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Stress inversion of heterogeneous fault-slip data with unknown slip sense – an OFA clustering technique tested on artificial and real data

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Mesozoic to early Cenozoic brittle fault zones are exposed in crystalline basement rocks in the Lofoten and Vesterålen area, North Norway. These fault zones contain abundant striated fracture planes, and may convey important information about the kinematic and dynamic evolution of adjacent fault-bounded rift basins offshore. However, determining slip sense is difficult as offset markers are rare and one has to rely on fault plane morphology. The fault-slip data does, in addition, show clear evidence of being heterogeneous.

The linear part of Fry's σ-space inversion method do not depend on slip sense and may, in conjunction with the Objective Function Algorithm (OFA), be used to separate heterogeneous fault-slip data and calculate respective stress tensors. However, tests on artificial data show that the inversions corresponding with the lowest obtained value of the objective function give erroneous results when errors are introduced in the dataset. The method also fails in determining the number of superimposed tensors.

We show that by contouring principal stress orientations from the OFA after e.g. 1000 runs, using all solutions with an objective function value below mean and different initial subdivisions, we get more reliable orientations for the principal stresses active during faulting. The method can also be used to evaluate the number of superimposed tensors in the heterogeneous dataset as an overestimation of tensors does not generate significant artificial clusters of principal stress orientations. We refer to this technique as OFA clustering.

Initial results using OFA clustering on field data from the Lofoten and Vesterålen area give principal stress orientations in agreement with plate reconstructions and the orientations of the main boundary faults offshore. Since no pre-classification of the fault-slip data is needed, all data points are used with no filtering, and slip sense is not required, the OFA clustering technique is a robust method for evaluating the number of superimposed stress states in a heterogeneous fault-slip dataset and their principal stress orientations.