The Influence of Interparticle versus Vuggy Porosity on Acoustic Velocity of Carbonates

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Project Purpose

1) To disprove the common assumption that carbonates with moldic and vuggy pore types principally display higher acoustic velocity than rocks with predominantly inter-crystalline/inter-particle porosity at equal total porosity. This assumption has been used to quantitatively estimate the amount of secondary porosity and separate-vug porosity by modeling porosity from acoustic logs (e.g. Schlumberger, 1974, Nurmi, 1984; Lucia and Conti, 1987; Wang and Lucia, 1993). New data question this assumption and indicate that rocks with inter-particle pore types also can display high acoustic velocity for a given porosity (Fig. 1). This would have implications for log and seismic-based porosity estimates.

2) To identify the processes, which stiffen the rock to achieve high acoustic velocity. The working hypothesis is that in vuggy rocks the stiff framework is produced mainly by the bulk of the rock encapsulating the vugs, while in rocks with inter-particle porosity contact cements weld the grains together to form a stiff and fast rock.

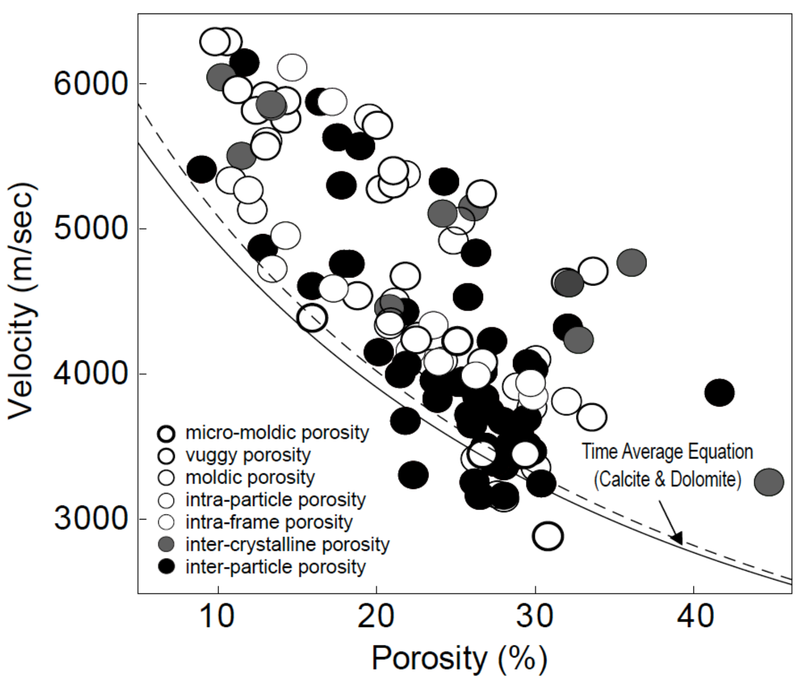

Figure 1: Velocity-porosity cross-plot of samples measured at 20 MPa with annotation of porosity types separated into two groups. Open circles are samples with vuggy/moldic and intra-frame/grain porosity, black and grey dots represent samples with inter-particle and inter-crystalline porosity. A large overlap exists between these two groups, indicating that rocks with inter-particle/inter-crystalline porosity can in some cases have a stiff framework and high velocity (from Weger et al., submitted AAPG Bulletin).

Scope of Work

The acoustic velocities, porosities and permeability of carbonates containing the two end-member pore types (vuggy/moldic and intergrain/intercrystalline) will be measured to assess the velocity-porosity transforms of rocks with these pore types. In addition, digital image analysis will be performed on thin sections from all measured samples to quantitatively describe and relate pore geometry to the petrophysical data. Furthermore, the diagenesis of each sample will be investigated using microscopy and SEM. Finally, high-resolution CT scans will be acquired of a selected number of samples. The 3D image data will be used to derive directly acoustic velocity vs. porosity, pore connectivity and porosity-permeability relationships via numerical simulation and compared with measured data on the same rock. This last task will be done in collaboration with the Center for Applied Mathematics, Australian National University in Canberra.

Project Description

It is well known that carbonate rocks with vuggy and moldic pores have high acoustic velocity at a given porosity but such high velocity is less often documented for rocks with interparticle and intercrystalline pores. Permeability is usually low in rocks with vuggy porosity (Lucia, 1995) but is high in rocks with intergrain/intercrystalline porosity irrespective of the acoustic velocity. Intervals where rocks with interparticle porosity have high velocity will produce a positive acoustic impedance but will not be tight, low porosity sequences and potentially contain high permeability.

Macro-porosity can be ineffective (in regards to velocity) if the solid frame around the pores carries the acoustic wave. The processes that form frame stiffening in rocks with inter-crystalline porosity vary. For example, Dvorkin and Nur (1996) document how contact cementation explains high velocity in high-porosity sandstones from the North Sea. In carbonates, early cementation often takes place at grain contacts as meniscus cements derived from meteoric waters in the vadose environment (Harris, 1978; Longman, 1980) or as micritic bridging cements in the marine realm (Figure 2). Even

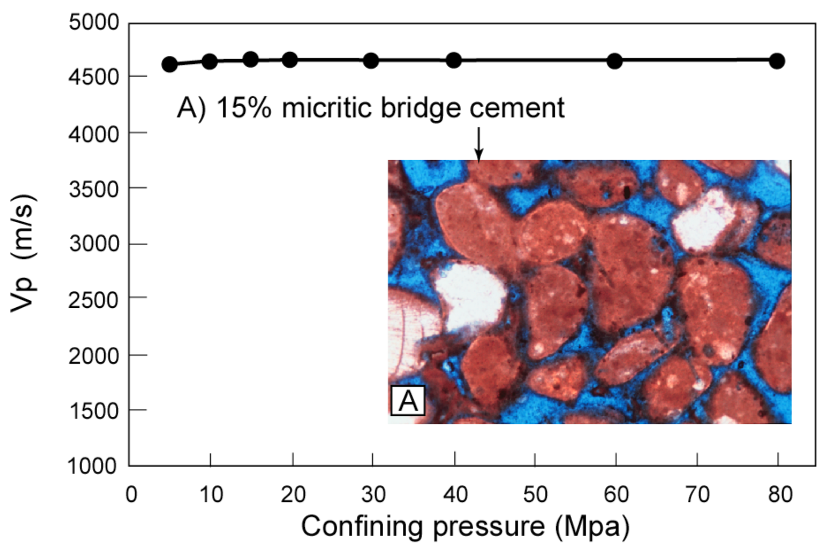

Figure 2: A modern peloidal grainstone with interparticle porosity (and microporosity within the grains) displays a high-velocity under confining pressures from 5 – 80 MPa. 15% of micritic bridging cement stiffens the rock to produce this high velocity.

small amounts of such bridging cement at grain contacts stiffens the rock dramatically to produce a high velocity. In dolomites interlocking of crystals might increase dramatically acoustic velocity because isolated rhombohedra grow together to form a stiff framework. The goals of this project are twofold; first to document that high-velocity rocks with intergrain porosity are more common than previously thought and, secondly, to document the processes that produces these high-velocities.

Key Deliverables

A data set of carbonates with high velocity but contrasting pore-types will be assembled and related to their permeability and digital image analysis parameters. The processes that produce high velocity from these contrasting pore types will be explained with a diagenetic analysis and high-resolution CT-scans and modeling.

Expected Results

The results are expected to prove that not only separate-vug porosity is ineffective for sonic velocity but also large intergrain porosity. These findings will explain why log-based porosity estimates are not always successful.

References

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