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Differences between static and dynamic elastic moduli: Importance of experimental methods

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The differences between static and dynamic elastic moduli remain a controversial issue in rock physics. Various empirical correlations can be found in the literature. However, the experimental methods used to derive the static and dynamic elastic moduli differ and may entail substantial part of the discrepancies observed at the laboratory scale. The representativeness and bias of these methods should be fully assessed before applying big data analytics to the numerous datasets available in the literature.

We will illustrate, discuss and analyze the differences inherent to static and dynamic measurements through a series of triaxial and petroacoustic tests performed on an outcrop carbonate. The studied rock formation is Euville limestone, which is a crinoidal grainstone composed of roughly 99% calcite and coming from Meuse department located in Paris Basin. Sister plugs have been cored from the same quarry block and observed under CT-scanner to check their homogeneity levels.

The triaxial device is equipped with an internal stress sensor and provides axial strain measurements both from strain gauges glued to the samples and LVDTs placed inside the confinement chamber. Two measures of the static Young's modulus can thus be derived: the first one from the local strain measurements provided by the strain gauges and the second one from the semi-local strain measurements provided by the LVDTs. The P- and S-wave velocities are measured both through first break picking and the phase spectral ratio method, providing also two different measures of the dynamic Young's modulus.

The triaxial tests have been performed in drained conditions and the measured static elastic moduli correspond to drained elastic moduli. The petroacoustic tests have been performed using the fluid substitution method, which consists in measuring the acoustic velocities for various saturating fluids of different bulk modulus. No weakening or dispersion effects have been observed. Gassmann's equation can then be used to derive the dynamic drained elastic moduli and the solid matrix bulk modulus, which is otherwise either taken from the literature for pure calcite or dolomite samples, or computed using Voigt-Reuss-Hill or Hashin-Shtrikman averaging of the mineral constituents.

For the studied carbonate formation, we obtain similar values for static and dynamic elastic moduli when derived from careful lab experiments. Based on the obtained results, we will finally

make recommendations, emphasizing the necessity of using relevant experimental techniques for a consistent characterization of the relation between static and dynamic elastic moduli.