Geophysical Research Abstracts
Vol. 18, EGU2016-10470, 2016
EGU General Assembly 2016

Modelling "reality" in tectonics: Simulation of the mechanical evolution of the Jura Mountains-Molasse Basin system, and routes to forward-inverse modelling of fold thrust belts.

David Hindle and Jonas Kley
University of Göttingen, GZG, Structural Geology and Geodynamics, Göttingen, Germany (dhindle@gwdg.de)

The ultimate validation of any numerical model of any geological process comes when it can accurately forward model a case study from the geological record. However, as the example of the Jura-Molasse fold thrust belt demonstrates, geological information on even the most basic aspects of the present day state of such systems is highly incomplete and usually known only with large uncertainties. Fold thrust-belts are studied and understood by geologists in an iterative process of constructing their subsurface geometries and structures (folds, faults, bedding etc) based on limited subsurface information from boreholes, tunnels or seismic data where available, and surface information on outcrops of different layers and their dips. This data is usually processed through geometric models which involve conservation of line length of different beds over the length of an entire cross section. Constructing such sections is the art of cross section balancing.

A balanced cross section can be easily restored to its pre-deformation state, assuming (usually) originally horizontal bedding to remove the effects of folding and faulting. Such a pre-deformation state can then form an initial condition for a forward mechanical model of the section. A mechanical model introduces new parameters into the system such as rock elasticity, cohesion, and frictional properties. However, a forward mechanical model can also potentially show the continuous evolution of a fold thrust belt, including dynamic quantities like stress. Moreover, a forward mechanical model, if correct in most aspects, should match in its final state, the present day geological cross section it is simulating.

However, when attempting to achieve a match between geometric and mechanical models, it becomes clear that many more aspects of the geodynamic history of a fold thrust belt have to be taken into account. Erosion of the uppermost layers of an evolving thrust belt is the most obvious one of these. This can potentially be dealt with by conditioning the top surface of the model to "trend" towards the present day topographic profile along the cross section, in a crude proxy for erosion. In the case of the Jura-Molasse fold thrust belt, the basal boundary condition also very likely plays a significant role in the thrust-belts evolution. A large, extra component of regional basement uplift appears to have occurred across the Swiss Molasse and Jura, according to geological indicators like the present day position and altitude of Miocene marine sedimentary units. In general, the Jura-Molasse example is thus highly instructive in the difficulties of incorporating all necessary geological realities into a numerical forward model of a specific geological situation.

Despite all this, we find that using a numerical forward model of minimal complexity (three rheological layers as opposed to at least eight suggested by the rheological stratigraphy of the chain) with no pre-existing weaknesses to predetermine locations of faults, we easily achieve a good facsimile of at least the distribution of shortening across the Jura-Molasse system. Localisation of shortening occurs on approximately similar numbers of major faults as in reality, and their positions in the section are also broadly similar to those known from field data. Dynamic parameters like stress evolution, recovered from the model, are also in broad agreement with paleostress level indicators from the Jura-Molasse. In our first experiments, we have used a grid of variations of basic mechanical parameters (friction of basal layer and strength of main, limestone unit) to map the model responses over a range of parameter space and search for the best fitting response. The potential to automate such searches and continuously optimise the fit to real data is clearly also there, given sufficient computer capacity. Hence, we can envisage a time when cross section balancing will be combined with and improved by a subsequent stage of forward mechanical modelling.