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Stress-Induced Permeability Anisotropy under Upper Crustal Conditions

D. R. Faulkner[1] **and O. O. Blake**[2]

[1] *Rock deformation laboratory, Geology and Geophysics, School of Environmental Sciences, University of Liverpool.*
[2] *Petroleum geoscience, Department of Chemical Engineering, University of the West Indies, St. Augustine, Trinidad and Tobago*

Abstract

The distribution of subsurface pore pressures is dictated by the permeability structure of the crust. An understanding of where and how fast the fluid will migrate is important to understand fluid-triggered seismicity, the viability of CO_2 storage projects, injection related to geothermal energy and production and management of hydrocarbon reservoirs. This applies to Trinidad as much as anywhere else, but has yet to be fully explored here. This has limited production here and so hampered income generation. Future research at the University of the West Indies Petroleum Geoscience Programme will address this issue. This paper outlines the intended direction of future research.

Permeability anisotropy can be produced in three ways; through an inherent anisotropy through natural layering, from an oriented fracture network, or by the application of a deviatoric stress field. In this study, permeability was measured in σ_1 and σ_3 direction for Westerly granite that was thermally treated to 250, 450, 650 and 850°C. Increasing the temperature produces an increased fracture density that is isotropically distributed. The samples were subjected to effective stresses from 10 to 50 MPa and differential stresses up to 25% of the failure stress. Increasing fracture density and decreasing effective stress both result in higher permeability. The application of differential stresses significantly reduces permeability in the direction of σ_3, whereas permeability in the σ_1 direction is largely unaffected. Consequently, a permeability anisotropy of over 2 orders of magnitude develops. Higher fracture density and lower effective stress contribute to the highest anisotropy. The results suggest the maximum permeability anisotropy for a sample at a given effective pressure is defined by the difference between the ‘intrinsic’ (crack free) permeability and the initial permeability; a function of crack density and effective pressure.