Links between lithology and borehole wall failure, examples from borehole imaging in Northern England

Andrew Kingdon, Mark Fellgett and John Williams, British Geological Survey

Keyworth, Nottingham, NG12 5GG, UK. Email aki@bgs.ac.uk.

The recent massive increases in US shale oil and gas production results from the widespread use of hydraulic fracturing to increase productivity from low-permeability reservoirs. Understanding the in-situ stress field around the borehole is fundamental to the efficacy and safety of fracturing operations.

Widespread use of high-resolution borehole imaging tools has facilitated new investigation of micro-scale relationships between stress and lithology. Previous dual-caliper log analyses had insufficient resolution to identify these relationships. Indeed borehole breakout analyses using caliper logs simplifies understanding of the stress orientation; the low resolution means that only breakouts zones of many metres in length can be identified. Contrastingly, borehole imaging tools can identify both breakouts as short as 25 centimetres and also sub-centimetre width Drilling Induced Tensile Fractures (DIFs).

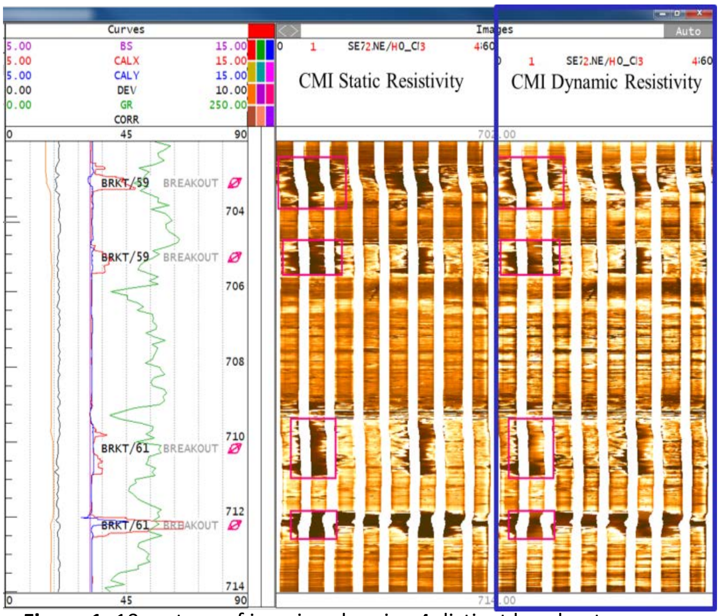

Figure 1: 10 metre s of imaging showing 4 distinct breakouts

Images from two wells in North Yorkshire indicate complex relationships between stress and lithology. Figure 1 shows a 10 metre section of resistivity imaging from Swinefleet 1 well, sampling the Carboniferous Pennine Coal Measures Group. Four distinct breakouts each of ~50 cm length are visible across this 10 m section; breakouts between 703 and 706 m are separated by a less resistive unit without obvious deformation.

Figure 2 shows Melbourne 1 some 23.5 kilometres north. DIFs are clearly visible both above and below a coal seam. Not only do these terminate at the coal's boundary but this seam shows clear breakouts.

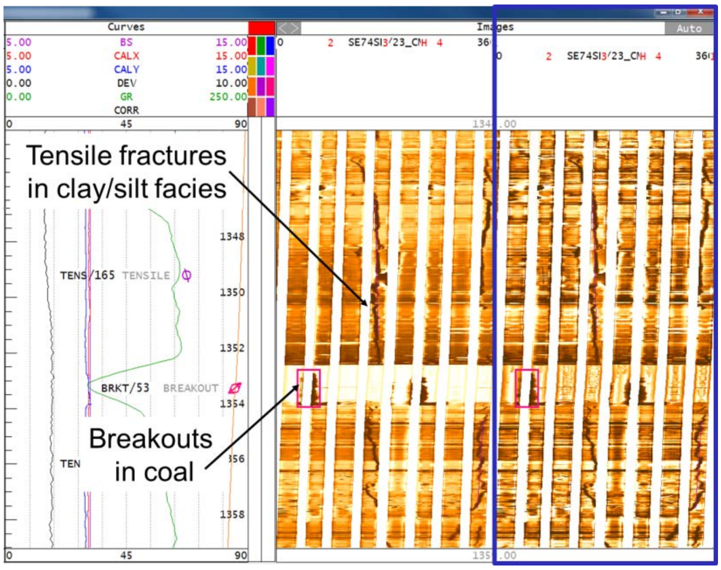

Figure 2: 10 m section of resistivity imaging showing breakouts and drilling induced tensile fractures.

These images show that lithologies are experiencing different failure types on sub-metre scales. This demonstrates significant lithological controls on rock failure from in-situ stress.

Both wells have been cored over intervals where breakouts and DIFs have been identified. Borehole imaging allows accurate depth matching of the core which can be sampled for rock testing. This allows a synthesis of failure under in-situ conditions, lithology and rock properties. Understanding these relationships requires detailed knowledge of the rock properties and how these affect deformation.

The 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. As in-situ stress magnitude data information is unavailable in both wells, further work is required to quantify the geomechanical properties. Detailed examination of borehole images in other wells highlights small-scale stress rotations around lithological boundaries. Deformation style and localised in-situ stress field perturbations can only be understood with detailed lithological understanding.

Borehole imaging therefore improves understanding of unconventional reservoirs. Further work will seek to upscale properties to quantify entire successions.