

## SUMMARY

The Goczałkowice IG 1 borehole was a key one to study lithology and stratigraphy of Cambrian and Devonian rocks in the Upper Silesian Block. The Precambrian basement, drilled in this borehole and slightly different from that observed in the other ones, as well as the alkaline intrusion, provided information on the geotectonic development of this block.

Ediacaran rocks in the Goczałkowice IG 1 borehole were found underlying Lower Cambrian deposits that are separated from the Ediacaran sediments by an over 40-metre-thick diabase dyke. The Ediacaran section is clearly tripartite. The top and basal parts are dominated by grey-green anchimetamorphic rocks of phyllite, metapelite and metapsammite types. The rocks are folded, strongly mylonitized and cataclased, and in places contain veins of erlan or skarn material. The middle part of the Ediacaran section consists of metamorphosed conglomerates containing rounded and angular fragments of igneous rocks, mainly plutonic alkaline gabroid rocks, diabases, less frequent diorites and granodiorites, and equivalent volcanic rocks. Quartzites, quartzite shales and phyllites are occasionally found among the conglomerate clasts.

The acritarch and trilobite assemblages, identified in the Cambrian clastic rocks, allowed determining their stratigraphic position. The age of acritarch assemblages from these deposits in the Goczałkowice IG 1 borehole was first determined in the 1980s. At those times, the species of *Timofeevia phosphoritica* and *Timofeevia lancarae* were described from the top of metamorphosed rocks in the Goczałkowice IG 1 borehole, which suggest their Middle Cambrian and Lower Tremadocian age. Rock samples from greater depths contained assemblages whose age was constrained to the Lower (*Holmia B*) – Middle Cambrian. The acritarch assemblages from the Goczałkowice IG 1 borehole, their age, and the sequence in the section were reinterpreted in the following years. Most of the section represents the Lower Cambrian, as evidenced by trilobite fossils. Based on organic microfossil assemblages from the uppermost part of the section, this portion of the sequence is firmly included in the Middle Cambrian. Studies that are more recent have not confirmed the presence of microfossil

assemblages characteristic of deposits younger than the Cambrian Series 2.

In the Goczałkowice IG 1 borehole, Cambrian trilobites occur in the Pszczyna Siltstones with Trilobites Member of the Goczałkowice Formation. So far, 15 specimens representing four taxa have been found: *Schmidtella panowi* (Holmiidae), *Berabichia* sp., *Strenuaeva* sp. and *Epichalnipsus* sp. (Ellipsocephalidae). The age of the trilobite assemblage corresponds to the Baltic zone of *Holmia kjerulfi* and is in accordance with the age determined from local acritarch assemblages (BAMA). Taxonomic composition of the trilobite assemblage is similar to the faunas of the lower part of the Series 2 from Scandinavia and the Holy Cross Mountains.

In this borehole, Cambrian deposits are overlain immediately by Devonian rocks. The base of the Devonian is an erosional surface; the Devonian rests on palaeontologically documented Lower Cambrian deposits of the Goczałkowice Formation. This boundary is accentuated by a clear lithological contrast: Cambrian dark siltstones and sandstones are overlain by gravels and pebbles of the bedrock. The Lower Devonian is represented here exclusively by the Upper Emsian Andrychów Formation. The Middle Devonian in the Goczałkowice IG 1 borehole comprises indeterminate parts of the Lachowice and Roztropice formations; however, they occur only up to a depth of 2316.0 m. Even the determination of the approximate boundaries of the Middle Devonian stages (Eifelian and Givetian) in the section currently seems impossible due to the scarcity of biostratigraphic data. The Upper Devonian (Frasnian) spans the upper part of the Roztropice Formation, including the Czatkowice Limestones Member. Such a stratigraphic position is indicated by the brachiopod and stromatoporoid fauna. A transitional interval, in which no stromatoporoids have been found and brachiopods do not provide clear stratigraphic indications, is also included in the Frasnian.

The top boundary of the Upper Devonian in the Goczałkowice IG 1 borehole runs most probably slightly below the top of the Roztropice Formation, where representatives of the Famennian genus *Pugnax* were

found. The Upper Devonian – Famennian section consists of informal stratigraphic units: black marls and marly limestones, a sand-carbonate unit, light dolosparites and granular limestones, laminated granular limestones, and part of fenestral limestones and dolomicrites. Affiliation of the former two units to the Famennian is confirmed by a brachiopod assemblage. The light dolosparites and granular limestones and the lower part of the laminated granular limestones contain Famennian conodonts from the *marginifera* – lower *expansa* interval. The age of the upper part of the laminated granular limestones, especially of the fenestral limestones and dolomicrites, is more problematic; up to a depth of 1920.1 m, there are no unequivocal biostratigraphic data available in the Goczałkowice IG 1 borehole. The Devonian/Carboniferous boundary runs not higher than the 1920.1 m depth, where representatives of the Tournaisian foraminifera genus *Chernyshinella* were found.

The Devonian of the southern part of the Upper Silesian Block – with the benchmark section of Goczałkowice IG 1 and outcrops in the Dębnik and Czatkowice areas – is the Poland's unique record of shallow-marine carbonate sedimentation that persisted until the end of the Devonian and continued into the Early Carboniferous.

In the Goczałkowice IG 1 borehole, Miocene deposits are underlain by Carboniferous molasse formations of the Variscan orogenic cycle, represented by coal-bearing deposits – the Mudstone Series, Upper Silesian Sandstone Series, and Paralic Series, as well as by terrigenous marine formations of the Malinowice Beds (the so-called Culm facies), overlying a pre-flysch carbonate association. Subaerial sedimentation is represented by the two remaining lithostratigraphic series – the Upper Silesian Sandstone Series and the Mudstone Series. The youngest lithostratigraphic unit of the terrestrial coal-bearing deposits – the Kraków Sandstone Series, known from other regions of the basin, is absent in the Goczałkowice IG 1 section.

The terrestrial deposits are separated from the overlying paralic sediments by a stratigraphic gap. In large areas of the basin, including the vicinity of the Goczałkowice IG 1 borehole, these deposits are in contact with the basement at the base of coal seam 510. This is the main stratigraphic gap in the Carboniferous section of the USCB.

No drill core is available from Miocene deposits in the Goczałkowice IG 1 borehole. Their lithological description is prepared on the basis of analysis of drill cuttings and well logs. The lithology of the Miocene deposits is very monotonous. These are predominantly clay shales, and only their lowermost part is slightly more diverse. Such lithology is typical of Miocene rocks filling the southern part of the Carpathian Foredeep in Upper Silesia.

Data from the Goczałkowice IG 1 exploratory borehole was used in the preparation of the *Detailed Geological Map of Poland 1: 50,000*, Pszczyna sheet (1992). On the surface map, it is located within the area of silts, clays and deluvial loess of the Vistula valley slope zone, between loess to loess-

like silts forming the Pszczyna Plateau and loams with an admixture of sands (alluvial muds) of the flood terrace.

The hypabyssal alkaline igneous intrusion, drilled in the Goczałkowice IG 1 borehole at a depth of 3129.2–3170.6 m, is composed of structurally variable diabases, depending on the distance from the contact with the aureole rocks. Rapid cooling of magma is responsible for the formation of a narrow marginal zone of rock that is hyalobasalt in appearance. Towards the interior of the intrusion, the grain size gradually increases and the glassy texture grades to intersertal and subophitic, in some places ophitic. These intrusive rocks are placed on the classification diagram ( $\text{Na}_2\text{O} + \text{K}_2\text{O}$ ) –  $\text{SiO}_2$  in the basalt field. The presence of normative hypersthene (13.2–22.8 wt%) and the position of analysis results in the AFM and Nb/Y vs. Zr diagrams proves a tholeiitic nature of the rock.

The negative Nb anomaly in the Goczałkowice diabases, like in the case of the Late Silurian diorite intrusion from Sosnowiec, may be a result of subduction of the Rheik Ocean plate under the south-eastern edge of the Old Red continent, which caused a selective enrichment of the mantle sources of alkaline magma in LILE and LREE.

The samples of Lower Cambrian mudstones (Goczałkowice Formation) and Lower Devonian carbonates (Uszowica Dolomite Formation) from the Goczałkowice IG 1 borehole, analysed with the Rock-Eval pyrolysis method, are characterised by the absence of potential to generate both liquid and gaseous hydrocarbons. The organic matter dispersed in these deposits is represented by oxidized or highly altered type IV kerogen. Low thermal maturity of the organic matter, indicated by the results of Rock-Eval analysis, is inconsistent with the thermal history of this region, which is most likely due to the type and amount of kerogen dispersed in the studied rocks.

Despite the lack of direct geophysical measurements in the Goczałkowice IG 1 borehole, azimuth of dip of beds has been confirmed by the analyses of technological fractures (in comparison with the stress analysis in nearby boreholes), borehole deviation, seismic profile, and palaeomagnetic studies. As a result, it was possible to determine indirectly the orientation of most of the observed tectonic structures. In this borehole, layers of the Devonian and Cambrian sedimentary cover gently dip at up to 5–25° systematically towards the north, probably with a slight deviation towards an azimuth of 350°. Within the Precambrian metamorphic complex, the layers dip steeply (up to 80°) probably towards the SW. The bedding planes reveal interlayer slickensides that are indicative of meridional direction in the sedimentary complex. There are numerous quartz veins and younger calcite mineralization in the Precambrian basement complex. Steep slickensides with gently sloping striae, showing orientation similar to the nearby Ruptawa Fault, suggest a right-lateral strike-slip movement along this fault zone.

One-dimensional modelling and the reconstruction of burial conditions and thermal history were performed for the Goczałkowice IG 1 borehole section. The total thick-

ness of eroded Carboniferous deposits was determined by numerical modelling that was based on results of vitrinite ( $R_o$ ) reflectance studies. As no such studies are available from the Goczałkowice IG 1 borehole, the  $R_o$  values from boreholes drilled close to Goczałkowice IG 1, *i.e.* the Czechowice IG1 and Amoco-Goczałkowice 1 boreholes, were used. The best fit of the model curve to the measured  $R_o$  data was obtained for the erosion of ~1000 m of Upper Carboniferous deposits during the Miocene, and the erosion of ~500 m of these deposits during Late Carboniferous and Permian times. The results of thermal modelling show that the highest heat flow value (80 mW/m<sup>2</sup>) was reached at the study site about 290 million years ago during the maximum extension, which previously led to the sedimentation of very thick Carboniferous deposits.

Well log measurements in the Goczałkowice IG 1 borehole were performed in nine runs within the depth interval of 0,0–3352,0 m. Some of the results (radiometric and selected electrometric and technical) were digitized in the 1990s. The limited set of geophysical surveys in the Goczałkowice IG 1 borehole and their quality significantly differ from the well log measurements and quality standards of recent years.

This volume provides methodology of measurements and results of laboratory tests of bulk density on drill-core

samples from the Goczałkowice IG 1 borehole. The density values have been averaged for individual stratigraphic units.

By examining the reservoir levels, it was shown that the mineralization of brines from the Cambrian deposits is within the range of 213–223 g/dm<sup>3</sup>. These are chloride-sodium-calcium, iodide, and thermal brines with a temperature of 102°C. A characteristic feature of the brines is high content of bromides and elevated content of iodides. The waters in the Cambrian rocks are hydrodynamically stagnant. These are highly metamorphosed relict waters. In the Upper Devonian rocks, there are relict brines containing 174 g/dm<sup>3</sup> TDS. Similarly, the mixed waters of the Carboniferous and Miocene aquifers are also of relict type. The total mineralization of these waters is 67 g/dm<sup>3</sup>. Insignificant amounts of hydrocarbons in the gaseous composition of the brines indicate non-prospectivity of the tested levels in terms of bitumen occurrence. The tests point to low reservoir parameters of the levels, which are not conducive to the accumulation of considerable amounts of crude oil and natural gas. The Carboniferous-Miocene brine from the Goczałkowice IG 1 well is not used for medicinal purposes due to its low discharge rate.

*Translated by Krzysztof Leszczyński*

