Physical modeling of the evolution of Tibet related to the present-day lithosphere structure

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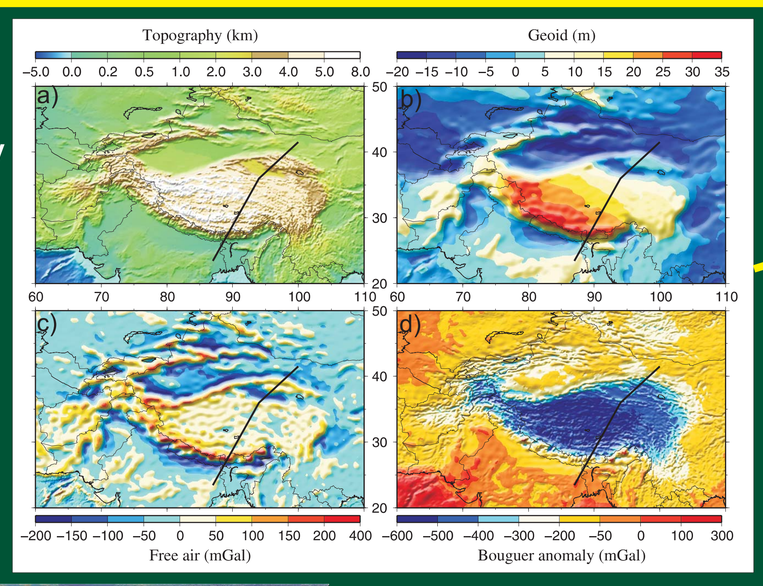
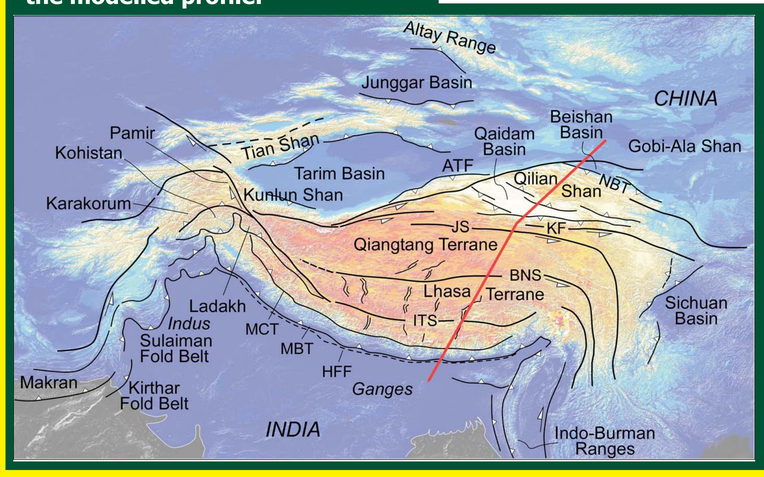
The Tibetan Plateau is the product of crustal thickening caused by collision, due to the northward movement of the Indian plate relative to Eurasia at nearly 50 mm/yr for the last 50 My. The plateau is now at ~5 km elevation with steep topographic gradients across the southern and northern margins, gradients also related to large lateral variations in the geoid and gravity anomalies. Uplift late in the tectonic evolution of the plateau, the widespread extension, and the associated magmatism have been attributed to removal of the lower part of lithospheric mantle and its replacement by hotter and lighter asthenosphere.

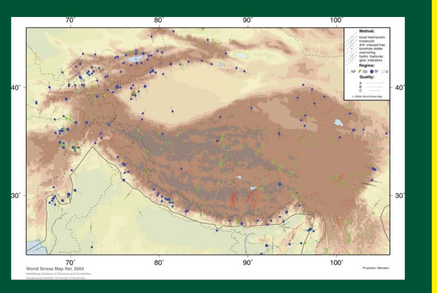
1. Data

Elevation, geoid, free air gravity and Bouguer gravity. Black line shows the position of the lithosphere structure modelled profile (pannel 2).



Tectonic map of the Tibetan plateau and surrounding regions. Colour shades show elevation. Red line shows the position of the modelled profile.

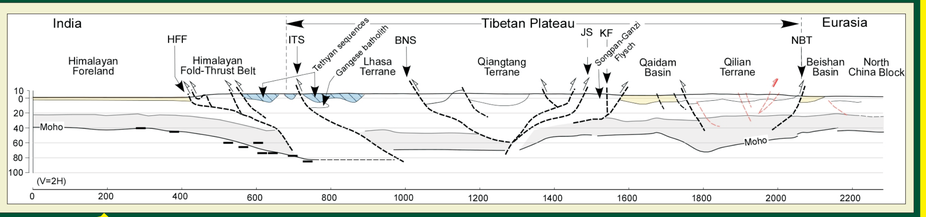




Maximum horizontal stress directions and tectonic regime (World Stress Map)

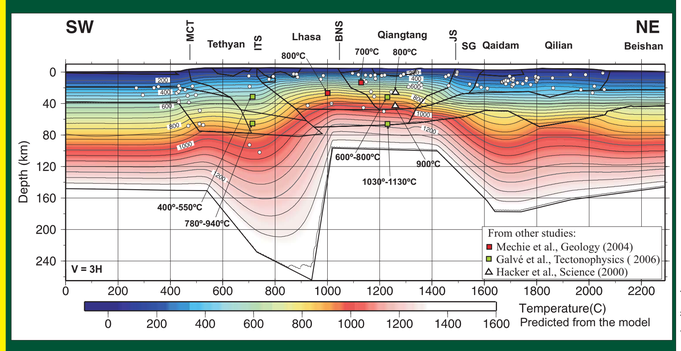
2. 2D lithospheric thermal and density model of the present day structure

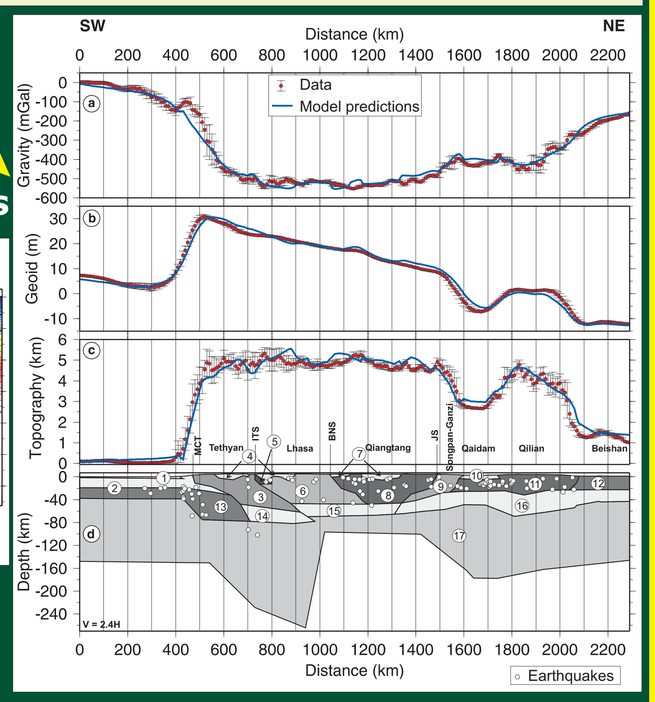
The geometry of the crust was inferred from geological and geophysical data, and the crustal and upper mantle densities from the proposed seismic velocities (vp and vs).



local isostatic equilibrium
steady state thermal regime

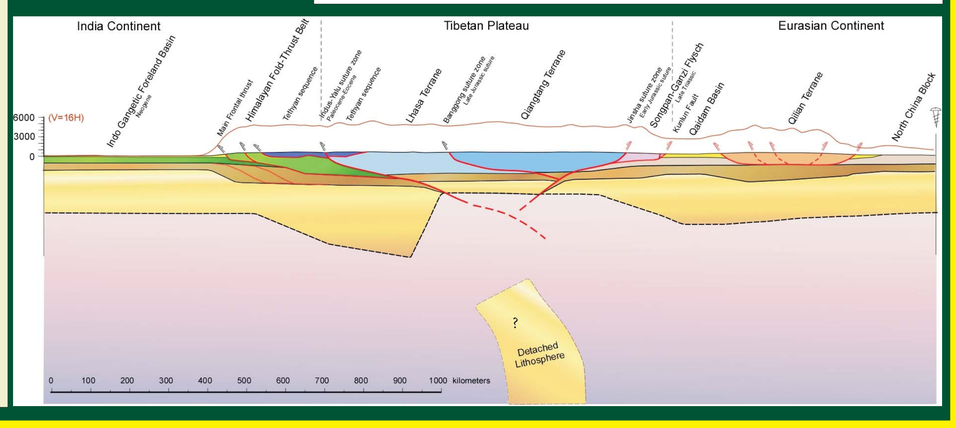
Modeling results





Jiménez-Munt I., M. Fernandez, J. Verges and J.P. Platt, submitted EPSL

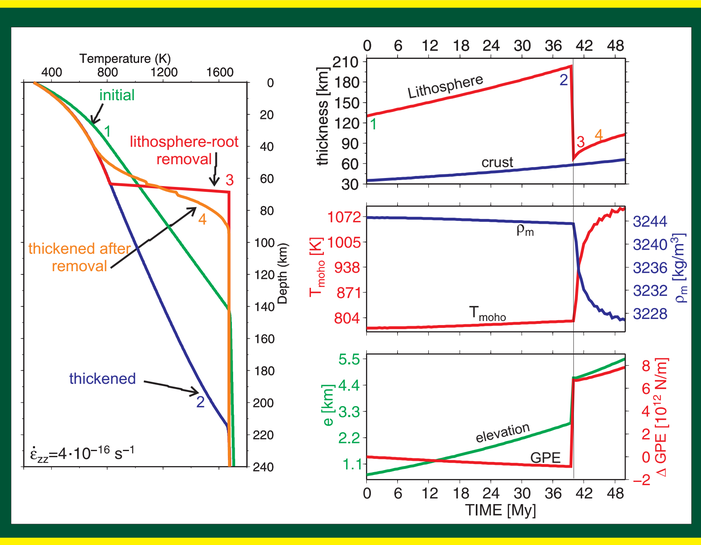
The height of the Tibetan Plateau is compensated by thick crust in the south and by hot upper mantle to the north.
The Tibetan Plateau as a whole cannot be supported isostatically only by thickened crust; a thin and hot lithosphere beneath the northern plateau is required to explain the high topography, gravity, geoid and crustal temperatures.



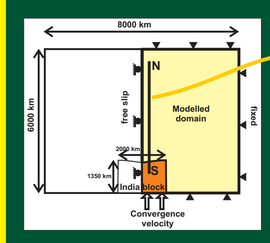
3. Removal of the lithospheric root

Example of a geotherm in different stages and the evolution of some variables, before and after the removal of the lithospheric root.
The lithosphere is assumed to be always thickening at constant strain rate.

T_{moho} : moho temperature
ρ_m : lithospheric mantle density
GPE : Gravitational potential energy



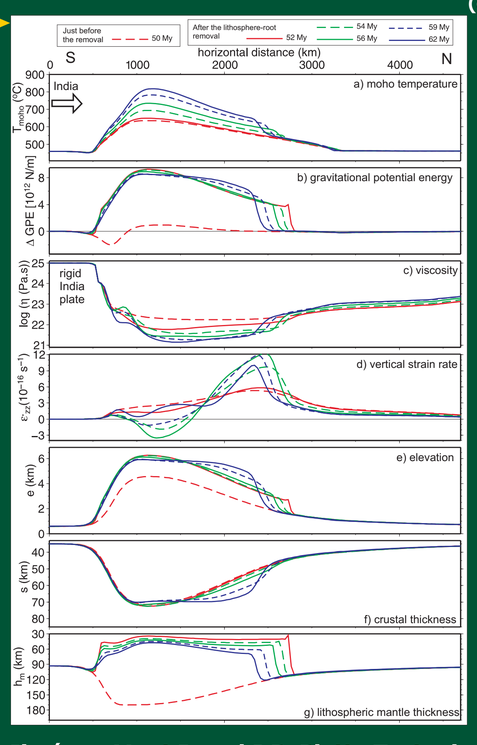
4. Long term geodynamical modelling plane stress approach

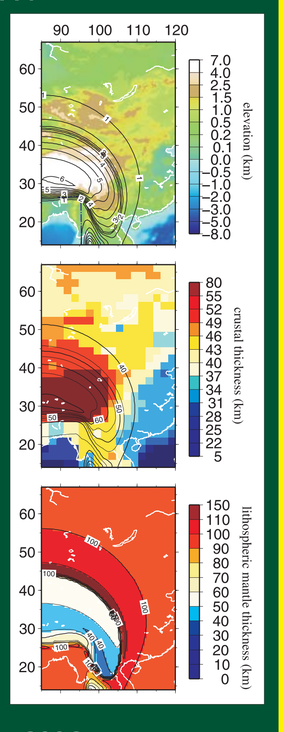


Cross section of the modelling results at different stages

The lithospheric root removed after 50 m.y. of convergence => Increases in Moho temperature, surface elevation, and GPE. Warming of the lithosphere => Decrease in its strength and viscosity => Unable to sustain the increased lateral variation of GPE => Convergence migrates to the north and some thinning takes place in the more elevated zones of the orogen (d).

Geologically rapid removal of the lithospheric root explains the current elevation of the plateau, its lack of surface slope, the steep south and north margins, and the pattern of the present deformation, including vertical thinning, E-W extension.
This modeling suggests that this removal took place within the last 12 m.y.

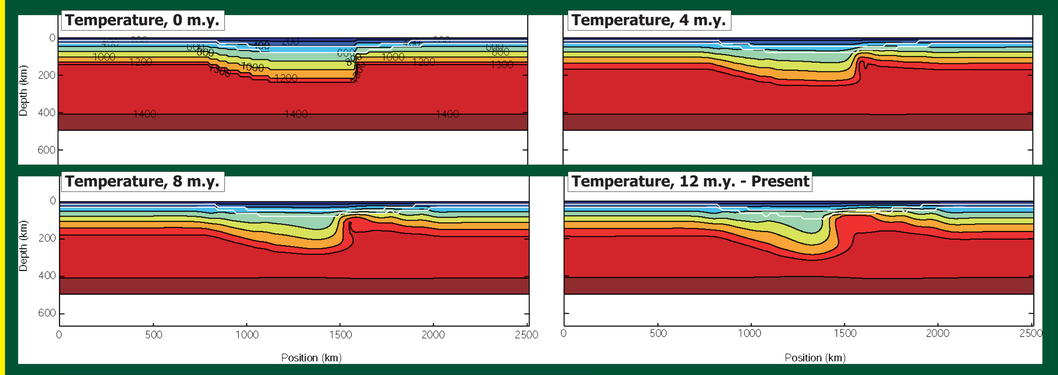




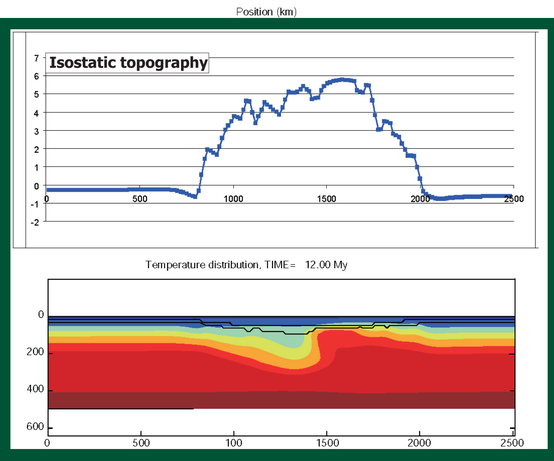
Model results after 57 m.y. of convergence and 7 m.y. after removal of lithospheric mantle.(a, b) contours is predicted from the model and colour pattern is data. (c) predicted from the model.

Jiménez-Munt I. and J.P. Platt , Tectonics, 2006

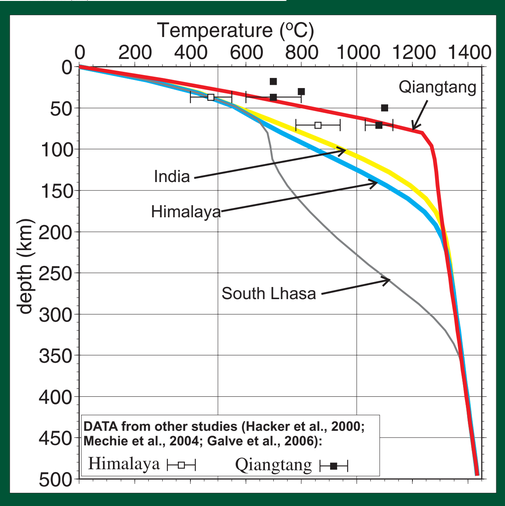
5. Geodynamical modelling, last 12 m.y., plane strain approach



Evolution of the temperature (colour pattern) and base of the upper and lower crust (white lines).



The isostatic topography (top, blue) computed for the final state (bottom, colors) shows a clear plateau. The northern part of the plateau is sustained by the upwelling of asthenospheric material whereas the southern part is sustained by crustal thickening (crust is shown in black lines).



Geotherms resulting from the model (colour lines) and temperature data within the crust (squares)

Tomography from Huang and Zhao (JGR, 2006) to be compared with the model results