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Title of doctoral thesis: ***Conditions of reservoir rocks exploration in the deep part of the Rotliegend basin with a view of discovering natural gas deposits***

Summary

Southern Permian Basin, which extends from the eastern coast of England through the Netherlands, northern Germany to Poland, is the most important region of natural gas mining in Europe. Natural gas deposits occur within Rotliegend strata at depths from over 1,000 to 5,300 metres primarily in aeolian and fluvial sandstones, and in the German and British sectors also in sandstones of the marginal facies of the great saline lake.
In the Polish part of the Upper Rotliegend Basin, a vast majority of gas accumulations has been so far discovered in its margins at the depth of 1,000 to about 4,000 metres in the uppermost parts of the Rotliegend directly beneath the impermeable Zechstein evaporite cover.
Unlike in the North German Basin, no hydrocarbon accumulation has been discovered so far in the deeper part of the Polish Basin, where the top of Rotliegend occurs at the depths greater than ca. 4,000 m, and potentially reservoir sandstone layers occur under a thick cover of playa-lake claystones.
Due to favourable lithological and facies conditions, the area of the central Polish Rotliegend Basin seems a predisposed region to discover this type of deposits. It also potentially implies possibility of the occurrence of unconventional tight gas reservoirs. The greatest challenge in the search for hydrocarbon accumulations in the analysed zone is to develop reliable geological models of the sedimentary basin infill and the variability of reservoir parameters. It is caused by limited number of borehole data. As a result, the geological interpretation of surface seismic surveys has remained the most important prospecting method.
The aim of the present doctoral dissertation is to assess the identification possibilities for potential gas traps buried beneath the Zechstein base in the deeper parts of the Rotliegend Basin. This assessment is based on geological interpretation of seismic data supported by stratigraphic seismic modelling.
Based on the models that describe the relationships between elastic and reservoir parameters of the rock, the analysis has been conducted to define the impact of porosity and gas saturation on elastic waves velocity in two sandstone types: fluvial (related to axial part of Permian Basin) and aeolian (from the marginal north-eastern zone) buried from 350 to 560 metres below the Zechstein base. On the grounds of the calculated parameters and by means of a multivariant 1D and 2D stratigraphic seismic modelling, there have been examined variations of seismic reflection amplitudes and phases imaging potential reservoir layers. In the final stage of interpretation, the conclusions obtained from seismic modelling have been compared with the results of seismic inversion.
It has been proven that the sandstone layers located within the playa claystones and whose porosity is higher than 5% may be detected by surface seismic methods. Increase in porosity, which leads to P-wave velocity reduction, highlights the contrast in acoustic impedance between over- and underlying layers, which causes the rise of the amplitude of reflections from the porous rock boundaries observed in synthetic sections. Also, when porosity of both examined types of sandstones was reduced to ca. 5%, no significant impedance difference has been observed as regards playa-lake sediments. It makes it impossible to produce distinct seismic reflections that stand out clearly from the background noise. It has been thus shown that in these conditions the layer of sandstones deposited among playa claystones may be undetectable by seismic imaging, which is an important fact considering the possibility of tight gas reservoirs occurrence. At the same time, it has been proven that indurated non-porous sandstones (ϕ=1%), especially those

with the increased content of calcite and anhydrite cement, are clearly imaged in seismic data.

One of the most important conclusions drawn from the conducted analyses is the lack of clear seismic effect of gas saturation both in the aeolian and fluvial sandstones. Due to the similar acoustic impedance values, there is no perceptible difference in the level of amplitude of reflections from the boundaries of water-bearing layers and the gas saturated ones on synthetic seismograms. The findings therefore indicate that as far as the examined formations are concerned, it is not be possible to provide a reliable identification for the gas saturation in the potential reservoir zones in the actual seismic data.

Finally, the conducted geological interpretation supported by stratigraphic modelling has made it possible to identify the potential gas traps within the Upper Rotliegend in the deep part of the Polish Permian Basin.