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Shale dynamic properties and anisotropy: an experimental approach

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Clayrocks, and shales in particular, represent approximately two-third of all sedimentary rocks. In oil and gas drilling operations, shales constitute $80\ \%$ of all the drilled sections, mainly because they overlie most hydrocarbon bearing reservoirs. Furthermore, several countries are considering clayrocks as possible host lithologies for radioactive waste confinement, and therefore carrying out research programs to estimate feasibility of such solution. In this trend, the french agency for radioactive waste management, ANDRA, is evaluating the reliability of the Callovo-Oxfordian layer, Jurassic in age, located in the eastern part of France (Bure), at a depth ranging from $400\ \mathrm{m}$ to $700\ \mathrm{m}$.

In general, the monitoring of elastic velocities in shales under mechanical loading are relatively uncommon in view of the abundance of this lithology in the shallow earth crustal rocks. This relative rareness is partly due to: (i) the inherent difficulty of transmitting transducer signals through the waterproof pressure chamber in a loading apparatus ; and, on the other hand, (ii) the specificities in preparing and handling shale samples for mechanical testing (chemical sensitivity to water, extremely low permeability...). Most of the dynamic experimental studies reported in the literature on shale samples were performed under hydrostatic loading conditions. Only very few triaxial experiements are reported in the literature.

The specific experimental setup available in our lab allows for the simultaneous measurement of five different velocities and two directions of strains on the same sample, under triaxial and pore pressure-controlled conditions of loading. This procedure reduces the number of experiments on differently oriented samples usually needed to identify the dynamic properties of a rock. It also minimizes the errors due to the particular difference between two samples of the supposedly same lithology.

The main outcomes of this experiment are : (i) identification of the apparent dynamic stiffness of the Callovo-Oxfordian shale from elastic velocity measurements (hexagonal symmetry) ; (ii) assessment of velocity and attenuation anisotropies, and their evolution under triaxial loading. This last step allows for the quantification of the intrinsic and stress-induced anisotropies, leading eventually to an estimation of the microcracks density and distribution evolutions in the shale sample under loading.

Eventually, combining these experimental data with a theoretical approach based on an extension of Biot theory of poroelasticity, it may be possible to quantify certain parameters such as permeability or diffuse damage under triaxial loading.