In-Situ Stress Properties in Fractured Reservoir Models

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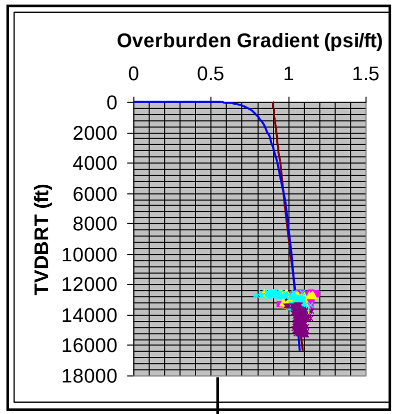
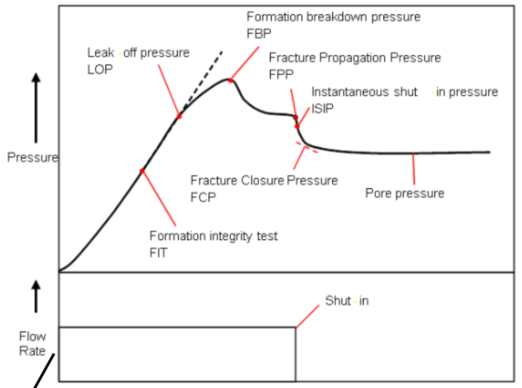
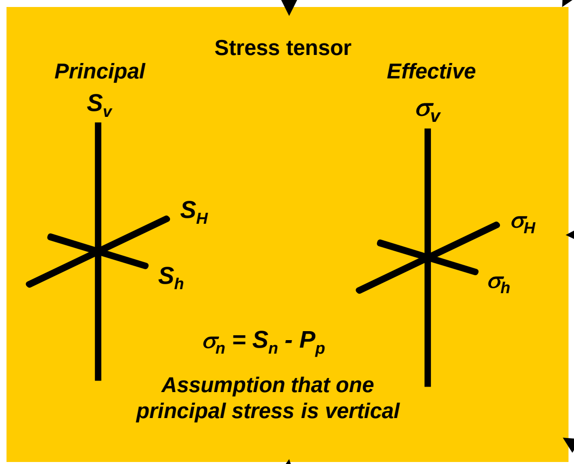
Data required

Density log integration for Sv magnitude

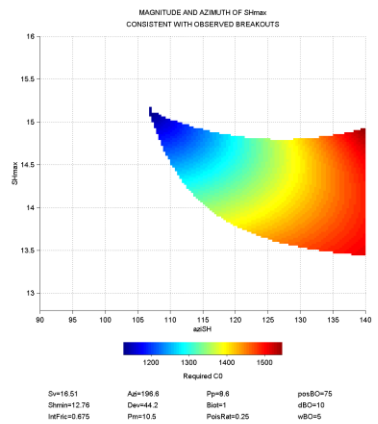


Leak-off pressure test for Sh magnitude

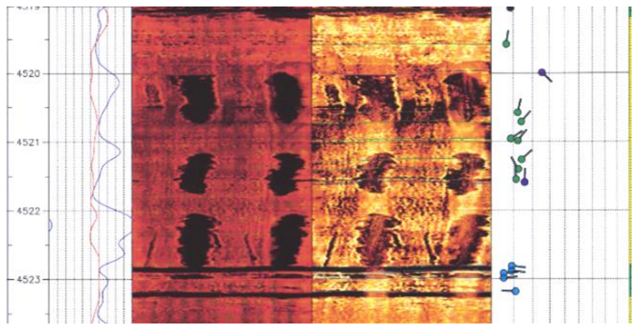




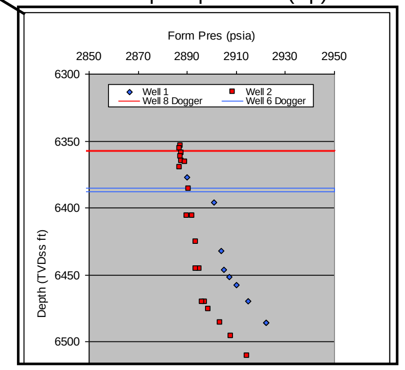
Geomechanical modelling for SH magnitude



Breakout Identification for SH orientation



RFT for pore pressure (Pp)



In-situ stress data is not routinely used by geoscientists, often from a lack of familiarity with how it is measured. Oilfield stress data can be derived from drilling reports, stimulation reports or specialised in-situ stress studies for wellbore planning or reservoir performance.

Earth stresses can be defined from three mutually orthogonal principal stress directions. Typically, one stress is vertical (SV) and two are horizontal (minimum = Sh and maximum = SH). Therefore, to fully define the stress tensor in most situations, the magnitudes of the three stresses need to be measured or calculated and the orientation of the maximum horizontal stress (SH) needs to be measured.

Effective stresses are the principal stresses minus the pore pressure and these are the important values for assessing slip potential on fractures and faults.

Each fracture or fault in the subsurface has stresses acting on it that can be resolved into a maximum shear stress and an effective normal stress. Higher effective normal stresses will act to close the fracture, higher shear stresses will act to slip the fracture.

Coulomb Failure Function (CFF) is defined by :CFF = shear stress (τ) – (μ * effective normal stress (σ_n))

This slip may enhance permeability if new fracture connections are made and/or mineral bonds broken. Correlations can then sought between the fractures with higher shear stresses with intervals of increased productivity.

Geocellular modelling packages are not regarded as the best tools for modelling faults, fractures and their related properties such as resolved stresses because of an inability to explicitly represent fractures and therefore control the fracture connectivity and heterogeneity. They also are unable to interactively model dynamic parameters. So why use these packages for modelling fractures and dynamic properties like in-situ stresses?

- Asset staff can use readily available static modelling packages like Petrel, IRAP RMS or GoCad without resorting to specialised 3rd party software with a steep learning curve or an expensive time consuming external study with potentially obscure and unusable results.
- Static modelling packages produce a 3D stress property that can be readily compared with other 3D properties or sampled into the wellbore and compared with log data. Simple first order questions like "is there a noticeable effect from the in-situ stress on fractures of this orientation" can be quickly assessed using the available data.
- Geocellular modelling packages can readily produce output that is compatible with finite difference reservoir simulators like Eclipse and VIP. Therefore, permeability modifier grids quickly produced for the simulation model, based on resolved shear stresses
- The stress properties can be used to assess the potential for enhanced permeability on natural fractures or faults to be drilled. This is relevant for both enhanced production and fault seal analysis.

The cross section pictures to the right show a sub-set of the stress input properties and the stress output properties for a fractured carbonate reservoir in a normal stress regime (Sv>SH>Sh). In this case a variable SH azimuth was used based on well data. It can be seen that the Coulomb Failure Function (CFF) is strongly related to the effective normal stress magnitude. Changing the pore pressure may yield more positive CFF values as the effective normal stresses vary strongly with pore pressure but the shear stress does not change as much. Changing the fracture orientations will have an effect on both the shear and normal stresses acting on the fractures.

The Mohr diagram on the right graphically shows how shear stress (τ) and normal stress (s_n) are related via the coefficient of sliding friction (red line).

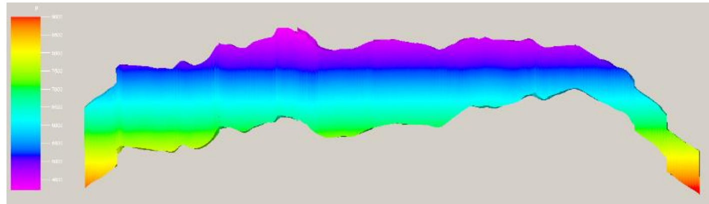
Cells with a positive CFF may be more permeable and cells with higher normal stresses may be less permeable compared to the default fracture permeabilities. This knowledge can be used to create a permeability multiplier in reservoir simulations to help improve the history match or provide options for forecasting.

In a well constrained model, the resolved stress distributions on fractures may also be relevant to well planning. For example, small fractures with high resolved shear stresses may be ideal candidates for production and could be targeted during stimulations.

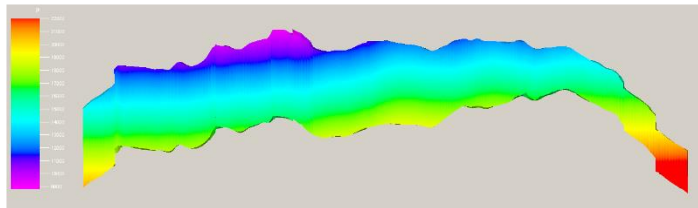
Modelled Inputs & Results

Stress Calculation Inputs

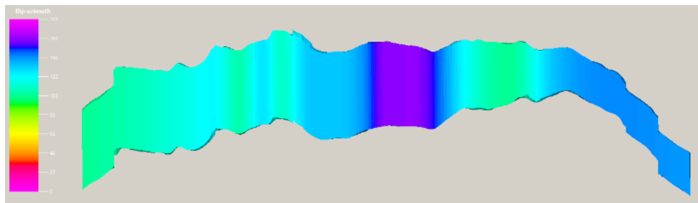
Pore Pressure



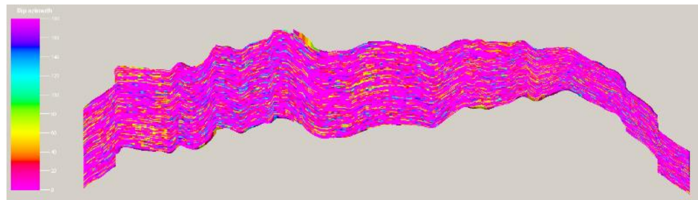
Sv magnitude



SH orientation (degrees)

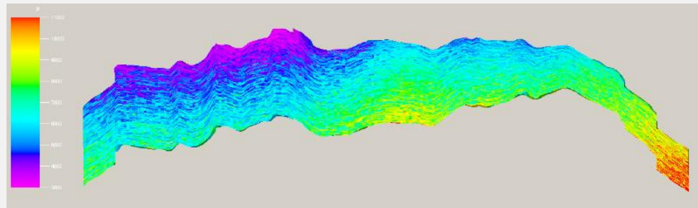


Fracture Azimuth (degrees)

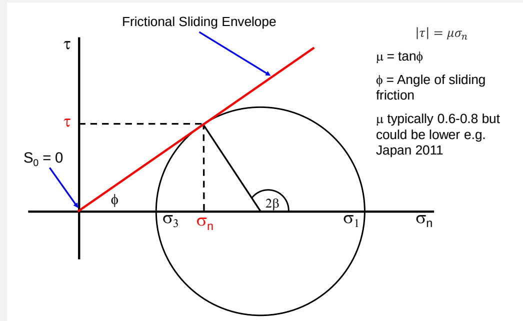


Stress Calculation Outputs

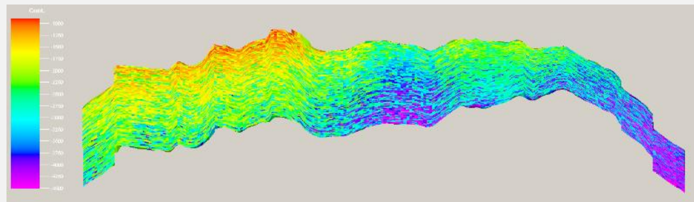
Effective normal stress magnitude



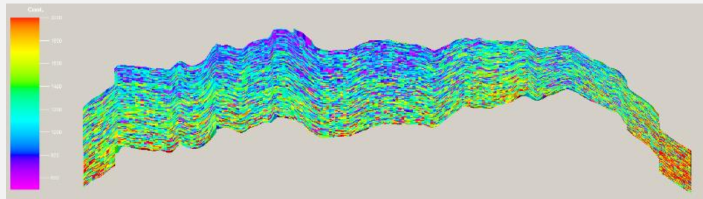
Mohr Diagram



Coulomb Failure Function (CFF) magnitude



Shear Stress magnitude



Courses: Geomechanics, Fractured Reservoir Characterisation, Modelling & Development