Geophysical Research Abstracts,
Vol. 11, EGU2009-231, 2009
EGU General Assembly 2009

Generation of buckle folds in Naga fold thrust belt, north-east India

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Naga fold thrust belt (NFTB), India, formed as a result of northward migration of the Indian plate initiated in Eocene and its subsequent collision with the Burmese plate during Oligocene. The NW-SE oriented compression generated a spectrum of structures; among them, we intend to focus on the folds- varying from gentle to tight asymmetric in geometry. Large recumbent folds are often associated with thrusting. Buckle folds forming under shallow crustal conditions are frequently reported from NFTB.

Buckle folding occurs mainly within sandstones with intercalated shale layers which are in the study area typical for the Barail, Surma and Tipam Groups. We have tried to explain the controlling factors behind the variation of the buckle fold shapes and their varying wavelengths throughout the fold thrust belt with the aid of analogue (sand box) modelling.

It is undoubted that competence contrast along with the layer parallel compressive stress are the major influencing factors in generation of buckle folds. Schmalholz and Podladchikov (1999) and Jeng et al. (2002) have shown that when low strain rate and low temperature are applicable, not only the viscosity contrast, but also the elasticity contrast govern the geometry of the developing buckle folds. Rocks deforming under high temperature and high pressure deform in pure viscous manner, whereas, rocks undergoing less confining stress and less temperature, are subjected to pure elastic deformation. However, they are the end members, and most of the deformations are a combination of these two end members, i.e. of viscoelastic nature.

Our models are made up of sieved sand (0.5 mm grain size) and mica layers (1-5 mm) This interlayering imparts a mechanical anisotropy in the model. Mica is not a pure viscous material, rather it displays more elastic behaviour. The mica layers in the model produce bedding parallel slip during shortening through internal reorganization of the individual mica crystals leading to the thickening of the layer. The experiments are performed in a low stress and low temperature environment (ambient temperature being room temperature). The models produce a spectrum of fold shapes ranging from tight asymmetric to gentle. The folds generate initially as gentle folds with rounded hinges in the thick incompetent mica layers and box folds in the thin incompetent mica layers. Thrusts develop and grow by intersecting the existing fold limbs. With incremental compression, the folds become tighter. The thin mica layer is more affected by thrusting than the thicker layer.

Our models have a clear advantage of using mixed layer models (sand + mica) over that of pure sand models, because mica accommodates the applied stress both by folding and thrusting. The pure sand models fail to reflect the subtle competence contrast and thus the buckle folds though they excellently simulate the upper crustal layer deformation through thrusting.

From our experiments we infer that the difference in fold and thrust morphology is governed by the interplay of two main factors; namely: degree of competence contrast and thickness of competent unit. High mechanical anisotropy give rise to box folds with steep straight limbs, horizontal hinge and conjugate axial planes when the competent unit is a thick one; whereas comparatively low mechanical anisotropy generates rounded buckle fold when the competent unit is a thin one.

The geometry of the buckle folds in the NFTB are in good agreement with our experimentally produced buckle folds. The competence contrast throughout the belt has been consistent, only minor variations of sand-shale content have been observed. The competence contrast remaining more or less constant throughout the region, the variable thickness of the stratigraphic units plays a significant role in determining the fold shape. The thicker incompetent units give rise to rounded tight folds and the thinner ones to open box shaped folds, both modified by simultaneously or later generated thrusts. This coexistence of folds as well as thrusts developing simultaneously has been well demonstrated with our models. Therefore, our modelling results give insight into the folding process and the occurrence of differing buckle fold geometry across the NFTB.

Reference:

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