Pitfalls Among the Promises of Mechanics-Based Structural Restoration

Lovely, Peter J.[1]; Pollard, David D.[1]; Flodin, Eric [2]; Guzofski, Chris [3]; Maerten, Frantz [4] (1) Geological and Environmental Sciences, Stanford University, Stanford, CA. (2) Chevron ETC, San Ramon, CA. (3) Chevron ETC, Houston, TX. (4) IGEOSS, Montpellier, France.

Mechanics-based (linear elastic) structural restoration offers distinct benefits over established kinematic methods. Among these benefits are (1) conservation of mass and momentum, (2) implementation of a constitutive law relating stress and strain, (3) accommodation of material heterogeneity in the form of elastic moduli, (4) non-uniform fault slip, (5) mechanical interaction of fault segments, and (6) improved ability to model complex, 3D deformation. Although linear elasticity is fully reversible, published mechanics-based restoration methods usually simulate a fundamentally different mechanical system from forward tectonic deformation. Restoration boundary conditions typically violate the earth's traction free surface, and lateral boundaries within the model earth, which are subjected to tectonic loading, are treated as traction free. While it has been acknowledged that such models cannot simulate stress distributions related to deformation, restoration strain has been treated as geologically meaningful, despite the linear elastic relation between stress and strain.

Synthetic examples consisting of a faulted elastic block demonstrate that forward strain and restoration strain are not equal in magnitude and opposite in sign, as supposed by restoration theory. Analysis of geologic field data from the Volcanic Tableland extensional fault system, Bishop, CA, demonstrates that strain inferred from a forward linear elastic model, representing slip on seismic scale faults, differs dramatically from strain inferred from restorations, in which seismic scale faults are treated as discrete contact surfaces. Restoration models that include boundary conditions that approximately reverse tectonic strain offer substantial improvement over models in which all subterranean boundaries are treated as traction free, but limitations of restoration methods persist. These boundary conditions, which reverse tectonic deformation, are inferred from paleostress analysis.

A further limitation of mechanics-based restoration methods is the assumption of linear elasticity. Geologic deformation may be governed by non-linear constitutive laws; however, the reversibility of linear elastic deformation lends itself to retrodeformational modeling. Further synthetic examples investigate the implications of assuming linear elasticity, and the implications of retrodeformational models which incorporate non-linear constitutive laws (e.g. plasticity) and non-zero fault friction.