A mid-crustal strain-transfer model for Tibetan plateau formation: A new perspective from high-resolution deep seismic-reflection profiling across NE Tibet

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Abstract. High-resolution seismic reflection profiling shows that the actively deforming middle Tibetan crust is dominated by discrete sub-horizontal shear zones that terminate major sub-vertical strike-slip structures such as the Kunlun fault. Middle-crustal shear zones appear to transfer locally concentrated shortening in the upper crust above and the mantle lithosphere below. This finding indicates that the weak Tibetan middle crust may not be active everywhere and in the same mode all at once. Rather, the mode of continental deformaiton may vary from place to place, depending strongly on lateral and vertical varying mechanical strength of the crust and mantle lithosphere.

1. Introduction

Current debate on continental deformation centers on whether the crust and mantle are coupled and how the weak middle crust deforms during continent-continent collision. The end-member models are shown below.

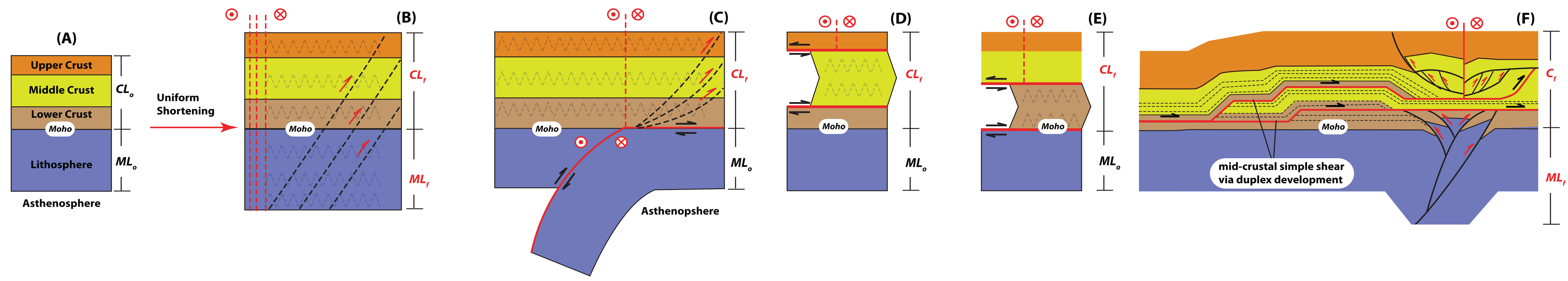
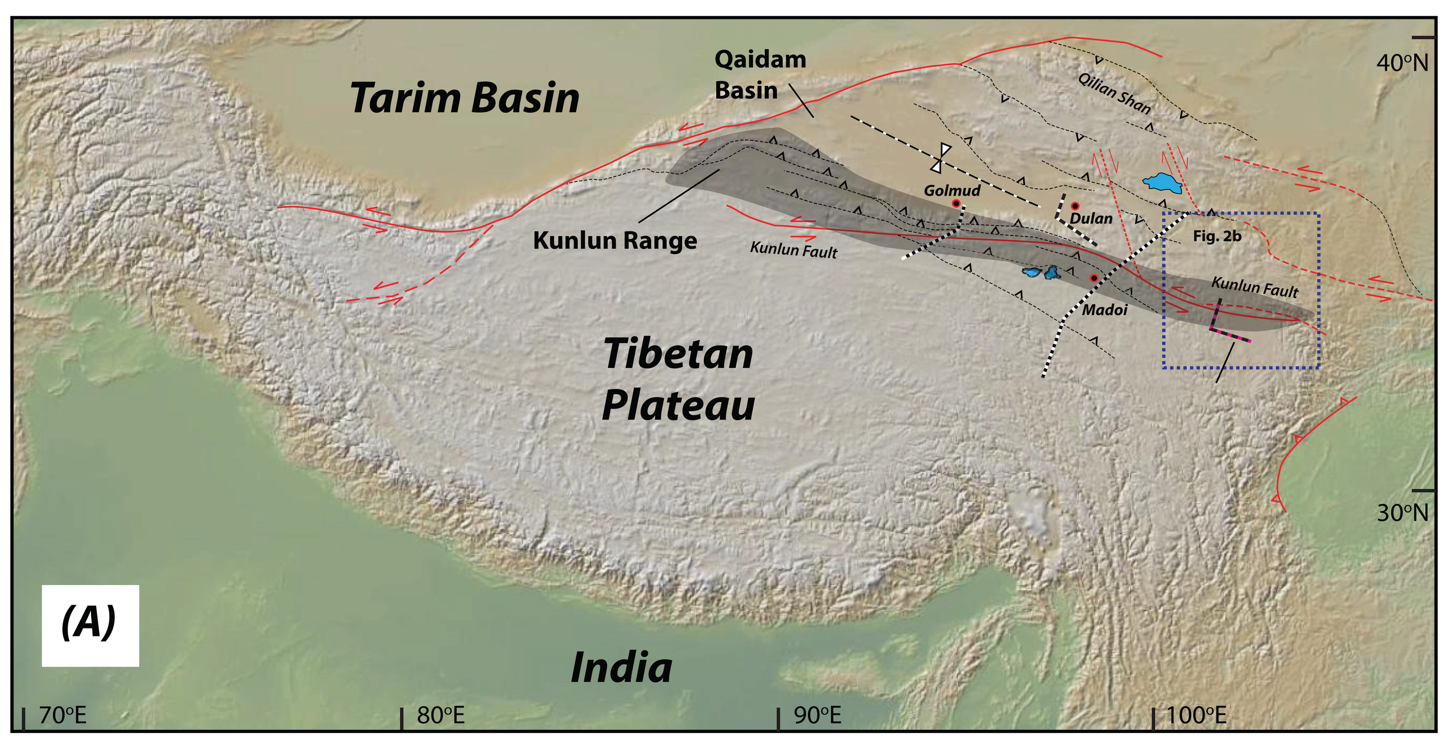


Figure 1. Schematic diagrams illustrating competing models for continental deformation. Thick horizontal red lines indicate locations of predicted decoupling zones and arrows show their sense of shear. (A) Continental lithosphere before deformation. (B) The thin-viscous-sheet model predicts vertically uniform strain and the absence of decoupling zone. Faults should be lithospheric and closely-spaced. (C) The oblique continental-subduction model predicts decoupling of the deformed crust from mantle lithosphere. Strike-slip faults root into the subduction zone, allowing continental lithosphere to move laterally. (D) and (E) The channel-flow model predicts lateral extrusion of the ductile middle and/or lower crust. The channel thickness may expand or contract vertically during ductile flow in the channel. The model requires two sub-horizontal decoupling zones with opposite senses of shear and faults in the crust do not penetrate into the mantle. (F) Simplified cross section based on this study. Two detachment zones are revealed, both having the same transport direction. Also, the mantle lithosphere and lowermost crust experienced significant shortening.

2. Regional Tectonics

The high-resolution seismic reflection profile is located in NE Tibet across the active left-slip Kunlun fault. The NE margin of Tibet is marked by gradual chance in topographic slope and has been considered as a primary candidate for middle-crustal channel flow.



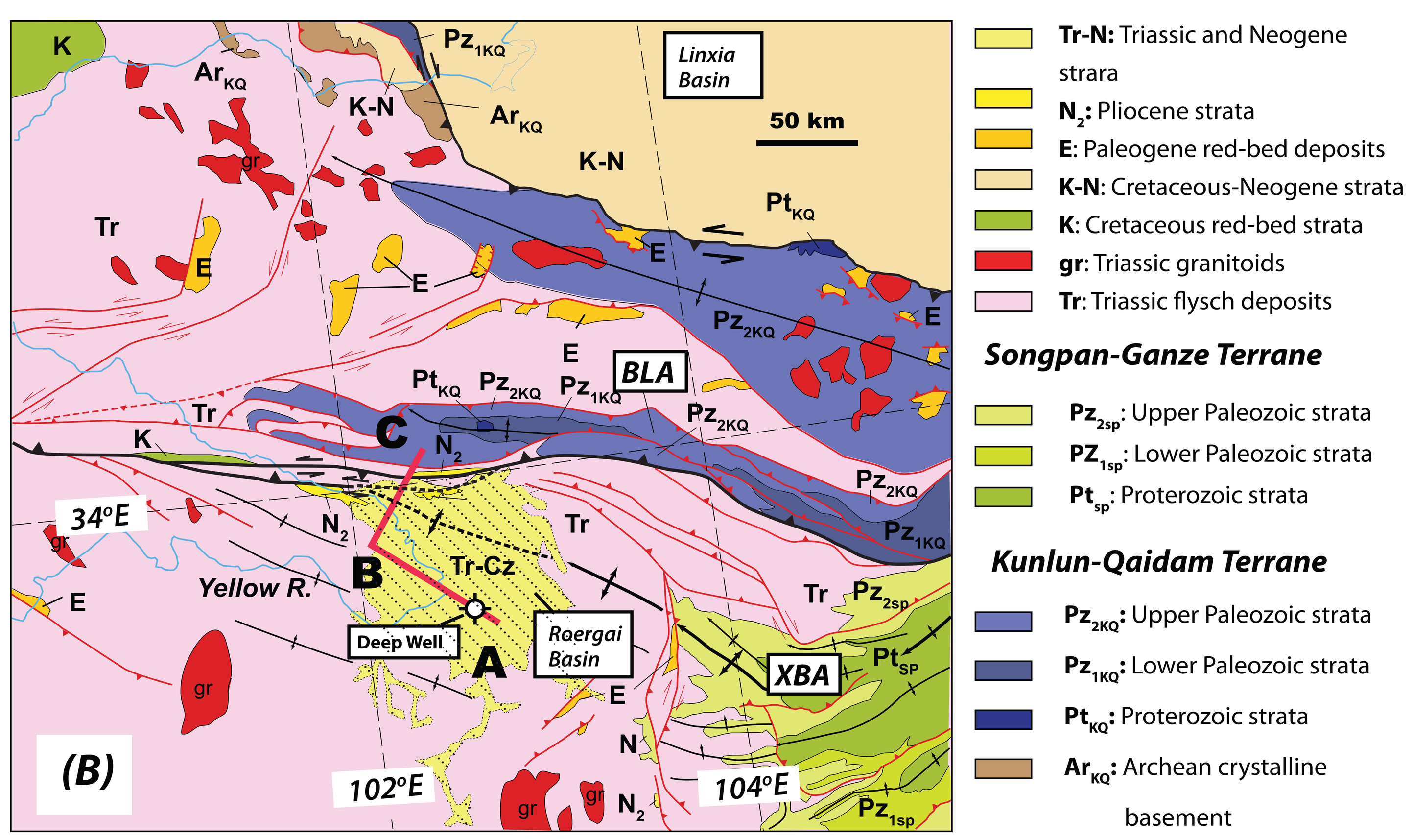


Figure 2. (A) Digital topographic map of the Tibetan plateau, the trace of the Kunlun fault and nearby structures, and the location of the study area. Cenozoic faults after Taylor and Yin (2009). (B) Simplified geologic map of the study area modified from Pan et al. (2004) with our own observations and interpretations. BLA and XBA are Bailongjiang and Xuebaoding anticlinoria.

3. Profile and Interpretations

The profile consists of two segments that lie nearly perpendicular to one another. This provides an excellent view of three-dimensional geometry of the structures imaged in the reflection profile.

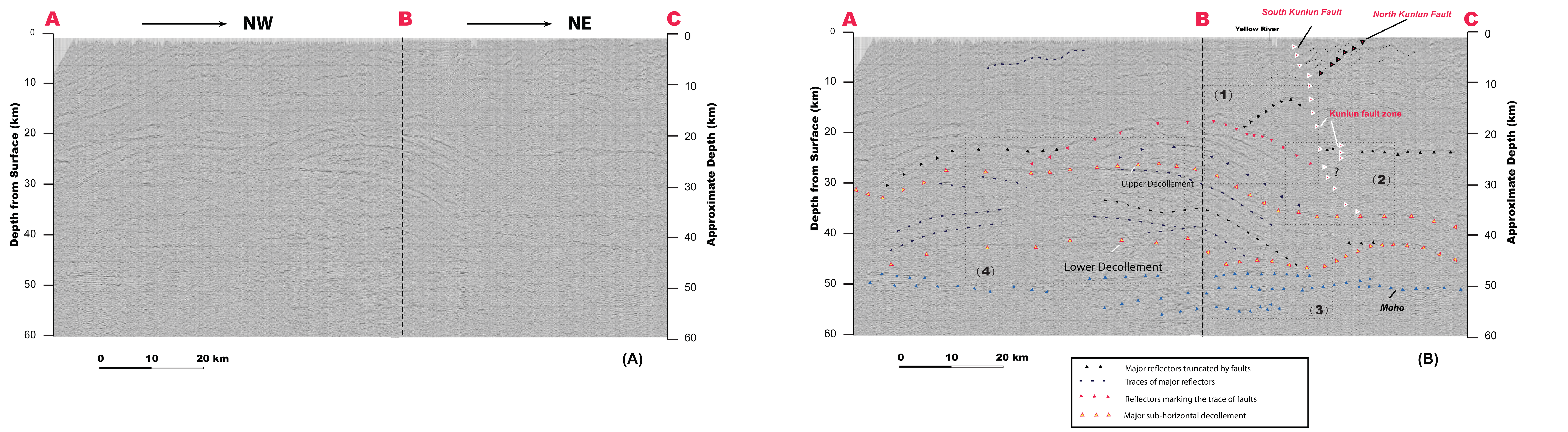


Figure 3. (A) Seismic-reflection profile across northeastern Tibet and locations of detailed seismic images. See Fig. 1b for location. (B) A three-dimensional perspective view of the interpreted seismic profile. Profile B-C lies in the regional contractional direction and thus illustrates well the thrust transport directions and fold geometry. Profile A-B runs parallel to the regional contractional structures and thus illustrates along-strike variation of the structures. ND, northern duplex, correlative to the Bailongjiang anticlinorium at the surface; SD, southern duplex, correlative to the Xuebaoding anticlinorium at the surface; LDS, lower duplex system with the upper and lower decollements as their roof and floor thrust in the lower section of the middle crust.

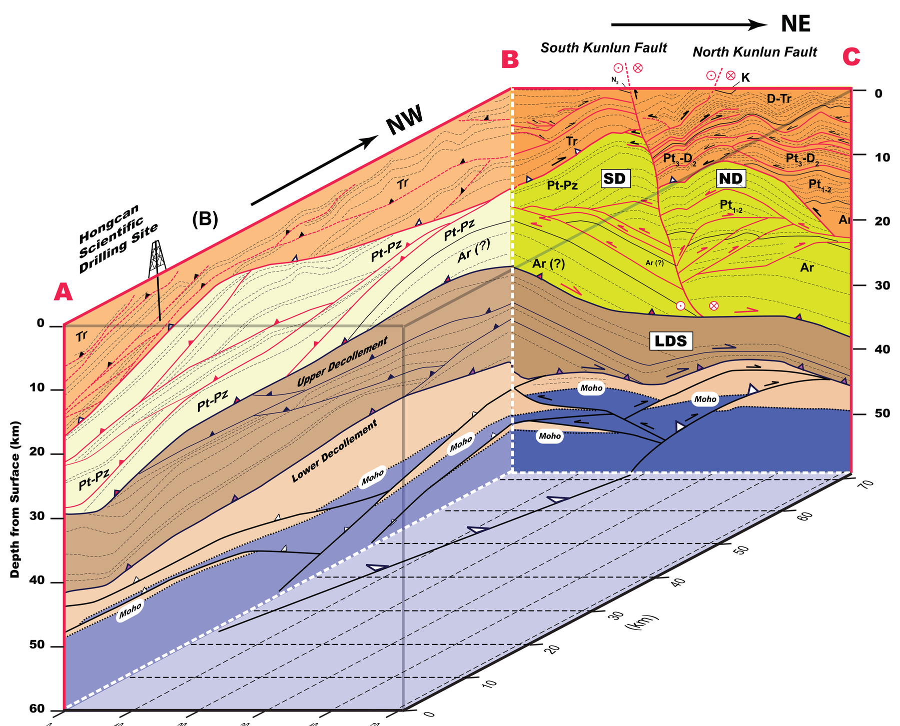


Figure 4. A three-dimensional perspective view of the interpreted seismic profile. ND, northern duplex below Bailongjiang anticlinorium; SD, southern duplex below Xuebaoding anticlinorium; LDS, lower duplex system with the upper and lower decollements as their roof and floor thrust in the lower section of the middle crust.

4. Tectonic Model

There may not be a single mode of deformation during continental deformation, which might be the reason for the protracted debates on the issue. The mode of deformaiton most likely is controlled by hetergeneous distribution of rock strength, in addition to varying boundary conditions.

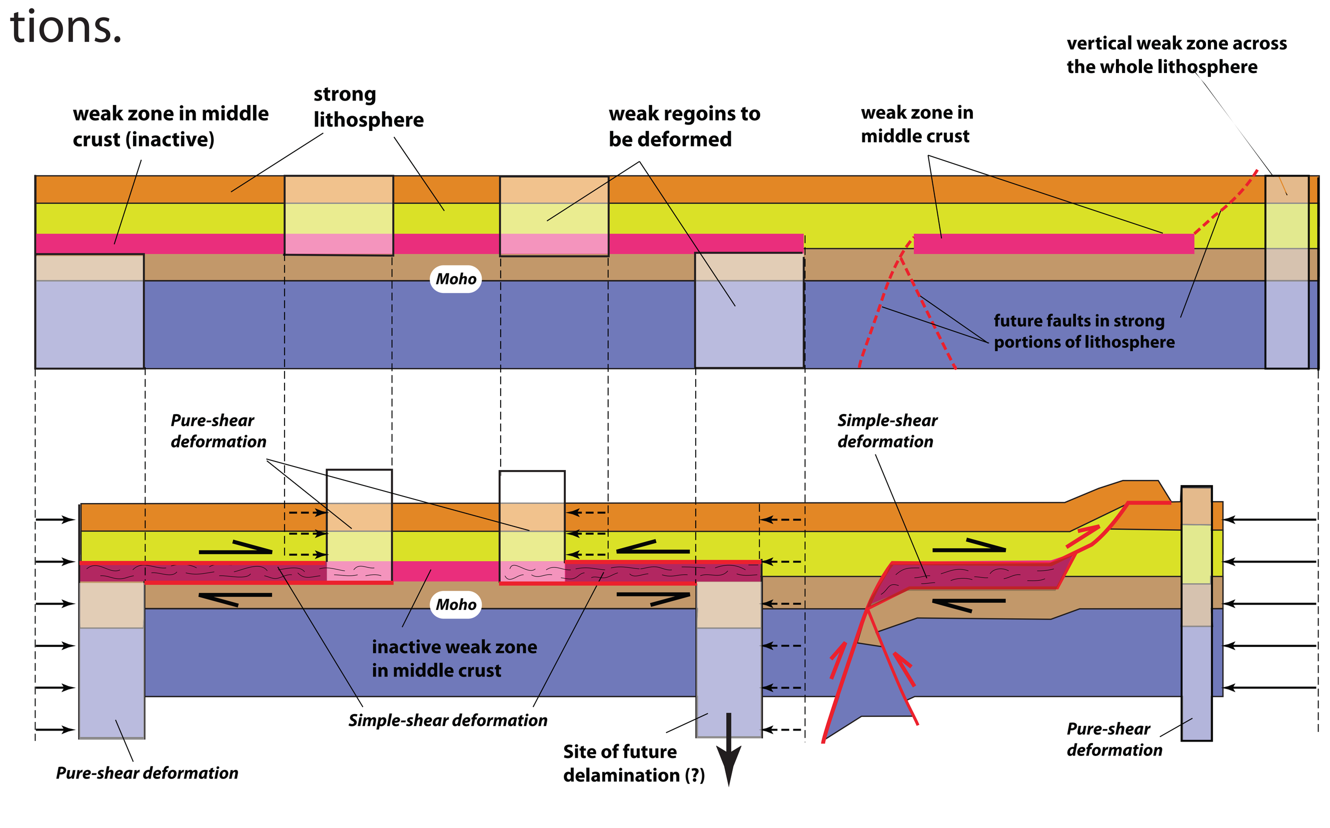


Figure 5. Mid-crustal strain-transfer model. (a) Prior to deformation continental lithosphere have hetergeneous distribution of mechanical strength due to early geologic history. The weak zones of the crust and mantle lithosphere will become future sites of high strain. The portion of the middle crust may be universally weakly, which is not activated. (b) Under vertically uniform shortening at the edge of the continental lithosphere, its interior responds by concentrating strain in weak zones. Portions of the weak middle crust were activated as simple-shear zones. They serve as transfer structures linking high strain domains above and below.