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Deep and near-surface consequences of root removal by asymmetric continental delamination: comparison from different initial scenarios

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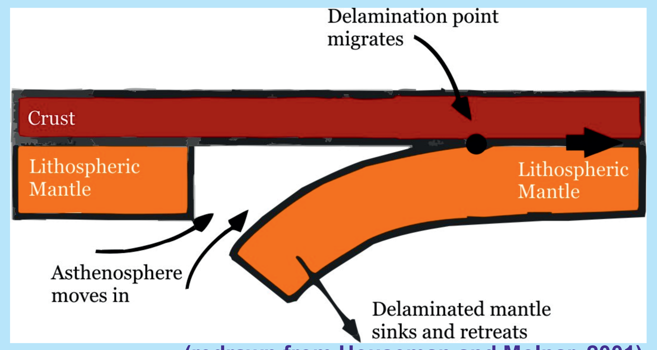
1.- Motivation

Delamination mechanism is commonly invoked to explain the lithospheric mantle removal. However, the topographic response to delamination is still matter of an open debate (e.g., Elkins-Tanton, 2007; Göğüş and Pysklywec, 2008).

In this study we present results of numerical simulations considering different initial setups, representative for geodynamic scenarios where delamination could potentially develop. We compare dynamic topographic computed from markers and isostatic topography for each setup.



(redrawn from Houseman and Molnar, 2001)

We refer to 'delamination' as the geodynamic process of peeling the lithospheric mantle off the crust; and it fulfills the two conditions of Bird (1978) model: 1) the asthenosphere comes into direct contact with the crust and 2) the point of delamination, where the lithosphere peels off the overlying crust, migrates.

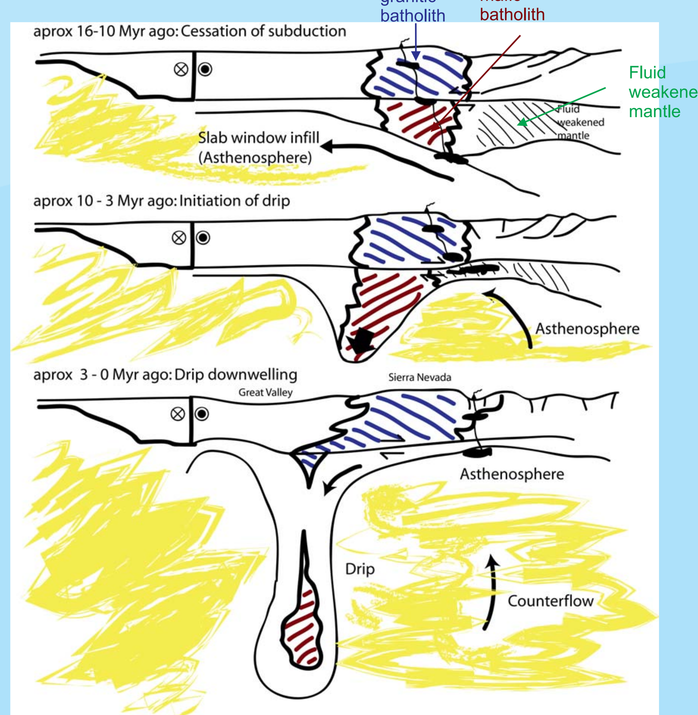
2.- Modelling

- We used the thermo-mechanical numerical algorithm TEMESCH (Valera et al. (2008, 2010).
- The heat sources considered here are: radiogenic heat production and adiabatic heating.
- The boundary between the lithospheric mantle and the asthenosphere is assumed to be a thermal boundary, with no compositional difference.
- We have used a Newtonian temperature-dependent (exponential) viscosity law (Rüpke et al., 2004).
- Marker topography is computed introducing an upper layer of low density and low viscosity material to mimic a free surface.

3.a- Post-subduction scenario simulations

Models with mafic and granitic batholiths

Inspiration:

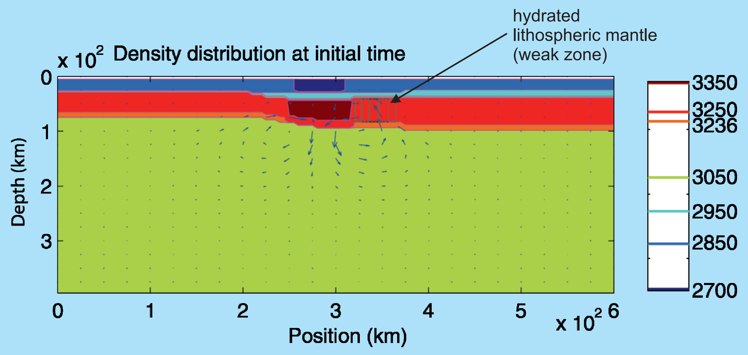


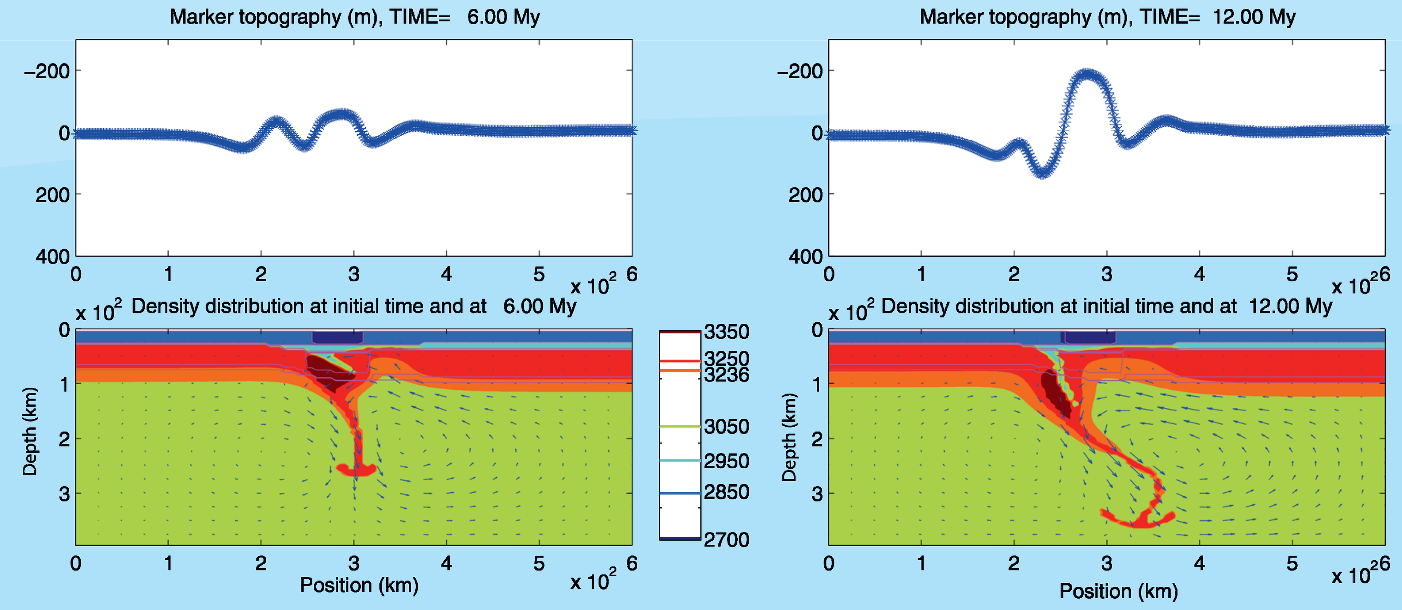
Sequence of events proposed by Zandt et al. (2004) for Sierra Nevada, CA.

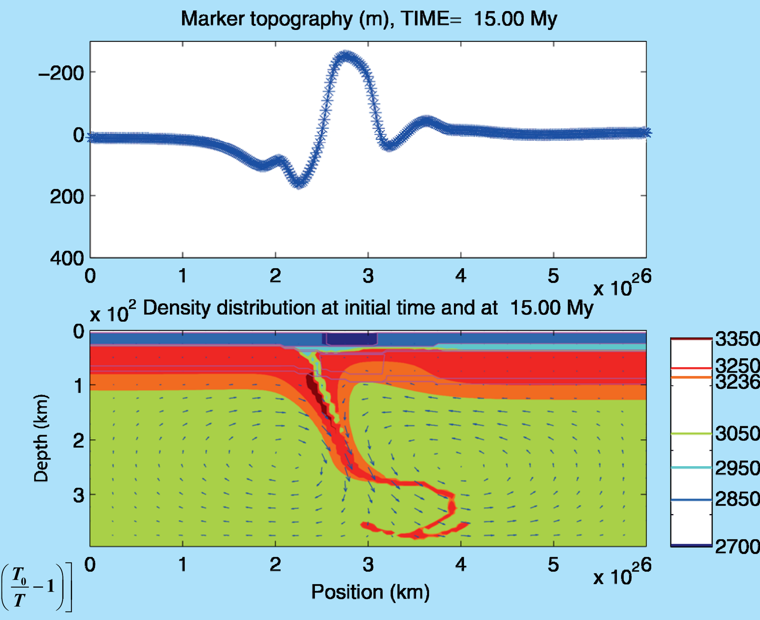
Initial setup:

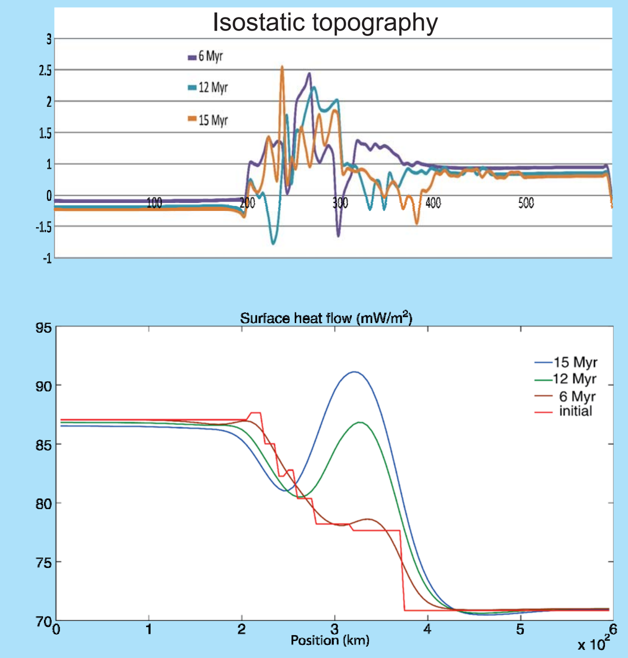
Color code	Material	ρ_0 (Kg/m³)	μ_{ref} (Pa s)
	Light sediments	1	10^{17}
	Upper crust	2850	10^{23}
	Lower crust	2950	10^{20}
	Granitic Batholith	2700	10^{23}
	Lithospheric mantle	3400	$2.5\ 10^{19}$
	Mafic Batholith	3500	$2.5\ 10^{19}$
	Hydrated L. M.	3400	$\mu_{max}<=10^{20}$
	Asthenosphere	3400	$2.5\ 10^{19}$

$$\rho=\rho_0(1-\alpha T)$$
$$\mu(T,z)=\mu_0\mu(z)\exp\left[b\left(\frac{T_0}{T}-1\right)\right]$$









Marker topography indicates subsidence due to the gravitational pull of the sinking mafic batholith and uplift due to the presence of the granitic batholith. Isostatic topography shows the same pattern, except at the final stage (~15 Myr).

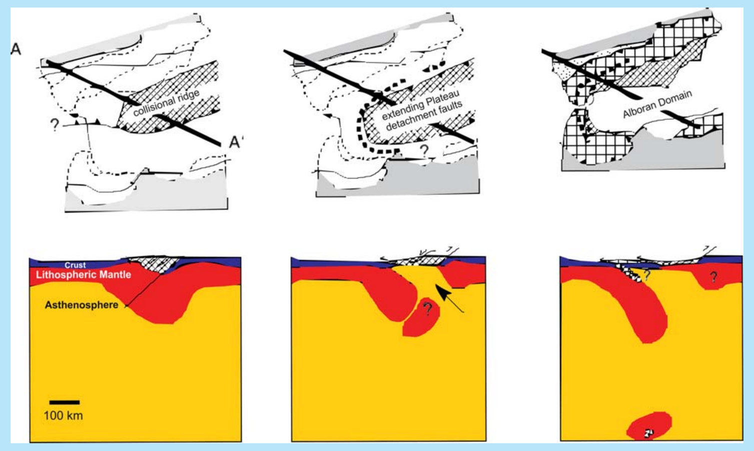
After 15 Myr, Isostatic topography shows a uplift, although with less elevation than before. The mafic batholith is sunk and its subsidence effect is overcome by the uplift effect of the thickened crust. In contrast, marker topography still shows the subsidence/uplift pattern.

Surface heat flow clearly reflects the asthenospheric material ascent. Moho adopts a small V-form.

3.b- Post-orogenic scenario simulations

Models with crustal and lithospheric root

Inspiration:

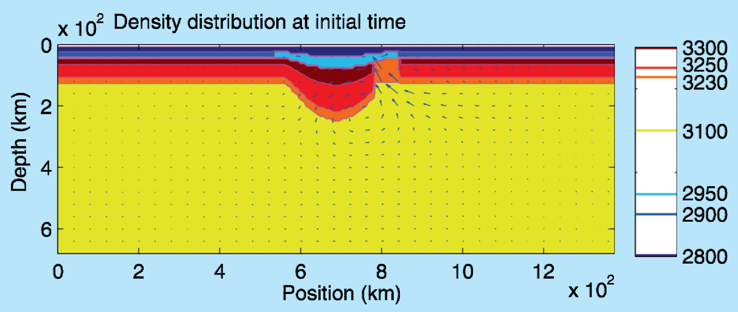


Conceptual delamination model for the Alboran Sea (modified from by Calvert et al. 2000.)

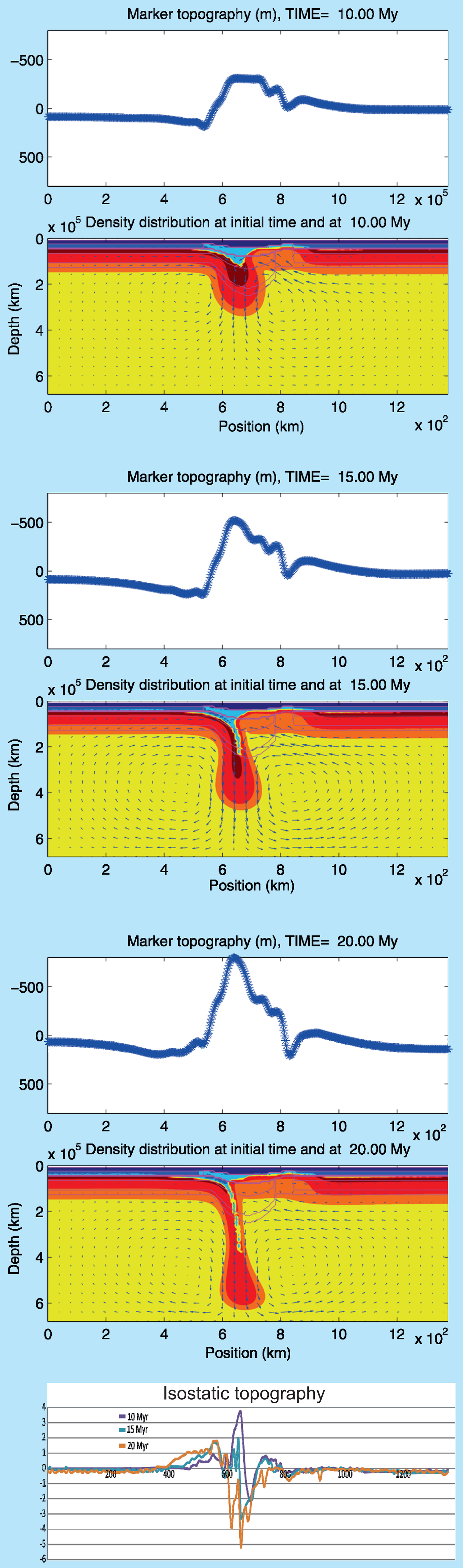
Initial setup:

Color code	Material	ρ_0 (Kg/m³)	μ_{ref} (Pa s)
	Light sediments	1	10^{17}
	Upper crust	2800	10^{23}
	Lower crust	2900	10^{20}
	Orogenic lower crust	2950 (a) 3050 (b)	10^{20}
	Lithospheric mantle	3400	$2.5\ 10^{19}$
	Asthenosphere	3400	$2.5\ 10^{19}$

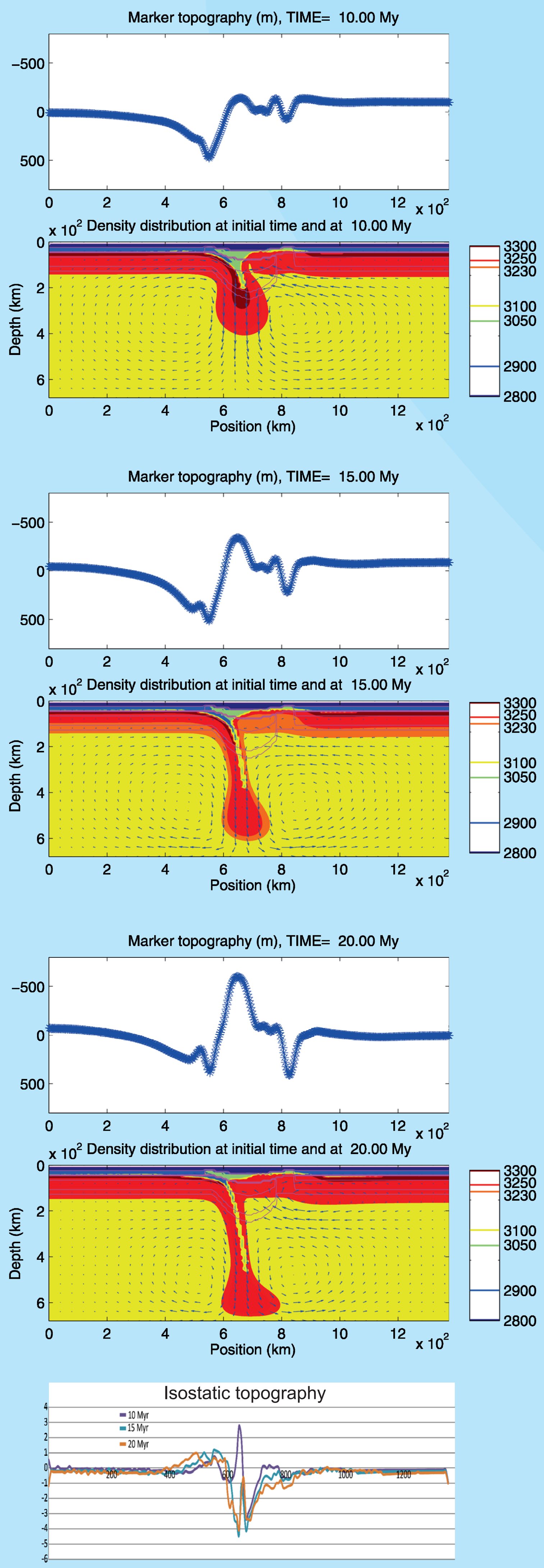
$$\rho=\rho_0(1-\alpha T)$$
$$\mu(T,z)=\mu_0\mu(z)\exp\left[b\left(\frac{T_0}{T}-1\right)\right]$$



a) Normal orogenic Lower Crust density (ρ=2950 Kg/m³)



b) Dense orogenic Lower Crust density (ρ=3050 Kg/m³)



Predicted geometry and motion of delaminated lithospheric slabs resemble the well-studied geometry of subducted slabs.

Marker topography shows uplift for the model with normal density for the orogenic LC, and a pattern of subsidence/uplift for the denser orogenic LC density model. In contrast, isostatic topography shows a pattern of uplift/subsidence for both models.

The process is fast and with significant horizontal motion, so the local isostatic topography cannot correctly take into account the fluid motion effects on topography.

4.- Conclusions

1) Predicted geometry and motion of delaminated lithospheric slabs resemble the well-studied geometry of subducted slabs.

2) We infer from our modeling that there is not a specific characteristic pattern of topography response associated with delamination, but it depends on the interplay between highly variable factors, as slab sinking velocity, asthenospheric upwelling and changes in crustal thickness.

3) For slow and predominantly vertical flow patterns, both local isostatic and marker topography give similar patterns of elevation/subsidence.

4) Marker topography gives correct trends of topographic response, but the absolute values are dependent on marker-field properties and characteristics of the upper layer. A comprehensive study of the marker topography to fully understand its behaviour is needed.

5) The topographic pattern given by marker topography is shown to be more sensitive to orogenic lower crust density changes than the one given by isostatic topography.

References

Bird, P. (1978), Initiation of intracontinental subduction in the Himalaya. J. Geophys. Res., 83, 4975-4987
Calvert, A., E. Sandvol, D. Seber, M. Barazangi, S. Roecker, T. Mourabit, F. Vidal, G. Alguacil, and N. Jabour (2000), Geodynamic evolution of the lithosphere and upper mantle beneath the Alboran Region of the Western Mediterranean: Constraints from travel time tomography. J. Geophys. Res., 105, 10871-10898
Elkins-Tanton, L. (2007), Continental magmatism, volatile recycling and a heterogeneous mantle caused by lithospheric gravitational instabilities, Journal of Geophysical Research, 112, B03405, doi: 10.1029/2005JB004072
Rüpke, L.H., J. Phipps- Morgan, M. Hort and J. A. D. Connolly, (2004), Serpentine and the subduction zone water cycle, Earth Planet. Sci. Lett., 223, 17-34.
Göğüş, H.O., and Pysklywec, R.N., (2008). Near-surface diagnostics of dripping or delaminating lithosphere, J. Geophys. Res., 113, doi:10.1029/2007JB005123.
Valera, J.L., Negredo, A.M., and Villaseñor, A., (2008). Asymmetric delamination and convective removal numerical modeling: comparison with evolutionary models for the Alboran Sea region, Pure appl. Geophys, 165, 16831706.
Valera, J. L., Negredo, A. M. and Jiménez-Munt, I, (2010), Deep and near-surface consequences of root removal by asymmetric continental delamination, Tectonophysics (in press), 10.1016/j.tecto.2010.04.002
Zandt, G., Gilbert, H., Owens, T. J., Ducea, M., Saleeby, J., and Jones, C. H. (2004). Active foundering of a continental arc root beneath the Southern Sierra Nevada in California, Nature, 431, 41-46.