HOW CEMENT CONTROLS THE ELASTIC PROPERTIES OF SANDSTONES

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ABSTRACT

Composition and cementation are two major parameters that control the elastic properties of granular media. By combining an exhaustive microscopic description of grain contacts for three porous sandstones (Berea, Boise and Nubian sandstones) with Vs and Vs measurements, we quantify the effect of cement on the seismic properties of sandstones. Specifically, velocities, elastic moduli, and Poirson’s ratio decrease with increasing clay content. Using acoustic microscopy (SAM) to quantify the micro-structural acoustic impedances, we find that the impedance of quartz cement in Boise sandstone is greater than the impedance of kaolinite cement in Berea and Nubian sandstones. These cement impedances relate to grain contact stiffness that controls the impediment of cm-sized sample obtained from the ultrasonic experiments. These results relating microstructure to seismic properties of sandstone can be useful for indirectly assessing the diagenetic texture, which is particularly important for modeling the spatial distribution of sandstone properties, such as cementation and porosity. The nature and amount of cement are major parameters controlling the deformation mechanisms in sandstones, i.e. the modes of localization and propagation of failure (Du Bernard 2002). Therefore by better characterizing indirectly its cement, it will be possible to constrain exactly the type of structural objects developing within the sandstone for any given stress boundary conditions.

SAM OBSERVATIONS

Back-scattered SEM images of Nubian sandstones. (A) Sandstone overview feature high porosity (black: impregnation epoxy resin). Delhi quartz grains (Q) are well rounded and rare quartz overgrowth have been recognized (black arrow) for this sample. Few pores are filled by kaolinite particles (Kao). In (A), microcracks in feldspar grains are due to the proximity of a deformation band (micro-fault). (B) At the contact grain, the cement is composed exclusively of kaolinite (Kao) that occurs as mesocement. (C) Detail of (B) showing elongated clay particles exhibiting a preferred orientation parallel to the surface of the detrital grains. This arrangement results in anisotropic morphology that round off the sharp corners of pores.

Back-scattered SEM images of Boise sandstones. (A) Anisotropic sandstone overview shows good porosity (black: impregnation epoxy resin) with some kaolinitic aggregates (Kao) filling pores. (B) Delhi quartz grains (Q) are sub-angular due to quartz overgrowths that form grain bridges (black arrow). Locally, some patches of kaolinitic particles (Kao) coat the quartz overgrowths showing the relative timing of cementation. (C) Mesocement-type cement formed by kaolinite particles (Kao) is locally well developed and completes the primary quartz cementation. In (C), the small bright grain is sparsite titanium oxide (Ti). (D) Detail of (C) showing the confused internal structure of a kaolinitic bridge.

Back-scattered SEM images of Berea sandstones. (A) Sandstone overview shows good porosity (black: impregnation epoxy resin) with some kaolinitic aggregates (Kao) filling pores. (B) Delhi quartz grains (Q) are sub-angular due to quartz overgrowths that form grain bridges (black arrow). Locally, some patches of kaolinitic particles (Kao) coat the quartz overgrowths showing the relative timing of cementation. (C) Mesocement-type cement formed by kaolinite particles (Kao) is locally well developed and completes the primary quartz cementation. In (C), the small bright grain is sparsite titanium oxide (Ti). (D) Detail of (C) showing the confused internal structure of a kaolinitic bridge.

MEASUREMENTS - CALCULATION OF ELASTIC MODULI

Changes in P- and S-wave velocity, bulk and shear moduli, Poisson’s and Vs/Vs ratios, and porosity as functions of pressure in all three samples. Due to the compliance of their contact zones, Berea and Nubian measures show pronounced pressure dependences. Oppositly, measures of Boise sandstone, which has competent cement, does not change much with pressure.

CONCLUSIONS & APPLICATIONS

• Velocities, elastic moduli, and Poirson’s ratio decrease with increasing clay content.
• The seismic properties can be directly related to the contact stiffness that is deduced from contact impedance (SAM images).
• The combined measurements of the impedance (SAM) and the P- and S-wave velocities can indirectly assess the diagenetic texture, particularly the clay proportion of cement.
• An indirect characterization of cement is important to constrain the type of structural objects developing within the sandstone for any given stress boundary conditions.

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