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Geomechanical and anisotropic acoustic properties of Lower Jurassic Posidonia shales from Whitby (UK)

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The Posidonia Shale Formation (PSF) is one of the possible resource shales for unconventional gas in Northern Europe and currently is of great interest to hydrocarbon exploration and production. Due to low permeability of shales, economically viable production requires hydraulic fracturing of the reservoir. The design of hydrofractures requires an estimate of stress state within the reservoir and geomechanical properties such as Young's modulus and Poisson's ratio.

Shales are often highly anisotropic and the models which neglect shale anisotropy may fail to predict the behaviour of hydrofractures. Seismic attenuation anisotropy, on the other hand, can play a key role in quantitative rock characterization. Where the attenuation anisotropy can potentially be linked to anisotropic permeability of shales, its fluid/gas saturation and preferred development of anisotropic fracture orientations.

In this research, by utilizing the so-called Thomsen's notations, the elastic anisotropy of our (fractured and unfractured) shales has been investigated using a pulse transmission technique in the ultrasonic frequency range (0.3-1 MHz). Assuming transverse isotropy of the shales, and taking the axis x_3 as the axis of rotational symmetry, directional Young's moduli and Poisson's ratios were obtained. The Young's modulus measured parallel to bedding (E_1) is found to be larger than the Young's modulus measured orthogonal to bedding (E_3). In case of the Poisson's ratios, we found that ν_{31} is larger than ν_{12}, where ν_{ij}relates elastic strain in x_j direction to stress applied in x_i direction.

Finally, attenuation anisotropy in dry and layer-parallel fractured Posidonia shale samples has been studied in the same frequency range. The attenuation of compressional (Q_P^{-1}) and shear (Q_S^{-1}) waves increases substantially with a macro (or wavelength) fracture introduction, especially for P and S waves propagating orthogonal to the bedding. In non-fractured and fractured dry shales, Q_P^{-1} is always larger than Q_S^{-1}. This inequality was also found for the fractured shale using different fluids (water, oil) on the fracture surface. A high-viscosity fluid decreases Q_P^{-1} and Q_S^{-1} in both (orthogonal and parallel to the bedding) directions, and the Q_P^{-1} to Q_S^{-1} ratio decreases with the increase of fluid viscosity.