Investigation of Hydraulic Fracture Re-Orientation Effects in Tight Gas Reservoirs

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Introduction: In tight gas formations where the low matrix permeability prevents economic production rates, hydraulic fracturing is required to produce a well at economic rates. The initial fracture opens in the direction of minimum stress and propagates into the direction of maximum stress. As production from the well and its initial fracture declines, re-fracturing treatments are required to accelerate recovery. The orientation of the following hydraulic fracture depends on the actual stress-state of the formation in the vicinity of the wellbore. During depletion the stress state alters and a stress reversal region could occur which causes a perpendicular propagation of the re-fracture (Fig.1).

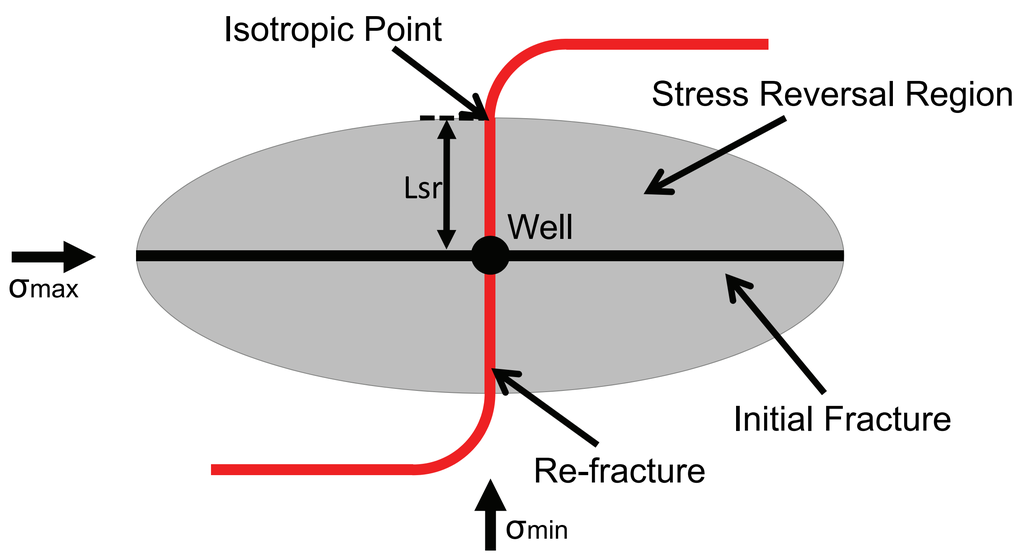

Figure 1. Schematic Showing Perpendicular Fracture Propagation (Redrawn after Siebrits and Elbel, 1998)

Computational Methods: For the investigation of stress reversal during depletion a two dimensional tight gas reservoir model was set up using COMSOL Multiphysics. The model represents a horizontal layer of infinite thickness with a centered vertical well and an initial fracture. The physics interface "Poroelasticity" was used to couple porous media gas flow and geomechanics. The coupling is governed by two constitutive equations derived by Biot:

1. For solid matrix: $\sigma = C\varepsilon - \alpha p I$
2. For pore fluid: $\partial\zeta = \alpha\varepsilon_{vol} + \frac{\partial p}{M}$

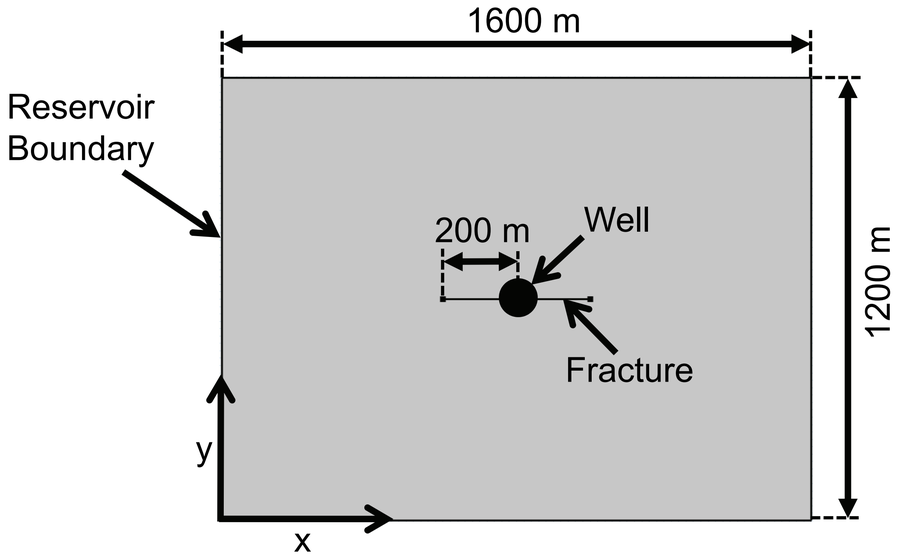

Figure 2. Reservoir geometry

Results:

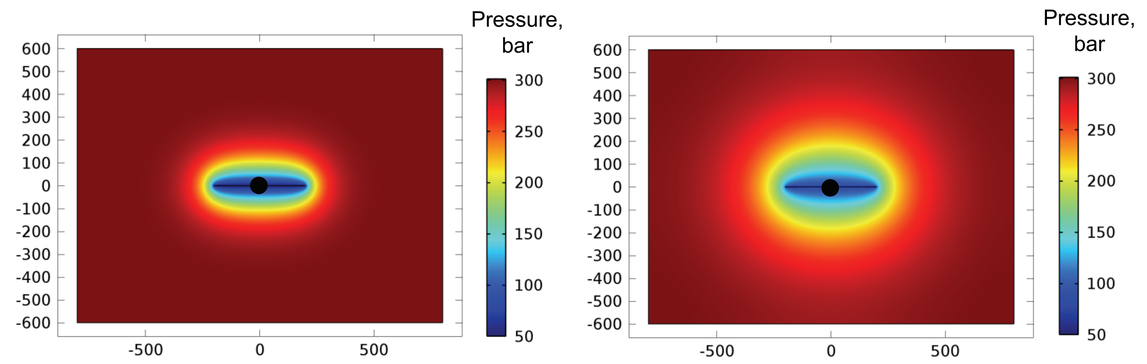

Figure 3. Pressure distribution after one year

Figure 4. Pressure distribution after five years

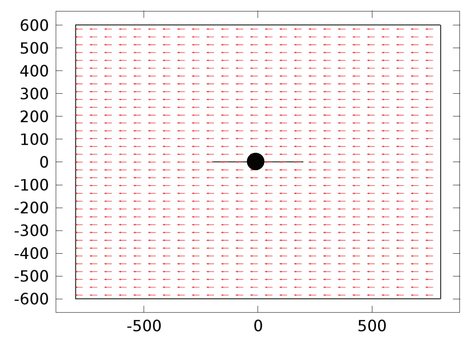

Figure 5. Initial maximum principal stress direction

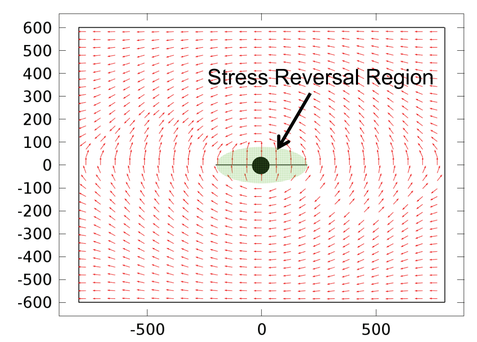

Figure 6. Maximum principle stress direction after five years

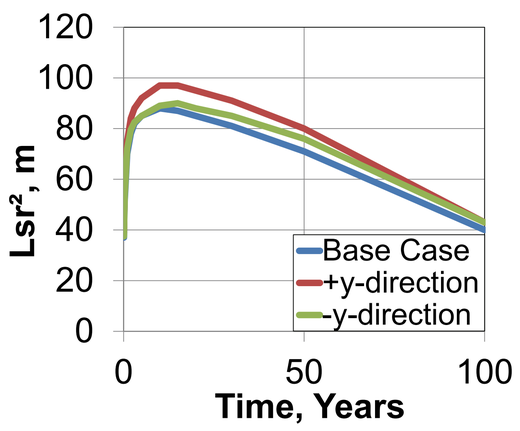

Figure 7. Analysis of heterogeneous permeability

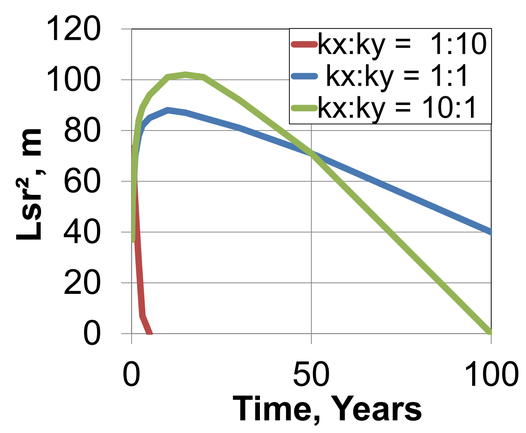

Figure 8. Analysis of anisotropic permeability

2. Lsr is the length from the well to the isotropic stress point in perpendicular direction to the initial fracture (cf. Figure 1).

Conclusions:

- ✓ COMSOL Multiphysics enables the coupled simulation of fluid flow and geomechanics
- ✓ The simulation shows that an elliptically shaped stress reversal region arises, if the difference between minimum and maximum stress is small
- ✓ Based on the simplified model the optimum time for re-fracturing treatment can be predicted
- ✓ The dimension of the stress reversal region initially extends fast and after reaching its maximum it shrinks slowly
- ✓ The actual value of the permeability influences the time but not the maximum dimension of the development of the stress reversal region
- ✓ Permeability heterogeneity has only small influence on the appearance of the stress reversal region
- ✓ Permeability anisotropy has strong influence both, on the maximum dimension and the time development of the stress reversal region

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