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Computation of Regional Stress Tensor from Small Scale Tectonic Data

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A b s t r a c t

Striations measured in a given faulted area are used for the determination of the stress tensor. Two methods for solving this inverse problem are presented. They were tested through an application to synthetic and actual data. The first test proved the ability to distinguish several tectonic phases. The results of the second test are in good agreement with geological interpretation.

1. Introduction

In the recent time great attention is paid to the determination of the stress state of rock environment. One of the possible approaches is based on the processing of angular measurements of striations on fault planes. Let us suppose that a certain tectonic phase is characterized by a single homogeneous stress tensor that fully determines the direction and sense of the movement on the already existing fault planes. Under this assumption, it is possible to determine the deviatoric part of the stress tensor (Etchecopar et al., 1981).

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When the region is subject to the action of one tectonic phase, we speak about a monophased problem, in the case of more phases - about a multiphased problem.

If we denote the unknown stress tensor by T', the unit normal to the fault plane by n, and the unit displacement vector on the fault plane by s, then the stress vector

$$\sigma = T'n \tag{1}$$

acting upon this plane has the normal and tangential component (Fig. 1):

$$\sigma_n = nT'n, \qquad \sigma_s = sT'n \tag{2}$$

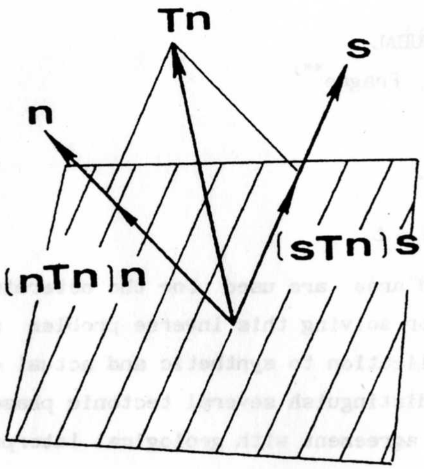

Fig. 1. Fault plane, striations and acting stresses. (n - unit normal to the fault plane, s - unit striae on the fault plane, expressing oriented direction of relative motion of the blocks, Tn - stress vector acting on fault plane with normal component (nTn)n and shear component (sTn)s).

Płaszczyzna uskoku, rysy i naprężenia (n - wektor jednostkowy prostopadły do płaszczyzny uskoku, s - jednostkowa rysa na płaszczyźnie uskoku wskazująca kierunek względnego ruchu bloków, Tn wektor naprężeń, działający na płaszczyznę uskoku, o składowej prostopadłej (nTn)n i poprzecznej (sTn)s).

The following relation holds for the stress vector acting upon this plane

$$T'n = (nT'n)n + (sT'n)s \tag{3a}$$

The agreement of the resulting stress sense with the sense of the movement on the fault is expressed by the condition

$$sT'n \geq 0 \tag{3b}$$

It is adventageous to use three independent angles, d, p, ω, which we obtain from the field measurement (Fig. 2), to the determination of the fault plane normal and of the displacement vector on it. If other angles are measured, it is possible to convert them to the three above-mentioned ones. An example of the conversion is given in the Appendix.

If the T' tensor fulfils condition (3), then all tensors T fulfil it too,

$$T = k_1 T' + k_2 I \tag{4}$$

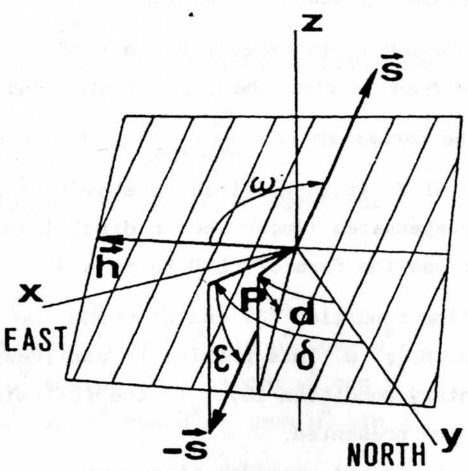

Fig. 2. Fault plane with field measurements. (x,y,z - coordinate system; d - azimuth of dip of fault plane; p - dip of fault plane; ω - pitch of striae i.e. angle between the horizontal direction of fault plane h and striae s; δ - azimuth of dip of striations (see the Appendix); ε - dip of striations (see the Appendix)).

Płaszczyzna uskoku z zaznaczonymi kątami pochodzącymi z pomiarów. (x,y,z - układ współrzędnych, p - nachylenie płaszczyzny uskoku, ω - nachylenie rysy, tj., kąt między kierunkiem poziomym płaszczyzny uskoku, h, i rysą s; δ - azymut nachylenia rys (patrz Appendix); ε - nachylenie rys (patrz Appendix)).

where I is the isotropic tensor $\begin{bmatrix}1&0&0\\0&1&0\\0&0&1\end{bmatrix}$ and k_1, k_2 are arbitrary constants; one may prove this by substituting (4) into (3a,b). It is expedient to select from all tensors that fulfil (3) the only one that fulfils further conditions. It will be further demanded that

$$T_{11} + T_{22} + T_{33} = 0 \tag{5}$$

and

$$T_{11}^2 + T_{22}^2 + T_{33}^2 = 3/2. \tag{6}$$

By introducing these two conditions, the number of independent parameters decreases from 6 (6 independent components of the T' tensor) to 4, which will be denoted α, β, γ, ψ. It is possible to introduce them, e.g., by the following parametrization of the T tensor:

$$T = \begin{bmatrix}\cos\psi & \alpha & \gamma\\ \alpha & \cos(\psi+2/3\pi) & \beta\\ \gamma & \beta & \cos(\psi+4/3\pi)\end{bmatrix}$$