

## SUMMARY

The Grudziądz IG 1 borehole was drilled in 1971–1972 in the middle part of the Lower Vistula Valley, SE of the town of Grudziądz. The area is situated at the borderland of three large Mesozoic tectonic units: Pomeranian Trough, Warsaw (Płock) Trough and Peribaltic Syneclyse (Baltic Depression).

The main research objective of the Grudziądz IG 1 borehole was to provide information on the Zechstein–Mesozoic succession and its immediate basement. It was also important to estimate properties of reservoir rocks and prospects for hydrocarbon accumulations in Mesozoic and Palaeozoic formations. Another objective was to study the geological structure of this area in terms of age and tectonic deformation of the sub-Zechstein rocks to facilitate interpretation of seismic data. The borehole was drilled as a typical parametric hole.

The drilling fully achieved its original geological objectives and reached the final depth of 3070.5 m (in Silurian deposits). The geological data provided by the borehole facilitated better interpretation of seismic profiles in this region and adjacent areas, as the borehole was drilled on a major regional seismic profile. Its lithological and stratigraphical section differs insignificantly from the planned one. Small discrepancies (a downward shift in the upper part of the section, and an upward shift in the lower part) are probably due to initially unknown (during drillhole planning) distribution of seismic velocities resulting in incorrect estimates of the depths to the main seismic horizons. Ultimately, the base of Zechstein appeared to lie approximately 100 m higher than the planned depth. Therefore, the drilling was stopped already at the depth of 3070.5 m, after drilling through a 41.5 m-thick Silurian series (unpierced).

The Zechstein succession is relatively complete in the Grudziądz IG 1 borehole. The Zechstein succession attains a considerable thickness of 600–800 m, resulting mainly from increased thicknesses of rock salt, especially the Older Halite unit (Na2). The Zechstein stratigraphic section is characterised by the occurrence of all lithological units of the PZ1, PZ2, and PZ3 carbonate-sulphate cycloths, and the presence of the reduced and fragmentary PZ4 cyclothem. Especially striking is the small thickness of the T4 unit, resulting probably from a large distance to source areas of clastic material.

No Devonian and Carboniferous formations have been encountered. The Silurian rocks, underlying the Zechstein succession, are represented by upper Ludlow deposits (Ludfordian, Kociewie Claystone and Mudstone Formation) composed of grey claystones with rare mudstone interbeds, interpreted as hemipelagic deposits.

The Mesozoic lithology and stratigraphy are similar to those observed in boreholes from the eastern area of the Pomerania Trough (Stobno–Cekcyn region). It gives evidence of an affinity between the Grudziądz area and the Pomeranian Trough. This fact is particularly well expressed in case of highly reduced Upper Triassic, Lower Jurassic and Middle Jurassic sections. There is also a small thickness reduction in the lower part of the Lower Triassic. The Lower Jurassic succession shows features typical of the northern and eastern parts of the Płock Trough as well as of the Mazury–Warmia region. A stratigraphic gas spans here the lowest part of the section represented by the Hettangian–Sinemurian Zagaje Formation. The Middle Jurassic succession of this borehole is relatively thin (50.0 m). The borehole provided data that contributed to the explanation of the problem of relationship between the clay and carbonate facies in the Oxfordian succession and in the Cenomanian–Turonian interval where foraminiferal evidence indicates Cenomanian age of the marly-clay series. In addition, the main sedimentary cycles have been identified in the Upper Cretaceous–Lower Palaeocene succession of the Grudziądz IG 1 borehole.

The only intervals showing features of “good” source rocks for hydrocarbon generation are some Lower and Middle Jurassic and Lower Cretaceous horizons. This is so-called “gas-generating” material in which hydrocarbon generation occurs at a high degree of alteration. However, examination of this matter shows that the degree of its maturity is extremely low. It has been found that the major burial phases in the Grudziądz IG 1 borehole section occurred during Late Silurian, Late Permian–Early Triassic, Late Jurassic and Late Cretaceous times.

Downhole well testing was performed to evaluate in detail the parameters of reservoir horizons. Weireline formation testers did not indicate any bitumen occurrence in Triassic and Jurassic rocks. Halliburton tester measurements revealed the occurrence of brine with natural gas in the Zechstein Main Dolomite. Favourable conditions for hydrocarbon accumulation are suggested for Zechstein and Buntsandstein deposits, as evidenced by the occurrence of highly metamorphosed and saturated brines containing considerable amounts of biophile elements. The presence of hydrochemical threshold in the Triassic markedly indicates bipartition of the artesian basin into zones of stagnation and increasing water exchange. It is expressed by irregularly downhole-increasing water mineralization: from 3.5 g/dm<sup>3</sup> in the Lower Cretaceous, 78.0

g/dm<sup>3</sup> in the Lower Jurassic and 360.0 g/dm<sup>3</sup> in the Buntsandstein to 370.0 g/dm<sup>3</sup> in the Zechstein. Lower Jurassic deposits contain 44.0°C thermal water which is a 7.8% brine with Cl, Na, Br, I, B and Fe. The measured discharge was approximately 35 m<sup>3</sup>/h and the discharge temperature was 40.5°C.

Groundwater from the Grudziądz IG 1 borehole is represented by fossil meteoric waters of long residence time in the rock mass. They occur in a zone of low water exchange, as evidenced by hydrochemical indicators and results of isotopic analyses. It should also be noted that therapeutic waters occurring at large depths in the Grudziądz IG 1 borehole show a low renewability ratio.

As evidenced from chemical analyses of 1972 and the period of 2002–2009, the concentrations of most of the groundwater components vary within small limits of 1 to 3%. The greatest differences refer to the contents of sulphates and iron that increases to over 10 mg/dm<sup>3</sup>, whereby this water is classified as a therapeutic ferruginous water.

The brine from the Grudziądz IG 1 borehole is currently used at the Department of Physical Medicine and Balneology of the Geothermal Energy Grudziądz for medicinal purposes. The water is extracted in the amount of approximately 12–17 m<sup>3</sup>/day, whereby its discharge temperature is most frequently of 12–16°C.