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New UK in-situ stress orientation for northern England and controls on borehole wall deformation identified using borehole imaging

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The nascent development of a UK shale gas industry has highlighted the inadequacies of previous in-situ stress mapping which is fundamental to the efficacy and safety of potential fracturing operations. The limited number of stress inversions from earthquake focal plane mechanisms and overcoring measurements of in-situ stress in prospective areas increases the need for an up-to-date stress map.

Borehole breakout results from 36 wells with newly interpreted borehole imaging data are presented. Across northern England these demonstrate a consistent maximum horizontal stress orientation (SHmax) orientation of 150.9° and circular standard deviation of 13.1°. These form a new and quality assured evidence base for both industry and its regulators.

Widespread use of high-resolution borehole imaging tools has facilitated investigation of micro-scale relationships between stress and lithology, facilitating identification of breakouts as short as 25 cm. This is significantly shorter than those identified by older dual-caliper logging (typically 1-10+ m). Higher wall coverage (90%+ using the highest resolution tools) and decreasing pixel size (down to 4mm vertically by 2° of circumference) also facilitates identification of otherwise undetectable sub-centimetre width Drilling Induced Tensile Fractures (DIFs).

Examination of borehole imaging from wells in North Yorkshire within the Carboniferous Pennine Coal Measures Group has showed that even though the stress field is uniform, complex micro-stress relationships exist. Different stress field indicators (SFI) are significantly affected by geology with differing failure responses from adjacent lithologies, highlighted by borehole imaging on sub-metre scales.

Core-log-borehole imaging integration over intervals where both breakouts and DIFs have been identified allows accurate depth matching and thus allows a synthesis of failure for differing lithology and micro-structures under common in-situ conditions. Understanding these relationships requires detailed knowledge of the rock properties and how these affect deformation. Strength and brittleness of the facies are indicative of their likely failure-modes which are in turn controlled by their lithology, diagenesis and clay mineralisation, often highlighting dm-scale stress rotations around lithological boundaries. Breakouts are seen to concentrate within “seatearths” (palaeosol intervals directly under the coals), whereas intervals immediately above coals are marked disproportionately by DIFs. In-situ stress magnitude data information is not yet available for these wells, further work is required to quantify the geomechanical properties.