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Structural and strength limitations on in situ rock stress in Earth's crust

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A large database of in situ rock stress tensor measurements has been compiled from national databases and from geoscience literature. This Earth stress tensor database does not satisfy the rigorous requirements of the World Stress Map database in that in many cases the errors associated with the measurements are unknown and multiple measurements have not always confirmed the reported result. Never the less the database includes thousands of tensors measured predominantly using the overcoring technique with various inclusions in and around civil and mining engineering excavations. It includes databases from Australia, Canada, China, England, Finland, France, Germany, Italy, Japan, Korea, Norway, Russia, South America, South Africa, Sweden, the USA and individual measurements from a variety of other countries.

The World Stress Map data is particularly useful for showing the pattern of stress orientations in Earth's crust but is somewhat limited with regard to discussions on the magnitude of measured stresses. The data within this Earth stress tensor database is limited in terms of orientation due to depth of measurement restrictions (0 to a few km's) and to the possibility of local perturbations caused by the measurement location with respect to topography, meta-stable structure and the influence of nearby excavations (some techniques require an excavation at depth to facilitate measurement). However, it does allow graphs to be prepared that show, albeit with scatter, some interesting relationships between scalar characteristics of the measure stress tensors, such as:

- Depth with the vertical stress.

- Depth with the principal normal stresses.
- Depth with the ratio of the vertical to average horizontal stress.
- Depth with the ratio of the subsidiary normal stresses in the horizontal plane.
- Depth with the principal shear stresses.
- Depth with the proportions of spherical and deviatoric stress.
- Proportions of various principal stresses with various stress invariants.
- Maximum shear stress with the associated normal stress.

Trends indicated by the data for the first four relationships have been reported previously in the literature for different methods of measurement and for different countries and continents. This database updates and basically confirms the findings of previous authors.

The last four relationships are singled out for detailed assessment and discussion in an attempt to link scalar characteristics of the stress tensors measured with respect to mechanical characteristics of Earth's crust that may limit the stress magnitudes measured. For example, of particular interest are the proportions of principal normal stress with the first stress invariant and how the major and minor principal normal stresses asymptote to the intermediate principal normal stress as magnitude increases, with the deviations $(\sigma_1 - \sigma_{2)}$, $(\sigma_2 - \sigma_{3)}$ and $(\sigma_1 - \sigma_3)$ (representing twice the principal shear stresses) dictating the rate at which shear stress can be accommodated by the 'rock'. Also of interest are comparisons between principal shear stresses and the strength of intact rock and, shear stress – normal stress conditions resolved onto crustal scale faults and shear zones with Byerlee and Mohr-Coulomb type relations. These and other relations are explored for continental cratons and basins, for different structural geology and geodynamic environments.