

Patterns in natural fractures during transitions between stress regimes

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The study is aimed at analysis of transitions between different stress regimes –Normal Fault, Strike-Slip and Reverse Fault following Anderson's classification –in terms of natural shear fractures corresponding to each regime. The study is mostly focused on spatial orientations of shear fractures emerging at each stress regime.

It is clear that not all natural fractures existing in a rock mass have the same response to changes in surrounding stresses. Some fractures are considered to be critically stressed in the given stress state which means that a small increase in differential stress (difference between maximum and minimum principal stresses) leads to fracture growth. The fracture is considered as critically stressed if shear stress acting on its plane exceeds normal stress multiplied by internal friction coefficient of the medium. Normal and shear stresses are calculated from principal stresses' values and fracture spatial orientation with regard to stress tensor principal axes. That means that for any given stress tensor one is capable of obtaining all the possible spatial orientations of critically stressed fractures.

In the current paper this problem is solved for different stress states for obtaining the typical patterns of fractures' spatial orientations when stresses are varied considerably enough to change the stress regime. Figure 1 represents a transition between Normal Fault and Strike-Slip regimes: a series of contours on Wolff nets serve as borderlines for poles to critically stressed fractures' planes. Each color represents its own triad of principal stresses (tables provide necessary match between color and stresses' values); maximum horizontal stress σ_H is assumed to act in North-South direction. Minimum horizontal stress σ_h and vertical stress σ_v are fixed at the values of 10 and 50 MPa respectively, while transition is caused by increase in σ_H magnitude from 10 to 160 MPa. During the first stage of transition (fig. 1(A), σ_H is between 10 and 30 MPa) poles to fractures tend to gather in Eastern and Western parts of the stereonet. On the second stage (fig. 1(B), σ_H is between 40 and 90 MPa) fractures' orientation remains stable with slight increase observed in east-northeast, west-northwest, west-southwest, and east-southeast directions. This tendency continues at final stage of transition (fig. 1(C), σ_H is between 100 and 120 MPa) where four main areas typical for Strike-Slip fracture orientation emerge. The same analysis may be completed for other analogous transitions with two fixed principal stresses and one being varied.

Transition between stress regimes may also be observed if principal axes of stress tensor rotate with principal stresses' magnitudes remaining constant. This scenario may take place near Earth's surface or near large faults due to changes in principal stresses' trajectories. Figure 2 represents transition from Normal Fault to Strike-Slip with principal stresses being fixed at 50, 20, and 10 MPa, while angle ϕ –angle between maximum principal stress direction and vertical –is varied between 0 and 90 degrees. Blue lines still serve as borderlines for the orientations of critically stressed fractures in each case; circles represent the directions of principal stresses (red for maximum, yellow for intermediate, and green for minimum principal stress). It should be noted that lower hemisphere Lambert equal area stereonet is used in this case.

Analogous constructions may be completed for any given stress tensor broadening the understanding of natural fractures' patterns and their relation to stress geomechanics providing a possibility to solve the

inverse problem of in-situ stresses estimation and their changes near geological structures utilizing the previously developed methods. As a result, some problems of drilling in vicinity of faults - one of primary objects for scientific drilling - may be solved, reducing the drilling risks and costs.

Keywords: Critically stressed fractures, Stress regimes, Stereonet, Drilling near faults

