Structural integrity of the diatom- and smectite-rich mud from the Nora Formation, Sten-1 well, Danish North Sea

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Hydrocarbon migration from chalk reservoirs to fine-grained overburden sediments raises concerns about wellbore stability in decommissioning wells. Understanding the petrophysical properties of these formations is essential. By interpreting seismic, well-logging, and petrographic data, we identified diatom-rich mud intervals in the Nora Formation of the Sten-1 well. This well represents several wells nearing decommissioning.

We characterized solid composition from 10 cuttings in the diatom- and smectite-rich mud using X-ray diffraction and interpolation. Due to the amorphous nature of diatoms (opal-A), we quantified opal-A and derived porosity using neutron and density logs (Fig. 1). Compositional analysis enabled us to derive the solid phase elastic bulk and shear moduli, and we calculated the saturated-state P-wave modulus which was converted to dry-state using the Iso-frame model.

Our results indicated a Biot coefficient (α) log ranging from 0.96 to 0.99, suggesting grain-to-grain electrostatic contact without cementation. Vertical elastic strain (ε) calculations showed elevated strain (0.2%) between 1510 to 1600 m msl, indicating potential structural damage and fracturing. Given the matrix is highly impermeable, we are investigating if fractures could facilitate fluid flow.

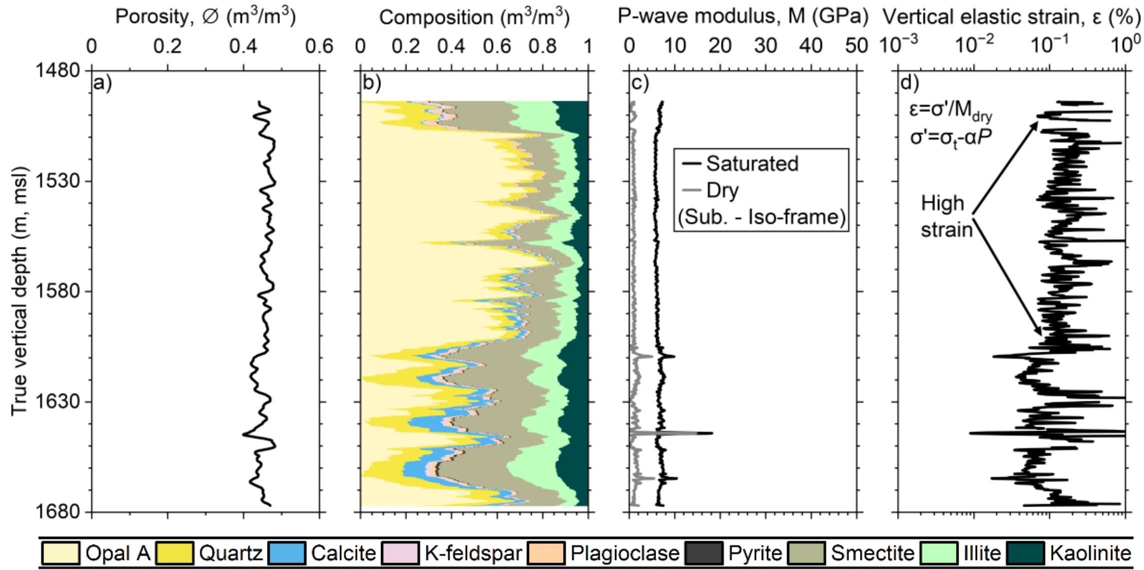

Fig. 1: Petrophysical properties of the water-saturated Sten-1 well, including a) porosity, b) volumetric solid phase composition, c) saturated- and dry-state P-wave modulus, with bulk and shear moduli derived from compositional analysis and linear combination of mineral moduli, and d) vertical elastic strain calculated from vertical elastic stress (σ') and dry-state P-wave modulus. Overburden stress (σ_t) was calculated using 1.98 g/cm^3 bulk density, and pore pressure (P) assumed equal to mud pressure.

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