THE CENTRAL-EAST ATLANTIC ANOMALY: ITS ROLE IN THE GENESIS OF THE CANARY AND MADEIRA VOLCANIC PROVINCES

Chiara Civiero[1*], Susana Custódio[2], Marta Neres[2,3], David Schlaphorst[2], João Mata[2], Graça Silveira[2,4]

(1) Dublin Institute for Advanced Studies (DIAS), Dublin D02 Y006, Ireland, (2) Instituto Dom Luiz (IDL), Faculdade de Ciências, Universidade de Lisboa, Lisbon, Portugal, (3) Instituto Português do Mar e da Atmosfera (IPMA), Lisbon, Portugal, (4) Instituto Superior de Engenharia de Lisboa, Lisbon 1959-007, Portugal

EGU General Assembly 2021
vEGU21: Gather Online

1. Introduction

- In the Central Atlantic Ocean, widespread volcanism has occurred since the Late Cretaceous.
- Conventional hotspot models (e.g., "Hawaii" model) cannot easily explain the irregular spatial distribution of the volcanism, the long history of volcanic activity or large periods of quiescence at some islands or seamounts within the Canary and Madeira Provinces.

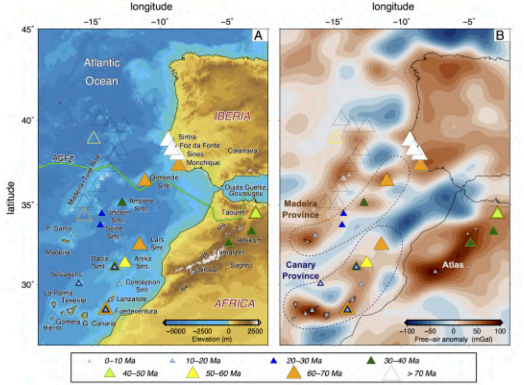


Figure 1. A. Elevation of Western Iberia, Northwestern Africa, and Central-East Atlantic. Triangles of different sizes and colors show the locations and ages of basaltic volcanism. B. Satellite-derived long-wavelength (300-km filtered) free-air gravity anomaly.

2. Regional body-wave tomography

Differently shaped low-velocity anomalies in the upper mantle (and topmost lower mantle) interpreted as:

- The Canary upwelling (~150-200 km wide), with a long tail throughout the upper mantle;
- The blob-type Madeira upwelling (~100 km wide), apparently disconnected from the MTZ;
- The sub-vertical low-velocity 'wall' below the Atlas Mountains, down to the base of the MTZ.

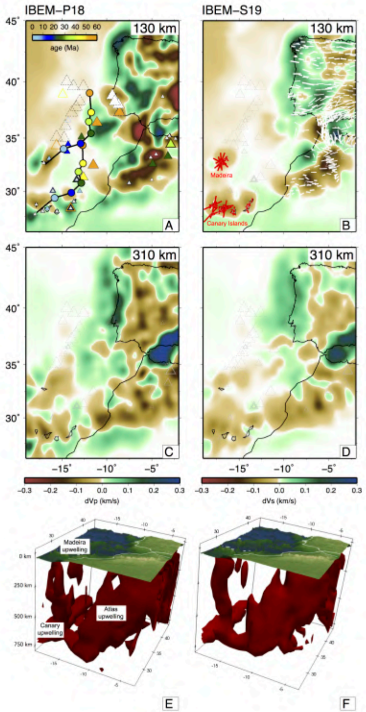


Figure 2. Slices at 130-km (A-B) and 310-km depth (C-D) of the regional models. Predicted hotspot tracks of the Madeira and Canaries are plotted on top. All the available SKS-splitting measurements in Iberia and Morocco are shown in white and those in the Canaries and Madeira (Schlaphorst et al., 2021) in red. E, F. 3D low-velocity structure shown as velocity anomaly isosurfaces.

3. Resolution tests

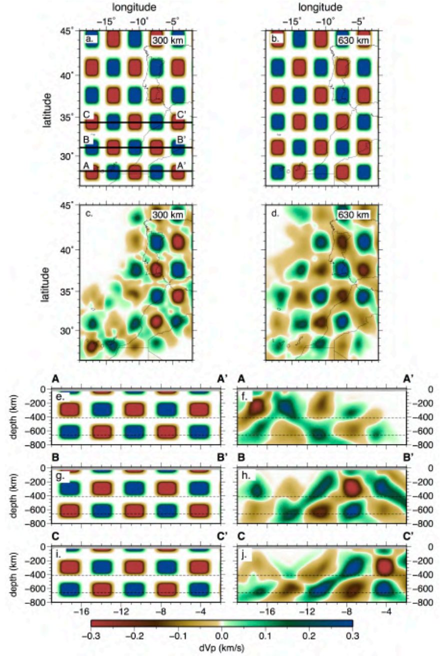


Figure 3. Checkerboard resolution tests for the P-wave tomography model IBEM-P18 (Civiero et al., 2018), using alternating high- and low-velocity anomalies of ~140 km width and ±0.5 km/s in amplitude.

*cciviero@cp.dias.ie

#vEGU21
vEGU21: Gather Online | 19-30 April 2021

4. Gravity signal

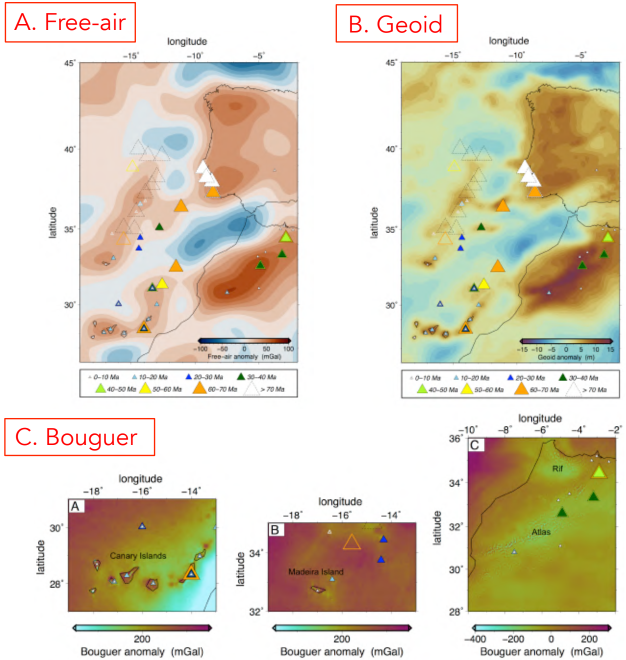


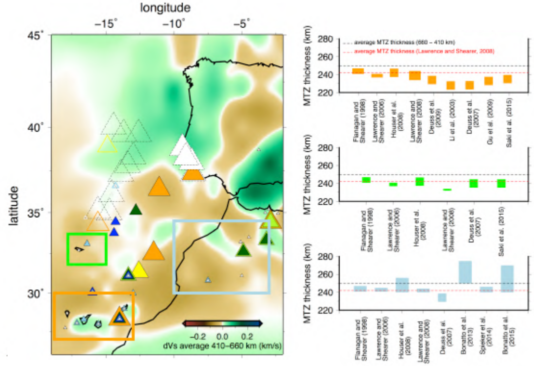
Figure 4. A. Satellite derived long-wavelength (500-km filtered) free-air obtained from the compilation by Sandwell et al., (2014).

B. The geoid anomaly illustrated is computed from the free-air anomaly data using the GMT 'grdfft' module.

C. The Bouguer anomaly is calculated from the free-air grid considering a standard crustal density of 2600 kg/m^3 onshore, and a density contrast of 1570 kg/m^3 between crust and water densities for the offshore domain.

- The Canary and Madeira's topographic highs have > 30 mGal positive long-wavelength free-air anomalies, which are stronger in amplitude where slow seismic velocities are imaged, i.e, around western Canaries and Madeira.
- High geoid anomalies that follow the orientation of the hotspot tracks and reach a maximum of 8-10 m below the hotspots, and local positive (> 240 mGal) Bouguer anomalies.
- The correspondence of strong gravity anomalies with areas of slow velocities supports the existence of deep-seated processes centered under the Canaries and Madeira.

5. Transition-zone thickness



- Thinned MTZ beneath the Canaries indicating that the MTZ is likely crossed by material hotter than the ambient mantle.
- A slightly thinned or close-to-average MTZ thickness is also found below Madeira by global studies.

Figure 5. Compilation of the MTZ thickness values below the Canary Islands, Madeira, and Atlas Mountains see Table).

6. Geochemistry

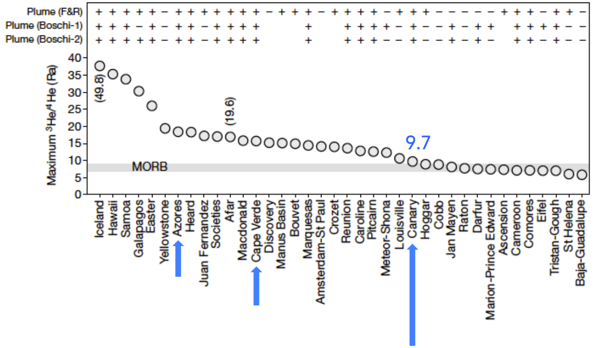


Figure 6. From Jackson et al. (2017). The maximum 3He/4He values at 38 hotspots organized in order of decreasing maximum 3He/4He.

- The maximum value at Canaries (R/Ra = 9.7) is only marginally higher than those usually reported for N-MORB (8±1). However, as shown by Day and Hilton (2011), such values were obtained for lavas with a strong HIMU component. This indicates the involvement of a component with significantly higher R/Ra than 9.7.
- No published R/Ra values for Madeira yet.

*cciviero@cp.dias.ie

7. 'Vote' analysis of the lower mantle

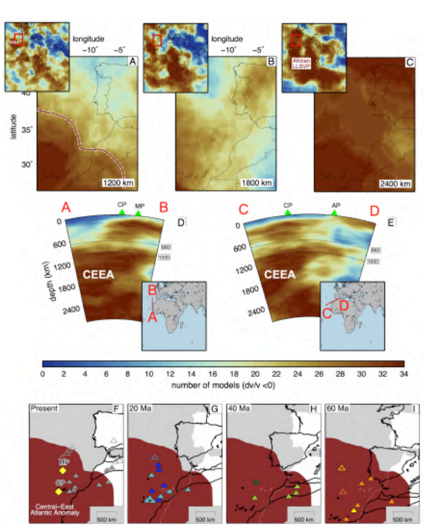


Figure 7. A-E. Low-velocity vote maps and cross-sections based on 34 global tomographic models. F-I. GPlates-based plate reconstruction of the Central-East Atlantic and adjacent regions from 60 Ma to present.

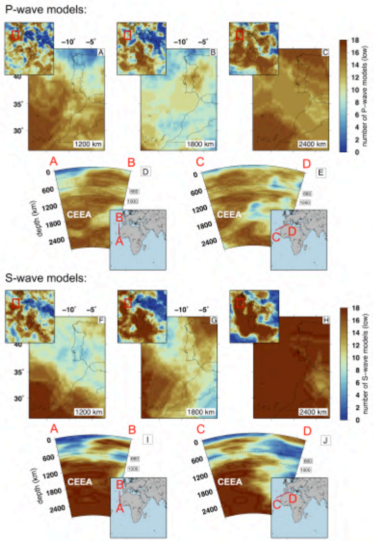


Figure 8. Vote images combining only the P-wave models (panels A-E) and the S-wave models (panels F-J). Note the CEEA is clear in both P- and S-wave vote maps, but the lateral extent is broader in the P-wave maps at ~1200 km depth.

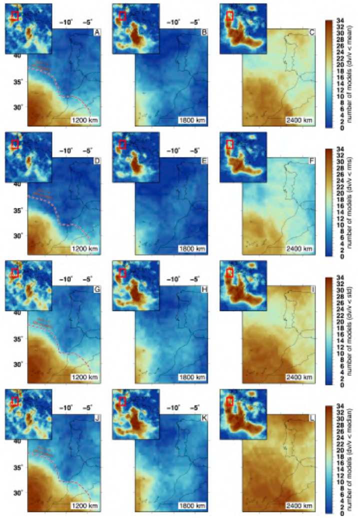


Figure 9. Vote maps at 1200-2400 km depth range using four different threshold metrics (mean, rms, std, and median) which are 'stricter' than the zero metric (dv/v <0) in Figures 7-8.

- A large dome-like low-velocity anomaly, the Central-East Atlantic Anomaly (CEAA), extends upward from the base of the African LLSVP.
- A 'layer' of hot material is stalled below the 660-km depth discontinuity, and possibly deeper, at ~1,000-km depth.

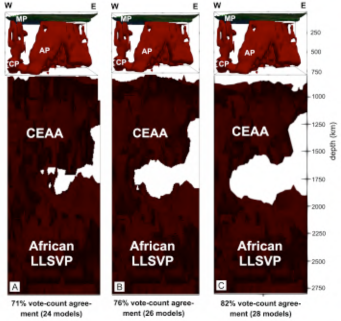
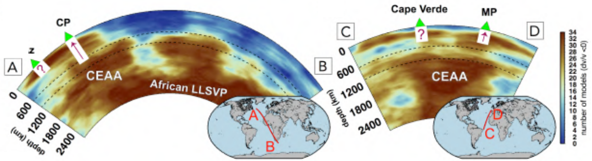


Figure 10. 3D isosurfaces plot of the 'CEAA' below our region of study detected in the vote analysis from 24 models (71% agreement, A), 26 models (76% agreement, B), and 28 models (82% agreement, C). The low-velocity structure resolved by the regional model IBEM-P18 is plotted in the upper mantle.



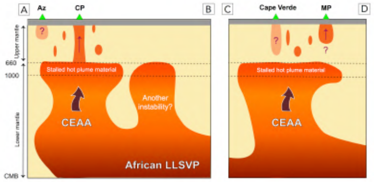


Figure 11. Left: 'Vote' cross-sections through the Canaries (CP), Azores (Az) (A-B) and through Cape Verde and Madeira (MP) (C-D). Right: Interpretative model of the mantle structure imaged.

8. Take-home message

- ✓ The Canary and Madeira hotspots are underlain by distinct upwellings sourced from the lower-mantle Central-East Atlantic Anomaly (CEAA).
- ✓ A vote analysis shows that the CEAA extends vertically upward from the base of the African LLSVP and stalls at ~700-1200 km depth.
- ✓ The plumelets seem at different stages of evolution and rise sporadically from mantle material accumulated below the 660-km discontinuity.

*cciviero@cp.dias.ie

#vEGU21
vEGU21: Gather Online | 19-30 April 2021