New constraints on the kinematics of mountain-building in Taiwan.

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[Simoes et al, subm. to JGR]

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The Taiwanese range.

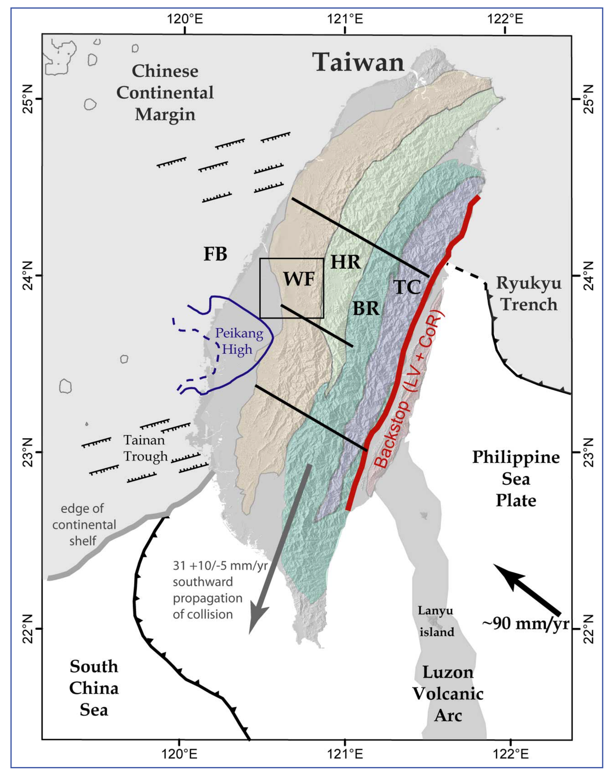


Figure: Geodynamical setting of the arc-continent collision of Taiwan Thick arrow shows the convergence of the Philippine Sea Plate relative to the Chinese Continental Margin predicted from the global plate geodetic model REVEL [Sella, et al., 2002]. Main structural units of Taiwan: CoR: Coastal Range – LV: Longitudinal Valley – TC: Tananao Complex – BR: Backbone Range – HR: Hsueshan Range – WF: Western Foothills – FB: Foreland Basin. Peikang Basement High after [Lin, et al., 2003]. Black lines indicate the three transects investigated by Beyssac *et al* [subm.]. box shows where the kinematics of shortening have been quantified (e.g. Simoes *et al*, 2006).

- Southward propagation of mountain growth
- High rates of deformation and erosion
- Tropical climate

How does the coupling between tectonics, erosion and climate influence mountain-building processes ??

Re-appraising mountain-building in Taiwan: geological data

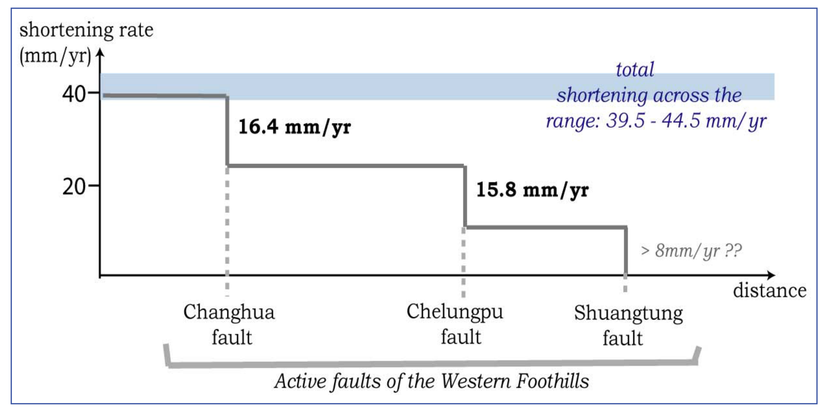


Figure: Long-term horizontal velocity (Simoes *et al*, 2006) and slip on major faults (Simoes *et al*, in press-a; Simoes *et al*, in press-b) relative to the backstop. This indicates that most (if not all) shortening is absorbed on the most frontal faults of the foothills, leaving little (if any) internal shortening within the Central Range. This kinematics holds for the last 2 Myr.

- Shortening localized on the most frontal faults
- Sustained exhumation below HR and TC in the Central Range.

The Taiwan range grows essentially by underplating below the Central Range.

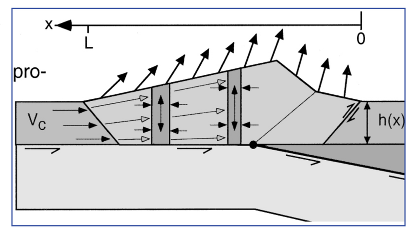
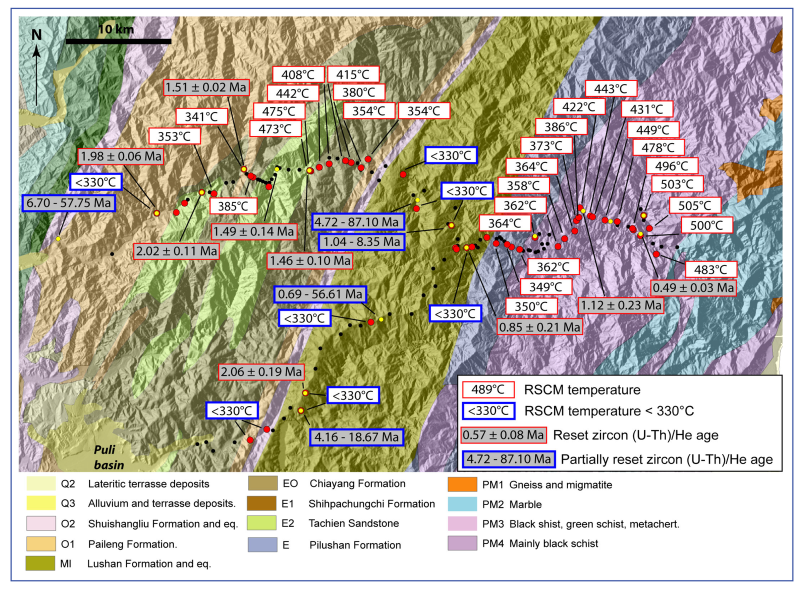


Figure: Schematic view of a critical-wedge growing by frontal accretion, from Willet *et al* (2001). In this case shortening is distributed within the range.



New data on long term evolution of the range: RSCM, (U-Th)/He on Zr (Beyssac *et al*, subm.)

↓

Documents where exhumation (and underplating) occurs

The well-accepted model of a critical-wedge growing by frontal accretion **does not apply** to Taiwan.

↓

New scenario proposed

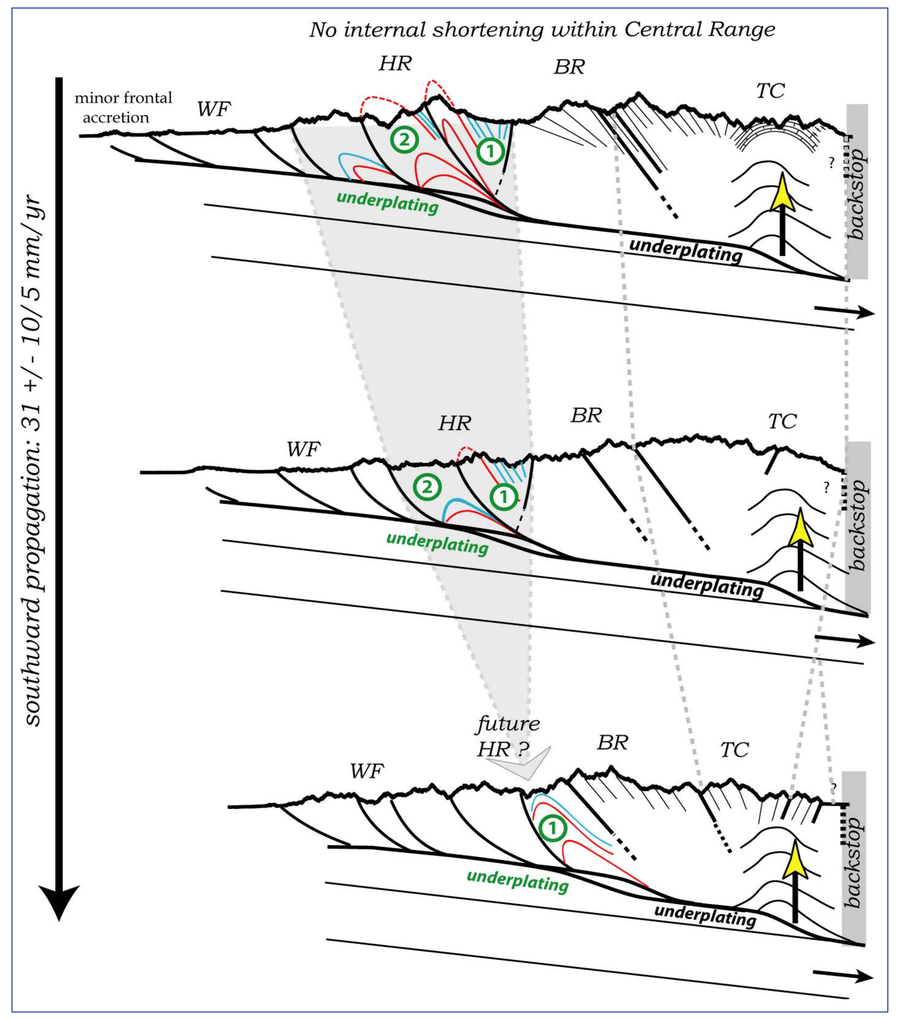


Figure: Kinematics of mountain-building in Taiwan. Shortening is localized on the thrus faults of the foothils (WF) indicating that range growth is sustained by underplating (Simoes et al, *2006*). Previous and new constraints on the thermal evolution of the range (e.g. Beyssac *et al*, subm.) indicate that underplating occurs beneath the HR and the TC. These constraints are provided by RSCM thermometry and by LT thermochronology. The three sections are reported on the map to the left.

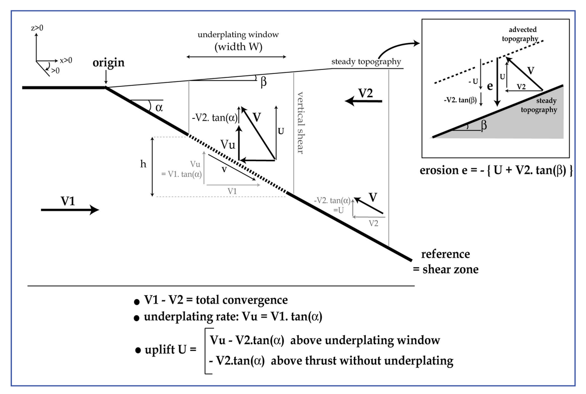
Thermo-kinematic modeling

Integration of all available geological constraints with the 2D finite-element code FEAP (Zienkiewicz & Taylor, 1989; Henry *et al*, 1997).

Kinematics prescribed

topography assumed steady state

Not initially prescribed:
- geometry of the basal detachment
- location and width of underplating windows.



Forward model adjusted to fit RSCM and LT thermochronological data (Beyssac *et al*, subm.)

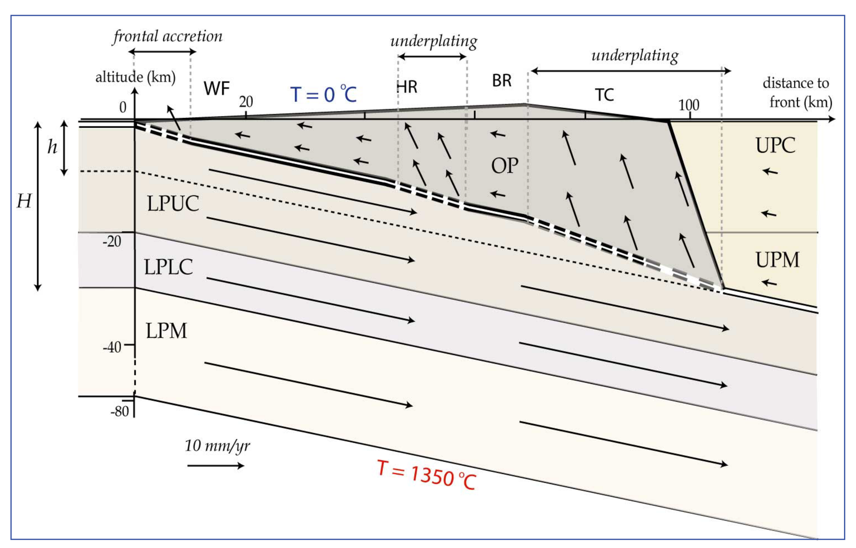
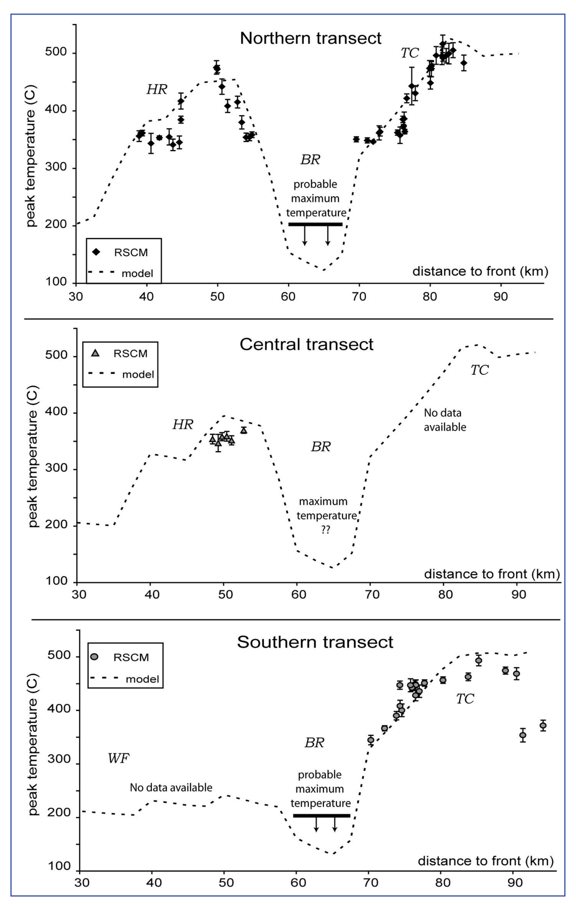


Figure:Geometry of our thermo-kinematic model, with the different domains of homogeneous thermal and kinematic properties: lower plate mantle (LPM), lower plate lower crust (LPLC), lower plate upper crust (LPUC), orogenic prism (OP), upper plate mantle (UPM) and upper plate crust (UPC). The basal decollement is taken as the reference for the velocity field. I is represented by a thick line, which is dashed where the different underplating windows are located. The velocity field computed for the lat 2 Myr is shown. Only the thickness h of the undurthrusted margin is incorporated into the range, the rest is subducted beneath the Philippine Sea plate.

Good fit to all available data along the three transects: model is therefore able to account for the temporal evolution of the range, as seen along-strike

Along a transect, variations in exhumation rates between the different structural units.



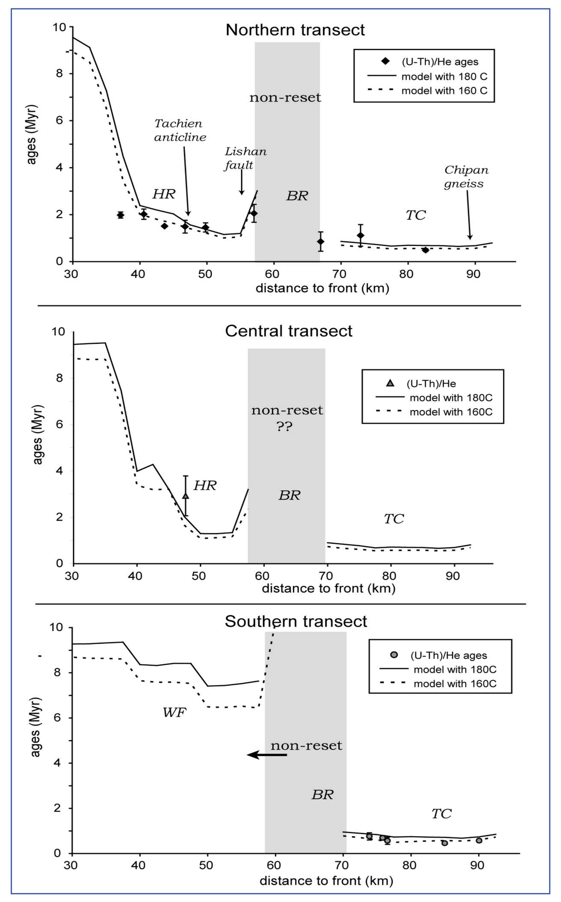


Figure (right) : Peak metamorphic temperatures retrieved from RSCM (Beyssac *et al*, subm) and predicted by our thermo-kinematic model for the three ransects across the range. Observed temperatures below 330 °C within the BR are not reported since this value represents the lower limit of applicability of the method (Beyssac *et al*, 2002). alternatively a probable maximum temperature of ~ 200 °C may be inferred for this area based on the non-resetting of (U-Th)/He ages on detrital zircons (Beyssac *et al*, subm) . Error bars represent a 2-σ interval.

Figure (left): (U-Th)/He ages on detrital zircon (Beyssac *et al*, subm.) with 2-σ error bars, and predictions from our thermo-kinematic model by assuming a closure temperature of 180 and 160 °C. Shaded area indicates where the ages are partially or non- reset over the BR. Where predicted ages are non-reset, no model predictions are shown.

Thermal structure derived for the three transects

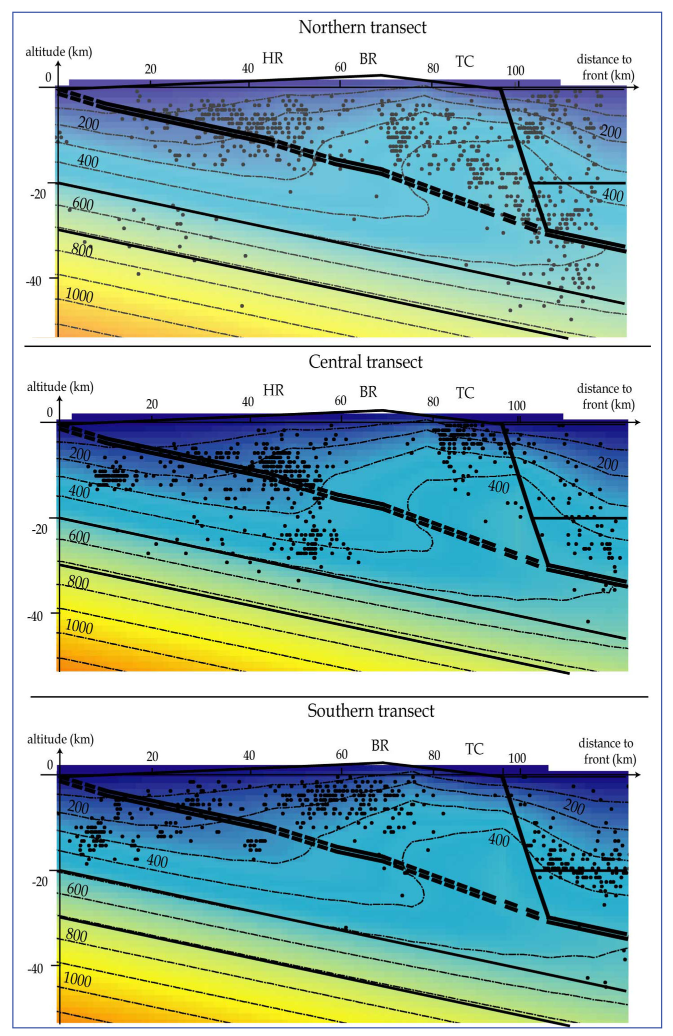


Figure : Predicted thermal structures for the three transects investigated . Temperatures do not change significantly laterally, supporting our 2D approach. Isotherms are represented every 100 °C contour. Also represented is the seismicity from the CWB (Central Weather Bureau) catalog, retrieved along a 30km swath around each one of the three transects. Only earthquakes of magnitudes over 3.5, from 1991 to 2000, have been plotted. No particular structure may be derived from this seismicity to support our derived deep geometry of the Taiwanese range. Interestingly, the seismic gap within the CR coincides quite well with the high topography, mostly for the northern and central transects, as well as with the 350 to 400 °C isotherms. This is also valid over the easternmost boundary of the prism.

Results:

Constraints for future investigations on the parameters controlling mountain-building (tectonics, erosion....)

Fluxes of rocks

Erosion rate averaged over the range: ~3mm/yr

Erosion rates of ~ 4 to 6 mm/yr over HR and TC, but ~0.5 mm/yr over BR where high topography.

only 23 % of the underthrusted crust participates to the range growth.

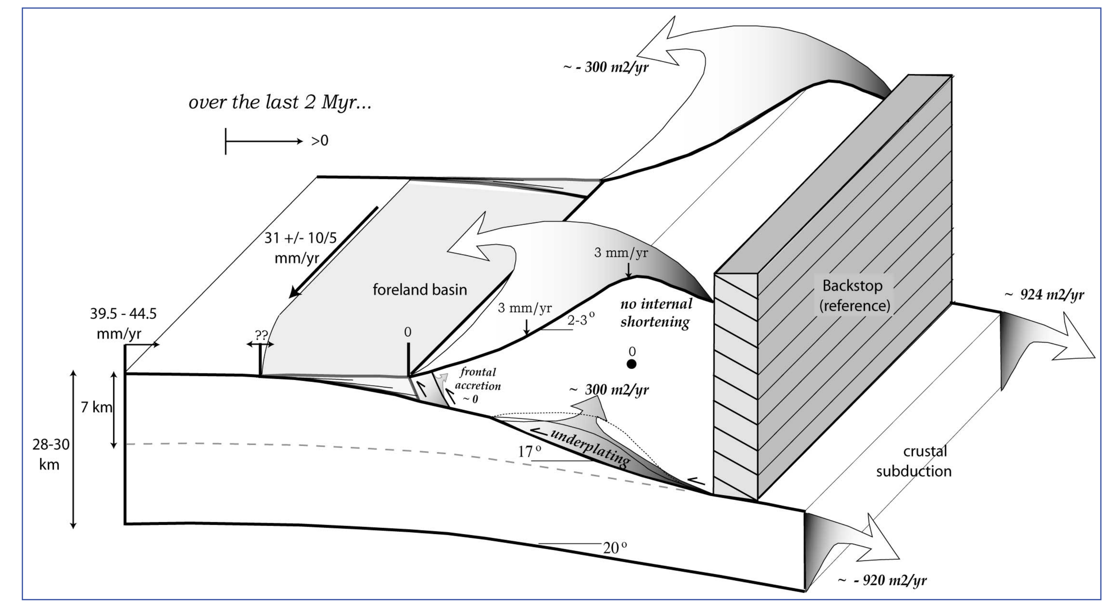
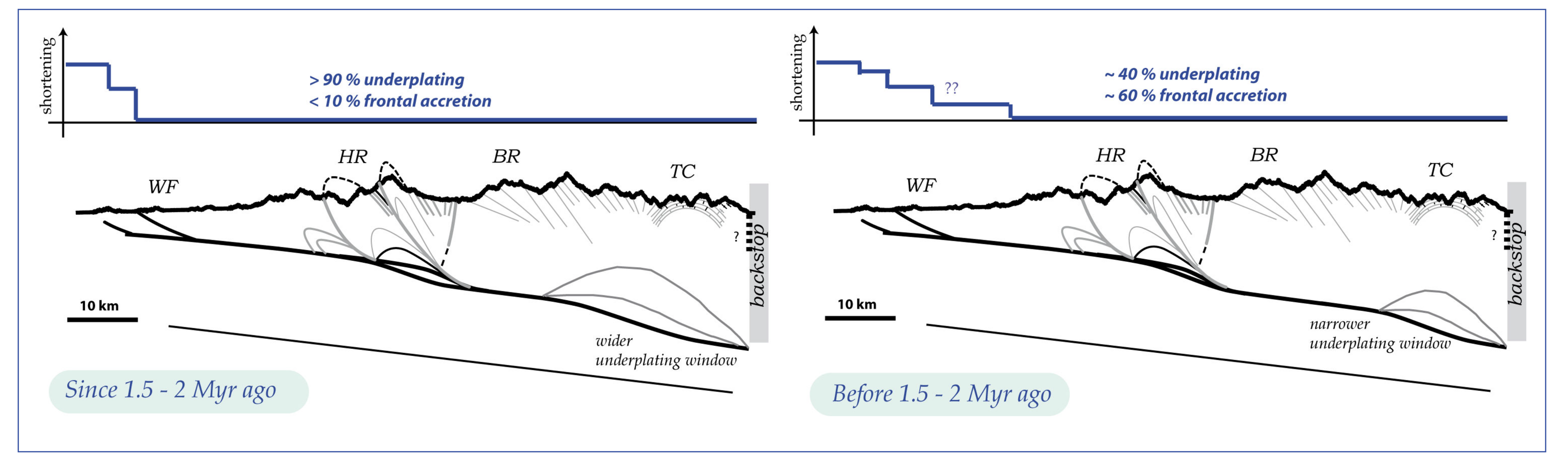


Figure: Sketch summarizing the kinematics of Taiwan quantified in this study. An average erosion rate of 3 mm/yr balances underplating below the internal portions of the range. Only a small portion of the underthusted crust participates the range growth. The flux of material lost by subduction into te mantle is significant. See also Simoes *et al* (2006). This holds for the last 1.5 to 2 Myr.

Major readjustments by 1.5 to 2 Myr ago.

To fit both gradient of peak metamorphic temperatures and LT ages over the TC (east Central Range) need to widen the underplating window beneath TC 1.5 - 2 Myr ago.

→ consistent with increase in sedimentation rates in LV basin to the east



This implies... → changes in the kinematics of deformation
→ changes in the proportion of underplating / frontal accretion

Why ?

Metamorphism, topography and dynamics of the wedge

Densities predicted for the PT conditions computed in the model can account for the observed topography and Bouguer anomaly.

Kinematics modeled from all available data therefore reflect the internal dynamics of the wedge

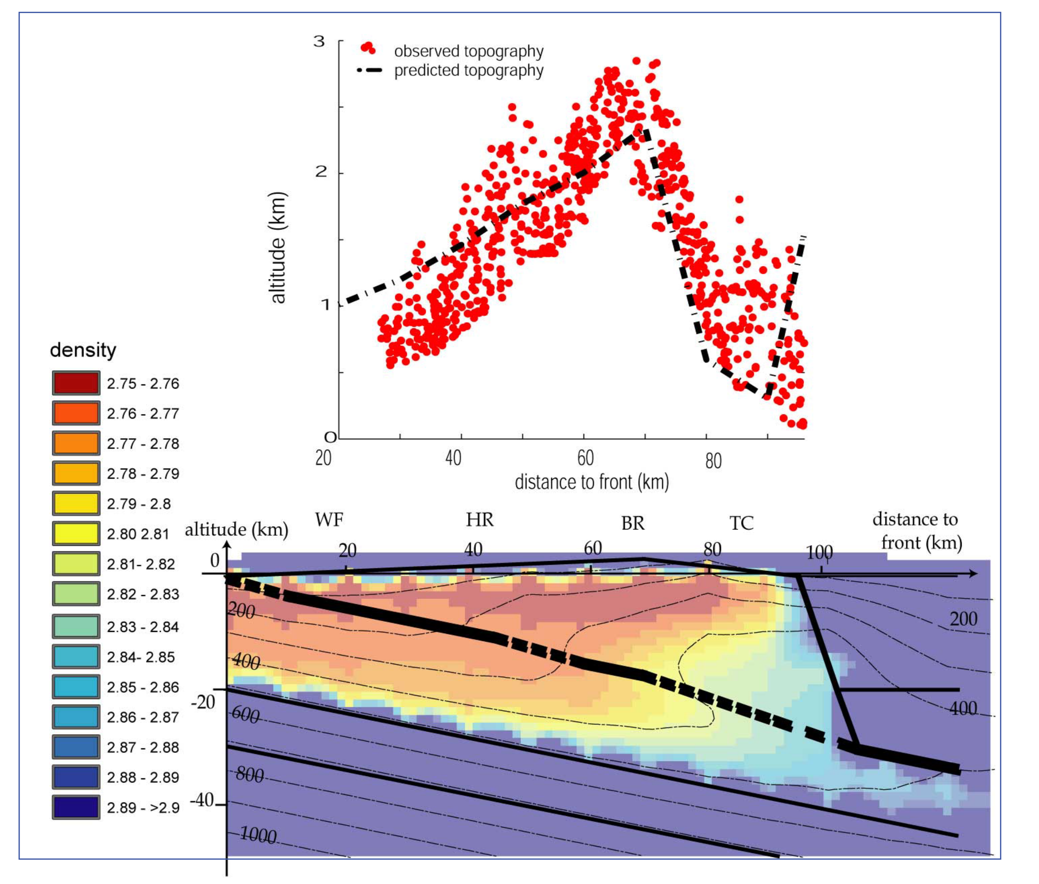


Figure : Predicted densities (bottom) and topography (top) in the case of the northern transect. Densities are calculated after Bousquet *et al* (1997) from the rock composition and from the PT conditions computed in our model. Fine lines indicate the isotherms of the computed thermal structure. The topography is predicted from the distribution of densities by assuming local isostasy and compensation within the asthenosphere (procedures described in Henry *et al* (1997). The observed topography (red dots) is taken within a 30 km wide swath across the northern transect.