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Title of doctoral thesis: **Downhole microseismic monitoring of hydraulic fracturing of unconventional gas deposits. Optimization of acquisition, processing, and interpretation methods**

Abstract

Measurements of microseismicity induced by hydraulic fracturing, commonly referred to as microseismic monitoring, are performed in order to locate hypocenters, determine the magnitude of induced events and determine the distribution of forces at their source. Microseismic monitoring is usually carried out in four stages, which include: design, acquisition, processing, and interpretation of the obtained results, often in correlation with the results of other geophysical methods.

The main purpose of the presented dissertation entitled: "Downhole microseismic monitoring of hydraulic fracturing of unconventional gas deposits. Optimization of acquisition, processing, and interpretation methods" was the adaptation and optimization of the technology of acquisition, processing, and interpretation of data from downhole monitoring of microseismic hydraulic fracturing of prospective shale gas deposits, occurring at considerable depths in the North of Poland.

The dissertation presents one of the first microseismic experiments in Polish geological conditions. An innovative approach to planning, acquisition, processing, and interpretation of downhole microseismic monitoring data is presented. The main inspiration for this thesis was the problem of recording microseismicity induced from significant distances from the monitoring array (reaching 1.5 km) and great depths (about 4 km).

As part of the work carried out, acquisition work was planned and supervised, and detailed processing and interpretation of data obtained as a result of hydraulic fracturing of shale gas layers in the horizontal section of the Wysin – 2H/2Hbis well was performed. A measurement system with a length of 334 meters was designed and patented, consisting of 18 three-component geophones with a variable interval between them, which was also used in another project carried out by PGNiG during hydraulic fracturing of the horizontal section of the Wysin - 3H.

The processing of the recorded downhole microseismic monitoring data consisted of two stages. The first involved the preparation of data and velocity models, for the second stage involving the marking of the first break of useful waves of detected events and their location. The processing was performed in an isotropic and anisotropic variant. 586 microseismic events were located, even from the first stages of hydraulic fracturing approximately 1,600 meters away from the monitoring well. At the stage of isotropic processing, the influence of a thin, high-speed gradient layer, located in the middle of the measurement system, on the recorded data was identified, causing the seismic ray to bend, and thus difficulties in achieving the desired accuracy of the depth location of events. This problem was solved at the stage of anisotropic processing.

It was revealed that considering the correction for the attenuation of the geological medium has a significant impact on the magnitude of the determined magnitudes. For all the located events during the fracturing of the Wysin – 2H/2Hbis well, the calculated magnitudes are in the range -2.32 to -0.94, with an average value of -1.88, when the correction for attenuation was not considered, and after its application, the magnitudes are in the range -2.26 to -0.83, with an average of -1.78.

One of the important information obtained from microseismic data is the volume of the SRV microseismic event zone, which for the considered case can be estimated at ~51 [million m3]. In addition, the Fracture Complexity Index (FCI) chart for the individual fracturing stages of the horizontal part of the Wysin – 2H/2Hbis well shows that the vast majority of fracturing stages are in the range of 0.1 – 0.5, which indicates the average complexity of the fractures created during hydraulic fracturing process.

Keywords: microseismic, shale gas, hydraulic fracturing, anisotropy