Late stage of the Gibraltar arc subduction system (western Mediterranean): from slab-tearing to continental-edge delamination

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1. INTRODUCTION

The goal of this study is to investigate by means of thermomechanical modelling the first order conditions for, and consequences of, lithospheric delamination associated with STEP (Subduction-Transform-Edge-Propagator) faults.

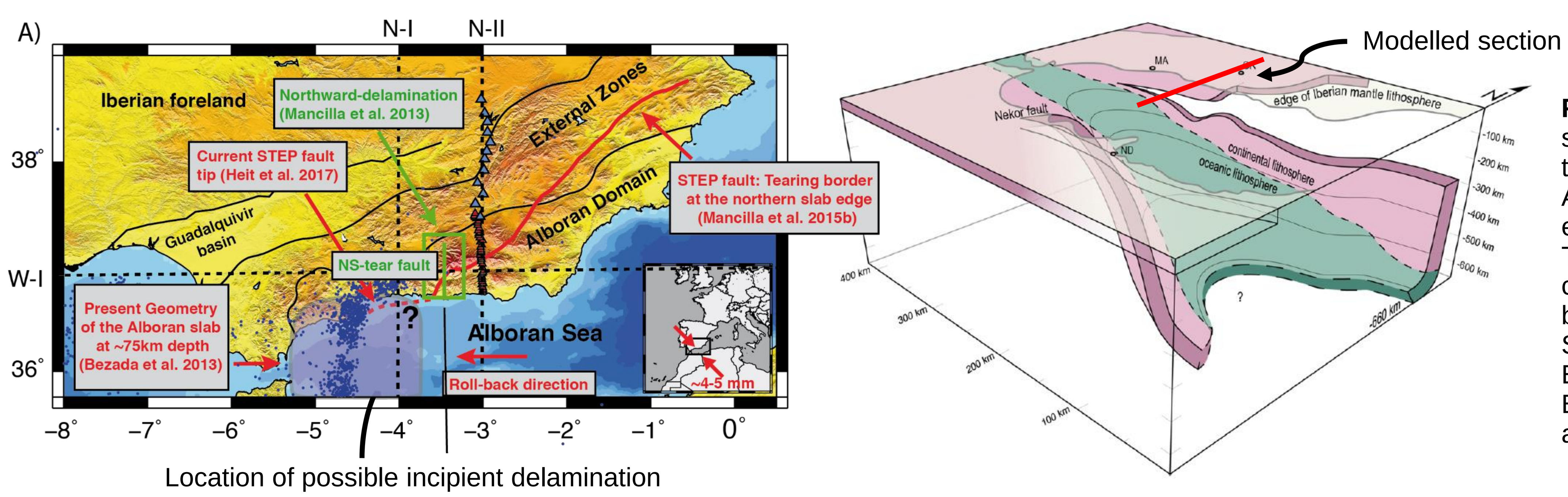

Fig. 1. The Gibraltar arc subduction system is the result of the fast westward roll-back of the Alboran slab at the westernmost end of the Mediterranean Sea. This westward motion is controlled, at its northern edge, by slab tearing along a so called STEP (Subduction-Transform-Edge-Propagator) fault under the Betics orogeny (from Mancilla et al., 2015b)

2. METHOD

We use the Finite Element open source code ASPECT 2.1 (Bangerth et al., 2019; Kronbichler et al., 2012) to solve the coupled equations of conservation of mass, momentum and energy for a 2D vertical section of an incompressible fluid.

The modelled domain simulates a 2-D vertical section running N-S at a longitude of about 3.5 ºW. The initial setup simulates the initial contact of the thickened Iberian lithosphere under the Betics and the thinned back-arc lithosphere of the Alboran Sea guided by the STEP fault. We adopt a visco-plastic rheology with a composite viscosity given by a combination of diffusion and creep dislocation viscous flow laws.

The incorporation of free surface on the top boundary (Rose et al., 2017) allows for properly modelling topographic response.

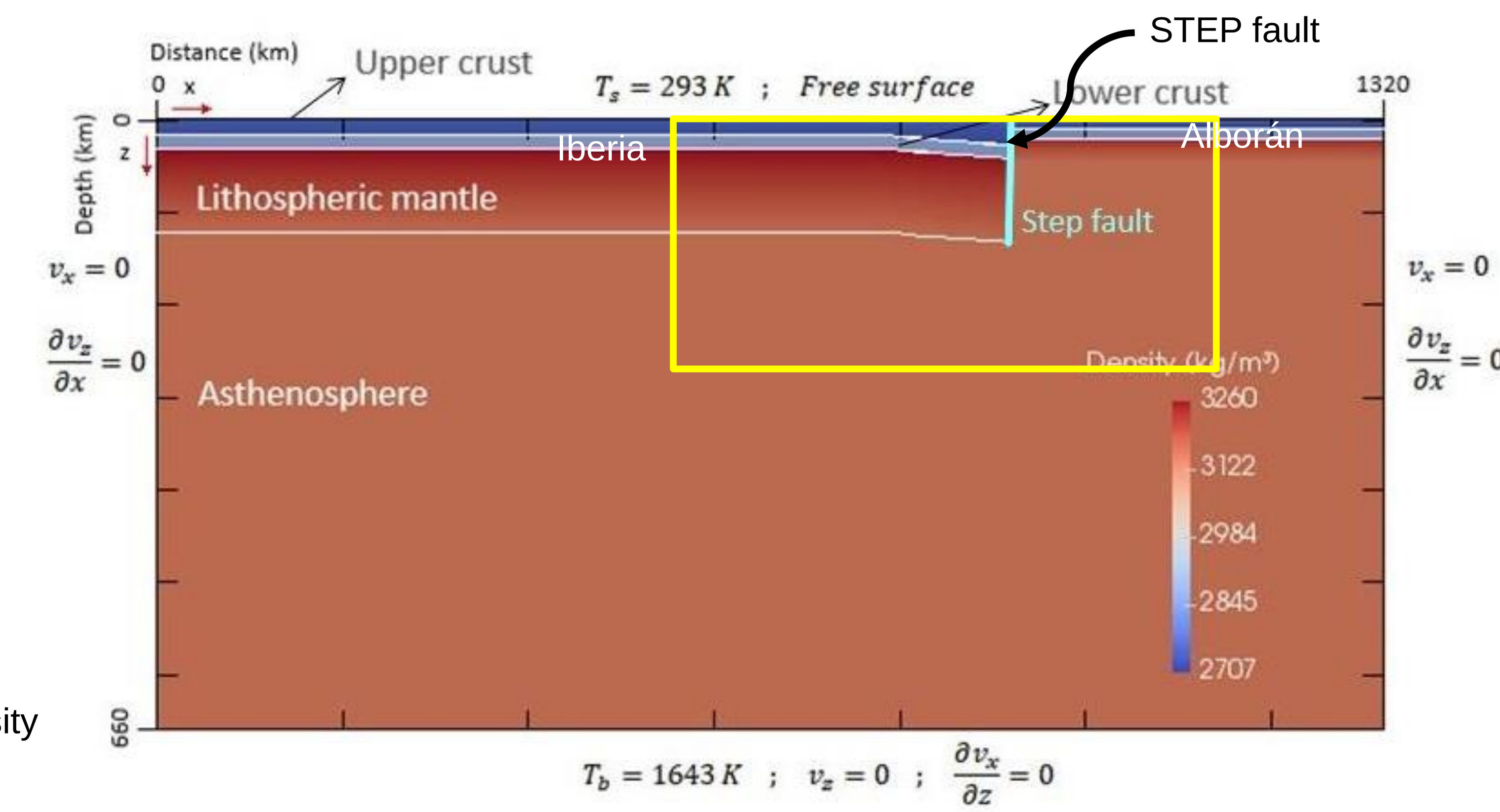

Fig. 2. Model Setup with the initial density distribution and boundary conditions

3. RESULTS

3.a Reference Model

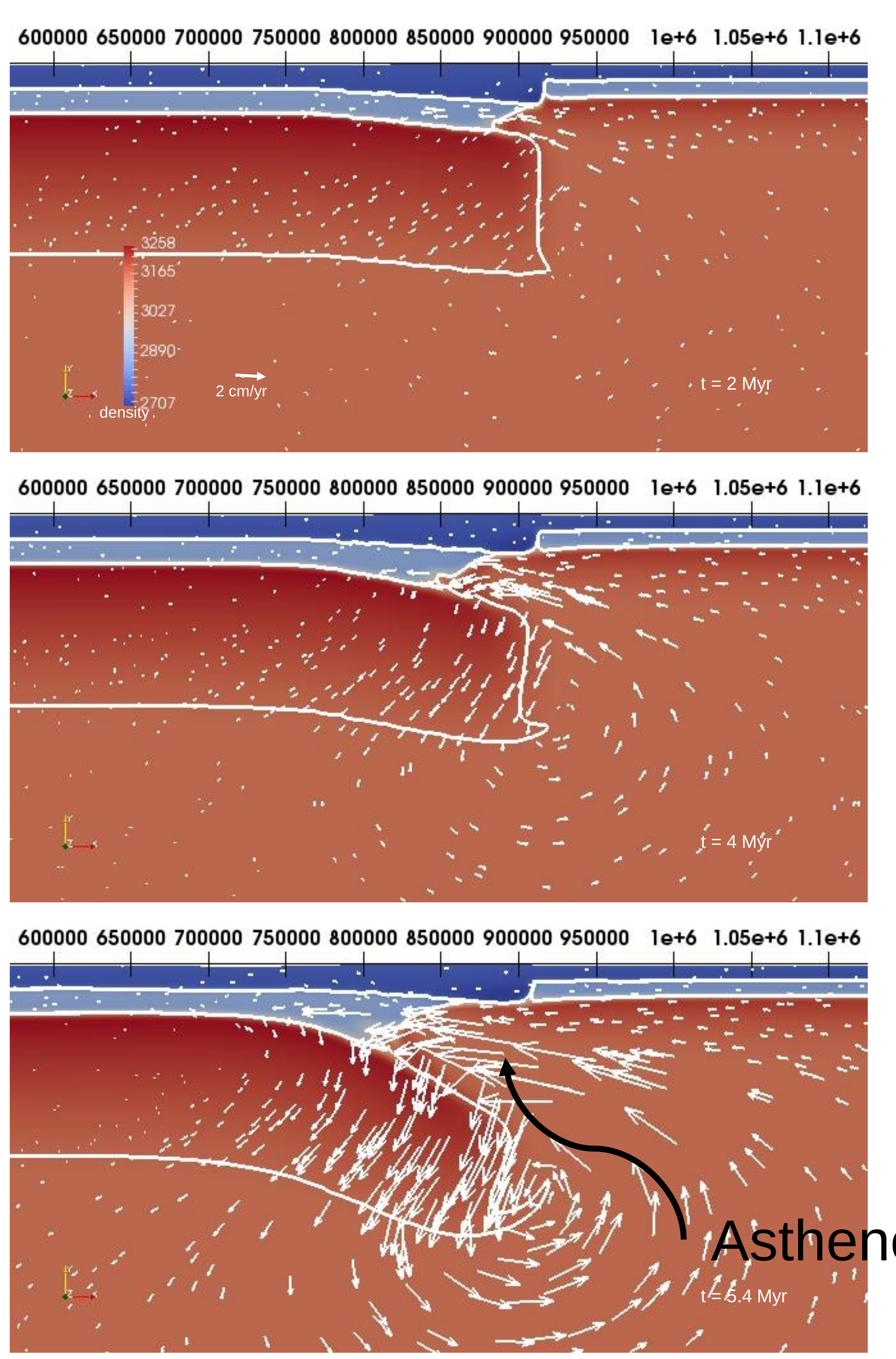

Fig. 3.- Distribution of density and velocity field at different times A) 2 Myr, B) 4 Myr and C) 5.4 Myr of the Reference Model. The progression of the asthenospheric lateral intrusion generates crustal thickening in front of the delamination hinge, and crustal thinning removing completely the lower crust.
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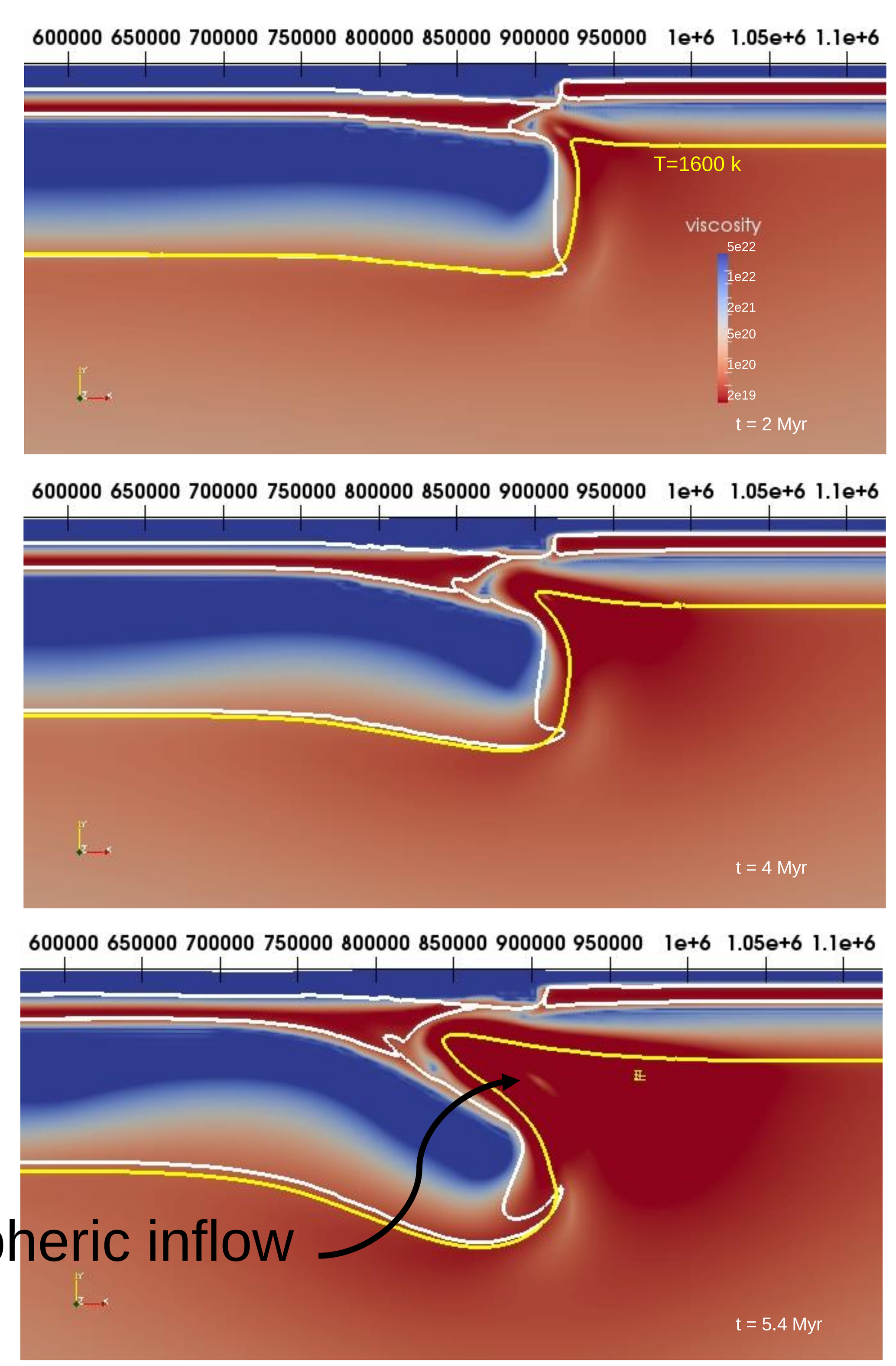

Fig. 4.- Distribution of viscosity (logarithmic scale plot) and location of the 1600 K isotherm at different times A) 2 Myr, B) 4 Myr and C) 5.4 Myr of the Reference Model
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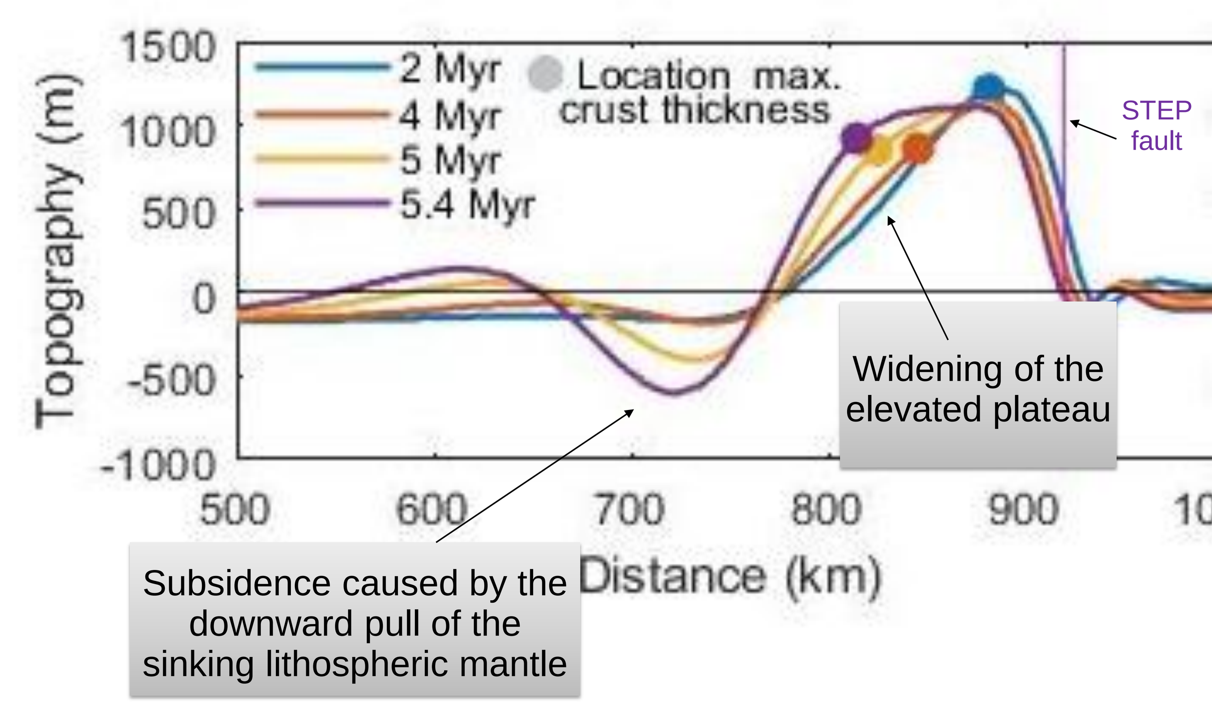
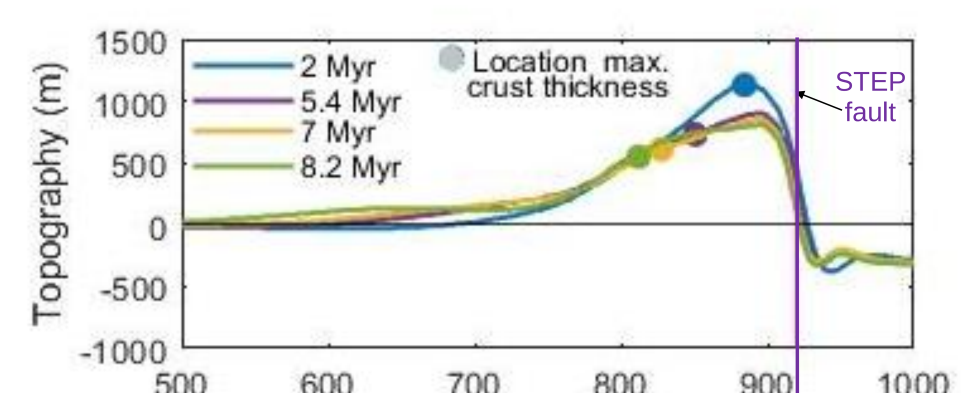


Fig. 5.- Topographic response of the free surface for the Reference Model.

3.b Slow Model



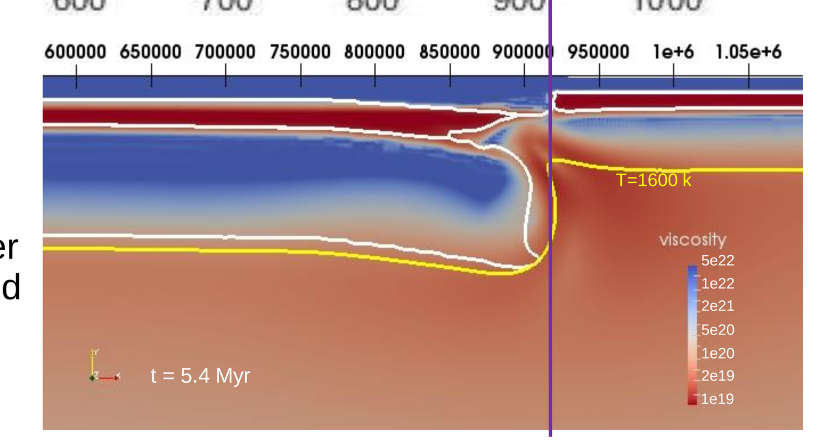


Fig. 6.- TOP Topographic response of the free surface for a slow model. BOTTOM same representation as Fig. 4 at 5.4 Myr, showing a lower evolution of delamination and causing a dramatically different topographic response.

4. DISCUSSION

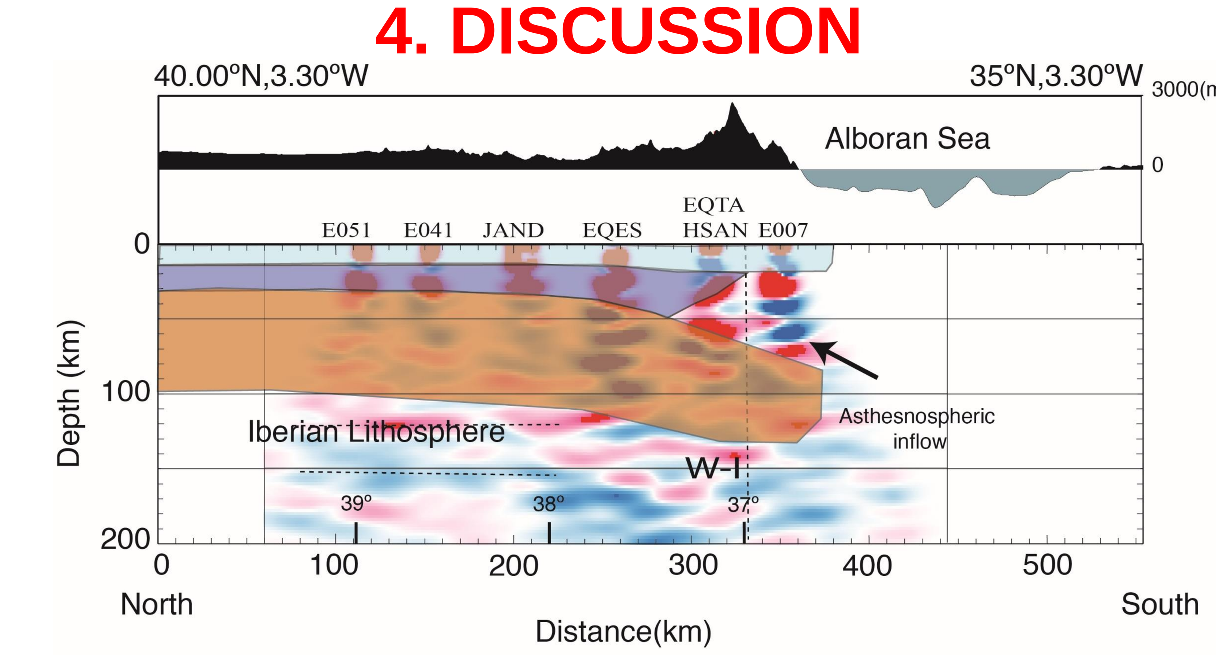


Fig. 7. .- Comparison of the CCP migration image of P-receiver function built using only the closest stations to the profile (modified from Mancilla et al. 2015a) with the simulated structure of the Iberian lithosphere for the Reference Model at 5.4 Myr. At the top, we display the topography along the profile.

Model predictions are consistent with a number of observations for the central Betics area where ongoing delamination has been proposed (e.g. Mancilla et al., 2013; 2015a; Heit et al., 2017); these features are the first order characteristics of the lithospheric structure, the offset between highest topography and thickest crust locations, and the observed topographic pattern of uplift in western Sierra Nevada, and subsidence in the Granada Basin

5. CONCLUSIONS

- Fast delaminating models predict a progressive widening of the elevated area, due to the dynamic effect of asthenospheric inflow, and adjacent subsidence due to the downward pull of the sinking lithospheric mantle slab.
- The lateral contrast in lithospheric structure resulting from STEP faults provides necessary conditions for the development of continental delamination, namely: a strong density contrast between the orogenic and the back-arc lithospheres, a relatively thick and weak lower crust in the Iberian margin, and a thinned (warm and weak) back-arc lithosphere allowing for asthenospheric upwelling and inflow along the orogenic lower crust.

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