Geophysical Research Abstracts, Vol. 9, 10376, 2007
SRef-ID: 1607-7962/gra/EGU2007-A-10376

Numerical models of hydrofracture propagation and field studies of mineral veins and joints in mechanically layered sedimentary rocks

S.L. Philipp, T. Bartelsen, S. Hoffmann, A. Oelrich, A. Gudmundsson
Geoscience Centre, University of Göttingen, Department of Structural Geology and Geodynamics, Goldschmidtstr. 3, 37077 Göttingen, Germany
(Sonja.Philipp@geo.uni-goettingen.de/ Fax +49-551-399700)

Hydrofractures are fractures that are formed as a result of internal fluid overpressure. They include dykes, mineral veins, many joints and man-made hydraulic fractures used to increase reservoir permeability. Theoretical models of hydrofractures in homogeneous and isotropic rocks show that any hydrofracture with a significant fluid overpressure (fluid pressure in excess of the fracture-normal stress) develops such high tensile stresses at its tips that it should continue its propagation upwards and eventually reach the earth surface. Rocks, however, are normally heterogeneous and anisotropic, in particular, most sedimentary rocks and volcanic rocks and many metamorphic rocks are layered. Changes in grain size, mineral content, fracture frequencies, or facies often coincide with changes in mechanical properties, particularly the Young's moduli. In sedimentary rocks, for example, stiff (high Young's modulus) limestone or sandstone layers commonly alternate with soft (low Young's modulus) shale layers.

Here we present numerical models (finite-element and boundary-element methods) of the stress fields affecting hydrofracture propagation in mechanically layered rocks. The results show that stresses commonly concentrate in stiff layers. Also, at the contacts between soft and stiff layers, the stress trajectories (directions of the principal stresses) may rotate. Which layers become stress barriers to fracture propagation depends on the external loading conditions: When a layered rock is subject to horizontal tension, the stiff layers are likely to take up most of the tensile stresses. The stiff layers then may become highly stressed and develop more fractures, whereas soft layers tend to act as stress barriers. By contrast, when such a layered rock is subject to horizontal compression, compressive stresses concentrate in the stiff layers, which may then act as barriers to hydrofracture propagation.

To compare these modelling results with natural hydrofractures we made detailed field studies of mineral veins and joints in mechanically layered sedimentary rocks. Here we present the results from two different lithologies: 1) limestone interlayered with calcareous shale of the Lower Jurassic Blue Lias Formation in the Bristol Channel Basin (South Wales and Southwest England) and 2) sandstone interlayered with shale of the Lower Triassic Buntsandstein in the North German Basin. Measurements of thousands of joints and hundreds of mineral veins show that most hydrofractures become arrested at layer contacts, particularly at contacts between layers with contrasting mechanical properties. The field results also indicate that the mechanical layering affects hydrofractures differently: for some hydrofractures the lithological layering coincides with the mechanical layering (e.g., many joints in the Bristol Channel, and particularly the E-W striking joints in the Buntsandstein, are restricted to individual sedimentary layers), so that the hydrofractures become stratabound. Other hydrofractures, however, propagate through many sedimentary layers (are non-stratabound; this applies to many mineral veins and some joints in the Bristol Channel, and most of the N-S striking joints in the Buntsandstein), meaning that the mechanical layer thickness is much greater than the lithological layer thickness. Non-stratabound hydrofractures may still be affected by the layering; in particular, they often change their attitudes (strike and dip; observed for many joints and veins in the Bristol Channel) and apertures from one layer to the next.

Our numerical models and quantitative field studies show that the mechanical layering in many rocks affects the propagation of natural and man-made hydrofractures. These results have significant implications for fluid transport in reservoirs (for petroleum, natural gas, geothermal and ground water). In reservoirs where most hydrofractures become stratabound, interconnected fracture systems are less likely to develop than in reservoirs with non-stratabound hydrofractures. Reservoirs with stratabound fractures may thus not reach the percolation threshold needed for significant permeability. The mechanical layer thickness may, however, be different for different hydrofractures and may also change with time. To understand these phenomena we need to combine modelling results and quantitative field studies.