TS 7.8 - From rifting to orogeny: the case of the Pyrenees and related basins

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A reconstruction of Iberia accounting for W-Tethys/N-Atlantic kinematics since the late Permian-Triassic

Paul Angrand — GET Université Paul Sabatier, Toulouse, France

Frédéric MOUTHEREAU — GET Université Paul Sabatier, Toulouse, France

Emmanuel MASINI — M&U sas, Saint Egreve, France; ISTerre, Université Grenoble Alpes, France

Riccardo ASTI — Université de Rennes, Rennes, France

Online version of this work

Under review for Solid Earth. Check out the initial submission:

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Watch the animated kinematic reconstruction: https://vimeo.com/414662449

Introduction

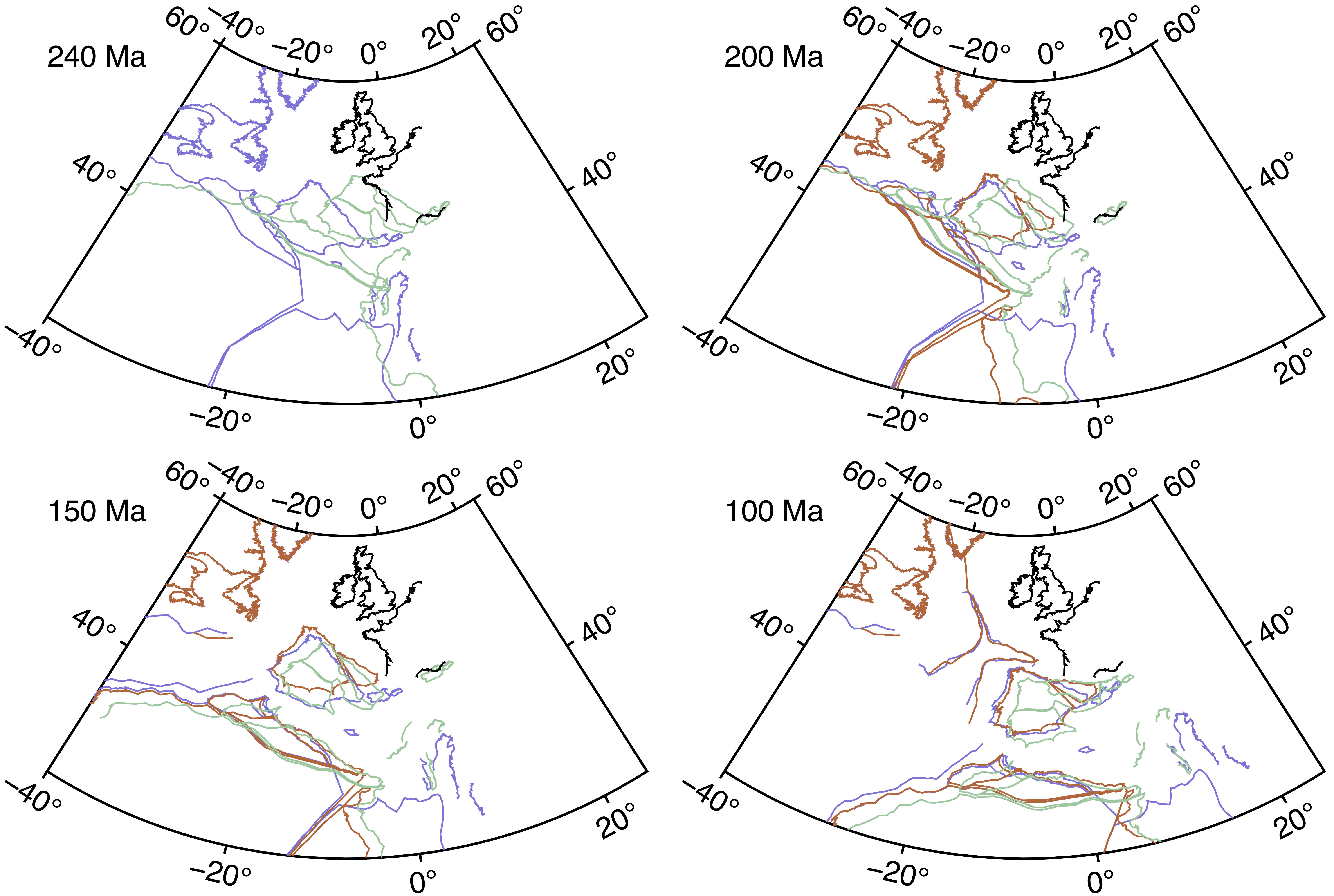
Questions

- Can we better define the spatial and temporal distribution of strike-slip movement between Iberia and Europe (~400-500 km)?
- Can we better constrain the Iberian kinematics since the late Paleozoic?
- What is the role of Late Permian-Triassic phase in the evolution of Iberia in the frame of the Atlantic-Tethys system?

Aims of this study

- Kinematic reconstruction from Late Permian to Middle Cretaceous (270-100 Ma) (that includes Atlantic and western Tethys domains)
- Intra-plate deformation in Iberia (Ebro continental block)

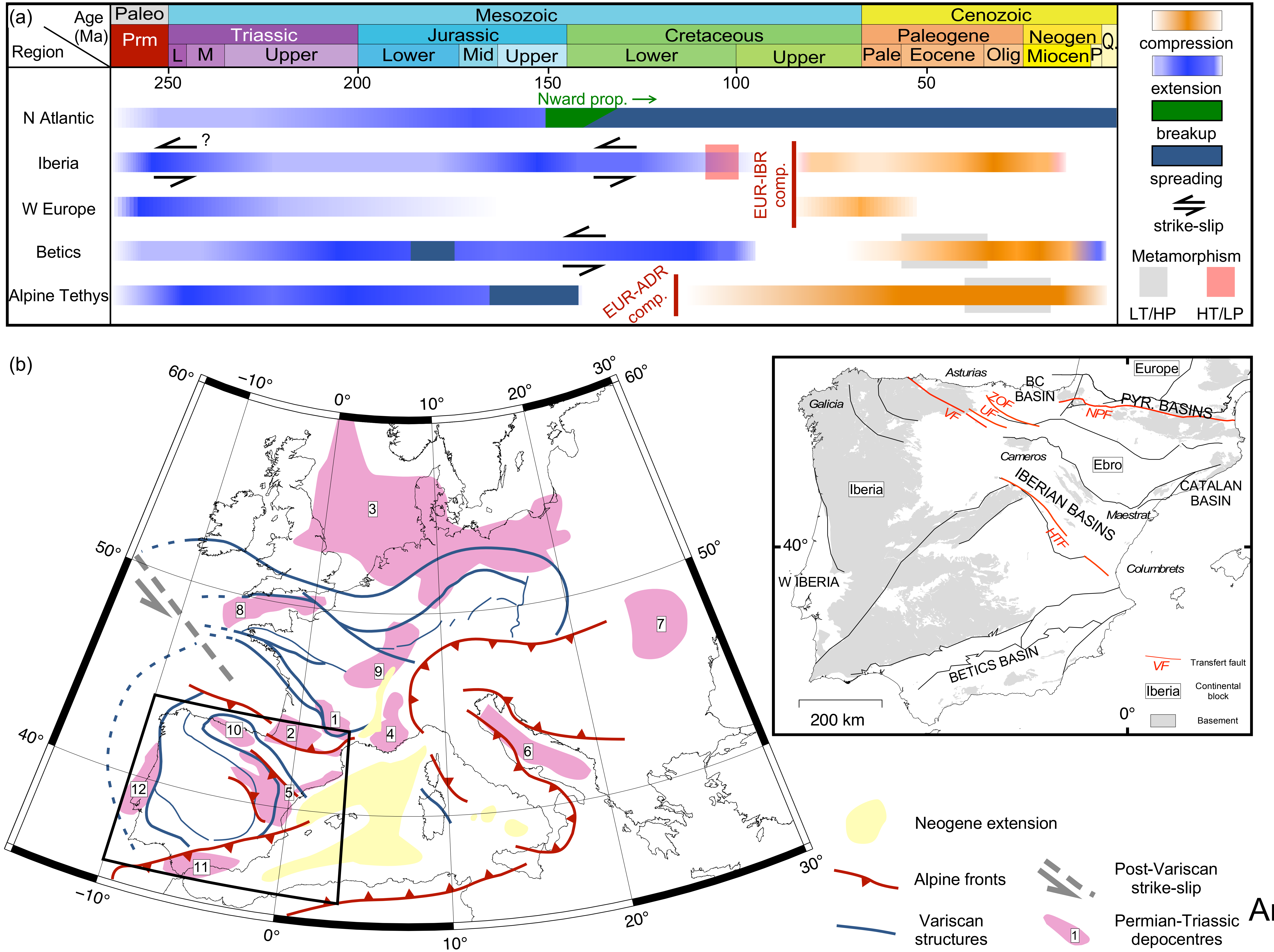
Example of previous reconstructions of Iberia



Muller et al., 2019 (global model)
Nirrengarten et al., 2018 (Atlantic-related model)
van Hinsbergen et al., 2019 (Tethys-related model)

Angrand et al., in review

Geological settings



Iberia is part of a diffuse plate boundary between Europe and Africa (since late Variscan times)

Polyphased deformation localized in the peri- and intra-Iberian basins (Aquitaine-Pyrenees, Basque-Cantabrian basins, Iberian basins, Betics)

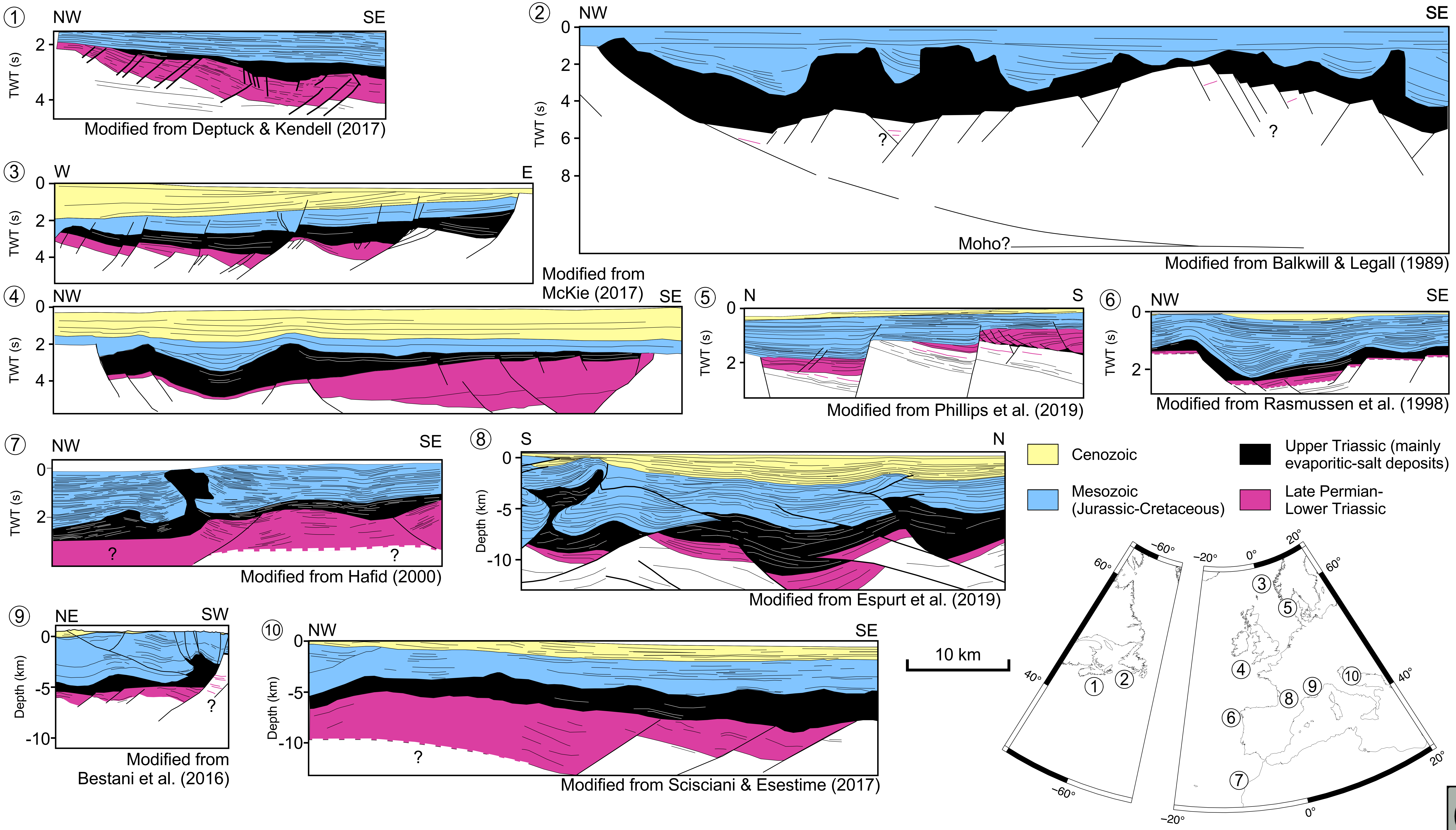
In Iberia, Alpine compressive structures and Mesozoic rift basins are superimposed on Late Permian-Triassic depocenters

Growing pieces of evidence in support of the major role played by intra-Iberia strike-slip deformation

=> but no geological evidence for lithosphere-scale strike-slip movements is yet clearly defined

Angrand et al., in review

Late Permian-Triassic rifting



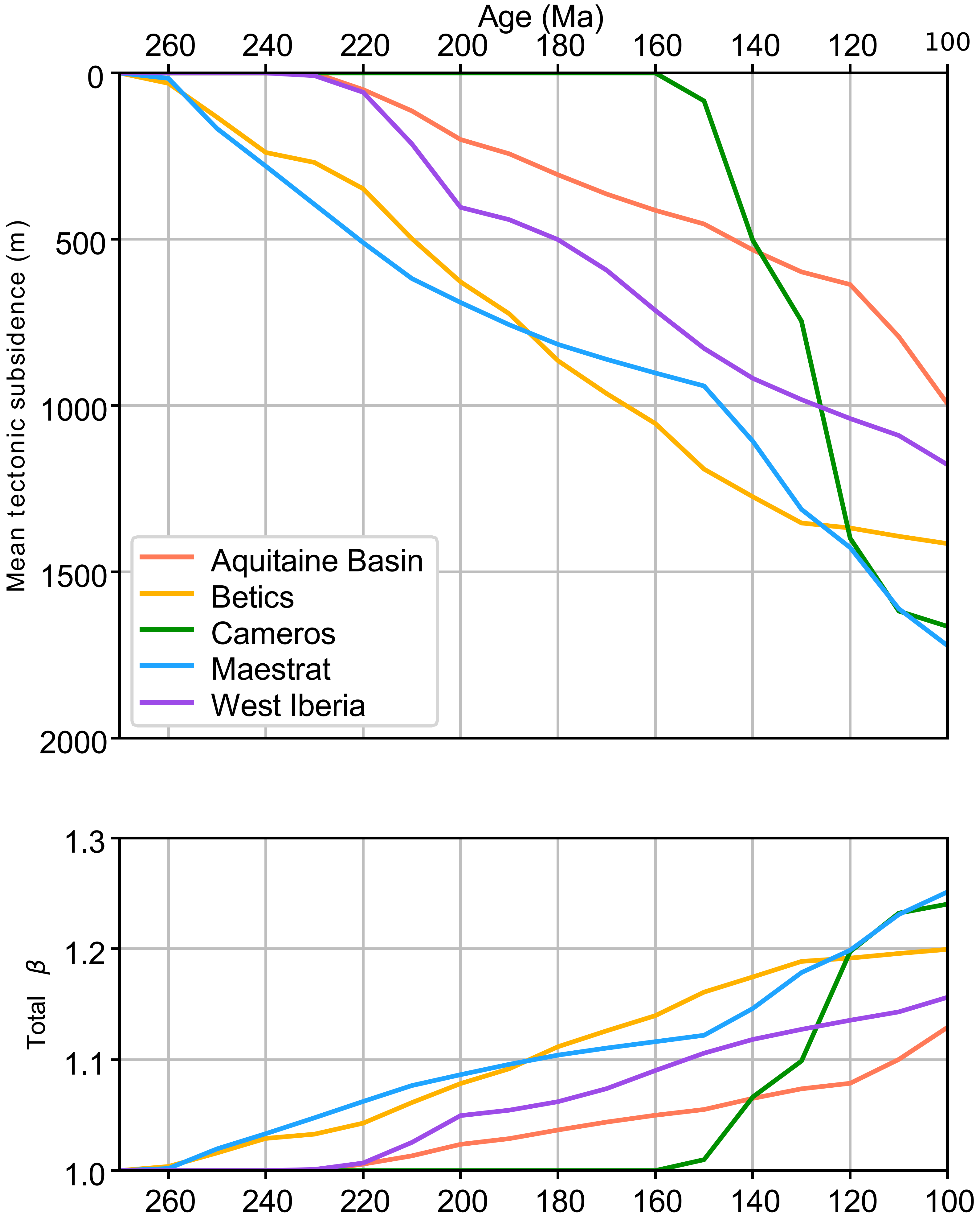
Crustal thinning is well documented on seismic lines along the Atlantic margins

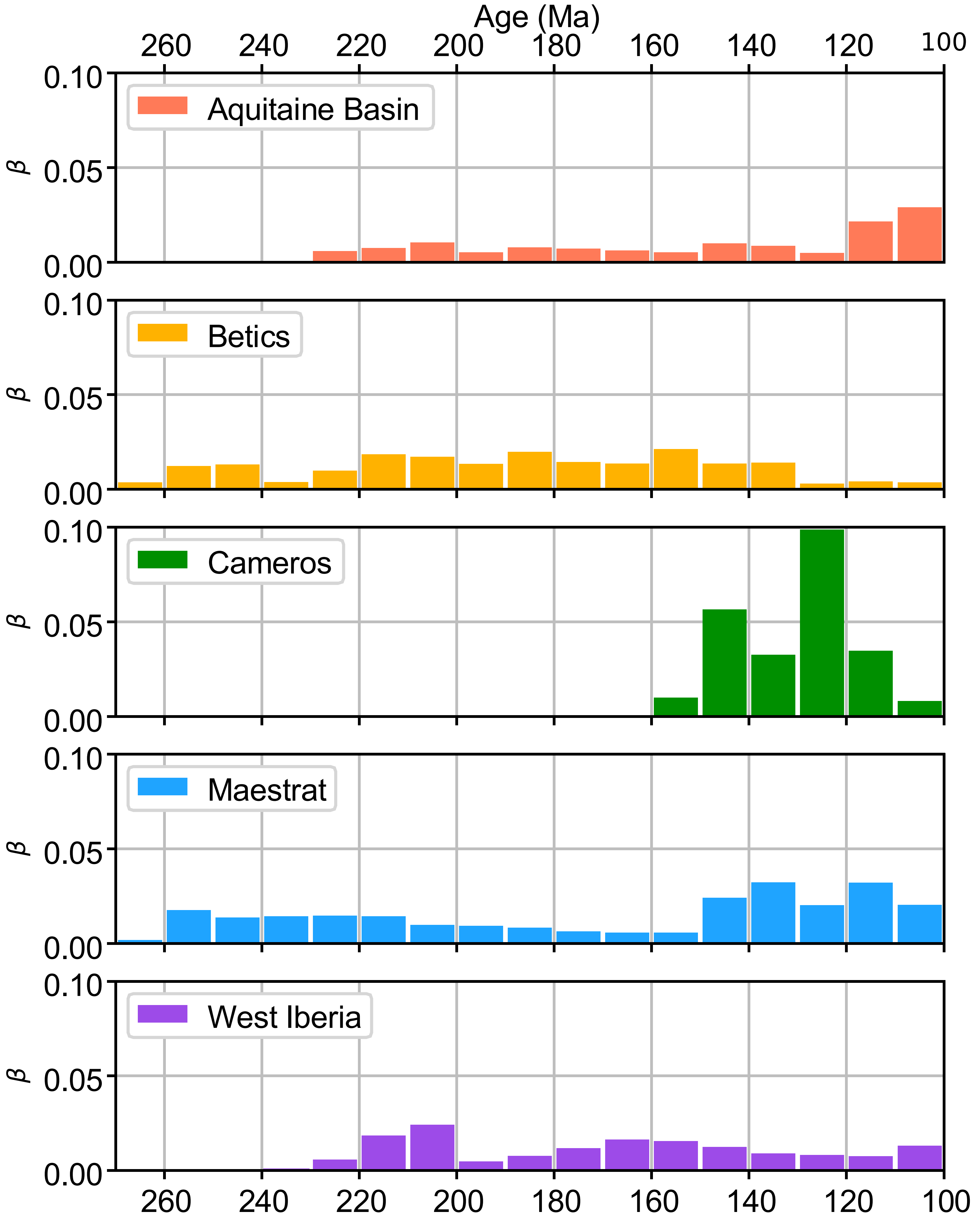
Thick late Permian-Triassic detrital rift-basins deposited above an erosive surface

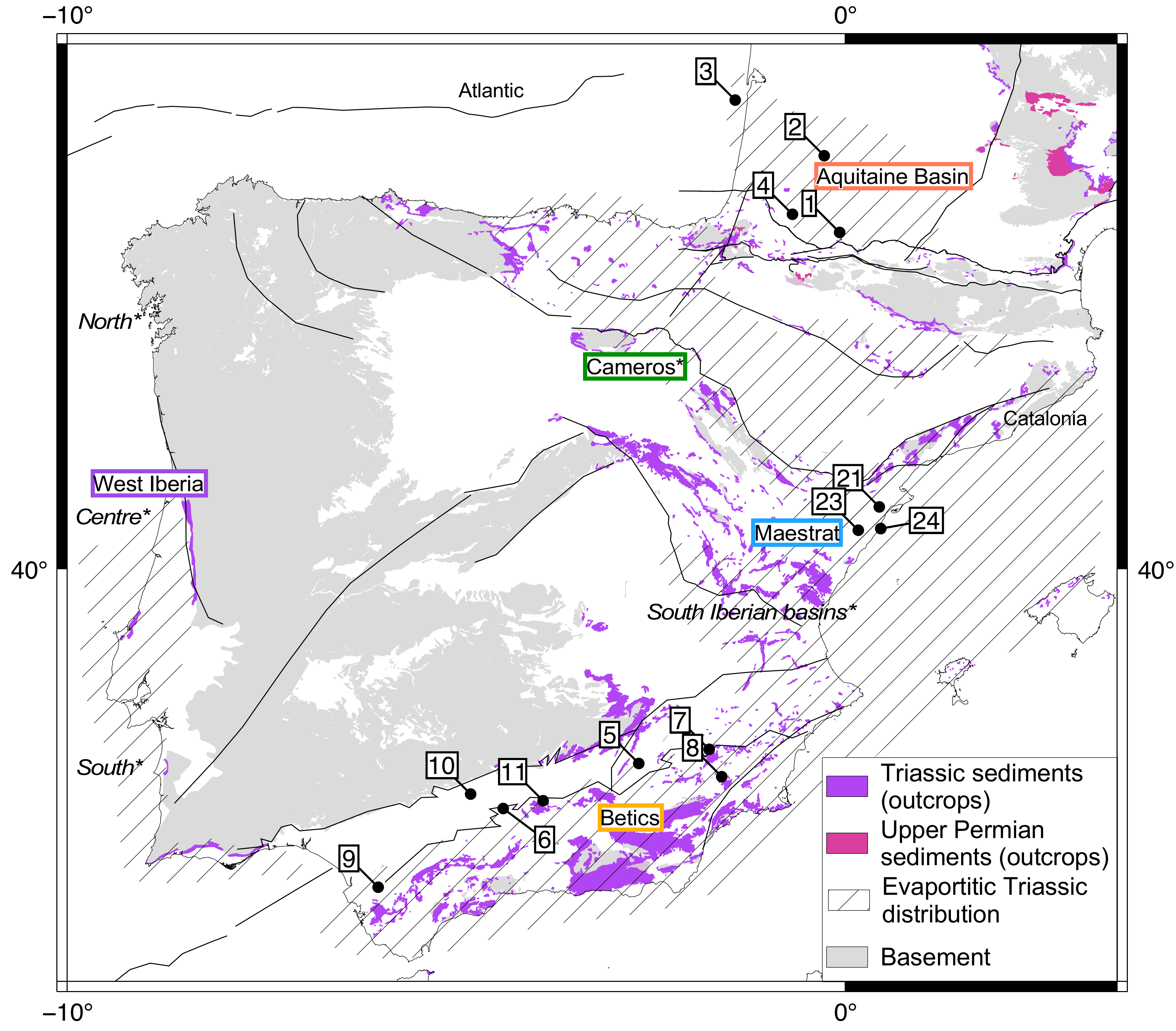
=> The whole N Atlantic/W European domain has been under extension/ transtension since the Late Permian-Triassic

Angrand et al., in review

Subsidence history in Iberian basins







Tethys and Atlantic rifting (L. Permian-L. Triassic and Jurassic) and the intra-Iberian-Pyrenean rift events (Late Jurassic-Early Cretaceous) are recorded in the subsidence

In the Iberian basins, L. Jurassic-E. Cretaceous rift is characterized by a relatively large and short-lived subsidence

It suggests the strike-slip nature of the boundary between Ebro and Iberia in the Late Jurassic

Angrand et al., in review

Kinematic reconstruction
Geological constraints

Domain	Area	Event/kinematics	Age (Ma)	References
Central Europe	Germanic/Polish Basin	Continental rifting	270 (?) to 250	Evan et al., 1990; Van Wees et al., 2000; Evans et al., 2003; Jackson et al., 2019
	Tornquist Zone	Right-lateral	Carboniferous to 250 (?)	Phillips et al., 2019
		Left-lateral	170	Phillips et al., 2019
		Right-lateral	145 to 125	Hippolyte, 2002; Phillips et al., 2019
West Europe (France)	Aquitaine Basin	Continental rifting	270 (?) to 145 ; 125 to 94	Curnelle, 1983; Brunet, 1984; Biteau et al., 2006; Serrano et al., 2006
	Pyrenees	Continental rifting - left lateral	270 (?) to 145	Curnelle, 1983; Lucas, 1995
		Hyper-extended rifting - left-lateral	125 to 94	Vielzeuf & Kornprobst, 1984; Golberg & Leyreloup, 1990; Lagabrielle et al., 2010
Iberia	Basque-Cantabrian Basin	Left-lateral	140 to 120	Quintana et al., 2015; Zamora et al., 2017; Nirrengarten et al., 2018
	Ebro Basin	Continental rifting	270 (?) to 145	Vargas et al., 2009
	Iberian Range	Continental rifting - left lateral	270 (?) to 145	Salas & Casas, 1993; Vargas et al., 2009
		Hyper-extended rifting	150 to 120	Salas & Casas, 1993; Arche & Gomez, 1996; Salas et al., 2001; Omodeo-Sale et al., 2017; Rat et al., 2019
Southern North Atlantic	W Galicia	Continental rifting	200 to 145	Murillas et al., 1990
		Lithospheric mantle exhumation	139 (?)/135-115	SHIPBOARD SCIENTIFIC PARTY, 1998; Mohn et al., 2015
		Initiation of oceanic spreading	133-100	Olivet, 1996; Strivastava et al., 2000; Schettino & Turco, 2009; Whitmarsh & Manatschal, 2012
	Bay of Biscay	Mantle exhumation	160 to 130	Thinon et al., 2001; Tugend et al., 2014
		Oceanic spreading	124-112 to 83	Thinon, 2002; Sibuet et al., 2004; Tugend et al., 2015
	South West Iberia	Continental rifting	200 to 161	Murillas et al., 1990
		Mantle exhumation	147	Sallàres et al. 2013
		Initiation of oceanic spreading	135-133 (Gorringe Bank)	Sallàres et al. 2013
North Sea	Artic rift system	Continental rifting	290 (?) to 200	Evans et al., 2003
	Rockall/Porcupine	Continental rifting	230 (?) to 112	Evans et al., 2003
	Orphan	Continental rifting	270 to 112	Nirrengarten et al., 2018; Hassan et al., 2019; Sandoval et al., 2019
Tethys and peri-Tethys	S Alpine Tethys	Continental rifting	270 to 220	Stampfli & Borel, 2002; Schmid et al., 2008; Scisciani & Esestime, 2017
		Breakup	180	Schmid et al., 2008; Puga et al., 2011; Marroni et al., 2017
	N Alpine Tethys	Oceanic spreading	170-161	Bill et al., 2001; Schaltegger et al., 2002
	Paleotethys	Subduction	early Carboniferous to 200	Stampfli et al., 2001; Stampfli & Borel, 2002; Evans et al., 2003
	Neotethys sensu stricto	Oceanic spreading	Early Permian (?)-	Van Hinsbergen et al., 2019
		Subduction	from 156	Schmid et al., 2008; Van Hinsbergen et al., 2019
	Ionian	Continental rifting	270 to 200 (?)	Muttoni et al., 2001; Tugend et al., 2019
		Oceanic spreading	onset at 180 ?	Tugend et al., 2019
	Vardar	Oceanic spreading	180 to 160 (?)	Channell & Kozur, 1997
		Subduction	145 to 110	Channell & Kozur, 1997
	Pindos	Oceanic spreading	250 to 200	Channel & Kozur, 1997; Stampfli et al., 2001; Schmid et al., 2008
		Subduction	from Late Cretaceous	Channell & Kozur, 1997
	Meliata	Oceanic spreading	220 to 200	Channel & Kozur, 1997; Stampfli et al., 2001; Schmid et al., 2008
		Subduction	180 to 160 (?)	Channell & Kozur, 1997
Central Atlantic		Continental rifting	250 to 200	Kneller et al., 2012
		Oceanic spreading	190 to 175	Labails et al., 2010; Olyphant et al., 2017

We use the following constraints:

(1) age of rifting, mantle exhumation, onset of oceanic spreading in the Atlantic

(2) the present-day position of ophiolites bodies and the timing of rifting, oceanic spreading and subduction for the Tethyan-related oceanic domains (Paleotethys, Neotethys, Pindos, Meliata, Vardar)

(3) at 100 Ma, Iberia is closed to the present-day position relative to Europe, so that the late Mesozoic-Cenozoic Pyrenean shortening is essentially orthogonal

More details in Angrand et al., in review

Kinematic reconstruction
Late Permian

- Subduction of the Paleotethys
- Neotethys opens and propagates westward
- Diffuse extension in W Europe
- Diffuse transtensional transfer zone along the Africa-Iberia-Adria boundary

Angrand et al., in review

Kinematic reconstruction
Triassic

250 Ma

- Subduction of the Paleotethys
- Opening of back-arc Pindos (Neotethys) and Meliata oceans
- Neotethys opens, and propagates westward
- Diffuse extension in W Europe
- Individualization of the Ebro continental block

Angrand et al., in review

Kinematic reconstruction
Lower Jurassic

- Closing of the Paleotethys
- Extension in the Atlantic (Central and North)
- Central Atlantic Magmatic Event
- This period marks a gradual change from Tethyan-dominated to Atlantic-dominated tectonism in Iberia.

Angrand et al., in review

Kinematic reconstruction
Middle Jurassic

180 Ma

- Closing of Meliata
- Opening of the Ionian Ocean
- Opening of the Central Atlantic and the South Alpine Tethys

Angrand et al., in review

Kinematic reconstruction
Late Jurassic

- Opening of the Alpine Tethys
- Subduction of the Northern Neotethys
- The Africa-Iberia plate boundary is clearly defined

Angrand et al., in review

Kinematic reconstruction
Lower Cretaceous

- Opening of the S North Atlantic
- Bay of Biscay-Pyrenean basins-Provence system
- Subduction of the Northern Neotethys

Angrand et al., in review

Kinematic reconstruction Lower Cretaceous

120 Ma

- Opening of the southern North Atlantic
- Closing of the S Alpine Tethys
- Subduction of the Northern Neotethys

Angrand et al., in review

Kinematic reconstruction
Middle Cretaceous

- Northward propagation of the N Atlantic
- Closing of the Alpine Tethys and of the Neotethyan system
- Almost orthogonal extension on the pyrenean rift

Angrand et al., in review

Kinematic reconstruction of Iberia

Take-home messages

- Left-lateral strike-slip movement did occur in the Pyrenees from the late Permian to the Early Cretaceous but ended as the Bay of Biscay opened
- Late Permian-Triassic extension in the Atlantic and Iberia (including Ebro) is key to quantify the strike-slip movement in Iberia that is otherwise not well resolved from the geological constraints in Iberian basins and from full-fit reconstructions in the Jurassic
- Salt tectonics that decouples syn-rift Iberian basins evolution from their basement likely explains the lack of geological constraints
- The major intra-Iberia NW-trending strike-slip fault system outlined by spatially disconnected rift basins played a significant role in the Late Jurassic-Early Cretaceous, in addition to the North Pyrenean rift system

Effect of the eastward movement of Iberia into the Alpine Tethys:

- Ebro was part of Adria before the onset of the Alpine Tethys opening
- The southern Alpine Tethys closed in the Early Cretaceous (~145 to ~100 Ma)
- The boundary between Iberia and Africa localized as a transform plate boundary at ~160 Ma, connecting the Alpine oceanic domains with the Central Atlantic