Investigating the plate kinematics of continental blocks and their role on the deformation experienced along the Iberia-Eurasia plate boundary using deformable plate tectonic models

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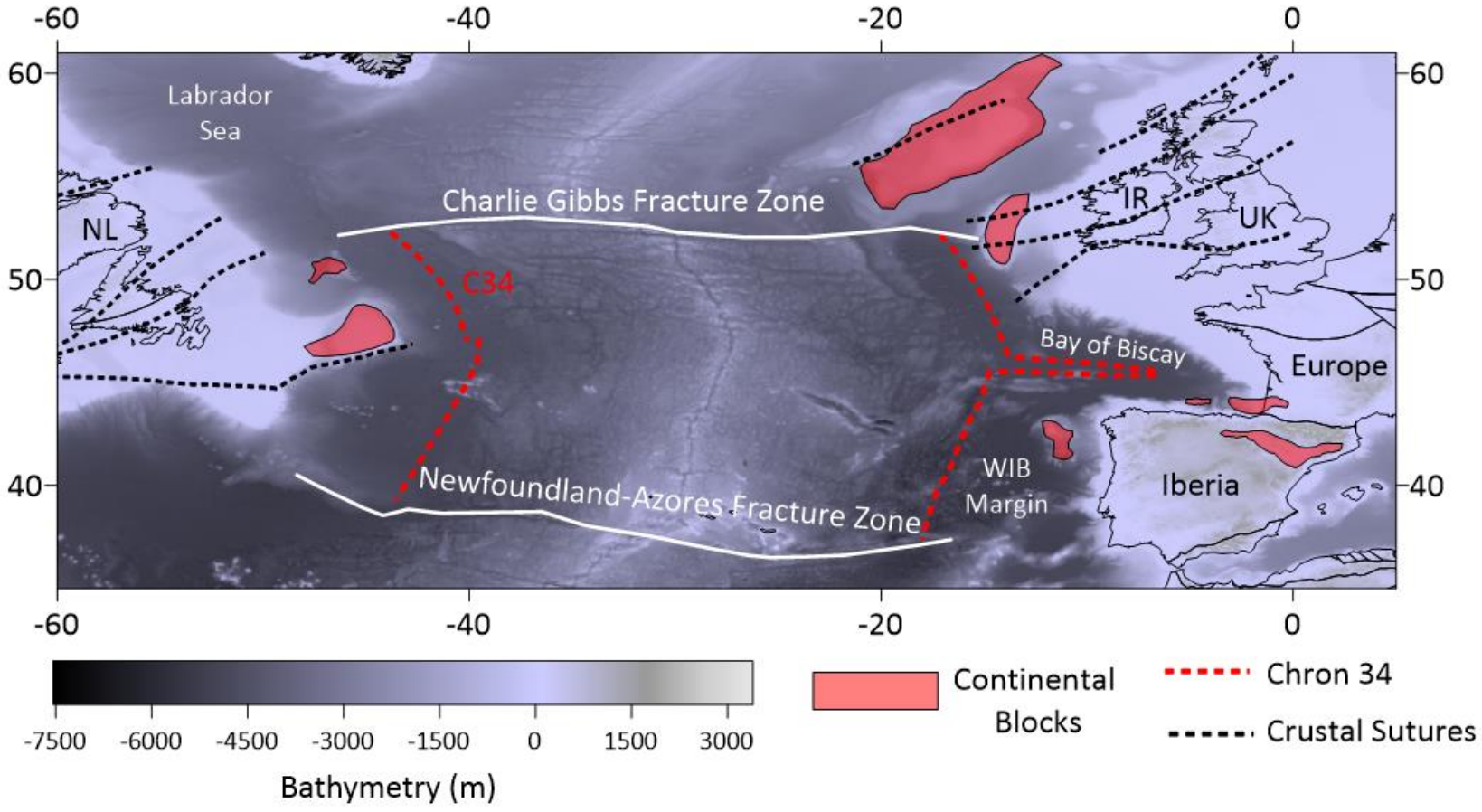
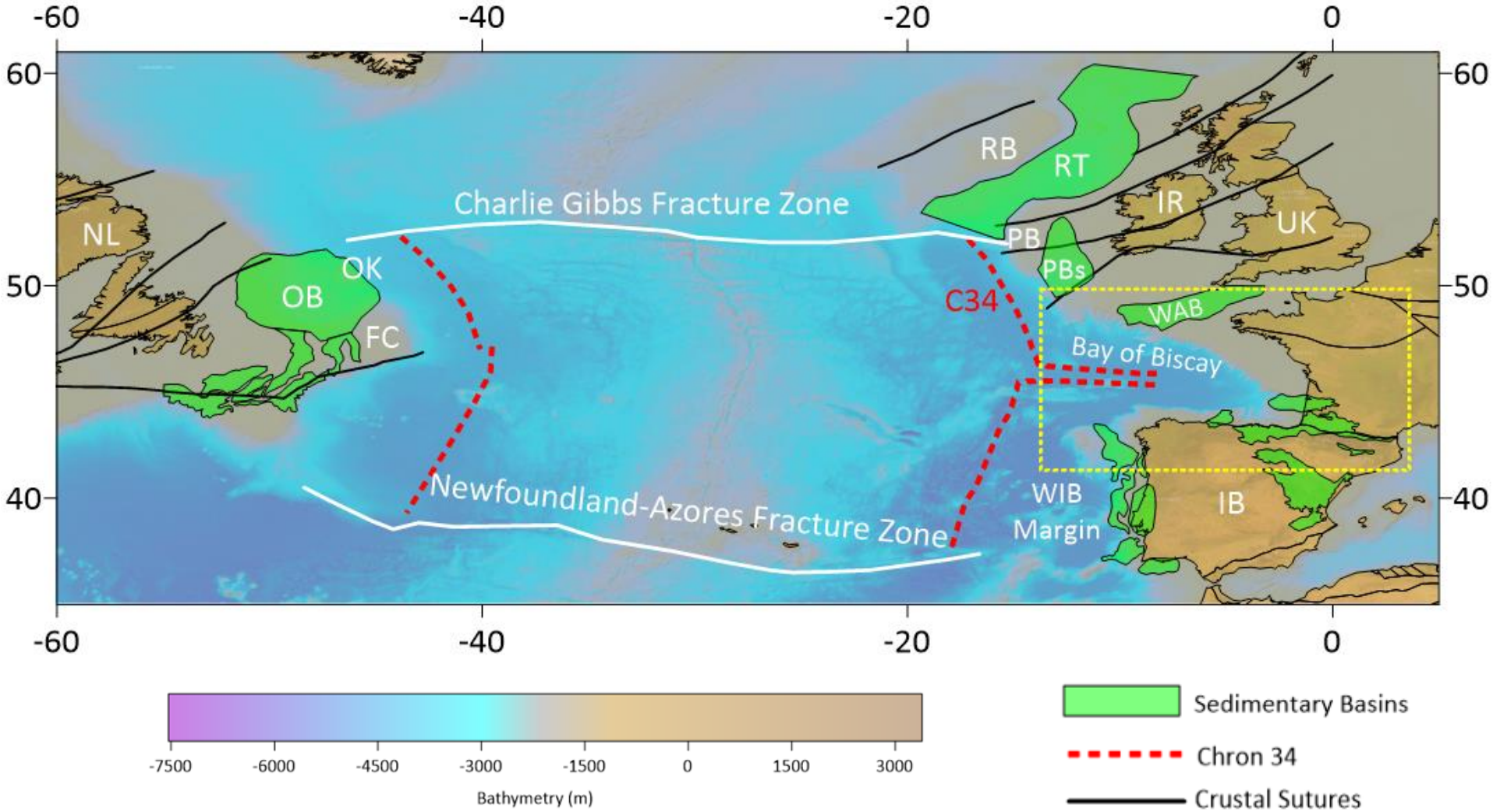
MAGRiT

Continental Blocks - Introduction



- Continental blocks:
  - Smaller blocks of continental crust surrounding larger tectonic plates.
  - Crustal thicknesses range from ~ 20 – 35 km thick.
- Numerous examples throughout the southern North Atlantic:
  - Galicia Bank (WIB margin)
  - Flemish Cap (NL margin)
  - Landes High (Bay of Biscay)
  - Ebro Block (Pyrenees)

Area of Interest – Iberia-Eurasia Plate Boundary



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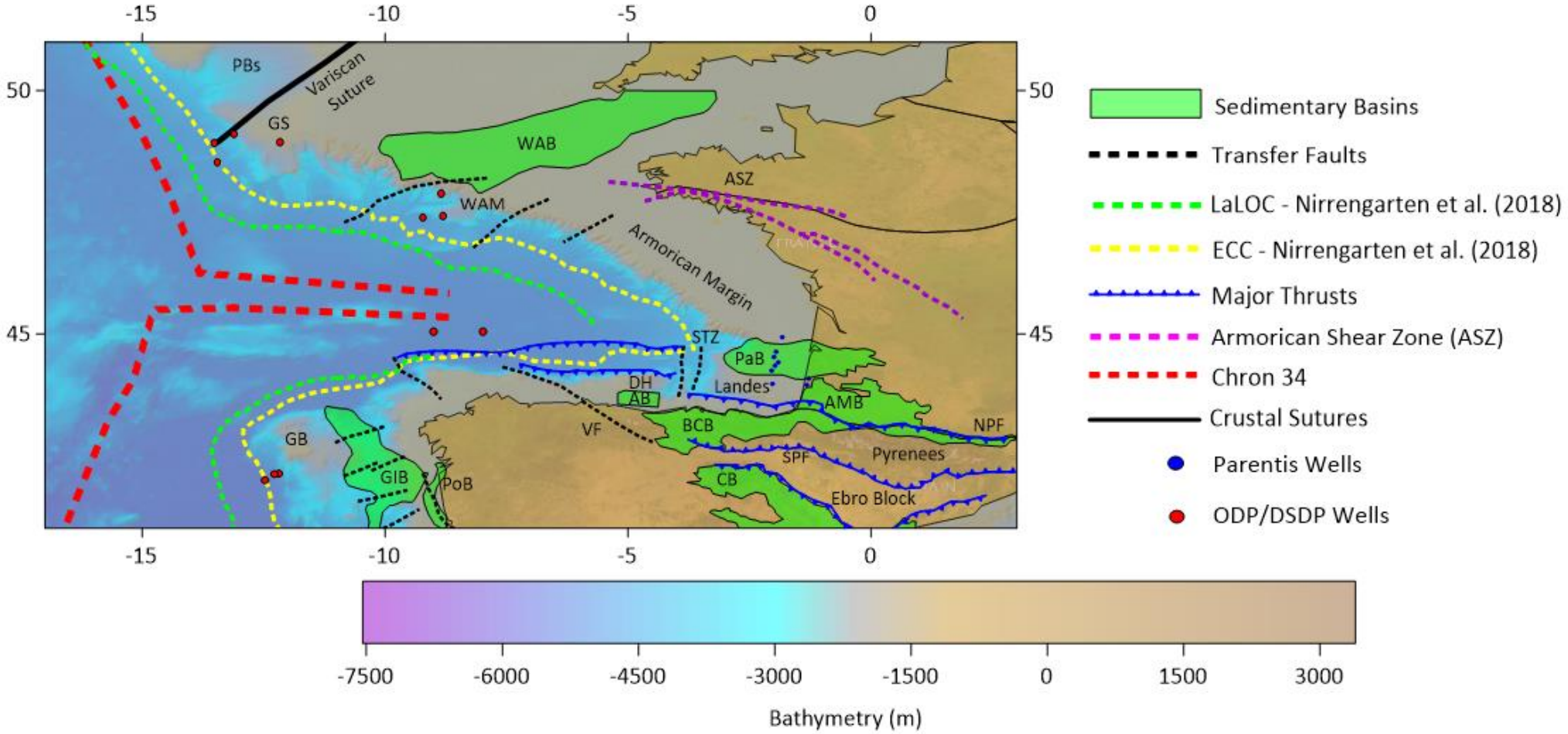
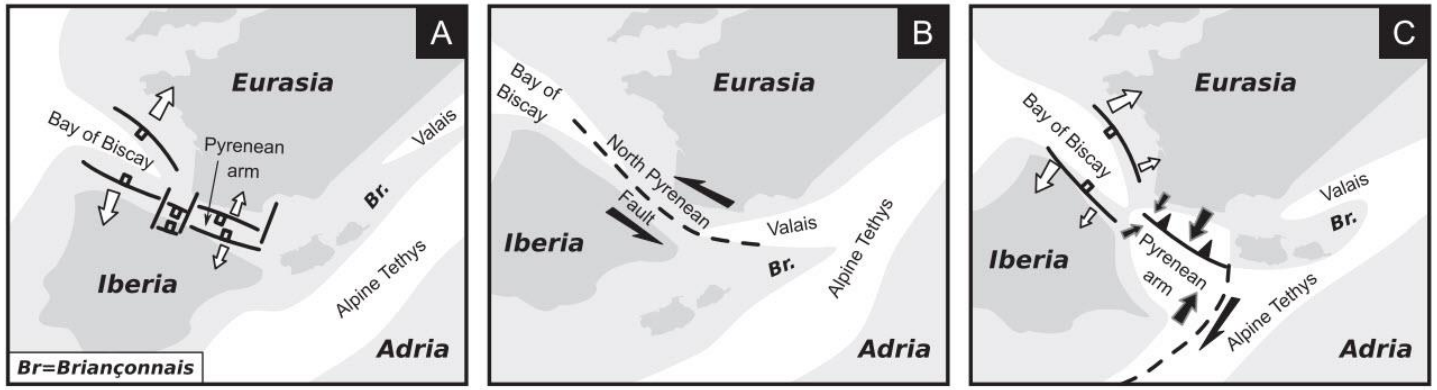
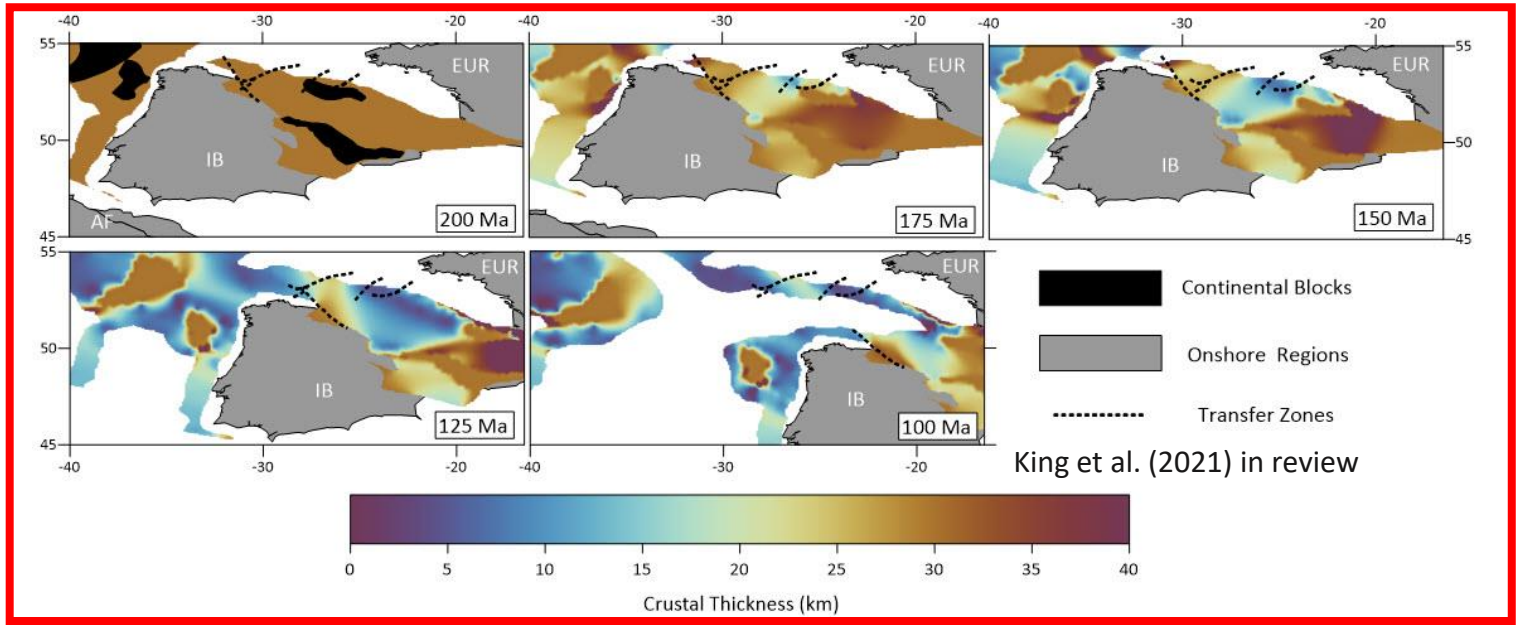


Motivation – Iberian Plate Kinematics

Tavani et al. (2018)

Mid-Cretaceous plate kinematic models of Iberia



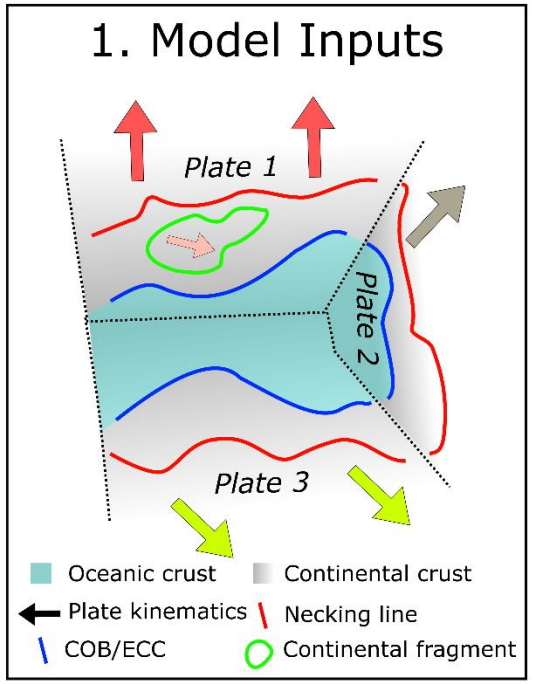


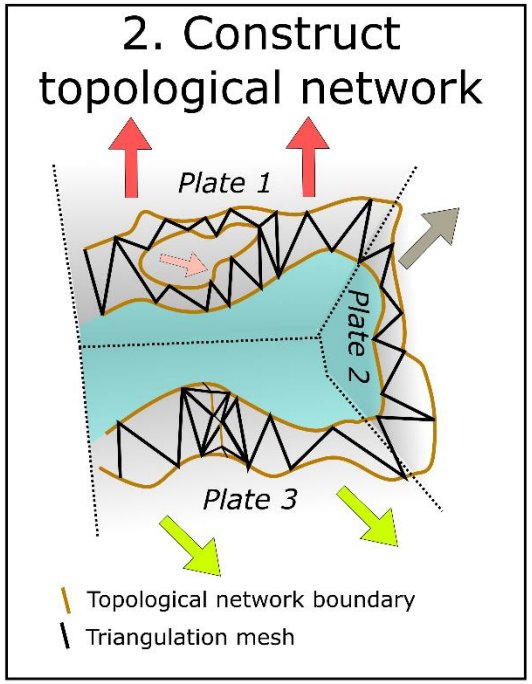
King et al. (2021) in review

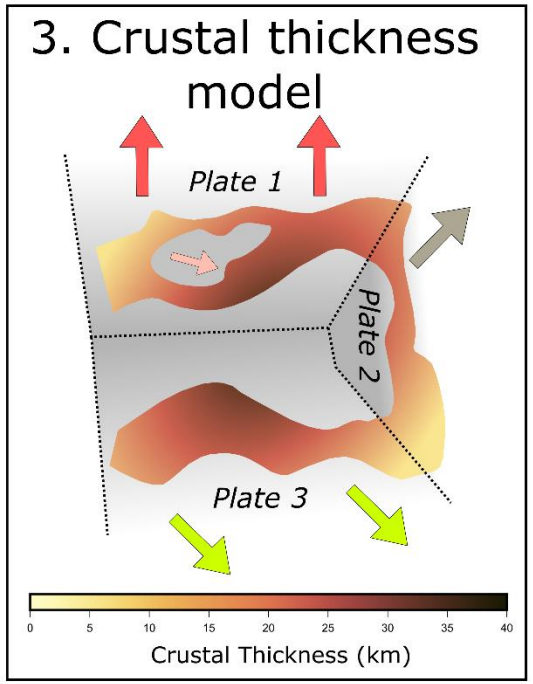
- Numerous rigid plate tectonic reconstructions of Iberia have been proposed.
- Our goal is to investigate previous reconstructions and build new ones using deformable plate tectonic models (example in the red outline).
- This will entail:
  - Investigating the kinematics of continental blocks:
    - Ebro Block
    - Landes High
    - Galicia Bank
  - Evaluate temporal variations in:
    - Strain Rate
    - Crustal Thickness
    - Stretching Factors

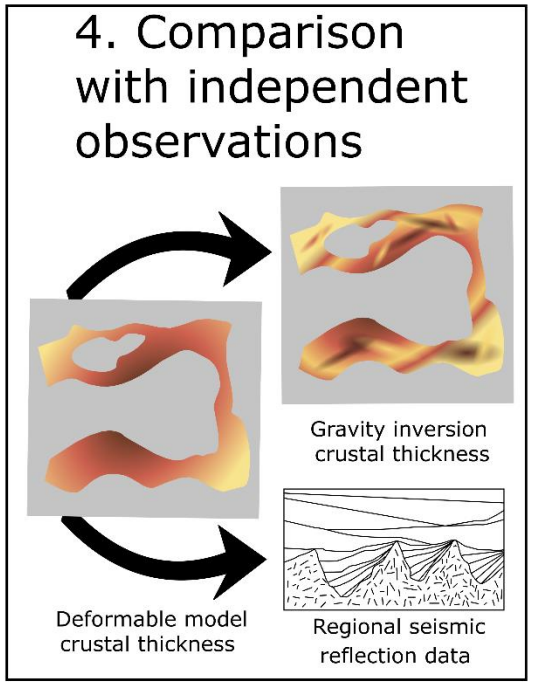
Methodology

- Deformable plate tectonic models built using GPlates 2.2.
- Model inputs:
  - Deformable boundaries
  - Continental blocks
- Model assumptions
  - Hard boundaries of deformation.
  - Constant crustal thickness assumption (e.g. 30 km) for a start time of interest.
  - Rheological and depth-dependent parameters not accounted for.
- Constrained by independent observations:
  - Gravity inversion
  - Seismic refraction/reflection profiles





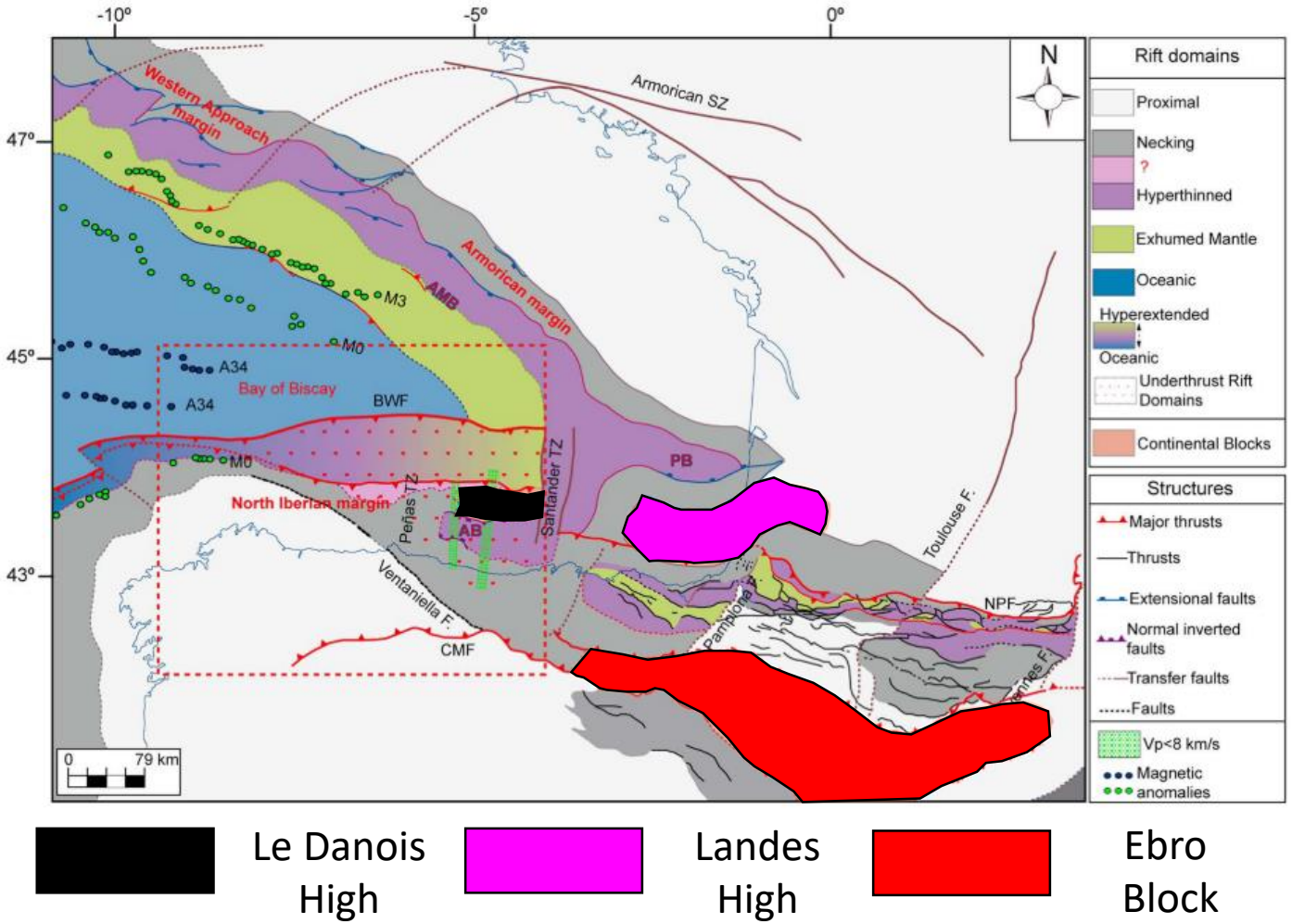




King et al. (2021) in review

Starting Point – Bay of Biscay Kinematics

modified after Cadenas et al. (2018)



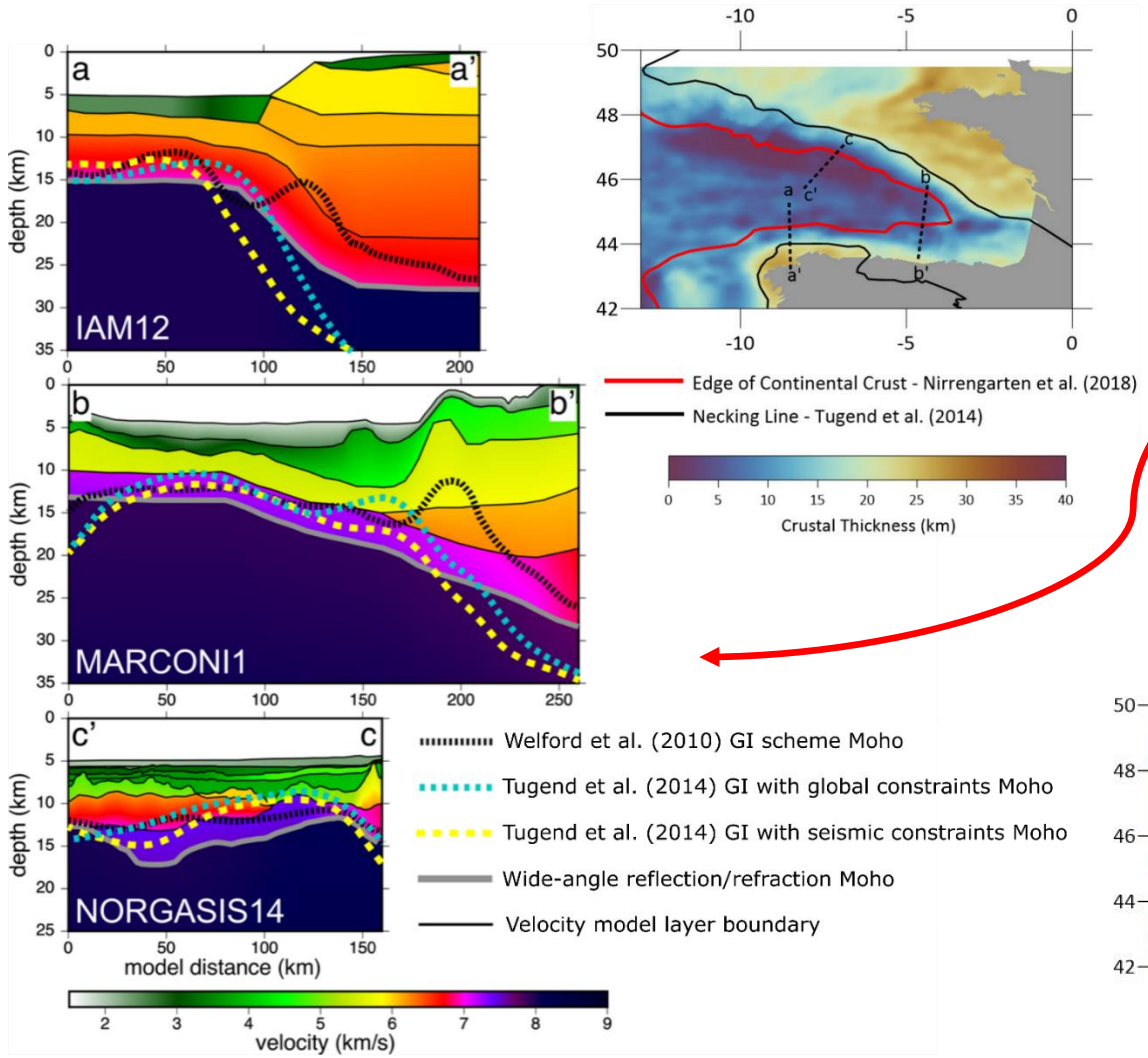
Le Danois High

Landes High

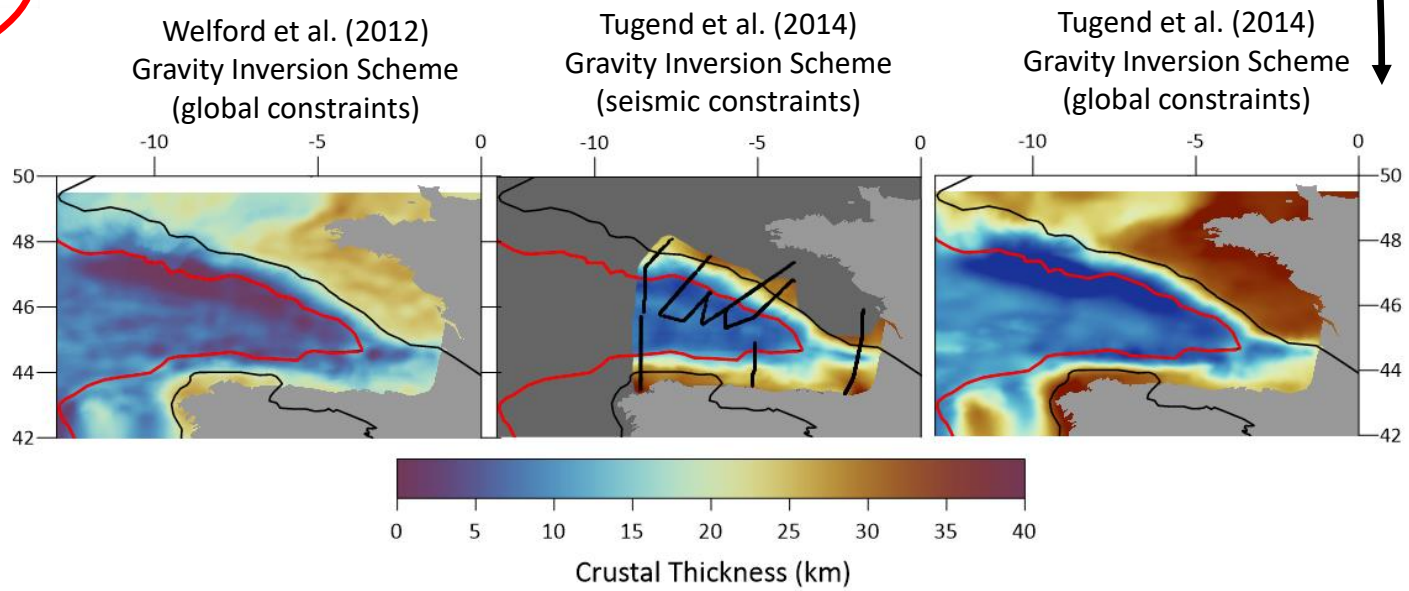
Ebro Block

- Investigating the plate kinematic evolution of the offshore Bay of Biscay-Parentis rift system:
  - North Iberian margin
  - Armorican margin
  - Western Approaches margin
- Product of poly phased rifting.
- Several continental blocks considered:
  - Landes High
  - Le Danois High
  - Ebro Block.

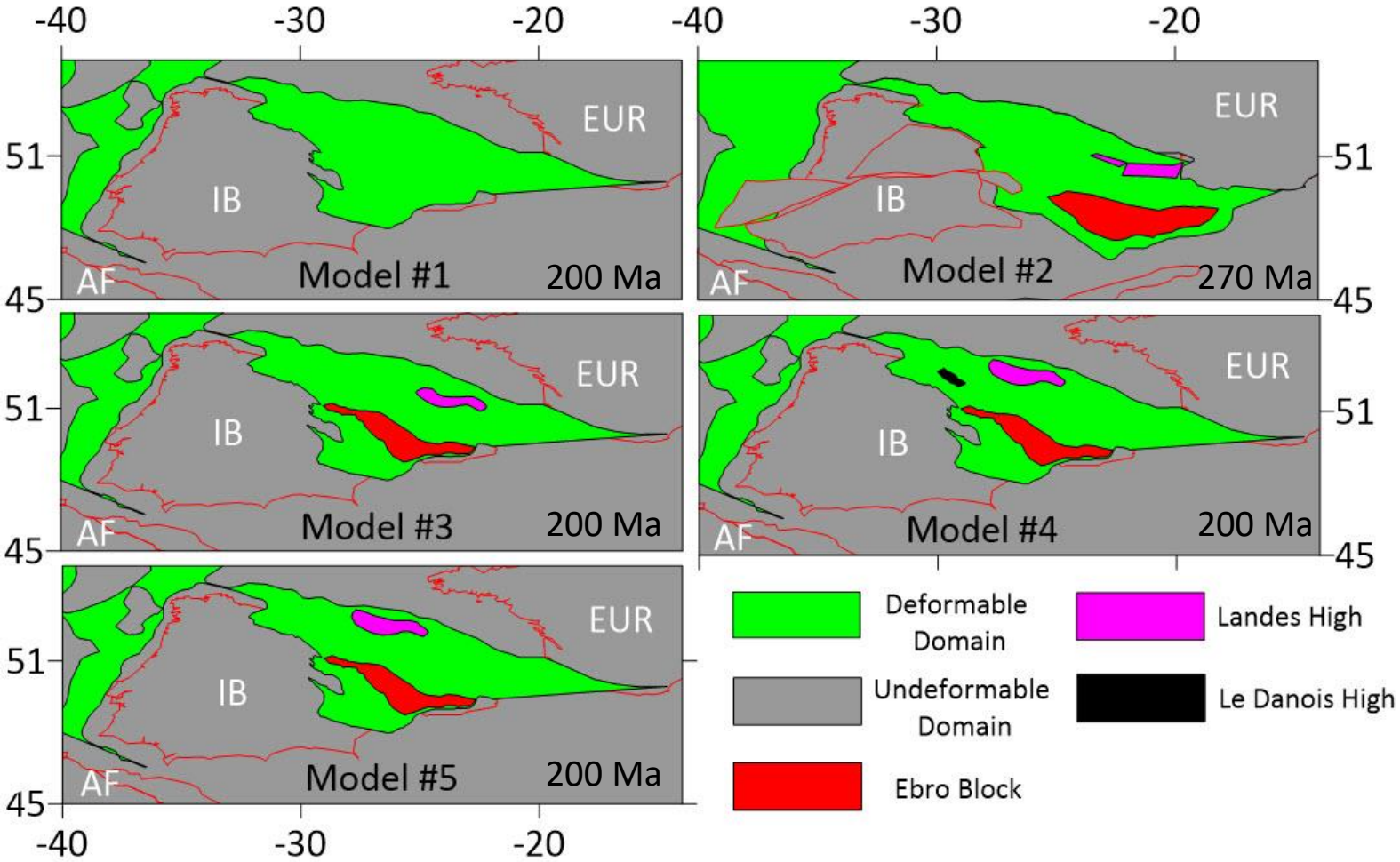
Bay of Biscay – Present Day Crustal Structure



- Gravity inversion crustal thickness estimates (below):
  - Welford et al. (2012) and Tugend et al. (2014) inversion schemes.
- Refraction velocity models (to the left):
  - Fernández-Viejo et al., 1998 (IAM12), Ruiz et al., 2017 (Marconi 1), and Thinon et al., 2003 (Norgasis 14).



Bay of Biscay Deformable Plate Models



King et al. (2021) in review

**Model specifics on the following slide

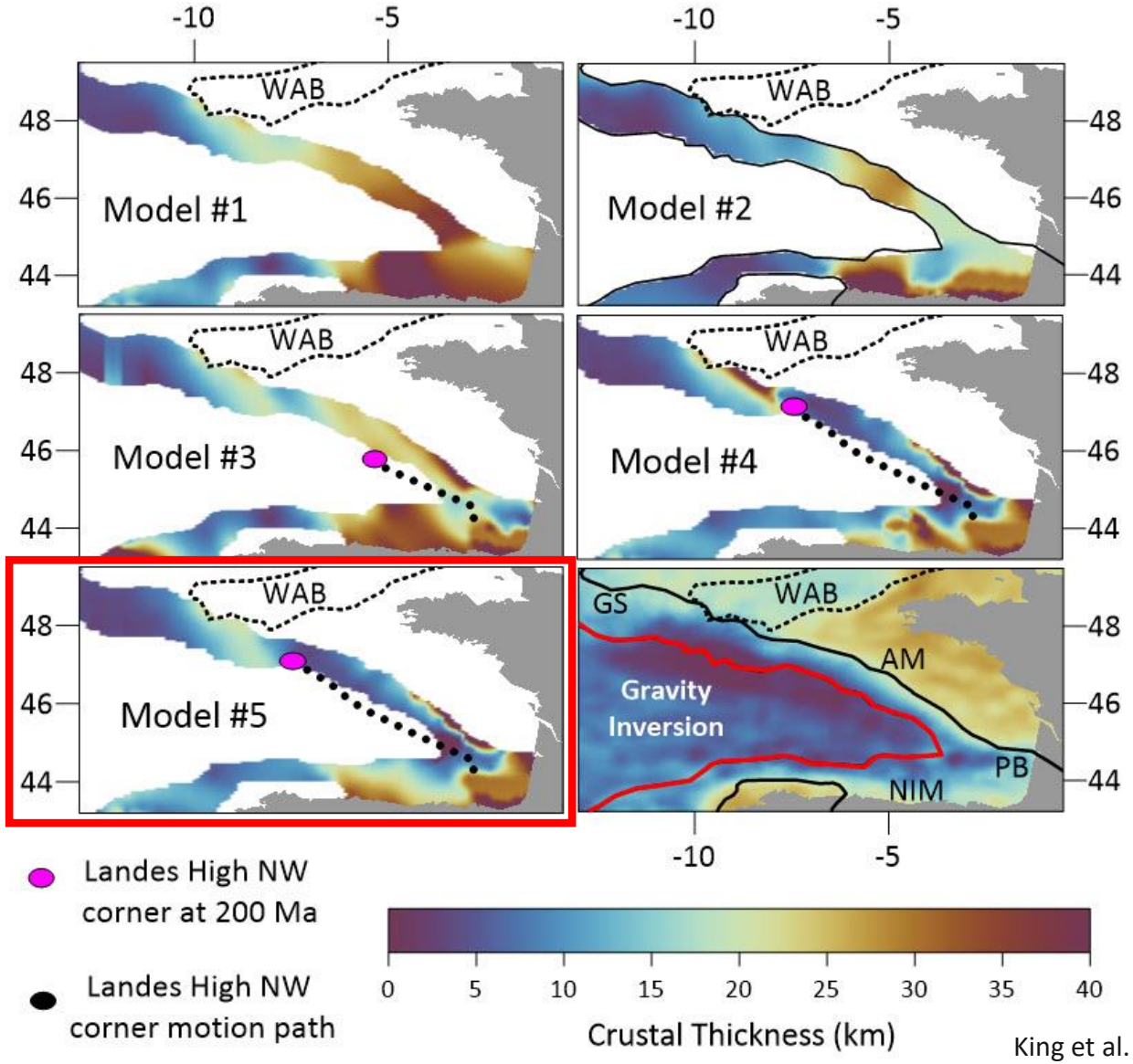
- 5 models considered.
- Variations between each model:
- **Deformable model boundaries:**
  - Necking line
  - Edge of continental crust (ECC).
- **Inclusion and kinematics of continental blocks:**
  - Landes High
  - Le Danois High
  - Ebro Block.

Bay of Biscay Deformable Plate Model Specifics

Model #	Iberia Poles of Rotation	Model Start Time	Le Danois High Included	Landes High Included	Landes High Starting Point	Landes High Geometry	Ebro Block Included	Ebro block geometry
1	Nirrengarten et al. (2018)	200 Ma	No	No	NA	Tugend et al. (2014)	No	NA
2	Angrand et al. (2020)	270 Ma	No	Yes	Angrand et al. (2020)	Angrand et al. (2020)	Yes	Angrand et al. (2020)
3	Nirrengarten et al. (2018)	200 Ma	No	Yes	Nirrengarten et al. (2018)	Tugend et al. (2014)	Yes	Tugend et al. (2014)
4	Nirrengarten et al. (2018)	200 Ma	Yes	Yes	This study	This study	Yes	Tugend et al. (2014)
5	Nirrengarten et al. (2018)	200 Ma	No	Yes	This study	This study	Yes	Tugend et al. (2014)

Present Day Crustal Thickness Results

Preferred Model



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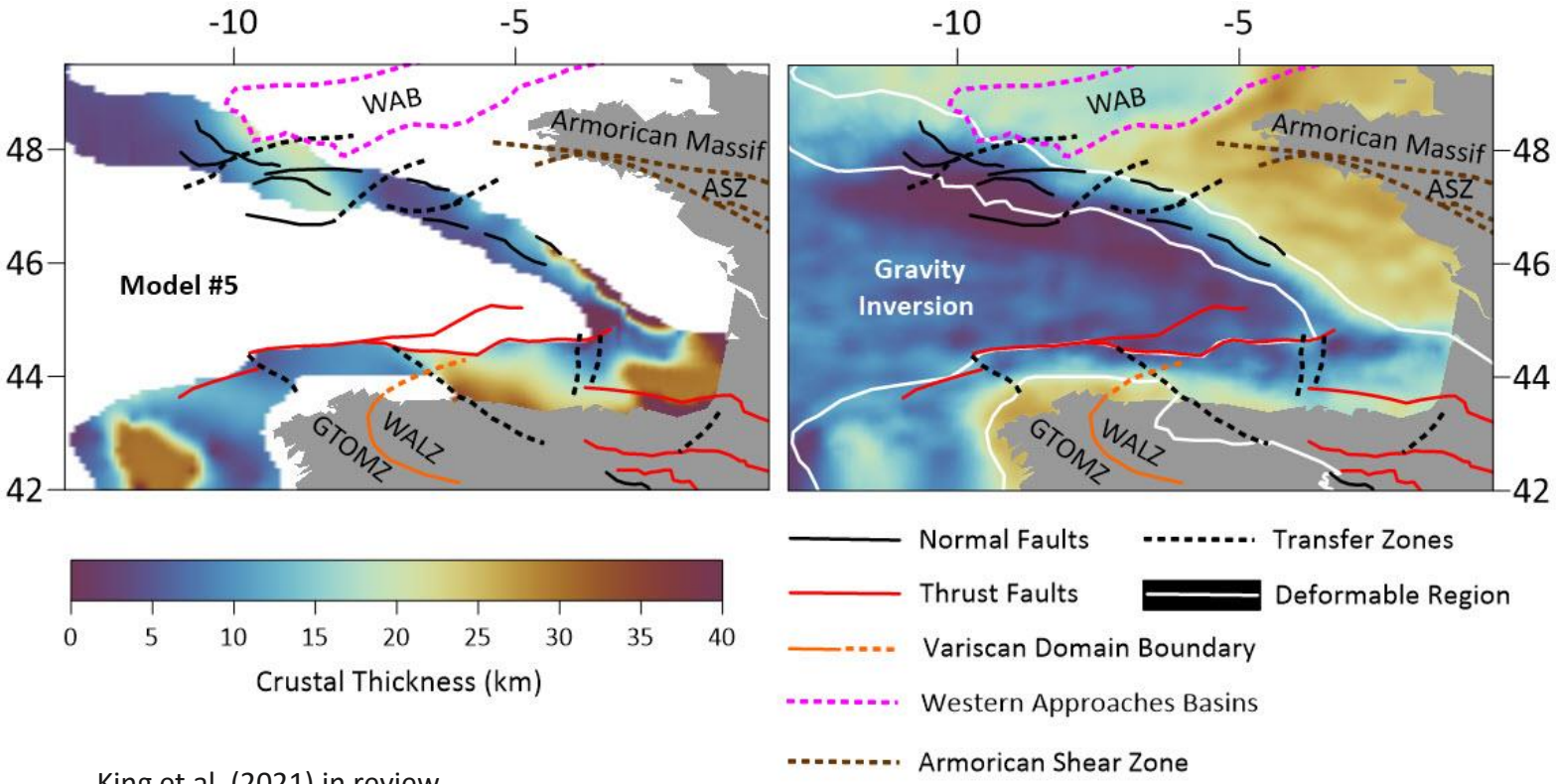
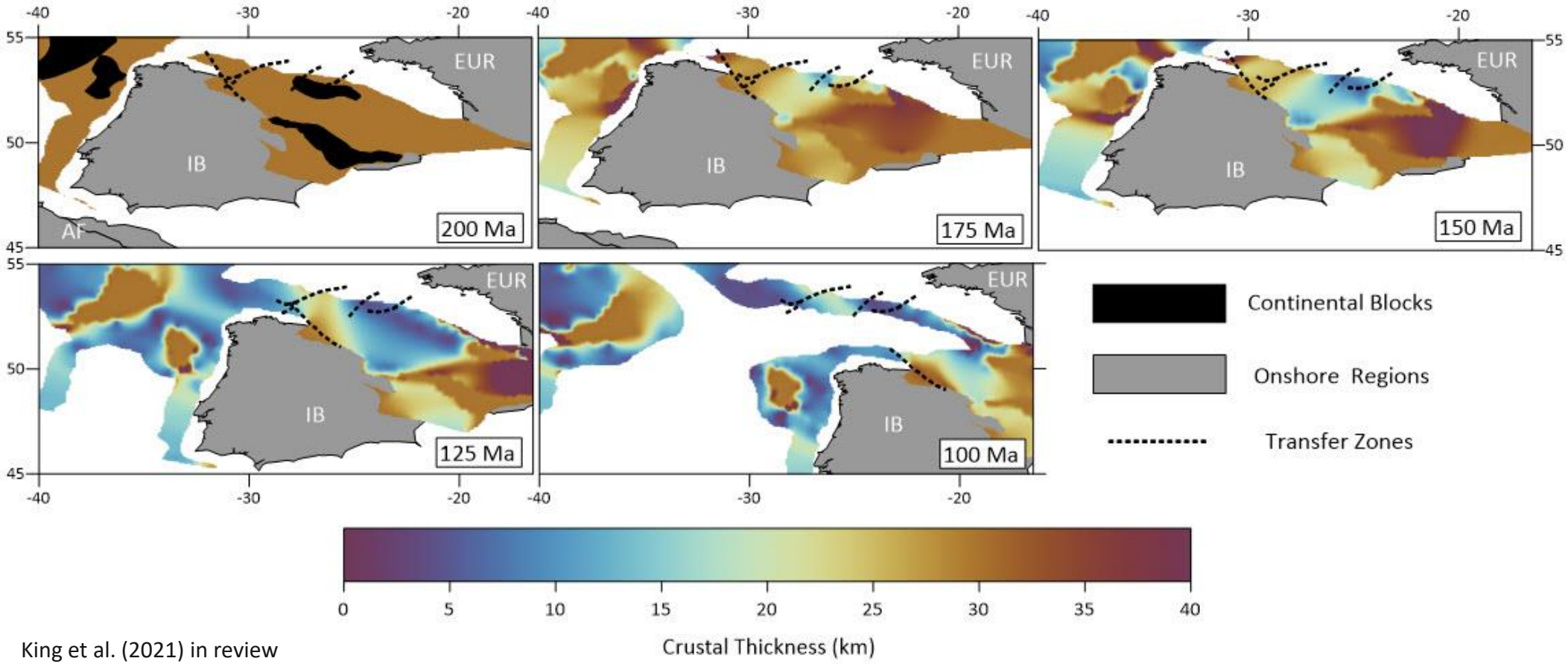
Preferred Bay of Biscay Model – Model 5



King et al. (2021) in review

- Similar crustal thickness variations as observed by gravity inversion.
- Best correlations with observations from seismic and well data.
- Largest discrepancies in areas with onshore to offshore structural complexity:
  - Western Approaches margin
  - Goban Spur
  - North Iberian margin

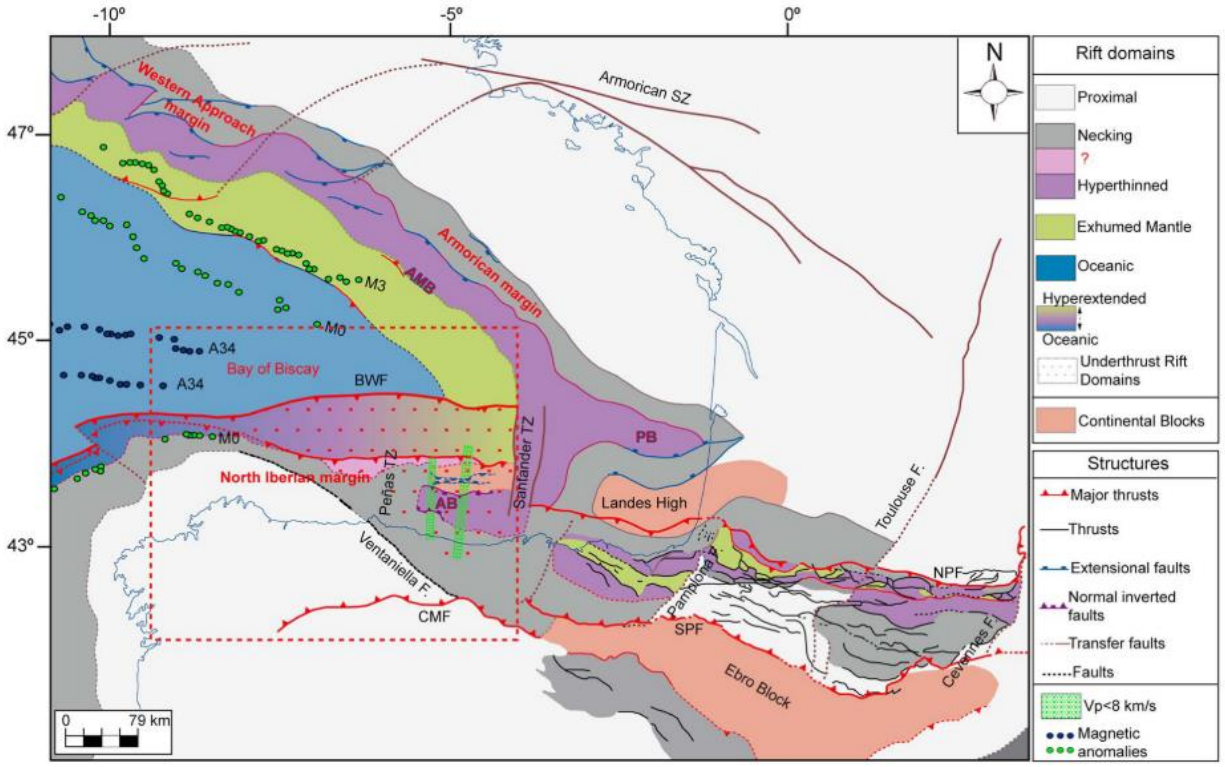
Model 5 Crustal Thickness Evolution



King et al. (2021) in review

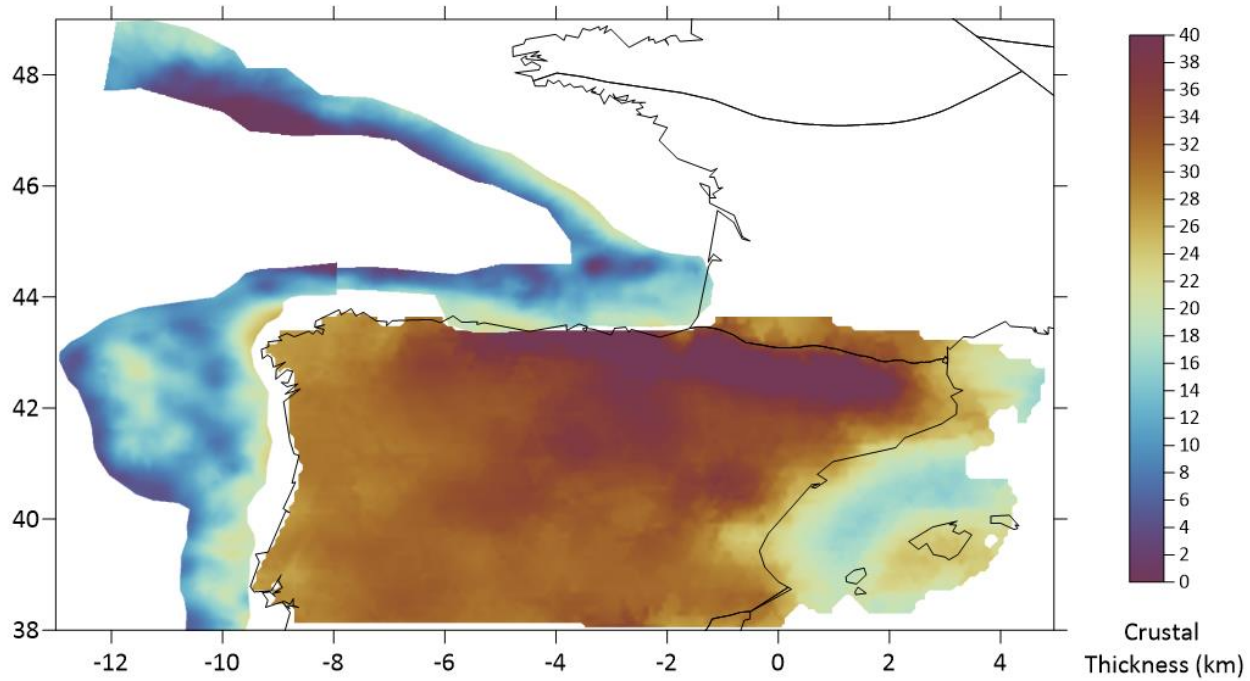
Next Step – Investigating the Pyrenean Realm

Cadenas et al. (2018)



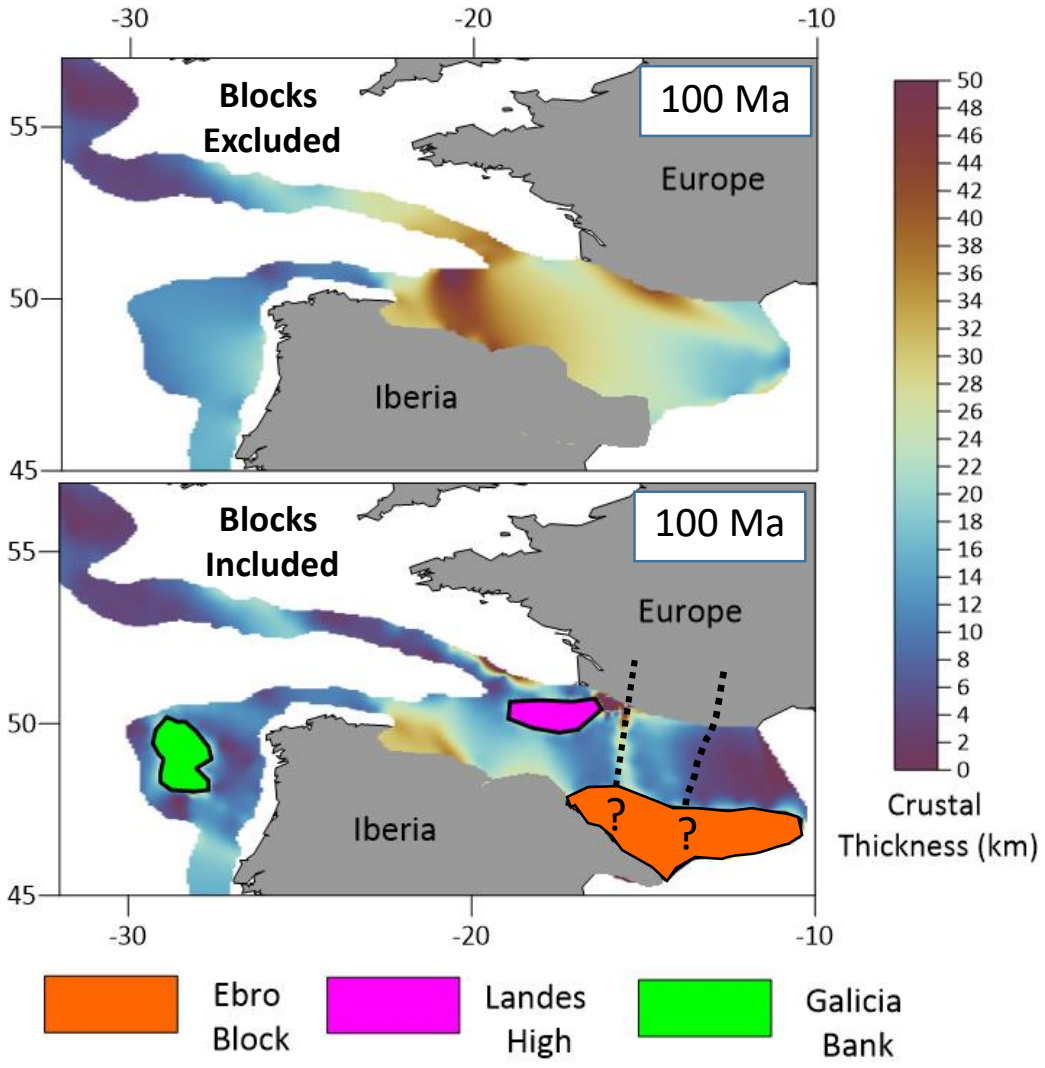
- Investigating the geometry and kinematics of the Ebro Block:
  - Previously published plate models
  - Newly presented plate models
  - Investigating rift domain boundaries

- Evaluating the kinematics of the Pyrenees from rift to orogeny.
- Constraining results using:
  - Crustal thickness (gravity inversion) and Moho depth constraints (passive seismic).
  - Crustal restorations
  - Geological field observations

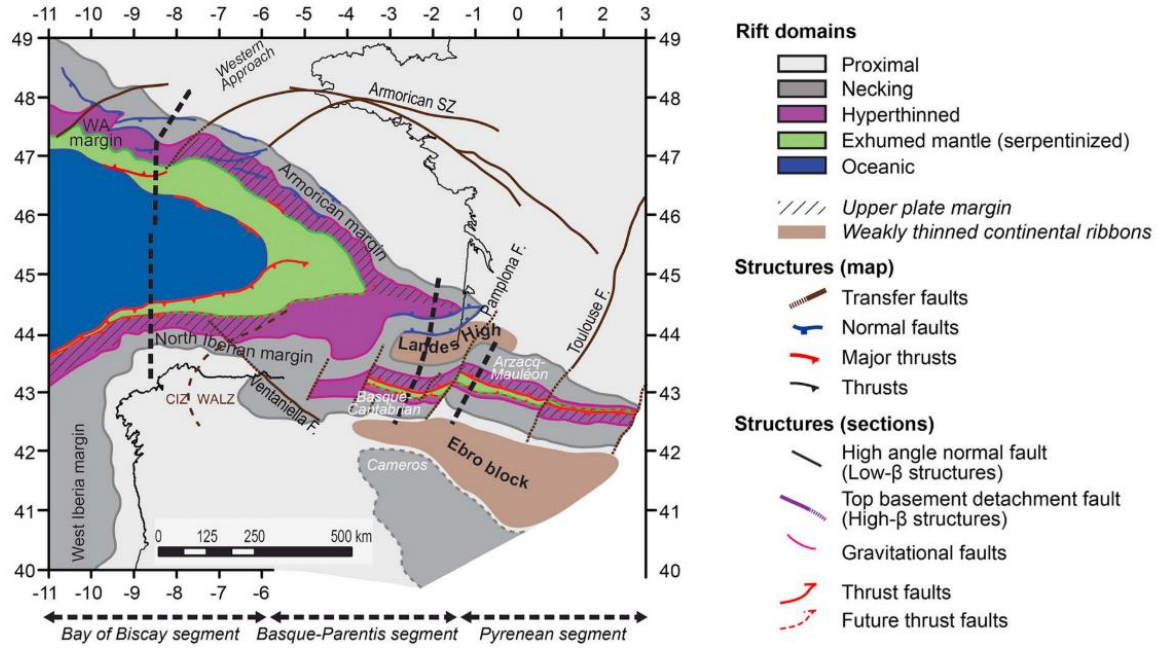


modified after Diaz et al. (2016)

Preliminary Results - Pyrenees



- Preliminary observations:
  - Strain partitioning during the Mid-Cretaceous highly segmented by inherited transfer zones (Pamplona and Toulouse zones) and the Ebro Block kinematics.
  - Variability in the kinematics of the Ebro Block during the Cretaceous induced by inheritance?



Tugend et al. (2014)

Conclusions

- Main conclusions of this work:
  1) Oblique extension and strain partitioning prior to the opening of the Bay of Biscay were largely influenced by the independent plate kinematics of the Landes High and its interplay with the Ebro Block.
  2) Ebro block played a very minimal role during formation of the Bay of Biscay, however, a much more influential role within the Pyrenean realm.
  3) Major lithospheric boundaries such as the Ventaniella Fault and Armorican Shear Zone appear to have played a significant role in rift segmentation and shaping the present day crustal architecture of the Bay of Biscay. It is likely that these lithospheric boundaries follow inherited/pre-existing Variscan and Late Carboniferous-Early Permian structural trends.
  4) Considering the independent kinematics of continental blocks and their impact on the deformation experienced along the Iberia-Eurasia plate boundary represents an alterative approach moving forward to develop a more detailed understanding of strain partitioning along the Iberia-Eurasia plate boundary.

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