Università di Trieste
Corso di Laurea Magistrale in Esplorazione Geologica

Anno accademico 2021 - 2022

Geologia Marina

Parte IV

Modulo 5.2 Mediterraneo 2 (Balearico, Alboran, Ionio)

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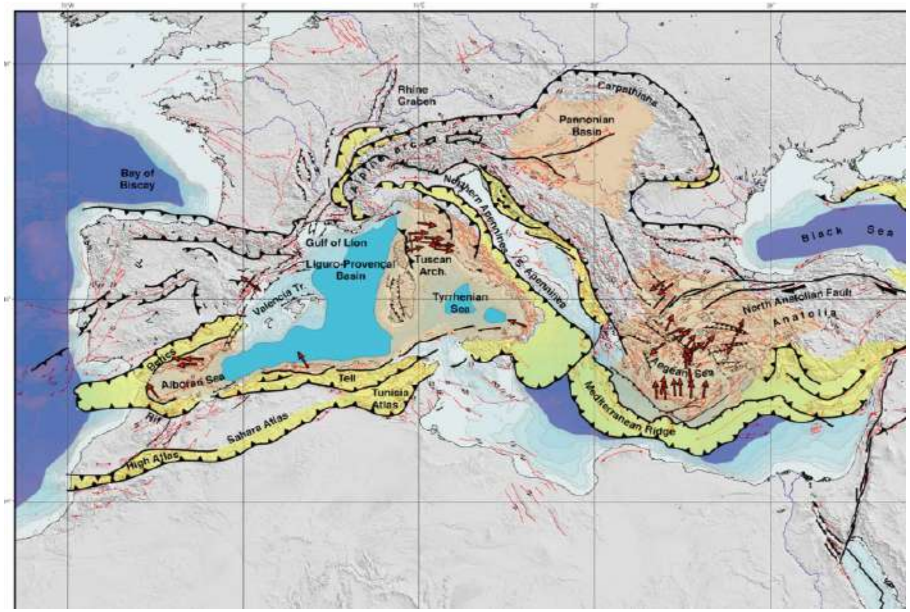
From Paleo-Tethys to the Mediterranean basins

ca. 250 million years ago

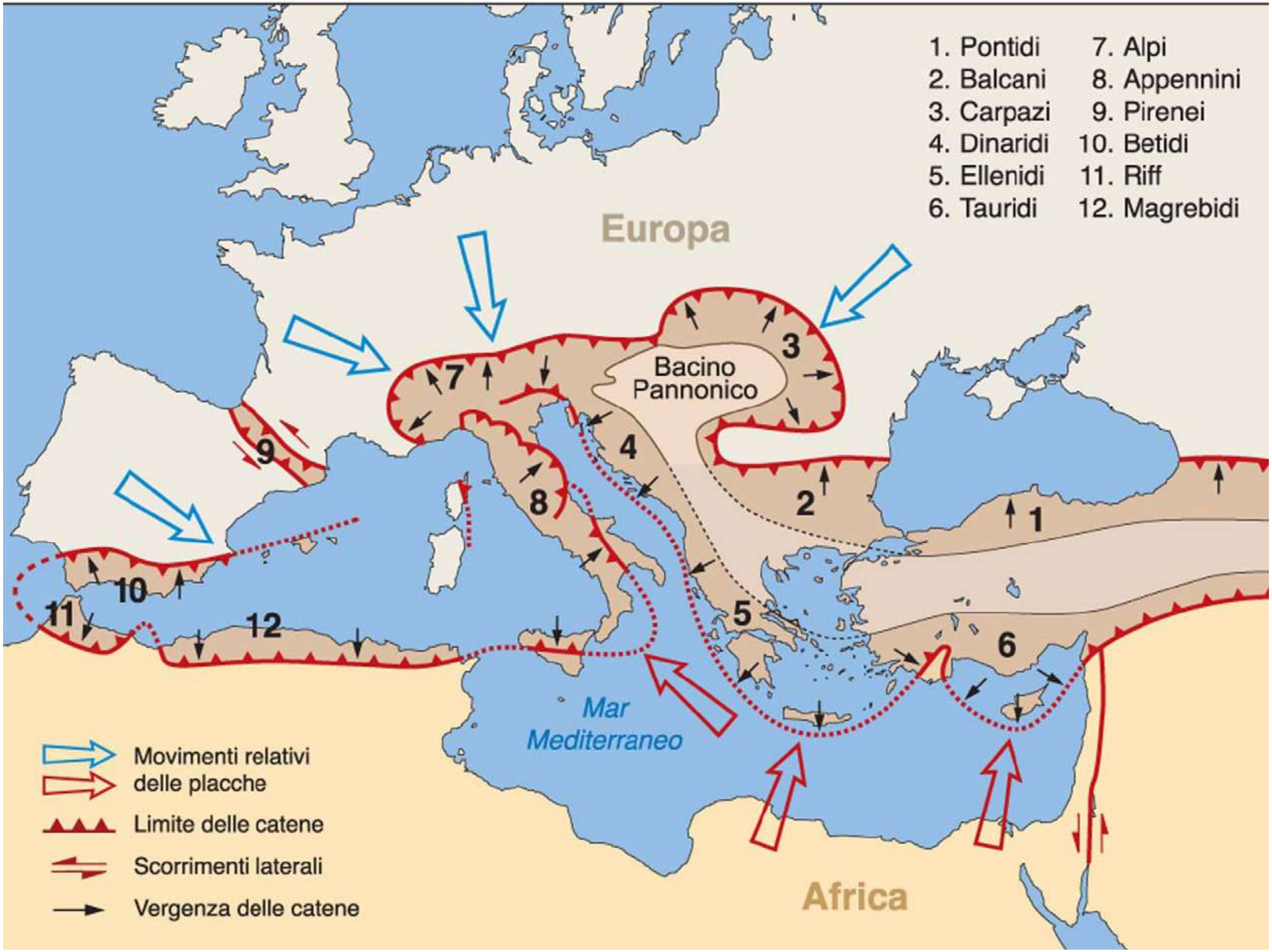


Today

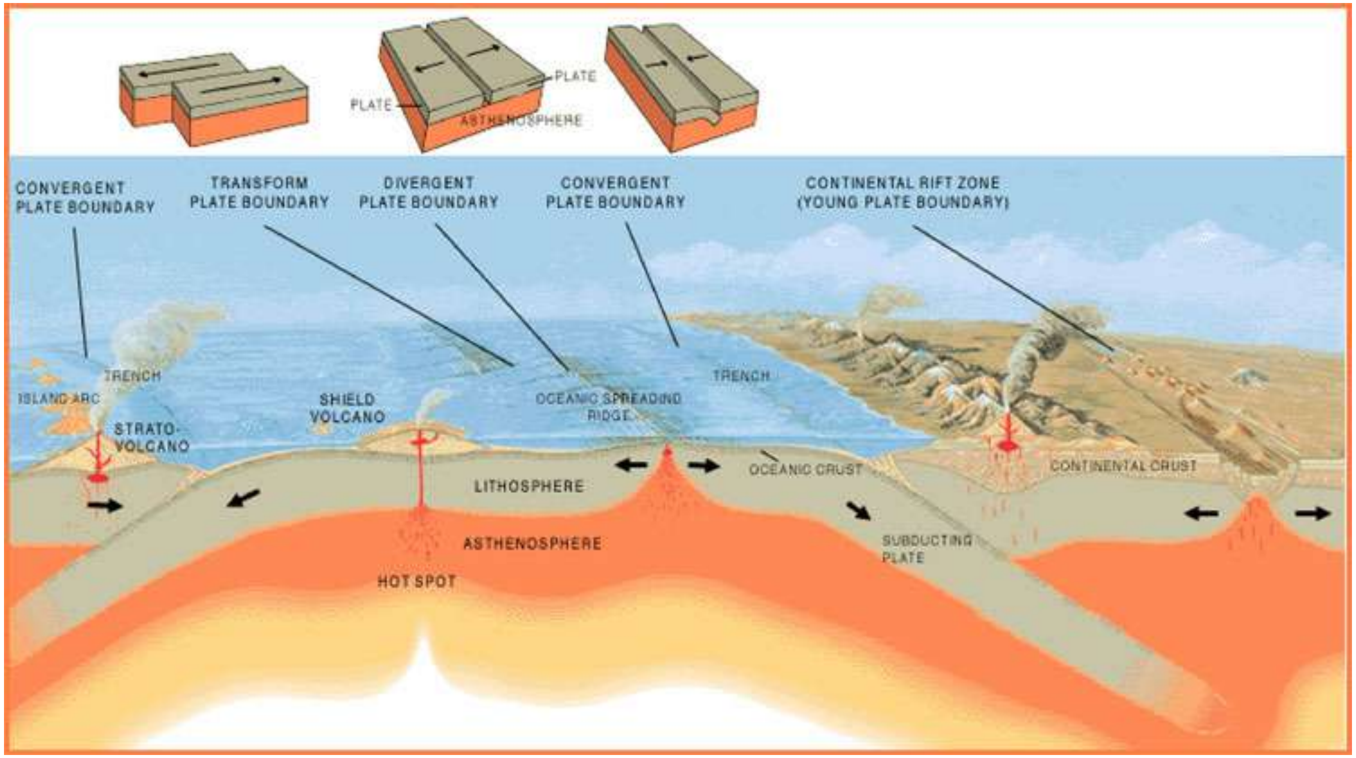
Planet Earth formed around 4,500 bilion yers ago

CIRCUM-MEDITERRANEAN OROGENIC BELTS

Alpine – Himalayan collisional system (Mesozoic-Present)



There are three kinds of plate tectonic boundaries: divergent, convergent, and transform plate boundaries.



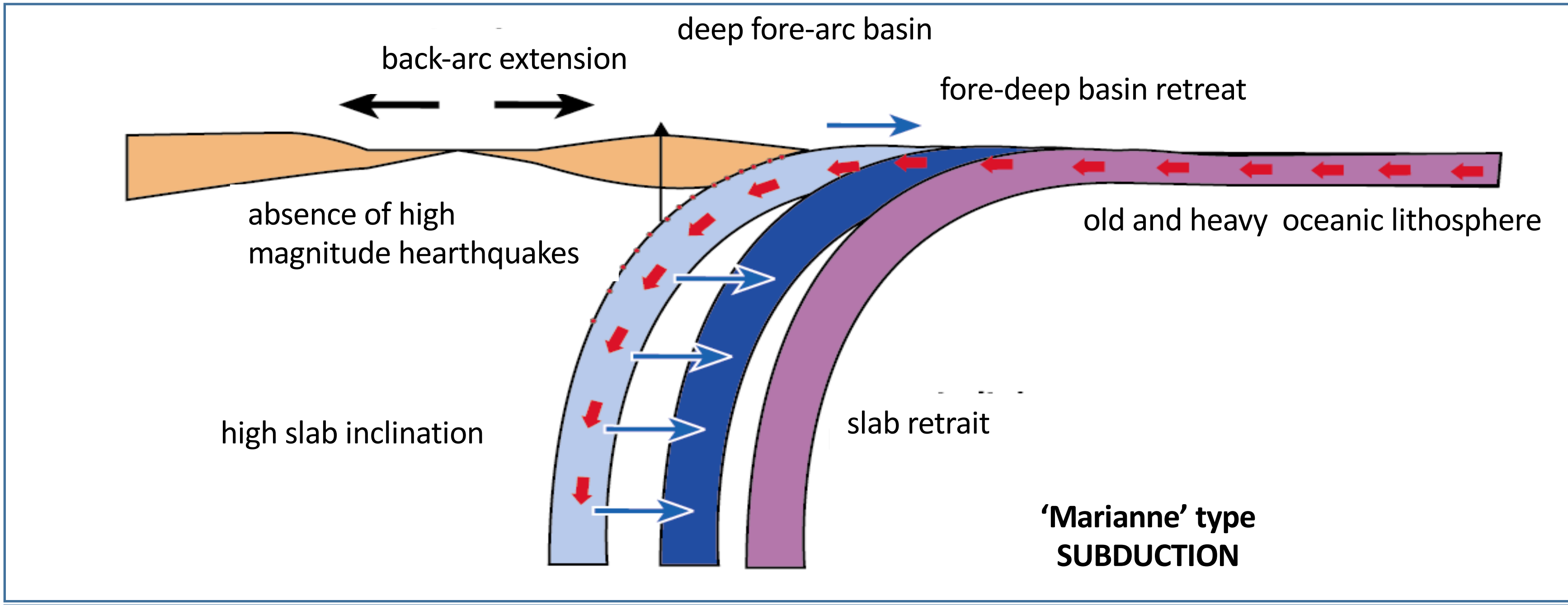
from NOAA Ocean Explorer

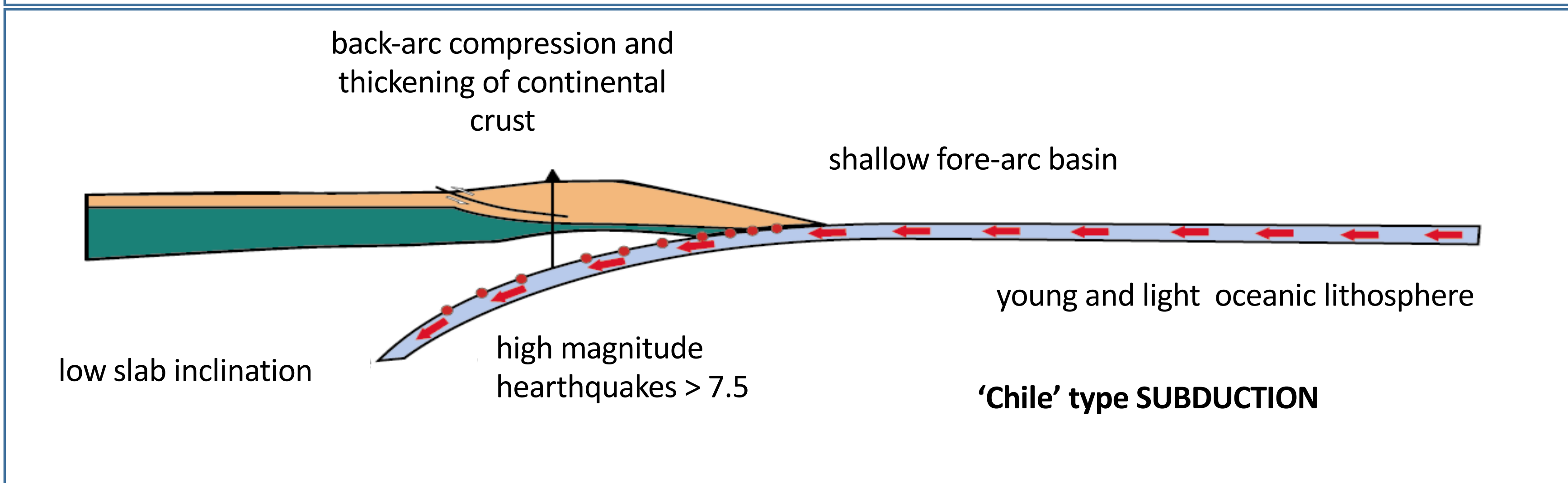
A **divergent boundary** occurs when two tectonic plates move away from each other. Along these boundaries, lava spews from long fissures and geysers spurt superheated water. Frequent earthquakes strike along the rift. Beneath the rift, magma—molten rock—rises from the mantle. It oozes up into the gap and hardens into solid rock, forming new crust on the torn edges of the plates. Magma from the mantle solidifies into basalt, a dark, dense rock that underlies the ocean floor. Thus at divergent boundaries, oceanic crust, made of basalt, is created.

When two plates come together, it is known as a **convergent boundary**. The impact of the two colliding plates buckles the edge of one or both plates up into a rugged mountain range, and sometimes bends the other down into a deep seafloor trench. A chain of volcanoes often forms parallel to the boundary, to the mountain range, and to the trench. Powerful earthquakes shake a wide area on both sides of the boundary. If one of the colliding plates is topped with oceanic crust, it is forced down into the mantle where it begins to melt. Magma rises into and through the other plate, solidifying into new crust. Magma formed from melting plates solidifies into granite, a light colored, low-density rock that makes up the continents. Thus at convergent boundaries, continental crust, made of granite, is created, and oceanic crust is destroyed.

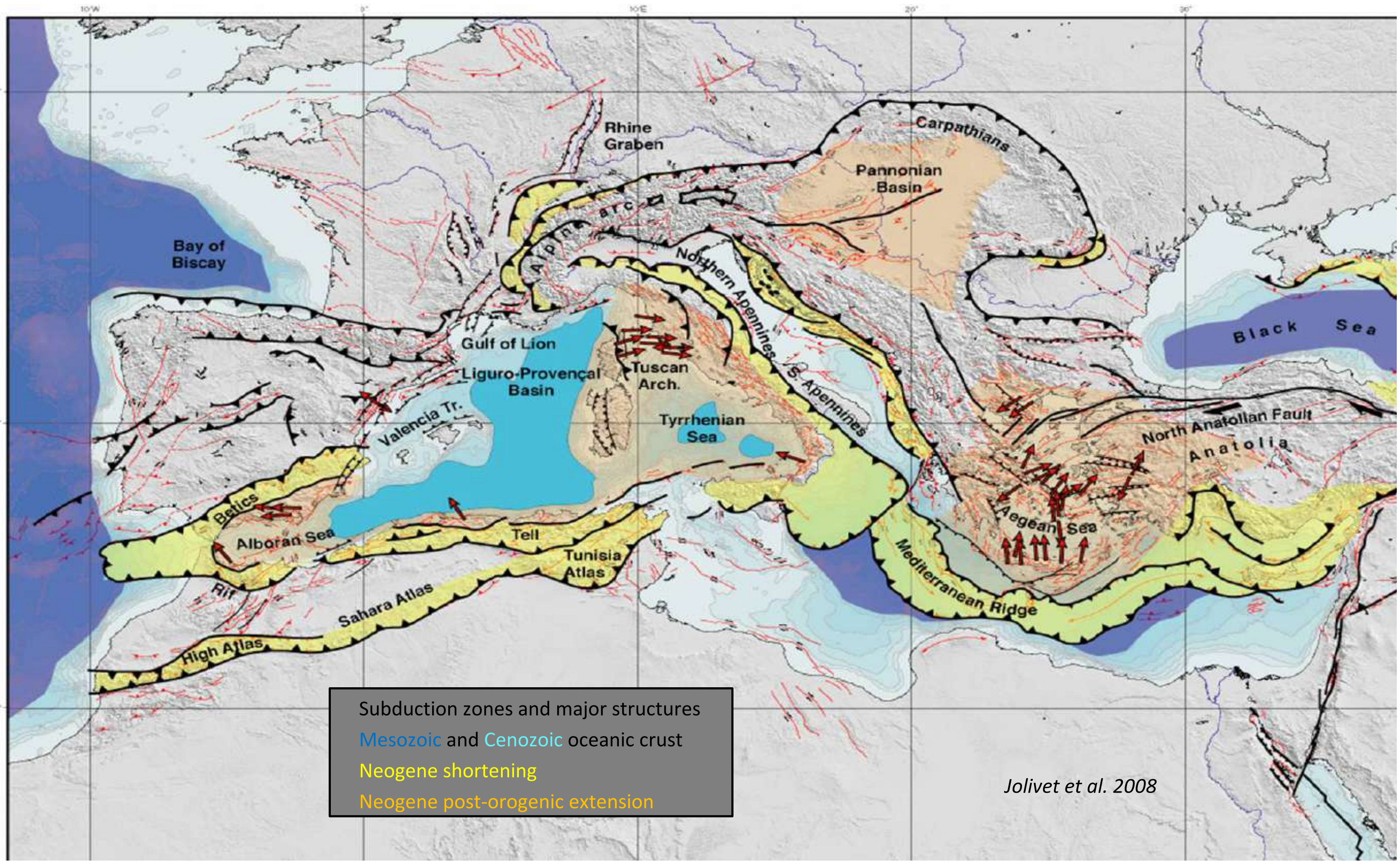
Two plates sliding past each other forms a **transform plate boundary**. Natural or human-made structures that cross a transform boundary are offset—split into pieces and carried in opposite directions. Rocks that line the boundary are pulverized as the plates grind along, creating a linear fault valley or undersea canyon. As the plates alternately jam and jump against each other, earthquakes rattle through a wide boundary zone. In contrast to convergent and divergent boundaries, no magma is formed. Thus, crust is cracked and broken at transform margins, but is not created or destroyed.

CONVERGENT PLATE BOUNDARIES





THE MEDITARRANEAN MAJOR TECTONIC STRUCTURES

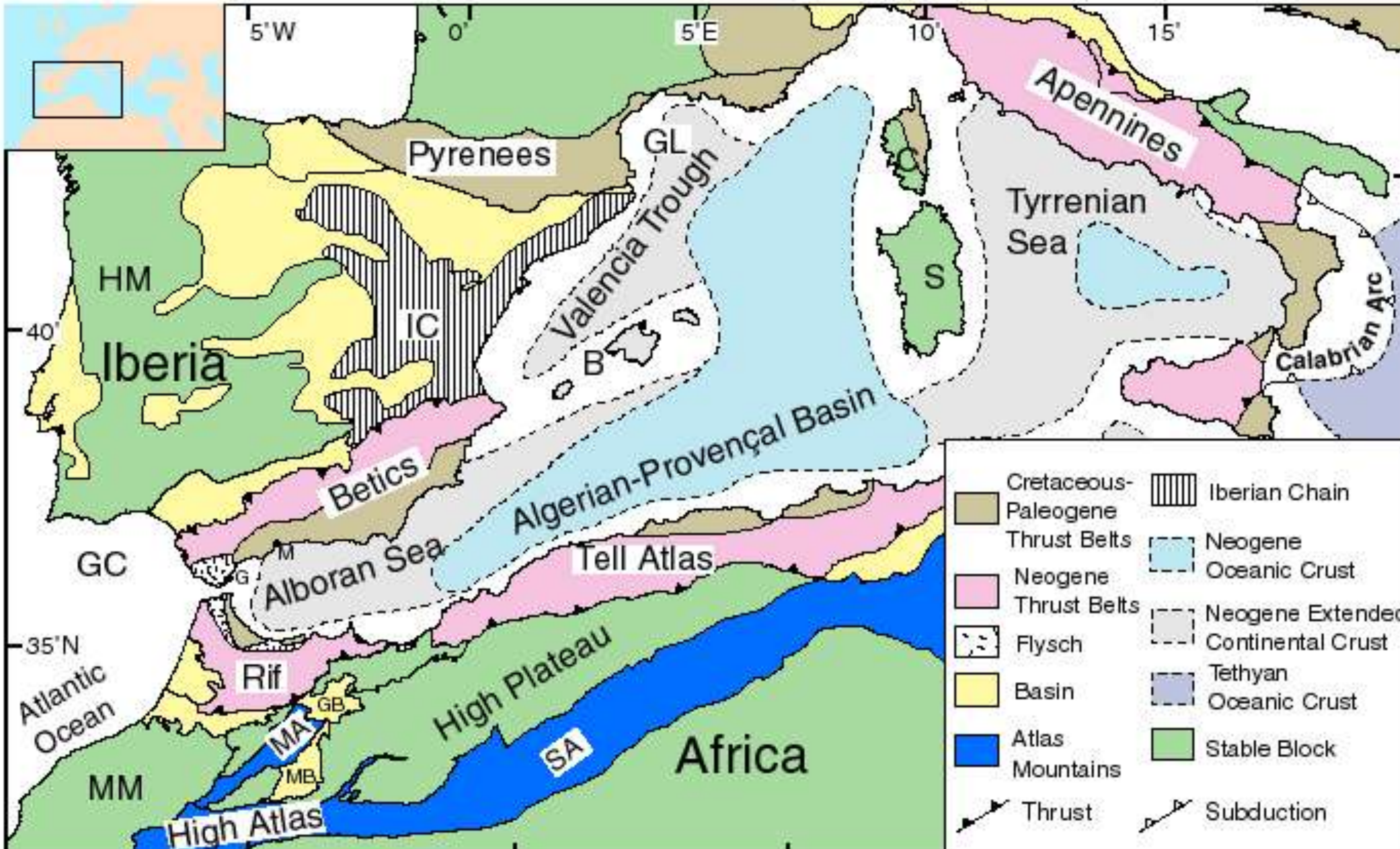


Subduction zones and major structures
Mesozoic and Cenozoic oceanic crust
Neogene shortening
Neogene post-orogenic extension

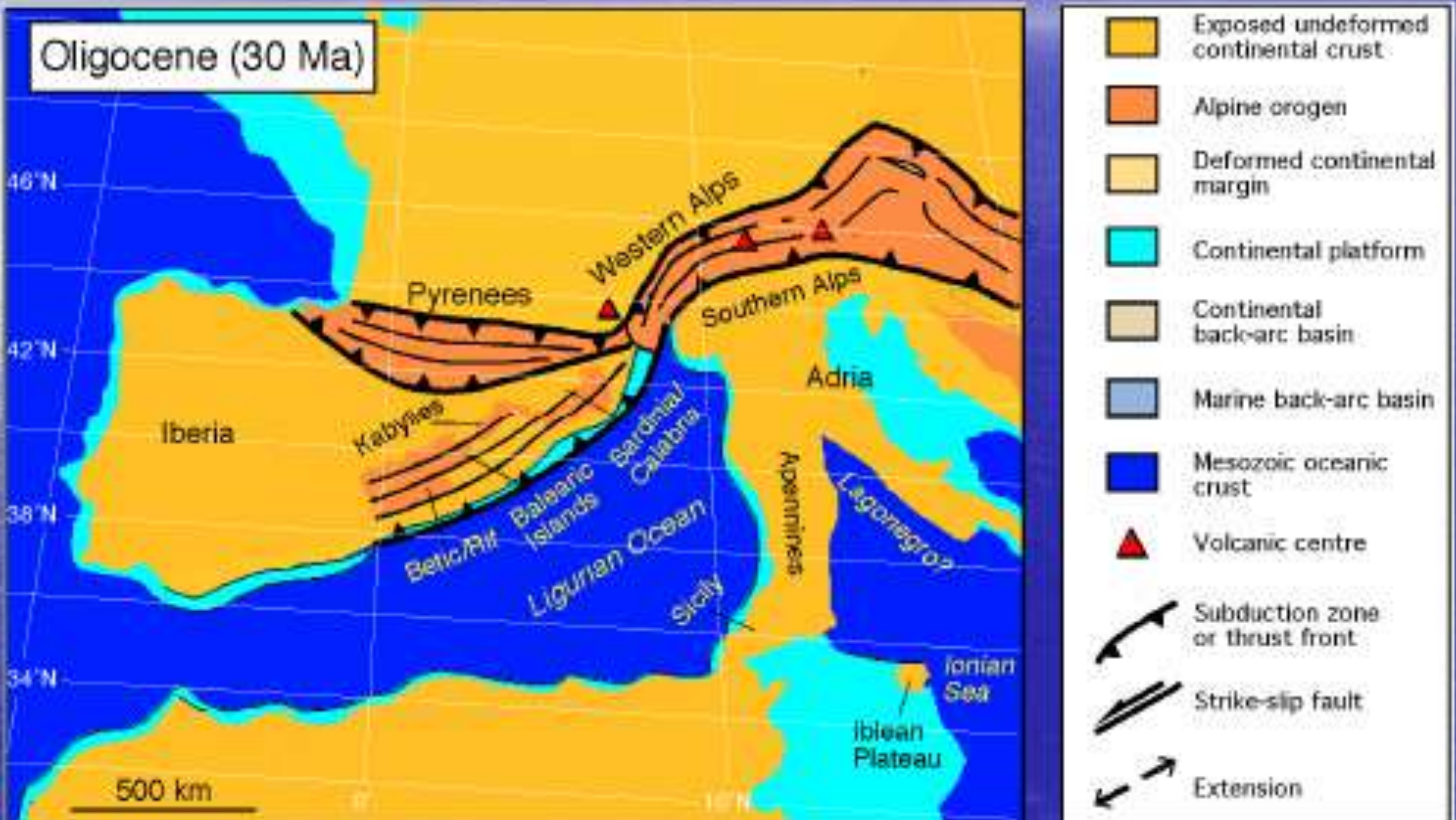
Jolivet et al. 2008

SEISMICITY AT PLATE BOUNDARIES

WESTERN MEDITERRANEAN BASINS

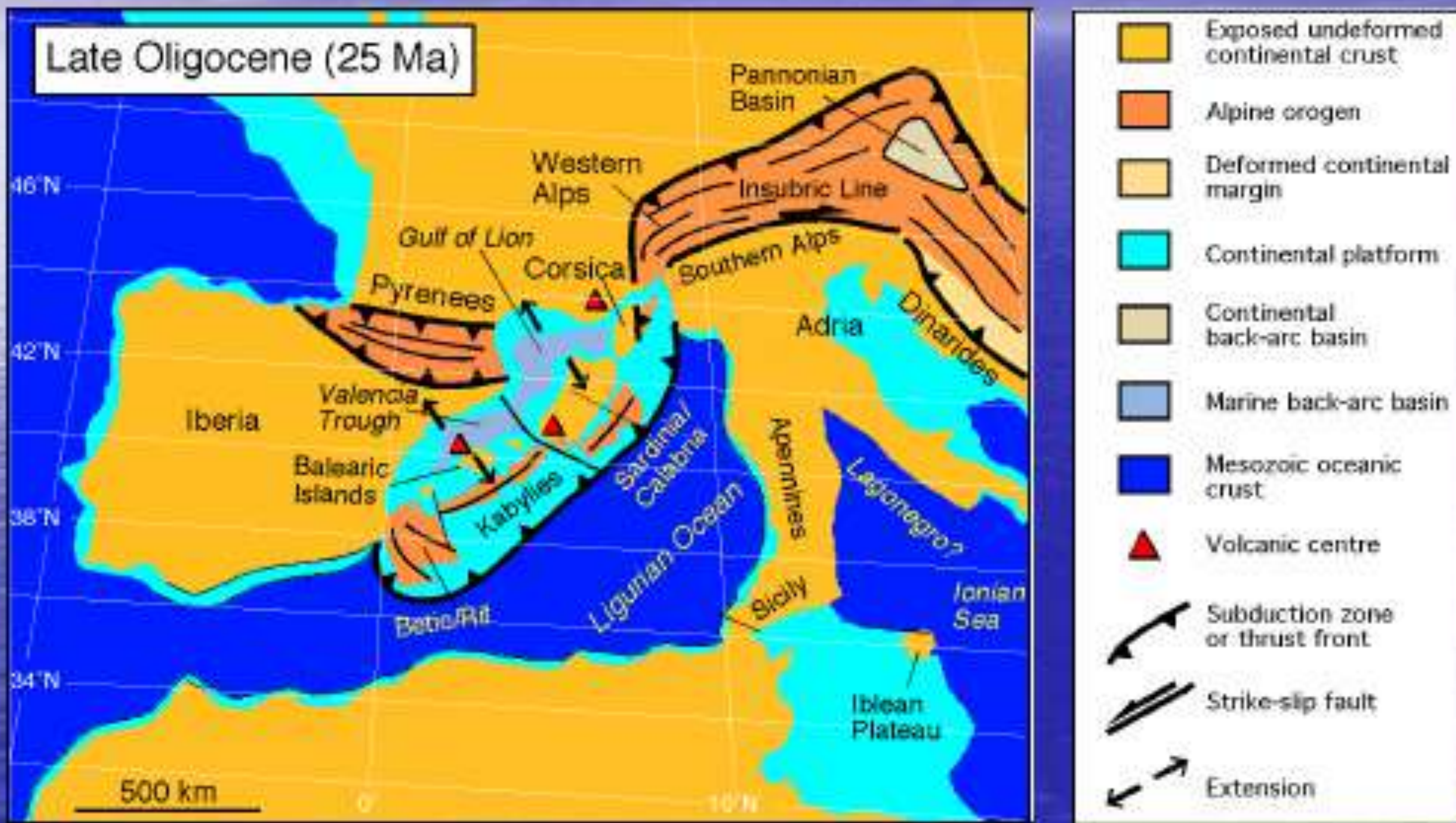


Development of the western Mediterranean basins



Rosenbaum et al. 2002. J. Virtual Explorer

Development of the western Mediterranean basins



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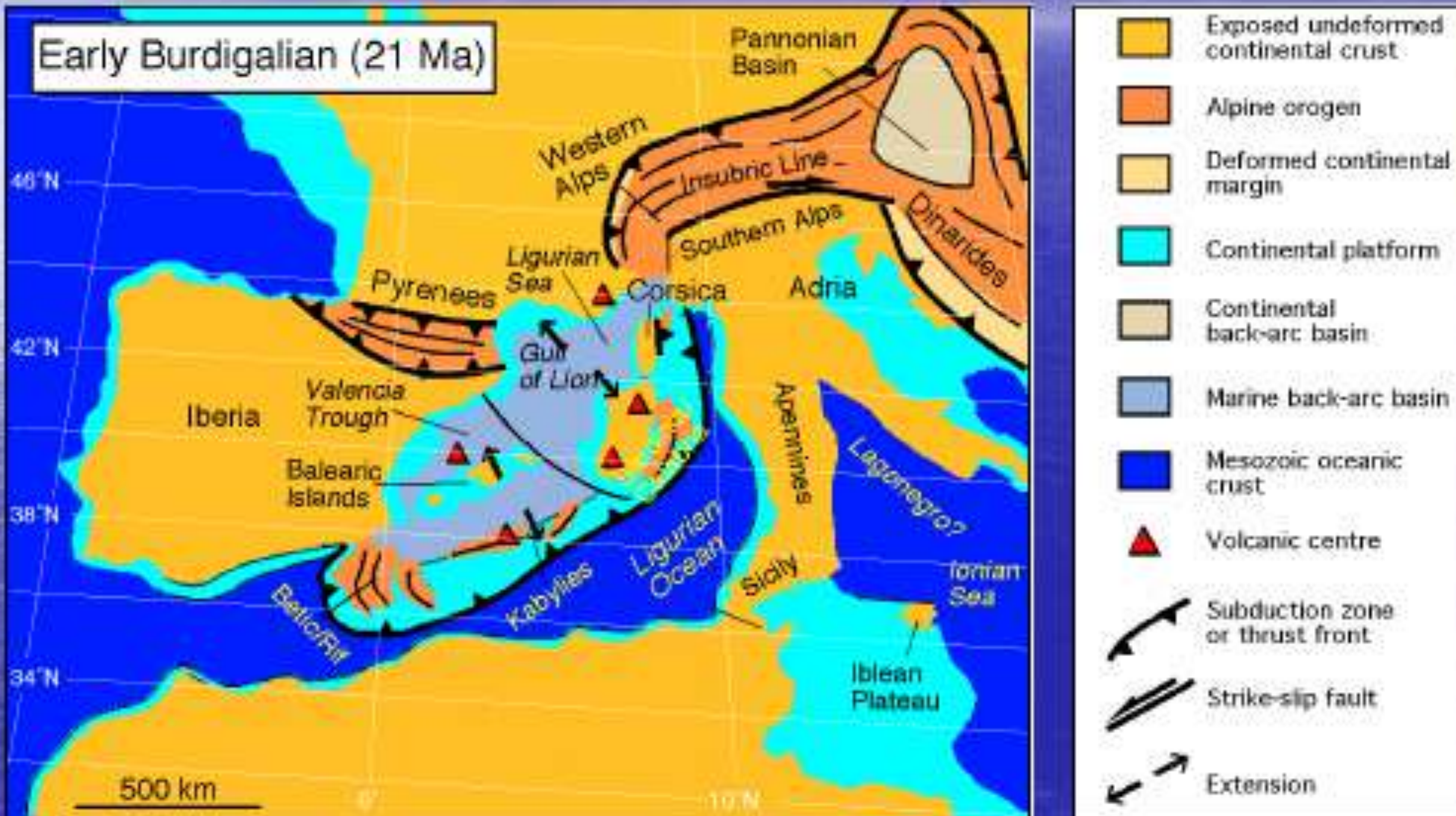

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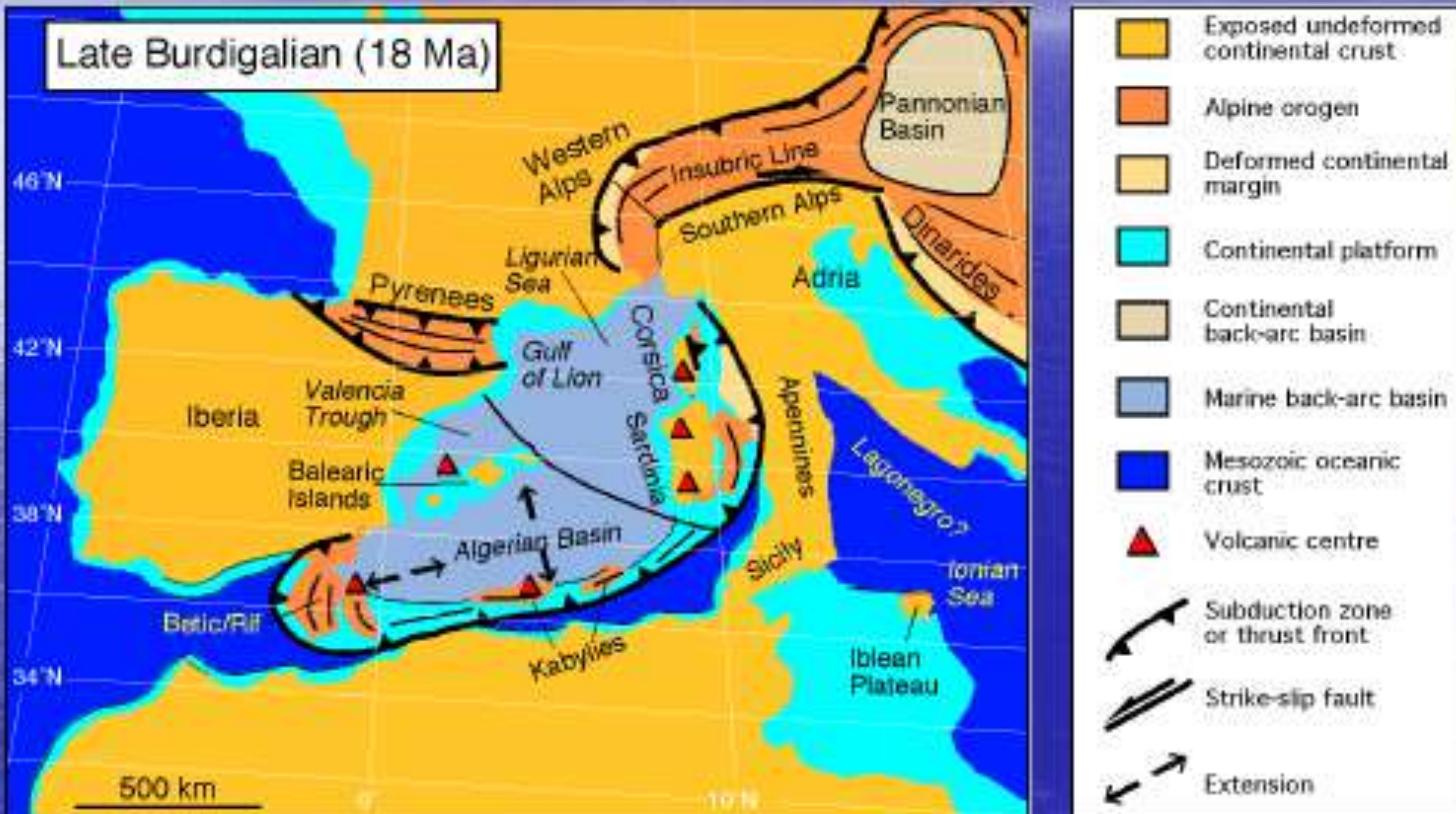

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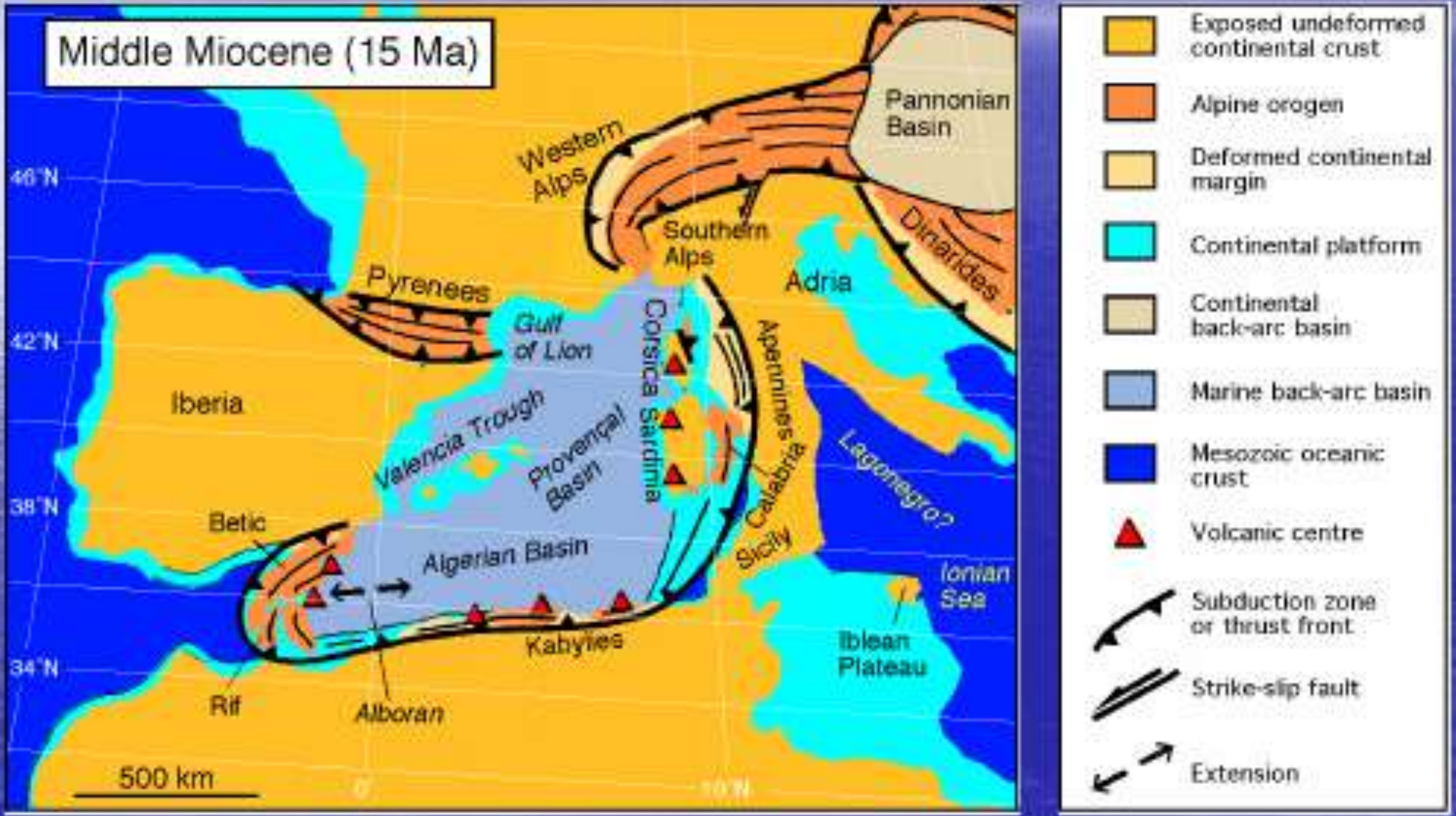

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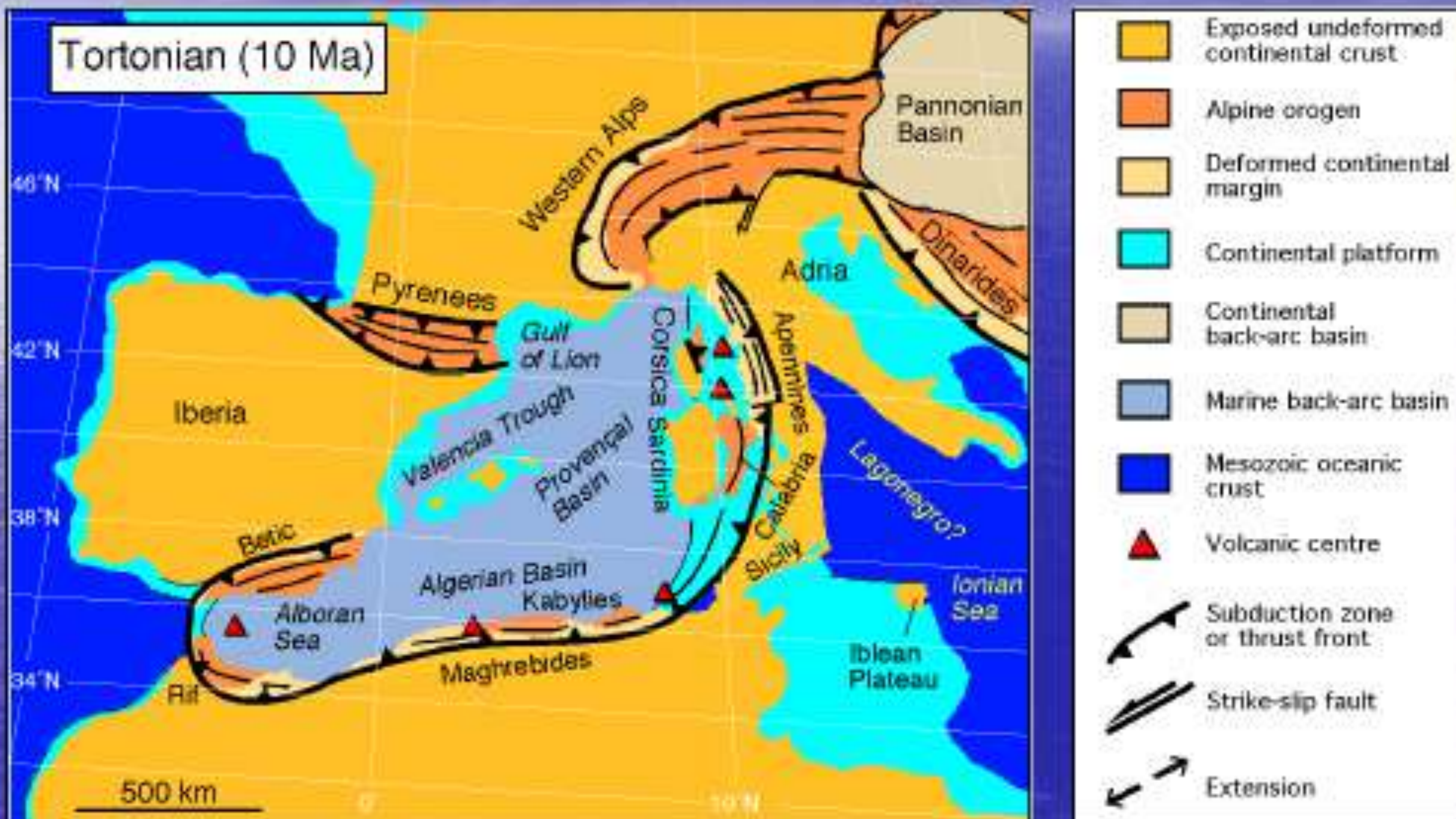

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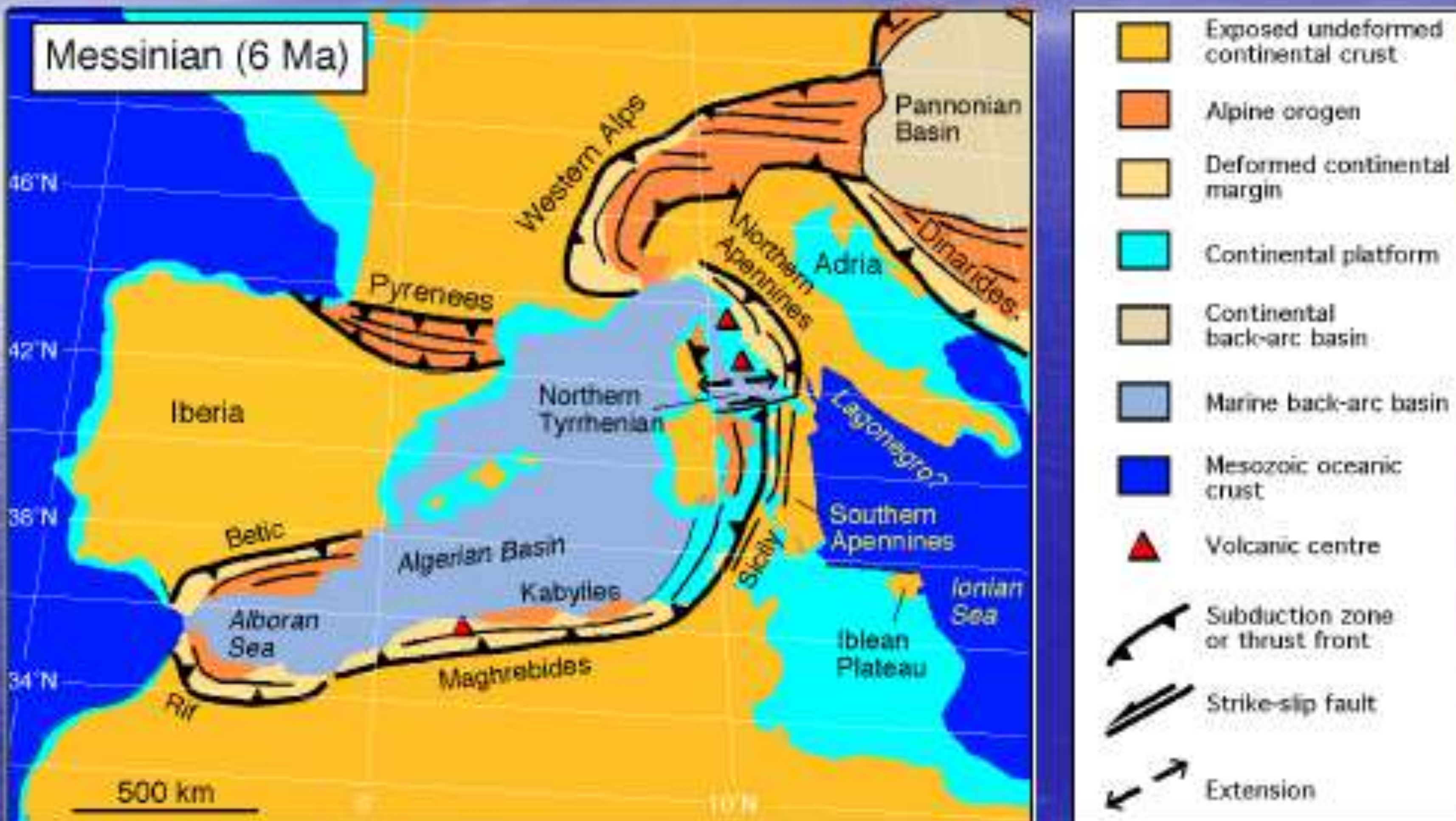

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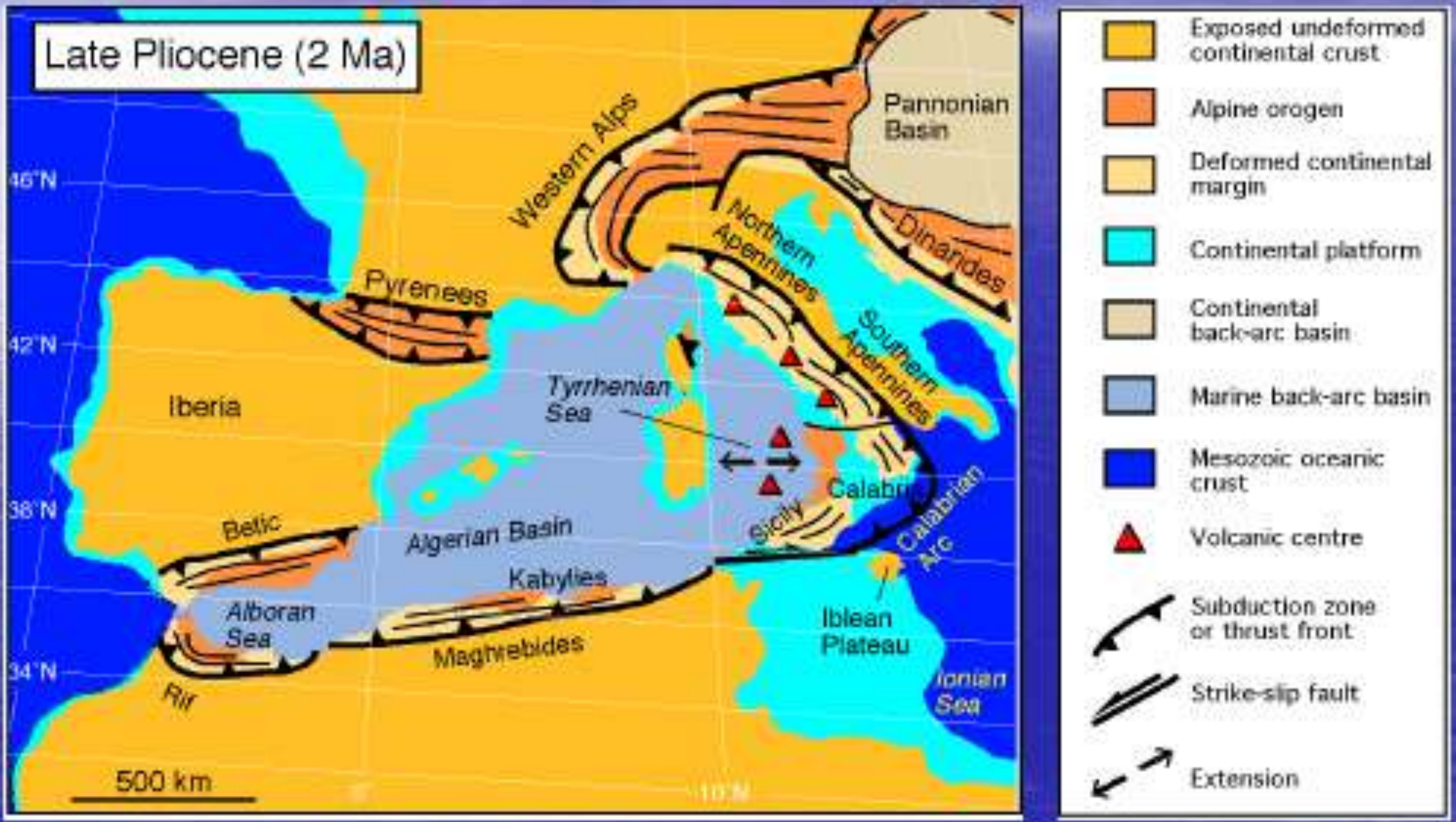
Development of the western Mediterranean basins



Rosenbaum et al. 2002. J. Virtual Explorer

Development of Western Mediterranean Basins (1)

- The western Mediterranean is the younger part of the Mediterranean (**late Oligocene to present**). It consists of a series of sub-basins: **Alboran, Valencia, Provençal, Algerian and Tyrrhenian** seas. These generally rejuvenate moving from west to east. They are partly floored **by oceanic crust** (Provençal and Algerian basins, and two smaller areas in the Tyrrhenian Sea). The remaining submarine part of the western Mediterranean basin is made of **extensional and transtensional passive continental margins.**

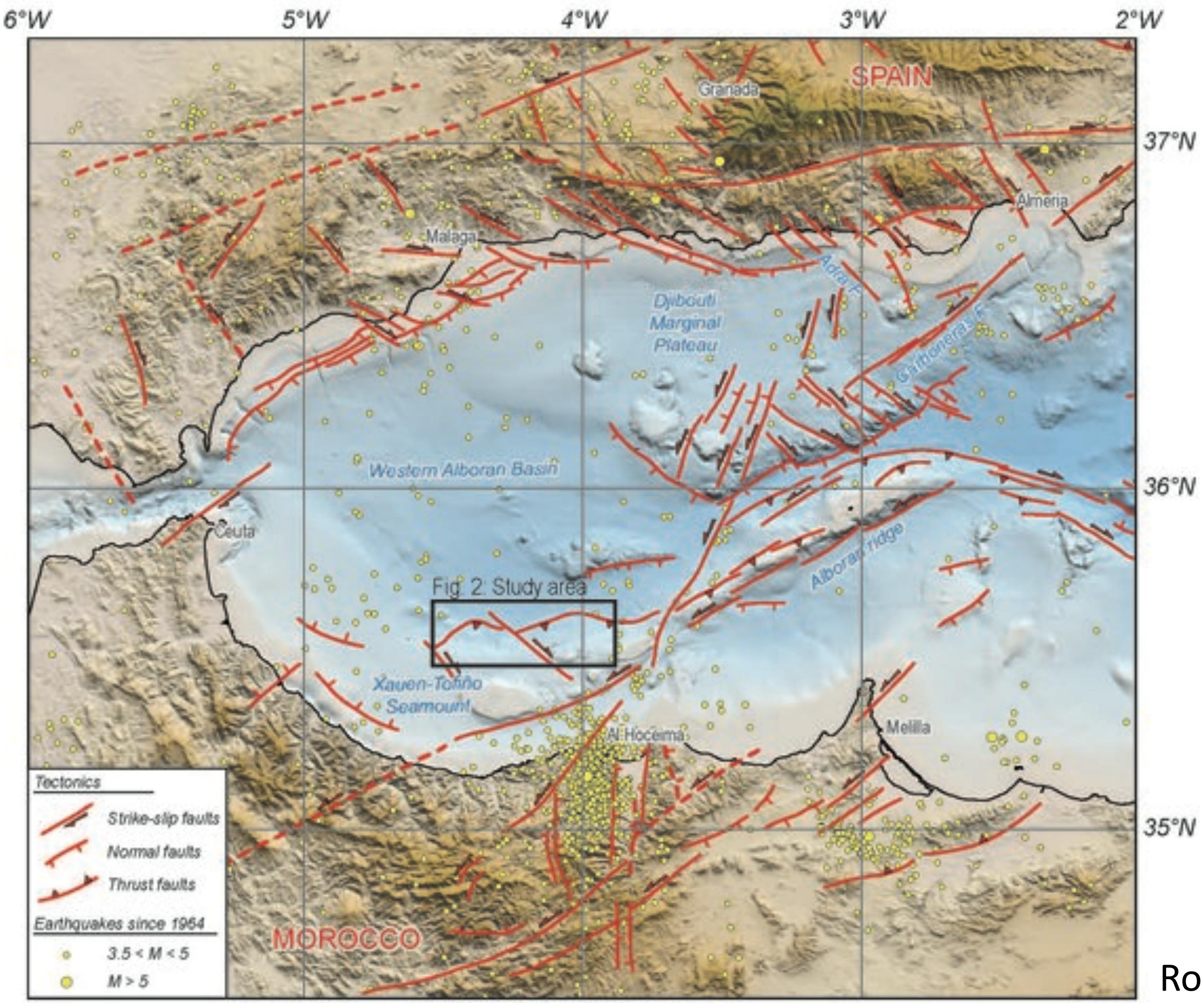
- The **Liguro-Provençal Basin** comprises the Ligurian Sea, the Gulf of Lions as well as the portion of the Mediterranean Sea located West of Corsica and Sardinia, and East of Menorca. It is the **oldest Western Mediterranean basin** and has a maximum water depth of **2800 m**. The lithosphere beneath the Liguro-Provençal basin **is thin** (less than **30 km**) the crust decreases in thickness to about **5 km** beneath the central part of the basin where it is oceanic, dated as late Aquitanian to late Burdigalian-early Serravallian (Miocene). Rifting in the Provençal-Ligurian basin started during latest Eocene-Early Oligocene (**34-28 Ma**) and ended in the middle Aquitanian. Subsequently, the central oceanic portion of the basin was generated between the late Aquitanian and late Burdigalian (**21-16 Ma**) associated with **the counter clockwise rotation of the Corsica-Sardinia Block.** Before drifting, this block of the Iberian plate was located close to the Provençal coast and the present-day Gulf of Lions**. The Liguro-Provençal Basin is considered to be a back-arc basin generated from the south-eastward roll-back of the Apennines-Maghrebides subduction**.

- The **Algerian Basin** is a deep basin (around **3000 m**) located between the Balearic Promontory and the North Africa margin. The crust in the Algerian Basin seems to have an oceanic character. In most of the basin the Moho depth is less then 14 km and the crust is 4 to 6 km thick.

Development of Western Mediterranean Basins (2)

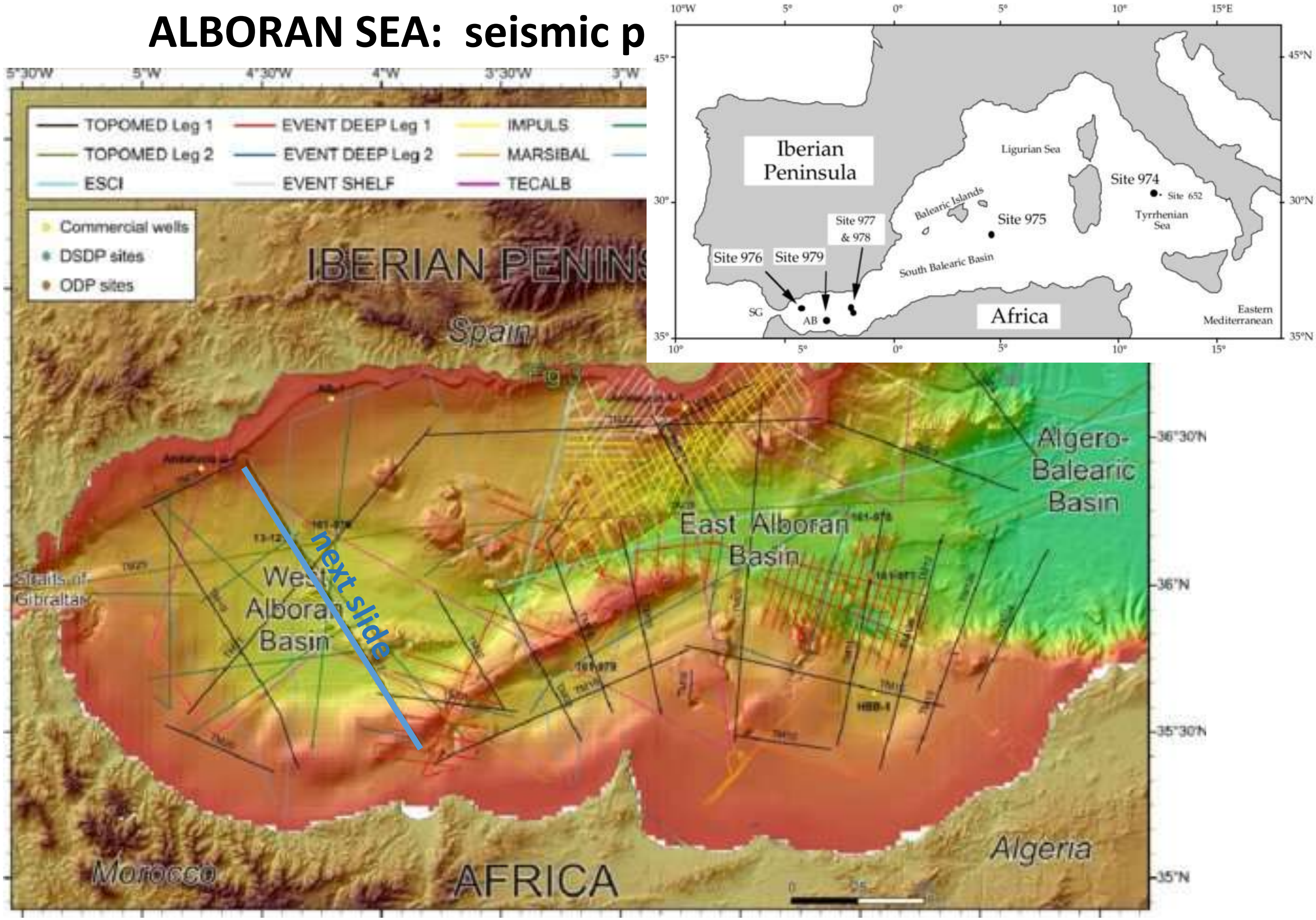
- The origin of the **Alboran Sea** is related to the push northward of the African plate with the European plate. This movement resulted in the opening of the Alborán Sea as an effect of the westward **roll-back caused by a subduction zone in the Gulf of Cadiz**. This phase ended in the Miocene (23 to 5 Ma).
- This push has caused several things: (1) the narrowing of the Alborán Sea in some hundred of kilometres; (2) the **closing of the Strait of Gibraltar** in the Upper Miocene, which, in turn, caused the **drying of the Mediterranean** and the deposition of a very thick layer (thousands of meters) of salt and evaporites (gypsums) as a result of water evaporation for 600,000 yr.
- During the **Pliocene (5 to 1.6 Ma),** the connection Atlantic-Mediterranean through the Strait of Gibraltar was re-established, thus, the Mediterranean **being filled again** with water from the Atlantic. According to some authors, the Mediterranean took around 36 yr to be filled again.
- **Crustal thickness of the Alboran Sea is 13 km**, and sedimentary column varies from 4 km (northern part) to 8 km (southern part).

Seismotectonic map of the Alboran Sea.
Earthquakes since 1900 are from the Instituto Geogràfico Nacional catalog
(http://www.ign.es/ign/layoutIn/sismoFormularioCatalogo.do).



Rodriguez et al 2017

ALBORAN SEA: seismic p



Gracia et al. 2014

Shaded relief map of the Alboran Sea with the location of high-resolution to deep penetration seismic cruises carried out during the last 20 years. DSDP, ODP and commercial wells are also located. In light green: Location of Figure 3 Sparker profiles.

ALBORAN SEA: Correletion of multichannel seismic data with biostratigraphy from IODP 979, 977

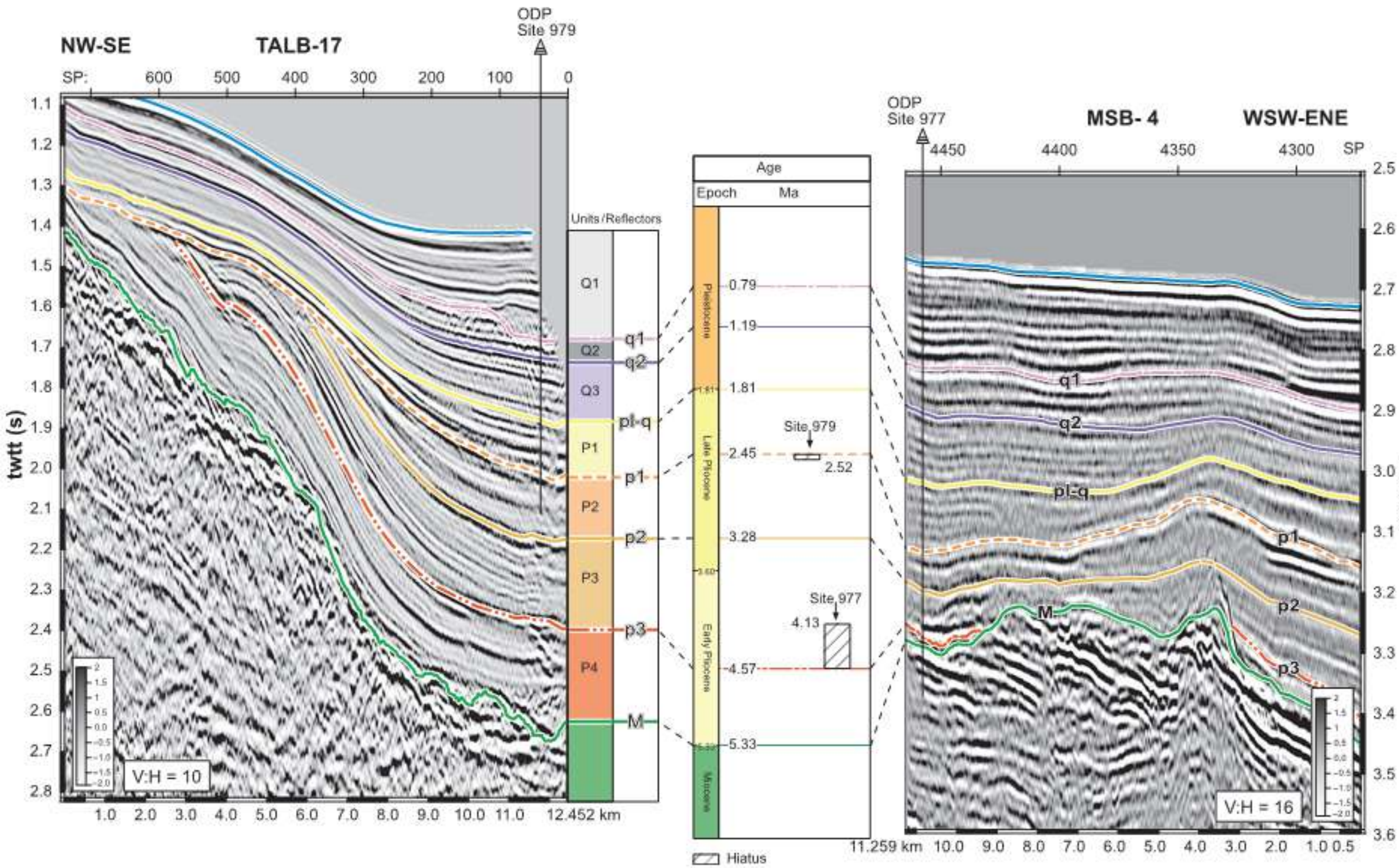


Fig. 3. Correlation of multichannel seismic data (see location in Fig. 2) with biostratigraphical data from ODP sites 979 and 977. Depths are in two-way travel time (twtt; two-way travel time) below sea-level.

Martinez Garcia et al. 2013

Deep Sea Drilling Project DSDP (1968 to 1983) and International Ocean Discovery Program IODP drilling in the Mediterranean Basin

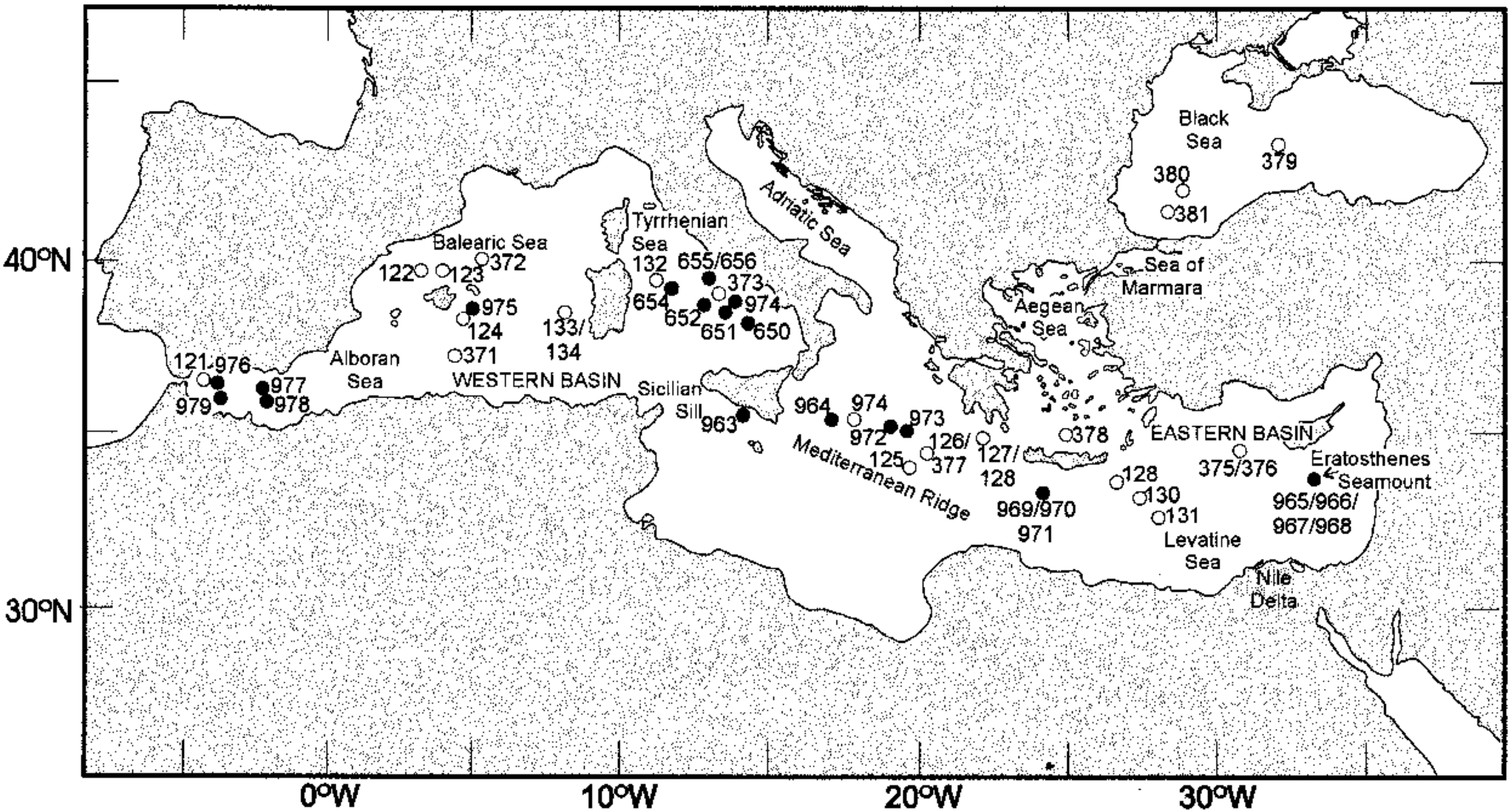


Fig. 4. Mediterranean basin showing the location of Deep Sea Drilling Project (DSDP) sites (circles), and Ocean Drilling Program (ODP

ALBORAN SEA: Late Cenozoic seismic stratigraphy

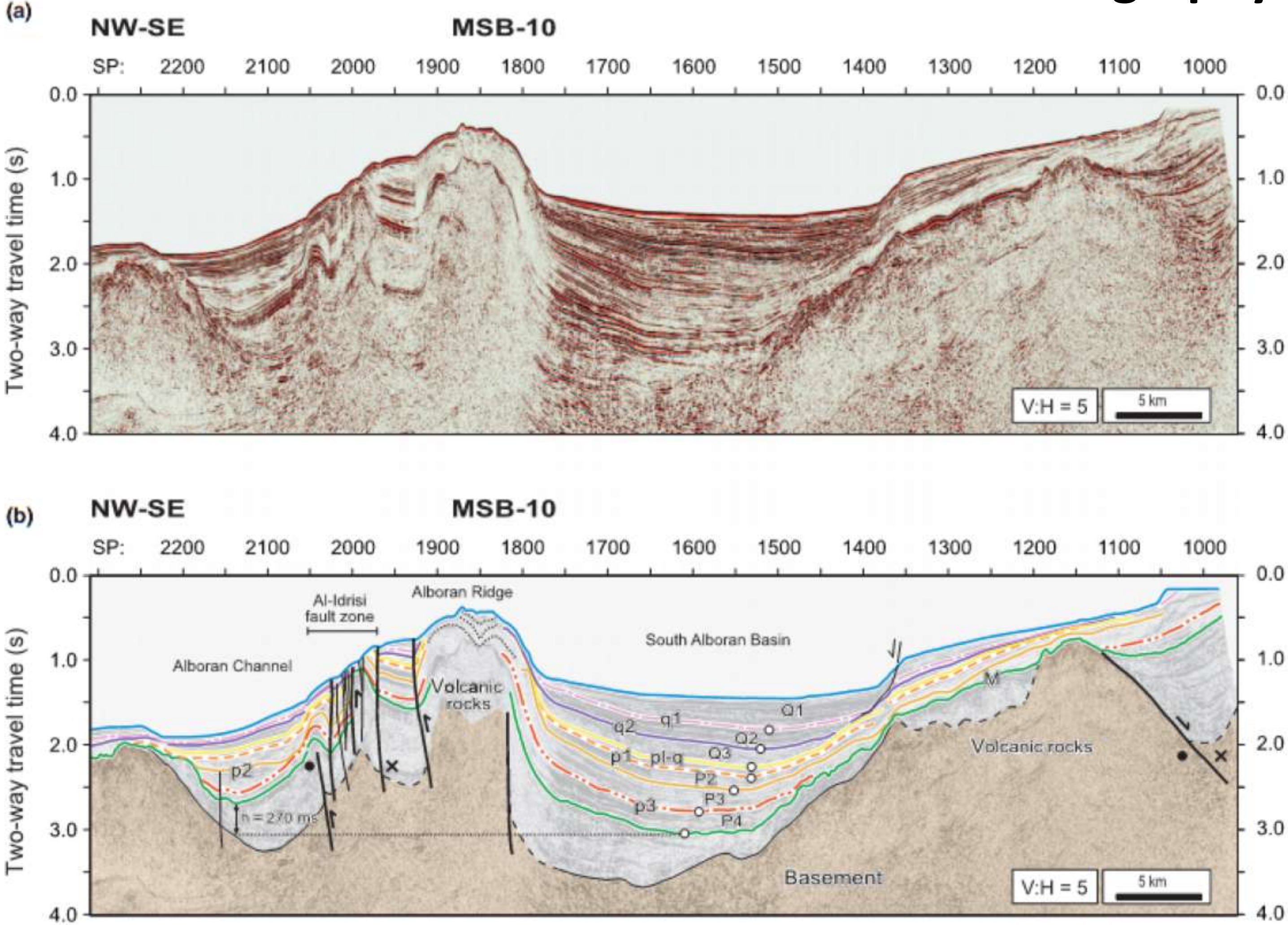
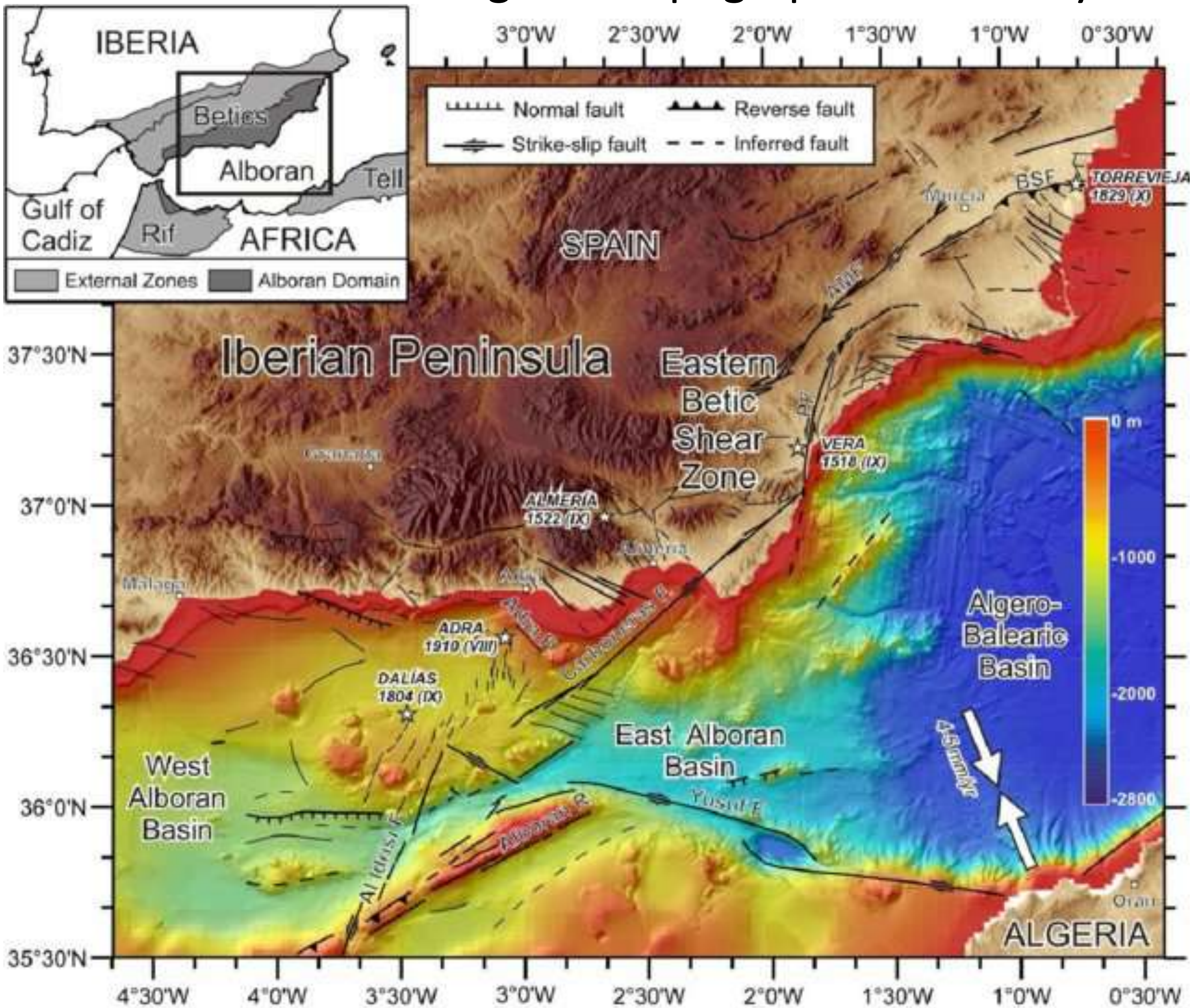


Fig. 4. (a) Uninterpreted and (b) interpreted multichannel seismic section across the western Alboran Ridge and South Alboran Basin. Key seismic reflections, age of unconformities and seismic units as defined in Fig. 3. Note migration of syncline hinge (white circles) and associated depocentre towards the SE in the SAB. Vertical offset between the Plio-Quaternary depocentres of the Alboran Channel and the SAB is also indicated (h = 270 ms twtt). Uncertainty on the position of the top of basement is indicated by dashed lines. Location of seismic line is shown in Figs 2, 5 and 6.

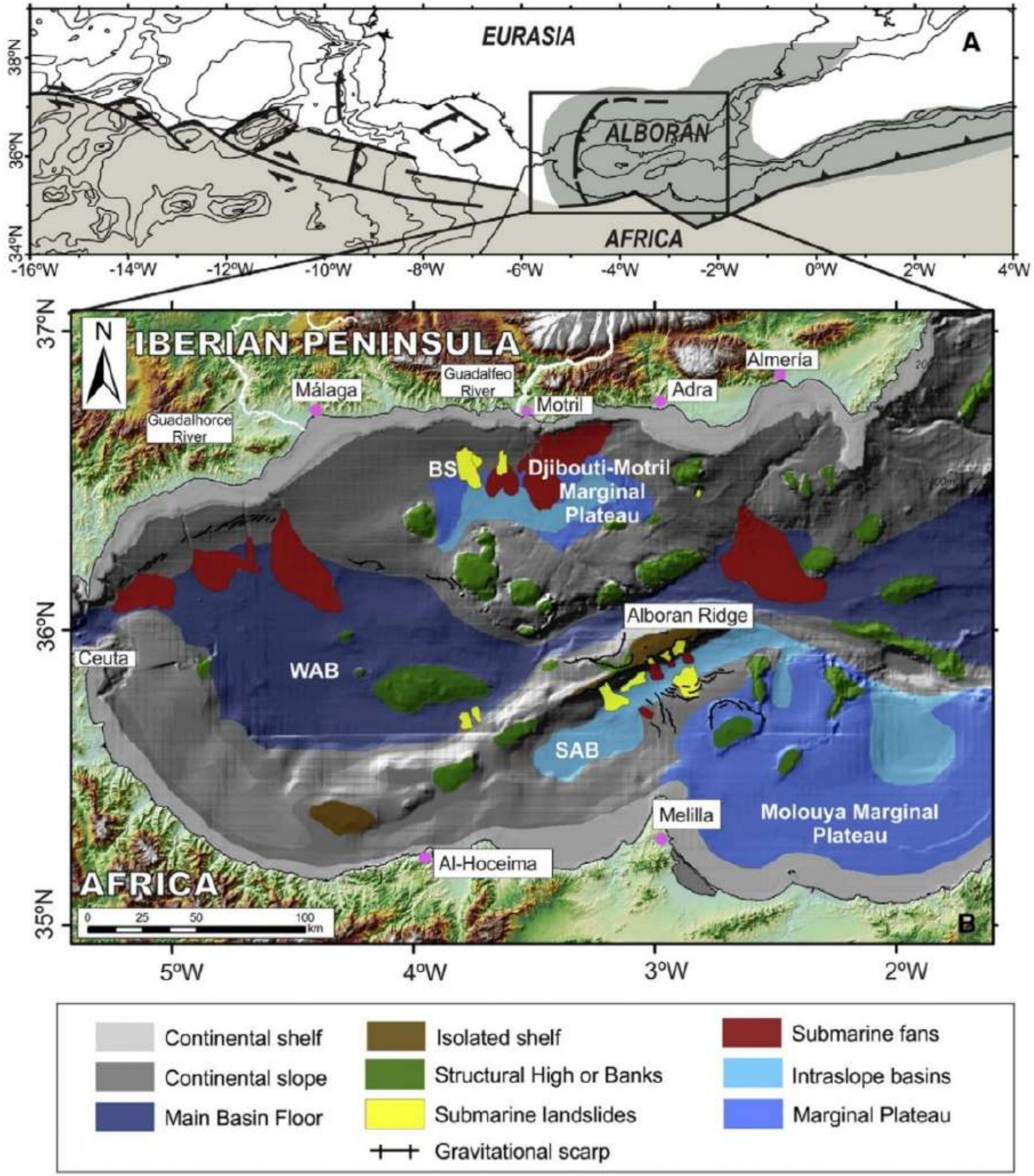
Martinez-Garcia et al. 2013

ALBORAN SEA: Regional topographic and bathymetric map



Regional topographic and bathymetric map of the SE Iberian Margin from digital grids by SRTM-3, IEO bathymetry (Ballesteros et al., 2008) and MEDIMAP compilation (MediMap et al., 2008) at ~70 m grid-size. White arrows show the direction of convergence between the Eurasian and African plates from NUVEL1 model (De Mets et al., 2010). Main faults are depicted. BSF: Bajo Segura Fault; AMF: Alhama de Murcia Fault, PF: Palomares Fault. Inset: Plate tectonic setting and main geodynamic domains of the south Iberian Margin at the boundary between Eurasian and African Plates (modified from Gràcia et al., 2012).

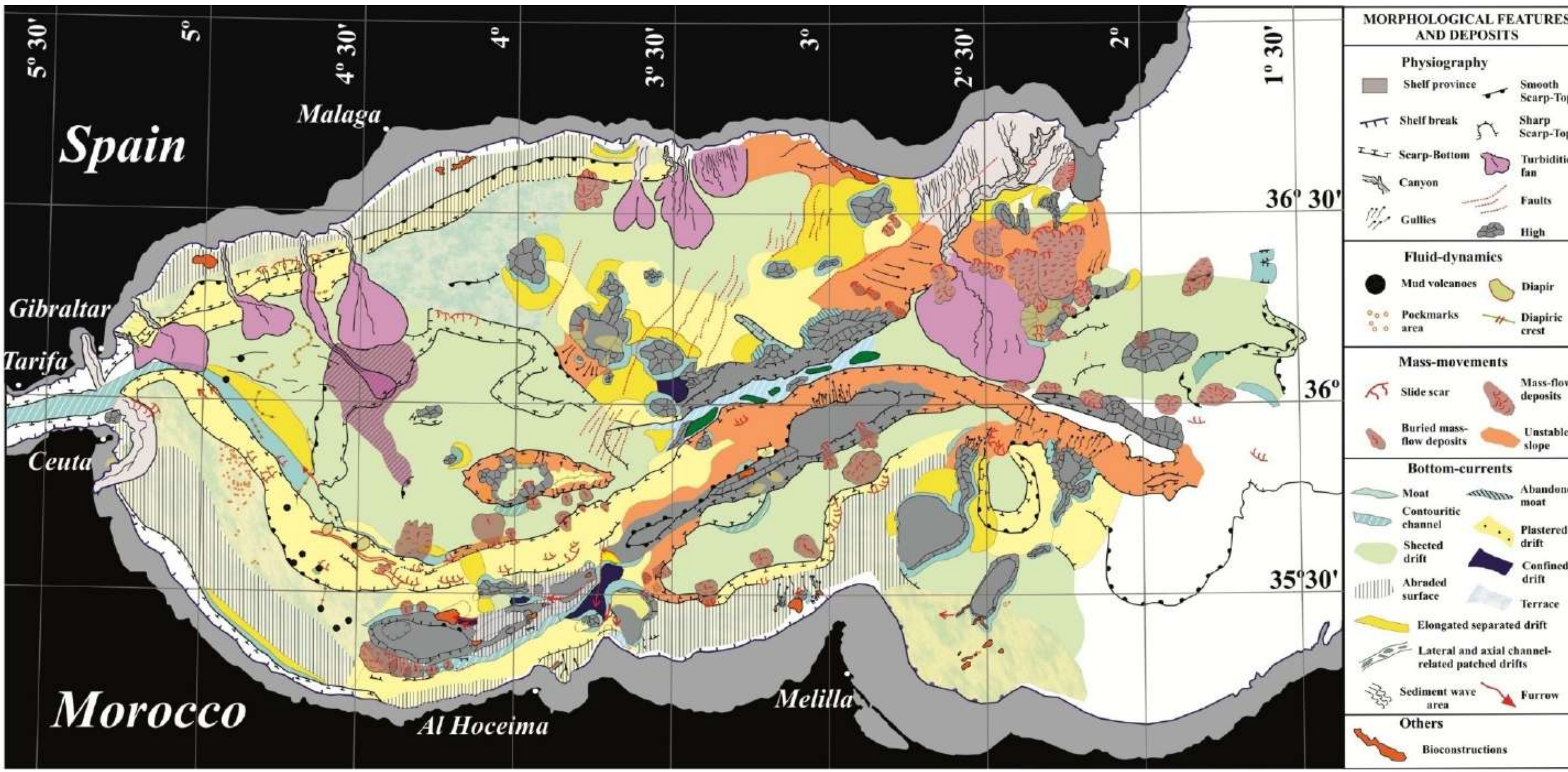
Gracia et al. 2014



ALBORAN SEA: main physiographic domains

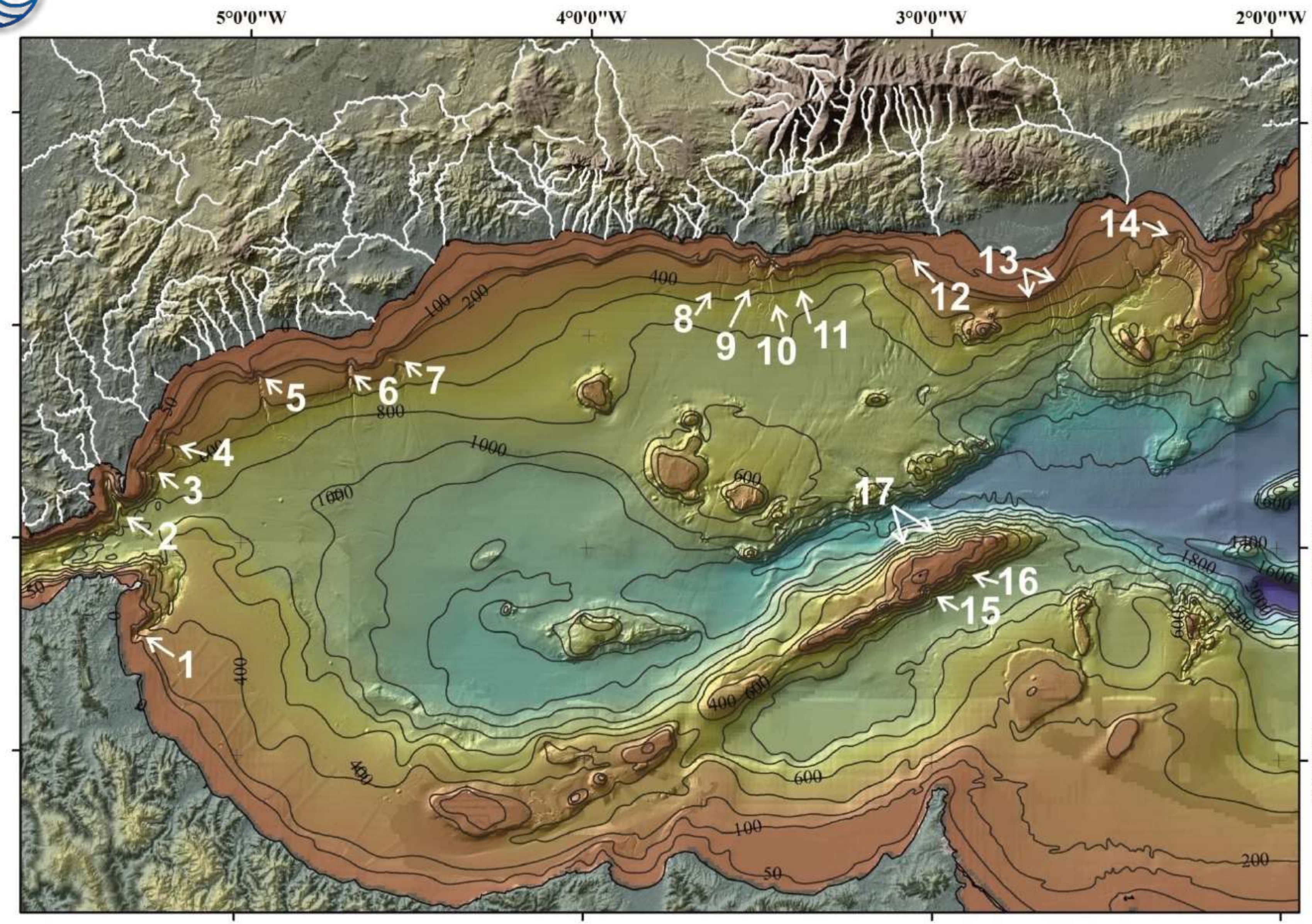
Martinez Garcia et al. 2013

ALBORAN SEA: main sedimentary processes (along slope vs. down slope)



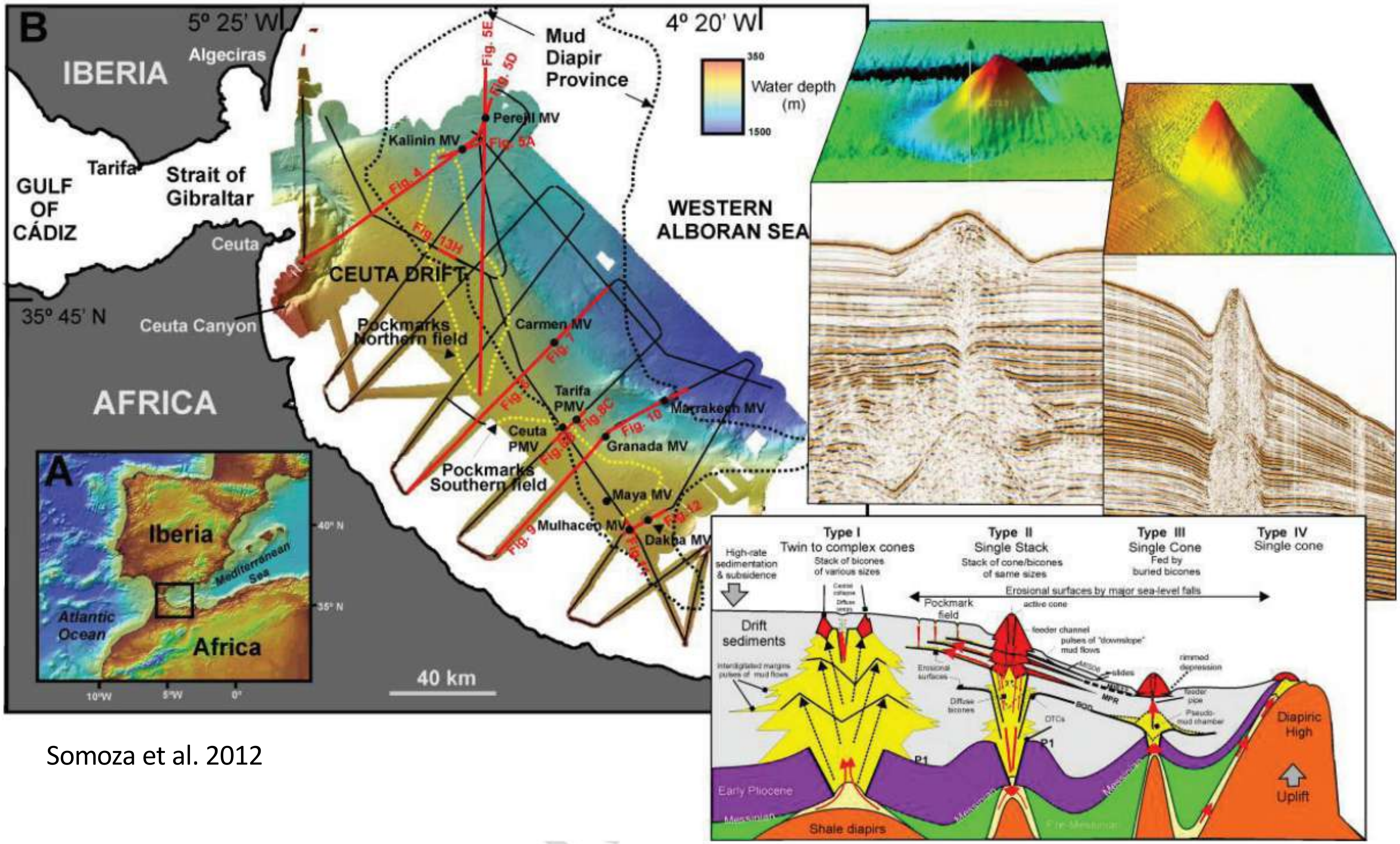
Ercilla et al. 2014

The submarine canyon systems



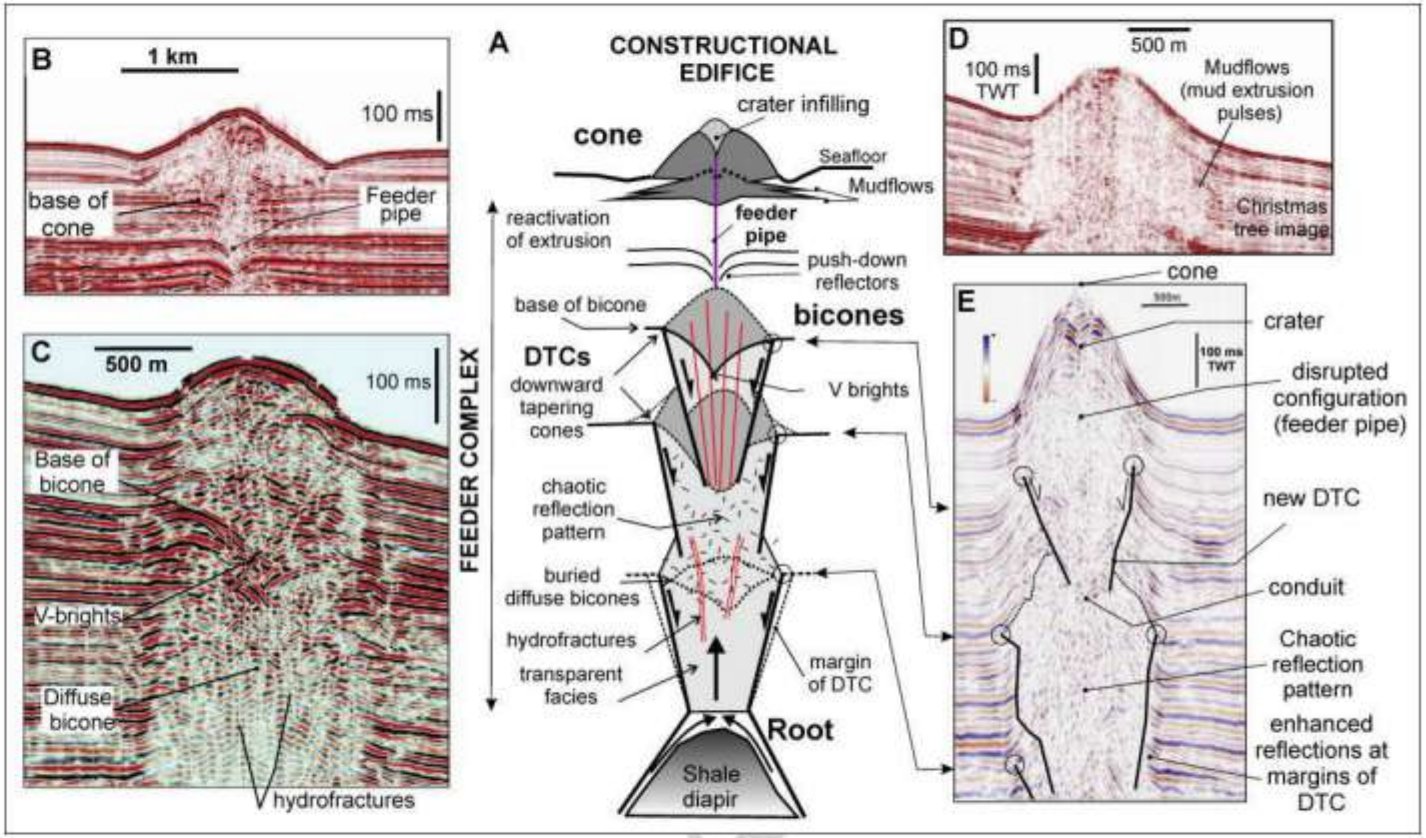
Vasquez et et al. 2015

Mud Volcanos in the Alboran Sea



Somoza et al. 2012

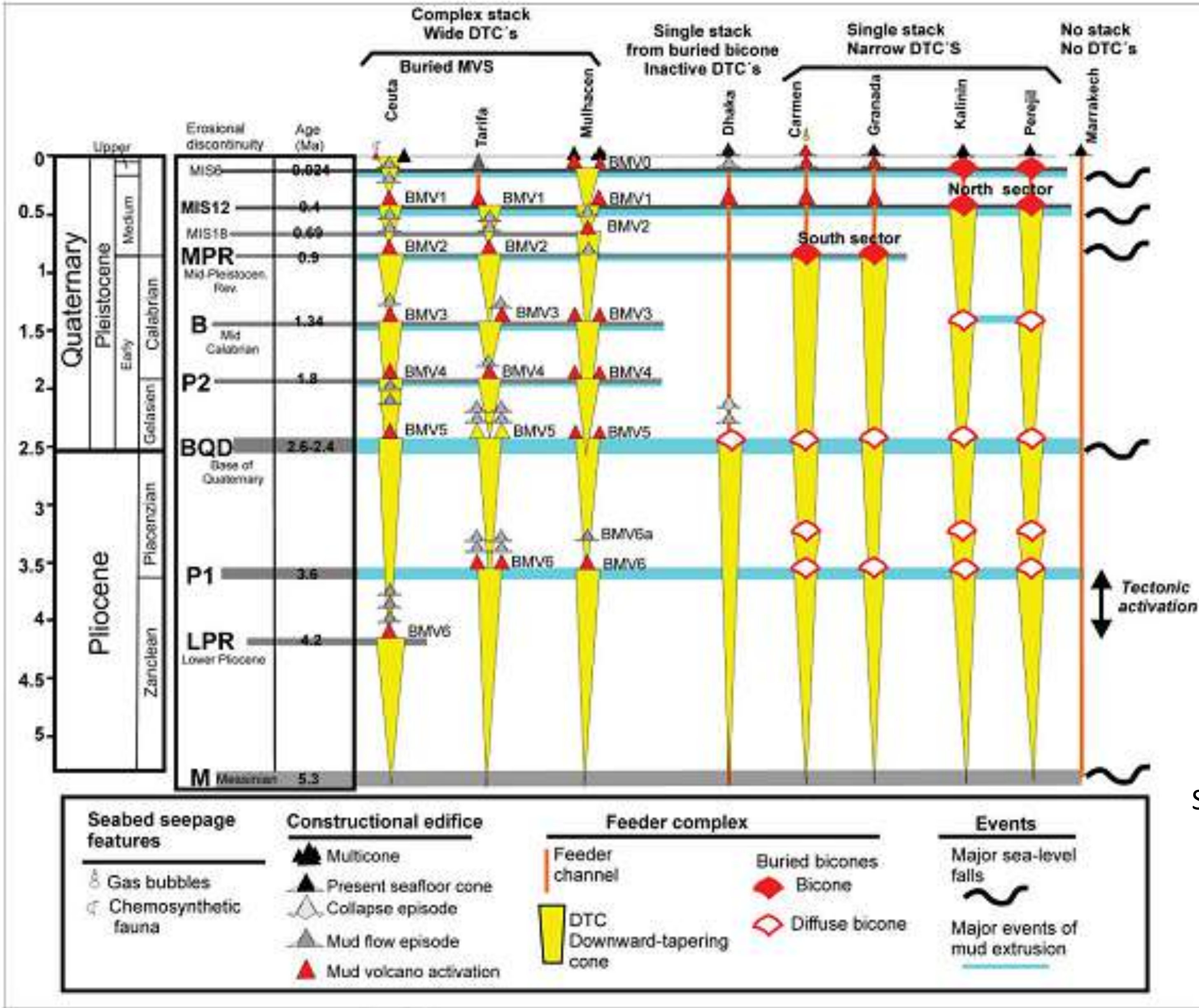
Mud Volcanos in the Alboran Sea



Somoza et al. 2012

A) Synthesis of the structural elements of a mud volcano system and seismic signature observed on the mud volcanoes of the Ceuta Drift. B) Dhaka MV; C) Camen MV ; D) Granada MV and E) Perejl MV

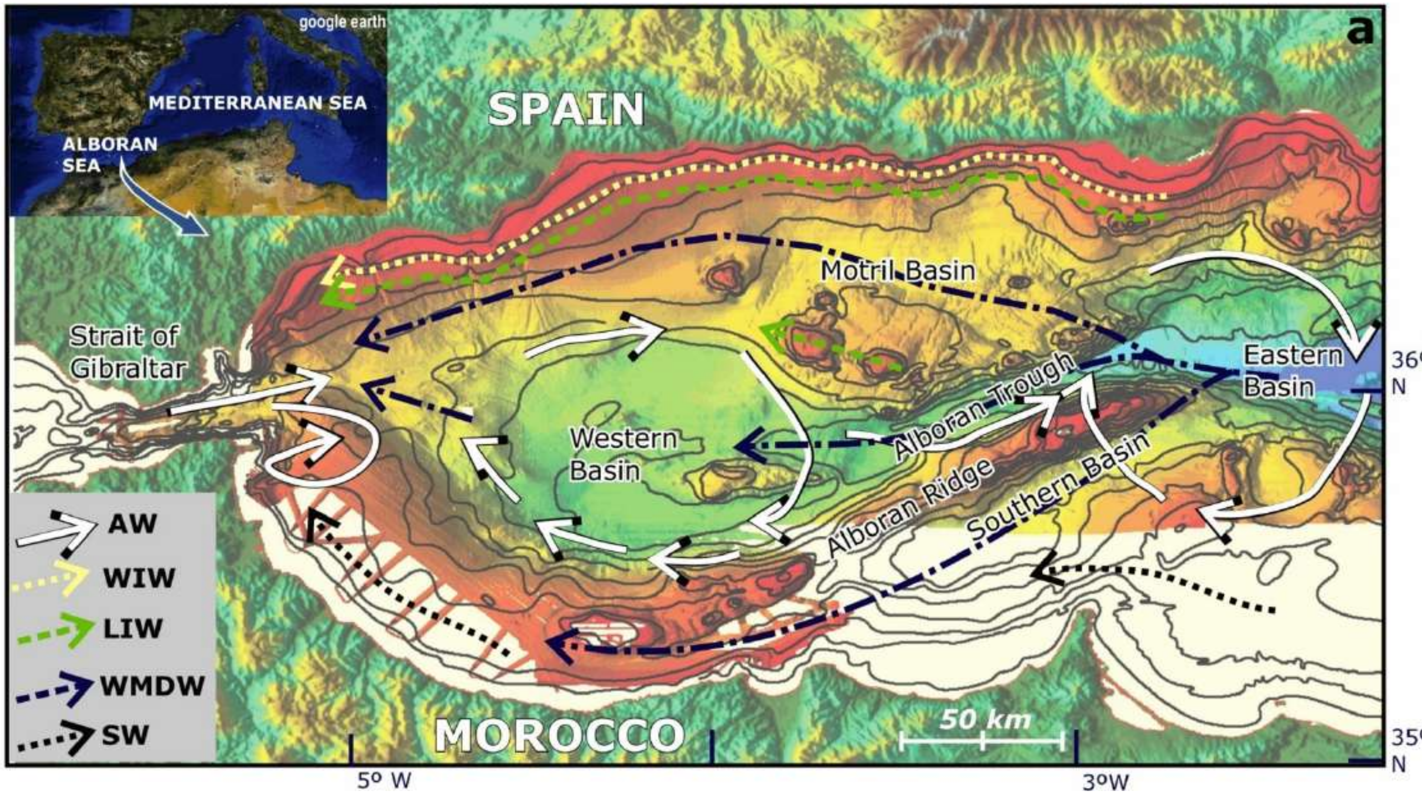
Mud Volcanos in the Alboran Sea



Correlation table of major stratigraphic unconformities with episodes of mud extrusion for the different types of mud volcanoes systems in the Ceuta Drift

Somoza et al. 2012

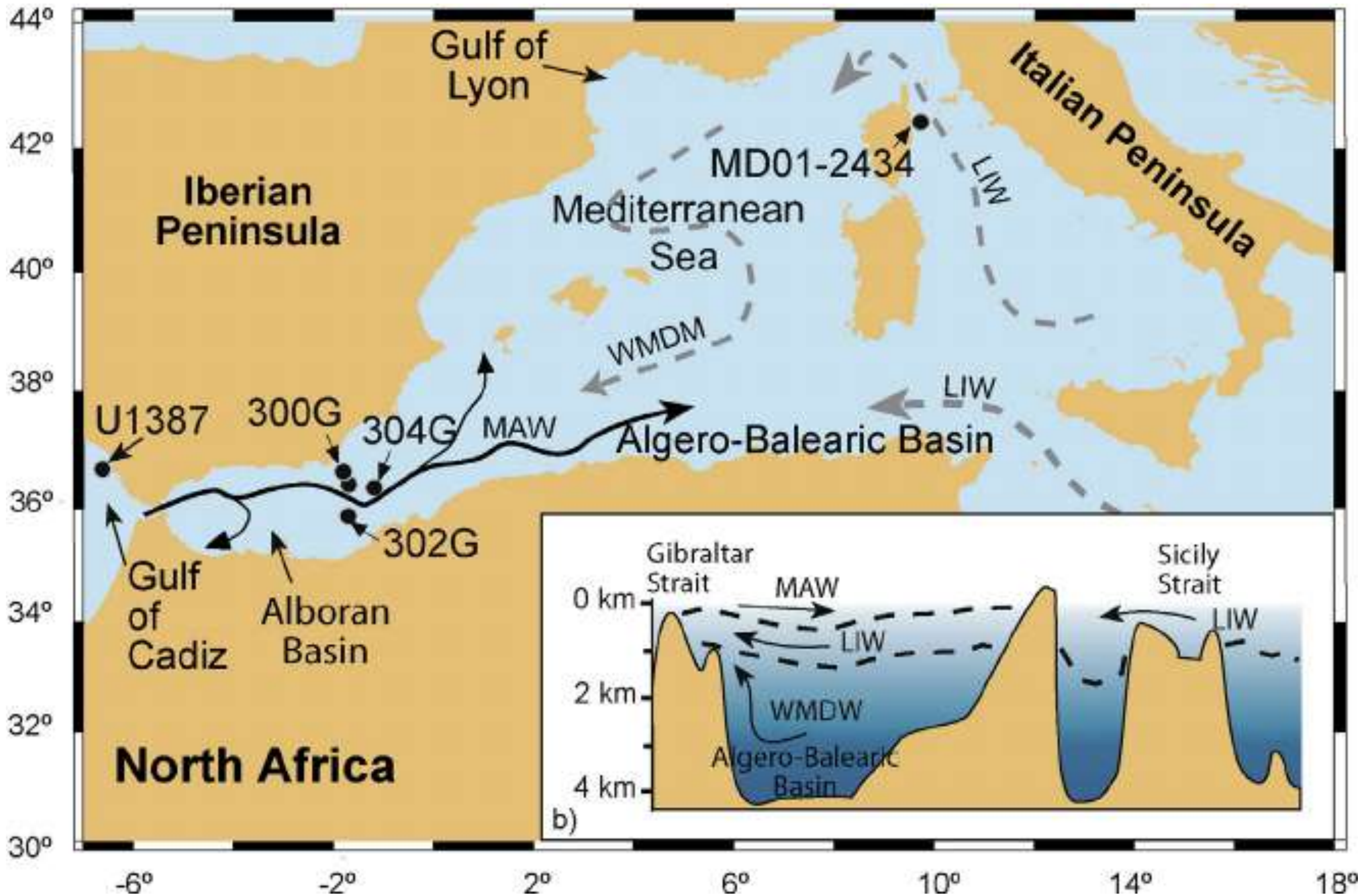
Thermohaline circulation in Alboran Sea



Ercilla et al. 2016

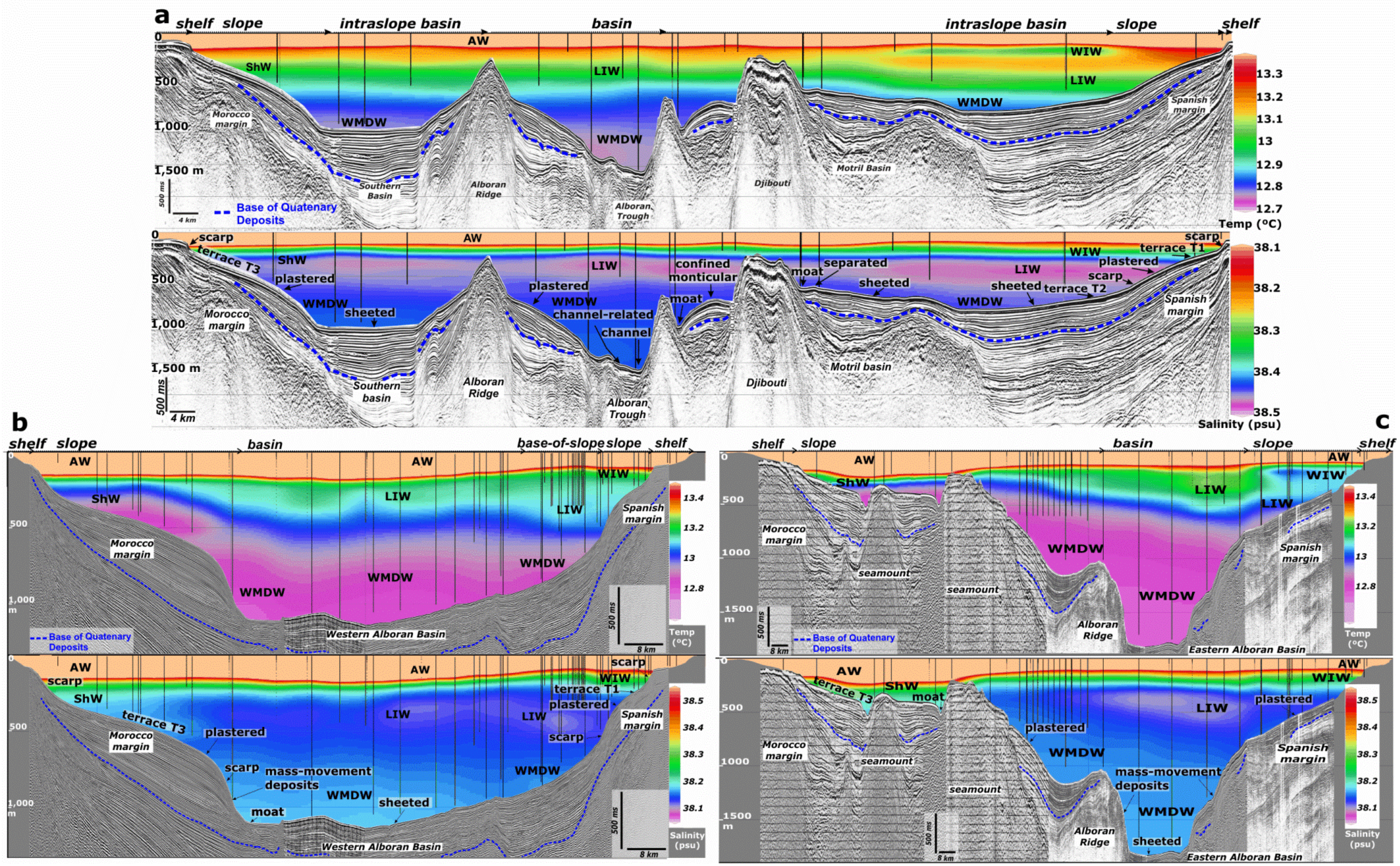
Through the Strait of Gibraltar incoming surficial Atlantic Water (AW),
The Levantine Intermediate Water (LIW),
The Western Mediterranean Deep Water (WMDW)

Thermohaline circulation in Alboran Sea



Jiménez-Espejo et al 2015

Thermohaline circulation in Alboran Sea



Ercilla et al. 2016

Present-day circulation in Alboran sea

Existing knowledge of the general present-day circulation indicates that, after entering the Alboran Sea through the Strait of Gibraltar, the **surficial Atlantic water AW** (down to 150–200 m water depth) describes two anticyclonic gyres, one in the West Alboran Basin and another in the East Alboran Basin (Parrilla et al. 1986; Millot 1999; Vargas-Yañez et al. 2002).

Mediterranean waters comprise two distinct watermasses that converge on the Strait of Gibraltar: **the Levantine Intermediate Water LIW,** which extends down to **600 m water depth**, and the **Western Mediterranean Deep Water WMDW (below 600 m water depth)** restricted largely to the Moroccan margin. Nelson (1990) suggested that this circulation pattern developed after the opening of the strait, although it was interrupted by an estuarine-type exchange of water masses during the early Quaternary (Huang and Stanley 1972).