Role of the Adria plate structural heterogeneities on the dynamics of the Central-~~Western~~ Mediterranean region

Rosalia Lo Bue[1], Manuele Faccenda[1], Jianfeng Yang[1]

[1]Università degli Studi di Padova - Dipartimento di Geoscienze

rosalia.lobue@phd.unipd.it

manuele.faccenda@unipd.it

Project funded by ERC StG 758199 NEWTON

https://newtonproject.geoscienze.unipd.it

METHODOLOGY

We combine geodynamic and seismological numerical modelling techniques to reproduce the recent large-scale evolution of the Central Mediterranean and the associated strain-induced upper mantle fabrics and seismic anisotropy.

3D petrological-thermo-mechanical models of subduction

Software: I3MG (Gerya, 2019)

+

Estimation of the Strain-induced LPO

Software: DREX_M
https://newtonproject.geoscienze.unipd.it/ecoman/
Update version of D-REX (Kaminski et al. 2004).

+

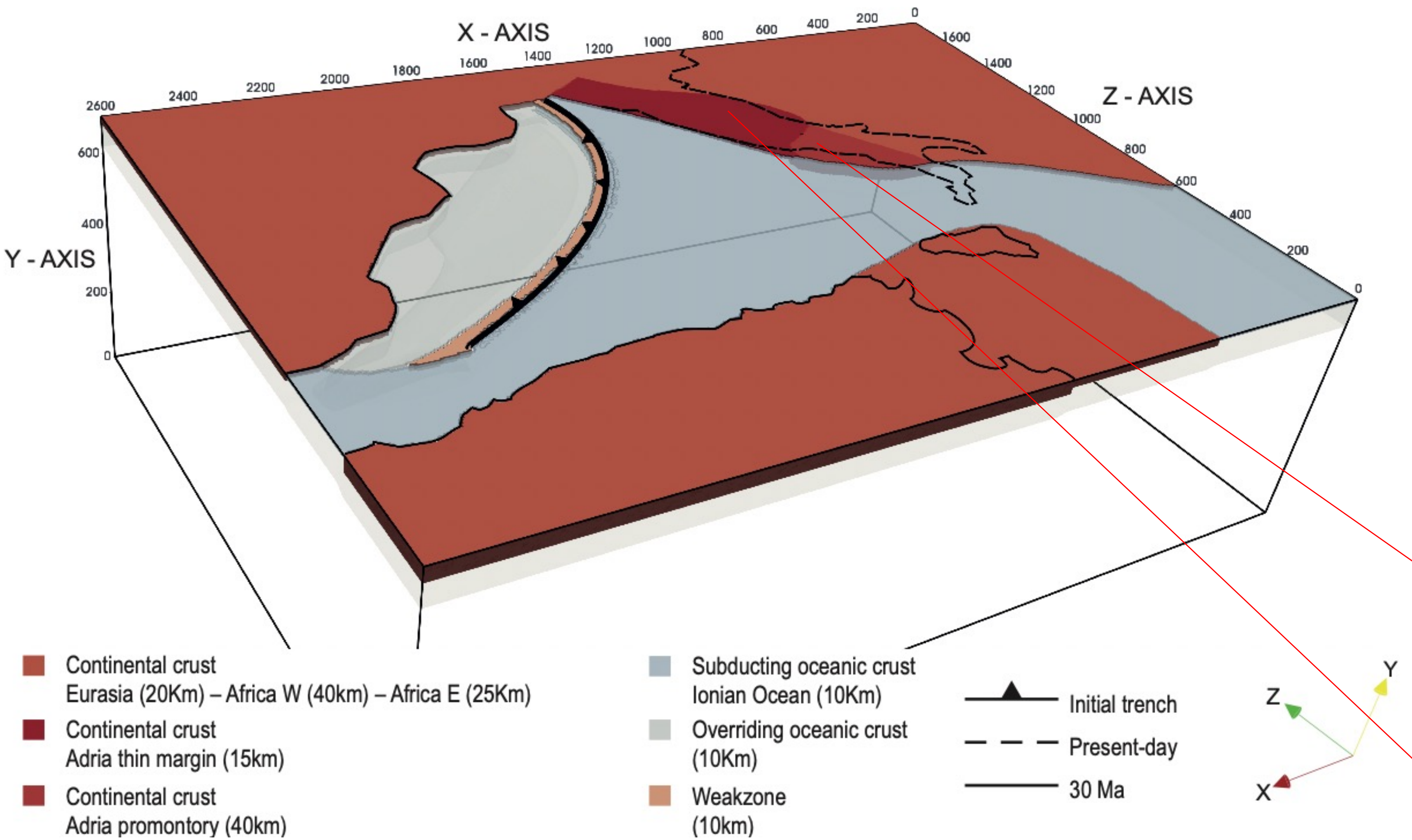
Synthetic SKS splitting

Software: FSTRACK (Becker, 2006)

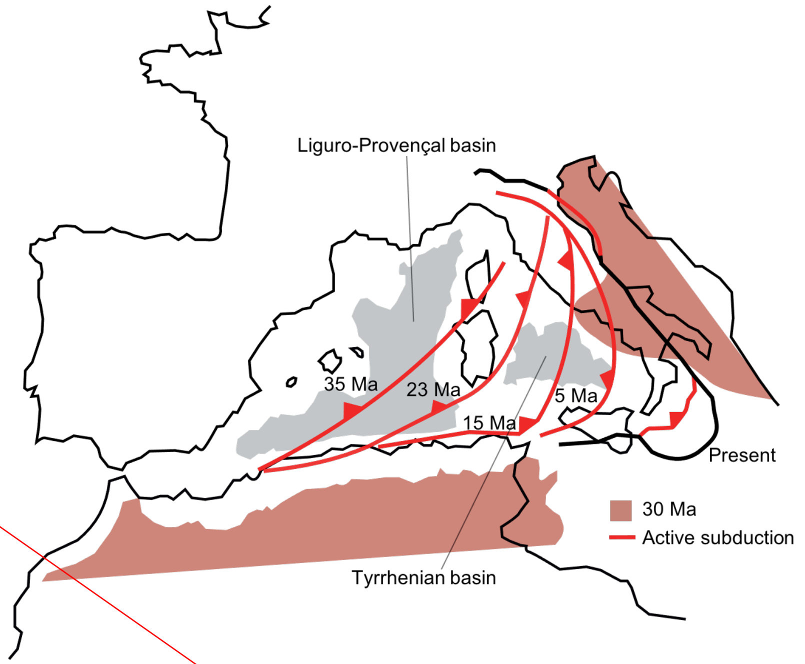
Synthetic P-wave anisotropy and Rayleigh wave azimuthal anisotropy

Rosalia Lo Bue[1], Manuele Faccenda[1], Jianfeng Yang[1] - [1]Università degli Studi di Padova, Dipartimento di Geoscienze
Rosalia.lobue@phd.unipd.it - manuele.faccenda@unipd.it - https://newtonproject.geoscienze.unipd.it

INITIAL MODEL SETUP FOR THE REFERENCE MODEL CM



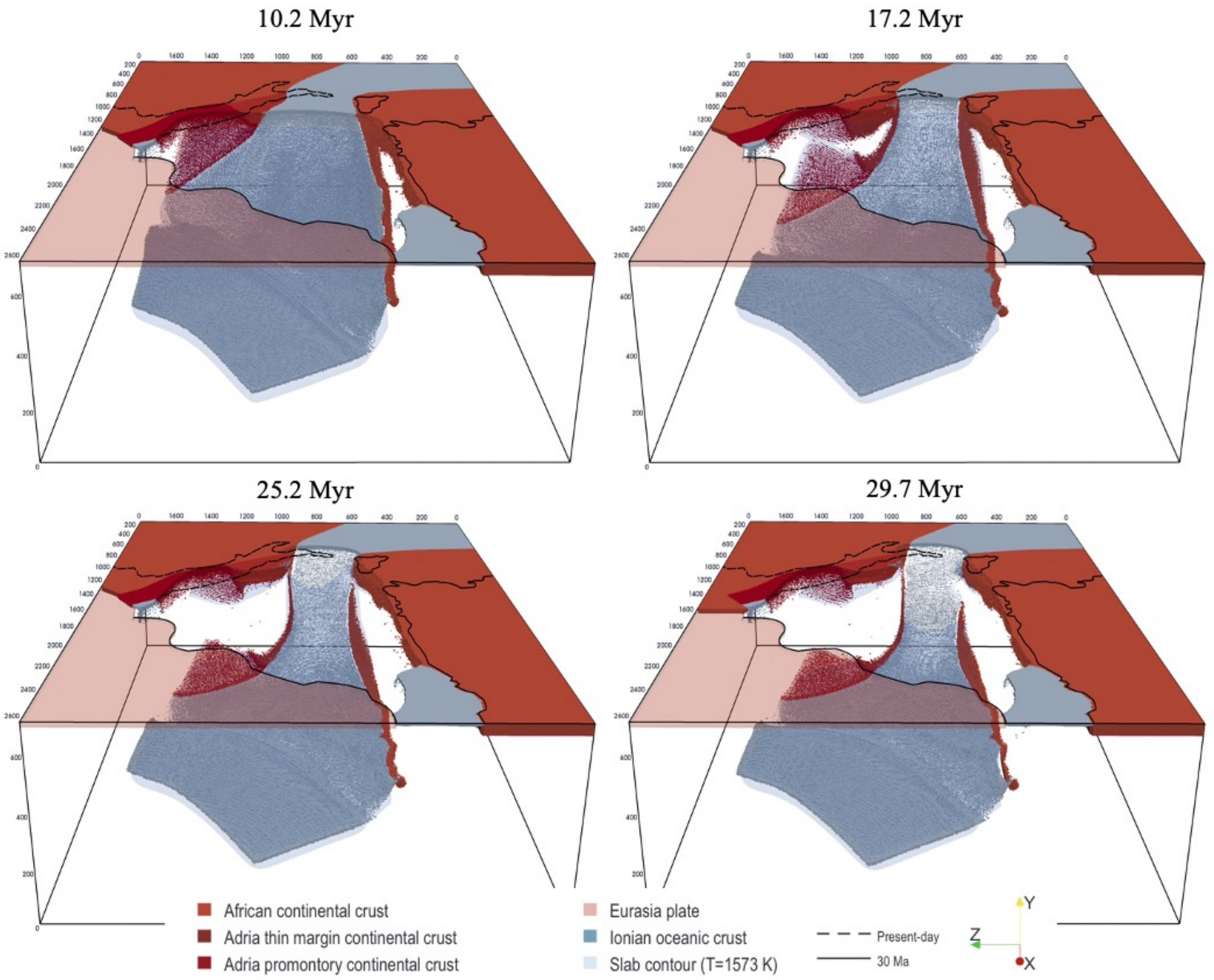
From paleogeographic reconstructions of 30 Ma proposed by Faccenna et al. (2014) ; van Hinsbergen et al. (2014).



The Adria plate is characterized by the presence of a stiffer continental promontory (dark orange) and a thin continental margin (red) as proposed by Lucente and Speranza (2001); Lucente et al. (2006). A wide slab is located from Gibraltar to Corsica extending down to ~200-300 km.

Rosalia Lo Bue[1], Manuele Faccenda[1], Jianfeng Yang[1] - [1]Università degli Studi di Padova, Dipartimento di Geoscienze
Rosalia.lobue@phd.unipd.it - manuele.faccenda@unipd.it - https://newtonproject.geoscienze.unipd.it

EVOLUTION OF THE REFERENCE MODEL CM



The Ionian slab rapidly migrate south-eastward with episodes of lateral tearing, segmentation and break-off.

Between ~15 Myr and ~16 Myr, slab break-off occurs beneath the Adria promontory. The rupture rapidly propagates laterally, allowing, in only a few million years, the formation of a wide slab window that breaks the single arc geometry and creating two separated arcs.

After about ~25-30 Myr, slab remnants are found in model areas corresponding to the present-day northern Apennines and southern Tyrrhenian sea. The northern slab segment is hanging down to ~150 km depth and extends deeper from ~400 km down to about ~660 km depth.

The southern slab segment instead extends continuously from the surface up to the mantle transition zone although incipient detachment is observed in its western edge.

(SupplementaryMovie1.mp4)

Role of the Adria plate structural heterogeneities on the dynamics of the Central-Western Mediterranean region

Rosalia Lo Bue[1], Manuele Faccenda[1], Jianfeng Yang[1] - [1]Università degli Studi di Padova, Dipartimento di Geoscienze
Rosalia.lobue@phd.unipd.it - manuele.faccenda@unipd.it - https://newtonproject.geoscienze.unipd.it

COMPARISON BETWEEN THE MODEL CM AND OTHER MODELS

Plate Name	Effective Thickness [km]		Friction coefficent [-]		Density [kg/m³]
MODEL CM					
Lithosphere	*Crust*	*Mantle*	*Initial*	*Final*	
Eurasia (150 Myr)	20		0.020	0.005	$\rho_{mantle} - 400$
		60	0.600	0.400	ρ_{mantle}
Africa W (150 Myr)	40		0.020	0.005	$\rho_{mantle} - 400$
		60	0.600	0.400	ρ_{mantle}
Africa E (150 Myr)	25		0.020	0.005	$\rho_{mantle} - 400$
		65	0.600	0.400	ρ_{mantle}
Adria Promontory (150 Myr)	40		0.600	0.400	2700
		50	0.600	0.400	ρ_{mantle}
Adria thin margin (90 Myr)	15		0.020	0.005	$\rho_{mantle} - 200$
		70	0.600	0.400	ρ_{mantle}
Ionian Ocean (90 Myr)	10		0.020	0.005	ρ_{mantle}
		80	0.600	0.400	ρ_{mantle}
Upperplate (1 Myr)	10		0.010	0.010	ρ_{mantle}
		80	0.600	0.400	ρ_{mantle}
Weakzone (70 Myr)	20	-	-	-	3200

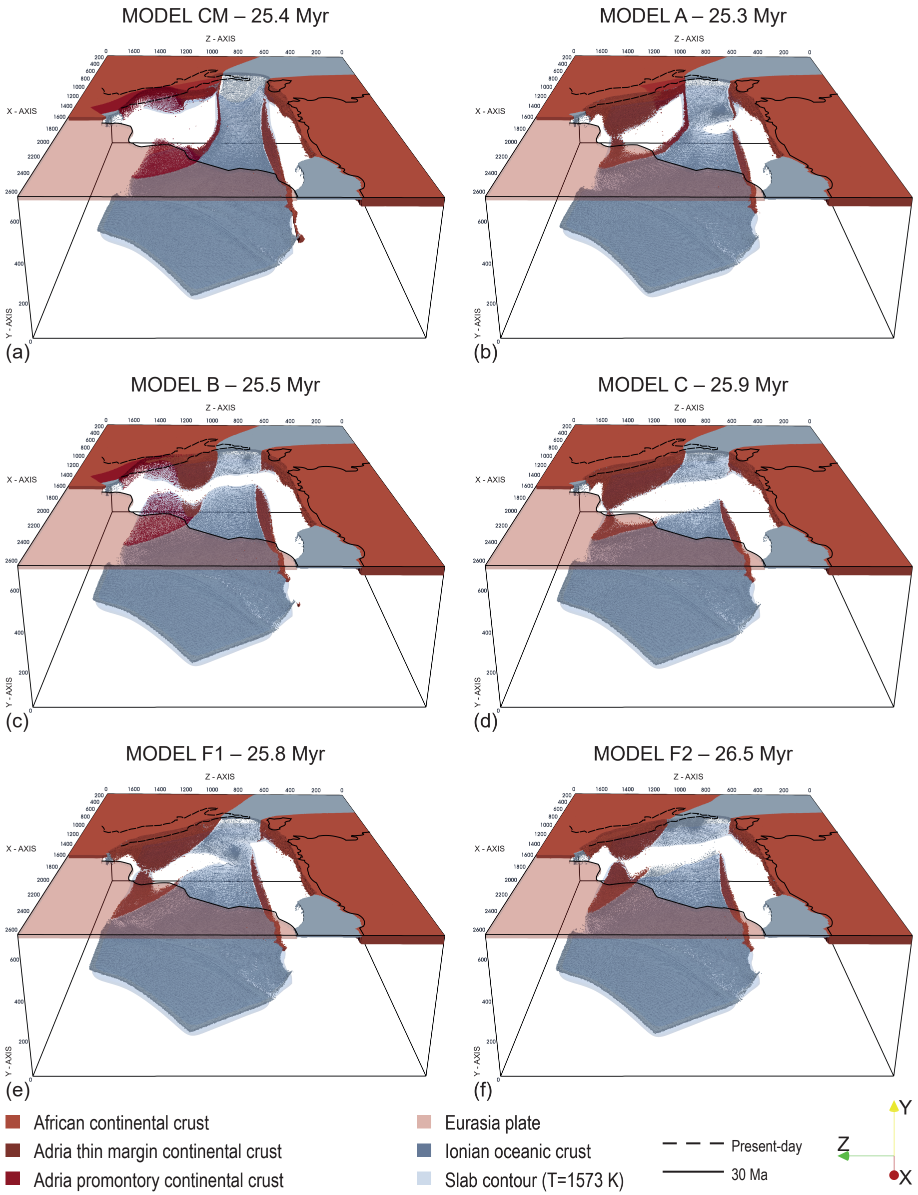
To evaluate the influence on trench shape and on the occurrence and timing of slab tears (e.g. Mason et al. 80 (2010)) of the structural heterogeneities within the Adria plate, we also explore a wide range of models where, with respect to the Reference Model CM, we varied the geometry of the Adria plate and the buoyancy and stiffness of the Adria promontory and Adria thin margin crust.

MODEL A	Adria thin margin is absent
MODEL B	Adria promontory is absent
MODEL C – F1 – F2	Adria promontory and Adria thin margin are absent
MODEL D1	Adria Promontory crust density: $\rho_{mantle} - 500$
MODEL D2	Adria Promontory crust density: $\rho_{mantle} - 400$
MODEL D3	Adria Promontory crust density: $\rho_{mantle} - 300$
MODEL D4	Adria Promontory crust density: $\rho_{mantle} - 400$
MODEL E	Adria Promontory crust Friction coefficient: 0.020 0.005

Rosalia Lo Bue[1], Manuele Faccenda[1], Jianfeng Yang[1] - [1]Università degli Studi di Padova, Dipartimento di Geoscienze
Rosalia.lobue@phd.unipd.it - manuele.faccenda@unipd.it - https://newtonproject.geoscienze.unipd.it

COMPARISON BETWEEN THE MODEL CM AND OTHER MODELS

The initial subduction dynamics of all models are similar to that of Model CM: the initial slab sinks through the mantle and retreats to the south-east. Important differences among models occur when the trench reaches the Adria continental.



MODEL A - Adria thin margin is absent

- Formation of a wide slab window and complete slab detachment at ~30Myr.
- Lower retreat of the Ionian and northern Apennines trenches.
- Linear shape of the northern Apennines trench.

MODEL B - Adria promontory is absent

- NO formation of a wide slab window and complete slab detachment between ~24 and ~25 Myr .
- Lower retreat of the Ionian trench.
- Arcuate shape of the northern Apennines trench and retreat till its present-day position.

MODEL C – both are absent

- At ~23Myr, the southern slab breaks at a depth between 150-200 km, while the northern slab breaks at a depth of ~300 km at ~30 Myr.
- Lower retreat of the Ionian and northern Apennines trenches.
- Linear shape of the northern Apennines trench.

MODEL F1 – both are absent and westward convex geometry of the Adria western margin

- Formation of a wide slab window and complete slab detachment at ~30Myr.
- Lower retreat of the Ionian and northern Apennines trenches.
- Linear shape of the northern Apennines trench.

MODEL F2 – both are absent and linear Adria western margin

- NO formation of a wide slab window and complete slab detachment between ~24 and ~25 Myr .
- Lower retreat of the Ionian and northern Apennines trenches.
- Linear shape of the northern Apennines trench.

European Geosciences Union | erc | NEWTON – NEw Window InTO Earth's iNterior | DIPARTIMENTO DI GEOSCIENZE

Role of the Adria plate structural heterogeneities on the dynamics of the Central-Western Mediterranean region
Rosalia Lo Bue[1], Manuele Faccenda[1], Jianfeng Yang[1] - [1]Università degli Studi di Padova, Dipartimento di Geoscienze
Rosalia.lobue@phd.unipd.it - manuele.faccenda@unipd.it - https://newtonproject.geoscienze.unipd.it

UPPER MANTLE FLOW, LPO AND SYNTHETIC SEISMIC ANISOTROPY

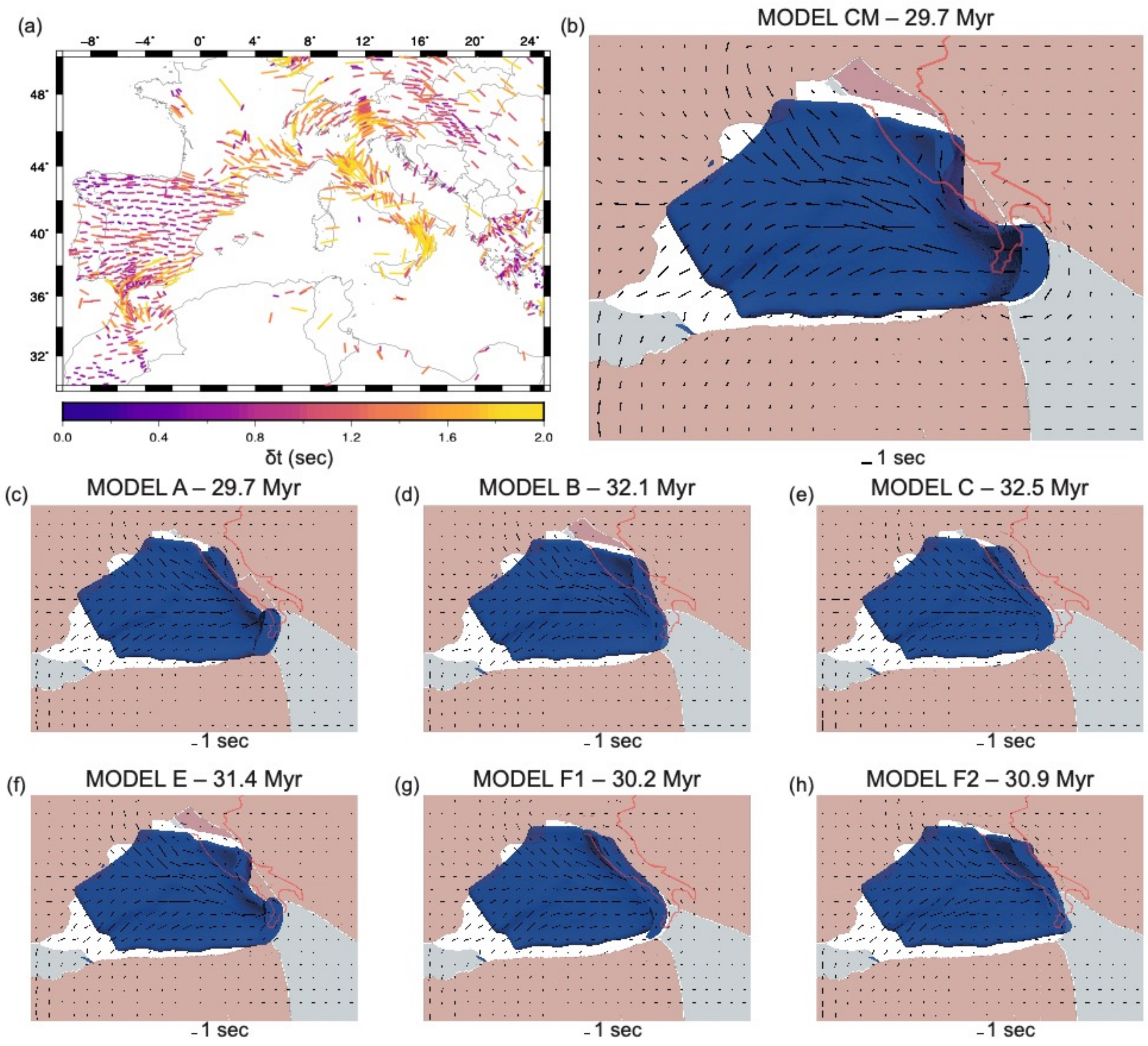
Our results reveal the dominant role of subduction-induced mantle flow in generating the observed seismic anisotropy and shear wave splitting.

Liguro-Provençal basin

Smoothly rotating direction pattern, with a dominance of NW direction in the north (southern France) turning progressively toward EW in the Corsica-Sardinia block.

Tyrrhenian domain

The fast shear wave component orients parallel to the stretching direction of the back-arc basin.

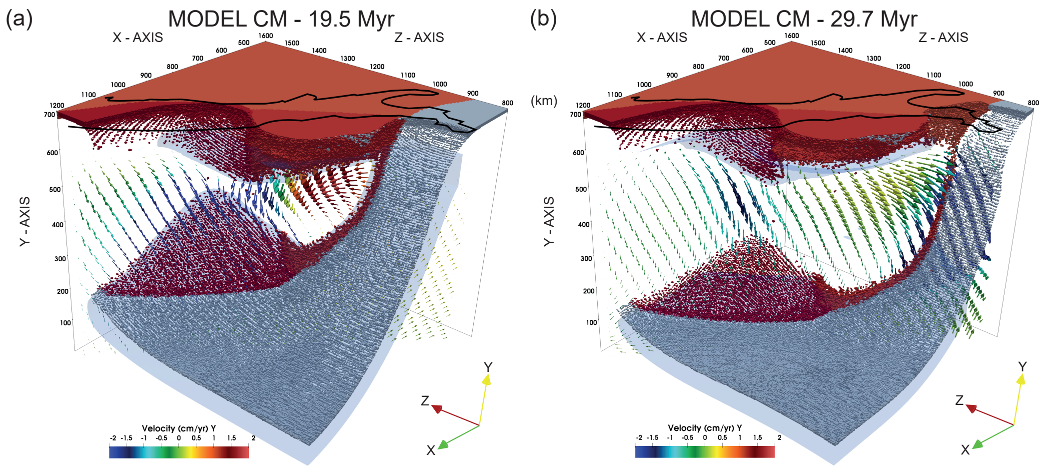


Beneath the Apennines

The pattern of SKS fast axes becomes parallel to the mountain chain, following its curvature from NW–SE in the north, to a more NS orientation along the Apennines foreland and to NE–SW in the farther south Calabria. In our reference Model CM, the SKS fast azimuths are somewhat trench-perpendicular beneath Central Adria as a result of the mantle flowing through the slab window.

Role of the Adria plate structural heterogeneities on the dynamics of the Central-Western Mediterranean region
Rosalia Lo Bue[1], Manuele Faccenda[1], Jianfeng Yang[1] - [1]Università degli Studi di Padova, Dipartimento di Geoscienze
Rosalia.lobue@phd.unipd.it - manuele.faccenda@unipd.it - https://newtonproject.geoscienze.unipd.it

FOCUS ON THE NORTHERN APENNINES REGION

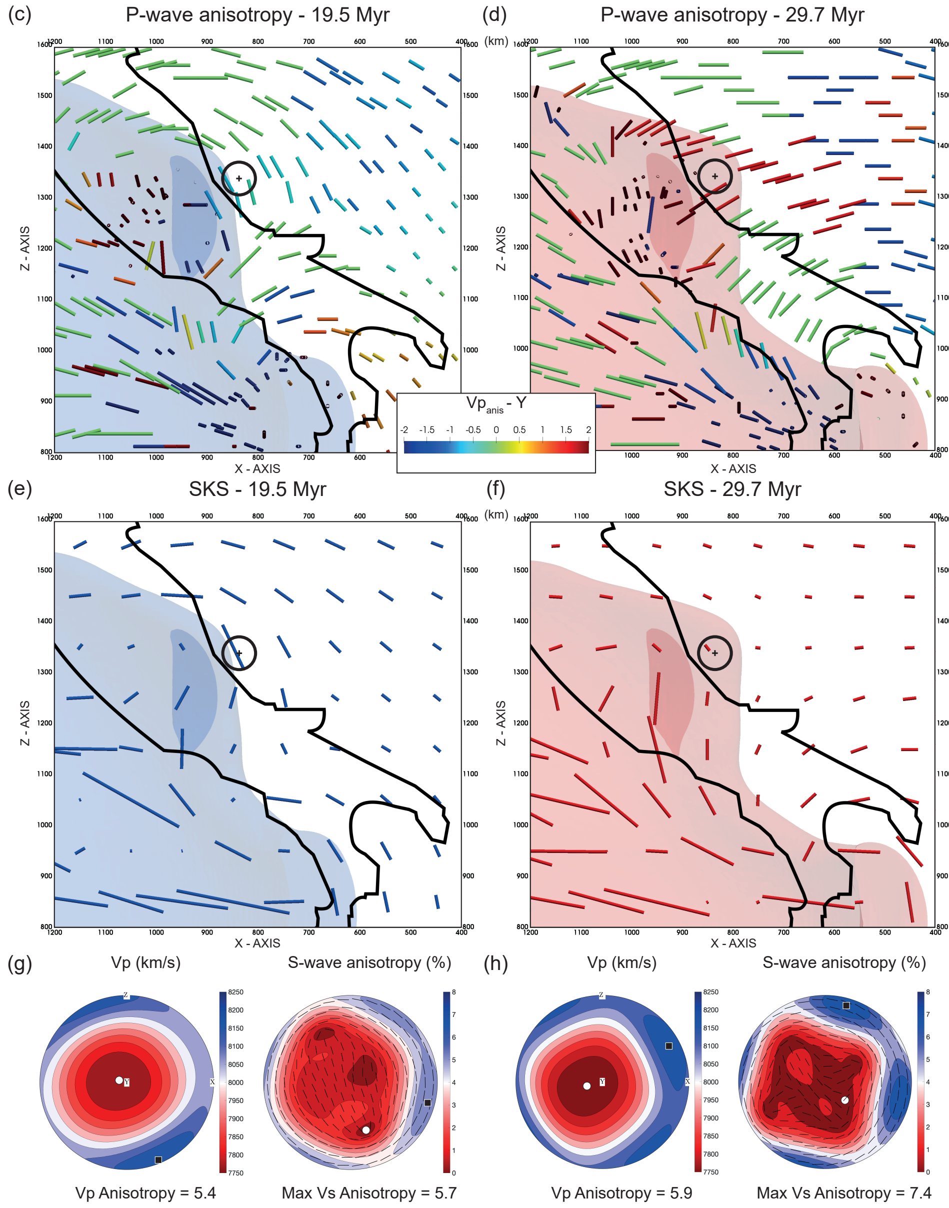


In the northern Apennines region there is significant change in P-wave and SKS anisotropic patterns between ~20 and ~30 Myr.

- 20 Myr - Strong and trench-parallel P-wave and SKS anisotropy results from the retreating western Adria margin (c,e).
- 30 Myr - The trench-parallel SKS fast azimuths are reduced and the P-wave fast directions at 130 km depth turns to trench-perpendicular dipping toward the sinking and detached Ionian slab (d,f).

This is because the detached Ionian slab induces a downward and radially converging mass flux (a,b) in the shallow upper mantle that progressively reorients the fast axis of the olivine crystals from ~NW to ~NE (g,h - Vp pole figures). The change in dip from sub-horizontal to SW dipping is responsible for the decrease in SKS splitting t (g,h - S-wave anisotropy pole figures).

The trench-perpendicular P-wave anisotropy measured by (Hua et al., 2017) could be interpreted with the presence of a large gap in the sinking Ionian slab as in the latest stages of Model CM (b,d). A more detailed characterization of the seismic anisotropy in the northern Apennines could provide useful information to determine whether the slab is continuous or not in the upper mantle.



Role of the Adria plate structural heterogeneities on the dynamics of the Central-Western Mediterranean region
Rosalia Lo Bue[1], Manuele Faccenda[1], Jianfeng Yang[1] - [1]Università degli Studi di Padova, Dipartimento di Geoscienze
Rosalia.lobue@phd.unipd.it - manuele.faccenda@unipd.it - https://newtonproject.geoscienze.unipd.it

CONCLUSION

Our modelling results confirm that the main geological and geophysical observables in the Central Mediterranean can be directly linked to the recent dynamics of the Ionian slab and Adria plate.

More importantly, we show that the presence of structural heterogeneities within the Adria plate and/or the geometry of its Tyrrhenian passive margin plays a fundamental role on:

(i) the development of a slab window below the Central Apennines as shown by seismic tomographies;
(ii) the curvature of the Northern Apenninic trench and its retreat till the Adriatic Sea;
(iii) the retreat of the Ionian slab till the present-day position in the Calabro-Peloritan region.

Thus, these results suggest that lateral variations in lithosphere thickness and stiffness can substantially influence the tectonic history, and that taking into account such structural heterogeneities is essential to properly interpret the geophysical and geological features of natural tectonic settings.

Rosalia Lo Bue[1], Manuele Faccenda[1], Jianfeng Yang[1] - [1]Università degli Studi di Padova, Dipartimento di Geoscienze
Rosalia.lobue@phd.unipd.it - manuele.faccenda@unipd.it - https://newtonproject.geoscienze.unipd.it