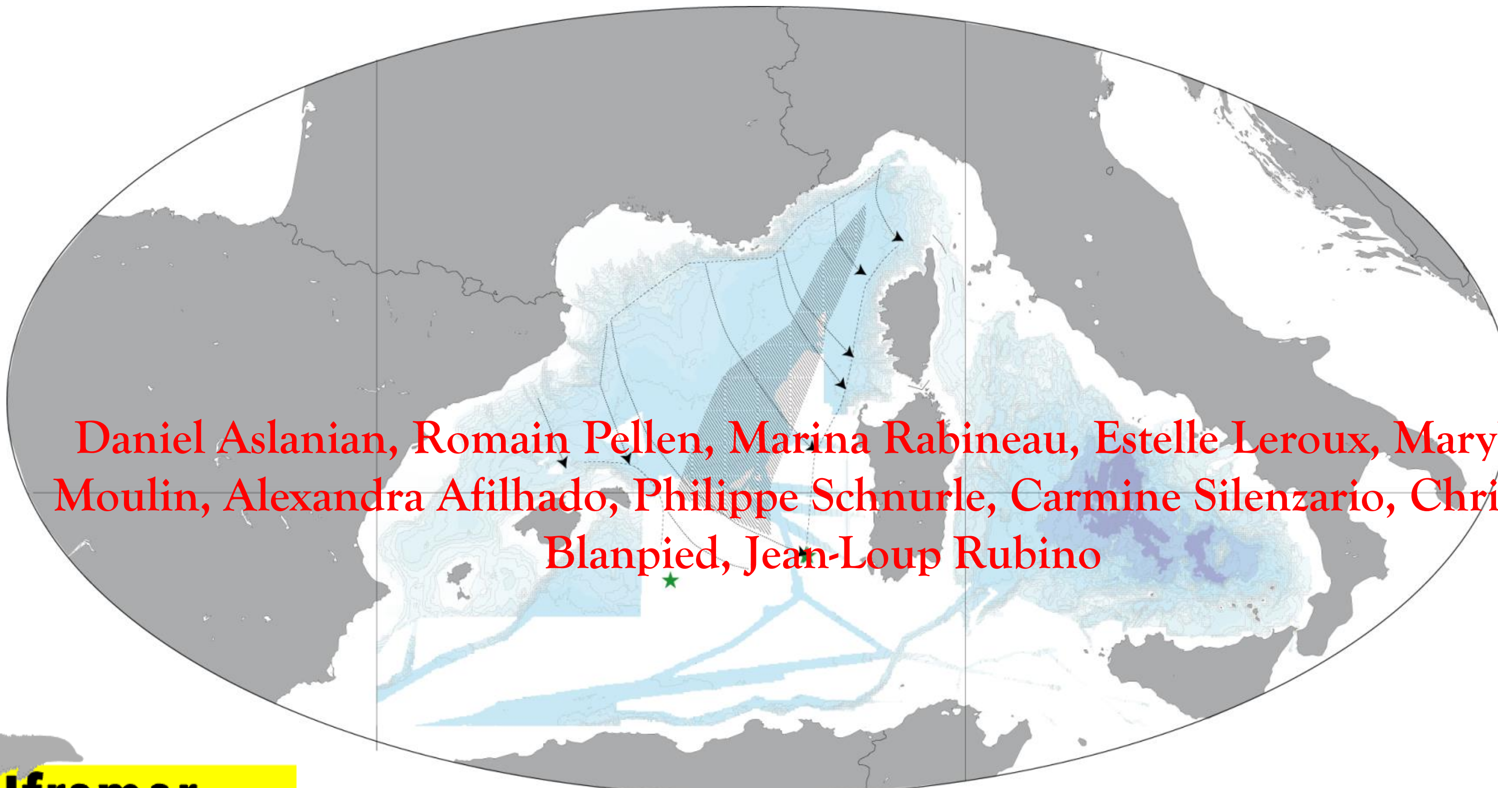
News Results on Valencia and Provençal Basins : geodynamic consequences on the Western Mediterranean Sea evolution



Daniel Aslanian, Romain Pellen, Marina Rabineau, Estelle Leroux, Maryline Moulin, Alexandra Afilhado, Philippe Schnurle, Carmine Silenzario, Christian Blanpied, Jean-Loup Rubino

Ifremer

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IUEM-OSU DOMAINES OCEANIQUES CNRS-UBO

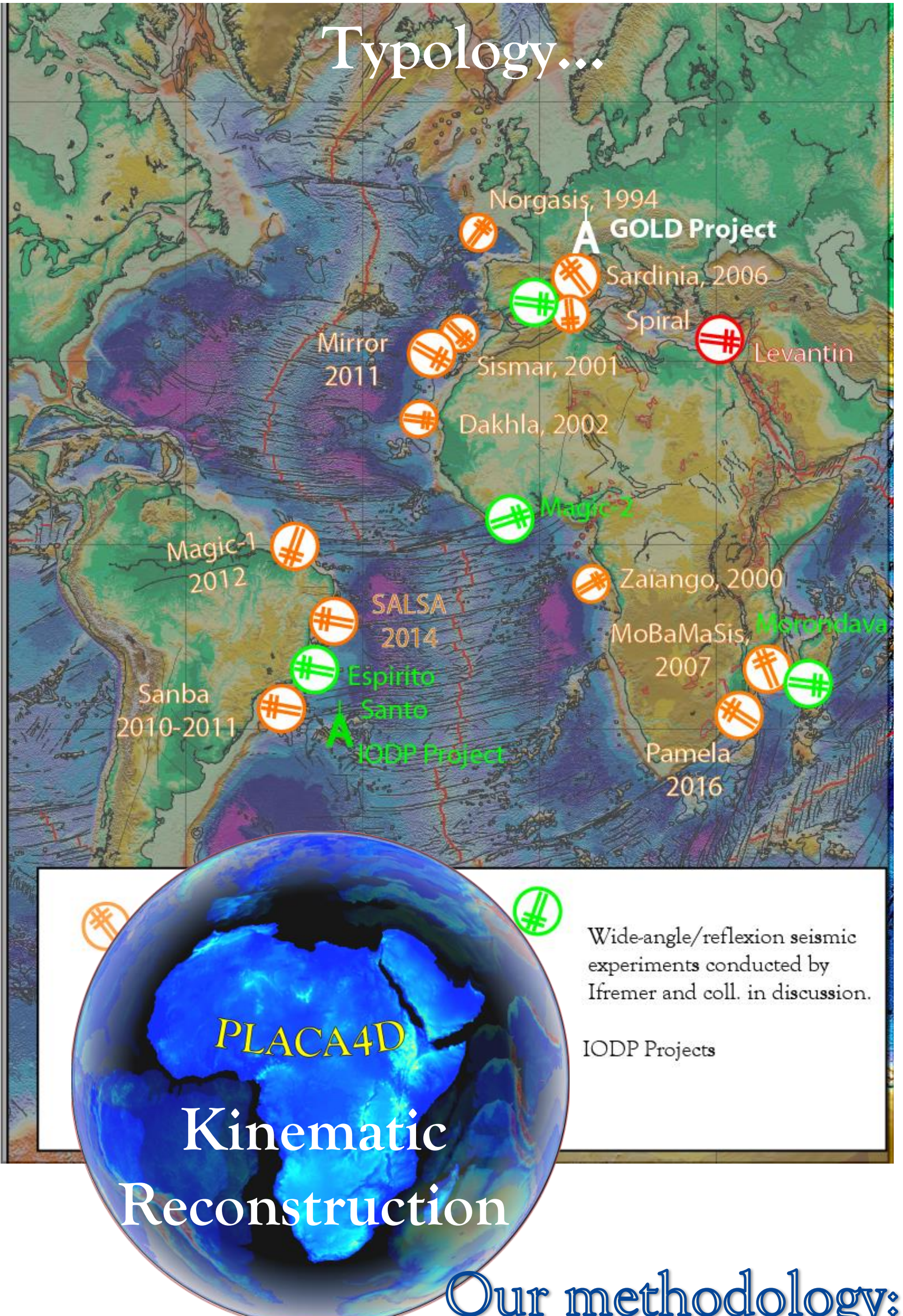
GROUPE RECHERCHE & INDUSTRIE GRi Méditerranée

TOTAL

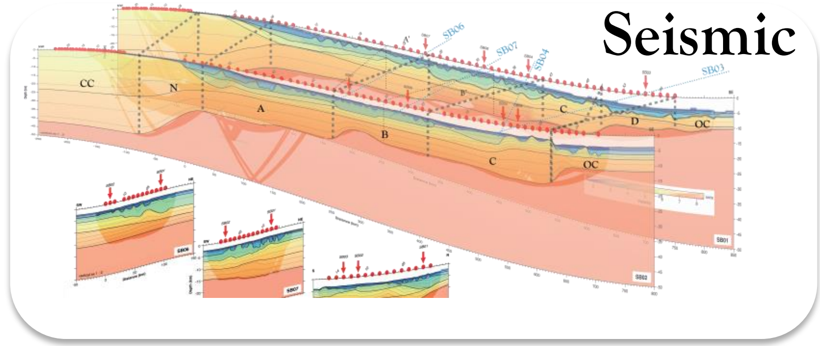
Schlumberger

ACTIONS MARGES

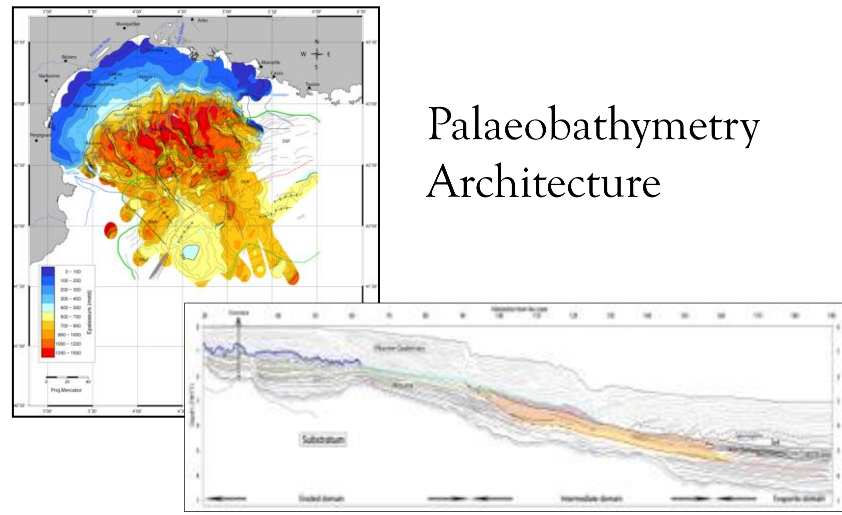
IFREMER methodology: An holistic approach



Seismic

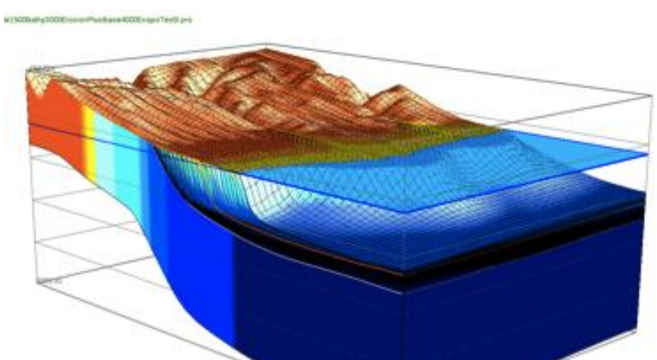


Sedimentary records



Palaeobathymetry
Architecture

Modelling: Falsification tests



Our methodology: an holistic approach

The unsolved questions

GEODYNAMIC & GEOLOGICAL CONTEXT
Geodynamic model: the unsolved questions

ALGERIAN BASIN

The northern African margin has been postulated to be the site of southward subduction initiation since the Pliocene [Deverchère *et al.*, 2005; Stich *et al.*, 2006; Baes *et al.*, 2011; Billi *et al.*, 2011], but the opening of the Algerian basin remains controversial regarding the kinematic evolution and the nature of the margins.

The disagreement stems firstly from the interpretation of the opening direction of the oceanic Algerian Basin :

- a first school of thought assumes **a dominant N-S opening** leading to a presently inactive slab under the North African margin [e.g., Gueguen *et al.*, 1998; Carminati *et al.*, 1998; Frizon de Lamotte *et al.*, 2000; Wortel & Spakman, 2000; Gelabert *et al.*, 2002; Rosenbaum *et al.*, 2002b; Rosenbaum & Lister, 2004; Schettino & Turco, 2006]. The westward rollback in the Gibraltar region is thus accommodated with no significant displacement (i.e., less than 200 km) of the Alboran block [Faccenna *et al.*, 2004; Jolivet *et al.*, 2009; Rossetti *et al.*, 2013] (Figure A). In this hypothesis, the slab started to roll back from Gibraltar to Corsica and the subduction started along a E-W trending collisional zone.
- A second school promotes **a dominant E-W opening** [Malinverno & Ryan, 1986; Royden, 1993; Lonergan & White, 1997; Rosenbaum *et al.*, 2002a] associated with slab rupture along and removal of slab under the North African margin [Gutscher *et al.*, 2002; Mauffret *et al.*, 2004; Spakman & Wortel, 2004; Duggen *et al.*, 2003, 2004, 2005] (Figure B). In this hypothesis, the slab is restricted to the Balearic-Sardinia/Corsica segment. These westward migration of the Alboran block would have induced a left-lateral deformation along the Western and Central Algerian margins and right-lateral deformation along the Balearic Promontory [Camerlenghi et al., 2009]. This scenario argues for a subduction starting along a fossil transform (subduction transform edge propagator (STEP)) fault.

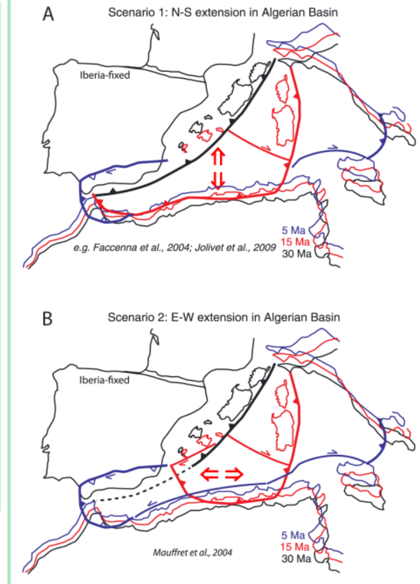
Whatever model chosen, the westernmost Algerian margin can be assumed to represent a purely strike-slip type margin [Domzig *et al.*, 2006], having formed as a STEP-fault system -Subduction-Transform Edge Propagator) [Govers & Wortel, 2005; Medaouri *et al.*, 2014]

Note also that a third model, with process of lithospheric delamination [Roure *et al.*, 2012], challenges the rollback theories of these two models.

ALBORAN BASIN

The complexity of the evolution of the Alboran domain results in several debates focusing on the Tertiary kinematics of the Alboran block (timing and amount of westward displacement if exists) [e.g. Gueguen *et al.*, 1998; Jolivet & Faccenna, 2000; Mauffret *et al.*, 2004, 2007;Duggen *et al.*, 2004; Platt *et al.*, 2006] and the amount, timing and nature of the magmatic and volcanic activity which has considerably (and extensively) modified and altered the crustal structures [e.g. Duggen *et al.*, 2004; Booth-Rea *et al.*, 2007] and may mask the importance of tectonic features and the nature of the basement [Medaouri et al., 2014].

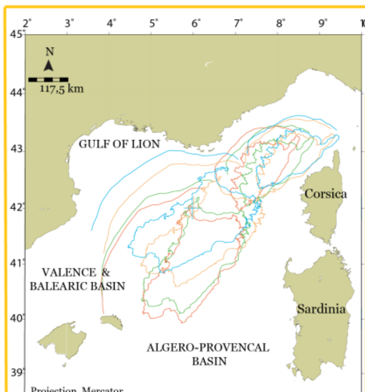
Therefore, subduction rollback, detachment and/or STEP (Subduction-Transform Edge Propagator), tearing slab, double vergence subduction zones, mantle diapirism, poloidal and toroidal mantle flows, delamination, convective removal, etc. are proposed the opening of the Algerian-Alboran deep basins [for e.g. summaries in Michard *et al.*,2002; Spakman & Wortel, 2004; Govers & Wortel, 2005;Valera *et al.*, 2008; Vergès & Fernandez, 2012; Duarte *et al.*,2013; Schellart & Moresi, 2013; Meyer & Schellart, 2013].



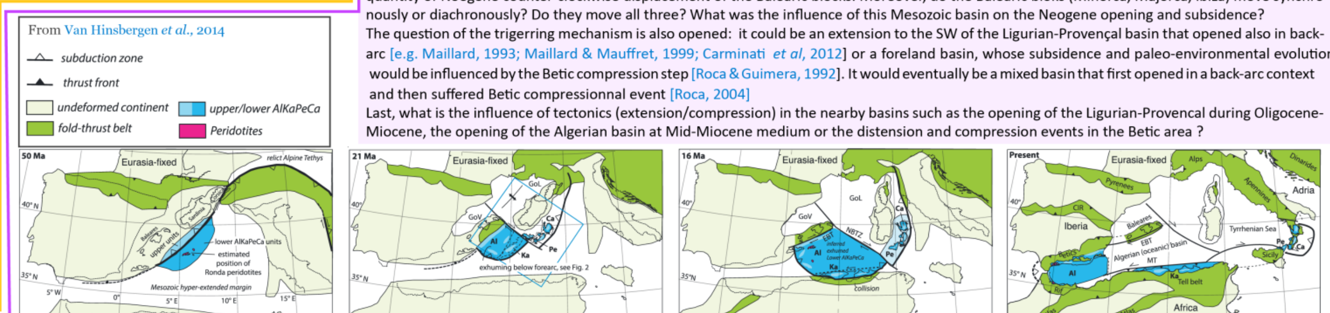
From Van Hinsbergen *et al.* [2014]

PROVENCAL BASIN

The Oligo-Miocene counterclockwise rotation of the Corsico-Sardinian block is commonly accepted for explaining formation of the Provencal basin. However authors disagree on its amplitude & timing (see next Plate 09/57), and also on the extent of resulting oceanic domain. This is mainly due to the different data (paleomagnetism, geology, gravity ...) and the spatial and temporal scales (position plate boundaries, integration of relative movement of the Balearic block ...) that are taken into account in the kinematic reconstructions. The modalities of interaction or non interaction of Alpine Orogen and history of the European Rift in structuring the Mediterranean are also a source of varying interpretations (see [Mattauer, 2007])



Comparison between different kinematic reconstructions for the Provençal basin: Gattacceca *et al*, 2007 (in green), Edel, 2001 (in red), Gueguen, 1995 and Olivet, 1996 (in blue), Bentoussi, 1990 (in orange)



VALENCIA & BALEARIC BASIN

The Gulf of Valencia is an aborted rift separated from the Ligurian-Provençal basin by the North Balearic Fracture Zone (ZFNB) and supposed to be opened in a NW-SE direction [Maillard *et al.*, 1992; Roca & Guimera, 1992]. It presents, at least in the eastern part, a Mesozoic structuration (Roca , Maillard, etc. ?). This previous structuration and basin thinning is not always take into account [e.g. Carminati *et al.*, 2013] and put into question the quantity of Noegene counter-clockwise displacement of the Balearic blocks. Moreover, do the Balearic bloks (Minorca, Majorca, Ibiza) move synchronously or diachronously? Do they move all three? What was the influence of this Mesozoic basin on the Neogene opening and subsidence?

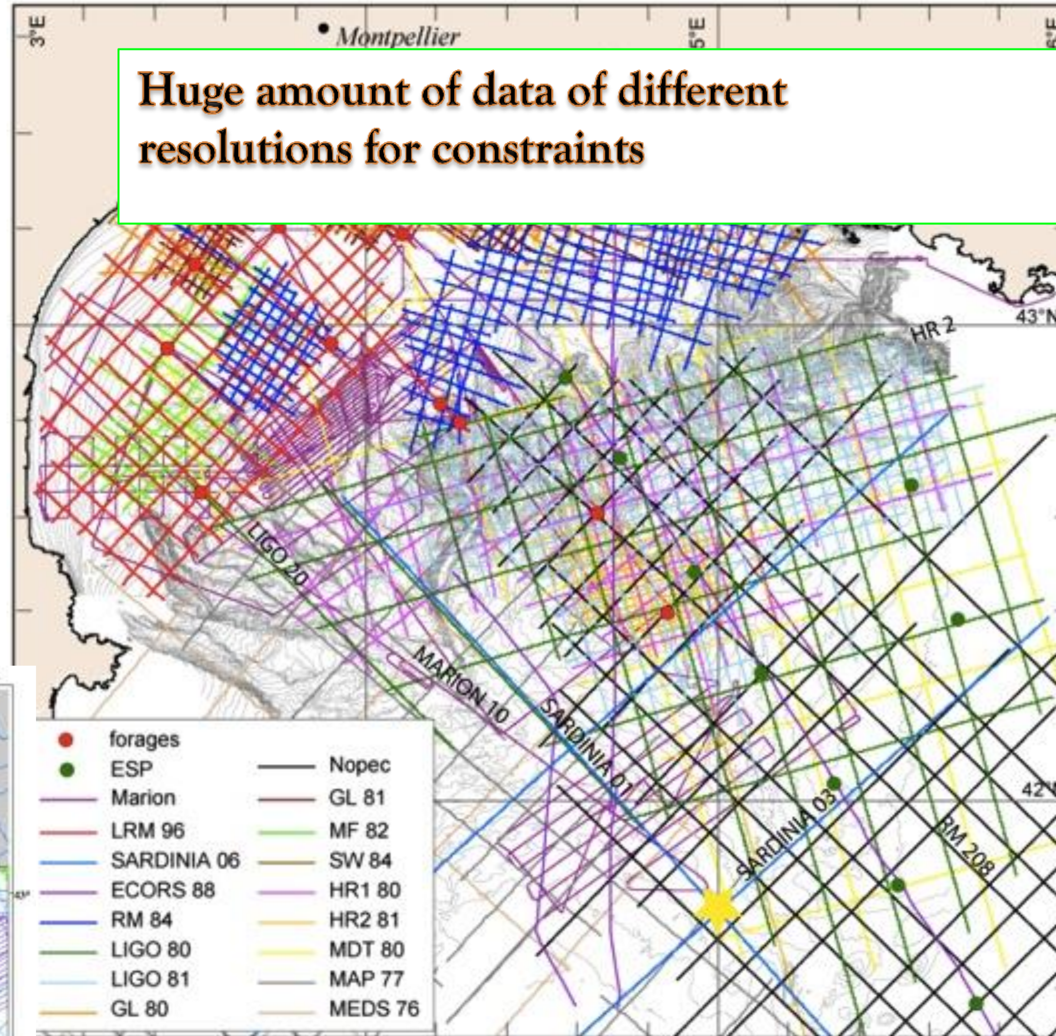
The question of the trigerring mechanism is also opened: it could be an extension to the SW of the Ligurian-Provençal basin that opened also in back-arc [e.g. Maillard, 1993; Maillard & Mauffret, 1999; Carminati *et al*, 2012] or a foreland basin, whose subsidence and paleo-environmental evolution would be influenced by the Betic compression step [Roca & Guimera, 1992]. It would eventually be a mixed basin that first opened in a back-arc context and then suffered Betic compressional event [Roca, 2004]

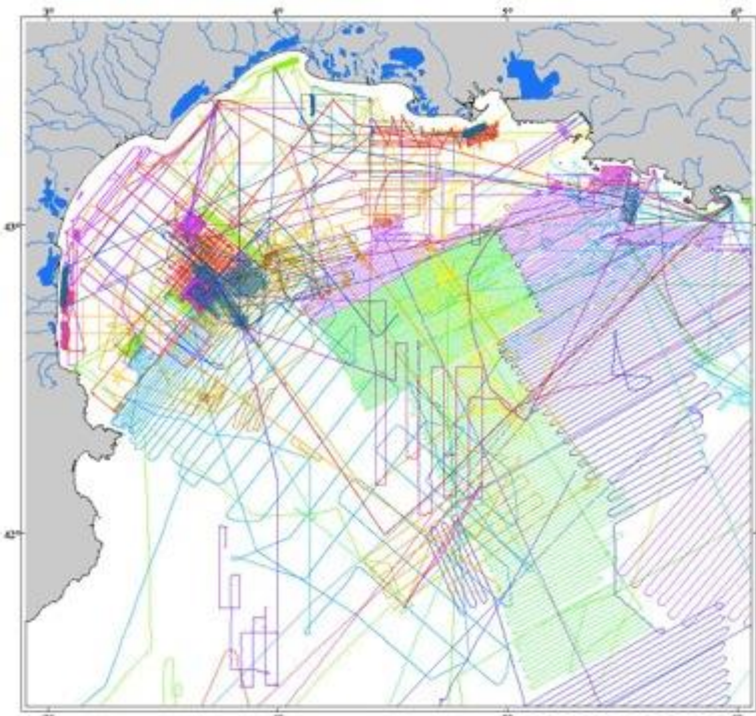
Last, what is the influence of tectonics (extension/compression) in the nearby basins such as the opening of the Ligurian-Provencal during Oligocene-Miocene, the opening of the Algerian basin at Mid-Miocene medium or the distension and compression events in the Betic area ?

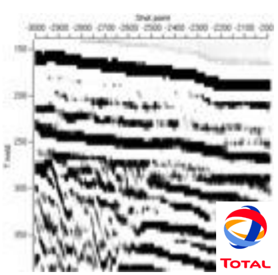
Provençal Basin

Huge Seismic Dataset
Conventional MCS from TOTAL
Academic high, very high resolution
Refraction Data Ifremer
+ drillings (pétroleum + Promess)

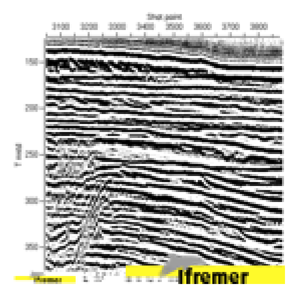
Huge amount of data of different resolutions for constraints



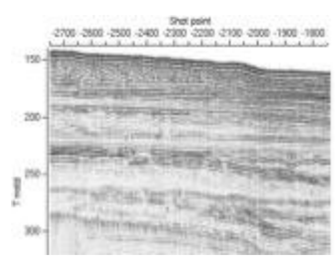




Pénétration : pluri-Kms

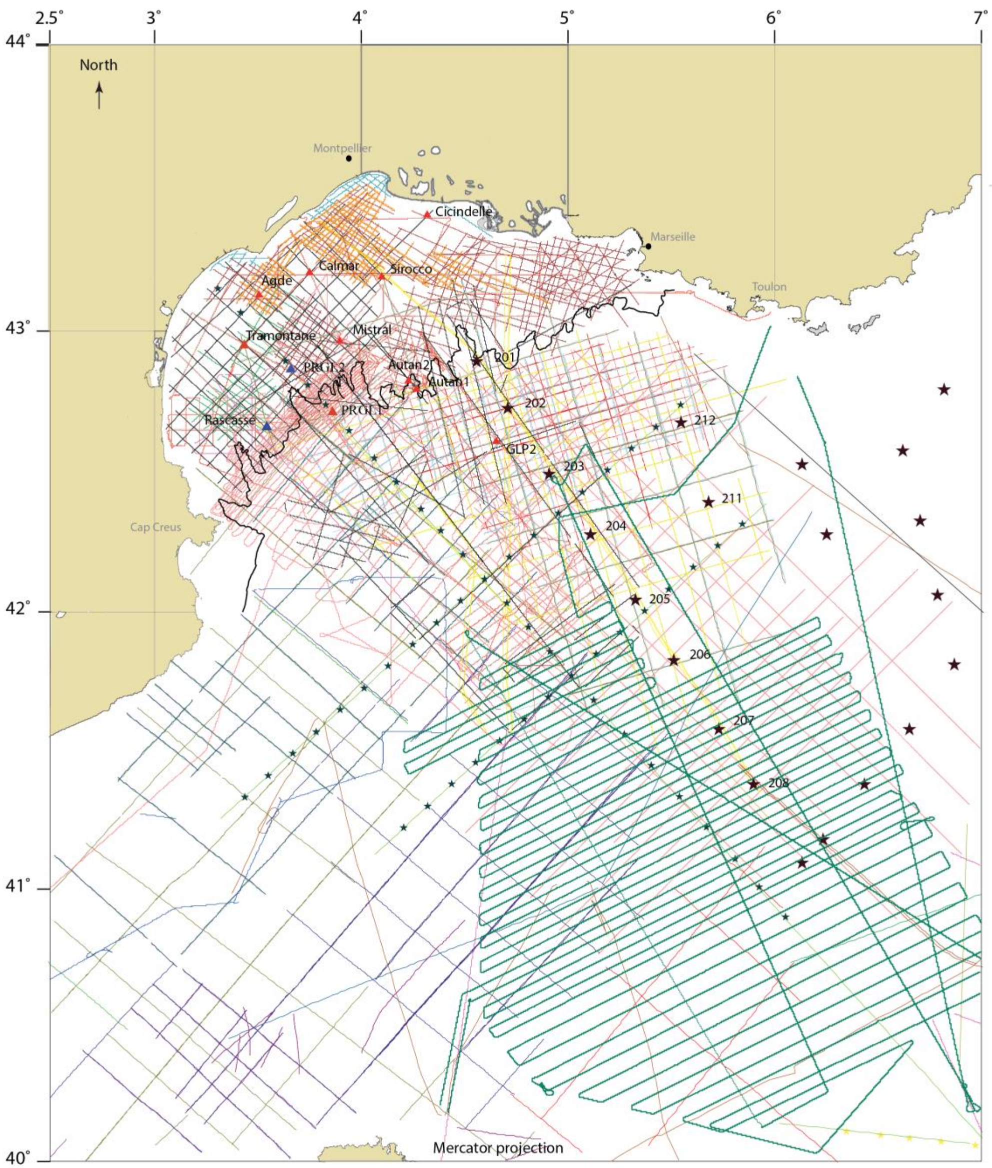


Pénétration : 0,5 Km



Pénétration : 100 m

Provençal Basin

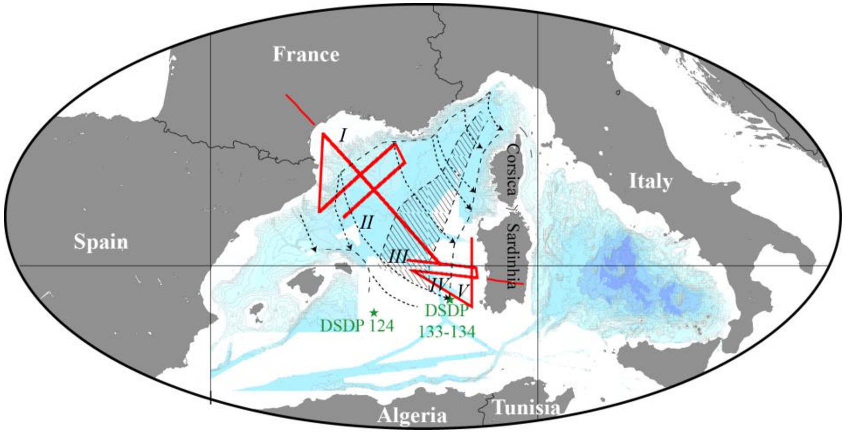


+ Wide Angle Data

Industrial Seismic Surveys:			Academic Seismic Surveys:
LRM96	MDT	MAP77	ECORS
SW84	MF82	MED76	Progres03
RM84	GL80	HR1	Marion00
80Ligo	GL81	RM01	Calmar99
Ligo81			Sardinia06

- PRGL boreholes
- Boreholes
- ESP
- OBS (Sardinia)
- present-day shelf break

Sismique Multi-Traces
Sismique HR
Sismique THR



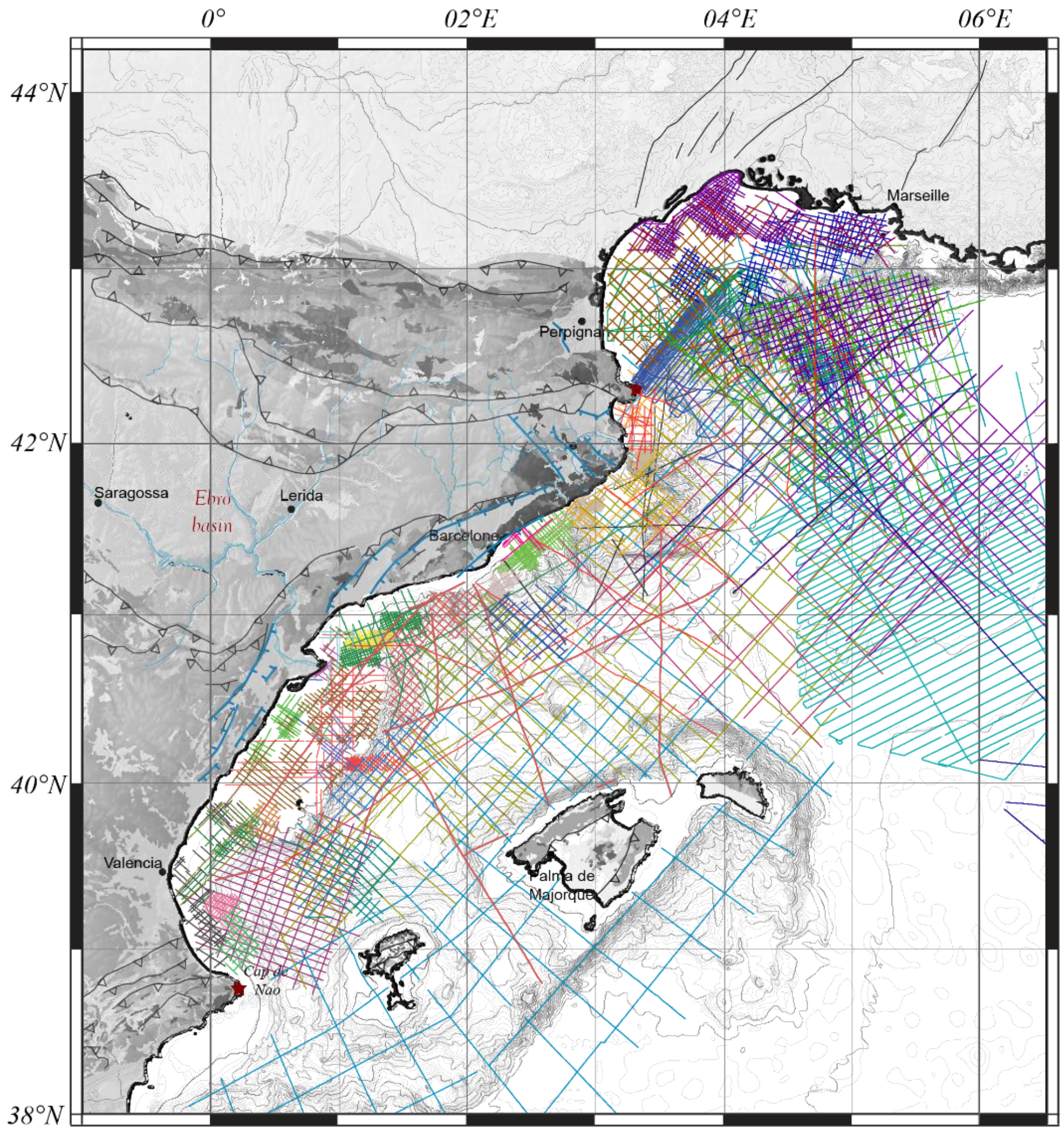
Sismique Réfraction Sardinia

Valencia Basin

• Bache, 2008; Garcia et al., 2011; Leroux, 2012; Driussi, 2015

• Ré-intégration de 637 industrial profilessismiques (Sigeco)

• + Collaboration with Total (SGV01) et Schlumberger (MSP74 et MEDS76)



Valencia Basin

• Bache, 2008; Garcia et al., 2011; Leroux, 2012; Driussi, 2015

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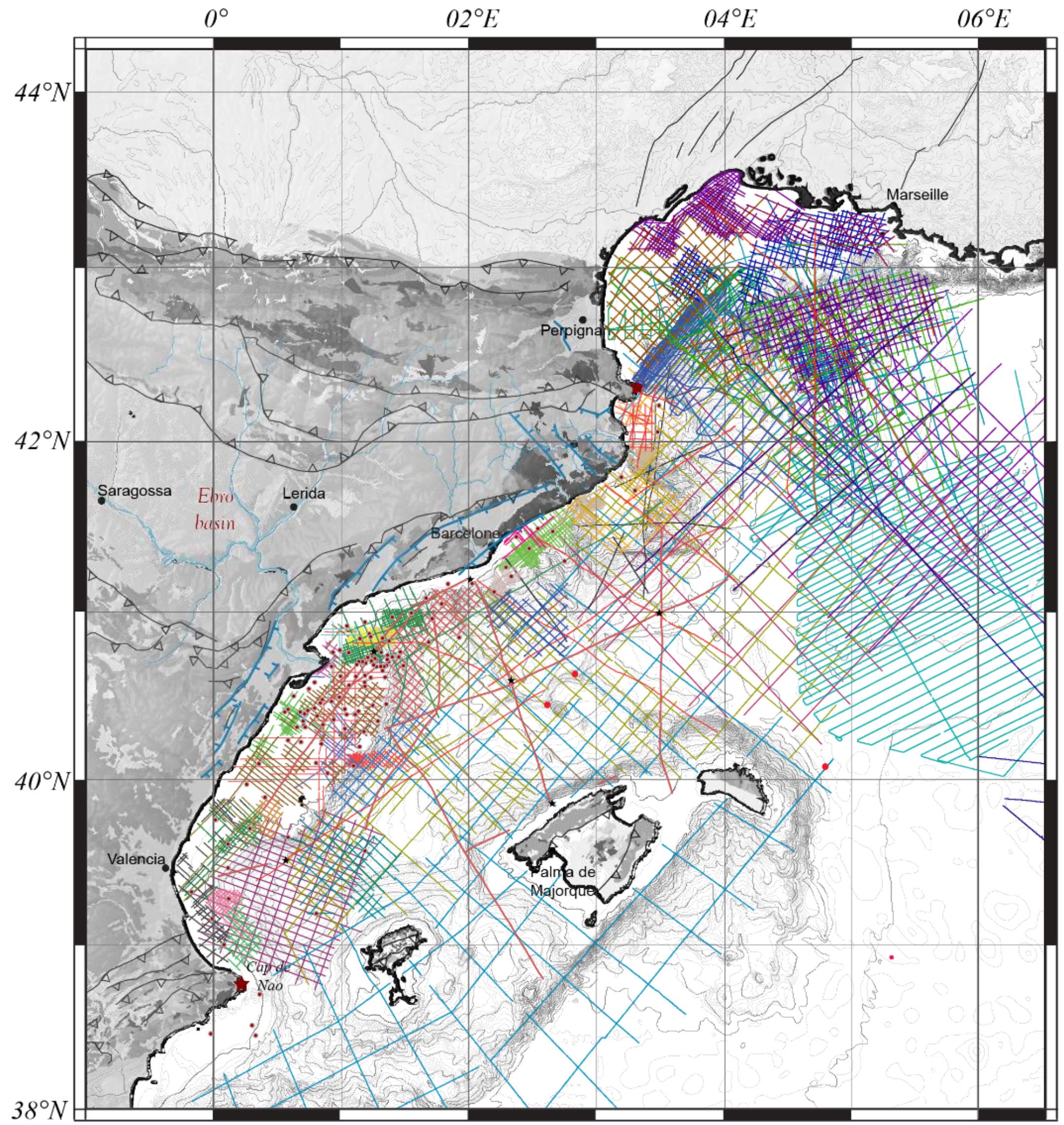
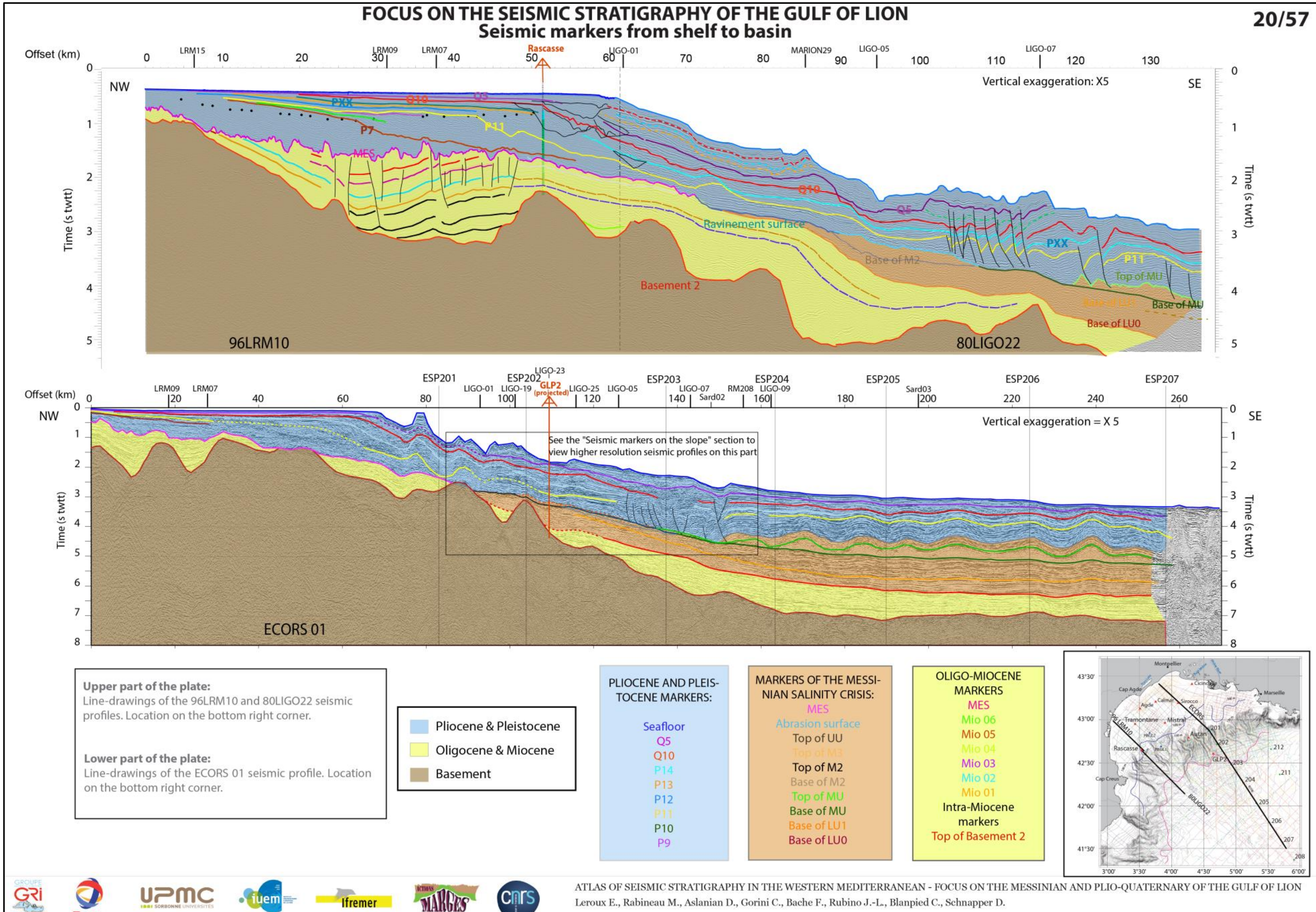
Drills (TOTAL) : 137 reports

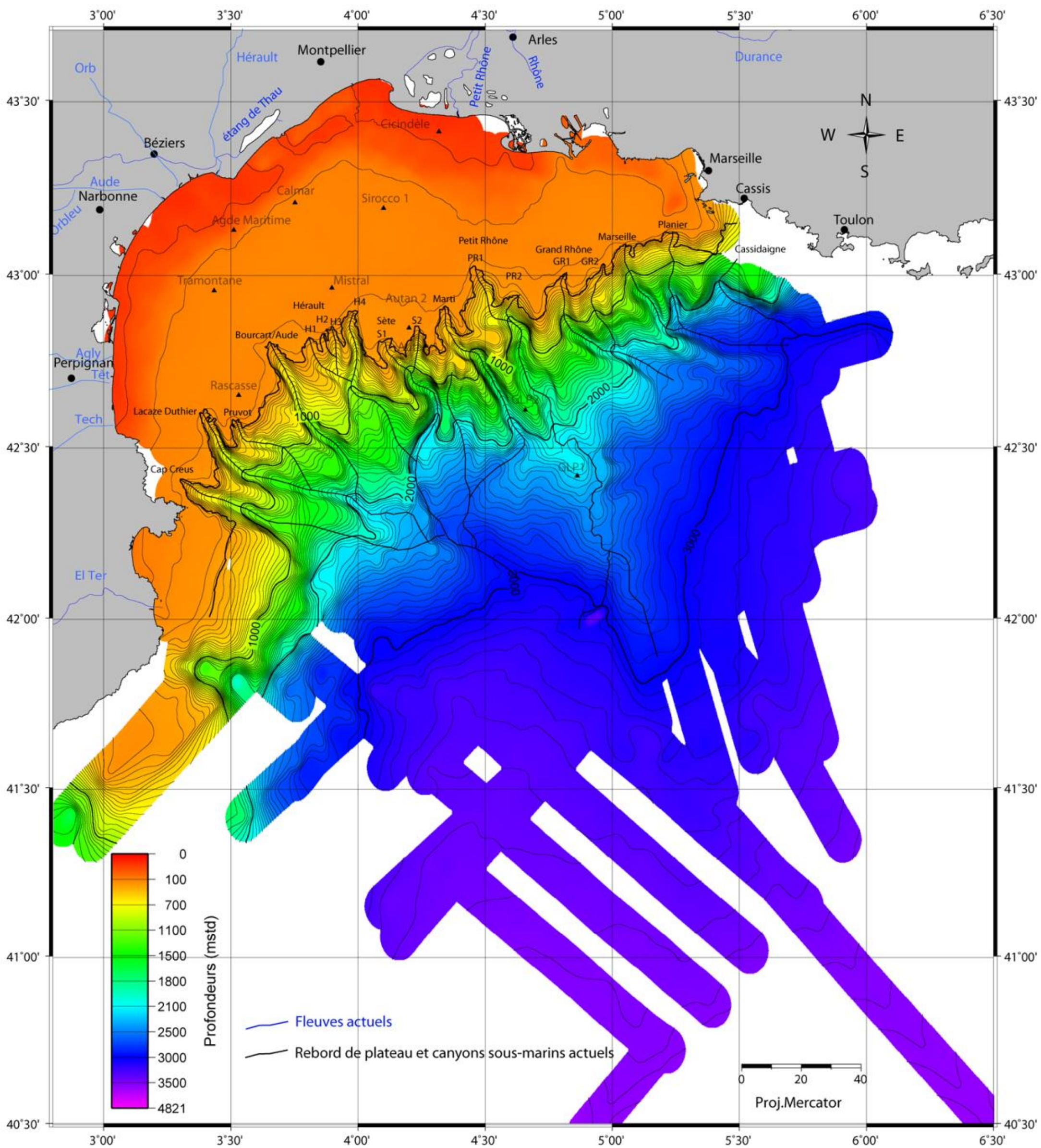


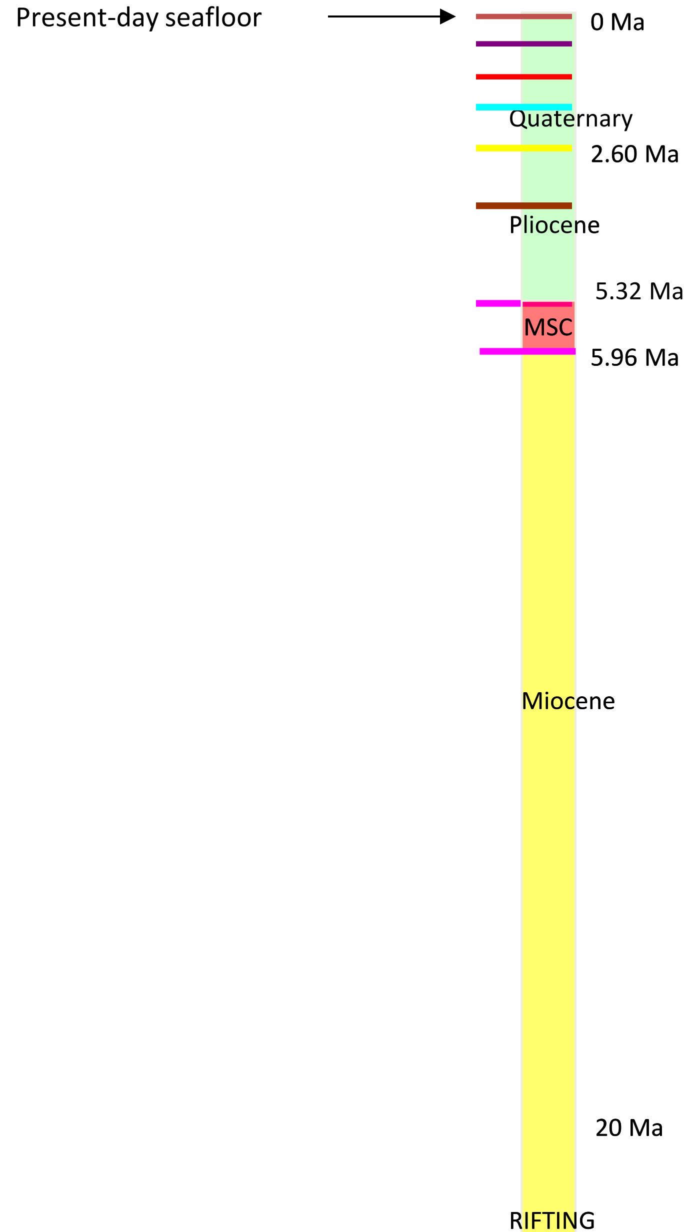
FOCUS ON THE STRATIGRAPHIC MARKERS OF THE GULF OF LIONS

Seismic markers (From Shelf to basin)



DEPTHS OF PRESENT-DAY SEAFLOOR





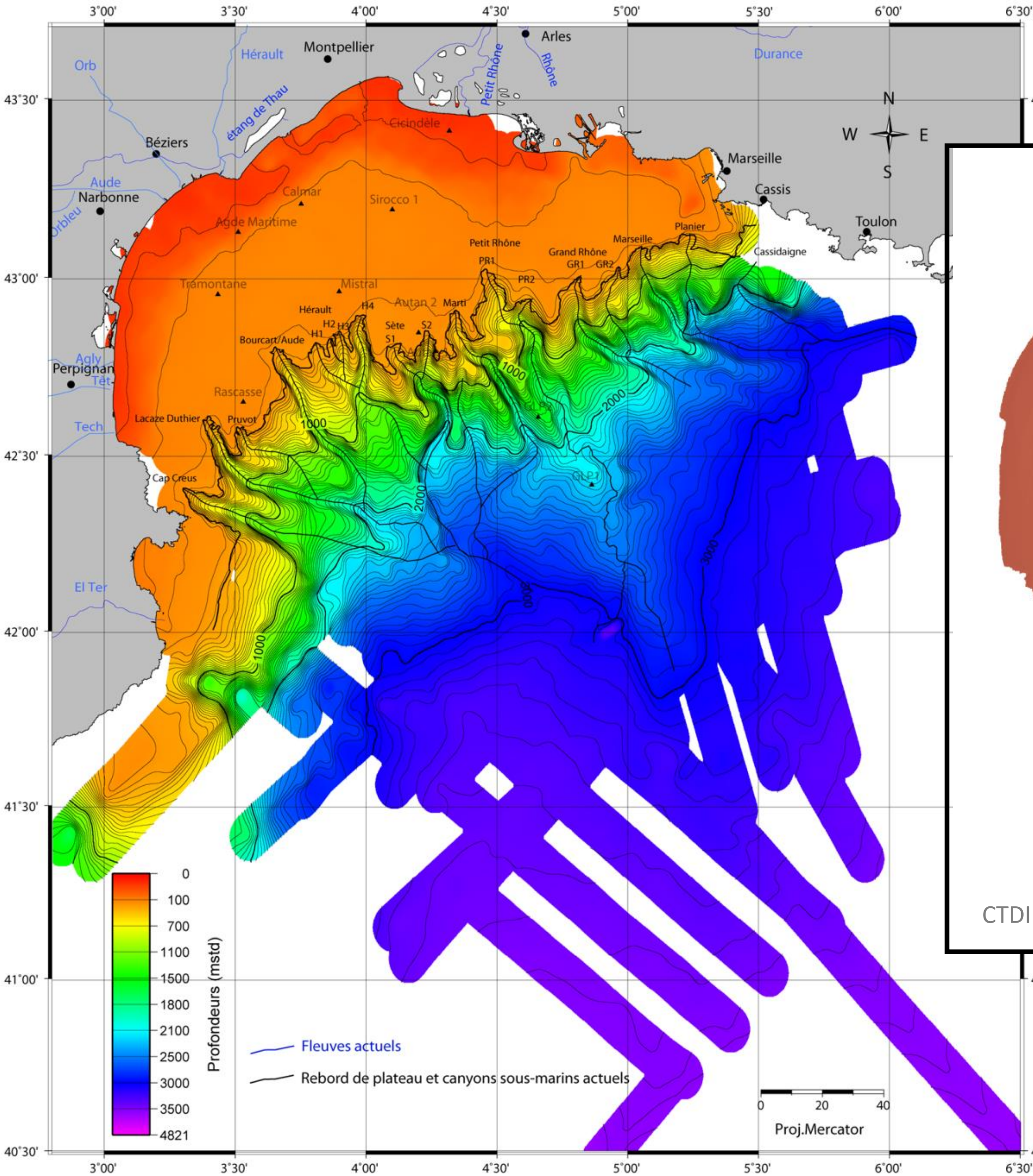
Leroux et al, Atlas In press

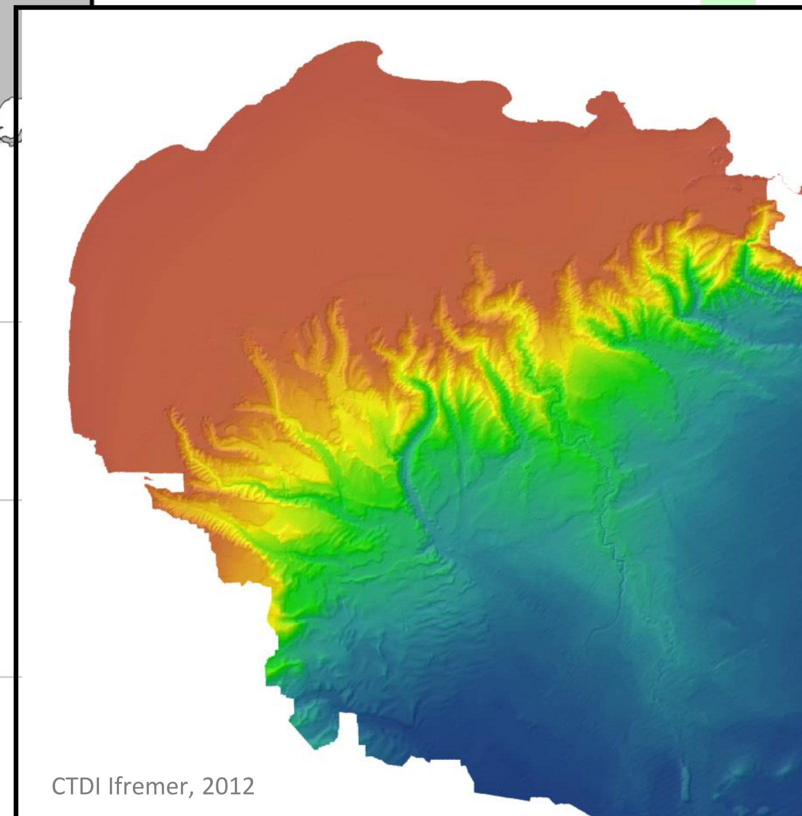
DEPTHS OF PRESENT-DAY SEAFLOOR

Present-day seafloor → 0 Ma

Quaternary

2.60 Ma





Ma

Ma

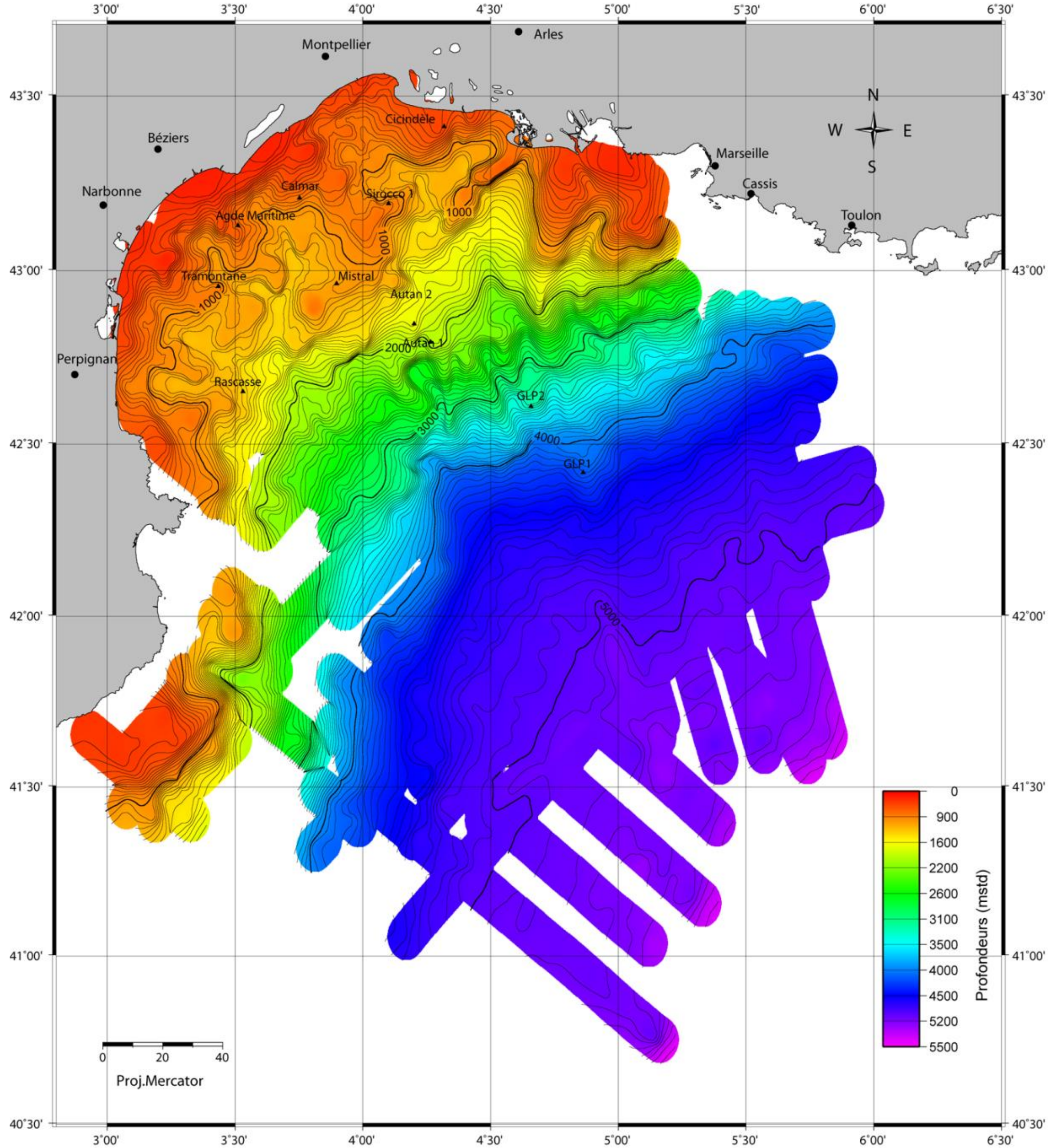
MULTIBEAM BATHYMETRY

20 Ma

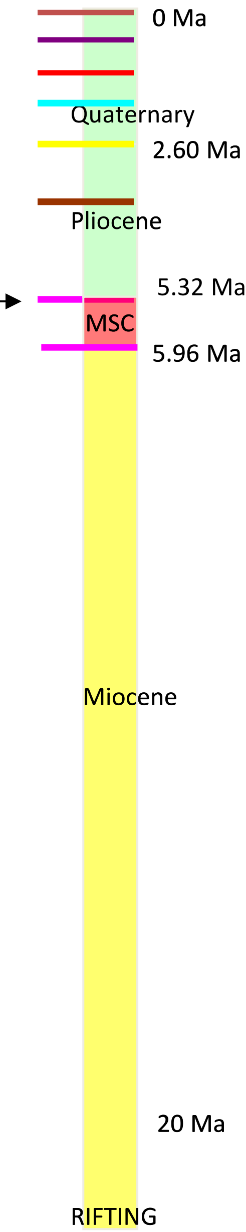
RIFTING

Leroux et al, Atlas In press

DEPTHS OF MESSINIAN TOP (5.32 Ma)

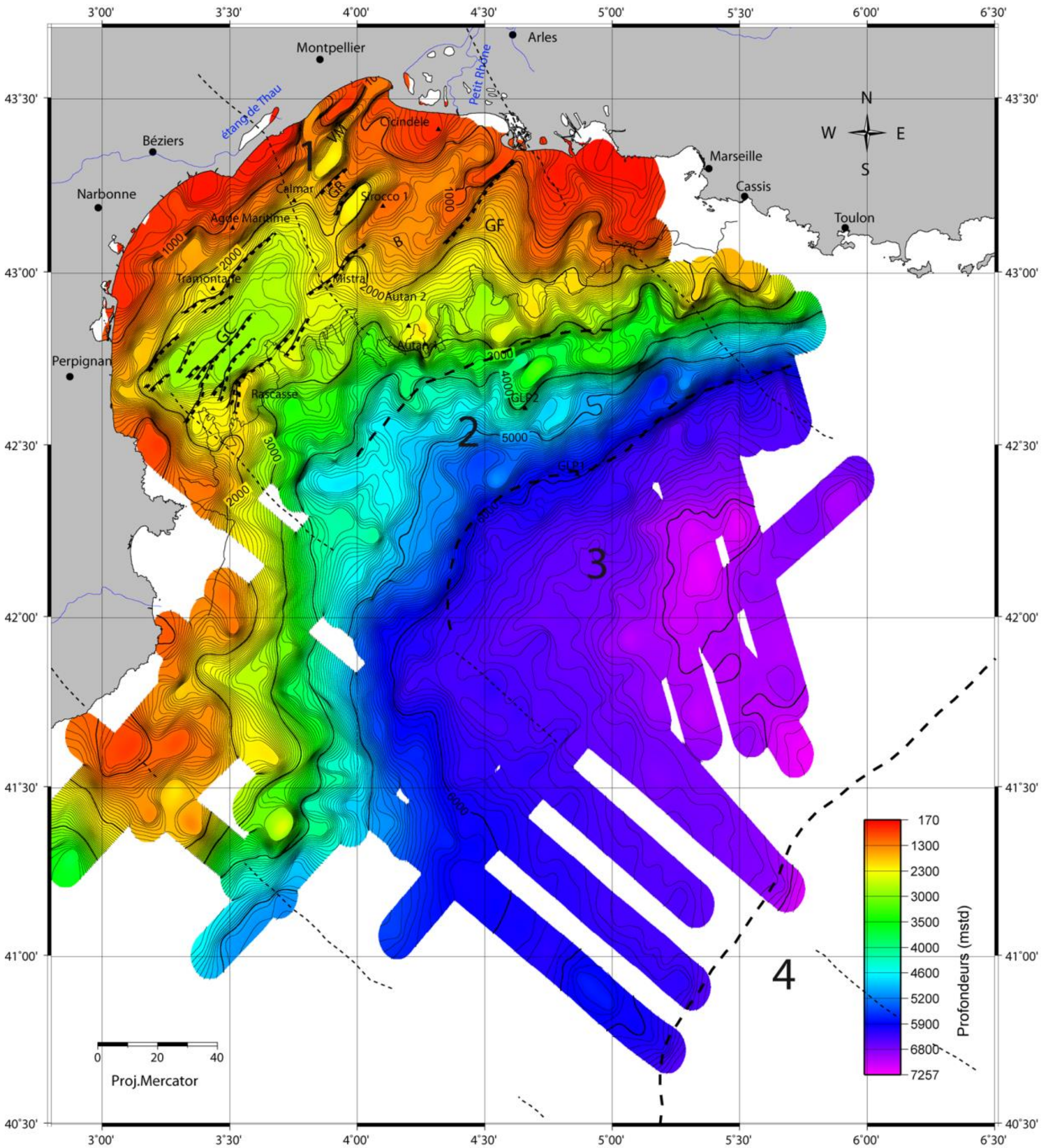


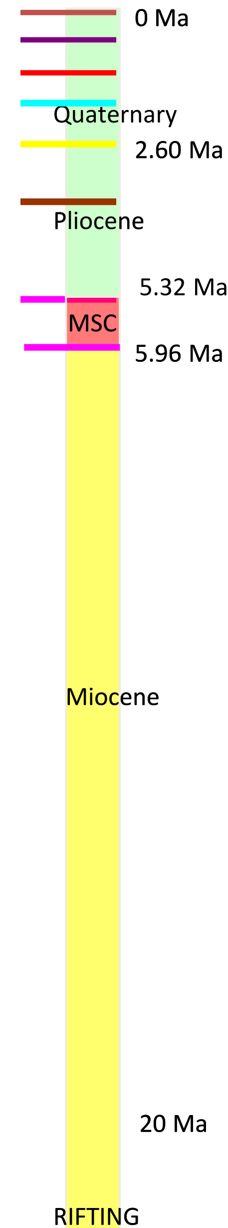
Top of Messinian deposits



Leroux et al, Atlas In press

DEPTHS OF BASEMENT

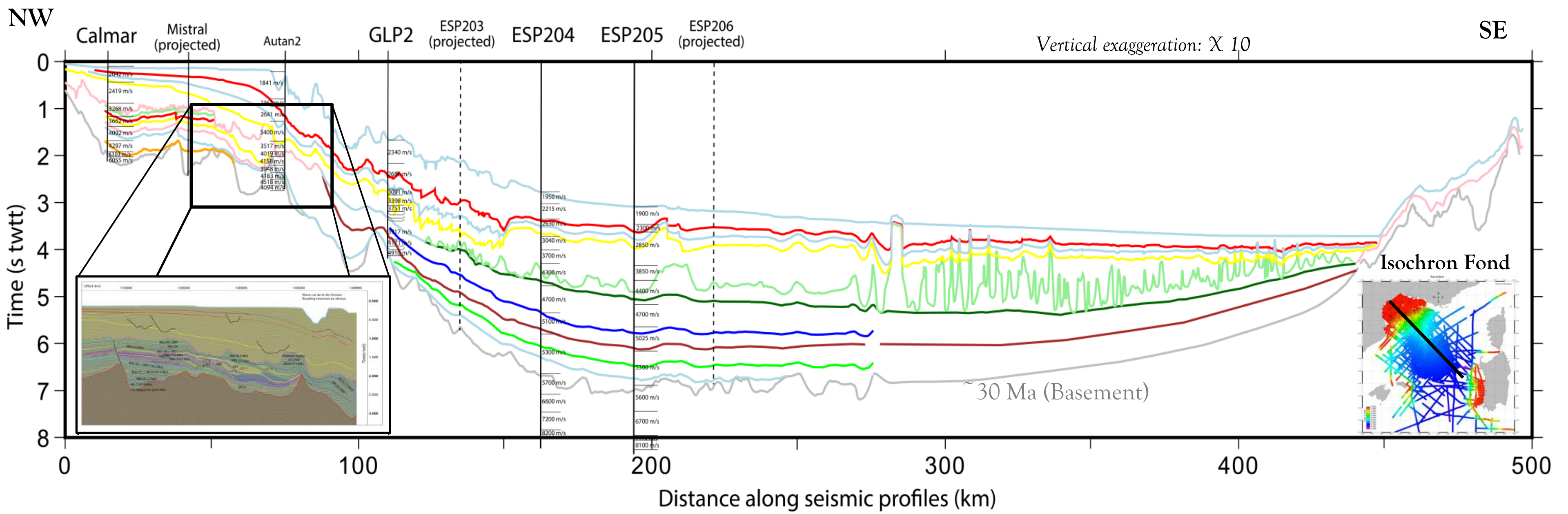




Leroux et al, Atlas In press

Top of basement
(base of syn & post-rift deposits)

From Gulf of Lion to Sardinia Margin



Gulf of Lion

- 0 Ma (Seafloor)
- 0.45 Ma
- 1 Ma
- 1.8 Ma
- 2.6 Ma
- 2.6 Ma
- 5.3 Ma (MSC)
- Top &Base Sel (5.9-5.3Ma)
- 5.9 Ma (MSCBase)
- 10 Ma
- 11.8 Ma
- 13,7/13.2 Ma (MFS Serravalieান)
- 16.2 Ma
- 17.2 Ma
- 20.4 Ma
- 21.2 Ma
- 23.8 Ma
- ~30 Ma (Basement)

West Sardinia Margin

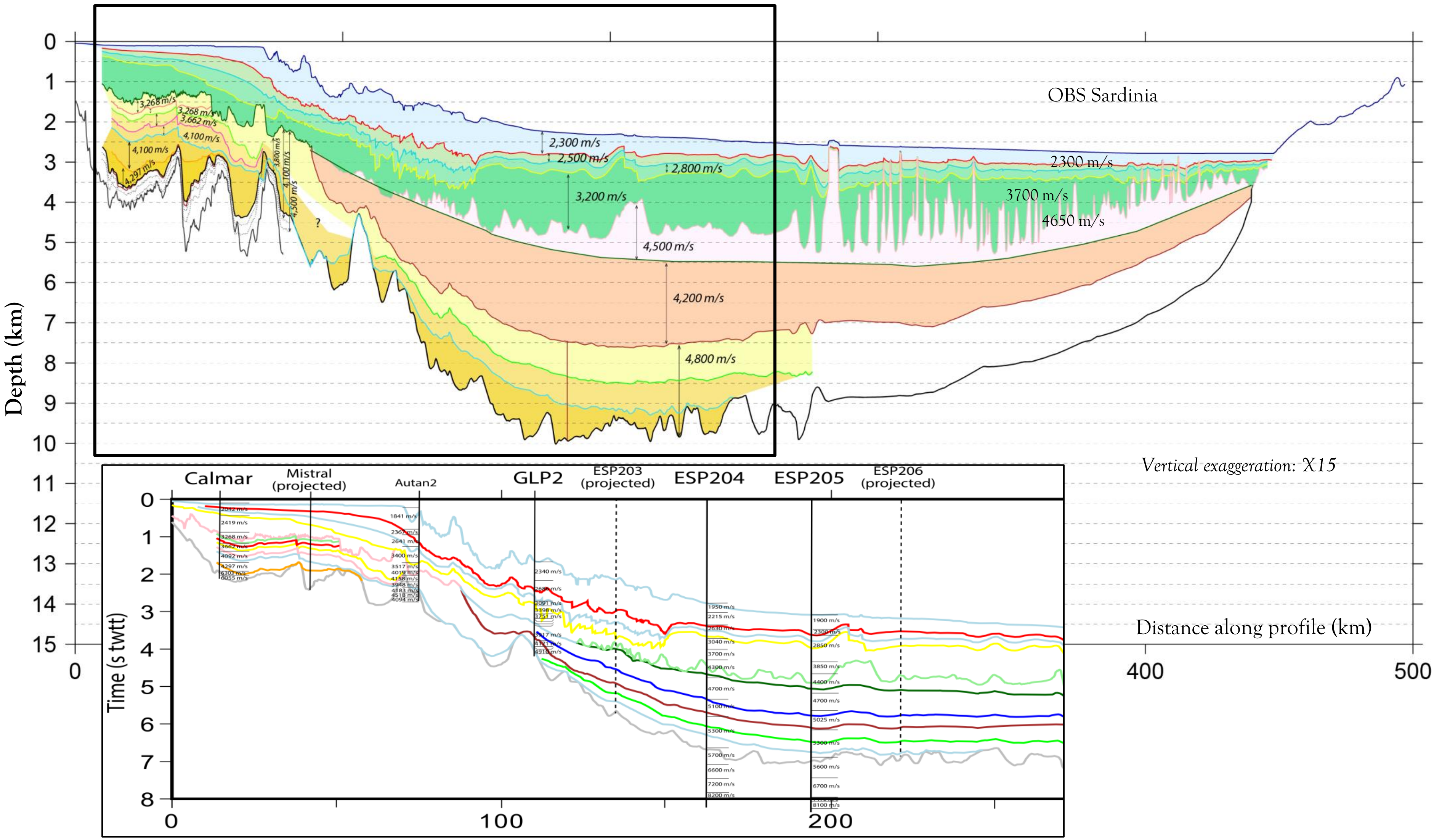
- 1 Ma
- 2.6 Ma
- 5.3 Ma (MSC)
- Toit du sel et Base du Sel (5.9-5.3Ma)
- 5.9 Ma (Base MSC)
- 11.8 Ma
- 16.2 Ma

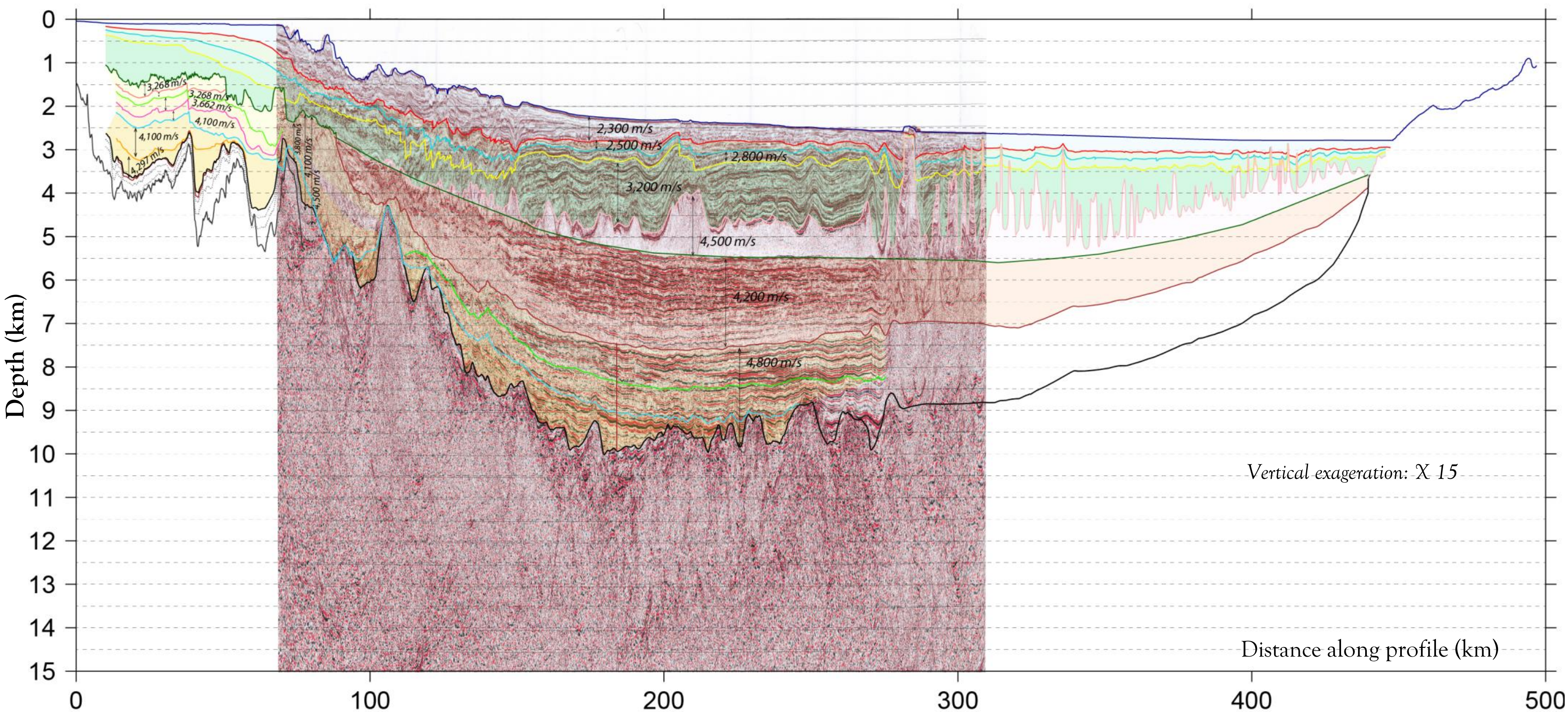
~ 30 Ma (Basement)

VALIDATION of the AGES at 2.6 Ma & 5.3 Ma (DSDP 134)
Nannofossiles, Foraminiferes – Comm. Pers. J.-P.Suc, S. Popescu

From Gulf of Lion to Sardinia Margin

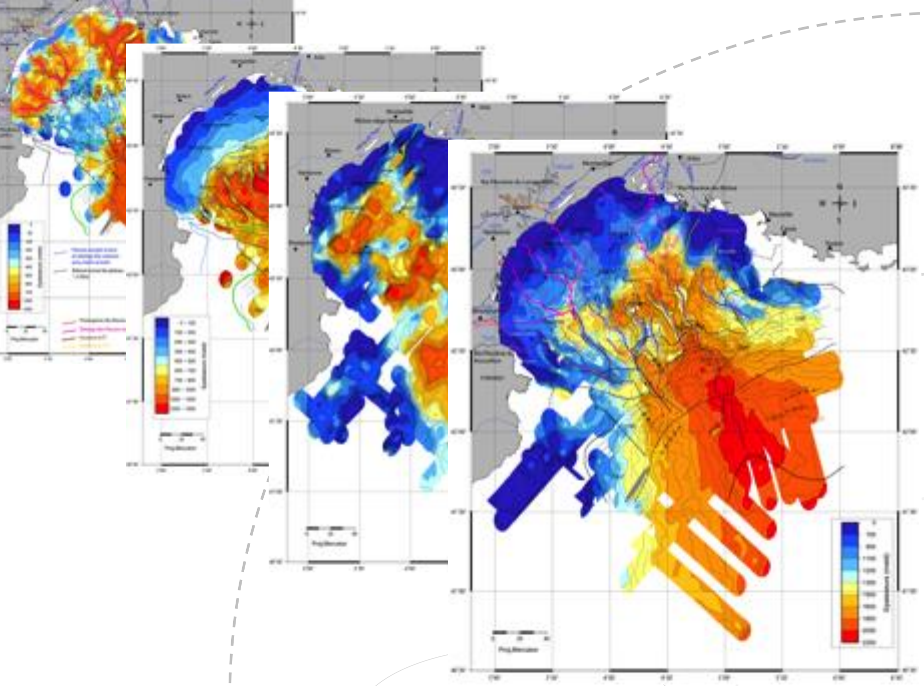
Seismic velocities : DRILLS + ESP + OBS (Sardinia)

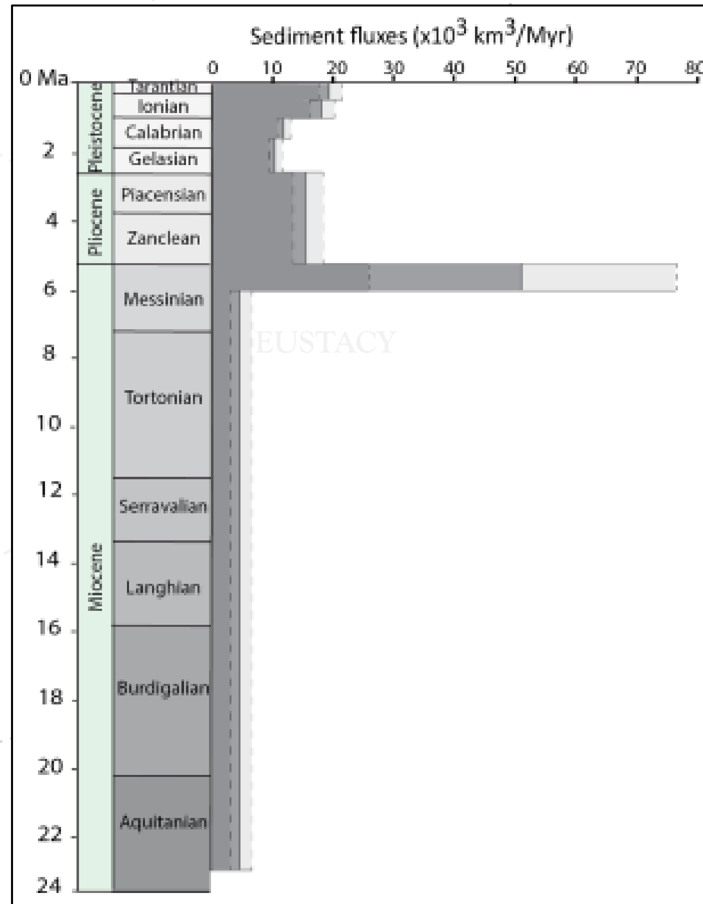




=> Validation des lois de vitesses

SEDIMENT GEOMETRY
SEISMIC VELOCITIES
COMPACTION
MULTIPROXIES APPROACH
(DIAGRAPHIES, BIOSTRATIGRAPHY, GEOCHEMICAL ANALYSES…)
GEOLOGICAL MODEL (FACIES, GEOMETRIES, AGES)





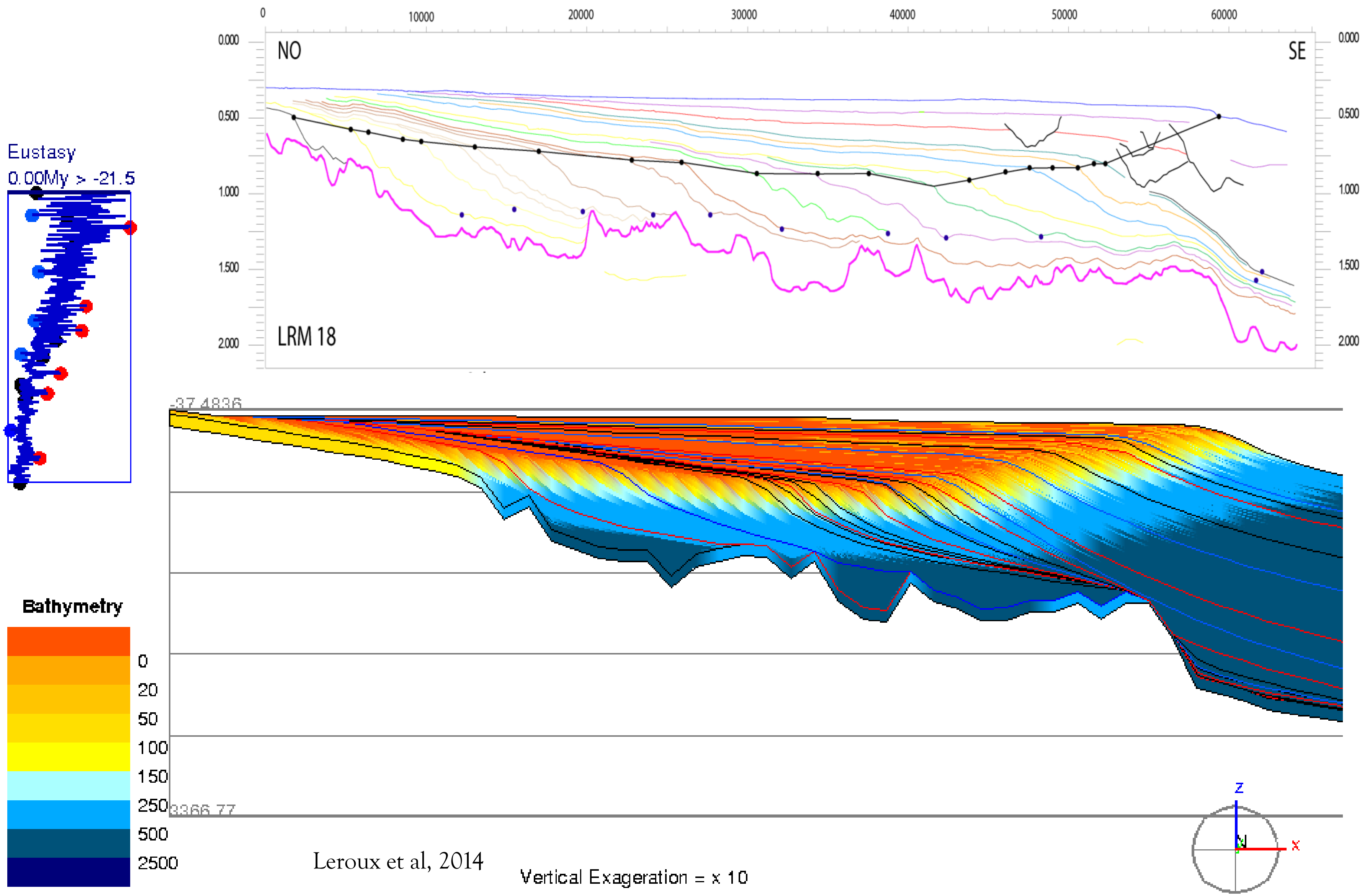
Garcia et al., 2009
Bache et al., 2010
Bache et al., 2012
Rabineau et al., 2006
Bache et al., 2009
Leroux et al., 2014
Rabineau et al., 2014
Leroux et al., 2015

SEDIMENT SUPPLY

Atlas sismique des marqueurs stratigraphiques post-rift dans le Golfe du Lion et bassin Provençal
Leroux et al., Edition 2015

Leroux et al, Atlas In press

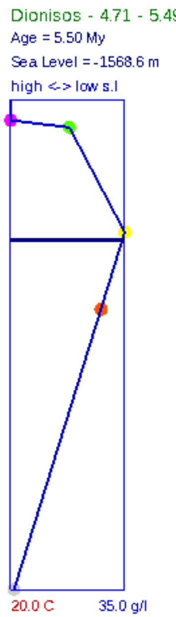
2D STRATIGRAPHIC MODELING WITH A CONSTANT SUBSIDENCE TILTING RATE OF 0,16° /MA ON THE LAST 5.32 Ma



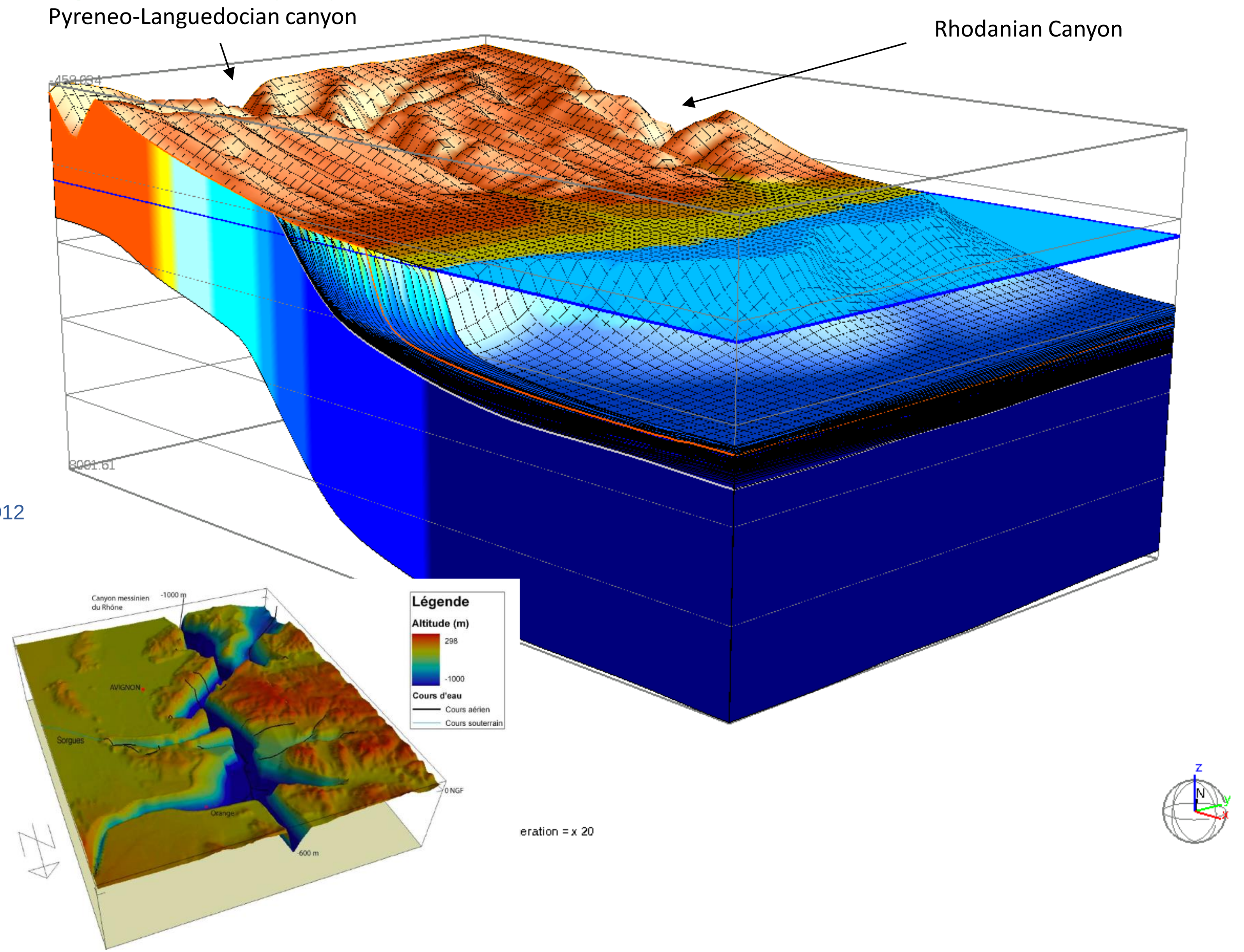
Agradation after progradation trend doesn't imply an acceleration of subsidence

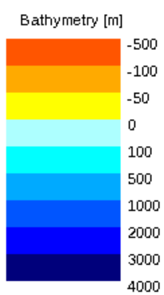
Rabineau et al., 2014; 2D modeling- Leroux et al., 2014 (Terra Nova)

Modeling the Messinian Salinity Crisis (6.00 Ma - 5.00 Ma) with a 10 000 years time-step

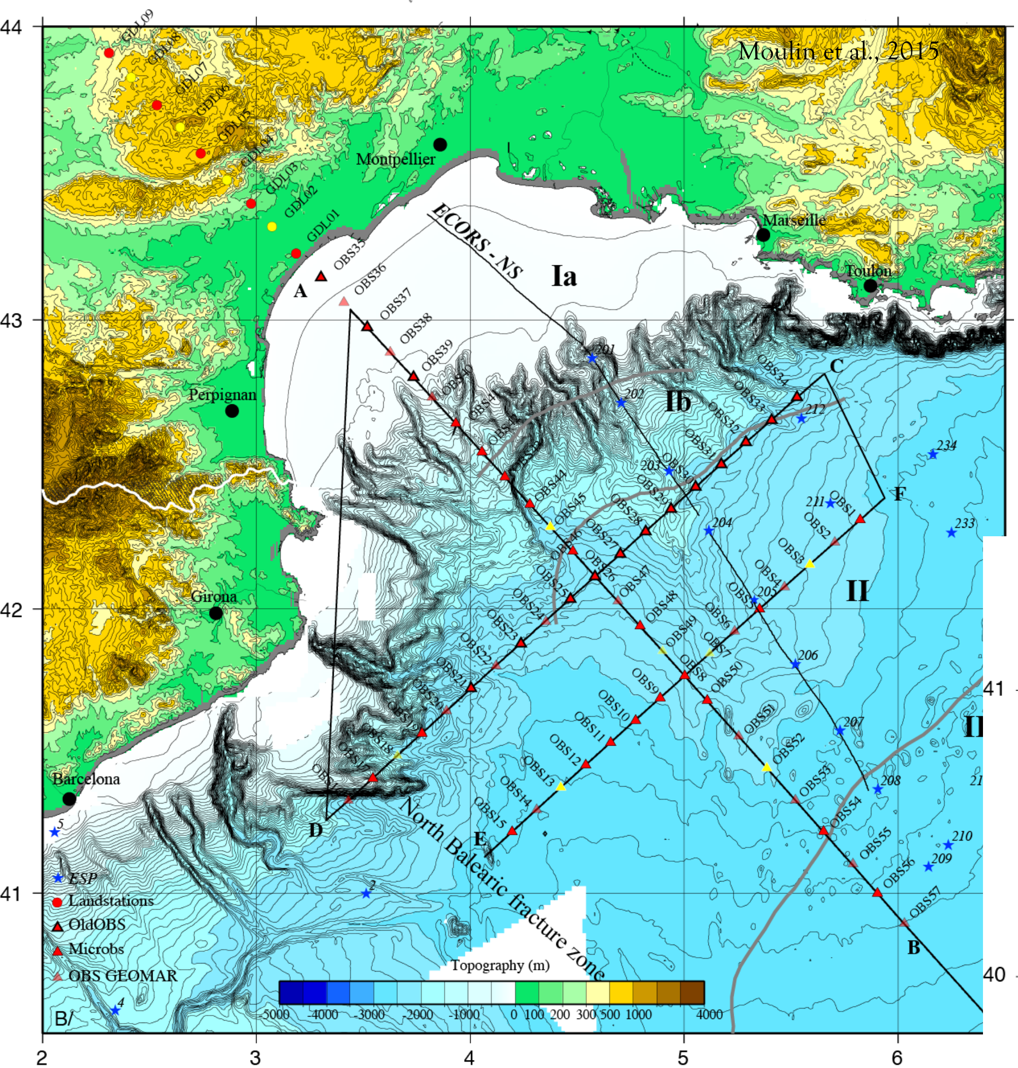


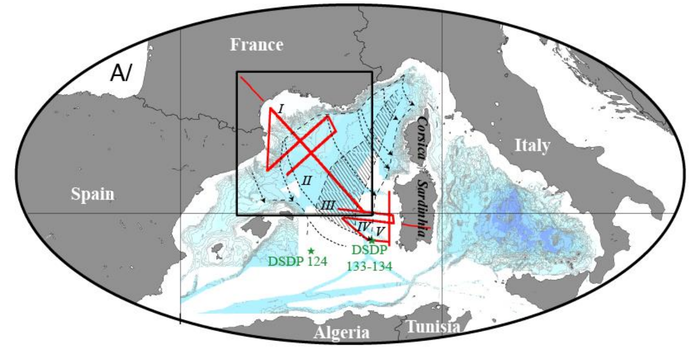
Sea-level scenario
from Bache et al., 2012

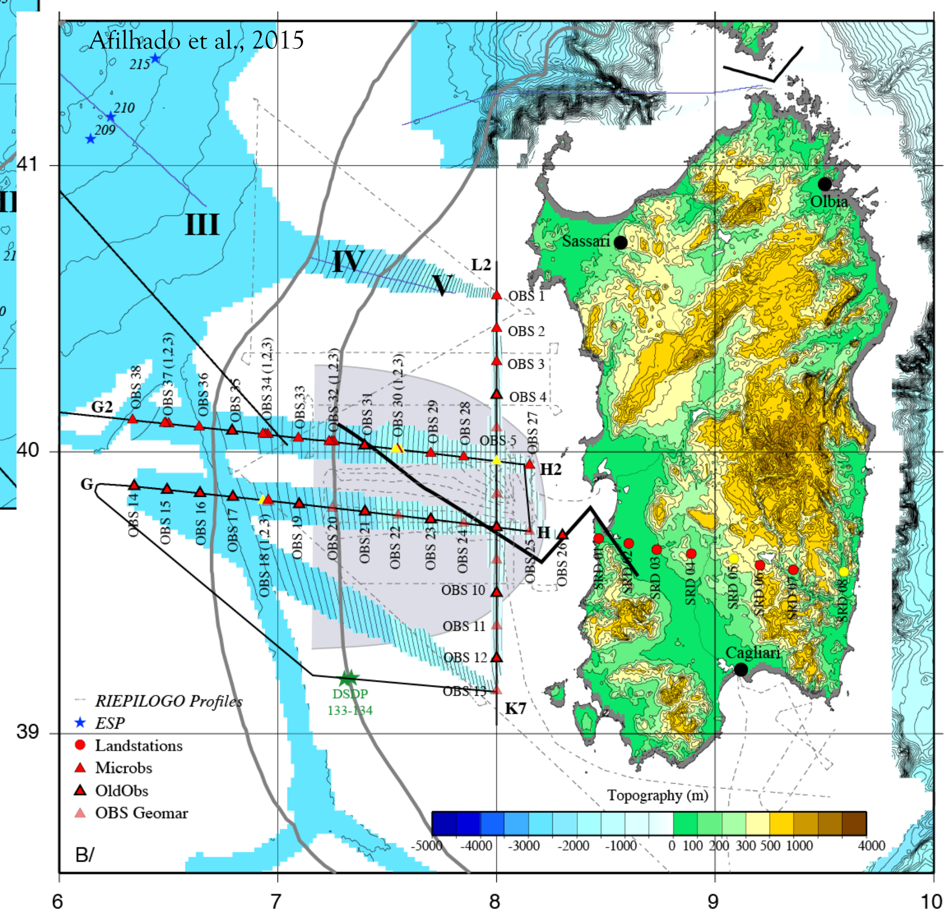




The Sardinia Experiment



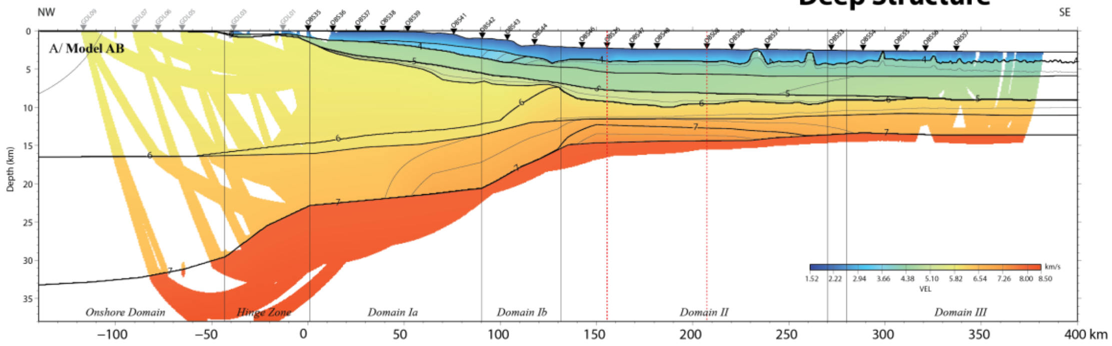


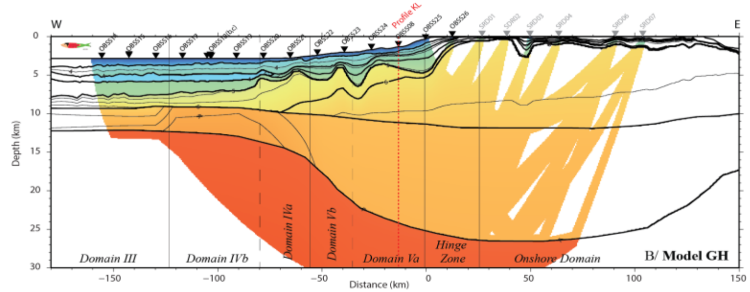


Moulin et al., 2015, Afilhado et al., 2015

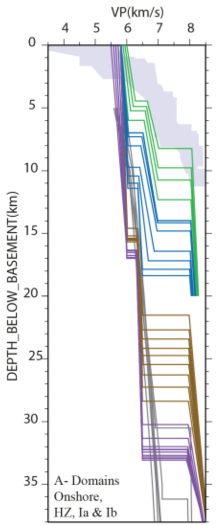
GEODYNAMIC AND GEOLOGICAL CONTEXT

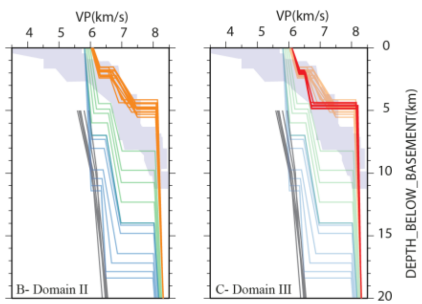
Deep Structure

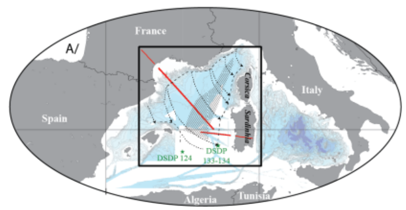


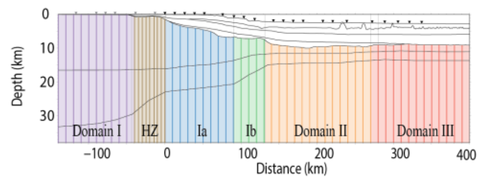


Velocity models for the two SARDINIA profiles including the model boundaries used during inversion (solid lines) and isovelocity contours every 0.20 km/s, OBS locations are indicated by inverted black triangles and land seismic stations by inverted grey triangles. Areas unconstrained by ray-tracing modelling are uncolored. The various domains are separated by thin black lines. V.E.= ~4. A/ GOL (Moulin *et al.*, 2015) B/ Sardinia (Aflilhado *et al.*, 2015).

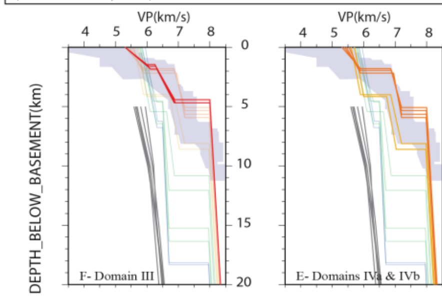


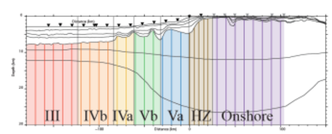


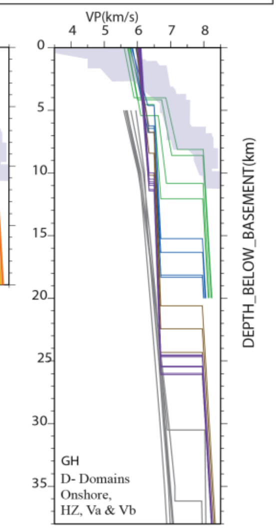




P-wave Velocity depth profiles below basement on both GOL and Sardinia Profiles (after Moulin *et al.*, 2015 and Afilhado *et al.*, 2015). The exact position of the extracted Vz-profiles is illustrated in the profiles below with the same colours. The three distinct domains on each profile are compared to the compilations made for continental crust (Christensen & Mooney, 1995) (gray lines) and a « normal » oceanic crust (White *et al.*, 1992) (blue shaded envelop). Velocity-depth profiles are extracted each 10 km in: A) & D) the continental slope domains (in blue (Va) and green (Vb); B) & E) the transitional domain (in dark orange (Iva) and light orange (IVb)) and C) & F) the atypical oceanic crust domain (in red).







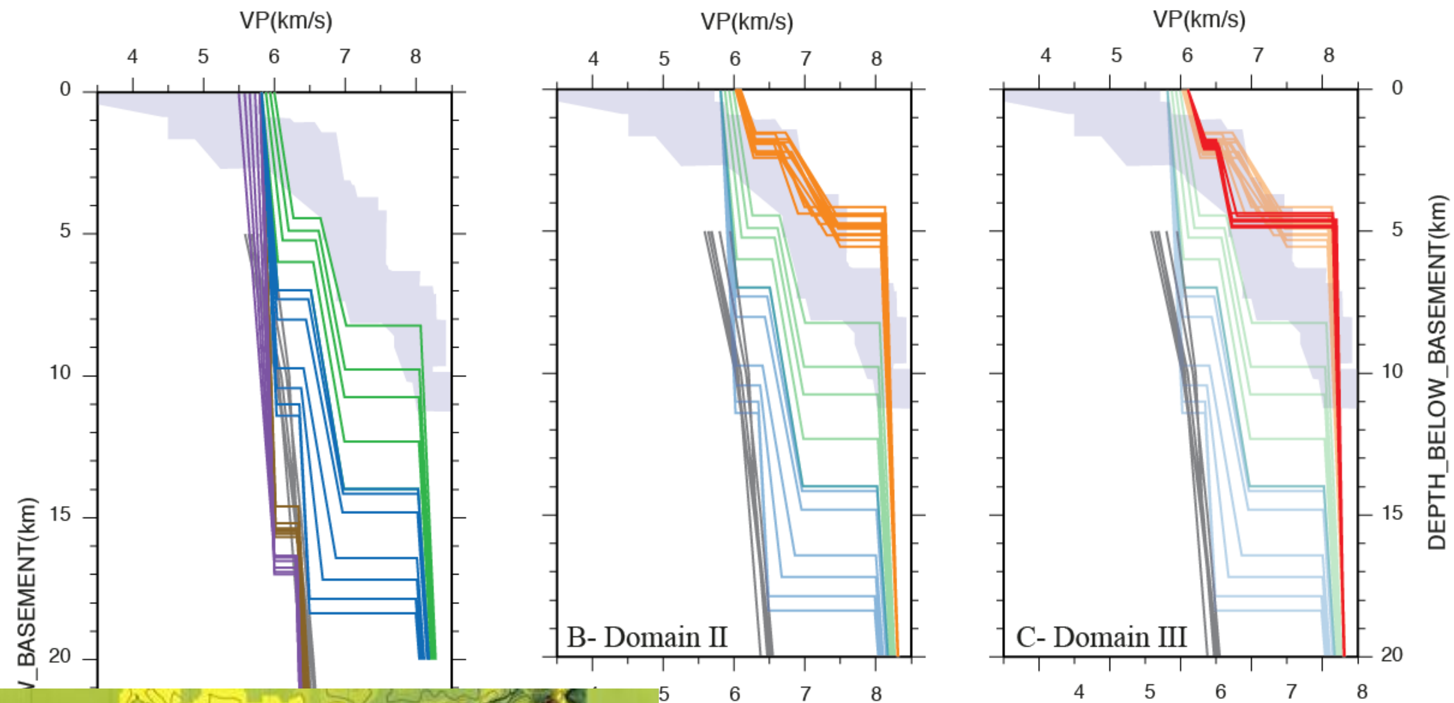
The 1D-VZ profiles underneath land seismic stations (purple lines) show similarities with the worldwide compilation of unthinned continental crust profiles (Christensen & Mooney, 1995), both in velocities and gradients. A very small velocity step marks the transition between the upper and lower crustal layer. From land to deep sea, three areas of thinning arte described: i) in the Hinge Zone (brown profiles) where the thinning occurred in the lower part; ii) in Domain Ia and Va (blue profiles), where the thinning occurred mainly in the upper part; and iii) in Domain Ib and Vb (green profiles), where the thinning occurred in both parts of the crust. In each domain, the decreasing of the thickness is connected with a slight increase of velocities in both layers.

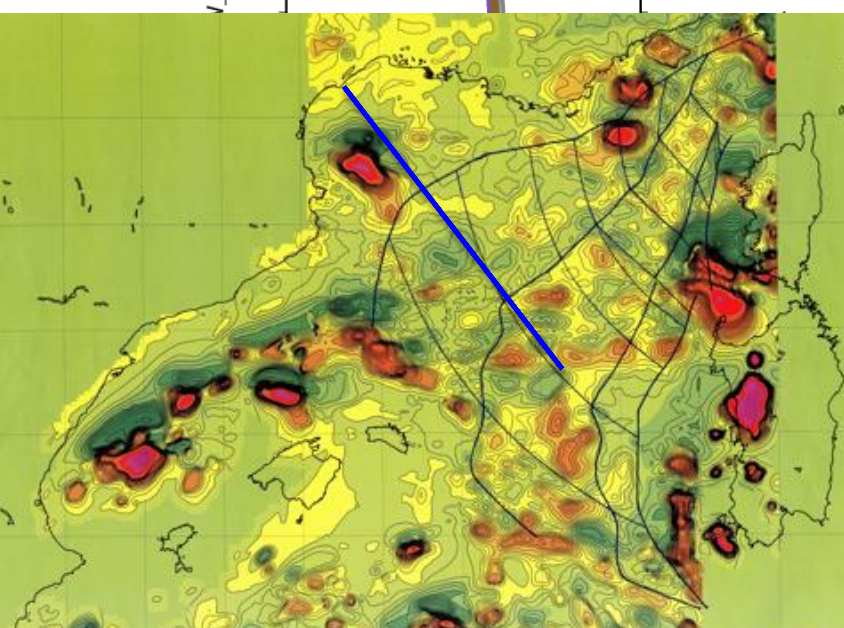
Domains II and IV are the place of an important change in the 1D-VZ profiles shape (light and dark orange profiles) in respect to the Domains I and V (blue & green profiles), with a strong velocity step between the two crustal layers (more than 1 km/s) and a strong velocity gradient in the lower crust These profiles do not fit a typical oceanic crust profile, nor an unthinned continental crust profile. The upper layer has a high velocity (>6 km/s) and the Moho is well marked by a step of about 0.5 km/s. Domain II may likely consist of a thin exhumed lower continental crust overlying a heterogeneous, intruded lower layer.

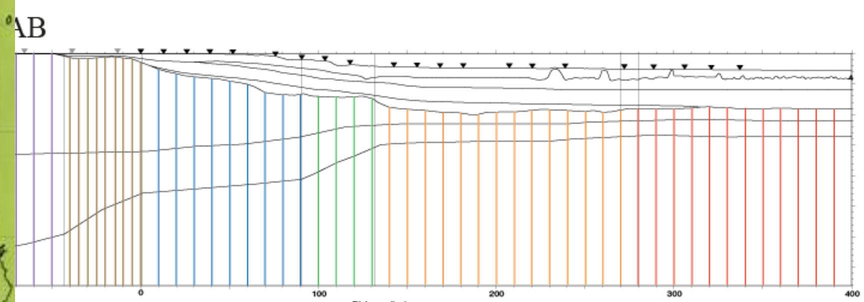
The comparison between the 1-D velocity structure of domain III and the typical oceanic crust (White *et al.*, 1992) shows a thinner crust mainly coherent with oceanic crust whilst in the Gulf of Lion, the domain III has a high velocity at the top of the crust (about 6km/s) and can be interpreted as oceanic crust with a missing layer 2 (consisted of pillow lavas) as described in the Atlantis Bank; on the Sardinia side, this domain seems to represent a more classical but thin oceanic crust.This similarity between domain III and domain IV raises the question of the role of the lower continental crust "flow", that can be gradually recrystallized to build the first atypical oceanic crust (Bott, 1971; Aslanian *et al.*, 2009: Sibuet *et al.*, 2012, Moulin *et al.*, 2015; Afilhado *et al.*, 2015).

Leroux E., Aslanian D., Rabineau M, Gorini C., Bache F., Rubino J.-L., Moulin M., Afhilado A., Schnurle P.

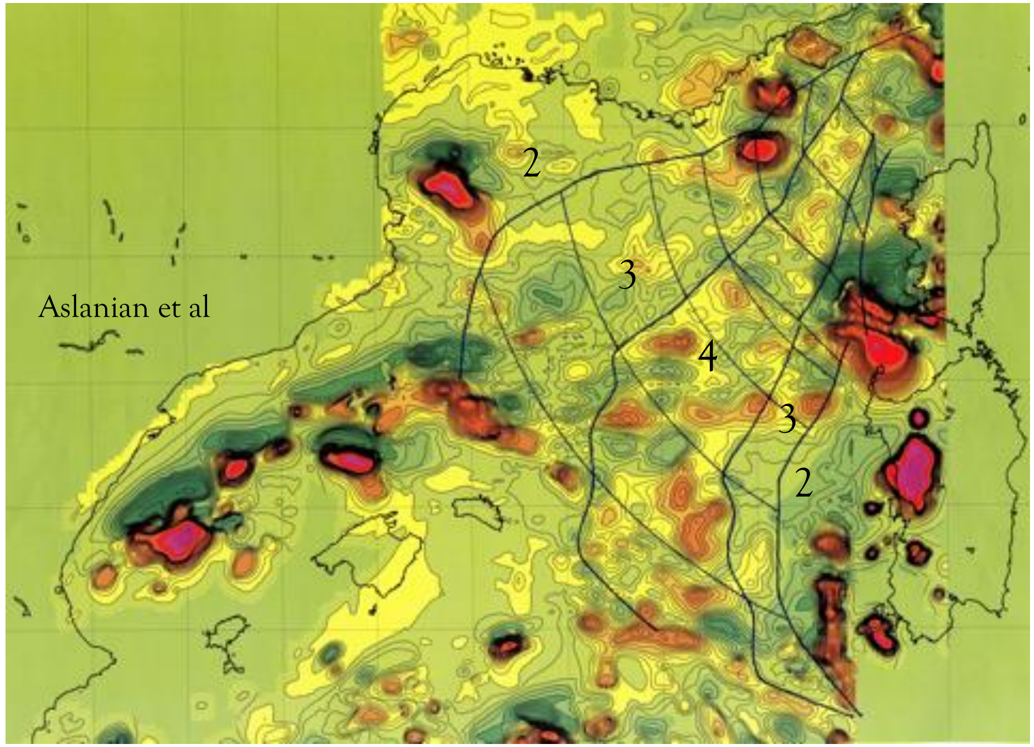
Discussion: *Nature of the oceanic crust?*



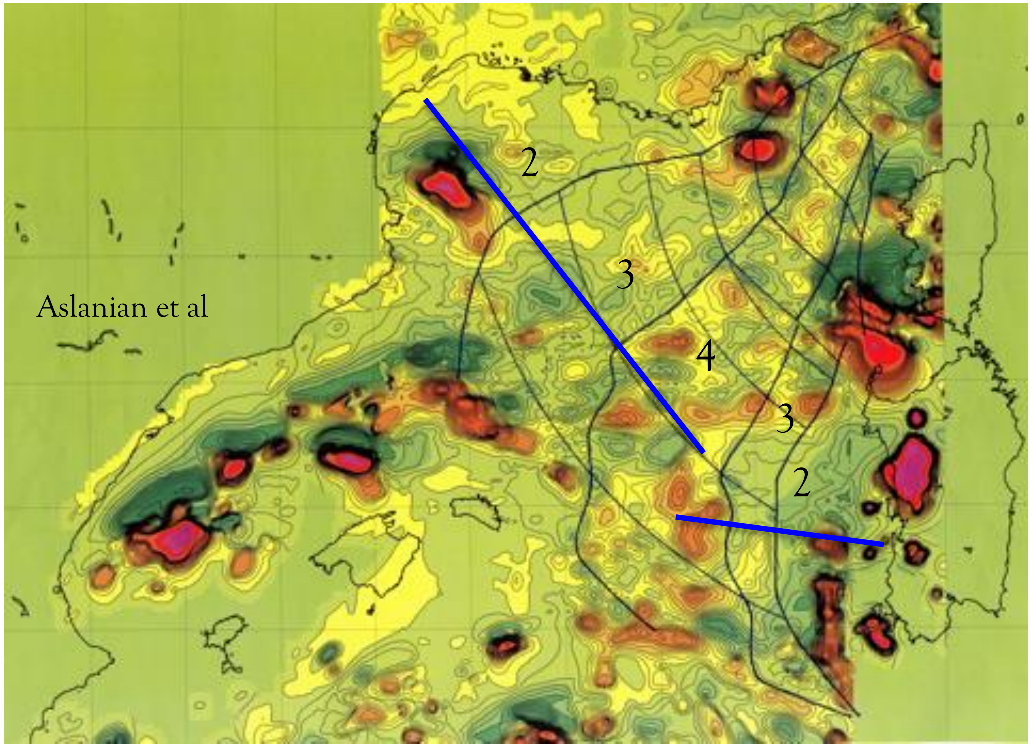


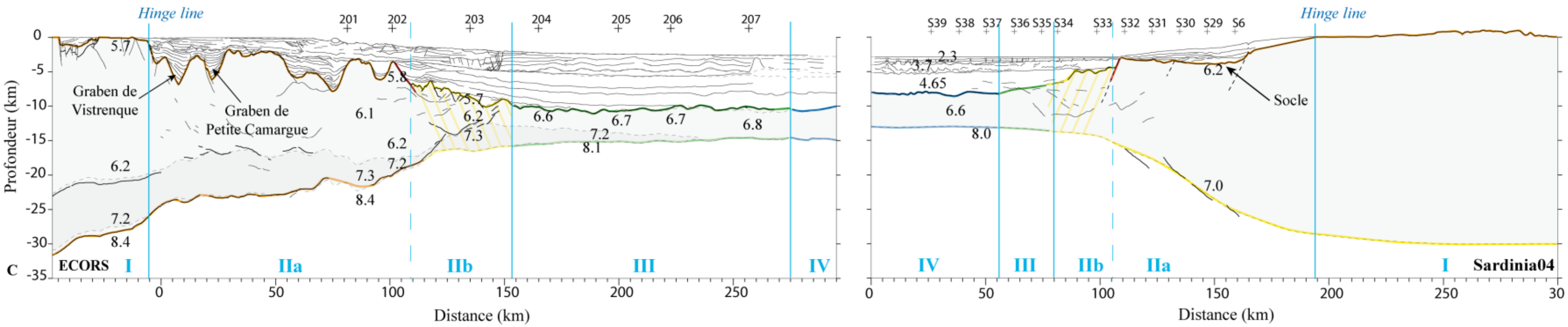


Moulin et al., 2015

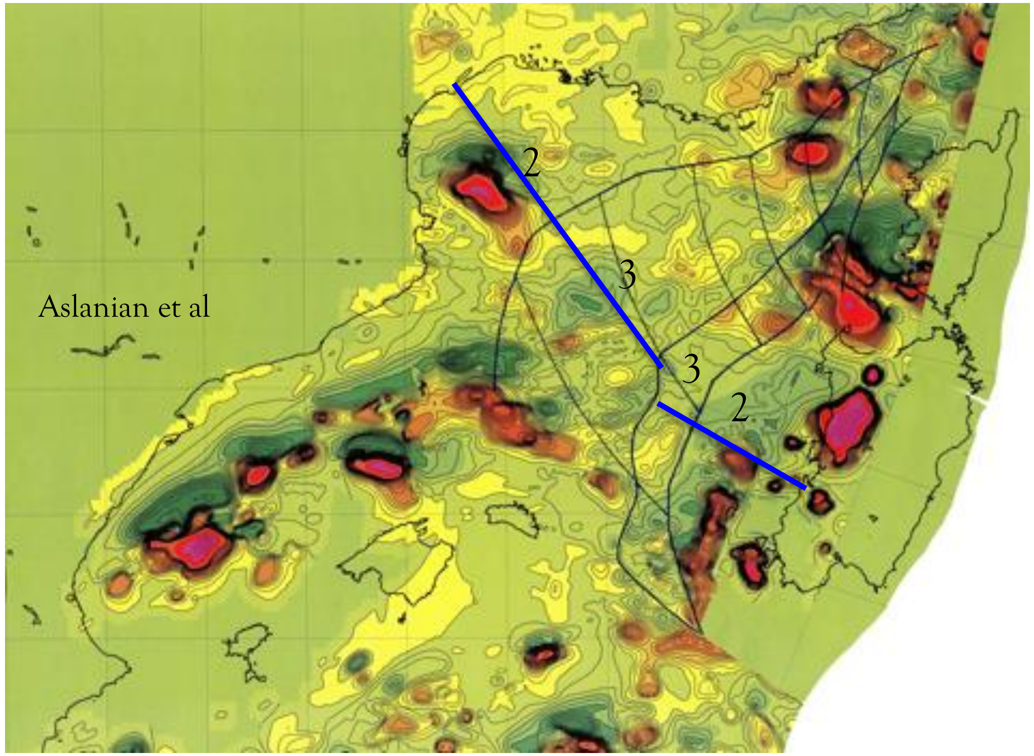


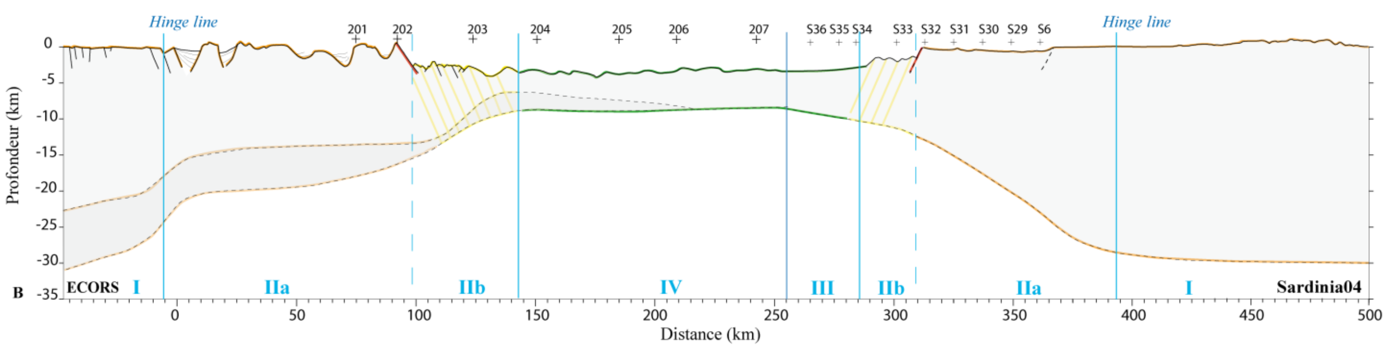
CURRENT STAGE, POST-RIFT



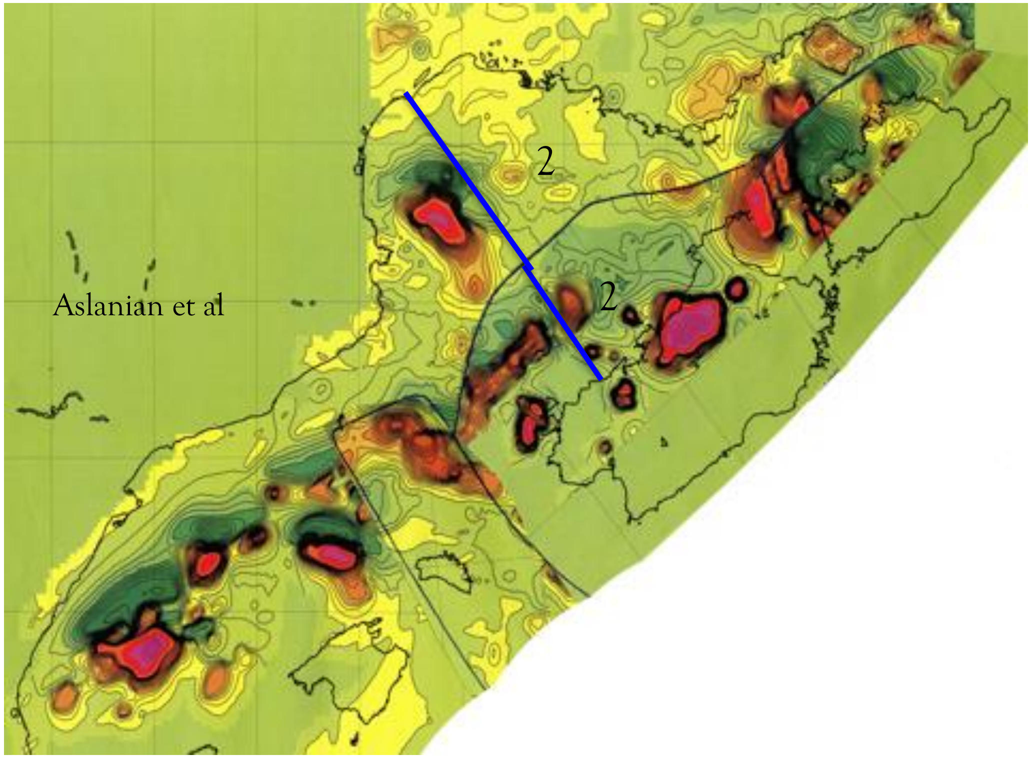


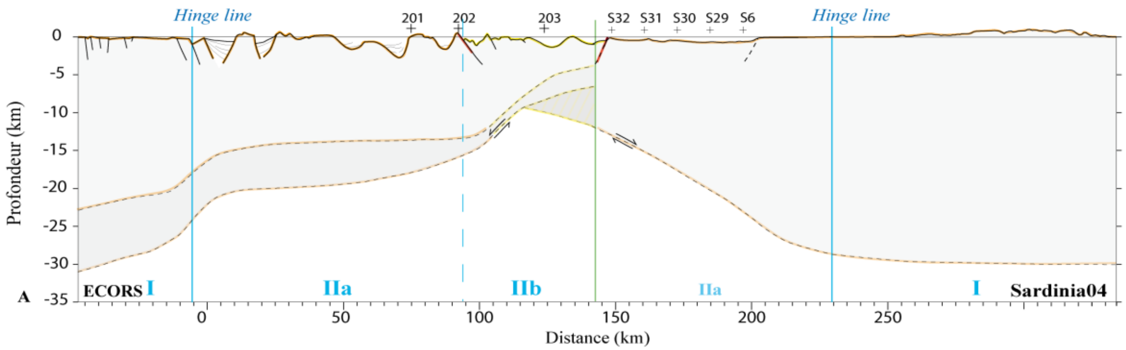
CURRENT STAGE, POST-RIFT





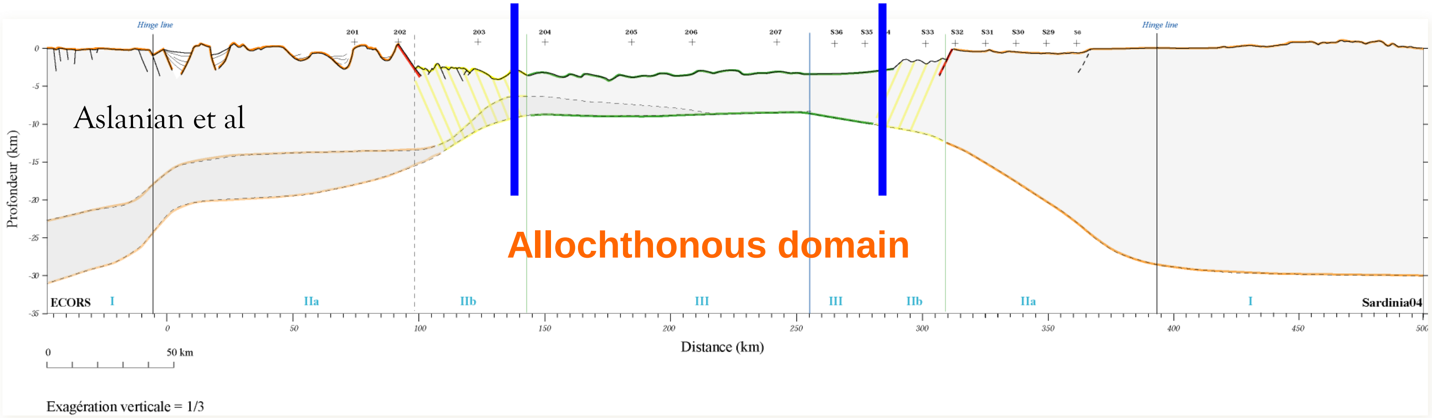
INTERMEDIATE STAGE , JUST BEFORE FIRST SEAFLOOR SPREADING



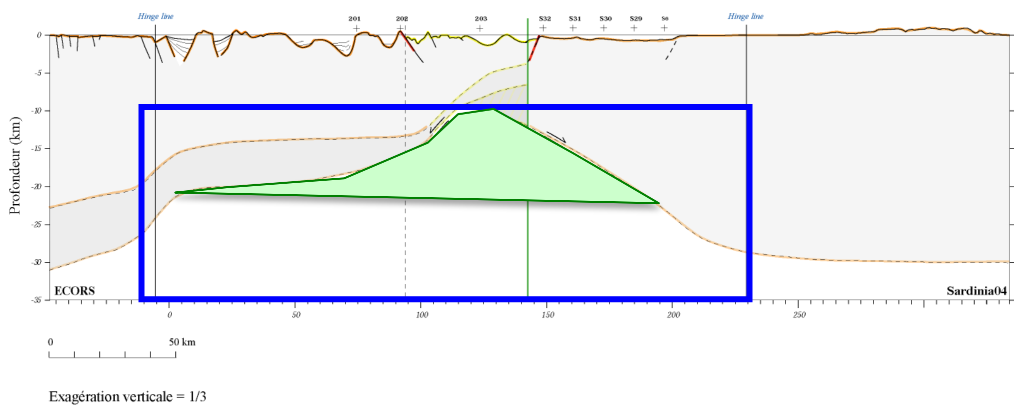


INITIAL STAGE BEFORE RIFTING

THINNING PRINCIPALLY MAINLY CONCERNS THE LOWER CRUST



Ajustment of the 2 quiet magnetic zones just before the opening of the central magnetic crust

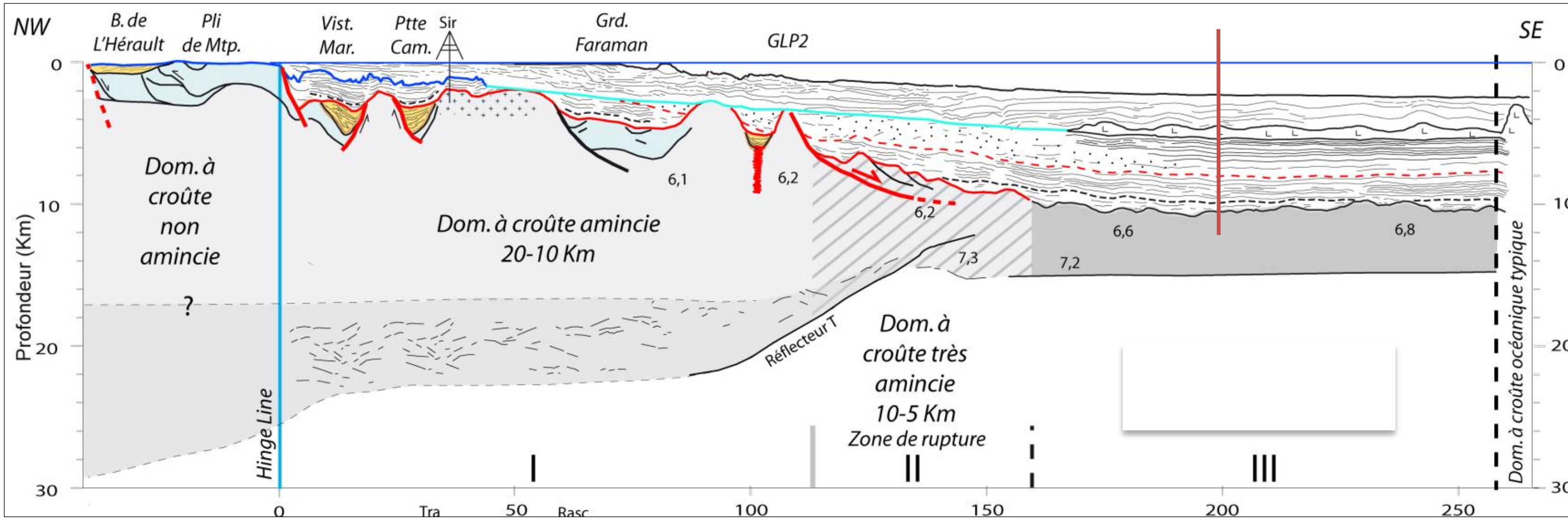


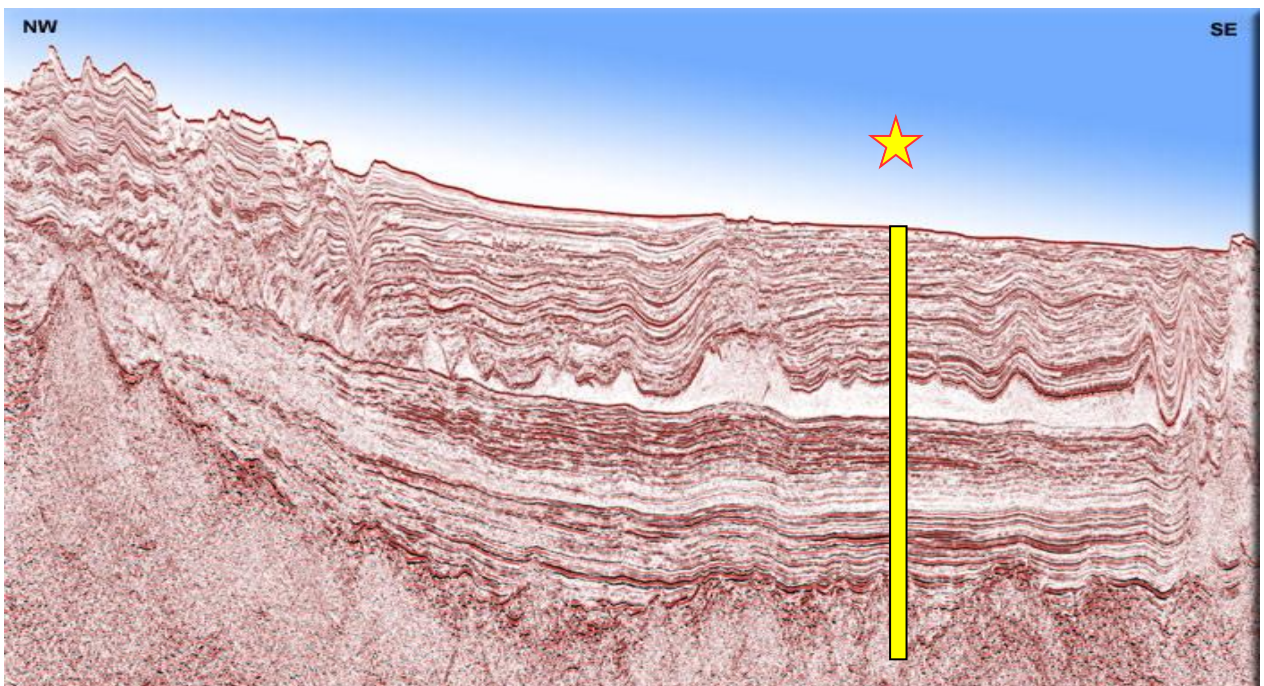
Ajustement at the tightest paleo-reconstruction

Missing piece of the Jigsaw

ULTRA DEEP DRILLING: THE GOLD PROJECT

GOLD

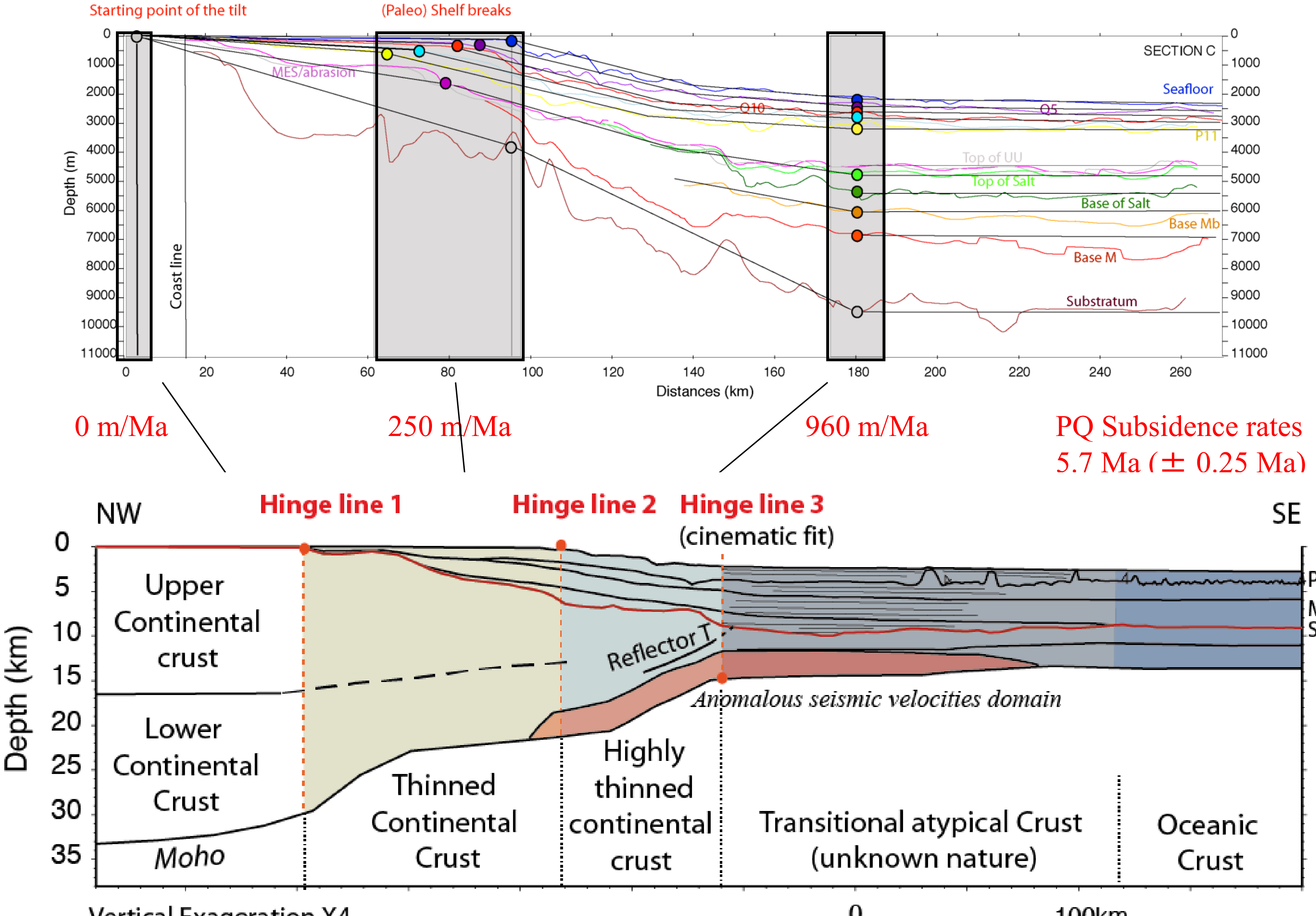




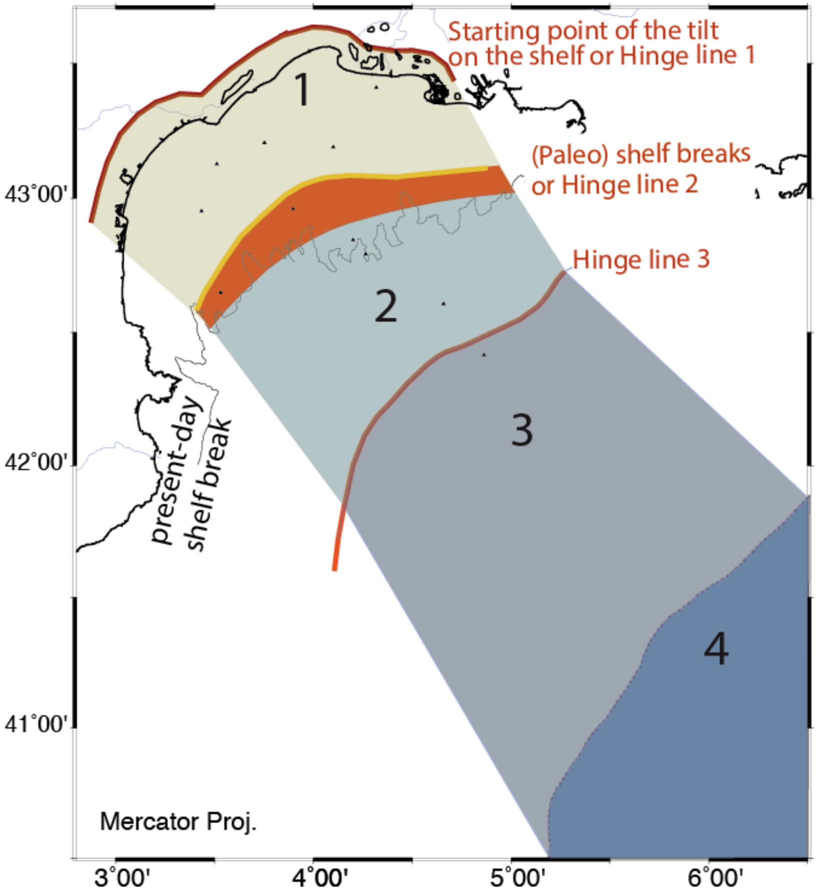
INDUSTRY
CONSORTIUM

Marina.rabineau@univ-brest.fr

MUD T O MANTLE CONNEXION



Leroux *et al.*, 2015



Correlation between the subsidence domains of the last 5 Ma sedimentation and the underlying crustal domains

Domains 1 and 2 (with continental crust more or less thinned) **are tilted**

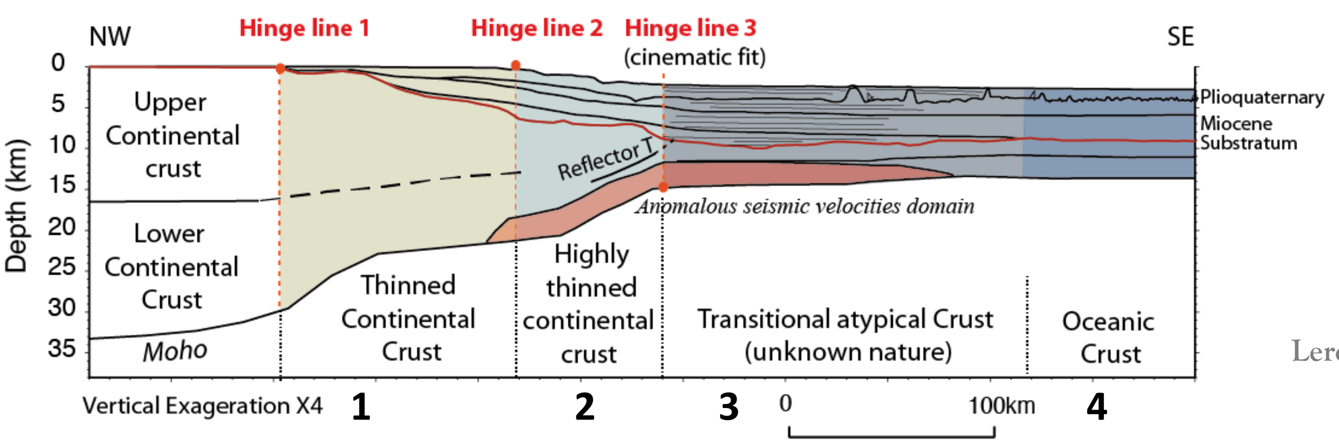
whereas

Domain 3 (transitional crust) **subsided purely vertically**

- Domain 1= Tilt on the shelf
- Domain 2 = Varying subsidence on the slope
- Domain 3 = Purely vertical subsidence
- Domain 4 = Oceanic crust

Domain 1

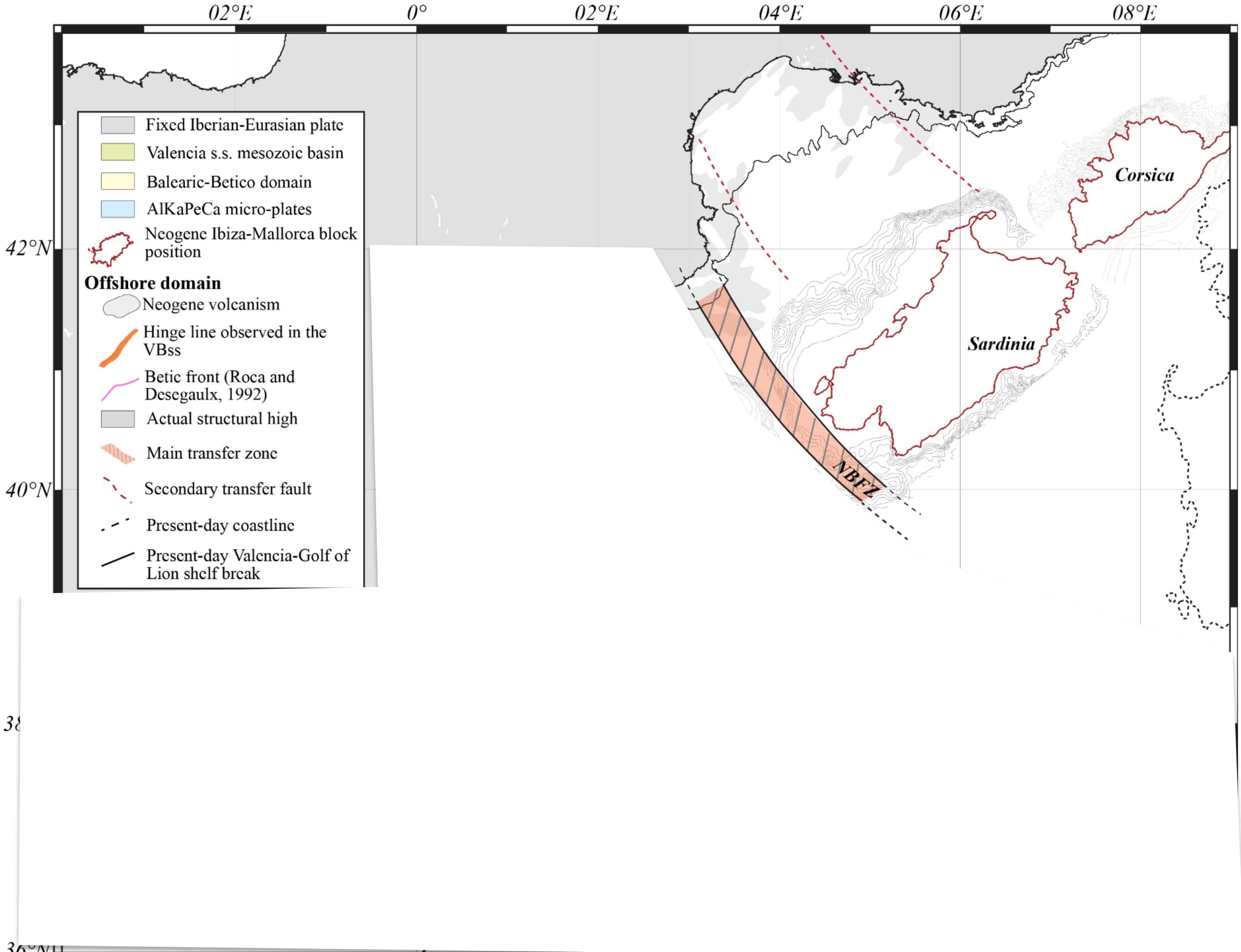
- Plio-Pleistocene tilting rate = 0,16° /Ma from hinge line 1
- Mean post-rift subsidence tilting rate = 0,06° /Ma (East) à 0,11° /Ma (West)



Leroux et al., 2015 (Terra Nova)

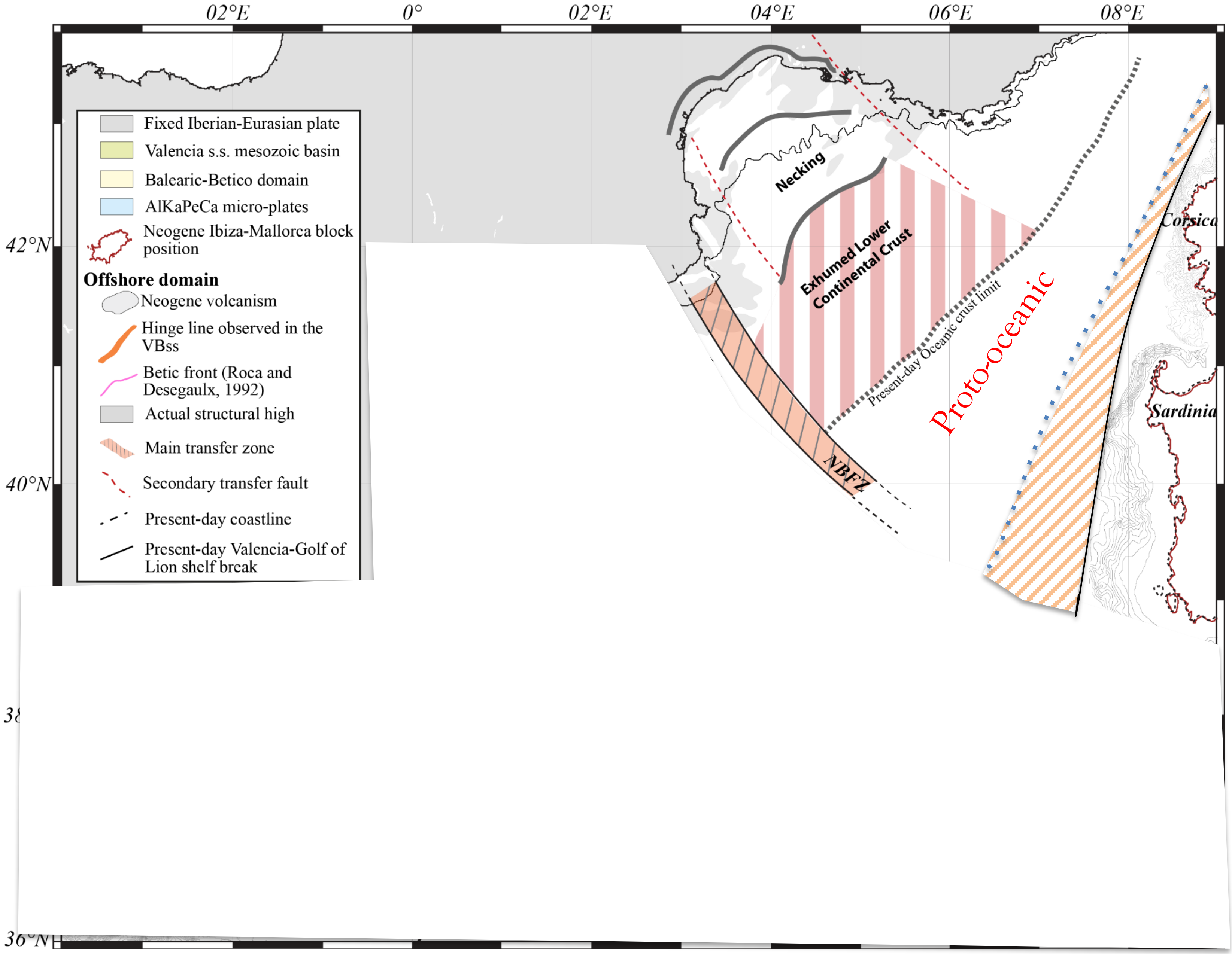
Geodynamic of the Gulf of Lion and crustal natures

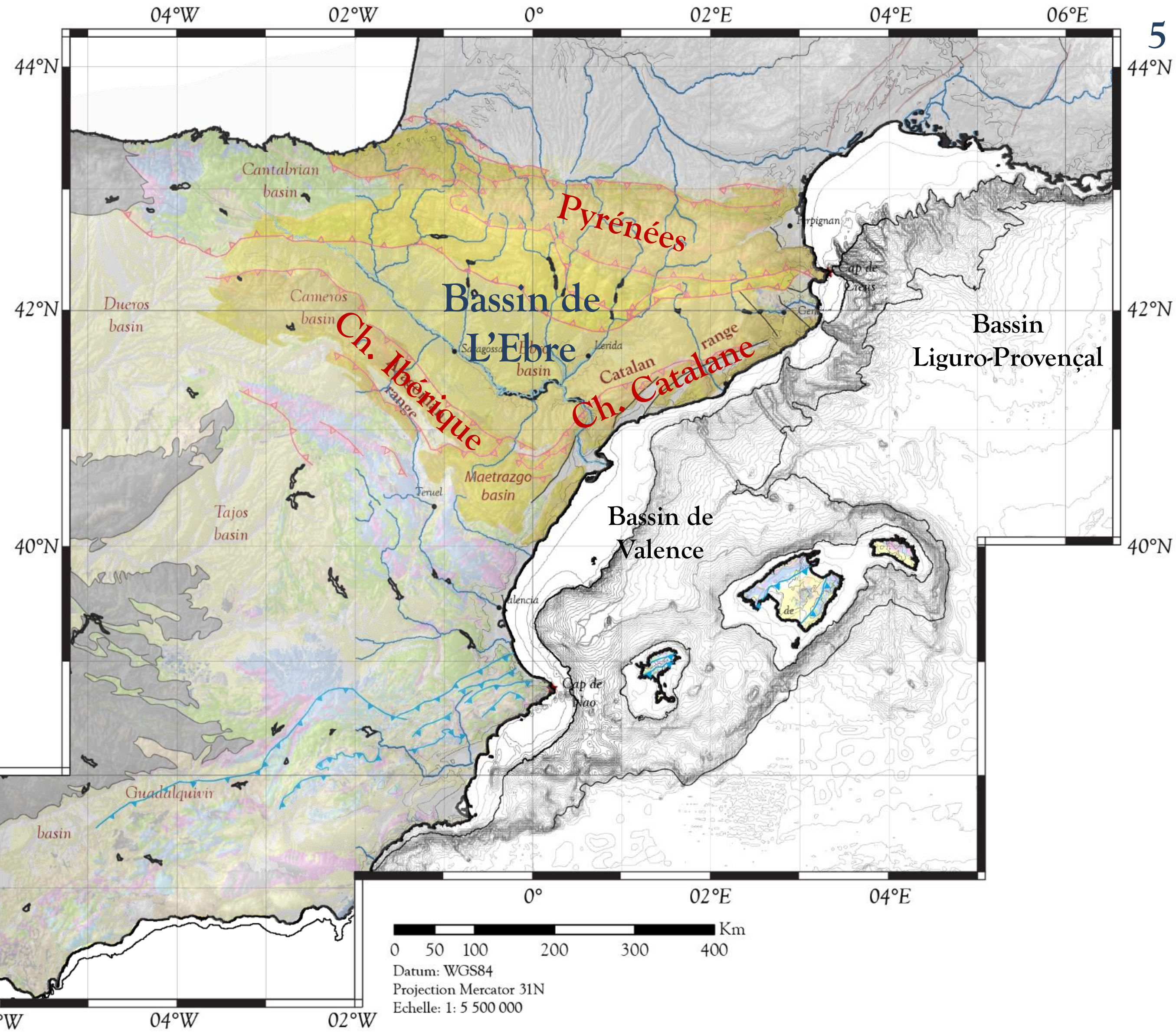
Fit



Geodynamic of the Gulf of Lion and crustal natures

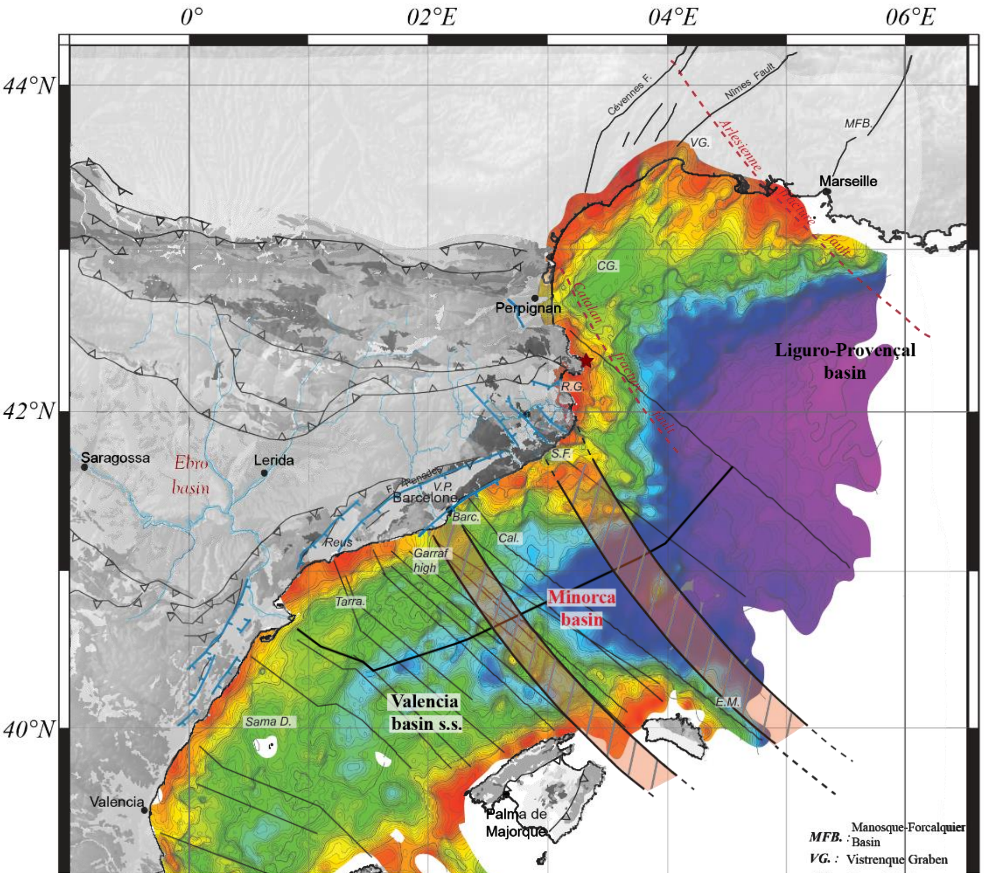
Actual time

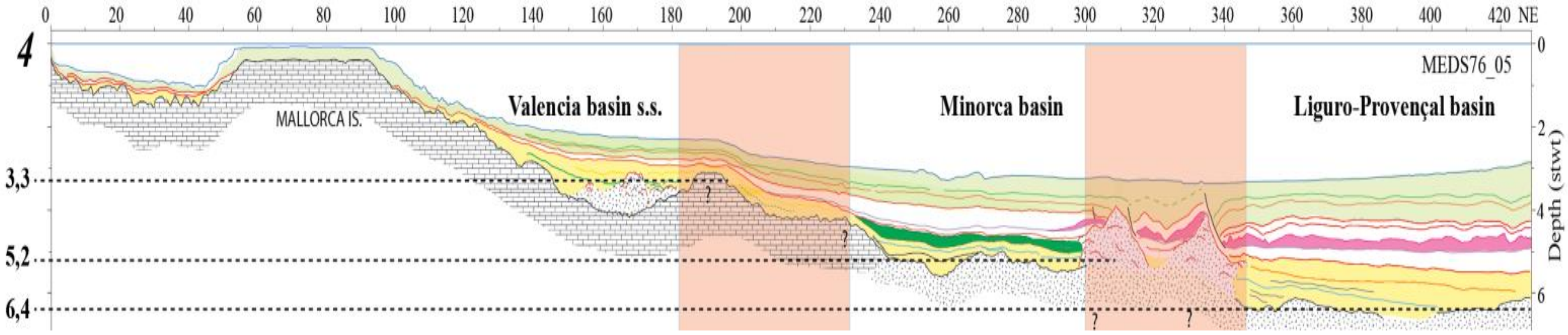




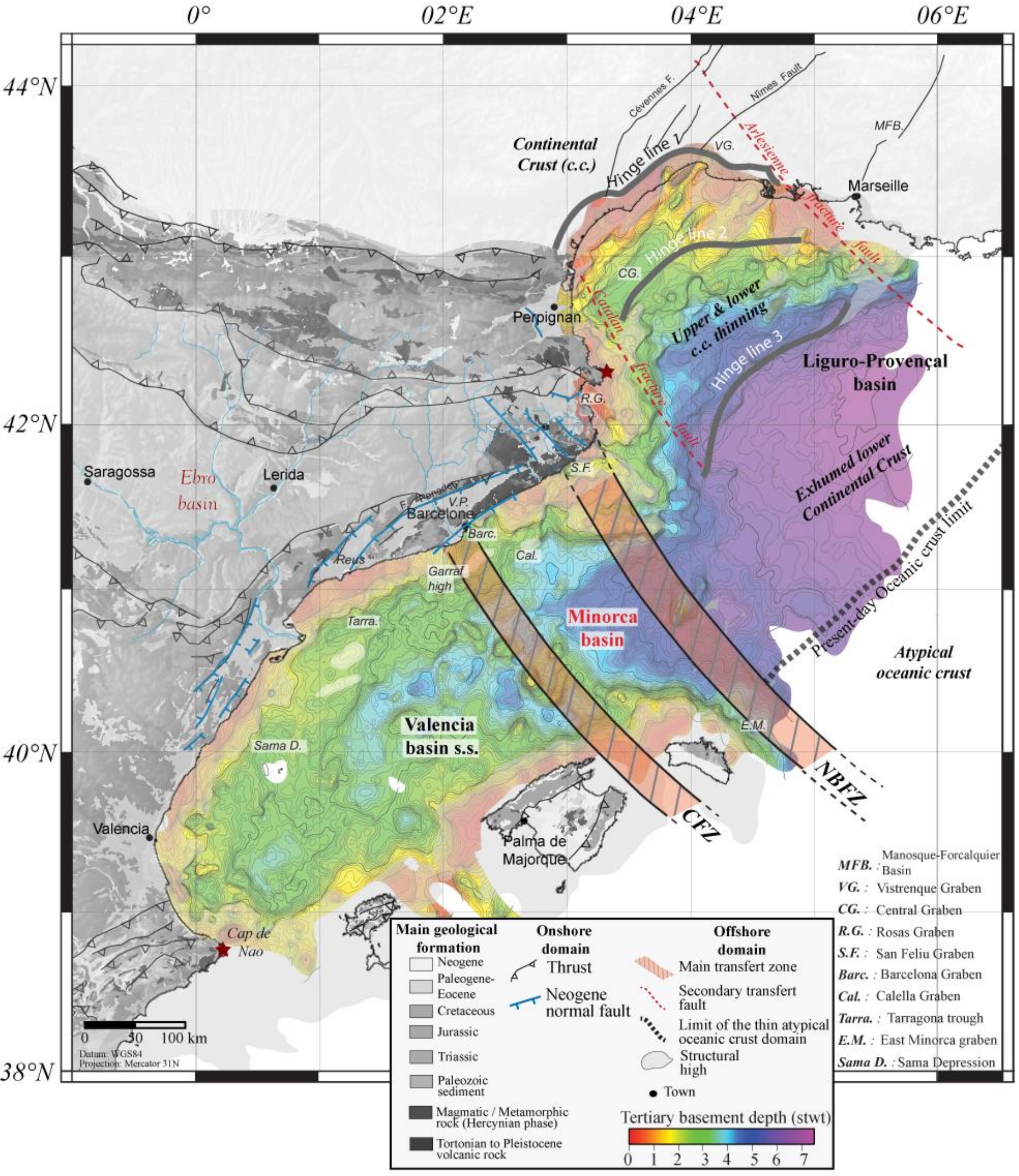
04°W
02°W
0°
02°E
04°E
06°E
44°N
42°N
40°N
Cantabrian basin
Pyrénées
Perpignan
Cap de Creus
Duero basin
Cameros basin
Bassin de L'Ebre
Ebro basin
Ch. Ibérique
Iberian range
Saragossa
Lerida
Catalan range
Ch. Catalane
Bassin Liguro-Provençal
Maestrazgo basin
Teruel
Tajos basin
Bassin de Valence
Valencia
Cap de Nao
Guadalquivir basin
Km
0 50 100 200 300 400
Datum: WGS84
Projection Mercator 31N
Echelle: 1: 5 500 000

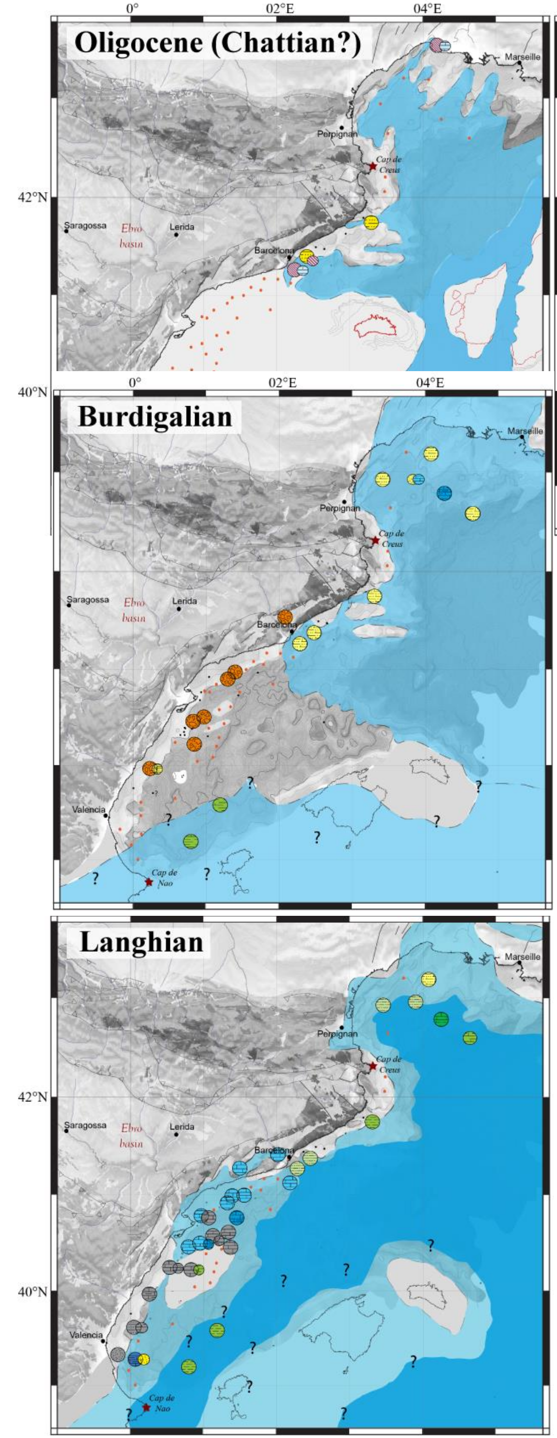
Segmentation of the Valencia Basin : the specificity of Minorca basin



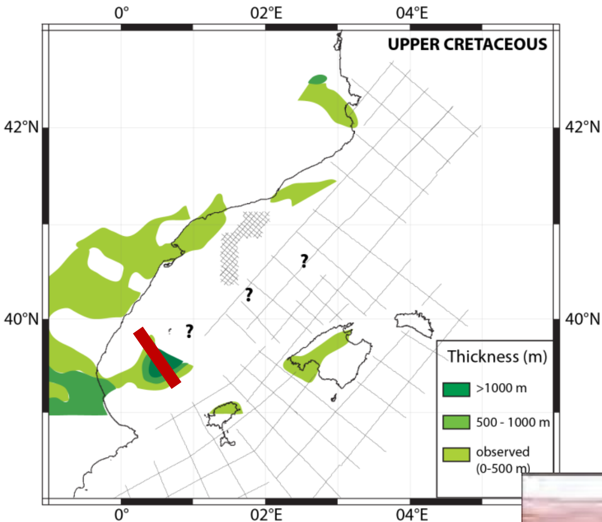


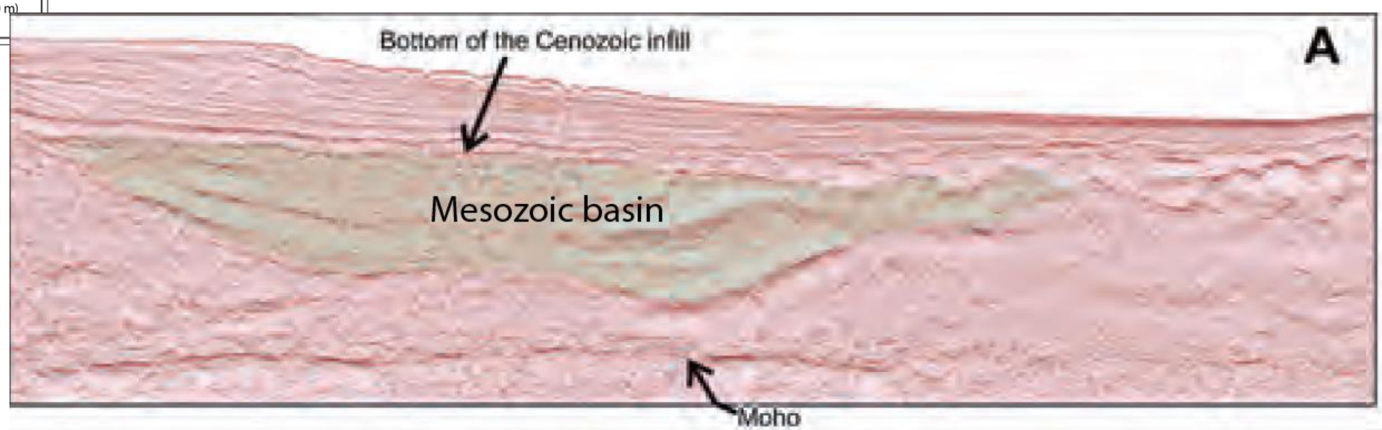
Segmentation of the Valencia Basin : Marine Water through time

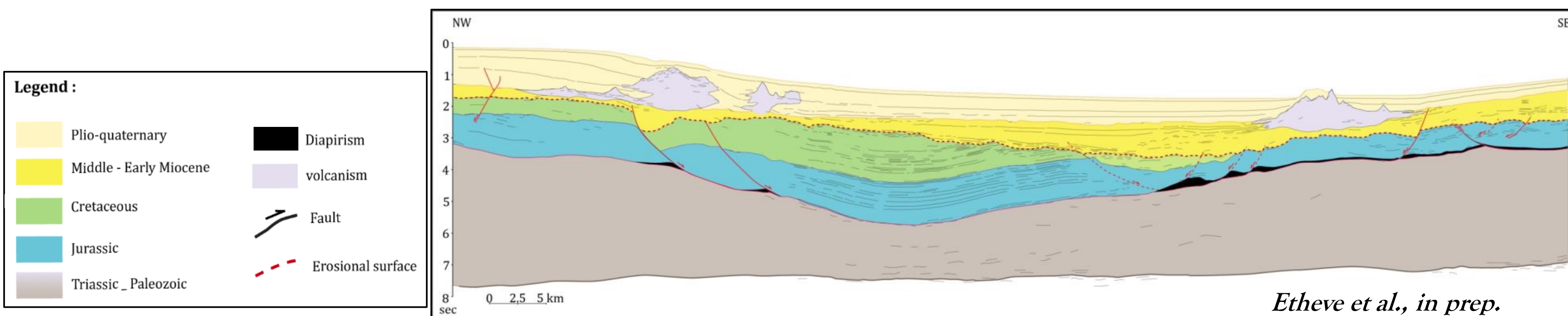




Segmentation of the Valencia Basin : the Valencia Basin sensu stricto : a Mesozoic Basin

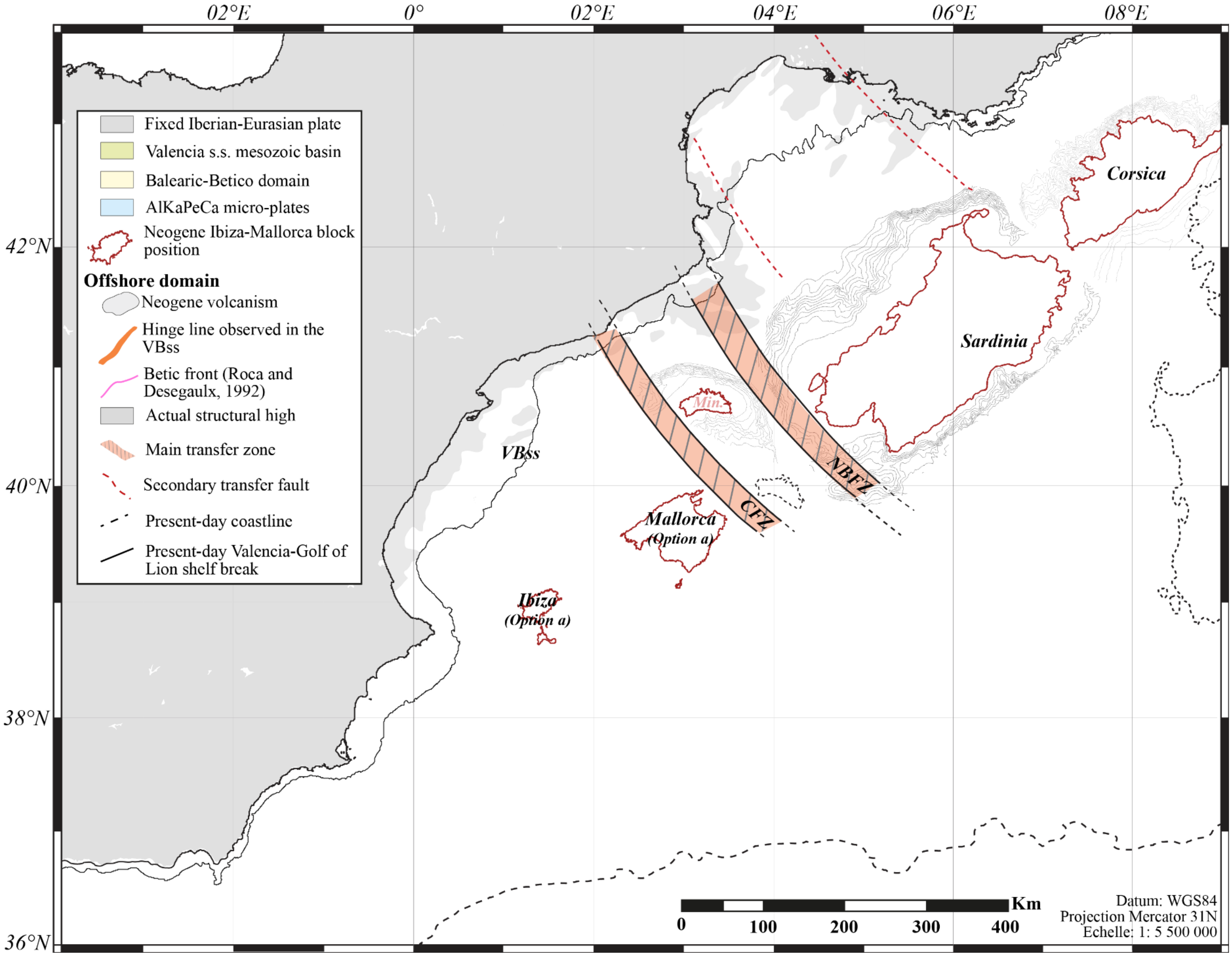






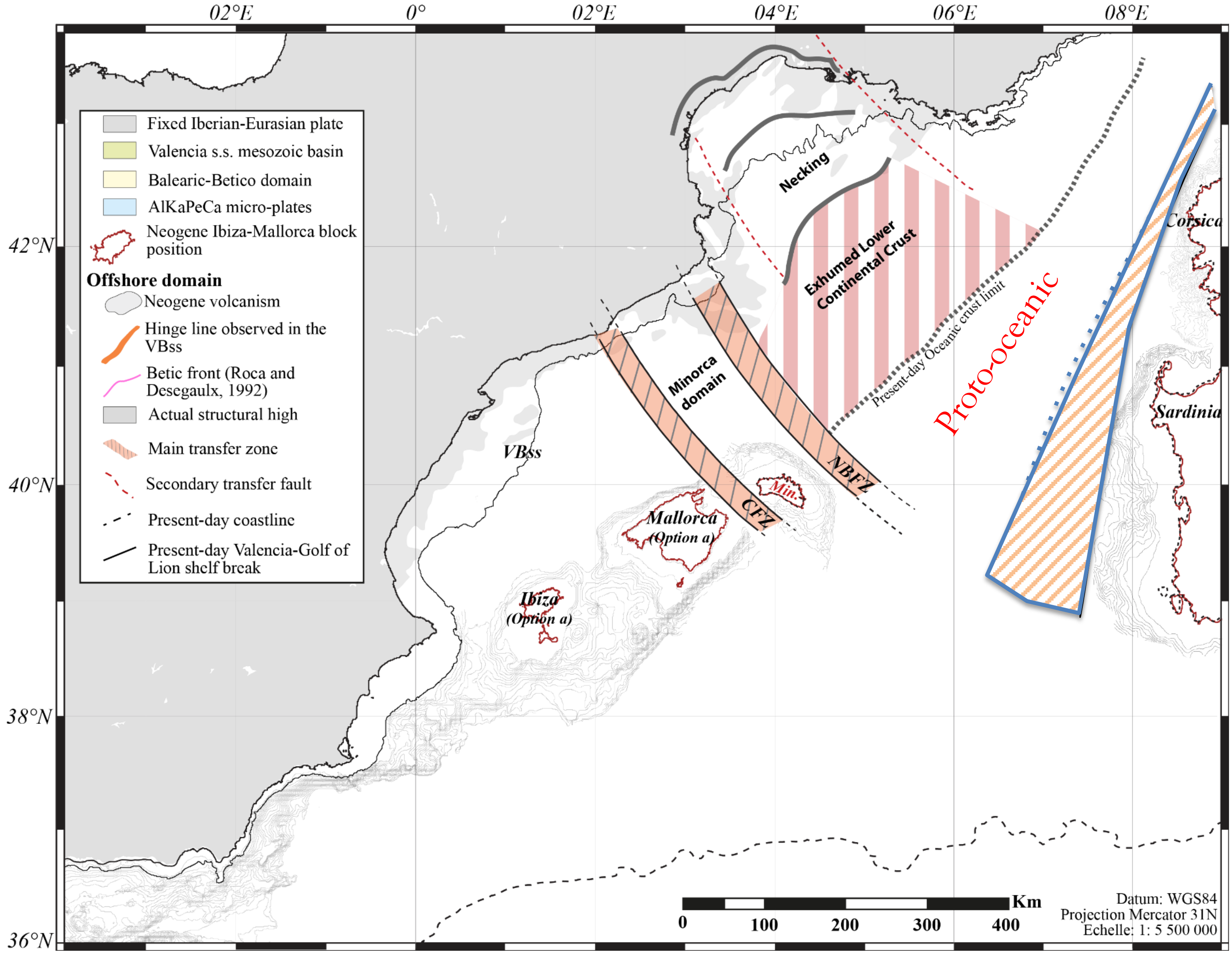
Etheve et al., in prep.

Geodynamic of the North West Mediterranean Sea and crustal natures

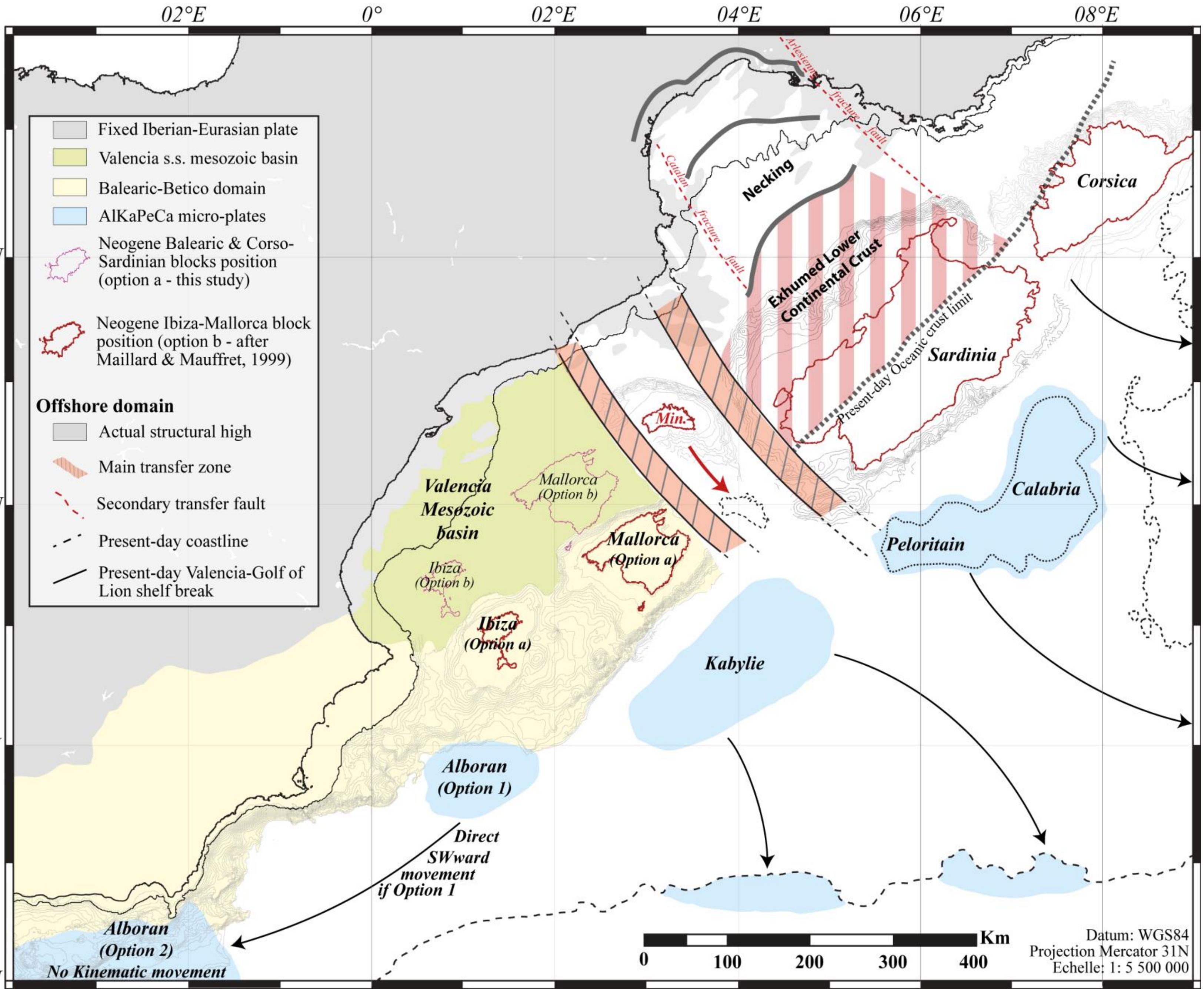


Geodynamic of the Gulf of Lion and crustal natures

Actual time

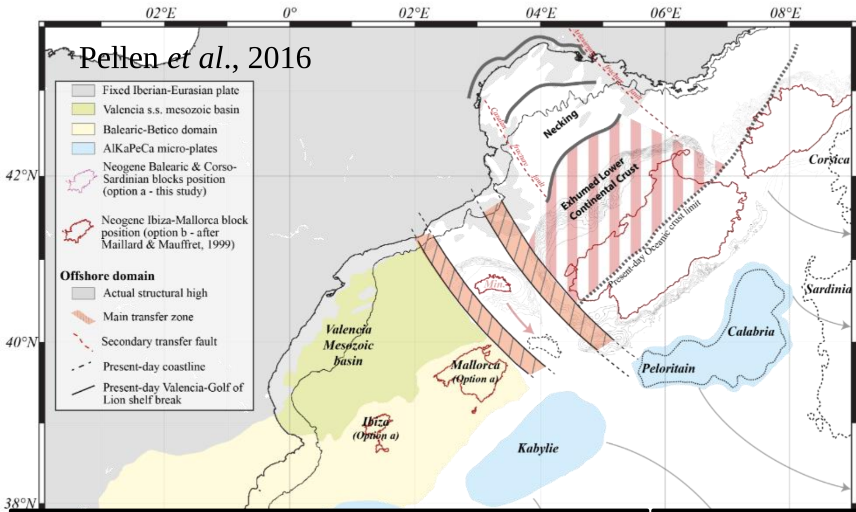


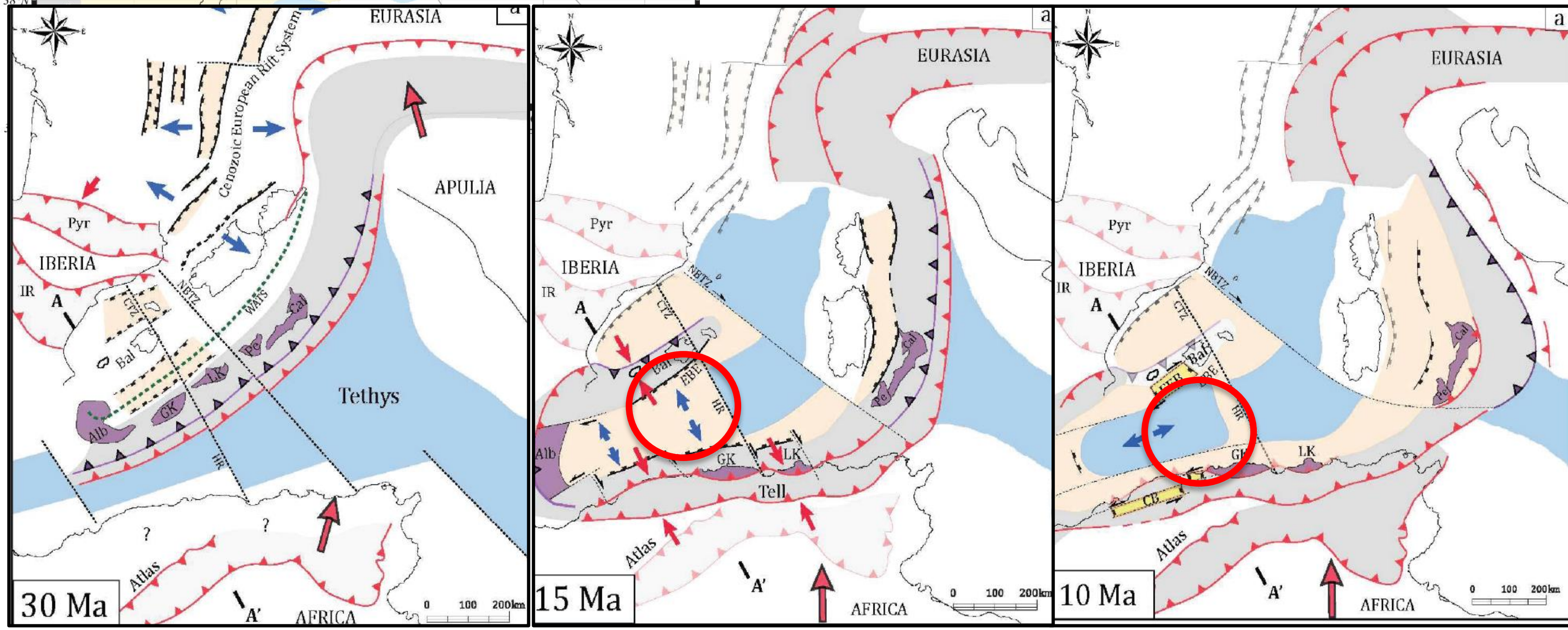
Geodynamic of the North West Mediterranean Sea : Position of the ALKAPECA blocs



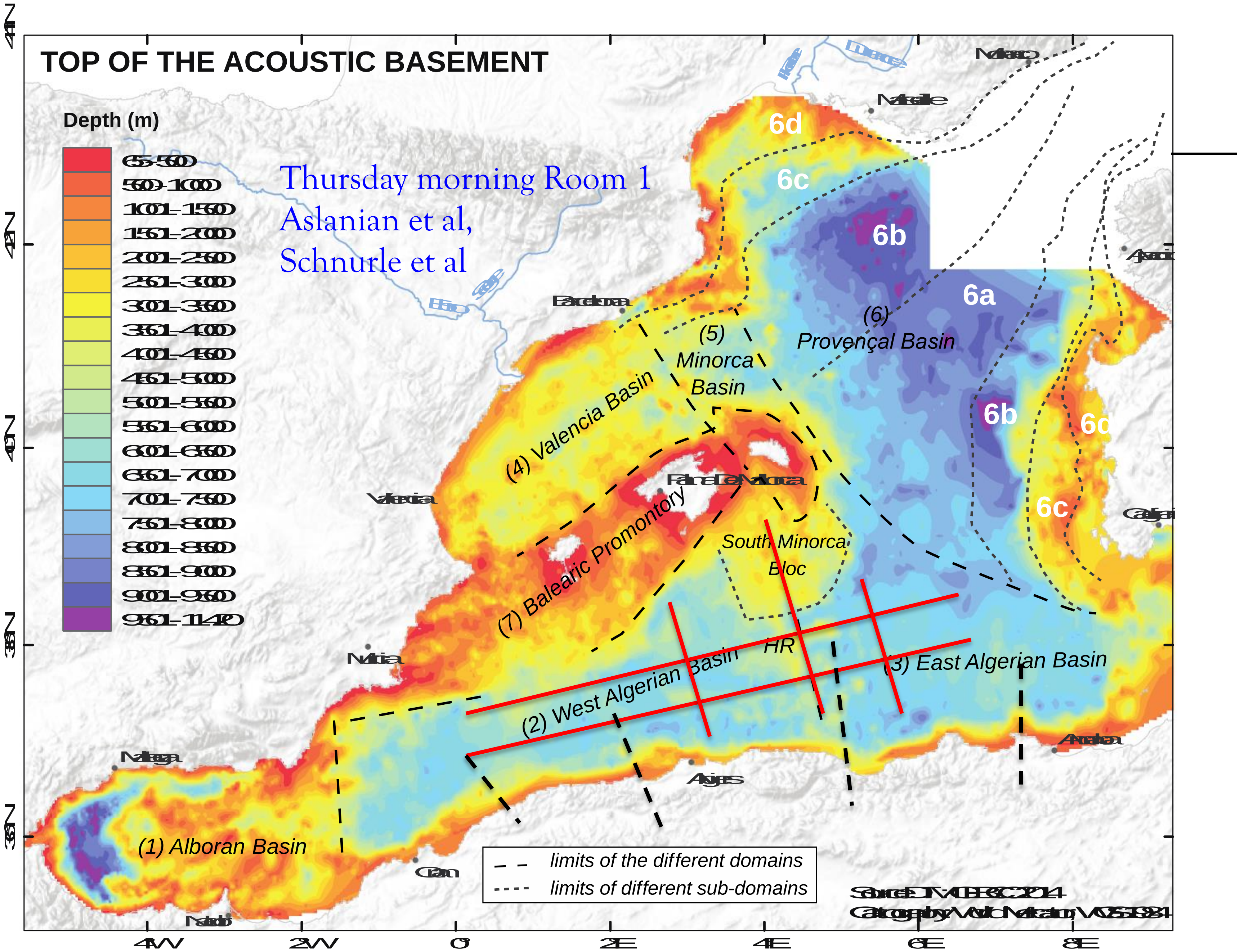
Pellen *et al.*,

Geodynamic of the North West Mediterranean Sea : Position of the ALKAPECA blocs





Etheve *et al.*, 2016



TOP OF THE ACOUSTIC BASEMENT
Depth (m)
Thursday morning Room 1
Aslanian et al,
Schnurle et al
6d
6c
6b
6a
(6)
Provençal Basin
(5)
Minorca
Basin
(4) Valencia Basin
(7) Balearic Promontory
South Minorca
Bloc
HR
(2) West Algerian Basin
(3) East Algerian Basin
(1) Alboran Basin
limits of the different domains
limits of different sub-domains