Superposed Folds in the Himalaya Indicating Late Stages of the Himalayan Orogeny: Implications for Seismicity

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The present stage of the Himalayan orogeny is characterized by simultaneous development of contrasting structural features that include early folds, superposed folds, thrust, normal, and strike-slip faults. The early folds have initiated simultaneously with the prominent Himalayan thrusts. The fold geometries are characterized by asymmetric folds in the vicinity of the thrusts, and symmetric folds at a distance from the thrusts. Development of superposed folds at late stages of deformation is shown in Figure 1. A positive listric fault (gradual decrease in dip amounts towards the basal décollement) in the basement is shown in Figure 1a. The fault terminates at the front face into a transfer fault (TF), and into an oblique ramp (OR) at the back face. The gray shade denotes an overlying layer prior to deformation. Thrusting along the basement fault during early deformation results in development of an asymmetric fault-propagation fold above the thrust and upright buckle folds at a distance from the thrust (Figure 1b). The fold hinge lines are parallel to strike of the fault. The deformation has also resulted in steepening of the thrust as a result of rotation of the fault surface with progressive deformation. The thrust locks at a steep dip and the folds also acquire rotation hardening at low inter-limb angles (Figure 1c). The locked fault tends to extend parallel to its strike resulting in formation of a conjugate set of strike-slip faults. The fold hinge lines also extended parallel to the hinge line. However the horizontal extension was restricted by the boundary condition imposed by the transfer fault and the oblique ramp. Hence the restriction has resulted in curvature of the fold hinge lines and formation of superposed folds. At lower structural levels where the thrust dip is gentle (because of listric geometry), the thrust may not lock simultaneously with the upper horizons. Hence the superposed deformation may remain absent at deeper levels as shown in Figure 1d. In the Himalaya these superposed fold hinge lines trend N-S to NE-SW, i.e. nearly orthogonal to the early fold hinge lines and parallel to the axis of maximum compression imposed by the movement of the Indian plate.

Apart from the development of superposed folds, the superposed deformation is also responsible for formation of the following structures.

1. Reactivation of thrust faults as normal faults along the oblique fault ramps.
2. Initiation of normal faults at higher topographic levels.

The study is important to understand the seismicity of the Himalayan orogenic belt.

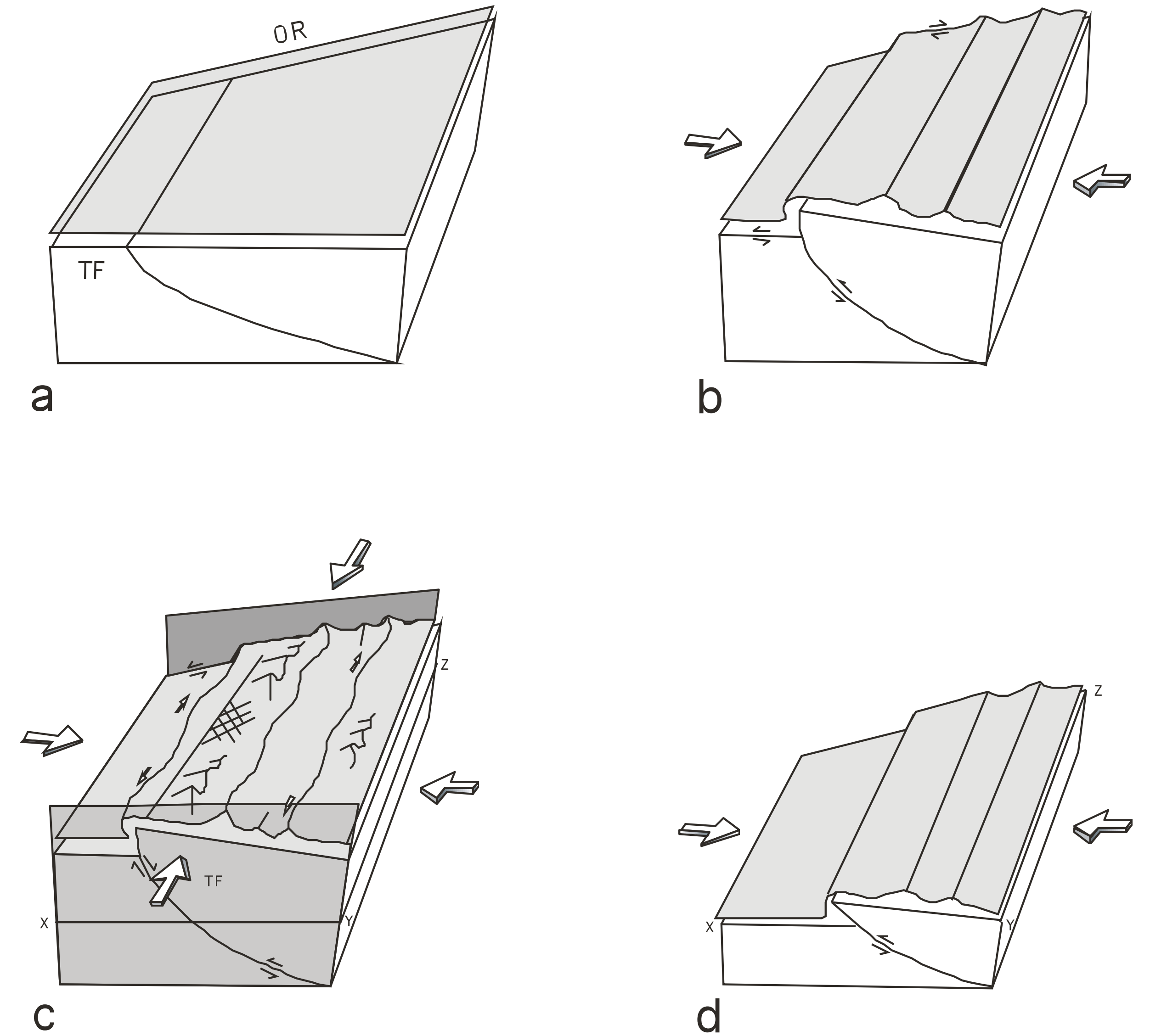

Figure 1. Simultaneous development of strike-slip and thrust faults at different structural levels.
a. A positive listric fault in the basement and an overlying undeformed layer shown in gray. OR, oblique ramp; TF, transfer fault.
b. Thrusting in the basement fault and folding of the cover layer. The oblique ramp and the transfer fault show a component of horizontal displacement as well.
c. Locking of the folds and thrust at late stages of deformation, extension of the fold surface parallel to hinge lines and extension of the hanging wall parallel to strike of the thrust. Obstruction of the extensions as a result of restriction provided by boundary conditions provided by the oblique ramp and the transfer fault thereby resulting in formation of conjugate set of strike-slip faults, curvature of the early fold hinge lines, and initiation of superposed folds. The curvature of the fold hinge lines along with the superposed folds gave the impression that the maximum compression direction is parallel to the early fold hinge lines.

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