ROCK PHYSICS MODELLING FOR DETERMINATION OF EFFECTIVE ELASTIC PROPERTIES OF THE LOWER PALEOZOIC SHALE FORMATION, NORTH POLAND

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Introduction

Ødegaard and Avseth (2003) proposed a technique called rock physics temple (RPT), in which the fluid and mineralogical content of a reservoir could be estimated on a cross-plot of Vp/Vs ratio against acoustic impedance of P wave. Relationships between elastic wave velocities and porosity or density of the formation are frequently used in many rock physics models.

Successful RPT should be made for specific sedimentary basin or area and calibrated for specific rock types with the use of appropriate rock physics models. This ensures taking into account local geological parameters such as lithology and mineralogy, reservoir properties i.e. porosity, fluid type and saturation, pressure, temperature gradient and diagenesis.

RPT modelling for Polish lower Paleozoic shale formations

Silurian and Ordovician shale formations from the Baltic Basin, Poland were investigated in this study. The deposits are mainly claystones, siltstones and mudstone, locally enriched in organic matter and saturated with hydrocarbons. There are also marly and calcareous formations, and carbonate deposits. Data used in the study are wireline logs that were recorded in three nearby wells: W1, W2 and W3.

With the use of the formation evaluation results that has been done in each investigated well it was possible to make a lithology discrimination. The formations were grouped into shales (1), shales with increased organic matter content and saturated with hydrocarbons (2), and carbonates and marls (3). Lithostratigraphic division and results of lithology discrimination are shown in Fig. 1 on a crossplot of Vp/Vs vs P-Impedance. Average mineral composition of matrix of each lithology group is shown in Tab. 2.

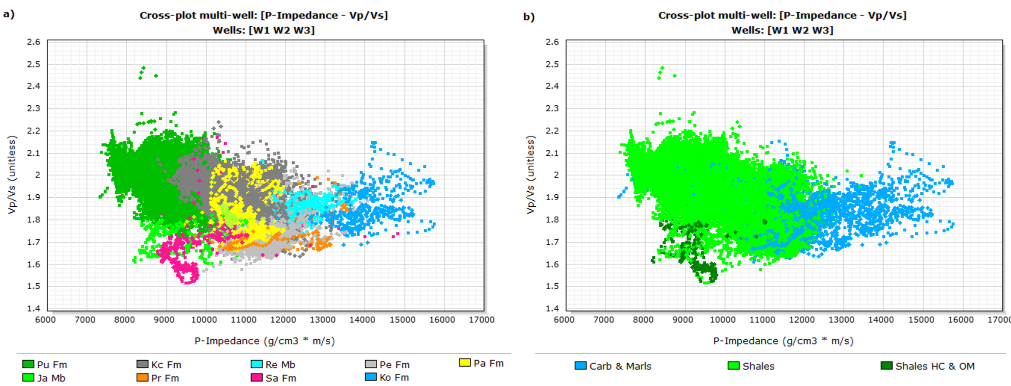

Figure 1. *Lithostratigraphic division and results of lithology discrimination in wells W1, W2 and W3.*

RPT modelling involved five steps (Mavko et al., 2009). 1. Computing the effective bulk and shear moduli, K_{ma_eff} and G_{ma_eff}, of the mulitmineral matrix with the use Hashin-Shtrikman-Walpol bounds (Tab. 2). 2. Computing the moduli of the dry rock frame for critical porosity and effective pressure, $K_{dry}(\phi_c)$ and $G_{dry}(\phi_c)$, using the Hertz-Mindlin theory. 3. Computing the moduli of the dry rock frame over a range of porosities, $K_{dry}(\phi<\phi_c)$ and $G_{dry}(\phi<\phi_c)$, using the lower Hashin-Shtrikman bound. 4. Performing fluid substitution with the Gassmann equations to calculate moduli for saturated rock, $K_{sat}(\phi, Sw)$ and $G_{sat}(\phi, Sw)$. 5. Computing the density and P and S waves velocities of saturated rock, $\rho_{sat}(\phi, Sw)$, $Vp(\phi, Sw)$, $Vs(\phi, Sw)$, and cross-plotting Vp/Vs ratio versus P-Impedance as a function of porosity and saturation.

Table 2. *Average mineral composition of matrix derived from lithological discrimination, and parameters used for calculating effective elastic moduli of multi-mineral rock-frames.*

Mineral	**Average mineral composition of matrix (W1 – W2 – W3 wells)**			**K [GPa]**	**G [GPa]**	**ρ [g/cm^3]**	**Source**
	(1) Shales	**(2) Shales with OM & HC**	**(3) Carbonates and Marls**				
Quartz	0,211	0,274	0,130	34	44	2.65	Mavko et al, 2009
Calcite	0,107	0,058	0,286	72	30	2.71	Mavko et al, 2009
Dolomite	0,008	0,025	0,088	76	49	2.87	Mavko et al, 2009
Sum of Clays	0,648	0,563	0,477	39	25	2.70	Stadmüller et al., 2018
Pyrite	0,017	0,009	0,012	147	132	4.93	Carmichael, 1989
Kerogen	0,009	0,070	0,007	5.53	3.20	1.25	Bała, 2015

Results

Results of RPT modelling for each lithology group, and for pure carbonates, are presented in Fig. 2.

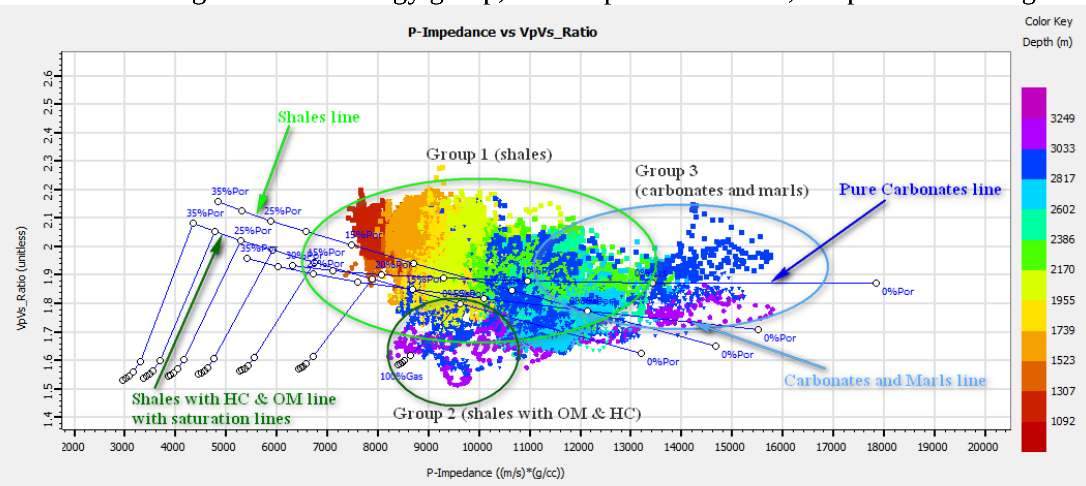

Figure 2. *Rock physics templates for shales, shales saturated with hydrocarbons, marls, and carbonates.*

Conclusions

Rock Physics Templates moderately modelled the trends for each lithology group. Other than Hertz-Mindlin model may improve the results and better estimate the elastic properties of the Polish shales formations from the Baltic Basin.

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