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Wettability acoustic probing in granular porous media

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Surface wettability determines the property of a solid surface in contact with a fluid. It plays a major role in reservoir engineering applications involving fluid transport phenomena. For example, it is critical to hydrocarbon recovery where wettability not only influences the sweep efficiency, but also influences the remaining oil distribution. Since the wettability tends to affect the mechanical properties of rocks, it provides a potential means to remotely monitor the movement of spilled nonaqueous phase liquids in the subsurface via acoustic monitoring. However, there is a lack of direct wettability measurement conditions in underground applications. As widely utilized methods in geophysical exploration, borehole sonic logging and seismic surveys could be used as a potential far-field probing tool for wettability changes. Understanding the acoustic response to wettability changes becomes crucial for this purpose.

To generate a favorable experimental condition for wettability acoustic monitoring, we establish an ultrasonic experimental basis for observing changes between hydrophilic and weakly hydrophilic conditions in (partially) saturated granular porous media. Glass beads are employed to construct granular porous media with fully interconnected pores and are chemical-treated to alternate the wettability condition. Particular attention is paid to ensure the uniform distribution of water across bead packings at different saturation levels, aiming to diminish the impact of patchy water distribution.

The P- and S-wave velocities and attenuations are measured with increasing saturation for the bead packings before and after chemical treatment, respectively. The results illustrate that the chemical treatment increases contact angles and improves the water–bead coupling, leading to higher velocity and lower attenuation of coherent waves. The Gassmann-Wood-Walton model predicts the behavior of coherent waves under different wettability conditions assuming a change in the coordination number. Once reaching a critical saturation, incoherent high-frequency waves are developed with higher propagating velocities. The treatment reduces the amplitude of these incoherent waves to some degree, probably due to the improvement of water–bead coupling. We interpret the observed incoherent waves in terms of the wettability-dependent ability for water to bridge neighboring beads. The velocity of incoherent waves is exceeding the Gassmann-Wood prediction at partial saturation but is close to the fully water-saturated condition. This is suggestive of a propagation path of incoherent pulses resembling the fully water-saturated condition. In our interpretation, this is because the presence of a critical amount of water creates a favorable and wettability-dependent condition to form liquid bridges connecting neighboring grains.

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Primary authors: Dr CHEN, Yangpu (China University of Petroleum (East China)); Prof. FU, Li-Yun (China University of Petroleum (East China)); MUELLER, Tobias

Presenter: Dr CHEN, Yangpu (China University of Petroleum (East China))

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