Tectonic evolution of the Mediterranean region from a global plate kinematics perspective: insights from a new deformable tectonic model

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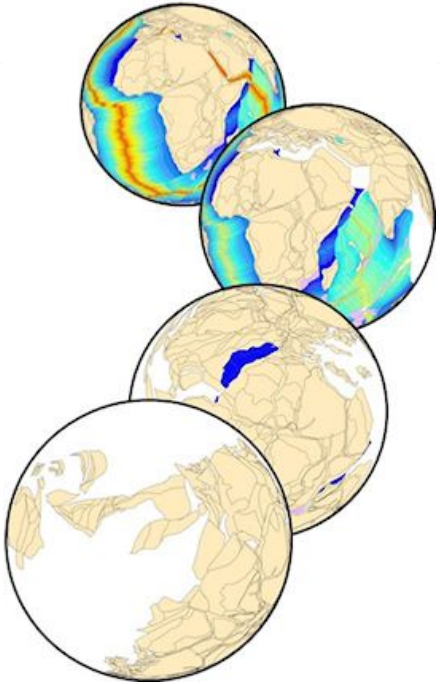
Introduction

Plate Kinematics is a proprietary plate model commercialized by CGG, it works in the ESRI – ArcGIS environment and enables users to reconstruct their dataset back in palaeo-space.
As part of the updating and reviewing process of the model, a new fully deformable tectonic model of the Mediterranean has been created.

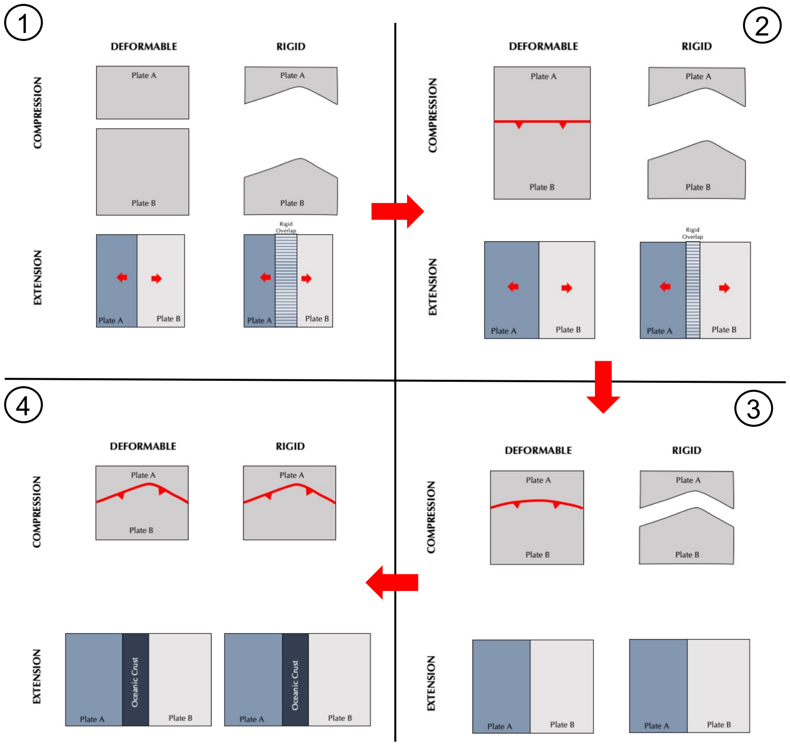
The presence of a defined global plate model allowed the interpretation of the key tectonic events in the Mediterranean as part of a wider global picture.

According to our interpretation, the Tethyan and Atlantic opening phases and the relative rotation of Africa and Eurasia led to the development of the Mediterranean from the Early Permian to the present day.

The addition of deformation as part of the modelling process enabled us to account for the shortening and extension that occurred in the area at a temporal resolution of 1 Ma.



Modelling the deformation

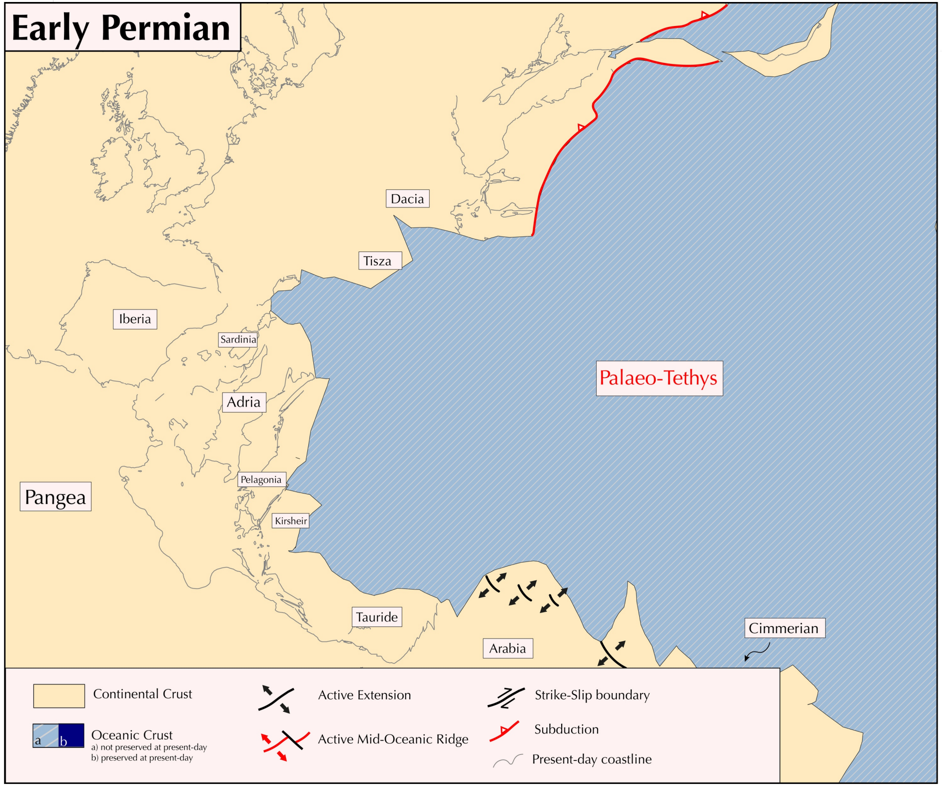


In most available plate models, plates are rigidly rotated back to their palaeo-position, meaning they preserve their present-day size and shape.

Deformation modelling allows us to account for the deformation occurred in a plate, enabling a more realistic and accurate reconstruction.

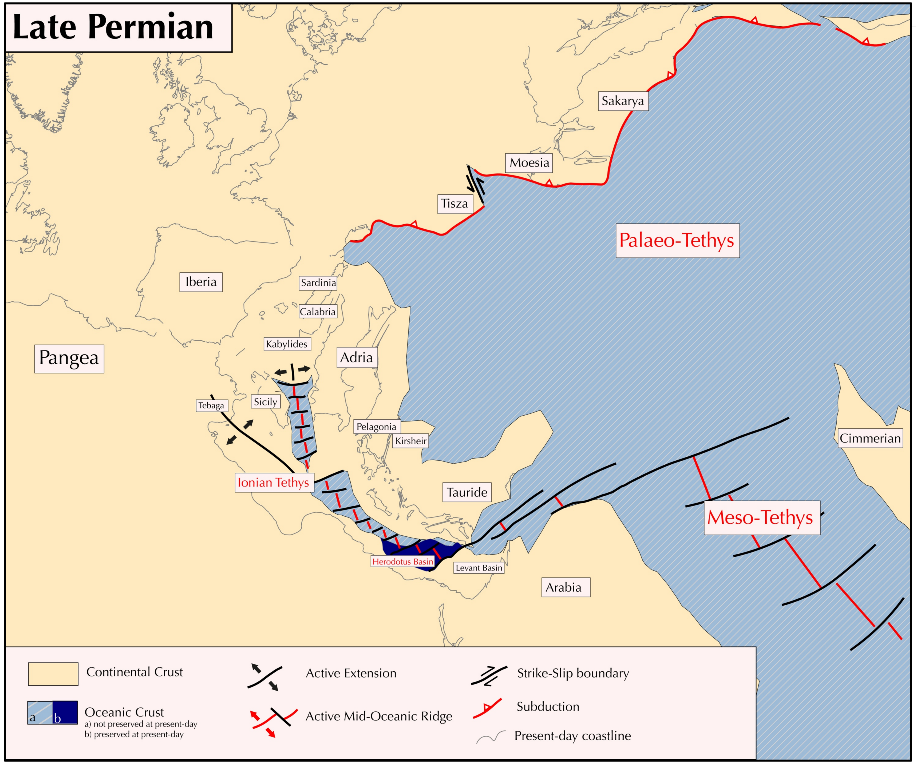
In the example, compression and extension correspond to shortening and stretching in the deformable plates (on the left of each step). In the rigid reconstruction, compression and extension produce either a gap and a rigid overlap between the two plates (on the right of each step).

Mediterranean Plate Model: Early Permian



Following the Hercynian orogenesis, the Mediterranean blocks were assembled together as part of Pangea.
In the Early Permian the Cimmerian continent began rifting apart from Eastern Pangea.

Mediterranean Plate Model: Late Permian

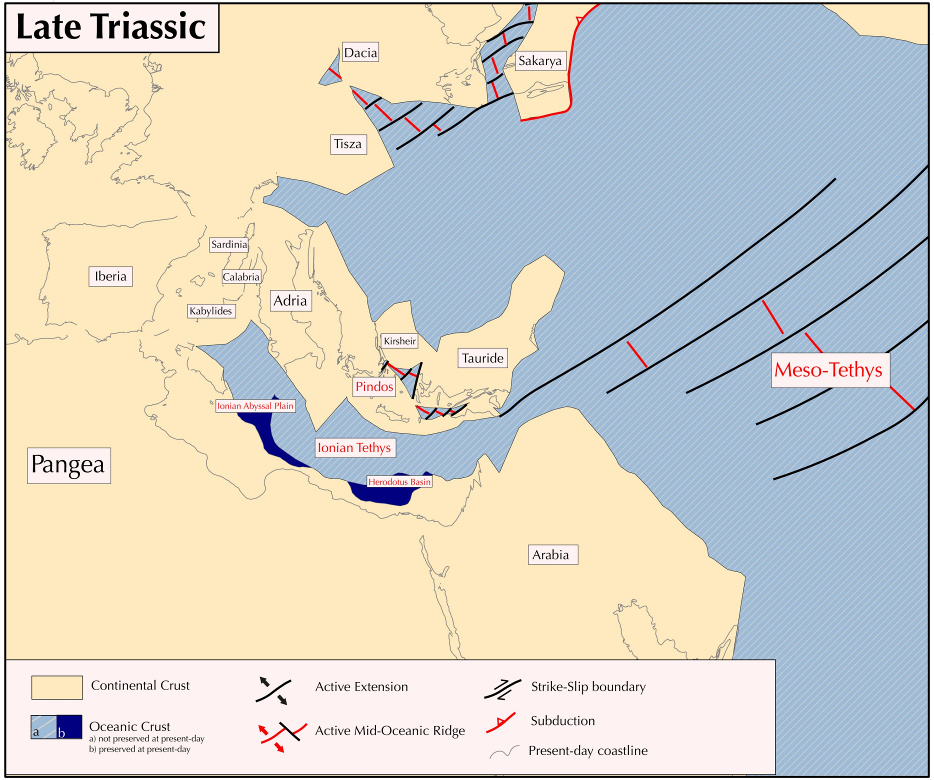


In the Permian the Tethyan realm experienced a new spreading phase here referred as Meso-Tethys Ocean that led to the break-up and drift of the Cimmerian continent.

The westward propagation of the Meso-Tethys resulted into the opening of the Ionian Tethys arm and produced a partial detachment of the Adria micro-plate from the African part of Pangea.

This interpretation is further supported by the presence of Permian pelagic sedimentation in Sicily (i.e. Sosio Valley) and Tunisia (i.e. Jebel Tebaga of Medenine); the Permo(?)-Triassic opening of the Lagonegro Basin in Southern Italy.

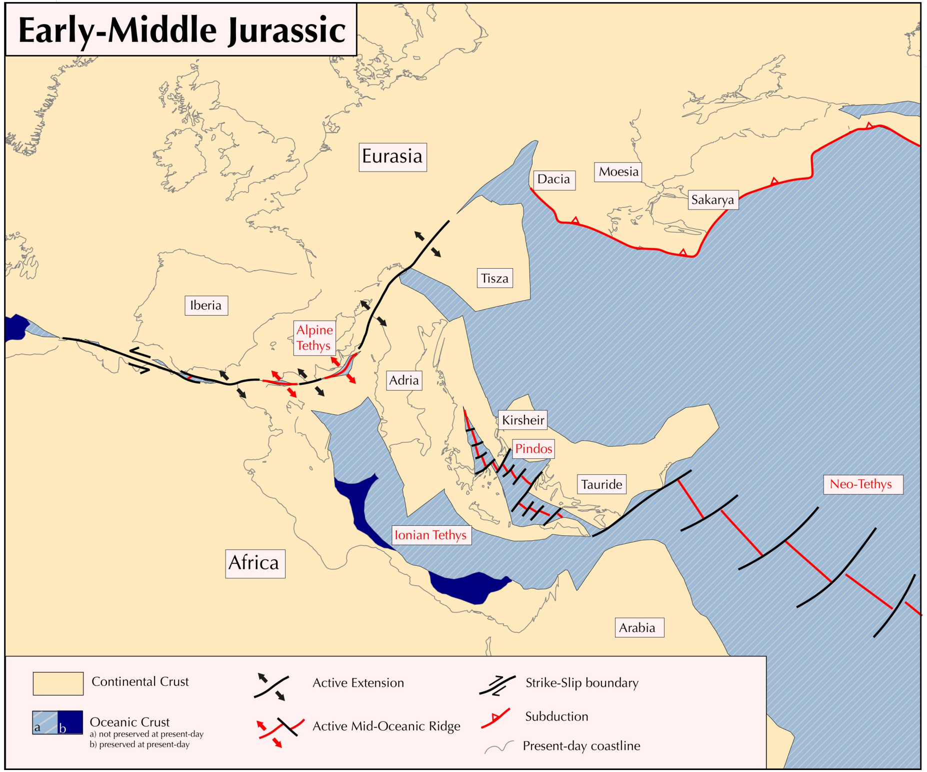
Mediterranean Plate Model: Late Triassic



In the Middle-Late Triassic the central portion of Pangea underwent extension until the opening of the Central Atlantic in the Early Jurassic.

The onset of this rifting phase induced Africa to move eastward with respect to Adria and Iberia. Due to this movement, the Ionian Tethys ceased spreading, and extension jumped further north leading to the opening of the Pindos Ocean.

Mediterranean Plate Model: Early-Middle Jurassic



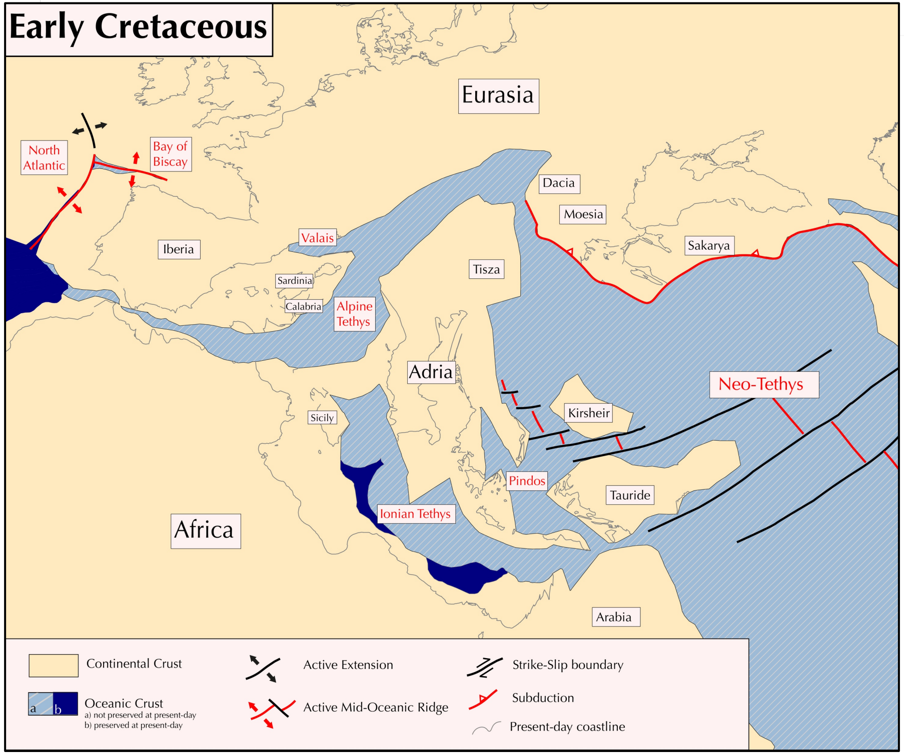
In the Early Jurassic the onset of oceanic spreading in the Central Atlantic region resulted into to the break-up of Eurasia and Africa.

The northward propagation of the Atlantic produced a sinistral-transform margin between Iberia and North Africa and led to the opening of the Alpine Tethys.

The retained continental connection between Adria and Africa enabled them to rotate as single entity.
The Adria-Africa connection is supported by:

- Palaeomagnetic data show a general coherence in the motion of Africa and Adria since Late Palaeozoic times (e.g. Rosenbaum *et al*., 2004).
- Evidence of dinosaur records from the Tithonian to the Santonian in the Apennines and Apulian carbonate platform suggest a land bridge between the African continent and Adria (e.g. Zarcone *et al*., 2010).
- The Numidian Flysch that outcrops in Sicily and the Southern Apennines is generally considered as a North African sourced flysch (e.g. Thomas *et al*., 2010; Fornelli *et al*., 2015) that developed in a thrust-controlled confined system (Pinter *et al*., 2016).
- Efficient transmission of S-waves between North Africa and Italy suggest mantle continuity (Mele, 2001).
- Unlikely preservation of the Ionian Tethys during the Eo-Alpine stage.

Mediterranean Plate Model: Early Cretaceous

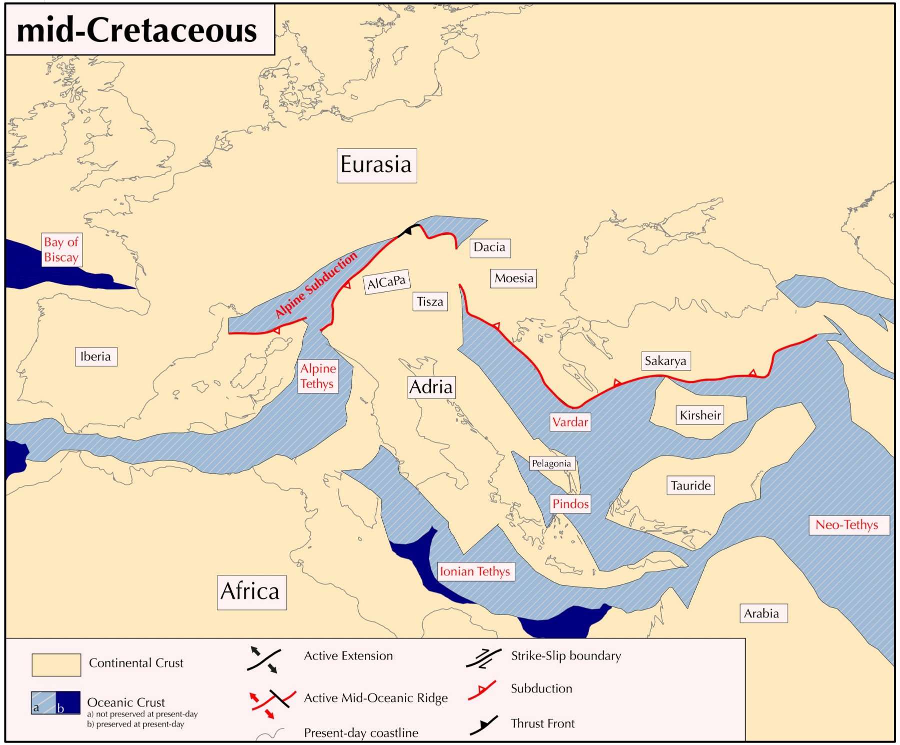


In the Early Cretaceous the South Atlantic quickly unzipped from south to north imposing a counter clockwise rotation to Africa.

The new kinematic configuration caused the Alpine Tethys to stop spreading. Therefore, the North Atlantic opened between Iberia and Newfoundland in order to accommodate the ongoing spreading in the Central Atlantic.

In the Eastern Mediterranean area, the Kirsheir Block detached from Adria as the Neo-Tethys propagated to northwest.

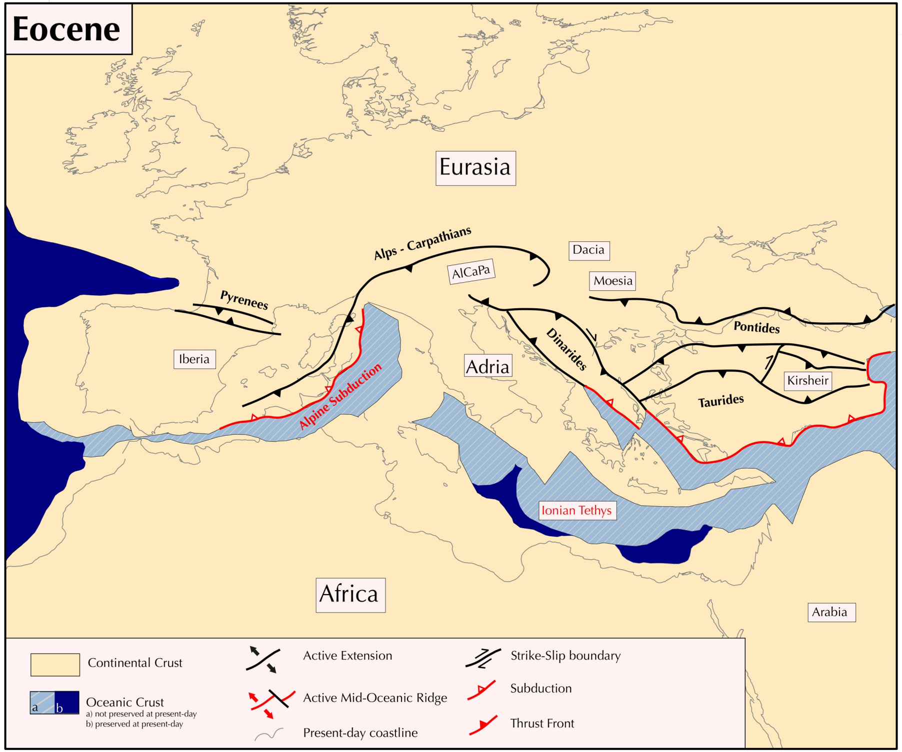
Mediterranean Plate Model: mid-Cretaceous



The ongoing spreading in the South Atlantic region and counterclockwise rotation of Africa resulted in convergence of Africa and Eurasia.

Around ~ 90 Ma Africa began moving northwest relative to Eurasia due to a complex system of spreading developing between Antarctica-Africa, Australia-Greater India and Greater India-Africa. It is also likely a result of activity of the Reunion Plume which also caused an increase in northward velocity of Greater India. This global reorganization of plates increased subduction in the northwestern segment of the Alpine Tethys which was followed by the main collisional stage in the Alpine region during the Paleocene and Eocene.

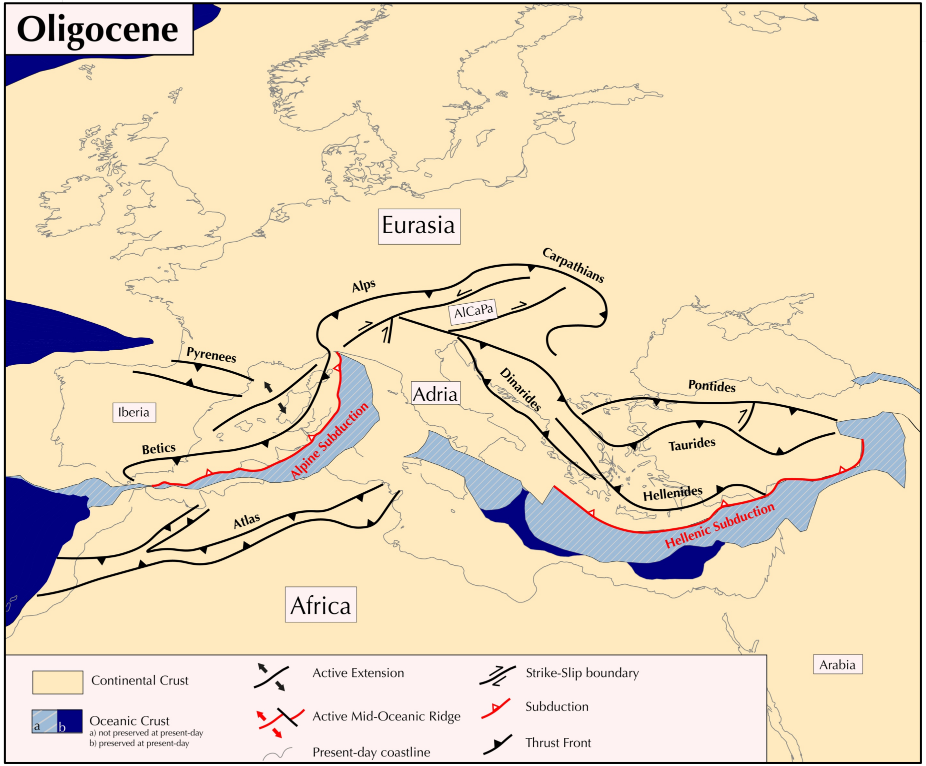
Mediterranean Plate Model: Eocene



The convergence between Eurasia and Africa was further accelerated by the opening of the Northern Atlantic between Norway and Greenland.

By the Eocene the region was dominated by collision and subduction. Oceanic crust survived in only the southern Mediterranean Area.

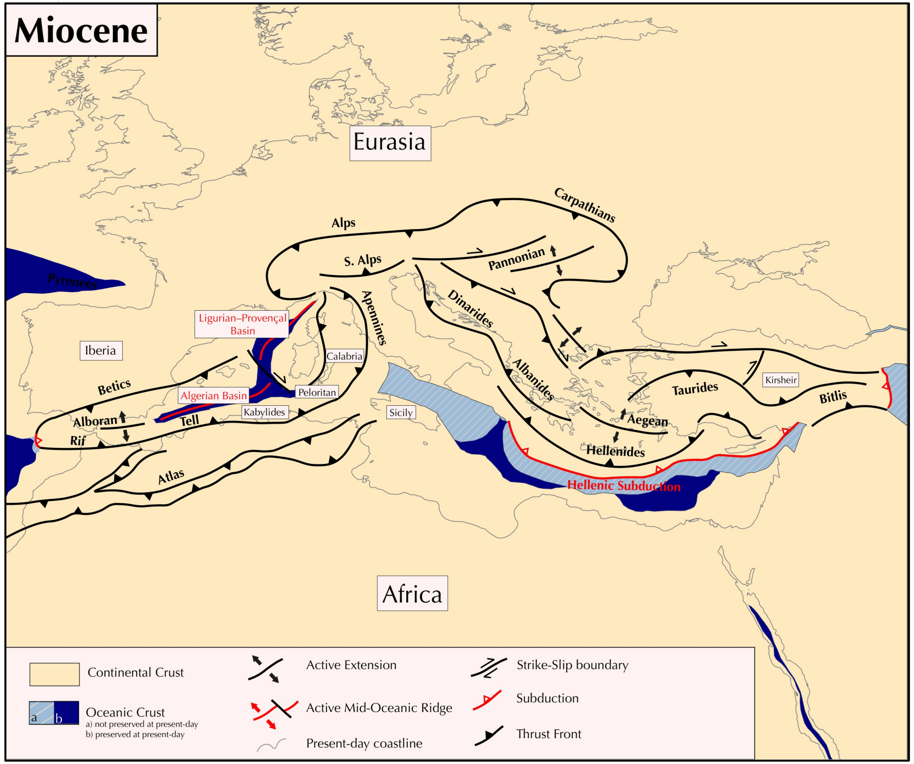
Mediterranean Plate Model: Oligocene



In the Oligocene the indentation of Adria was accommodated by a complex system of strike-slip features that led to the lateral extrusion of AlCaPa.

Back-arc extension started in the Western Mediterranean between Iberia and Sardinia – Corsica.

Mediterranean Plate Model: Miocene and Pliocene



In the Miocene the Alpine Tethys was fully subducted.
Back-arc extension occurred in the Alboran-Algerian-Ligurian-Provençal basins and in the Pannonian and Aegean basins.
The Calabria-Peloritan-Kabylides blocks collided with Adria and North Africa. Also the eastern corridor closed with the development of the Bitlis Massif.
The only survived oceanic crust was Ionian Tethys that at this stage represented the weakest feature of the region.
The ongoing convergence of Africa and Eurasia favored the lateral extrusion of the Calabrian Block, the onset of a new subduction in the Ionian area and the opening of the Tyrrhenian Basin.