ESCOLHER CIÊNCIA

DESCOBRE O CIENTISTA QUE HÁ EM TI

Escolher Ciência

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FROM PANGEA TO ATLANTIC IN THE ALMOGRAVE SECTOR

2014

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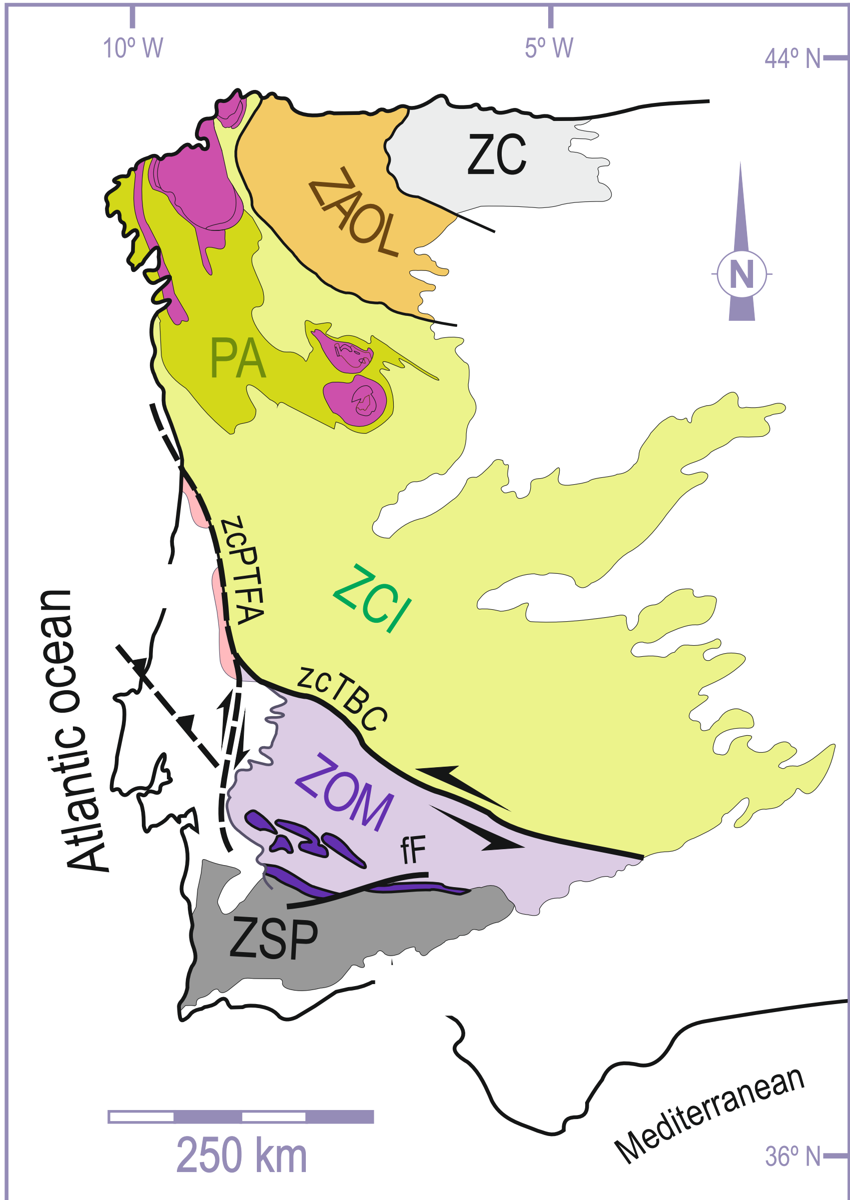
MAIN GEODYNAMICAN ZONES OF THE VARISCAN FOLD BELT IN IBERIA

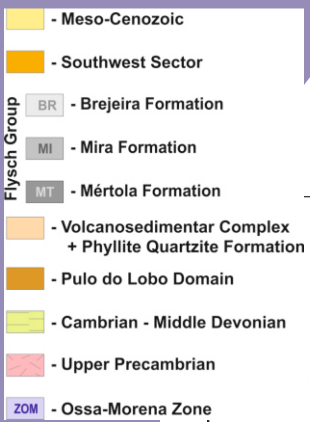


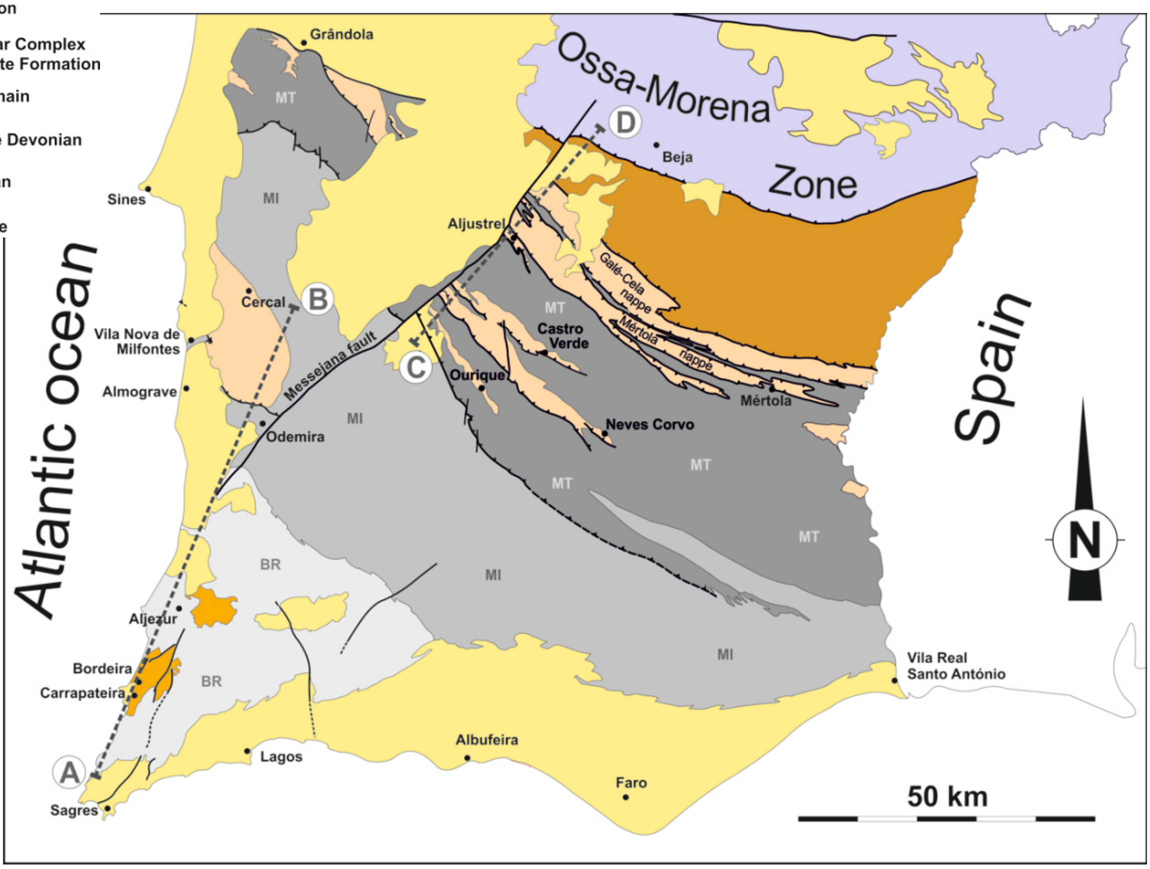
- **ZC** - Cantabrian Zone
- **ZAOL** - West Asturian Leonese Zone
- **ZCI** - Central Iberian Zone
- **PA** - Parautochthonous with Central Iberian affinities
- NW Iberian allochthonon
- **ZOM** - Ossa-Morena Zone
- **ZSP** - South Portuguese Zone

zcPTFA - Porto-Tomar-Ferreira do Alentejo shear zone
zcTBC - Tomar-Badajoz-Córdova shear zone
fF - Ficalho fault

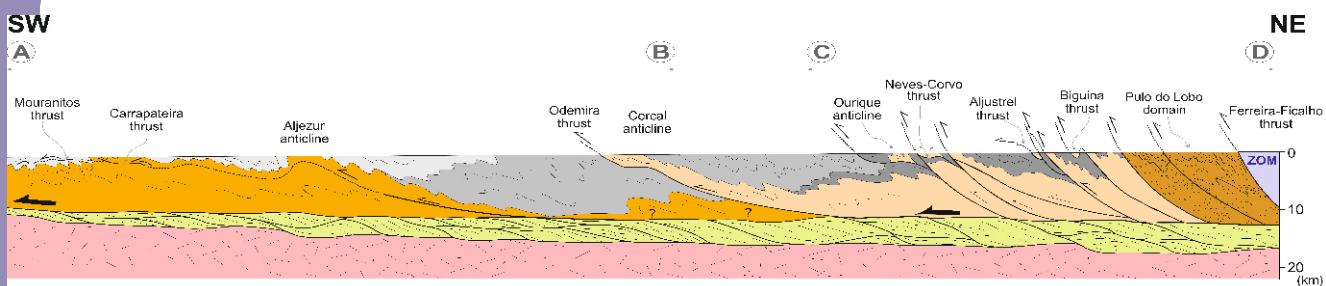
SW Portugal Geology; the transition between two tectonic cycles

In the SW cost of Portugal one could find remarkable outcrops. The preserved geology emphasizes the geodynamical evolution of, not only Portugal, but also of the Pangaea supercontinent assemblage and latter disruption leading to the Atlantic oceanic domain.





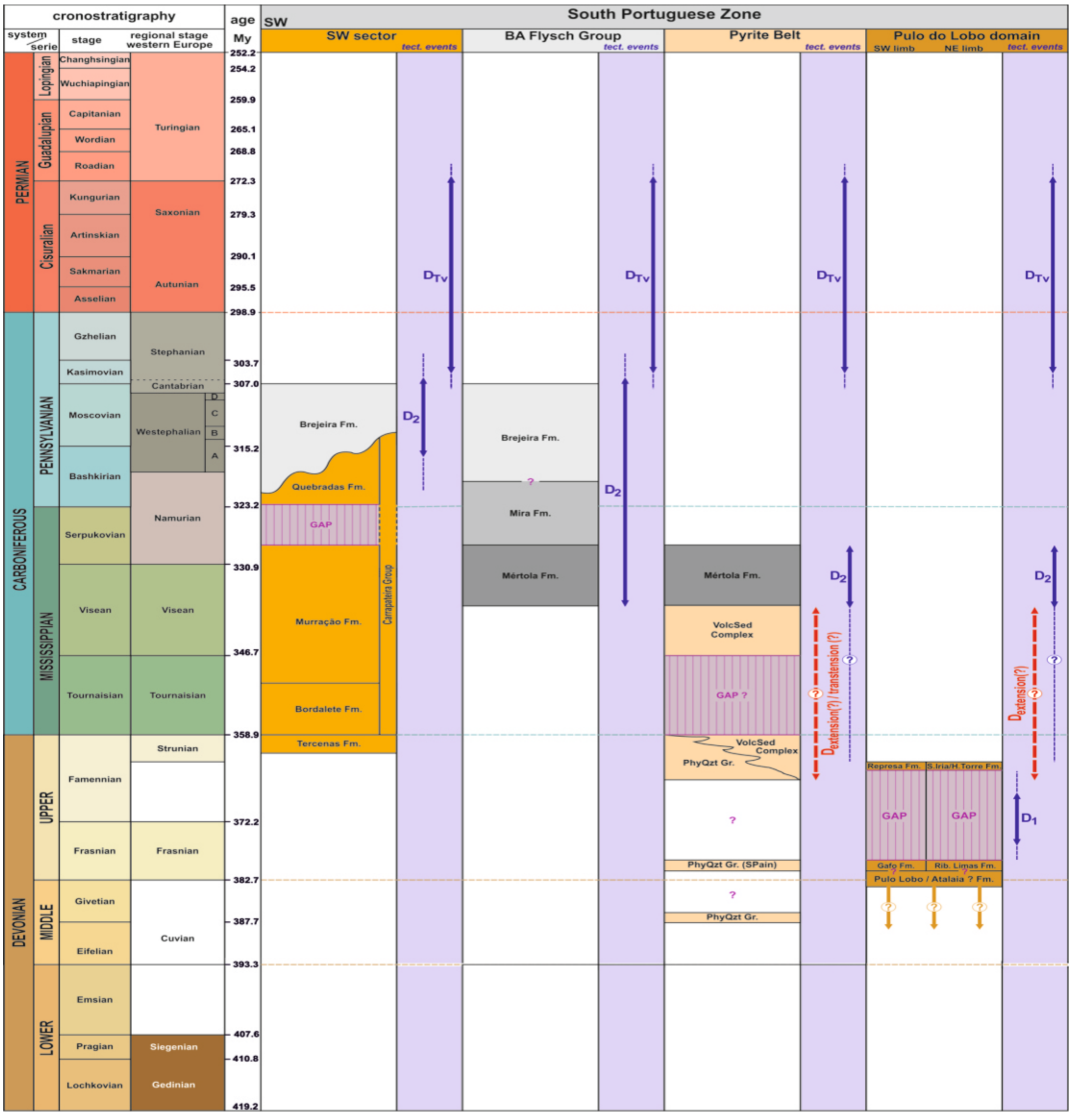
SW Portugal geological map (adapt from LNEG maps)

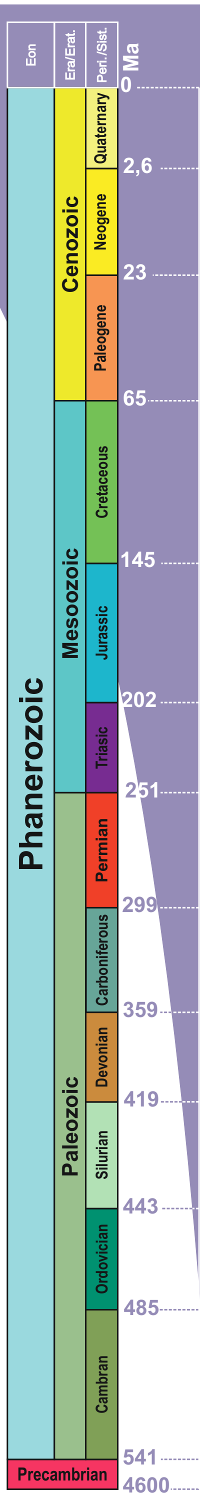


geological cross-section of SW Portugal

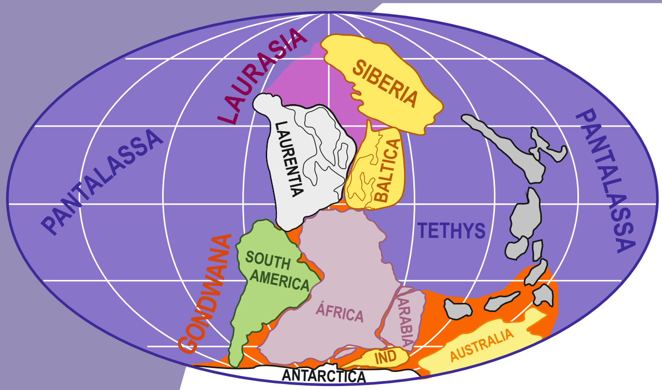
International Chronostratigraphic Chart; a simplified version

In order to understand the geodynamical evolution of any region, it's inescapable to have in mind the main divisions of the International Chronostratigraphic Chart. It could then be possible to have an idea of the temporal relations between major geological formations presented in the region.





Pangea; the last of a supercontinent family

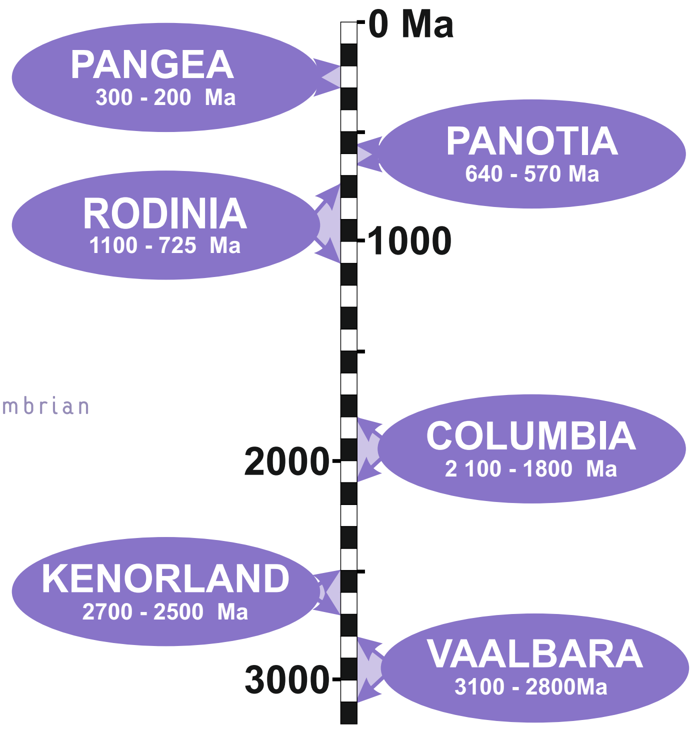


The last supercontinent... Pangea

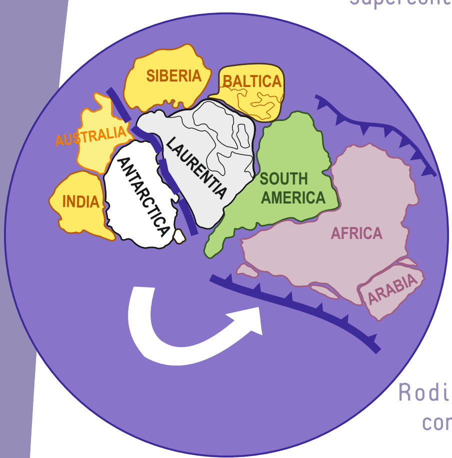
At the end of Carboniferous (*i.e.* circa 300 million years, Ma), all the continents are joined in the so-called Pangea supercontinent. It was surrounded by the great Pantalassa ocean and the minor Tethys interior ocean.

This was not the only supercontinent on Earth evolution and several previous ones have been proposed. Recent studies emphasize what could be considered a supercontinent cycle.

Panotia; the last Precambrian supercontinent



(adapt. from Nance et al, 2014)



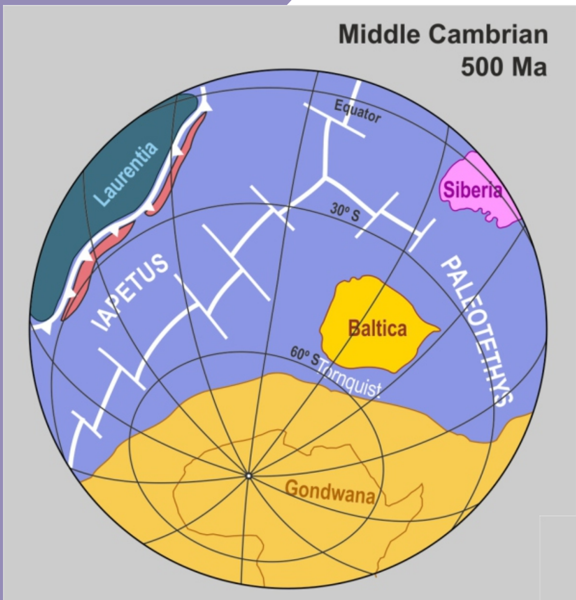
Rodinia; another variation of the continents junction.

Iberia in the Pangea realm; a peculiar position

The Iberia peninsula presents a very peculiar position in the Pangea supercontinent. Indeed, it was located in a median position near the western end of the Tethys ocean and in the vicinity of the boundary between the Gondwana and Laurasia major plates. Such position led Iberia to have a crucial role, not only during the assemblage of Pangea due to the collision between the southern Gondwana and the northern Laurasia during Upper Paleozoic, but also during the closure of Tethys ocean in the Meso-Cenozoic times.

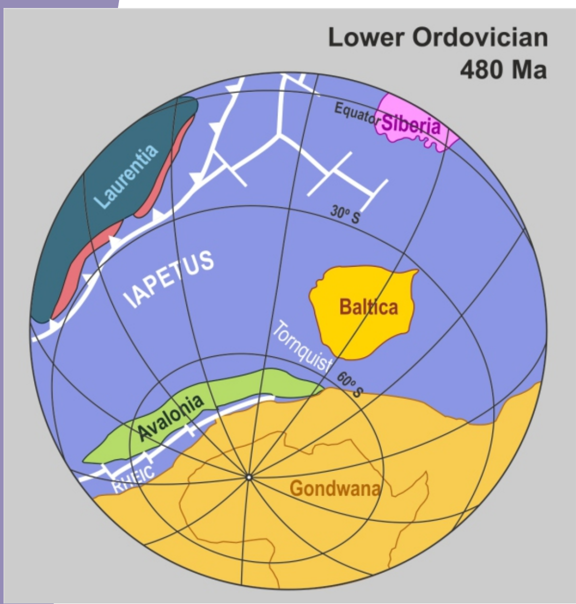
The Iberia position in the Pangea supercontinent.

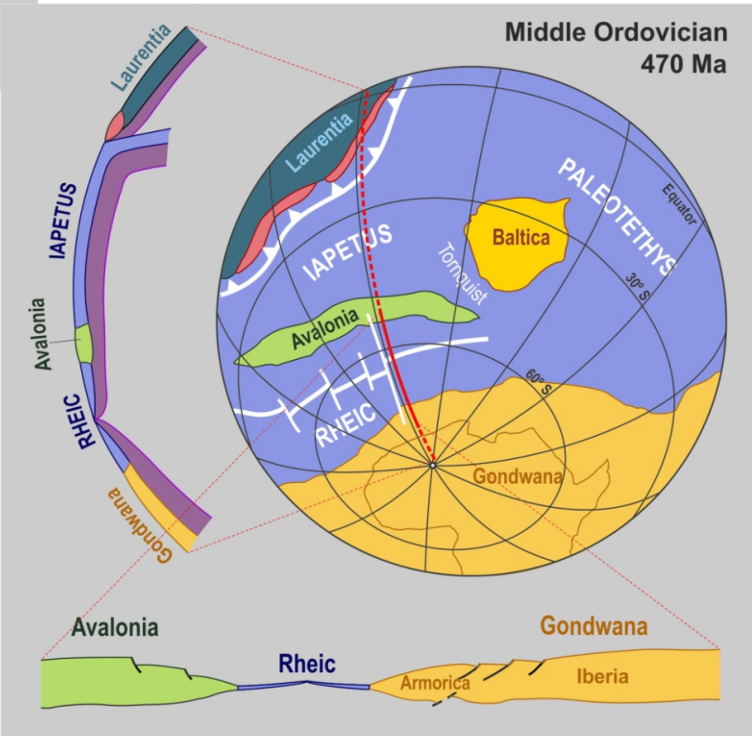
The Lower Paleozoic evolution of Iberia; the predominance of extensional regimes



From the beginning of Cambrian there was a widespread stretching along the northern margin of the large Gondwana plate. This extensional regime gives rise to several basins (e.g. in the Ossa-Morena and Central Iberian zones) where thick sedimentary piles have been build, leading to the development of some minor plates (e.g. Avalonia) due to the opening of the major Rheic ocean. The widening of the Rheic was coeval of the closure of the northern Iapetus ocean subducted bellow the Laurentia.

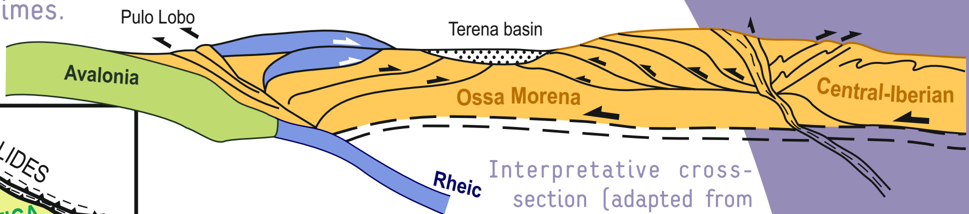
The metassediments that are now outcropping along the SW Portugal have not yet been formed (they are Carboniferous) and most of the models agree that the basement below them should be the Avalonia.



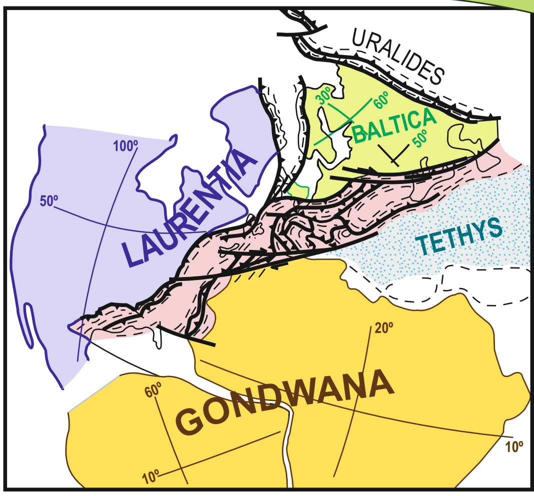


The Upper Paleozoic evolution of Iberia; from the Rheic closure to the Variscan Fold Belt

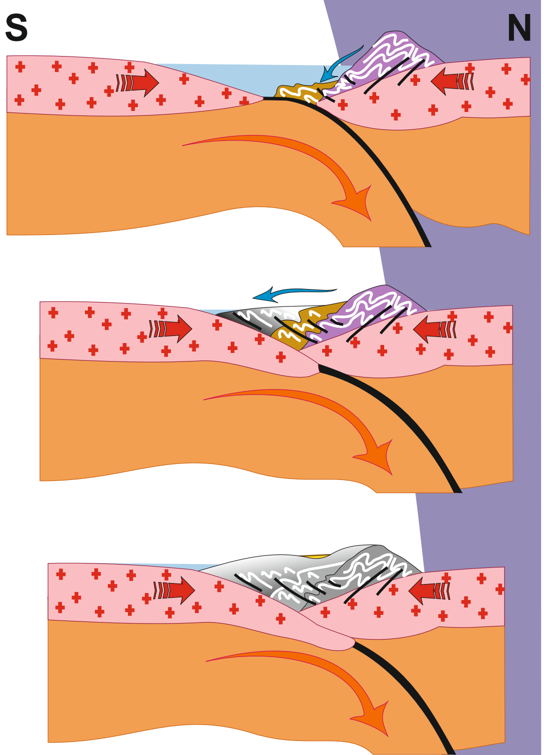
During Lower Devonian Rheic ocean was subducting bellow Gondwana giving rise to the beginning of the Varican Fold belt. The northern Laurasia major continent will collide to Gondwana in the Carboniferous times.



Interpretative cross-section (adapted from Ribeiro, *et al*, 1996).



The variscan fold belt (in pink) in the context of Gondwana northern continents collision (adapted from Ribeiro & Sanderson, 1996).



Devonian folds in Ordovician metassediments of northern Portugal (Marão Mountains).

Carboniferous folds in Carboniferous metassediments in southern Portugal (Arrifana beach).

This collision is diachronic and the deformation is older in northern Portugal progressing towards the South. The flexure of the subducting lithosphere will give rise also to a southward propagation of the ocean basins, which explains that the Carboniferous metassediments in the South Portuguese Zone are older in North (Mértola Flysch) and younger in the South (Brejeira flysch).

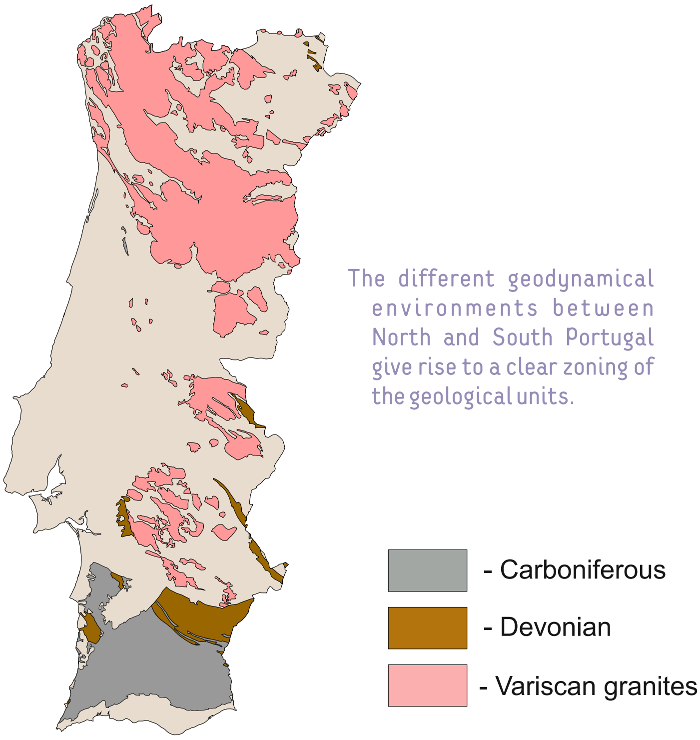
Northern *versus* Southern Portugal in Carboniferous; from the depth to the oceanic domains

Permian-Carboniferous granitic rocks dominate in northern Portugal.

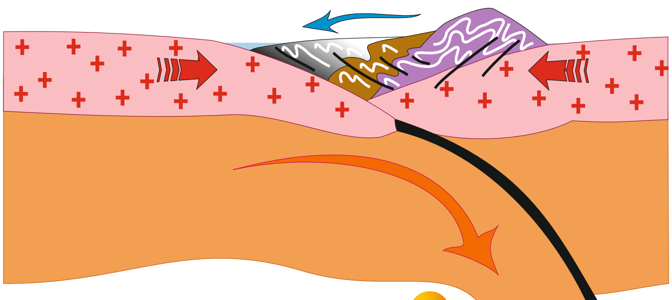
Upper Carboniferous vegetal fossils in mountain lake metassediments (northern Portugal).

Groove marks in greywackes of upper carboniferous turbidites (south-western Portugal).

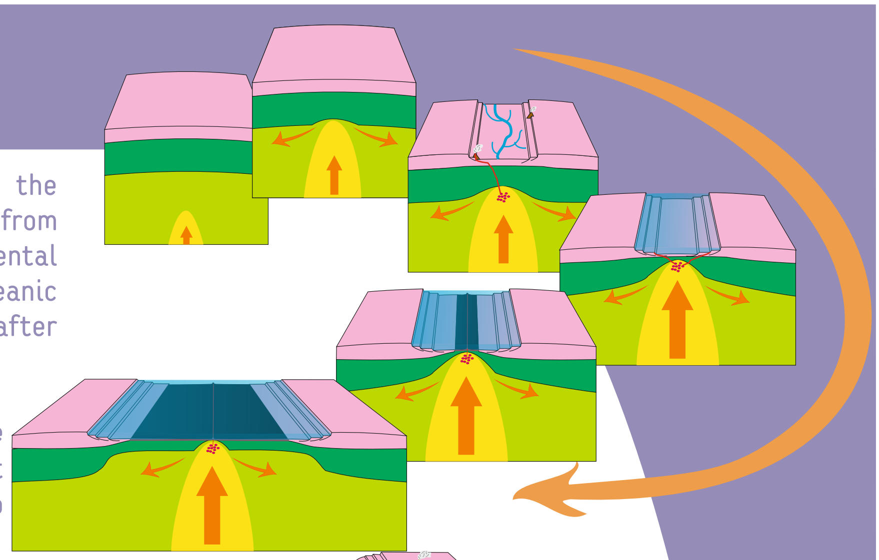
The diachronism of the collision leading to Pangea formation induces during Carboniferous a strong contrast between the geological environments of northern and southern Portugal. While in the North high mountains predominate, in the South there are still marine domains with deposition of turbidite sediments along the continental platform.



The different geodynamical environments between North and South Portugal give rise to a clear zoning of the geological units.

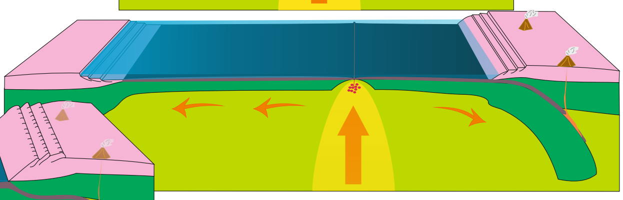


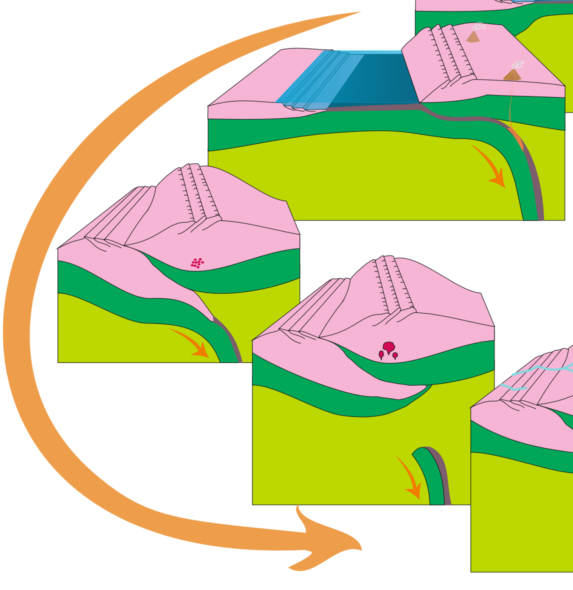
Permo-Triasic; the transition between two Wilson Cycles



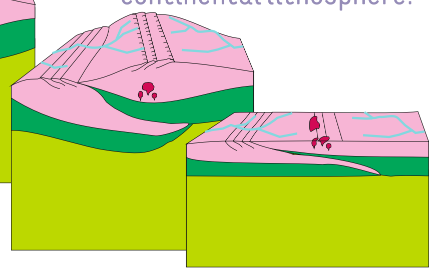
The Wilson Cycle described the evolution of an oceanic realm from the stretching of a continental basement inducing the formation of oceanic crust, until the collision and later erosion after the onset of a subduction zone.

It could be divided in an **extensive stage** where an intracontinental rift evolved to an oceanic one due to continental drifting...



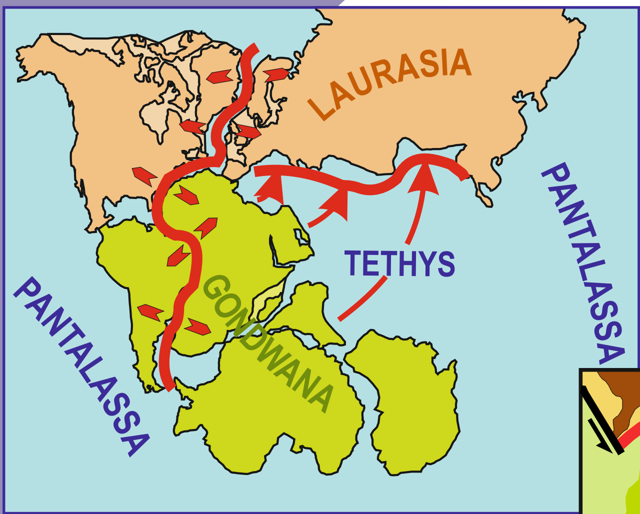


and a **convergent stage** beginning with a subduction zone that led to the total consumption of the oceanic lithosphere and the collision of the two opposed continents. The latter dominance of the erosion / isostatic processes gives rise to a "normal" thick continental lithosphere.

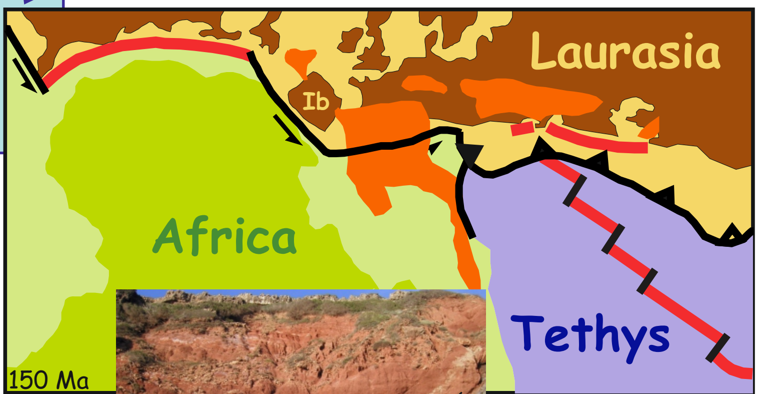


In the Iberian Paleozoic it's possible to emphasize a complete Wilson cycle (the Variscan one), essentially related to the opening and closure of the major Rheic ocean; during the Lower Paleozoic mainly predominates the extensive stage, while the Upper Paleozoic is related to the collision one. The transition from the Paleozoic to the Mesozoic also mark the transition from the Variscan Wilson cycle to the beginning of a new one, related to the opening of the Atlantic ocean. As the subduction along the Atlantic margins has not yet began (or is very incipient), the Atlantic Wilson cycle is still in the extensive stage.

Jurassic;
the great flooding



During the Triasic and Jurassic times the break-up of Pangeia was a very active process. The genesis and widening of Atlantic ocean was facilitated by the subduction of the variscan Tethys along its northern margin; this is similar to what have happen during the expansion of the Rheic while the Iapetus is closing (see page 5).



Normal fault controlling the deposition of Triasic sediments (Sagres region).

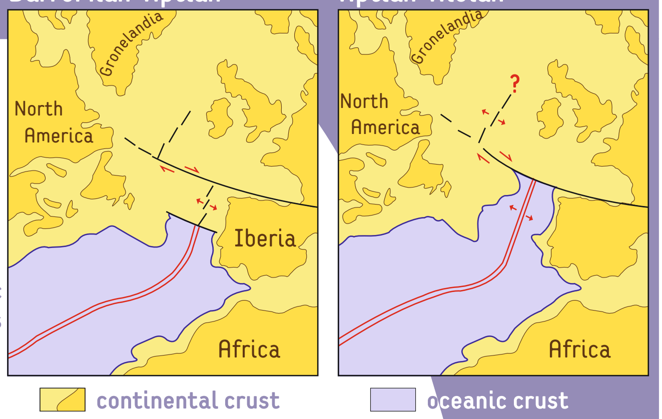
In Triasic the intracontinental rifting is pervasive giving rise to several basins bounded by normal faults (adapted from Twiss & Moores, 1992).

During Jurassic the deepening of the grabben major structures induced their pervasive invasion by water coming from the adjacent ocean; the marine sedimentation becomes common. Nevertheless, only South of Azores-Gibraltar fault there are beginning formation of oceanic crust (adapted from Twiss & Moores, 1992).

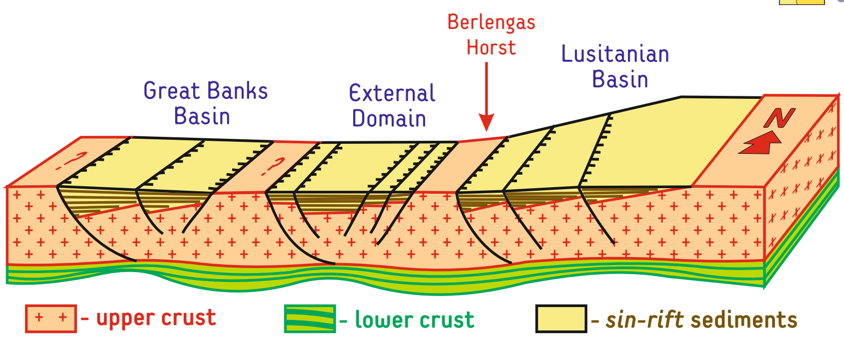
Jurassic limestones (Western Portugal region).

Cretaceous; the expanding Atlantic

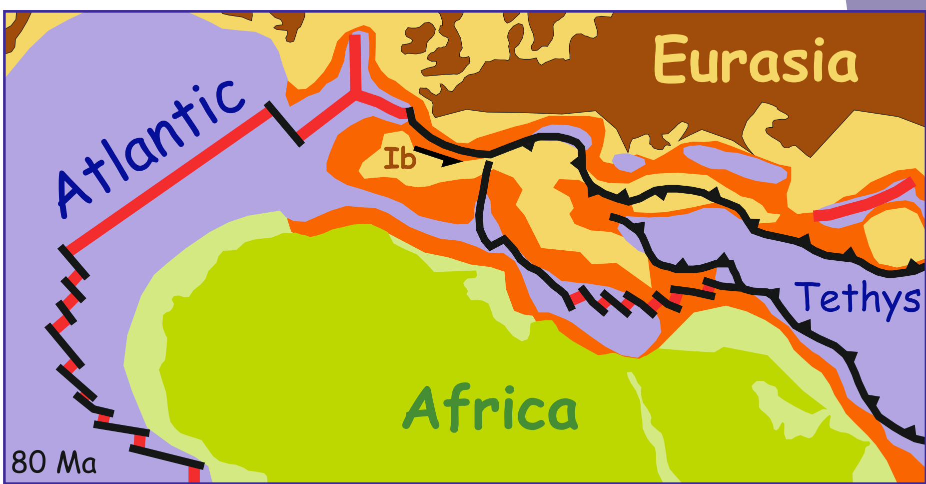
During Cretaceous the spreading along the Atlantic realm continue and the oceanic crust began to develop north of the Azores-Gibraltar transform fault.



The progression of the Atlantic oceanic rift to north was a diachronic process (adapted from Kullberg, 2000).

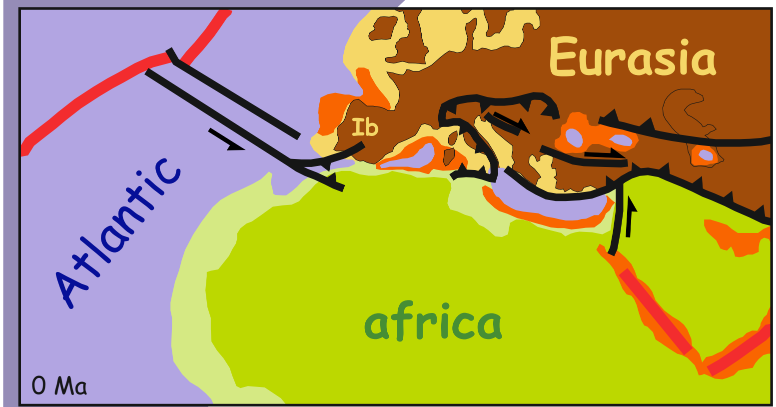


If during the Jurassic the extension is predominant in the Lusitanian Basin, during Cretaceous it will concentrated west of the Berlengas horst where the new Atlantic oceanic crust began to form (adapted from Kullberg, 2000).



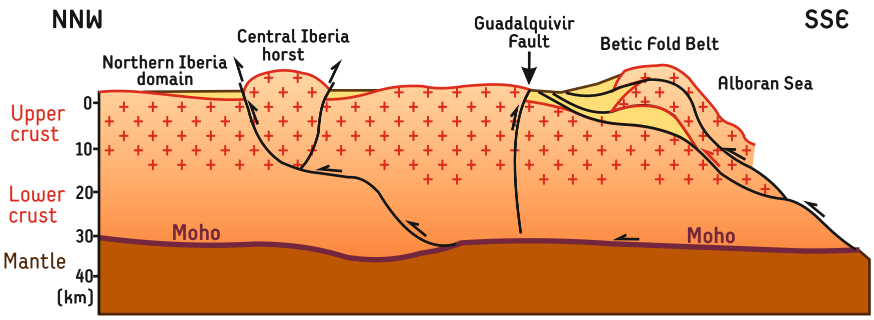
By the end of Cretaceous the subduction of the Tethys oceanic crust is almost finished and the Alpine Fold Belt is almost turning to continental collision stage (adapted from Twiss & Moores, 1992).

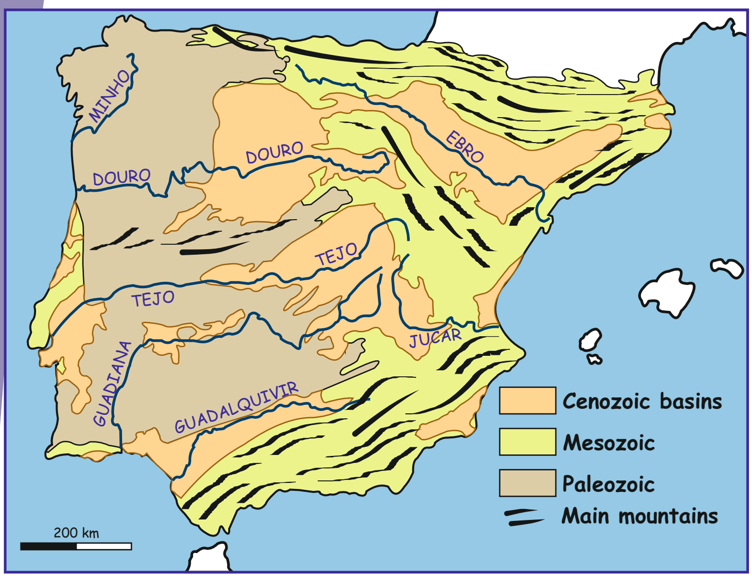
Cenozoic; from the Atlantic generalization to the Tethys closure



During the Lower Cenozoic the Tethys subduction was accomplished and began the collision between Africa and Eurasia. The extensional regime that have predominate during most of the Mesozoic, change to a collision stage (adapted from Twiss & Moores, 2000).

The collision between Africa and Eurasia continental crust, lead to several major horst and graben structures in Iberia (adapted from Ribeiro, 2013)...

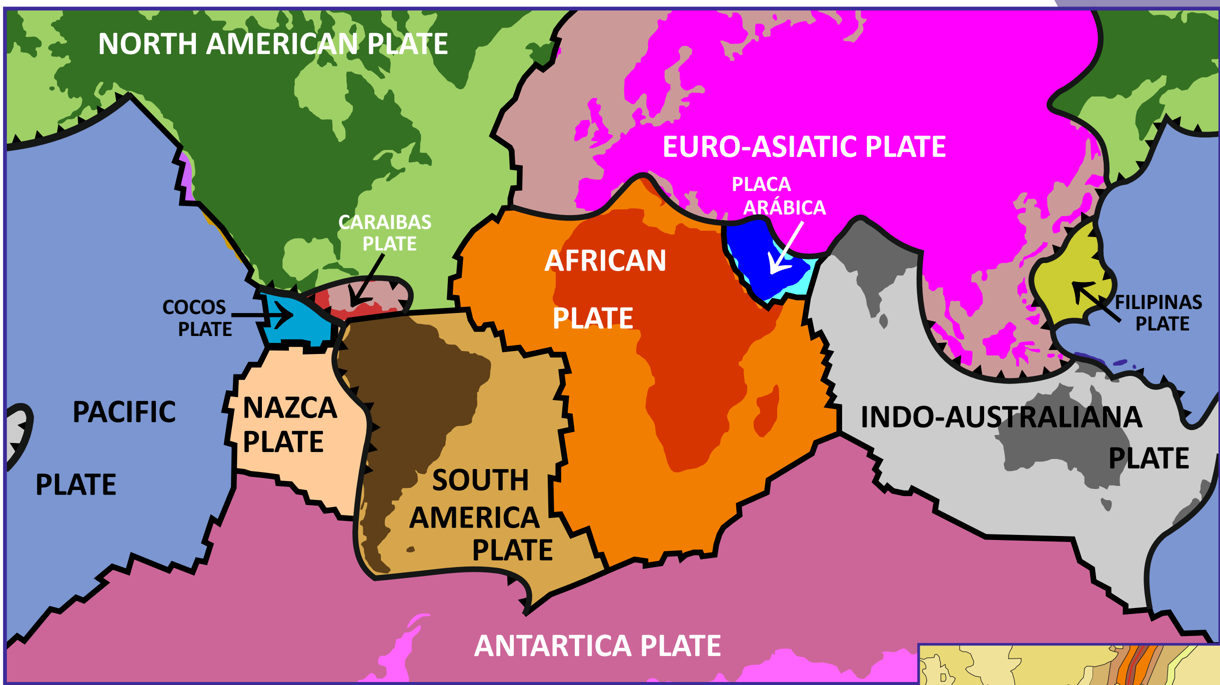


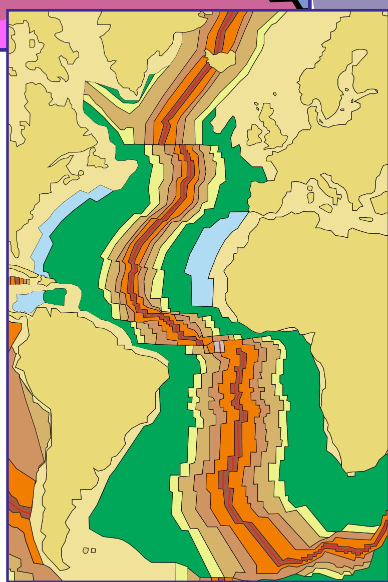


which control most of the geomorphologic features of Iberia (adapted from Ribeiro, 2013). (adapted from Ribeiro, 2013)...

Quaternary; the *'modern'* Plate Tectonics

The previous processes give rise to a geodynamical situation around Iberia that could be understand in the context of active Plate Tectonics.



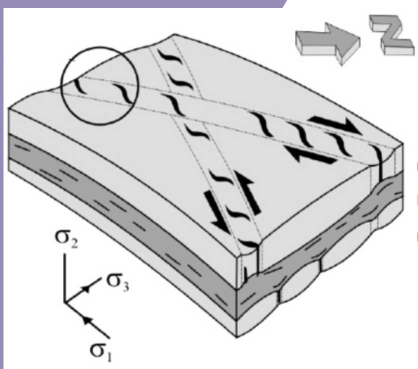


- Middle Jurassic
- Upper Jurassic
- Cretaceous
- Paleocene
- Eocene
- Oligocene
- Miocene
- Holocene

Such Tectonic must be understood considering a very long continental crust evolution (since the Precambrian) and a much younger oceanic crust evolution (since Jurassic times).

STOP 1;
Almograve beach

In the Almograve beach, beautiful outcrops of Upper Carboniferous lower metamorphic turbidites of Mira Formation help to understand, not only the deformation processes during the late stages of Variscan orogeny, but also the sedimentation ones.

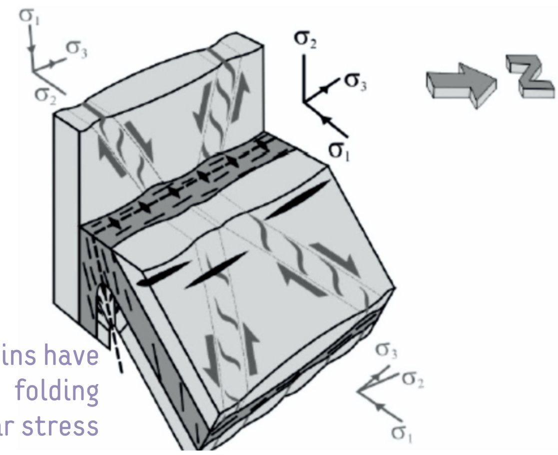


In this region, the older deformation (*D1a*) is marked by en-echelon conjugated veins related with a stress-field with major sub-horizontal compression NE-SW and a minor one, also sub-horizontal and NW-SE (Dias & Basile, 2013).

Conjugated en-echelon quartz veins seen in the bedding plane of a fold limb.

Detail of previous veins developed along the necks of *D1a* boudinage structures.

The interference between mesoscopic structures (*i.e.* veins and / or folds) allow the individualization of different deformation pulses.



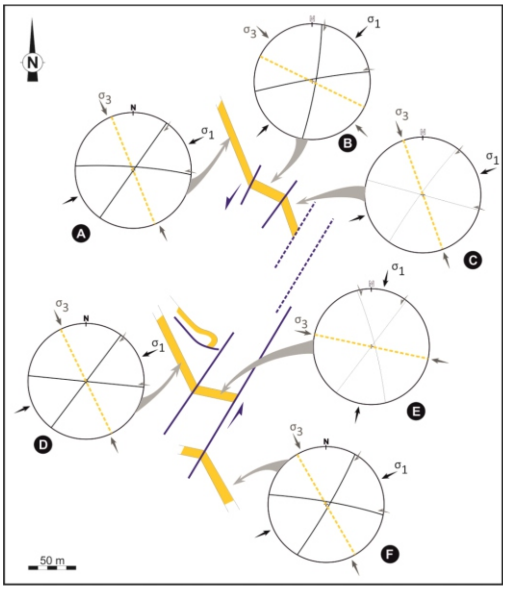
The early en-echelon veins have been folded by the main folding event (*D1b*), with a similar stress field (Dias & Basile, 2013).

from the turbidites deposition to the Variscan deformation

D1b folds with sub-horizontal axes and steeply plunging axial plane are the main tectonic structures found in the Almograve sector.

Due to the thick greywacke layers with usually thin interbedded beds, there are often strong folding disharmonies.

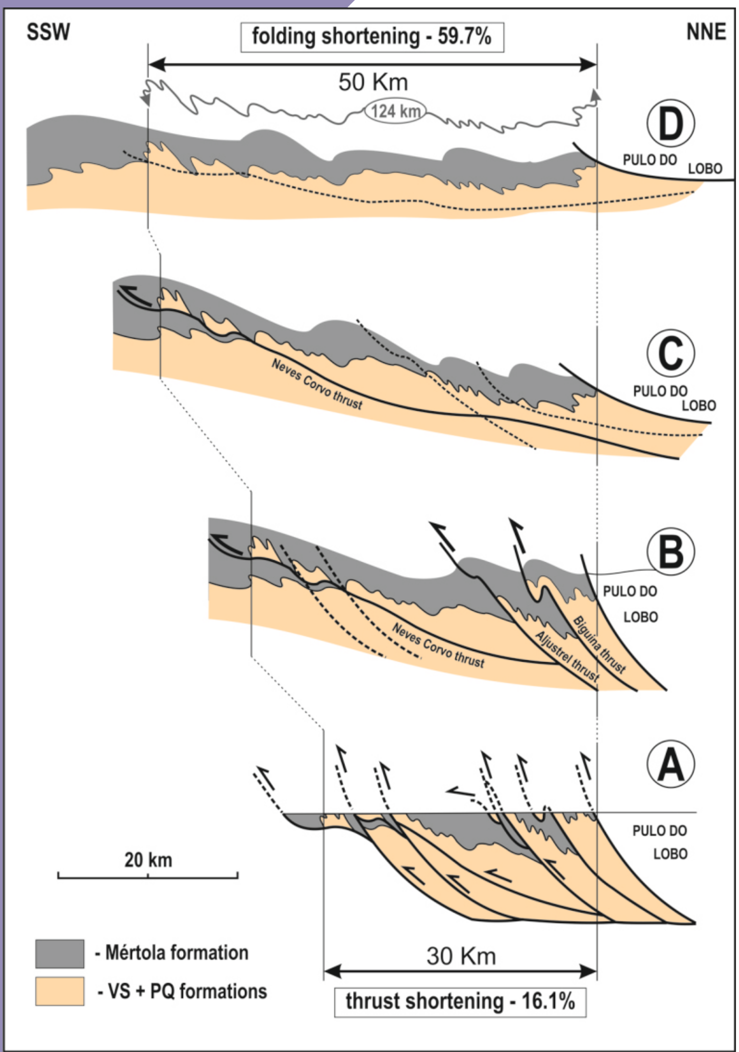
The slatty *D1b* cleavage is only developed in places where the deformation is higher



The interference between *D1* and *D2* structures give rise to a complex pattern of folds with axes ranging from sub-horizontal to subvertical.

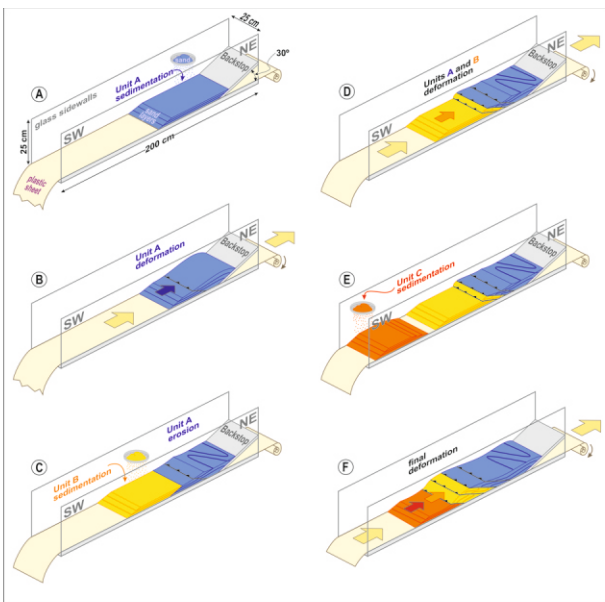
The Tardi-Variscan deformation (*D2*) give rise to NNE-SSW sinistral strike slip faults, with a britlle to brittle-ductile behaviour that deflected previous structures (Dias & Basile, 2013).

STOP 2;
Arrifana restaurant



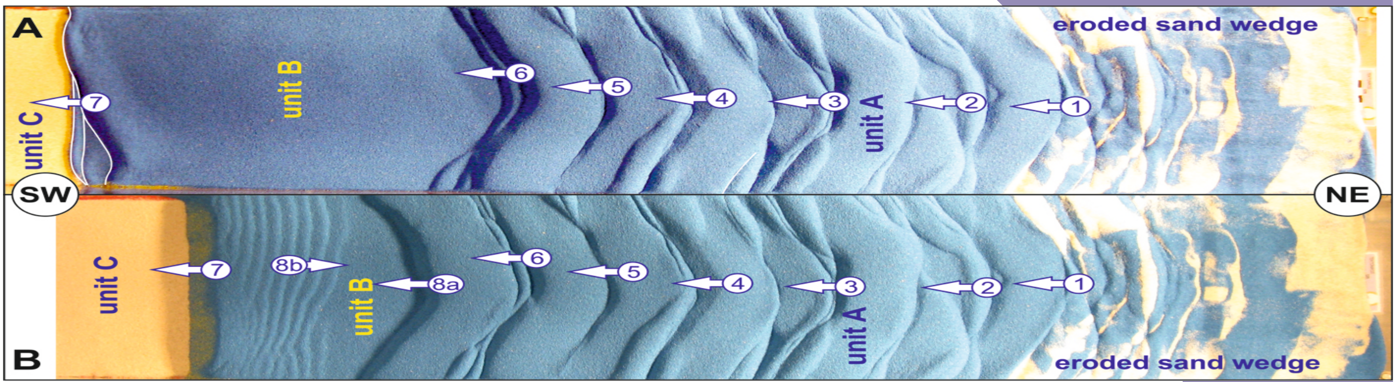
The analogue modelling is a powerful tool in the understanding of the structural evolution of a region. The deformation of accretionary wedges have been frequently studied using sand box experiments; the South Portuguese Zone evolution has been recently modelled (Bolacha & Dias, 2013)

In the performed experiments the work began by estimating the shortening induced by the folding and thrusting using published cross-sections (adapted from Bolacha & Dias, 2013).

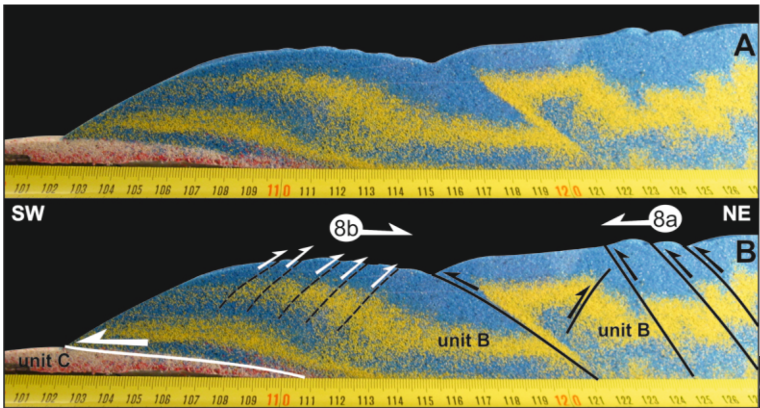


This allows the planification of a multi-staged experiment scaled to the geology of the South Portuguese Zone (adapted from Bolacha & Dias, 2013).

from the lunch to the analogue modelling of an accretionary wedge



Plane view (after erosion of the inner domains) of one of the experiments, showing the south-western propagation of the thrusts as it has been emphasized in the South-Portuguese Zone (adapted from Bolacha & Dias, 2013).



Detail in a cross-section view of the frontal part of one of the experiments, showing the complex pattern of the interference resulting from the progressive thrusting deformation (adapted from Bolacha & Dias, 2013).

Detail of the Mouranitos thrust in the external sectors (Sagres region) of the South Portuguese Zone (adapted from Dias & Basile, 2013).

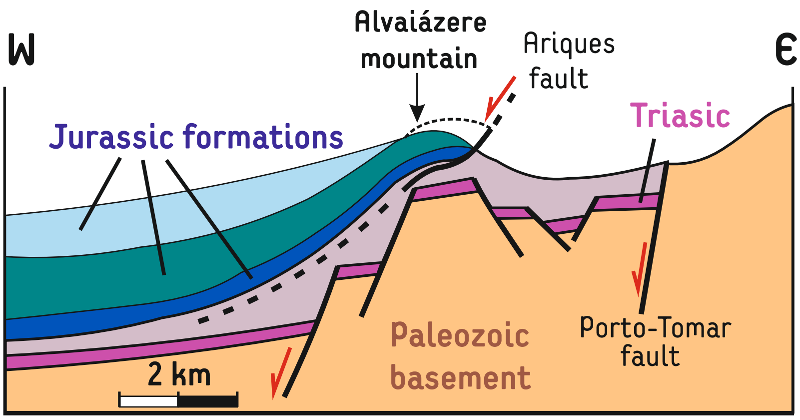
STOP 3; Carrapateira village / Amado beach

The region around Carrapateira preserved a small Lower Mesozoic basin where the Triasic and Jurassic sediments have been preserved. Such basins, overlies a Carboniferous basement being bounded by steep faults in a structure process similar to the formation of the Lusitanian Basin in western Portugal.

Google Earth satellite image of the coast around Carrapateira village.

Sin-sedimentary normal faults in Triasic sediments of SW Portugal.

Structural relation between the Lower Mesozoic and the Paleozoic Basin north of Lisbon (adapted from Kullberg, 2000); a similar situation is found in the Carrapateira sector.

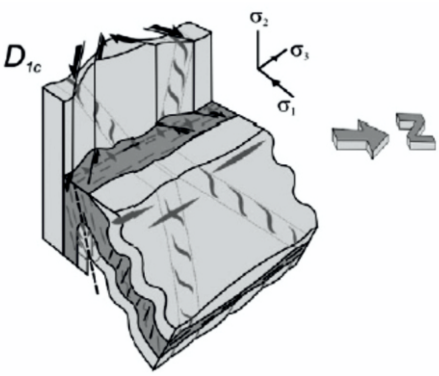


from Fold Belt erosion to the beggining of Oeanic spreading

The Sagres Cape is developed in Lower Jurassic limestone where the high cliffs are eroding a raised quaternary beach.

In the vicinity of this Cape, Triasic very low dipping sediments underline the Jurassic limestones.

Bellow the Triasic a spectacular unconformity developed above Upper Carboniferous low grade metassediments (Telheiro beach).



This subvertical folds could be considered regional D1c (Dias & Basile, 2013) because they refold previous folds that could be considered D1b (see Almograve stop).