Combining laboratory and computational experiments to increase rock physics knowledge

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A good understanding of the effect of rock and pore fluid properties on seismic waves is necessary for the characterization of a subsurface hydrocarbon reservoir from a seismic data set. Information about the rock and fluids in the reservoir can be obtained, for example, through well logging and laboratory tests with samples cored from the wellbore. Together with seismic data, this information can be extrapolated for the dimensions of the reservoir to provide valuable quantitative estimates for production. Additionally, this information can be extrapolated in time for monitoring the spatial redistribution of fluids during production. Making such space and time extrapolations more accurate using seismic data is the main goal of rock physics. For that, identifying and understanding the physical processes taking place in a reservoir rock at different scales is a key step and the subject of our research.

We (Quintal et al., 2011a) show that combining laboratory and numerical experiments is a powerful tool to achieve an unbiased comprehension of the rock physical processes at different scales. While in laboratory experiments it is very difficult, or even impossible, to control all the physical processes, in numerical experiments all physical parameters can be controlled exactly. Numerically, it is even possible to study different physical processes separately from each other, which otherwise coexist in nature or in the laboratory.

A knowledge-feedback between laboratory and numerical rock physics is demonstrated on two examples of current challenges in rock physics: (i) understanding the influence of the rock microstructure on effective elastic properties (Madonna et al., 2012; Figure 1) and (ii) identifying the dominant physical mechanism responsible for intrinsic attenuation in saturated rocks at seismic frequencies (Quintal et al., 2011b; Figures 2 and 3).

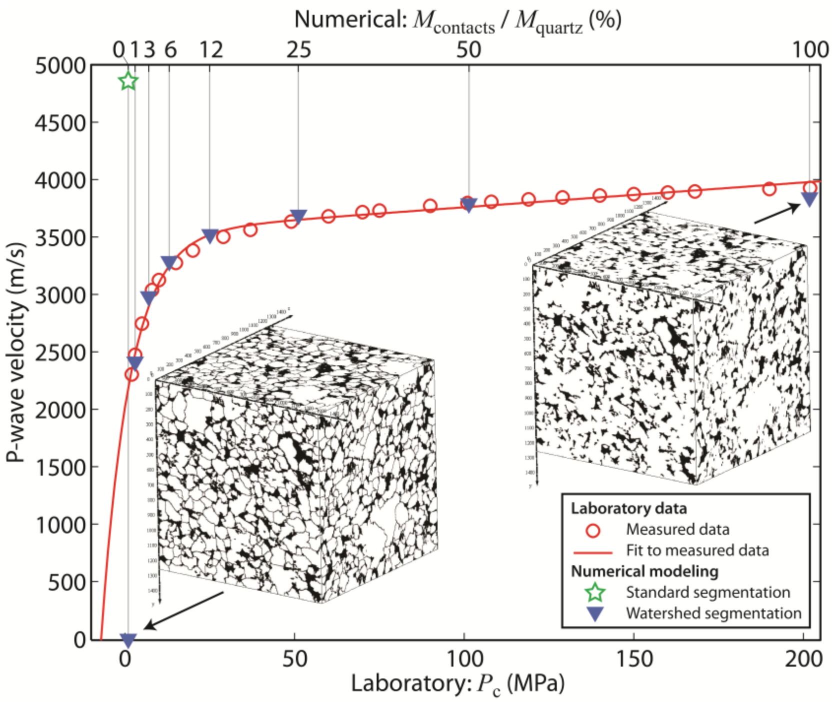

Figure 1. Laboratory and numerical results for the P-wave velocity as a function of confining pressure, P_c. The digital rock models are generated by standard segmentation (star) and watershed segmentation (triangles) of micro-CT data. The identified grain contacts have a P-wave modulus ranging from 0% to 100% of the P-wave modulus of quartz (upper abscissa). The two insets show the two end-member digital rock models containing grain contacts with a P-wave modulus equal to zero and M_{quartz}, respectively. The cube volume is 2 cm^3.

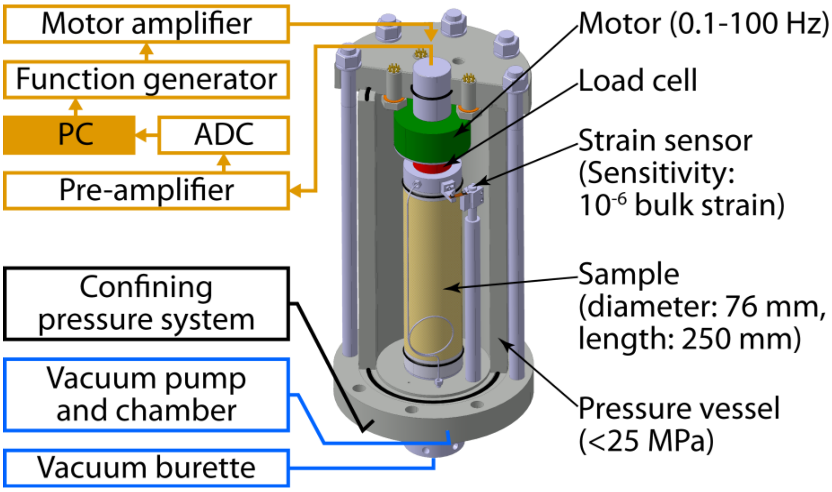

Figure 2. CAD-model of the Broad Band Attenuation Vessel, BBAV (Tisato and Madonna, 2012). The applied strain sensor measures the bulk attenuation and not a local attenuation.

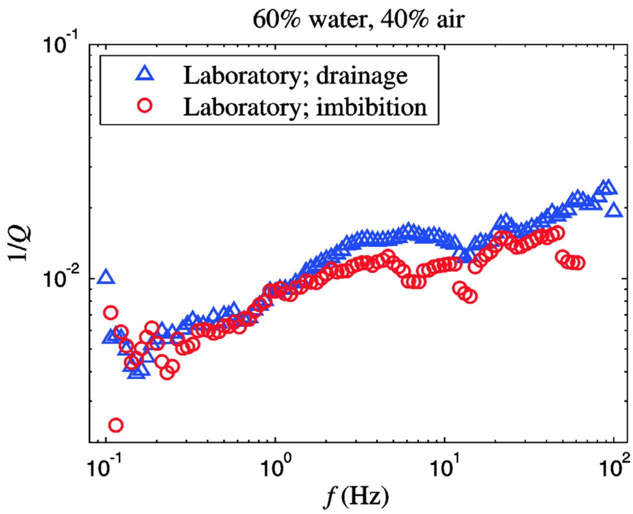

Figure 3. Laboratory results for frequency-dependent attenuation (1/Q) for a Berea sandstone sample saturated with 60% water and 40% air, measured with the BBAV (Figure 2). Two saturation methods were applied in the laboratory: imbibitions and drainage. The significant differences in attenuation are interpreted as an effect of the different saturation distribution in the rock resulting from the two different saturation methods. Numerical attenuation simulations aiming at a better understanding of these experiments will be presented.

Both presented challenges are subject to ongoing research conducted in The Rock Physics Network at ETH Zurich (ROCKETH; www.rockphysics.ethz.ch) and the presented studies are a snapshot of work in progress. Therefore, this presentation also aims at giving an overview of our rock physics research group.

References

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