14.06: Evaluation of borehole-fluid loss mechanisms in elastic and elasto-plastic rocks

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ABSTRACT

I compare five quantitative models suggested to determine the borehole pressure (P_b) associated with the initiation of borehole-fluid loss through fractures in the formation surrounding the borehole (Table 1). I compare the models for a vertical borehole in a region with a normal stress setting ($\sigma_{h,0} < \sigma_{H,0} < \sigma_{v,0}$) for elastic and elasto-plastic formation rock behaviors. For elastic rock behavior, I use analytical solutions (Table 1), and for elasto-plastic rock behavior, I use finite-element solution of the Modified Cam Clay model in undrained conditions. My comparison shows:

- Fluid loss due to shear fracturing requires a lower borehole pressure than the loss due to tensile fracturing.
- The shear-fracturing borehole pressure changes significantly with the anisotropy of in-situ horizontal principal stresses (Fig. 2): when $\sigma_{h,0} = \sigma_{H,0}$, $P_b \cong \sigma_{v,0}$, and when $\sigma_{h,0} \neq \sigma_{H,0}$, $P_b \cong \sigma_{h,0}$.
- Fluid loss due to reactivating a critically-oriented fracture in shear occurs at a borehole pressure significantly below $\sigma_{h,0}$.
- Shear failure of borehole wall rocks precludes tensile fracturing of the rocks.
- Plastic deformation of borehole wall rocks increases the borehole pressure needed for fluid loss due to shear fracturing.

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Mechanism	Description	Reduced loss borehole pressure ($P'_b = P_b - u_0$) (Elastic formation)
1	Tensile fracturing	$3\sigma'_{h,0} - \sigma'_{H,0}$
2	Reopening a radial fracture that is normal to $\sigma_{h,0}$	$\frac{3\sigma'_{h,0} - \sigma'_{H,0}}{2}$
3	Reactivating a critically-oriented fracture in shear	$\sigma'_{v,0} + \frac{C_0}{\tan(\phi')} - (\sigma'_{v,0} - \sigma'_{h,0})\frac{1+\sin(\phi')}{2\sin(\phi')}$
4	Shear fracturing in $\sigma_v - \sigma_t$ plane	$3\sigma'_{h,0} - \sigma'_{H,0} - (\sigma'_{v,0} - UCS)\frac{1-\sin(\phi')}{1+\sin(\phi')}$
5	Shear fracturing, opening, propagating	$\min(\max(P'_{b,vt}, P'_{n,vt}, \sigma'_{h,0}), \max(P'_{b,rt}, \sigma'_{h,0}))$ $P'_{b,vt} = 3\sigma'_{h,0} - \sigma'_{H,0} - (\sigma'_{v,0} - UCS)\frac{1-\sin(\phi')}{1+\sin(\phi')}$ $P'_{n,vt} = [(1-\sin(\phi'))\sigma'_{v,0} + (1+\sin(\phi'))(3\sigma'_{h,0} - \sigma'_{H,0})]/(3+\sin(\phi'))$ $P'_{b,rt} = [(1+\sin(\phi'))(3\sigma'_{h,0} - \sigma'_{H,0}) + (1-\sin(\phi'))UCS]/2$

Table 1: Borehole-fluid loss models along with their analytical solutions for a formation with elastic rock behavior.

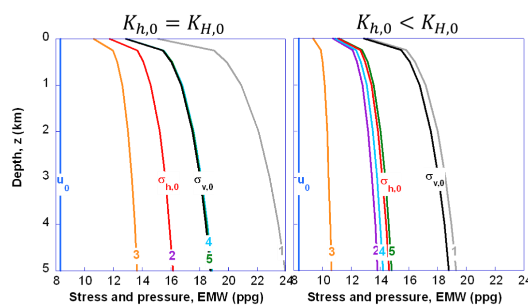

Figure 2: Borehole pressure gradients predicted by models in Table 1 in Equivalent Mud Weight (EMW) for a formation with elastic rock behavior. The left and right plots are respectively for a region with isotropic and anisotropic in-situ horizontal stresses. The plots are based on an assumed overburden stress-depth profile and hydrostatic pore pressure.

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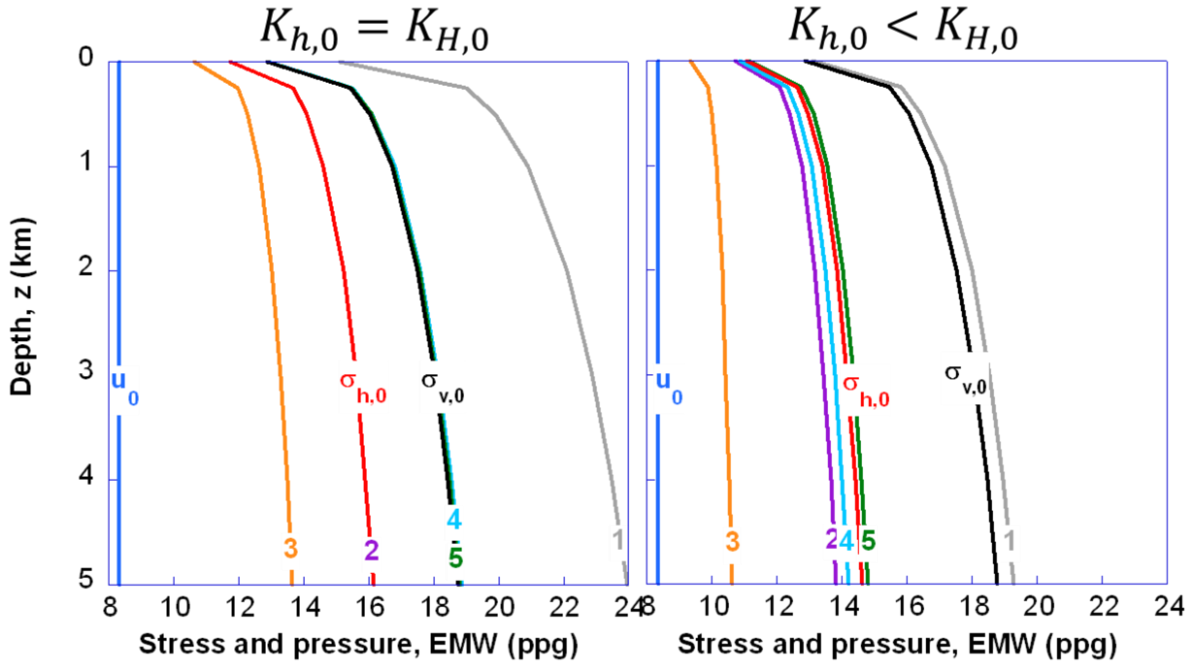

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