Fault Response Modelling – Application of Elastic Dislocation theory in earthquake research and industry

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When a fault slips, subsequent displacement, strain and stress can be analytically calculated using Elastic Dislocation theory (Comninou & Dundurs 1975). A methodology to model displacement fields and the distribution of strain in a poroelastic medium for any slip introduced on a discrete fault using Midland Valley’s Fault Response Modelling tool in the Move™ software is presented here.

With the ability to calculate Coulomb stress changes in the ambient rock body, Fault Response Modelling also offers possible solutions for the likelihood of receiver faults to slip and to produce potential earthquake aftershocks. By including lateral variation of mechanical properties, such as elastic moduli, strength and friction, the calculation can also take into account the influence of lithological variations to influence the modelled field of displacement, strain and stress.

Case studies are used here to demonstrate the application of Fault Response Modelling in research and industry. A dataset from the 2008 Nura earthquake in Kyrgyzstan (Teshebaeva et al., 2014), successfully illustrates how the displacement and stress changes associated with observed aftershocks around the source fault are reproducible in Move by calculating Coulomb stress (Figure 1a, b). In addition to this, a case study from the La Concepción oilfield in the north-western Maracaibo Basin in Venezuela demonstrates how Fault Response Modelling has been used to predict fracture orientations in a fractured reservoir (Porras et al., Petrobras Energía, S. A. 2007, Figure 1c). A final example demonstrates the prediction of gold deposits inside the present fault and fracture framework in the Carlin fault system in north-western Nevada, USA. Gold deposits were predicted where Fault Response Modelling generated proxies for fracture intensities and identified volumes with the maximum Coulomb stress change (Micklethwaite, 2011, Figure 1d).

References:

Micklethwaite, S. 2011. Fault-induced damage controlling the formation of Carlin-type ore deposits.

Figure 1:

a) Compared to “observed” satellite data, Fault Response Modelling calculated similar “modelled” values for the apparent displacement.
b) Modelled isosurface (grey mesh) representing area around faults with Coulomb stress changes of >0.17 MPa on optimally orientated planes following the modelled earthquake. Distribution of the observed aftershocks (black points) was reasonably reproduced by modelling.
c) La Concepción fault system with slip gradient displayed on the faults (upper image) and different fracture sets predicted by Fault Response Modelling (lower image).
d) Point volume demonstrating the highest Coulomb stress change around faults as a proxy for fracture intensities in the Carlin fault system.