

The assessing of the quality of geothermal reservoirs on the example of the Lower Triassic aquifer in the Mogilno-Łódź Trough (Polish Lowlands)

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Abstract. Petrographic and petrophysical investigations of the aquifers allow to estimate their productivity and infectivity, as well as allow for better recognition of the origin of the chemical composition of geothermal waters. Deep deposition of the Lower Triassic sediments in the analysed area (locally above 5000 m b.s.l.) is conducive to high temperatures (above 90°C) within the reservoir and causes deterioration of reservoir parameters. The Lower Triassic geothermal reservoir consists of fine and mixed grain-size sands and sandstones layers from 10 to 650 m thick; depending on the depth. The water within the reservoir exhibits mineralization ranging from 2 to over 100 g L⁻¹ and its temperature ranges from 30 to 100°C. The mineralization of waters varies from 140 g/dm³ (Warsaw basin) to over 350 g/dm³ in the deep zones of the basin (axial fragments of the Mogileńsko-Łódź trough). The average permeability of reservoir layers in the Polish Lowlands is 145.5 mD.

1 Introduction

In the last few decades there has been an increase in interest in geothermal energy in Poland. Nowadays, geothermal energy is mainly used for heating purposes in recreation and balneotherapy, what has been expressed by seven new centres open in recent years [1-5]. Despite this, it should be noted that the exploration of geothermal energy carries the risk of not finding suitable subsurface reservoirs. Success of the of the geothermal projects base on ability to understand and mitigate the uncertainties associated with subsurface environment. The paper focused on important aspect of geological identification of the structural characteristic of reservoir rocks as one of the most important elements of the geological research work.

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2 Geological background

The area selected for detailed analyses covered the central part of Poland (Mogilno-Łódź Trough region, Fig. 1). The Lower Triassic geothermal reservoir consists of fine and mixed grain-size sands and sandstones layers from 10 to 650 m thick; depending on the depth. In the perspective area, the top of the Lower Triassic formation is located at depths of about 2,200 m, b.g.l. to over 5000 m b.g.l. in the axial part of the Mogilno-Łódź Trough. The depth of deposition of aquifers contributes to the high temperatures prevailing within the Lower Triassic reservoir. The water within the reservoir exhibits mineralization ranging from 2 to over 100 g L⁻¹ and its temperature ranges from 30 to 100°C. The mineralization of waters varies from 140 g/dm³ (Warsaw basin) to over 350 g/dm³ in the deep zones of the basin (axial fragments of the Mogileńsko-Łódź Trough). The average permeability of reservoir layers in the Polish Lowlands is 145.5 mD. The depth of deposition of aquifers contributes to the high temperatures prevailing within the Lower Triassic reservoir [6-8].



Fig. 1. Location of the examined boreholes and geothermal energy applications in Poland (based on [5]) 1 – district heating systems, 2 – health resorts, 3 – recreation centres, 4 – wood drying, 5 – fish farming, 6 –recreation centres in realization, 7 – heating system at early stage, 8 – some planned co-generation plants

3 Methods

In order to recognize parameters of rocks that form potential deep reservoirs, 8 samples of the Lower Triassic rock formations were collected from the 3 borehole cores: Września IG-1, Florentyna IG-2, and Pitorków Trybunalski IG-1. A small number of samples resulted from the limitations of the size of cores in archives. Collected for detailed mineralogical, petrographic study cores had to meet the size requirements for microscopic examination. Basic parameters such as porosity, permeability, specific surface area have been identified. Thin sections were used for microscopic and pore analysis. Laboratory studies included macroscopic and microscopic observations. Rock samples were subject to microscopic

optical examination, accompanied by scanning electron microscopy (SEM) and X-ray diffraction inspections (XRD). Porosity analysis of the rocks examined was carried out through petrophysical inspections of rocks by means of measurements of capillary action.

4 Results and discussion

Rock samples occurring within the Lower Triassic form show large petrographic variations. In the profile from Września IG-1: 2387.5 m b.g.l. allochthonous limestone was observed (Fig. 2a) and from the depth of 2728.4 m b.g.l. occurs mudstones (Fig. 2b,c). In the profile of Florentyna IG-2 – subarkose arenites (Fig. 2d). Large petrographic differentiation also occurs in the Piotrków Trybunalski profile. Sample from depth 3746.1 m b.g.l. represents anhydrite (Fig. 2e), from 3920.0 m b.g.l. and 4193.1 m b.g.l. quartzite sandstones (Fig. 2f).

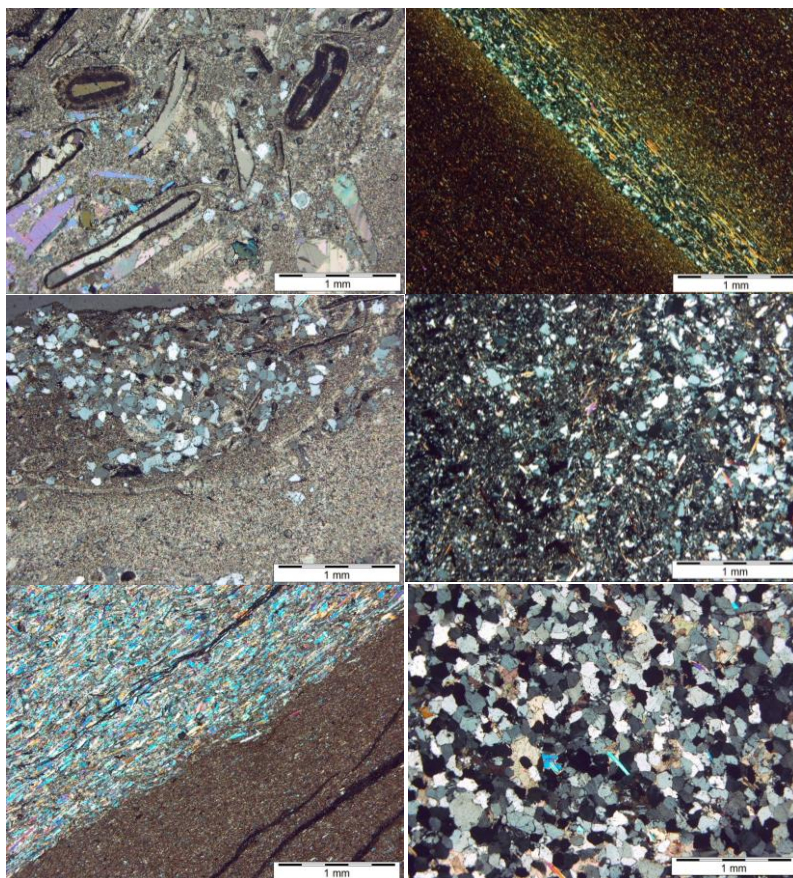


Fig. 2. Transmitted light microscopic images of rock samples from Lower Triassic formations, crossed polarizers: a - oncoids in limestone (Września IG-1: 2387.5 m b.g.l.), b - mudstone with marked laminated texture (Września IG-1: 2728.4 m b.g.l.), c - insert of cluster material (Września IG-1: 2387.5 m b.g.l.), d - grain skeleton of sandstone (Florentyna IG-2: 2698.5 m b.g.l.), e - anhydrite present in lighter laminates (Piotrków Trybunalski IG-1: 3746.1 m b.g.l.), f - carbonate binder in sandstone (Piotrków Trybunalski IG-1: 3920.0 m b.g.l.)

A scanning electron microscopy confirms different mineral composition and petrographic character of the examined rock samples. In the Września IG-1: 2387.5 m b.g.l. the main

mineral is calcite accompanied by anhydrite (Fig 3a). The samples taken from the Florentyna IG-2 profile are mainly sandstones, where a large quantitative branch has mica - formed in the form of muscovite (Fig. 3b). Petrographic variability can also be seen in the Piotrków Trybunalski profile. In the sample from the depth of 3746.1 m b.g.l. occurs anhydrite (Fig. 3c) accompanied by dolomite, while in the other two are sandstones in which the grain skeleton also contains muscovite with inclusions of apatite grains (Fig. 3d).

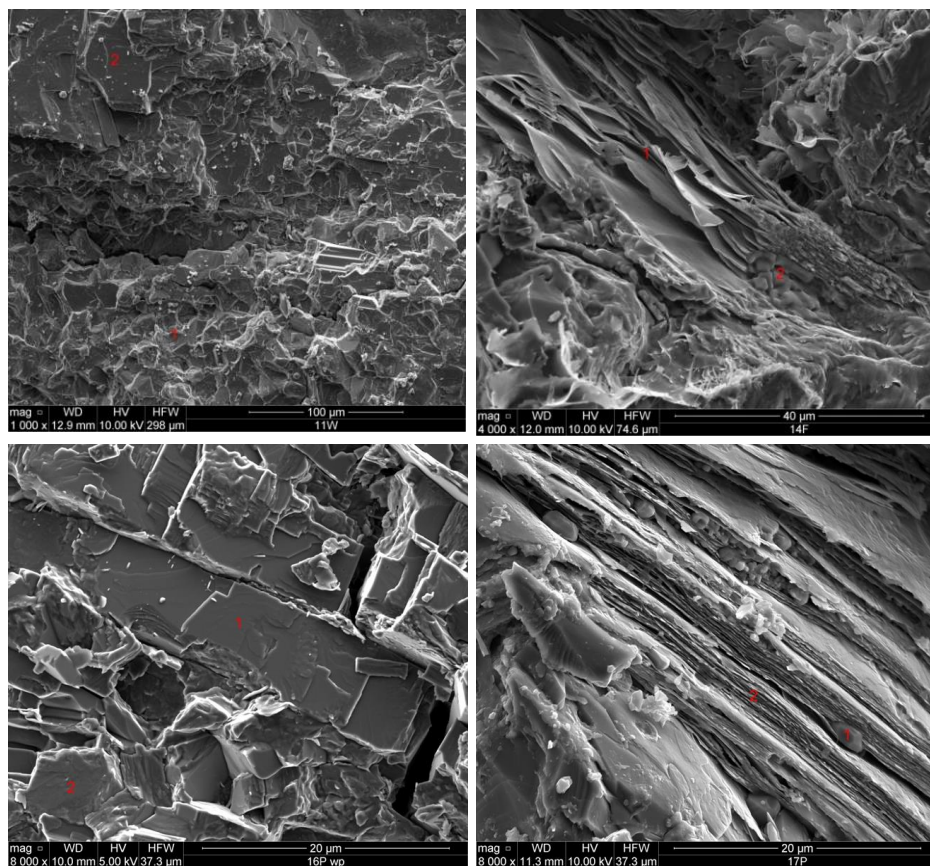


Fig. 3. Microstructures of rock samples found in the Lower Triassic profile: a – calcite grains (Września IG-1: 2387.5 m b.g.l.); b – muscovite sheets (Florentyna IG-2: 2698.5 m b.g.l.); c – anhydrite grains (Piotrków Trybunalski IG-1: 3746.1 m b.g.l.); d – biotite with apatite appendages (Piotrków Trybunalski IG-1: 3920.0 m b.g.l.)

Observations in the polarization and scanning microscope have been confirmed by diffraction analysis. The mineral composition of selected rock samples from the Lower Triassic sediment profile is shown in Figure 4.

The results of petrophysic analysis is presented in table 1. The total porosity of the studied rocks ranges from 0.25 to 11.9%, effective porosity from 0.23 to 11.34%. The surface area varies from 0.19 to 4.33 m²/g. Samples from Września IG-1 (2387.5 m b.g.l.), Piotrków Trybunalski IG-1 (3746.0 m b.g.l.) and Florentyna IG-2 (2990.0 m b.g.l.) porosity ranges from 0.25 to 0.55%. The size of the specific surface area for these samples is 0.0 m²/g, which may indicate the occurrence of micro-voids.

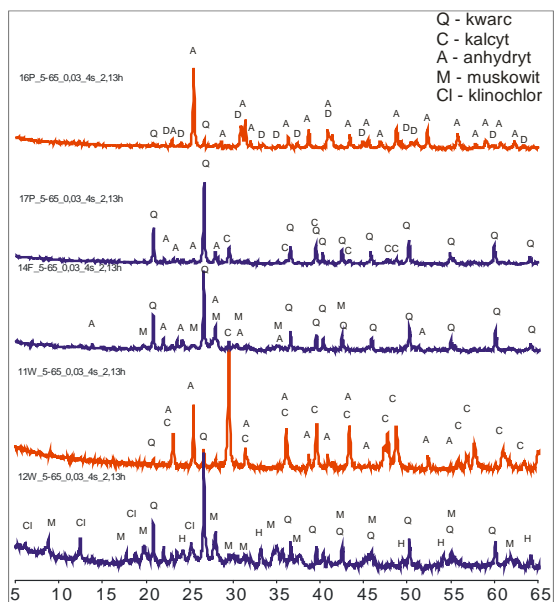


Fig. 4. Diffractograms of the mineral composition of rock samples from the Lower Triassic formations

Table 1. Average values of petrophysical parameters of rocks in the well sections analyse

Well (stratigraphy)	Depth [m b.g.l.]	Material density [g/cm ³]	Total porosity [%]	Skeletal density [g/cm ³]	Total density [g/cm ³]	Effective porosity [%]	Average capillary [μm]	Specific surface area [m ² /g]	Pores > 1 μm [%]	Permeability [mD]	
										X	Z
Września IG-1	2387.50	2.77	0.25	2.68	2.67	0.23	0.00	0.00	-	0.033	<0.007
Września IG-1	2728.40	2.83	1.49	2.69	2.66	1.31	0.02 ₁	1.21	31	0.001	-
Piotrków Tryb. IG-1	3746.0	2.96	0.38	2.83	2.82	0.34	0.00	0.00	-	<0.008	0.001
Piotrków Tryb. IG-1	3920.0	2.7	3.09	2.6	2.53	2.8	0.23	0.19	19	0.041	0.038
Piotrków Tryb. IG-1	4193.1	2.72	3.99	2.62	2.52	3.63	0.11	0.52	35	0.389	0.095
Florentyna IG-2	2698.5	2.78	7.47	2.65	2.48	6.64	0.02	4.33	11	0.200	-

Florentyna IG-2	2774.2	2.7	11.9	2.66	2.35	11.3 4	0.11	1.83	13	0.132	0.014
Florentyna IG-2	2993.0	2.72	0.55	2.56	2.55	0.47	0.00	0.00	11	0.200	-

Based on the amount of permeability (>0), it can be concluded that these samples are non-porous, and the permeability is related to the micro-voids that occur in them. Samples from Września IG-1 (2728.5 m b.g.l.) and Florentyna IG-2 (2698.5 m b.g.l. and 2744.2 m b.g.l.) have a specific surface area above $1 \text{ m}^2/\text{g}$. The size of porosity and specific surface indicates the microporous character of the pore space. Parallel permeability in the analyzed rocks contain from 0.001 to 0.389 mD, perpendicular permeability ranges from 0.001 to 0.095 mD. In these samples, the surface area is zero, non-zero permeabilities are the result of the occurrence of microfissures.

Analyzing the values of porosity and permeability, samples with a porosity below 1% can be considered as sealing rocks, samples with a porosity higher than 1% can be classified as moderately good reservoir rocks.

5 Conclusions

Petrographic and petrophysical investigations of the geothermal aquifers allow to estimate their productivity. Presented results of the petrographic and petrophysical analysis of the cores from Lower Triassic come from the selected boreholes located in the Mogilno-Łódź Trough in the Polish Lowlands. Presented investigations have confirmed that sedimentary rocks in the central part of Poland, at depths above 2,200 m below surface, are characterised by low values of porosity and permeability. The results of the petrographic and mineralogical studies of core samples showed that in the selected area rather poor reservoir parameters should be expected, translating into low efficiency of boreholes.

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