IMPROVED RECOGNITION OF ROCK FORMATION ON THE BASIS OF WELL LOGGING AND LABORATORY EXPERIMENTS RESULTS USING FACTOR ANALYSIS

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Introduction

Rock recognition on the basis of well logging supported by petrophysical laboratory experiments is an important part of the qualitative and quantitative geological interpretation. Great number of logs is always the goal in planning borehole investigations to obtain results with uncertainty level as low as possible. Processing of various logs and their comprehensive interpretation sometimes generates technical and petrophysical problems with unambiguous treatment of results because modern well logs provide interpreters with great amount of data. Sophisticated statistical tools are useful in clever data management to get maximum indispensable geological information without problems with unambiguity. Factor analysis belongs to the group of statistical procedures enabling mutual relationships investigations between great number of data and revealing hidden relations between unknowns which prove necessity of analysis of selected factors. Factors in analysis have substantive interpretation related to the considered problem and preserve information included in primary variables.

Materials and methods

Laboratory measurements results obtained from selected sections of the Silurian and Ordovician mudstone formations in three boreholes located in the on-shore Baltic Basin in Northern Poland (66 samples) were the basis for investigations (Jarzyna et al., 2017; Jarzyna and Wawrzyniak-Guz, 2017). Cored depth intervals were between 2870-3235 m. Majority of samples were composed of mudstones. Several sandstones and tuffs were also represented. Samples from the mudstone (Pasłęk and Sasino) and calcareous rocks (Prabuty) formations were considered with independent approach to the Jantar member of the Pasłęk formation. Jantar member and Sasino formation were treated as *sweet spots*, i.e. potentially prospective shale gas beds. Data set was composed of laboratory outcomes from Mercury Injection Porosimetry, Helium Porosimetry, special total porosity measurements – water and kerosene immersion porosimetry (Topór et al., 2016), Nuclear Magnetic Resonance experiments, Rock-Eval geochemical measurements, Nitrogen Absorption/Desorption Method, Pressure Decay Permeability method. There were also available results of the elemental analyses and mineral components interpretation made on the same geological samples. Well log data from three boreholes comprised standard curves, i.e. resistivity (LLD, LLS), nuclear (GR, POTA, URAN, THOR), acoustic (DT) and caliper (CAL) logs, together with the results of the comprehensive interpretation as regards lithological components: volume of shale, sandstone, limestone, dolomite, kerogen – VSH, VSAND, VLIME, VDOLO, VKER, respectively; porosity, total – PHI and effective – PHIE; water saturation – SW and irreducible water – SWIRR; and others depending on range of measurements and interpretation made in individual well. Factor analysis (FA) was performed with Statistica 13 Statsoft software. The method enabled reducing great number of well log variables to significantly lower number of mutually independent (non-correlated) factors (Hair et al., 2006). Varimax technique made possible minimization of variables number with high loading factors by orthogonal rotation simplifying the factors interpretation. Quartimax rotation enabled minimization of factors number necessary to explain each variable and made easier interpretation of the observed variables. Equamax rotation being the combination of both upper mentioned techniques made easier interpretation of factors and variables interpretation.

Results

The goal of research was applying FA to select the most informative logs and laboratory data to make lithology classification and selection parameters which were sufficient for unique lithology characterization from the depositional view point. Data sets in statistical analyses consisting of laboratory outcomes and well logging raw curve values together with the results of interpretation were composed of variables from three individual boreholes and processed separately, and next, brought together and processed as one data set. The proportions between number of laboratory and well logging data were preserved, taking also into account thickness of the layers (Table 1). The goals of research was to compare the final results of classification based on different number data sets. It is commonly known that well logging provides the huge number of samples while laboratory data sets are limited. The idea was to check if the number of well logging data proportional to number of laboratory outcomes provide the same or at least similar result as full available well logging data set. Mudstone and shale formations are heterogeneous and random sampling in the statistical approach may not give satisfactory result. The next question arose, how to select the most informative well logging data set to assure objective results.

Table 1. Proportions between numbers of data in laboratory and well logging data sets.

Wells	Well 1	Well 2	Well 3	Total	Well 1	Well 2	Well 3	Total
Data	Laboratory				Well Logging: available / randomly selected			
Total	23	25	18	66	865/423	1062/604	1145/508	2920/1555
Pasłęk	4	0	1	5	475/56	450/136	680/43	1605/319
Jantar	5	5	7	17	140/140	120/120	130/130	390/390
Prabuty	2	0	4	6	55/32	80/24	80/80	215/136
Sasino	12	20	6	38	195/195	260/260	255/255	710/710

Conclusions

Including laboratory results into FA parallel with well logging data and assuming that both type of data influenced the objective results, similarly required respective selection of data to make all of them representative on the same level.

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