Combined stress and deformation analyses of heterogeneous calcite twin data: Theory

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The mechanical twinning in calcite results in simple shearing along twin lamellae, allowing us to evaluate the shear strain of a calcite grain from the widths and orientations of the lamellae (Conel, 1962). Based on this principle, tectonic strains were evaluated in various areas in the world using Groshong’ s (1972) least-square technique. However, it is difficult to separate deformations from such a calcite aggregate that experienced polyphase tectonics.

This problem was solved in this work by combining the methods of stress and strain analyses of calcite twins. First, the orientation data from twin lamellae were inverted to determine non-dimensional deviatoric stress tensors by means of fuzzy clustering of the data; and the number of stresses to be read from a sample was determined through a Bayesian information criterion. The fuzzy clustering yielded the probabilities of each twin lamella to be formed by the detected stresses.

Using the probabilities, we classified the twin lamellae into groups, the members of which were formed in the same tectonic phase (though the time sequence of the phases cannot be determined). The classification allowed us to evaluate the strain and rotation tensors of the calcite sample during each tectonic phase.

Keywords: stress inversion, strain analysis, mechanical twin, fuzzy clustering

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Combined stress and strain analyses of calcite twins: Application to a natural data set and comparison with fault-slip analysis

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Our method of the combined stress and strain analyses was applied to e-twins in a calcite vein sampled in the Amatsu Formation, central Japan. The depositional age of the sampling horizon is about 11 Ma (Kameo et al., 2002).
As a result, we found two stresses, both of which had WNW-ESE trending sigma3-axes. One of them was of the normal faulting regime with the stress ratio of 0.55; the other was of the regime between normal and strike-slip faulting with the stress ratio of 0.82. Their differential stresses normalized by the critical resolved shear stress were 5.3 and 3.7, respectively. Formation of the twin lamellae under the stresses showed the equivalent strains of 4.4 and 3.6%, respectively. The principal axes of the strain tensors were more or less parallel to the principal stress axes. In addition, the paleostress analysis of the mesoscale faults around the site where the calcite was obtained resulted in similar stresses. Therefore, the stress and strain analyses of calcite twins and mesoscale faults showed consistent results.

Keywords: Calcite twin, Stress inversion, Strain analyses

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Exploring variations of earthquake moment on patches with heterogeneous strength

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Finite-fault inversions show that earthquake slip is typically non-uniform over the ruptured region, likely due to heterogeneity of the earthquake source. Observations also show that events from the same fault area can have the same source duration but different magnitude ranging from 0.0 to 2.0 (Lin et al., 2016). Strong heterogeneity in strength over a patch could provide a potential explanation of such behavior, with the event duration controlled by the size of the patch and event magnitude determined by how much of the patch area has been ruptured. To explore this possibility, we numerically simulate earthquake sequences on a rate-and-state fault, with a seismogenic patch governed by steady-state velocity-weakening friction surrounded by a steady-state velocity-strengthening region. The seismogenic patch contains strong variations in strength due to variable normal stress. Our long-term simulations of slip in this model indeed generate sequences of earthquakes of various magnitudes. In some seismic events, dynamic rupture cannot overcome areas with higher normal strength, and smaller events result. When the higher-strength areas are loaded by previous slip and rupture, larger events result, as expected. Our current work is directed towards exploring a range of such models, determining the variability in the seismic moment that they can produce, and determining the observable properties of the resulting events.

Keywords: Earthquake Dynamic, Earthquake Source

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Discrete element simulation of faulting in a subduction zone

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The stress field, fault pattern, and earthquake distribution in an accretionary prism are linked to the topography and geometry of the subducting slab. The influence of underthrust Seamounts, in particular, is now well documented. However, the faulting mechanisms driven by the slab geometry are still incompletely understood. Here, we simulate the effects of slab interface geometry (i.e., smoothness, bending, and subduction angle) on the deformation of the accretionary wedge using the Discrete Element Method (DEM), a technique now proven to be reliable in modelling dense granular flow, rock deformation, fault propagation and folding. We explore how faulting and deformation are related to slab geometry along the Sumatran section of the Sunda megathrust. We validate the credibility of our model by comparing the results with GPS measurements from the Sumatran Tectonic Geodesy Array (SuGAr) on the forearc islands, the Sumatra fault Monitoring network (SuMo) on Sumatra Island and geophysics expedition from the Mentawai Gap - Tsunami Earthquake Risk Assessment project (MEGA-TERA). Spatial patterns of seismic distribution and mechanisms are compared to predictions from our physically-based model. Most of the earthquakes appear to take place near subducting seamounts. Such earthquakes may contribute to seismic hazard along segments of the subducting plate.

Keywords: SUBDUCTION, SIMULATION

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Horizontal stress profiles reconstruction based on elastic properties and natural fractures' characteristics. NanTroSEIZE case study.

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A great amount of data acquired for IODP expedition sites in the Nankai Trough area made it possible to use a previously proposed approach of utilizing wellbore imager data to estimate the horizontal stresses distribution along wells' trajectories. Horizontal stress profiles were reconstructed for site C0002 with a decent accuracy (being in consistence with studies of other researchers) and the same profiles were estimated for several other sites in the area.
A reconstruction of stress profiles for site C0002 was based on data provided by the leak-off tests (LOTs) performed during expedition 338. The inverse problem of stress reconstruction was solved by introducing a relationship between stress field and fractures observed at the azimuthal focused resistivity images provided for the well. Although the initial formulation of the applied approach had requested a study on both resistivity and ultrasonic imagers, it has been found out that some estimations may be carried out on a single image data with extra investigations of gamma-ray, resistivity and velocity logs with the use of composition of the medium (mineralogy and organic matter). A corresponding research was carried out for this site to estimate the horizontal stresses profiles which proved to be consistent with the LOT results and breakout model.
In spite of absence of data on minimum horizontal stress magnitude from LOT performed for other sites in the area there still remains data on the fracture orientations from wellbore imagers –crucial input data for the applied approach. This approach was modified to provide some estimations on the stress profiles without direct measurements of minimum horizontal stress. The resultant stress profiles have a wider range of possible magnitudes compared to C0002 site although they still contain valuable information regarding the in-situ stress state in the area.
The modifications of the approach applied in the case, results of the stress profiles reconstruction and their comparison with other researchers' results are presented in the paper.

Keywords: Geomechanics, In-Situ Stress, NanTroSEIZE, Logging While Drilling

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