

An integrated workflow for borehole image interpretation – structural geology, sedimentology and stress field

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Summary

Borehole image analysis involves identification and spatial distribution of geological features (fractures/faults, breakouts, bedding, lamination, cross-bedding, trace fossils, facies), which can be compared with seismic/core or act as direct input for 3D reservoir modelling. Borehole images are used to orient cores and to evaluate structural tilt, faulting and fracturing as well as sediment transport directions and depositional architecture/environments. In addition, the stress field can be inverted in combination with other, rock mechanical data. Based on a recent case study an integrated workflow for borehole image interpretation is presented.

The structural tilt is evaluated in stereographic displays (Fig. 1) and projection along the well trace. Changes in tilt may be related to in-well faulting (block rotation) and/or angular unconformities. Fault zones with significant displacement may cause distinct fault drag and juxtaposition of different strata/facies. The integration of meso-scale borehole image data with macro-scale seismic and micro-scale cores is essential. Fractures are often associated with fault zones and reflect the stress field at time of generation. Different orientation of open and closed (mineralised) fractures implies different stages of fracturing and a change in stress field orientation. Fractures and fault-related juxtaposition of facies may play a major role on reservoir performance (baffle, barrier or conduit for fluid flow?). Relevant input parameters for the fracture model are provided as e.g. fracture orientation, density, aperture and porosity.

The current stress field is best observed and evaluated by combining borehole image with dipole sonic tools. A thorough characterisation of the shear wave is vital for further interpretation. Drilling-induced fractures and breakouts (Fig. 2) are easily detected in borehole images representing reliable indicators for the stress field orientation at the time of logging. However, for slanted and highly deviated wells the full stress tensor including the stress magnitudes is necessary to evaluate the stress field orientation. Other rock mechanical data may be utilised from core measurements or derived from empirical relations of elastic properties (Poisson's ratio and Young's modulus). Alternatively, the stress field can be simulated using numerical models to match the current observations.

After removal of the structural tilt from the dip data set, sedimentary features such as cross-beds or slumps may indicate sediment transport directions. In combination with standard petrophysical curves the image facies and their stacking patterns are interpreted with respect to the depositional environment and included in a sequence stratigraphic framework. The resulting time lines aid palaeo-geographic reconstructions. A correlation with core observations provides important calibration of the image facies and a powerful, high-resolution data set spanning the scale from core to seismic. An integration with seismic-scale reservoir models is self-evident. Resistivity variations of borehole images are on a considerably higher resolution compared to standard open-hole logs and connected to

lithology and pore fluids. Hence high-resolution statistical evaluation of the image data enables thin-bed analysis (Fig. 3) or vuggy porosity calculations, which provide detailed N/G estimates.

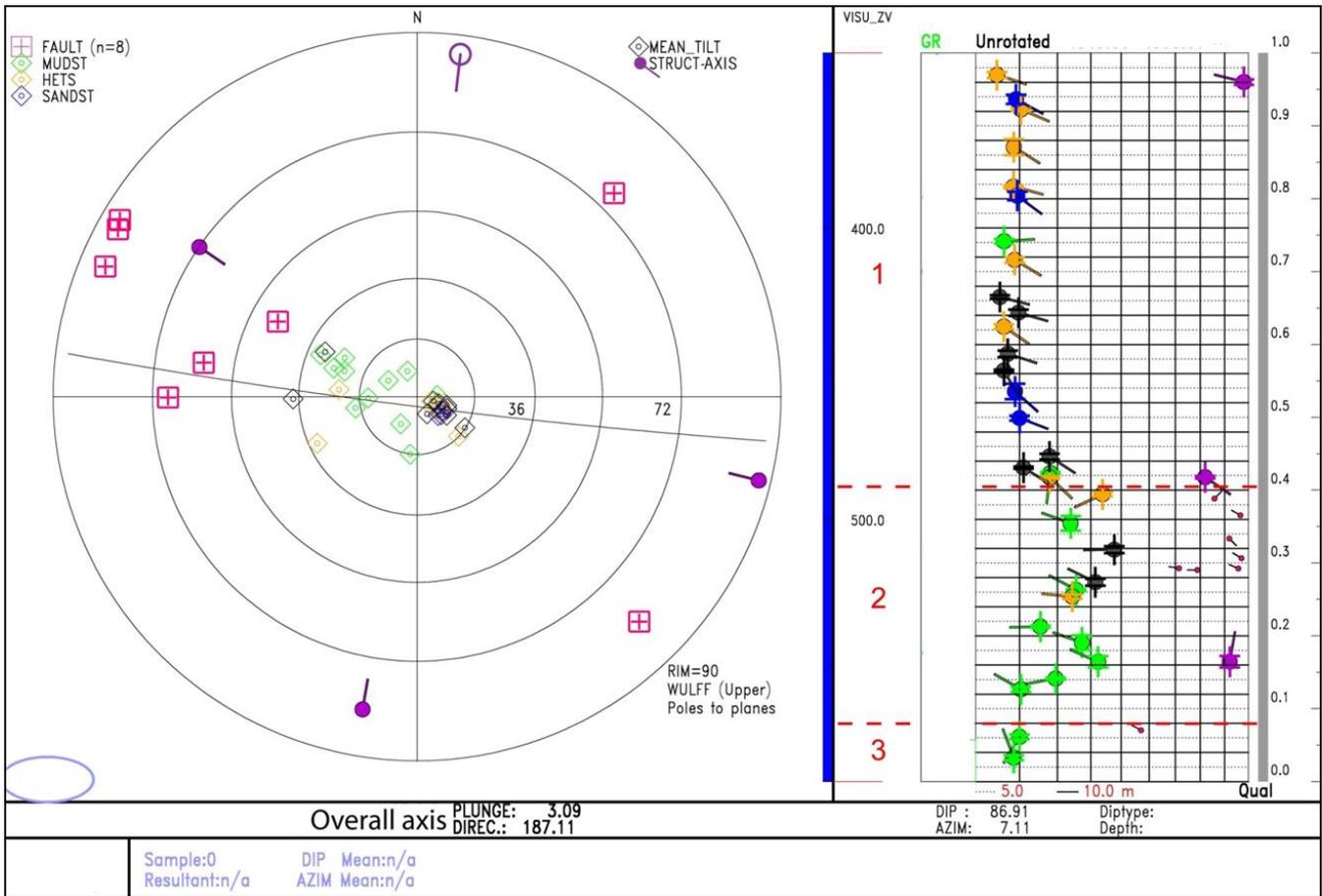


Fig. 1: Stereogram for structural tilt evaluation. Note the change in tilt related to fault block rotation.

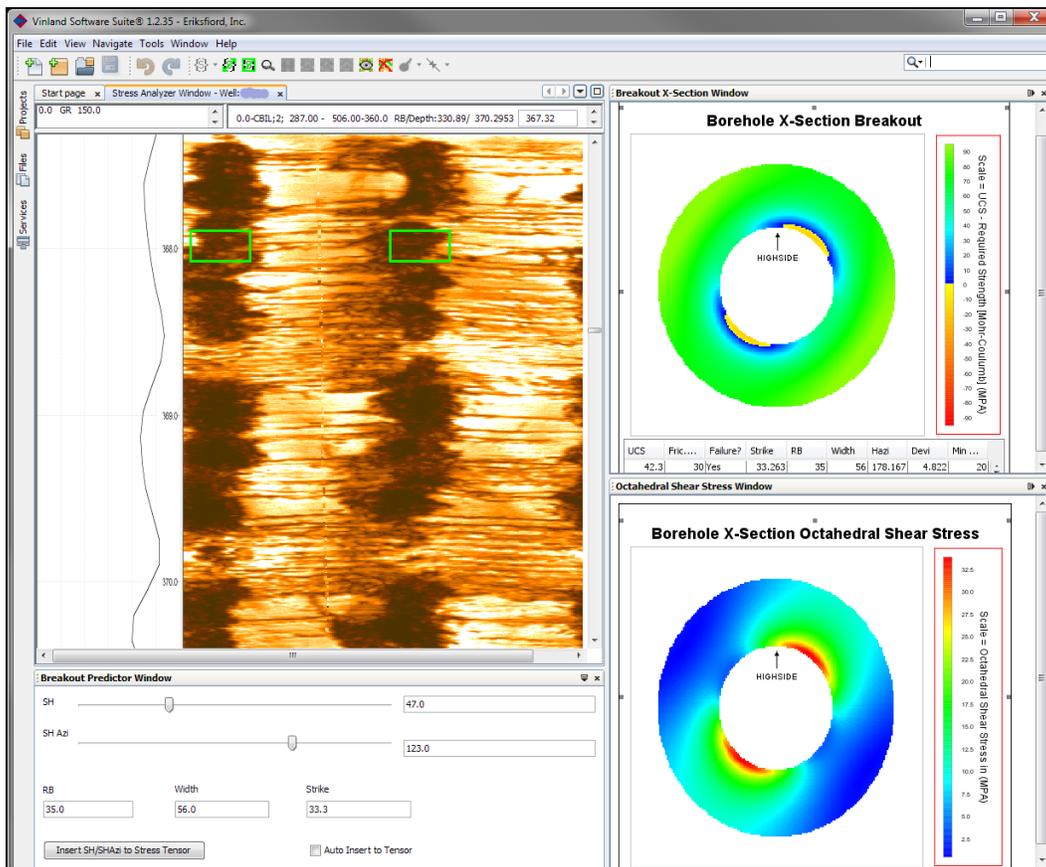


Fig. 2: Breakout in acoustic borehole image for stress field evaluation.

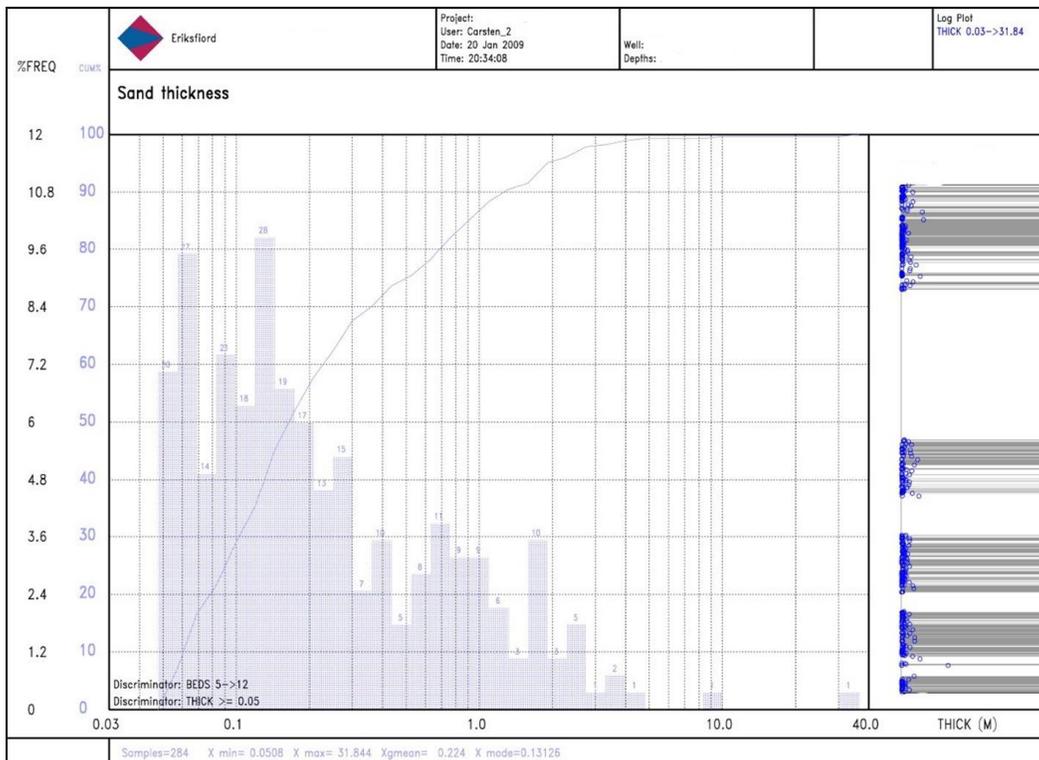


Fig. 3: Bed thickness histogram for N/G analysis.