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# Effect of decollement rheology and deformation rate on the structural development of fold thrust belts in sand box models and their implications for the Naga fold thrust belt (NE India)

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Previous studies on decollement kinematics have shed light on the differing structures of fold thrust belt forming above lithologically different decollements, such as shales, carbonates and evaporites. Factors, affecting the decollement kinematics most are (1) rock rheology and (2) deformation rate.

This study is intended to explain the deformation style of the Naga fold thrust belt (NFTB, NE India) with the aid of sand box modelling performed at a basal temperature of 50°C and deformed at varying strain rates from $3*10^{-6}$ $s^{-1}$ to $4*10^{-3}$ $s^{-1}$. The models are made up (from bottom to top) of a 0.25 cm thick layer of temperature-sensitive PDMS (polydimethylsiloxane), overlain by 1.75 cm of alternating black and yellow sand. The basal PDMS layer simulates a shale decollement. Decollements in the NFTB are generally developed in the Barail Shale of Oligocene age at 50°C (the depth of the Barail Shale is about 2 km and the prevailing geothermal gradient is 25°C/km). The sand layers simulate the brittlely behaving sandstones which prevail in the NFTB. All of the models were subjected to 35% compression, as the NFTB experienced similar shortening. The varying deformation velocities were chosen to model differing decollement rheologies.

PDMS simulates shale decollement, which is mobile when overpressured and undergoes compression. The rheology of PDMS changes considerably with the applied temperature and strain rate. PDMS, although generally regarded as Newtonian, does behave non-Newtonian at strain rates of $10^{-3}$ $s^{-1}$. The relation between decollement pore fluid overpressure with that of model strain rate, the material rheology, scaled body forces, density of the decollement in nature can be expressed as:

$$\lambda \quad = \quad 1- [\ V\ \eta_{model}\ /\ f\ H_{model} \quad \rho_{nature} g\ H_{nature} \quad \sigma^{*}]$$

where

$\lambda$ = coeifficient of pore fluid overpressure in the decollement,

V = the deformation velocity with which the models are deforming,

$\eta_{model}$= viscosity of the decollement material,

f = the co efficient of overpressure, and is estimated 0.85 for frictional decollement,

$H_{model}$ = thickness of the decollement in the models,

$\rho_{nature}$ = density of the shale decollement in its natural analogue,

g = the acceleration of gravity,

$H_{nature}$ = thickness of the decollement in nature,

$\sigma^{*}$ = the scaled body forces.

Hence, it can be suggested that, the value of pore fluid overpressure is dependent on the variables like velocity of the deformation, viscosity and thickness of the model decollement, nature to model ratio of body forces, density and thickness of the natural analogues. The values for natural analogue and model decollement thickness are constant, only the viscosity (dependent on temperature and applied strain rate) varies with different models, in turn altering the co efficient of overpressure values.

Rapid shortening rates (model group 1, deforming at a strain rate varying from $4*10^{-5}$ $s^{-1}$ to $4*10^{-3}$ $s^{-1}$) generate more complicated structures than that of those shortening at lower rates (model group 2, deforming at a strain rate varying from $3*10^{-6}$ $s^{-1}$ to $1.6*10^{-5}$ $s^{-1}$). Thrust related folds predominate in model group 1, whereas, thrusts and backthursts dominate in model group 2.

Group 1 models display closely spaced horse blocks. Shortening in the horse blocks is accommodated mainly by box folding and they generate fewer backthrusts than group 2 models. Group 2 models develop large spacing between the horse blocks and show structural highs bordered by both forethrusts and backthrusts. The horses are persistent along strike direction. Group 1 models are higher and possess higher structural taper than the group 2 models. In both the models, it is observed that, once a new structure forms, deformation cease to act in the old structure and it is structurally abandoned.

Results of these physical models therefore demonstrate very well that the deformation rate and the decollement rheology are the key factors in controlling the structural style of a fold thrust belt. Comparing the modelling results with the published seismic section of the NFTB, it becomes very clear that structures observed in the models of group 2, i.e. those models deformed at slow strain rates, are very close to the deformation structures observed in the NFTB. The seismic section shows a basal decollement forming a low angle thrust that reaches up to the surface. Thrust horses are separated by broad synclines. Furthermore, the data reveal the buried nature of the thrust front with a triangle zone geometry. This observation is in agreement with the results of the group 2 models, which show development of dominantly forward imbricate thrust sequence. Obviously, the deformation evolution and structural features of the NFTB is governed by its weak substrata deforming under slow strain rate resulting in the generation of imbricate thrust zone.