Cementation factor and water saturation in carbonates vs. seismic amplitude

Krakowska Paulina*, Niepsuj Magdalena*
1Department of Geophysics, Faculty of Geology, Geophysics and Environmental Protection, AGH-University of Science and Technology, Poland

Cementation factor is one of the main coefficients in petrophysics. It is included in the basic petrophysical equation called Archie equation. Wrong determination of cementation factor causes incorrect evaluation of water saturation. The purpose of the analysis is to check alternative method reliability of cementation factor calculations in carbonates. Sampled carbonates indicate microporosity, fracturing and stylolites. Variety of P-wave and S-wave velocity and velocity ratio are the source of information about lithology of reservoir rocks and confirm also level of hydrocarbon saturation (show perspective areas). To achieve accurate and excepted results there is a need to combine high quality seismic data, petrophysical and geological knowledge.

Workflow

1. Cementation factor m calculations using three new approaches:
   • Connectivity equation
   • Borai formula
   • Shell formula

Cementation factor vs. connectivity equation (Eq. 1)

\[ m = \frac{2.2 - \ln \left( \frac{S_m - S_c}{1 - S_c} \right)}{\ln \phi} \]

Borai formula (Eq. 2)

\[ m = 1.87 + \frac{0.019}{\phi} \]

Shell formula (Eq. 3)

Discrepancy between well log data (fig. 1) and reservoir tests was observed in analysed interval (4800-4900 m). Reservoir tests indicated gas saturation in contradiction to well logs (decrease in resistivity measurement). What may be the cause of this discrepancy? Wrong determination of cementation factor m is one of the ideas. There was made an attempt to calculate cementation factor m using three new approaches. The result are: m from connectivity equation= 1.341 and 2.004, m from Borai formula= 2.042, m from Shell formula= 1.987, input m= 1.913.

2. Water saturation S_c calculations using new determined cementation factors m

3. Use of fluid substitution method, which assume diverse water saturation, to calculate P-wave and S-wave velocities, Vp/Vs ratio and also density

Fluid substitution - assumed water saturations - Brie’s equation - results

4. 3D Crossplots construction

The best result was obtained after using connectivity equation for m=1.341 (SWTAF - blue curve on fig. 2). Water saturation SWTAF presents the highest gas saturation in analysed zone what was proved by reservoir tests. Fig. 2 presents differences in P-wave and S-wave velocities. P-wave velocities show strongest parting than S-wave velocities. However Vp/Vs ratio is one of the best gas indicators because of the highest gas sensitivity what is observed as a curve separation. Fig. 3 and 4 present 3D crosplots. Low P-wave and S-wave velocity values express low water saturation.

To create theoretic seismic synthetics (fig. 5) the Ricker signal was used. Theoretical modelling was carried out in order to estimate wave field diversity depending on water saturation. Too small differences between these theoretic seismic synthetics were observed. They do not qualify to draw a conclusion about determination of gas saturation degree. Theoretical Modelling can be use for qualitative seismic interpretation. Amplitude analysis are not enough distinctive. Mainly it is related with P-wave velocity decrease under influence of variable gas saturation in pore space.

Conclusions:
Correct determination of cementation factor is essential for proper water saturation estimation. Changes in P-wave velocities are likely seen than in S-wave. Decrease of the Vp/Vs ratio may be treated as a gas indicator in reservoir rocks. Fractures and microporosity play an important role in geophysical interpretation.