (1540.0–1933.0 m; 393.0 m in thickness) is represented mainly by claystones and siltstones deposited in shallow-water deltas and a shallow clay shelf, as well as by numerous and relatively thick limestones representing a shallow carbonate shelf environment. These deposits compose transgressive systems tracks that formed during a relative sea-level (RSL) rise, and highstand systems tracts (HST).

The Serpukhovian section (1185.0–1540.6; 335.6 m in thickness) consists mainly of claystones and siltstones deposited in shallow-water deltas and a shallow clay shelf during a sea-level rise and a highstand (HST). The Bashkirian (1057.0–1185.0 m; 128.0 m in thickness) is composed of river-channel sandstones, claystones, siltstones and stigmarian soils of fluvial floodplains, deposited during a relative sea-level rise. The section is also represented by siltstones and claystones deposited in shallow-water deltas and a shallow clay shelf during a sea-level rise and a highstand. In the lower part of the Bashkirian, there is presumably a stratigraphic gap, also reported from the rest of the Lublin Basin, which corresponds to the Upper Alportian and Kinderscoutian stages from Western Europe.

The Carboniferous is overlain by Jurassic deposits in this borehole, and the stratigraphic gap spans the Upper Pennsylvanian, Permian, Triassic and the Lower, Middle and lowermost Upper Jurassic. Jurassic deposits were encountered at a depth of 921.0–1057.0 m (136.0 m in thickness) and are represented by the Upper Jurassic of the Tyszowce and Ruda Lubycka Formations – ? Upper Oxfordian and Kimmeridgian. The Jurassic chronostratigraphy is based on well log data analysis and correlation with the marker Grabowiec IG 3 borehole. The Tyszowce Formation is built, in its lower part, of sandstones, claystones/siltstones and conglomerates, and in its upper part – of sandstones, clayey sandstones and siltstones. These deposits were probably deposited in the sabkha environment. The Ruda Lubycka Formation is represented by lagoonal dark grey dolomites.

The youngest deposits in the Komarów IG 1 borehole are Cretaceous rocks found in the interval of 0.0–921.0 m (921.0 m in thickness), represented by the Upper Albian included in the Lower Cretaceous, as well as by the Upper Cretaceous stages from the Cenomanian through Maastrichtian. The Cretaceous rocks lie upon a denudation surface of Upper Jurassic (Upper Kimmeridgian) deposits. The stratigraphic gap in this area spans nearly all the Lower Cretaceous and uppermost Jurassic deposits. The boundaries of the Cretaceous chronostratigraphic units are approximate and determined based on the correlation of borehole geophysical measurements with reference to the marker boreholes.

Of high importance are also palaeontological data from the core material, especially the analysis of foraminiferal assemblages and macrofaunal studies. The Cretaceous succession begins with the Upper Albian sands, sandy marls and marls quickly passing into the Upper Cretaceous marly and carbonate deposits. The entire section is represented by carbonates grading in places into marls (Lower Santonian, Campanian, Lower Maastrichtian) or siliceous-carbonate rocks (marly opokas in the Lower and Upper Maastrichtian). No evidence of gaizes, chalk-like limestones or chalk has been reported.

The considerable thickness of the Maastrichtian (which accounts for 50% of the total Cretaceous thickness) suggests a significant increase in subsidence rate within the basin at that time. Excepting the Upper Albian sandstones, the proportion of terrigenous material in the Upper Cretaceous rocks is small and the calcium carbonate ($CaCO_3$) content is not less than 50.68% measured in an opoka from the Lower Maastrichtian. As proved by the structural analysis, the Palaeozoic structural pattern, with the Lublin Graben developed in this area, had a significant effect on the Late Cretaceous sedimentation and palaeogeography.

Petrological studies of organic matter were carried out on Devonian and Carboniferous deposits. The Devonian rocks contain organic material that is poorly differentiated in terms of both its origin and form of occurrence. It is represented mainly by vitrinite-like components (solid bitumens and zooclasts). Liptinite material usually occurs in trace amounts, and there are only a few Middle Devonian horizons that contain infrequent bitumen impregnations.

The Carboniferous deposits contain abundant syngenetic, mainly humic organic matter composed of three basic maceral groups: vitrinite, inertinite and liptinite. Thermal maturity of organic matter, determined on the basis of vitrinite (Carboniferous) and vitrinite-like material (Devonian) reflectance coefficients increases moderately in the vertical section from 0.80% R_o at a depth of 1081.0 m (Bashkirian) to 1.17% R_o at a depth of 2517.1 m (Lower Devonian).

The degree of organic matter alteration in the Carboniferous rocks corresponds to the main (Bashkirian, Serpukhovian) and late (Visean) phases of oil generation, with the reflectance coefficient varying in the range of 0.79–1.05% R_o. The Devonian deposits are characterised by slightly higher thermal maturity corresponding to the late phase of oil generation with the possibility to generate wet gas and condensates (1.06–1.17 % R_o).

Geochemical studies have proven that there are only some intervals in the Komarów IG 1 section, which can be composed of "good" source rocks for hydrocarbon generation.

Generally, the amount of bitumens present in the studied rocks is not high, and the organic matter is not highly altered. The Devonian rocks contain sapropelic-type organic matter and a considerable amount of epigenetic labile components. Bacteria and marine algae were the source of organic matter in the Devonian rocks.

The Carboniferous deposits, especially Pennsylvanian, contain sapropelic-type organic matter with an admixture of humic material. In the lower part of the Carboniferous section, the humic material is highly altered, suggesting its allochthonous nature. In the Serpukhovian deposits, allochthonous material is accompanied by poorly altered autochthonous humic material.

Pyrolytic analysis of the Carboniferous deposits shows the occurrence of organic matter as a mixture of more and less degraded Type-III kerogen, as well as reveals the presence of oil- and gas-generating Type-II and Type-III kerogen. Among the analysed deposits, there are also non-source rocks, poor source rocks and source rocks of moderate potential for hydrocarbon generation. Some rocks should be considered very good potential source rocks.

The degree of thermal alterations indicates that the rocks are in the main phase of liquid hydrocarbon generation in the upper and middle part of the oil window, and have not yet reached their ultimate hydrocarbon generation level. However, some of the rocks are characterised by thermal maturity of low- and high-temperature thermocatalytic alterations for the oil and gas windows. The Carboniferous rocks contain light and heavy crude oil, and resins with asphaltenes in the low and very low value ranges, while the kerogen content is very high.

Bashkirian and Serpukhovian rocks from in the Komarów IG 1 borehole are dominated by kerogen and they contain no impermeable horizons that from as a result of saturation with heavy oils, resins and asphaltenes, which could be barriers to hydrocarbon migration.

The measured porosity of the Devonian deposits is low, ranging from 0 to 3.26%, with no permeability. Better reservoir properties have been found in the Carboniferous rocks, of which only sandstones were analysed. They are characterised by the porosity values in the range of 1.29–10.50% (usually about 6%), and lack of permeability.

Modelling studies of the Komarów IG 1 section show the presence of several phases of increased burial and high deposition rates, e.g. in the Devonian, Visean and Late Cretaceous. After periods of rapid burial, erosion and without deposition phases took place.

The comparison of the lithological section, interpreted based on the analysis of drill cores, with the section constructed from the analysis of well logs shows the existence of significant differences in the depth of occurrence of lithological boundaries, particularly in the Devonian, which can be up to 13 m.

During the borehole drilling, crude oil and natural gas shows were observed on drill core surfaces. During sampling of the 2301.8–2548.6 m horizon, a small natural gas deposit of low producing rate was discovered in the Devonian rocks. The deposit is located within a trap in an anticline extending in line with the Izbica–Zamość–Ugniew fault. The potential producing rate was 34 Nm^3/min.

The gas was characterised by a favourable chemical composition; the content of combustible constituents was 96.6% vol. The commissioning of the borehole was cancelled due to the frozen drill string, and the hole was backfilled. The formation test at 919.0–929.0 m depth revealed a highly mineralized flow of chloride-sodium, iodide water (2.7%) with the discharge rate of 0.173 m^3/h.