A detailed crust to upper mantle structure: Comparison between Algerian and Alboran domains in the Western Mediterranean

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Abstract

We present a comparison of the detailed present-day crust to upper-mantle (400km) structure in the Western Mediterranean along two transects in Alboran and Algerian domains. The transect across the Alboran domain is NW-SE oriented crossing the Betics and the Alboran Basin and the northern margin of Africa between the Tell and Rif mountains. The Algerian domain transect is also NW-SE oriented crossing the Valencia Trough, the Balearic Promontory, the Algerian basin and ending in the Tell-Atlas Mountains in the northern margin of Africa. The structure is computed using integrated geophysical-petrological modelling tool (LitMod2D) which combines petrological, geochemical and geophysical dataset in a self-consistent framework. We model thermal, compositional, density and seismological structure, also incorporating slabs imaged by seismic tomography, constrained by simultaneously fitting elevation, gravity, geoid, surface heat flow and seismic tomography models to reduce the uncertainties in the modelling. Preliminary results suggest that crust is thickest beneath the Betics and thins beneath the Alboran basin within a distance of ˜100 km. Farther SE, crust gradually thickens beneath the north margin of Africa, between Tell and Rif mountains over ˜300 km distance. The LAB shows a similar trend though it is affected by the presence of the slab underneath Betics. For the Algerian domain transect, maximum crustal thickness occurs beneath the Tell-Atlas Mountains with noticeable variations across the Algerian basin, Balearic Promontory and Valencia Trough, the LAB showing a similar tendency. Comparing the modelled geometries suggests that both transects have opposite trends with the deepest Moho and LAB in the NW side of the Alboran transect and in the SE side of the Algerian transect, imposing important restrictions on the geodynamic evolution of the Western Mediterranean.

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Poster PDF

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1. Introduction

In the western Mediterranean (Alboran and Algerian basins), different models have been proposed for its evolution and are still debated. Although these models differ in the initial paleogeographic setting of the subduction, they all have subduction process (e.g. slab rollback, back-arc extension, slab tear) common to them.

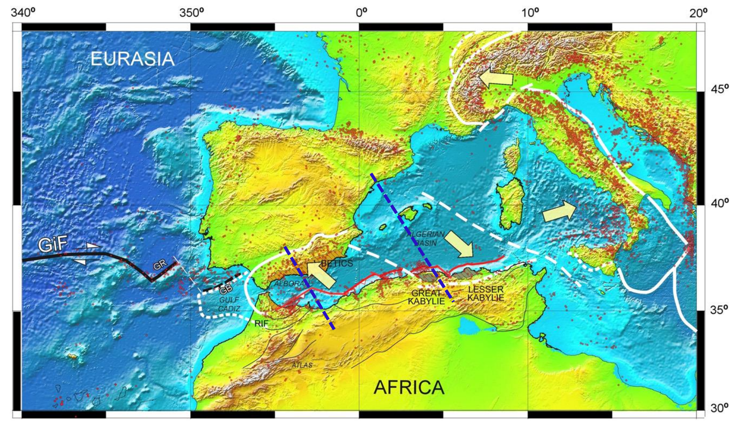


Figure 1.1 Map of the western Mediterranean showing the kinematic model proposed by Vergés & Fernàndez, (2012) based on the interaction of plates with opposite polarity, separated by transform faults (dashed white lines). Thick yellow arrows indicate the direction of the retreating slabs. Continuous white lines show the geometry of arcuate orogenic systems. Dashed blue lines show the location of the Algerian and Alboran domain transects presented in this study.

Motivation

This work is based on the geodynamic model of Vergés and Fernàndez (2012) that propose a lateral change of subduction polarity in Algerian and Alboran domain. Opposite polarity subduction should produce antisymmetric crustal and lithospheric structures across Algerian and Alboran domain. The main aim of this work is to compute detailed crustal and lithospheric structure and compare the results with the implications of this model.

2. Approach

- 2D petrological-geophysical models combing petrological, geochemical and geophysical data.
- 2D thermal and density structure compatible with the mineral composition and the seismic velocities of the mantle
- Detailed crustal and lithospheric scale structure.

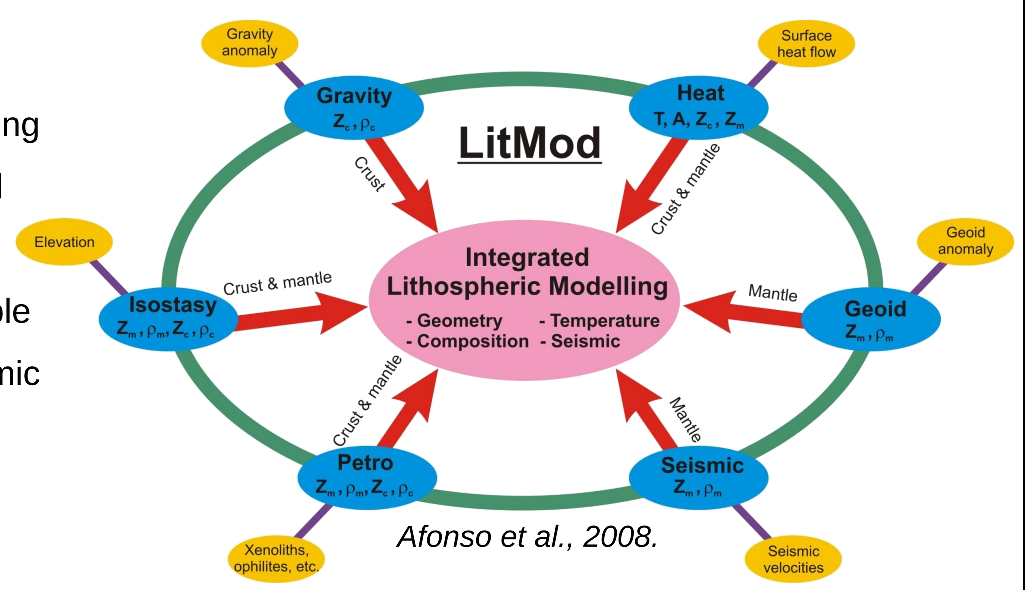


Figure 2.1 Schematic figure showing flow of the LitMod2D.

**Note: For detailed methodology checkout:*

T43H-0520 New improvements on LitMod2D package: A tool for integrated geophysical-petrological modelling of the lithosphere and upper mantle Thursday, 13 December 2018 13:40 - 18:00 Walter E Washington Convention Center - Hall A-C (Poster Hall).

Scan the QR code for the Poster

3. Geophysical Observables

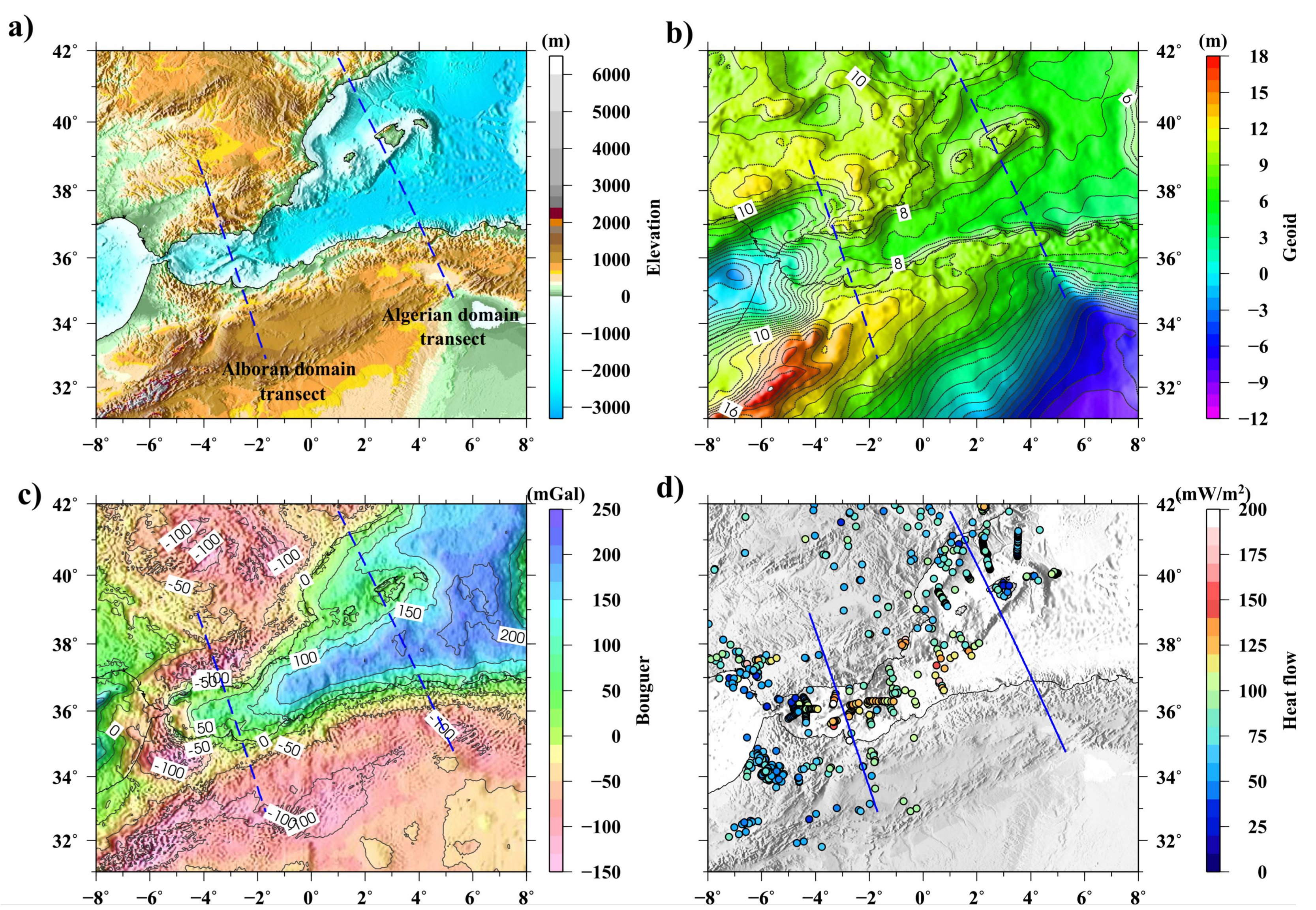
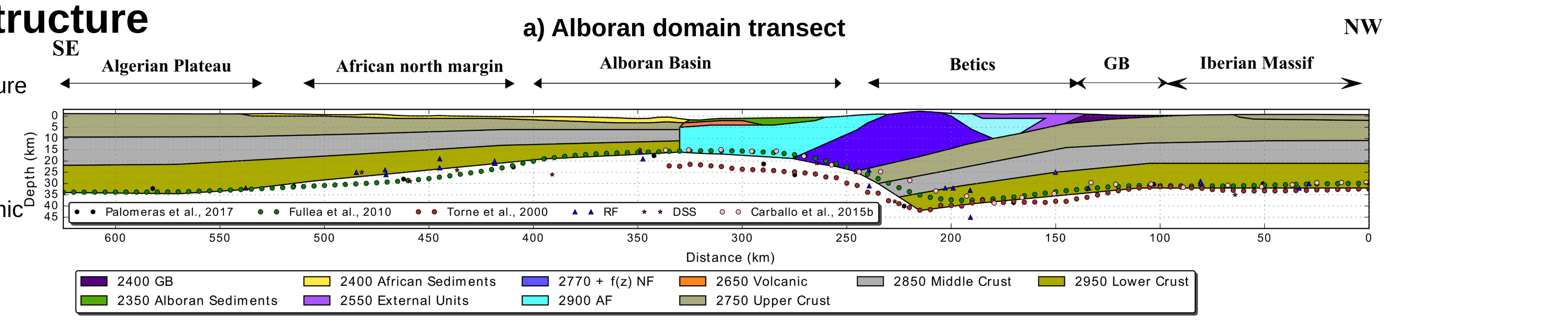


Figure 3.1 Geophysical data. a) Elevation map from ETOPO1 Global Data Base, location of the two transects in dashed blue line. b) Geoid height from EGM2008 Global model filtered to degree and order 9. c) Bouguer anomaly, onshore from Ayala (2013). Offshore and Africa bouguer anomaly is calculated from the free air anomaly using Fullea et al., (2008) code. d) Surface heat flow measurements from Fernàndez et al., (1998), Marzàn Blas (2000).

4. Crustal structure

- Crustal scale structure is constrained by published Moho depths, active seismic lines and geology.



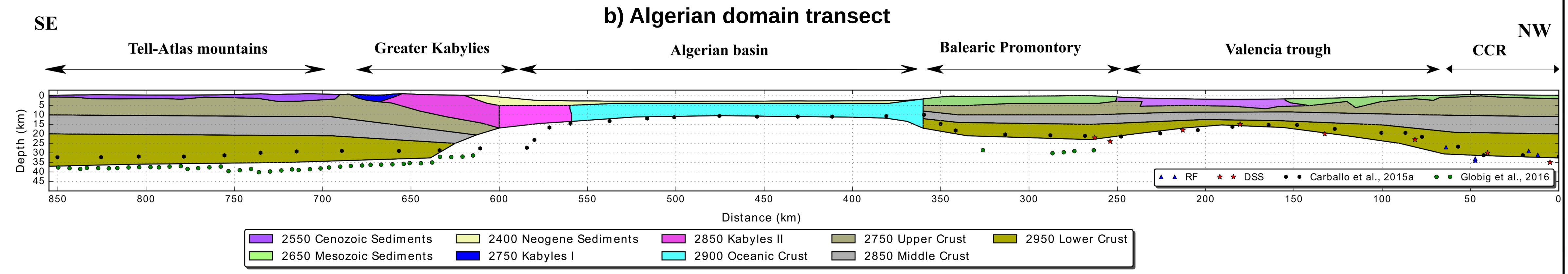


Figure 4.1 Crustal structure corresponding to the best fitting model for a) Alboran domain transect and b) Algerian domain transect. Densities used in each body are color coded (see the legend below each plot). Moho depths from previous studies (including active seismics, receiver functions, surface wave dispersion and joint modelling of gravity and elevation) are also plotted.

5. Compositions used in the upper mantle

Table5.1 Major oxide weight% for compositions used in the upper mantle.

Oxide wt%	**African continental lithosphere Av. Garnet Tecton** (Griffin et al., 1999b)	**Iberian Lithosphere in Iberian Massif CVP** (Villaseca et al., 2010)	**Iberian Lithosphere in CCR Pr_6**	**Valencia trough PUM-J** (Jagoutz et al., 1979)	**Algerian & Alboran PUM-MS** (McDonough and Sub, 1995)	**Sublithosphere DMM** (Workman and Hart, 2005)
SiO_2	44.5	44.51	45.4	45.2	45.0	44.71
Al_2O_3	3.5	3.76	3.7	4.0	4.5	3.98
FeO	8.0	8.75	8.3	7.8	8.1	8.12
MgO	39.8	37.9	39.9	38.3	37.8	38.73
CaO	3.1	3.28	3.2	3.5	3.6	3.17
Na_2O	0.24	0.36	0.26	0.33	0.36	0.13
Mg#	89.86	88.53	89.55	89.74	89.26	89.47

- In the upper mantle weight % of major oxide (Na_2O-CaO-FeO-MgO-Al_2O_3-SiO_2, NCFMAS system, Palme and O'Neill, 2013) are used to calculate thermo-physical properties using Gibbs-free energy minimisation (Connolly, 2005).

6. Upper mantle structure

- Upper mantle structure is constrained by available tomography models. High and low velocity anomalies from tomography models are incorporated in the modelling as anomalies.
- Long wavelength component of observables is well constrained.
- Computed tomography from LitMod2D fairly matches the observed tomography.

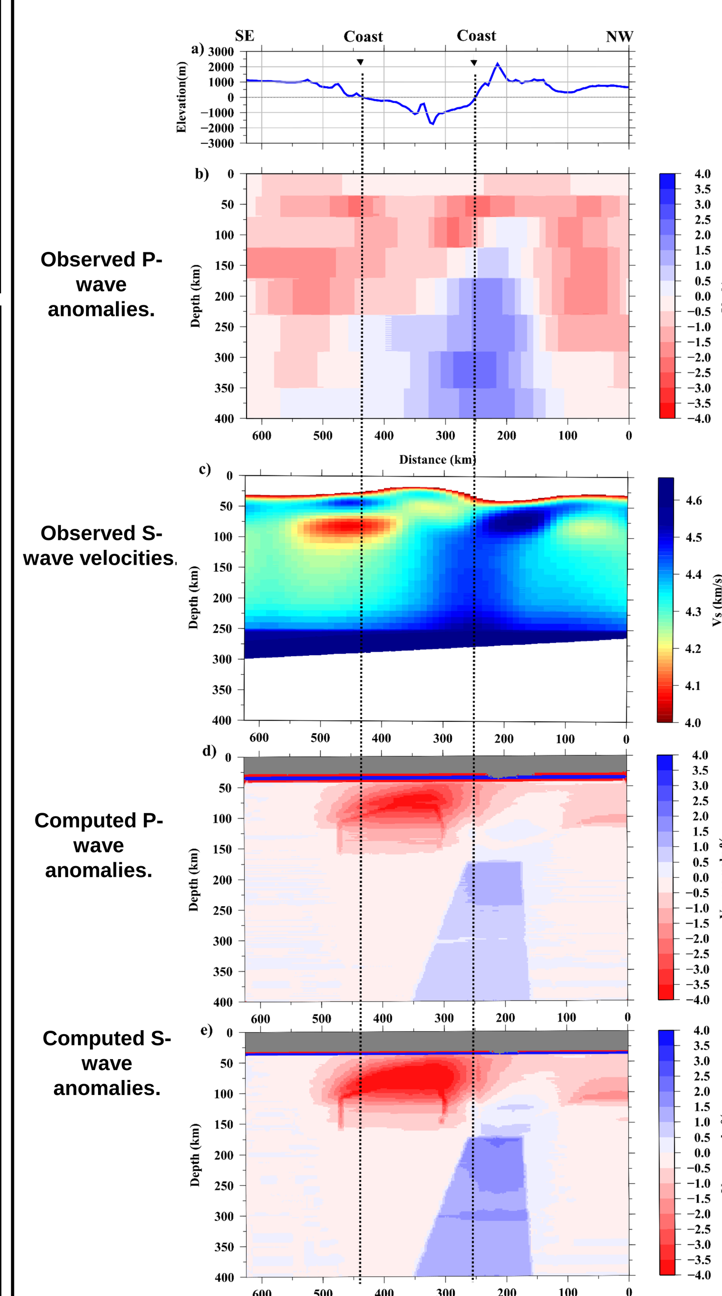


Figure 6.1 Seismic tomography models along Alboran domain transects, a) P-wave travel time topography from Villaseñor et al., (2003), b) Absolute S-wave velocity model from Palomeras et al., (2017). c) and d) calculated P- and S-wave velocity anomalies in this study.

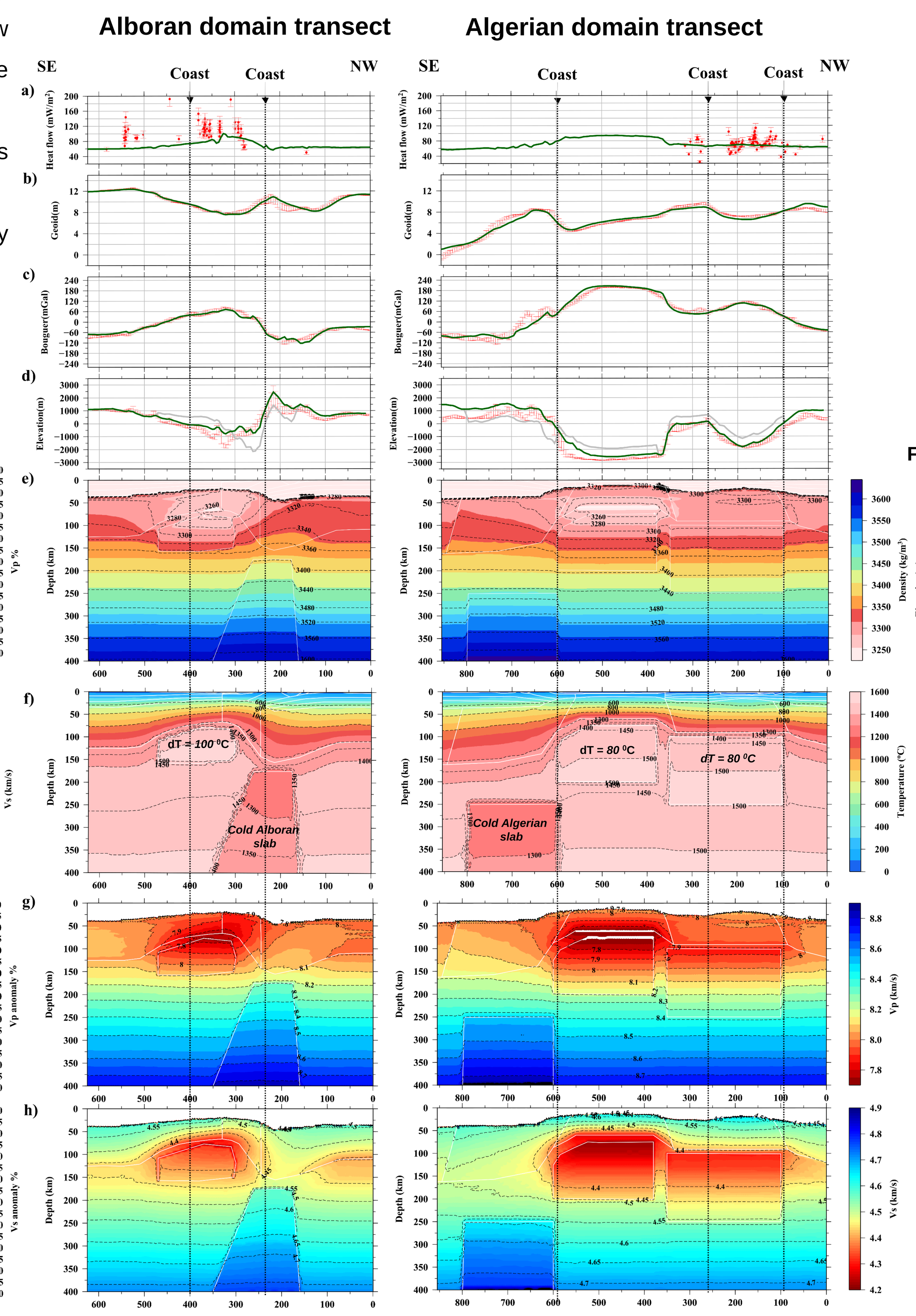


Figure 6.2. Upper mantle structure for the Alboran (left) and Algerian (right) domain transects. a) - d) Heat flow, geoid height, buoguer anomaly, and elevation (observed in red, calculated in green and coupled elevation is plotted in grey color). e) - h) shows density, temperature, P-wave velocities and S-wave velocities with depth along transects.

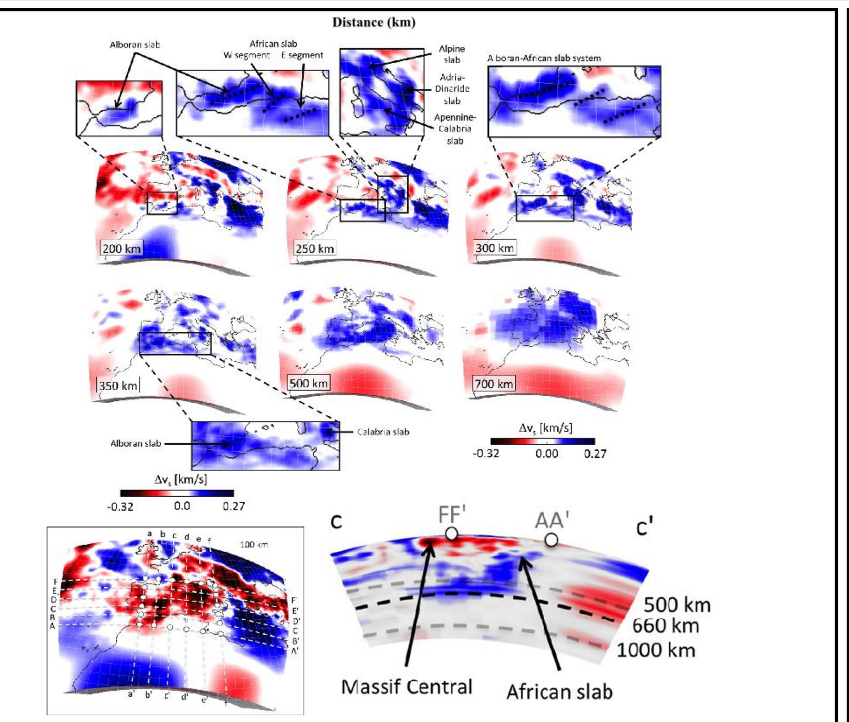


Figure 6.3 Full wavefrom inversion tomography from Fichtner & Villaseñor, 2015.

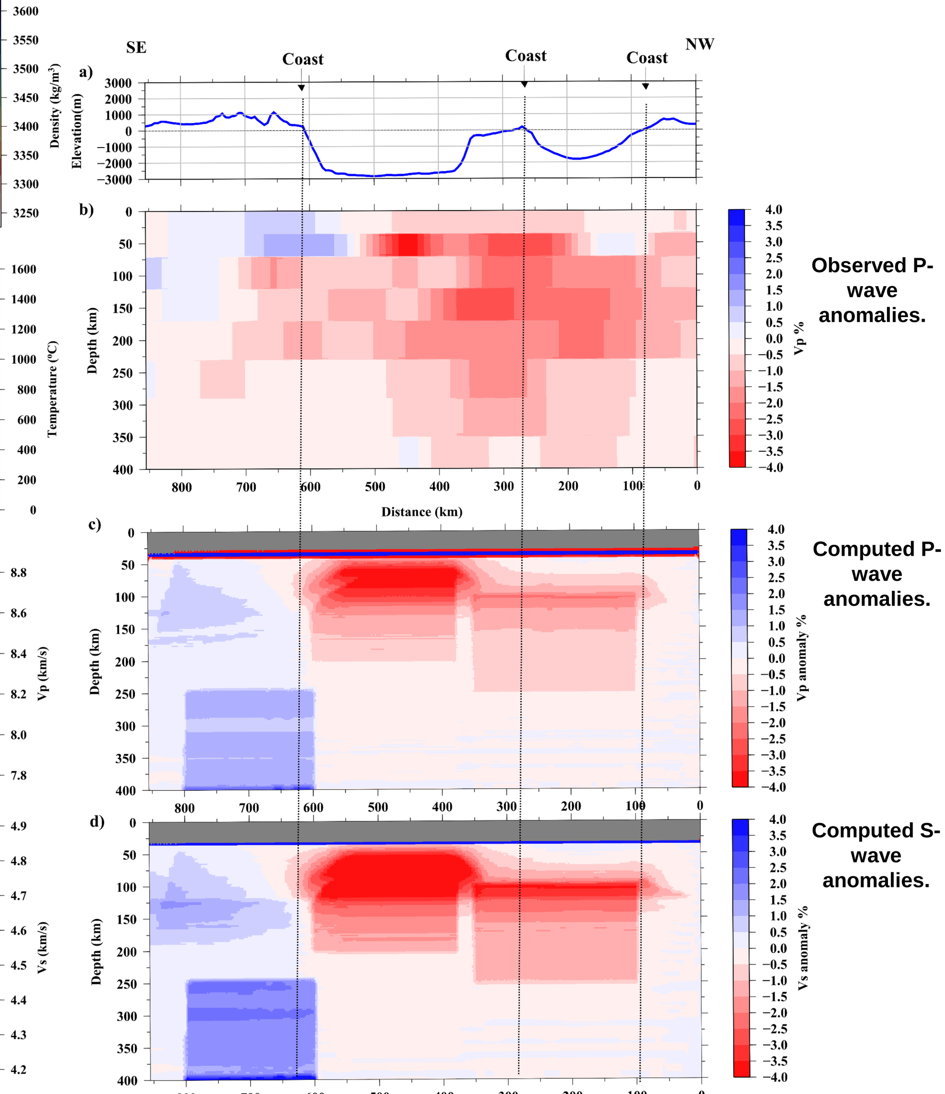


Figure 6.3. Seismic tomography models for Algerian domain transect a) P-wave travel time topography from Villaseñor et al., (2003). b) and c) calculated P- and S-wave velocity anomalies in this study.

7. Conclusions

- Present day detailed crustal and upper mantle structure is computed using integrated geophysical-petrological modelling.
- In the Alboran domain transect crust is thickest beneath the Betics (~35-40 km) and thins beneath the Alboran basin (~15-18 km) within a distance of ~100 km. Farther SE, crust gradually thickens beneath the north margin of Africa, between Tell and Rif mountains over ~300 km distance. The LAB shows a similar trend though it is affected by the presence of the slab underneath Betics.
- In the Algerian domain transect, maximum crustal thickness (~33-36 km) occurs beneath the Tell-Atlas Mountains with noticeable variations across the Algerian basin (~10-12 km), Balearic Promontory (~22-24 km) and Valencia Trough (~16-22 km). The LAB showing a similar tendency.
- Comparing the modelled geometries suggests that both transects have opposite trends with the deepest Moho and LAB in the NW side of the Alboran transect and in the SE side of the Algerian transect, imposing important restrictions on the geodynamic evolution of the Western Mediterranean.

8. Future work

- To improve the misfit for high frequency signal in the geophysical observables.
- Elevation is calculated under local isostasy assumption. Future task would be to include flexure in elevation calculations.
- To compare the crustal and upper mantle structure with the implications of geodynamic models.
- Alpine convergence has affected the area during and after the subduction. Here, aim would be to infer the convergence related to Alpine convergence.

Acknowledgements

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References

Afonso, J. C., Fernàndez, M., Ranalli, G., Griffin, W. L., and Connolly, J. A. D. (2008). Integrated geophysical-petrological modeling of the lithosphere and sub-lithospheric upper mantle: Methodology and applications. Geochemistry, Geophysics, Geosystems.
Vergés, J. and Fernàndez, M. (2012). Tethys-Atlantic interaction along the Iberia-Africa plate boundary: The Betic-Rif orogenic system. Tectonophysics, 579:144–172.
Carballo, A., et al. "From the North-Iberian Margin to the Alboran Basin: A lithosphere geo-transect across the Iberian Plate." Tectonophysics 663 (2015): 399-418.
Carballo, Alberto, et al. "Thermal and petrophysical characterization of the lithospheric mantle along the northeastern Iberia geo-transect." Gondwana Research 27.4 (2015): 1430-1445.
Spakman, Wim, and Rinus Wortel. "A tomographic view on western Mediterranean geodynamics." The TRANSMED atlas. The Mediterranean region from crust to mantle. Springer, Berlin, Heidelberg, 2004. 31-52.
Aïdi, Chafik, et al. "Deep structure of the continental margin and basin off Greater Kabylia, Algeria–New insights from wide-angle seismic data modeling and multichannel seismic interpretation." Tectonophysics 728 (2018): 1-22.
Diaz, J., J. Gallart, and R. Carbonell. "Moho topography beneath the Iberian-Western Mediterranean region mapped from controlled-source and natural seismicity surveys." Tectonophysics 692 (2016): 74-85.
Fullea, J., Fernandez, M., Zeyen, H., 2008. FA2BOUG—a FORTRAN 90 code to compute Bouguer gravity anomalies from gridded free air anomalies: application to the Atlantic–Mediterranean transition zone. Computers & Geosciences 34, 1665–1681.
Fullea, J., Fernandez, M., Afonso, J.C., Verges, J., Zeyen,H., 2010. The structure and evolution of the lithosphere–asthenosphere boundary beneath the Atlantic–Mediterranean Tran- sitionRegion. Lithos 120 (1–2), 74–95.
Fernandez, M.,Marzan, I., Correia, A., Ramalho, E., 1998. Heat flow, heat production, and lithospheric thermal regime in the Iberian Peninsula. Tectonophysics 291, 29–53.
Marzán Blas, I., 2000. Régimen térmico en la Península Ibérica. Estructura litosférica a través del Macizo Ibérico y el Margen Sur-Portugués. Tesis Doctoral Universidad de Barcelona (192 pp.).
Fichtner, A., Villaseñor, A., 2015. Crust and uppermantle of thewestern Mediterranean— constraints from full-waveform inversion. Earth Planet. Sci. Lett. 428, 52–62.
Villaseñor, A., Spakman, W., Engdahl, E.R., 2003. Influence of regional travel times in global tomographic models. Geophysical Research Abstracts. EAE03-A-08614, EGS- AGU-EUG Joint Assembly, Nice, France, vol. 5.
Palomeras, I., A. Villaseñor, S. Thurner,A. Levander, J. Gallart, and M. Harnafi (2017), Lithospheric structure of Iberia and Morocco using finite-frequency Rayleigh wave tomography from earthquakes and seismic ambient noise, Geochem. Geophys. Geosyst., 18, 1824–1840.