Rock stress boundaries deduced from rock stress measurements

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Jamison and Cook (1978) analyzed the state of stress in the crust based on a set of some 50 3-D stress measurements from all over the world. They found a linear relationship between the maximum shear stress and the sum of the maximum and minimum principal stresses. This indicates that the Coulomb failure criterion gives a good description of the crustal stresses. Tthe sizes of the shear stresses do not fit the shear strength of the rock but do fit the shear stresses limited by friction on shearing fractures. Extensive drillings have shown that the crustal rock contains large number of fractures (faults and joints of all sizes). All these fractures will slip if their Coulomb failure stress (CFS) exceeds zero. Thus the shear stresses are limited by frictional sliding on the numerous fractures.

Cook (1981) studied the behaviour of frictional sliding of granitic rock by use of stiff laboratory machines. The availability of stiff machines made it possible to study not only the sudden unstable slips (produced by less stiff machines) but also brittle stable slip. Cook studied the slip behaviour at different pressures and temperatures. He found that at shallow depths one expect in general brittle and stable slip (not unstable slip, earthquakes). This prevailed for the top 5 km of granitic crust. Between 5 and 20 km depth one got brittle unstable slip and when temperature and depth increased one got eventually ductile and stable deformations for the granite. This turned out to be in good agreement with the depth distributions of the Baltic shield seismicity, Slunga(1985).

The expected stable slip on shallow fractures means that the tectonic loading will increase the shear stresses until some fractures will slip stably. This stable slip preserve the shear slip close to zero. This explains the Jamison and Cook observation that the measured stresses were as large as the CFS allowed. Note that the stress observations are from the interiors of the small blocks while the CFS limitations just concern the block boundaries and joints within the blocks. These fracture (CFS) limitations thus strongly affects the interiors of the small blocks.

Brown an Hoek (1978) published a very often referenced picture showing observed crustal stresses by plotting the depth against the ratio between the mean horizontal stress and the vertikal stress. This ratio is often denoted k and thus $k = (SH+Sh)/2/Sv$. The main feature of the data set was the clear excess of horizontal stresses at very shallow depths, especially above some 300m. A large number of similar diagrams have been published by many authors and normally they also show hyperbolic curves fitted to embrace the observations, typically $0.5 + 1500/Z > k > 0.3 + 100/Z$ are used.

These curves have no direct physical meaning but are just chosen as they give good fitting boundaries on the k-values of the Brown and Hoek data set. Slunga (1988) showed the result by Jamison and Cook (stresses are as large as the friction allows) directly leads to boundaries on the k-values and that these curves not only has a simple physical meaning, they also show a significant difference from the numerical fitting. This encouraged me to later go on and use the same assumptions to put boundaries on the pore pressure within wet crust which then was the base for the QuakeLook complete stress tensor estimate from observed microearthquakes.