Geophysical Research Abstracts
Vol. 19, EGU2017-15666, 2017
EGU General Assembly 2017

Quantitative analysis of surface deformation and ductile flow in complex analogue geodynamic models based on PIV method.

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Recently, a PIV (particle image velocimetry) analysis method is optical method abundantly used in many technical branches where material flow visualization and quantification is important. Typical examples are studies of liquid flow through complex channel system, gas spreading or combustion problematics.

In our current research we used this method for investigation of two types of complex analogue geodynamic and tectonic experiments. First class of experiments is aimed to model large-scale oroclinal buckling as an analogue of late Paleozoic to early Mesozoic evolution of Central Asian Orogenic Belt (CAOB) resulting from nortward drift of the North-China craton towards the Siberian craton. Here we studied relationship between lower crustal and lithospheric mantle flows and upper crustal deformation respectively. A second class of experiments is focused to more general study of a lower crustal flow in indentation systems that represent a major component of some large hot orogens (e.g. Bohemian massif). The most of simulations in both cases shows a strong dependency of a brittle structures shape, that are situated in upper crust, on folding style of a middle and lower ductile layers which is influenced by rheological, geometrical and thermal conditions of different parts across shortened domain. The purpose of PIV application is to quantify material redistribution in critical domains of the model. The derivation of flow direction and calculation of strain-rate and total displacement field in analogue experiments is generally difficult and time-expensive or often performed only on a base of visual evaluations.

PIV method operates with set of images, where small tracer particles are seeded within modeled domain and are assumed to faithfully follow the material flow. On base of pixel coordinates estimation the material displacement field, velocity field, strain-rate, vorticity, tortuosity etc. are calculated.

In our experiments we used velocity field divergence to quantify the redistribution and flow of anatectic lower crust and to evaluate upper crust thickenning and topography evolution. As this method is very sensitive to resolution and color contrast of obtained images and used materials are mostly uniform within individual rheological layers and domains, we utilized various markers as flakes of a fluorescent wax or glitter to increase overall sensitivity.

Applying this method to oroclinal buckling experiments we derived velocity field divergence associated with upper crustal deformation and evolution of topography. Scaled, dimensionless negative values of divergence reach minimum ($\sim$ -1) in two elongated domains propagating from inflection area of modeled orocline. These values correlate with significant upper crust material removing and-or with redistribution of crustal material associated with formed pop-up and pop-down structures. Maximum positive values ($\sim$ 0.1) correspond with material spreading alongside forming platforms that are situated in foreland of maximum elevations.

Application of PIV method on lateral view, where ductile middle and lower crust is vertically folded during lithosphere shortening and indentation, revealed possibility to track melt migration from base of lower crust through interlimb area towards hinge zone of individual folds. Simultaneously with folds locking and material accumulation, whole structures are exhumed at the middle crust level. Melt flow and heat exchange with surrounding environment is responsible for increased plasticity of the middle crust marked by higher strain-rates observed inside fold envelope. It is also responsible for significant elevation above hinges during later stages of model evolution. Heterogeneous nature of deformation is well documented by heterogeneities in derived divergence field within folds interiors.

Our results show distinct advantages of PIV method for post-processing of geodynamic and tectonic analogue

models and demonstrate great potential of this method for quantitative processing of wide spectrum of analogue approaches to different natural systems.