Mariusz Grzegorz Łukaszewski

„The use of self-learning systems in seismofacial and structural analysis of seismic data in zones of potential occurrence of conventional and unconventional hydrocarbon accumulations”

Keywords: Machine Learning, seismic attributes, automation of cognitive processes, classification models, visualizations, Carpathian Foredeep.

Summary

Different types of hydrocarbon accumulations have their own trace in the seismic record, the so-called seismic signature, the finding of which and correct interpretation are the key to exploration success. At the same time, the constantly growing volume of seismic data and the diverse geophysical and geological information they contain make the use of Machine Learning (*ML*) techniques to automate cognitive processes more and more obvious. *ML* algorithms have an unique ability to find patterns in data sets on which self-learning processes are carried out, and they do it incomparably faster than the most experienced interpreters. The most important advantage of self-learning systems is the ability to exceed the limits of human perception when identifying phenomena, objects and potential conventional and unconventional hydrocarbon accumulations.

The expected final product of the research conducted in the presented dissertation was the development of a procedure (*Machine Learning workflow*), which, when applied to the analyzed interesting *3D* seismic volume interval, will enable the generation of models classifying seismic facies with a high degree of accuracy. It was assumed that such an approach would enable the interpreter to overcome the barrier related to the quality and resolution of the available seismic data and would make possible the detection of mixed objects of a specific environmental provenance. The relatively short execution time of seismic projects and the ability to extract geological information hidden "between seismic traces" from the seismic image are currently the main commercial advantages. These two mentioned challenges became the starting point for the work carried out and documented in the doctoral dissertation. In line with the idea of implementation doctorates, it combined the methodological aspect of optimizing the interpretation cycle with the cognitive aspect, which involved a detailed geological examination of a fragment of the sedimentary profile from the Carpathian Foredeep.

Seismic data from a modern *3D* survey was selected as the study object, located in the north-eastern part of the Polish area of the Carpathian Foredeep. The research covered a fragment of the sedimentary profile formed by the Upper Badenian and Sarmatian supra-evaporite formations, called the Machów Formation. In the studied area of the foredeep basin, the sedimentation processes were influenced by the broadly understood foreland uplift zone, and the interpretation of seismic data confirmed the significant dynamics of tectonic processes in the basement of the Miocene formations, highlighted by the high variability of sedimentation environments in time and space. This information makes the studied area an exceptionally interesting place to search for unconventional objects.

The interval of seismic data selected for diagnostic studies is related to a fragment of the succession of the central part of the Sarmatian formations. The subject of the research presented in this dissertation is a geological object identified during the conventional interpretation of *3D* seismic data. It is located directly in the natural gas deposit zone. The origin of this trap has not yet been clearly defined, and the production history in individual wells is not consistent with the results of seismic attribute analyses.

The research presented in the doctoral dissertation was aimed at both optimizing the interpretation process and detecting geological objects that, for various reasons, remain invisible in the seismic image subjected to standard interpretation. According to the assumptions, first of all, a methodology for working with *ML* algorithms was developed, consisting of a specific sequence of many partial procedures that can be used depending on the assumed interpretation goals. The impact of comprehensive preparation of seismic input data (*data preconditioning*) on an unprecedented increase in resolution, enabling a better understanding of the studied geological objects and the processes that led to their formation, was also presented.

The benefits of the described *ML* algorithms for in-depth analysis and identification of geological objects scattered in a volume of *3D* seismic data was also assessed. As a result of the tests and analyses, it was found that self-learning systems represent a high level of usefulness in deciphering history or geological information in the form of features, relationships and patterns in seismic data, and significantly exceed the limits of human perception. The geological interpretation of the results presented in the dissertation showed that the proposed procedures allow for detailing the existing sediment models. It also proved that this solution enables better imaging of *HC*-saturated zones.

Thus, the doctoral thesis showed that thanks to the use of an innovative procedure using self-learning systems in the structural and seismofacies interpretation of seismic data, new, previously unattainable exploration opportunities were obtained in the field of conventional and unconventional hydrocarbon accumulations in clastic formations of the Carpathian Foredeep.

The dissertation was carried out as part of the third edition of the "Implementation Doctorate" program of the Ministry of Science and Higher Education. The practical application of the achieved results is important for Geofizyka Toruń S.A., which is the workplace of the PhD student.