High-Velocity Carbonates with High Permeability: Implications for Reservoir Quality in High Acoustic Impedance Intervals

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High acoustic impedance intervals on seismic data are typically interpreted as low porosity rocks with little reservoir quality. It is known that in carbonates high impedance intervals can have a relatively high porosity if the rock contains a lot of moldic and separate vug porosity. New data sets document that rocks with interparticle porosity also can display high acoustic velocity and high permeability at a given porosity, implying that high impedance areas can also contain high quality reservoir rocks.

Acoustic velocity measurements of core plugs are combined with digital image and petrographic analysis from several sites (a giant oil field in Abu Dhabi, Marion platform offshore Australia, and several samples from modern environments in Bahamas). In a velocity-porosity cross plot both, samples with interparticle porosity and samples with moldic/vuggy porosity, display positive deviations of up to 2500 m/s from the Wyllie time-average equation. The two sample sets differ, however, in regards to permeability. The moldic group has low permeability while the interparticle set has higher permeability. The samples from the giant oil field in Abu Dhabi display a remarkable trend of increasing permeability with increasing velocity at any given porosity, indicating that the high velocity/high impedance intervals contain the best quality reservoirs.

In order to achieve a high velocity at a relatively high porosity the rock needs to have a stiff frame. Petrographic analysis demonstrates that early marine micritic cements at grain contacts, meteoric meniscus cements, and to a lesser degree fringing cements produce such a stiff frame in carbonates. In a Holocene sample (23% porosity) small amounts of micritic contact cement produce a P-wave velocity of 4500 m/s. This velocity is maintained throughout the increasing confining pressure from 5 to 80MPa, which equals approximately 3 km of overburden pressure. This indicates that small amounts of contact cements can preserve primary porosity to great burial depth.

The implications of these findings are two-fold. Samples with interparticle porosity can display high velocity similarly to samples with separate-vug porosity. This adds uncertainty to quantitative estimates of separate-vug porosity from velocity logs. In certain cases high acoustic impedance is related to permeability which can improve reservoir characterization and exploitation.