Università di Trieste
LAUREA MAGISTRALE IN GEOSCIENZE
Curriculum Geofisico
Curriculum Geologico Ambientale

Anno accademico 2021 – 2022

Geologia Marina

Modulo 5.2 **Mediterraneo 2 (Alboran, Balearico e Ionio) Part 2**

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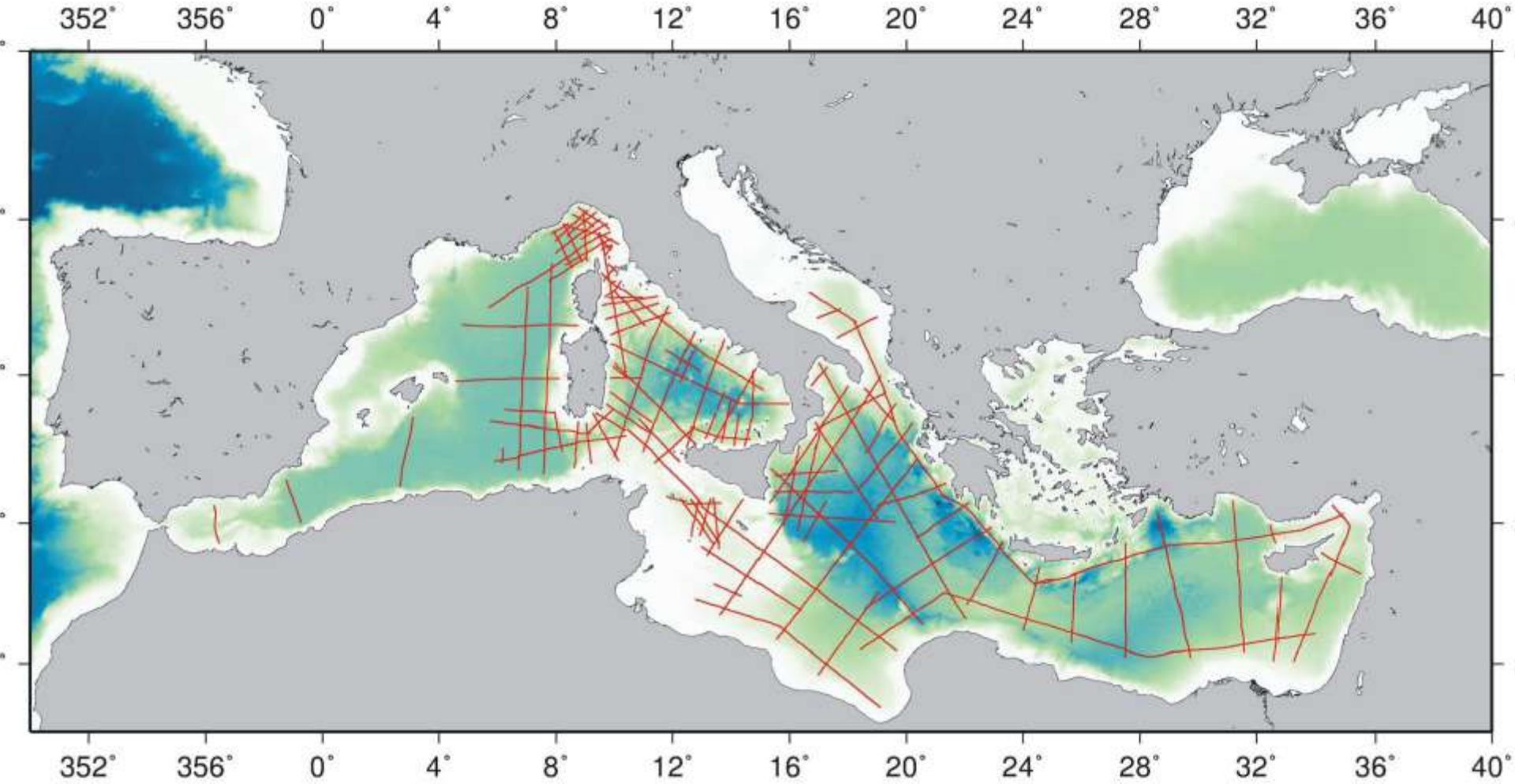
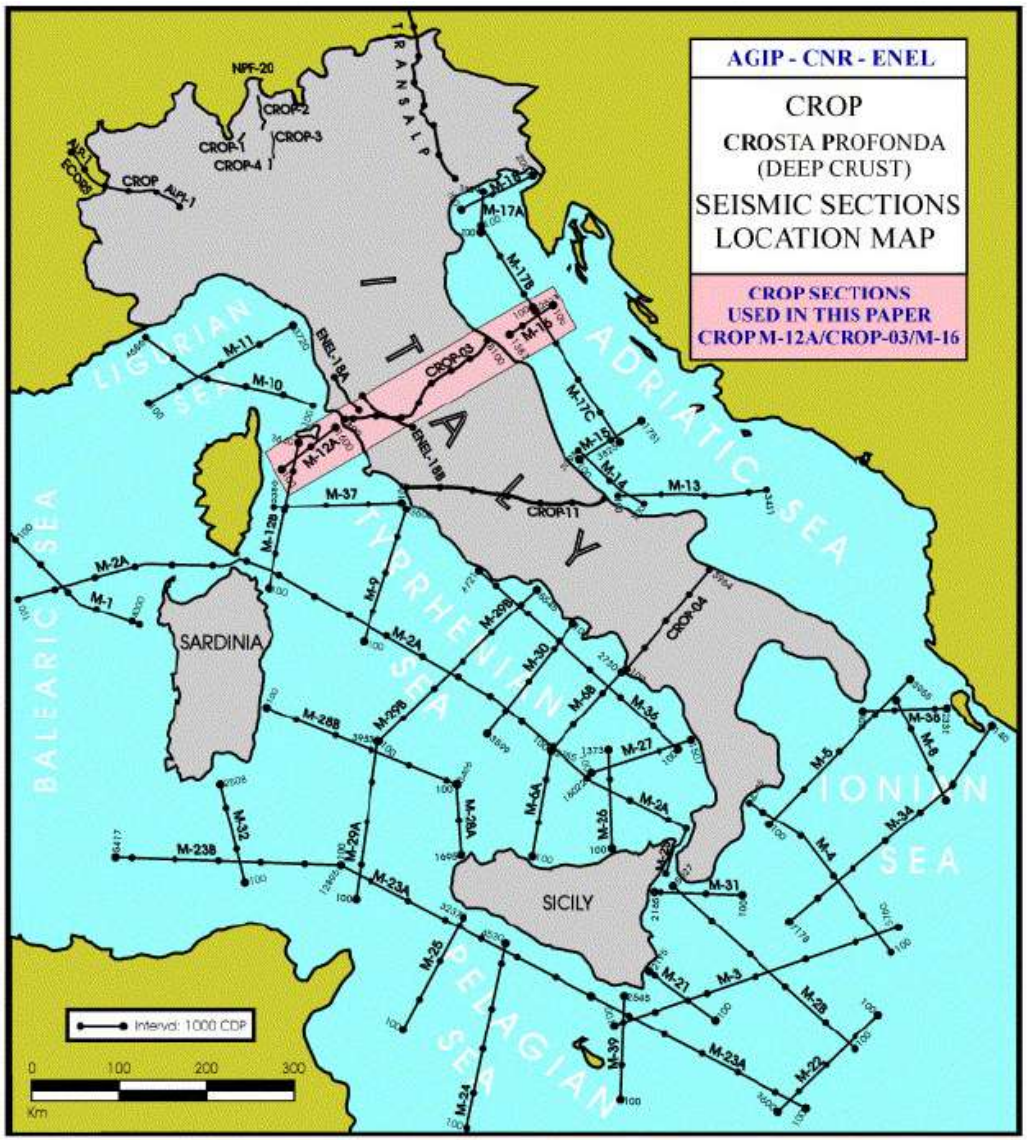
MS map

(seismic profiles collected from 1968 to 1982)

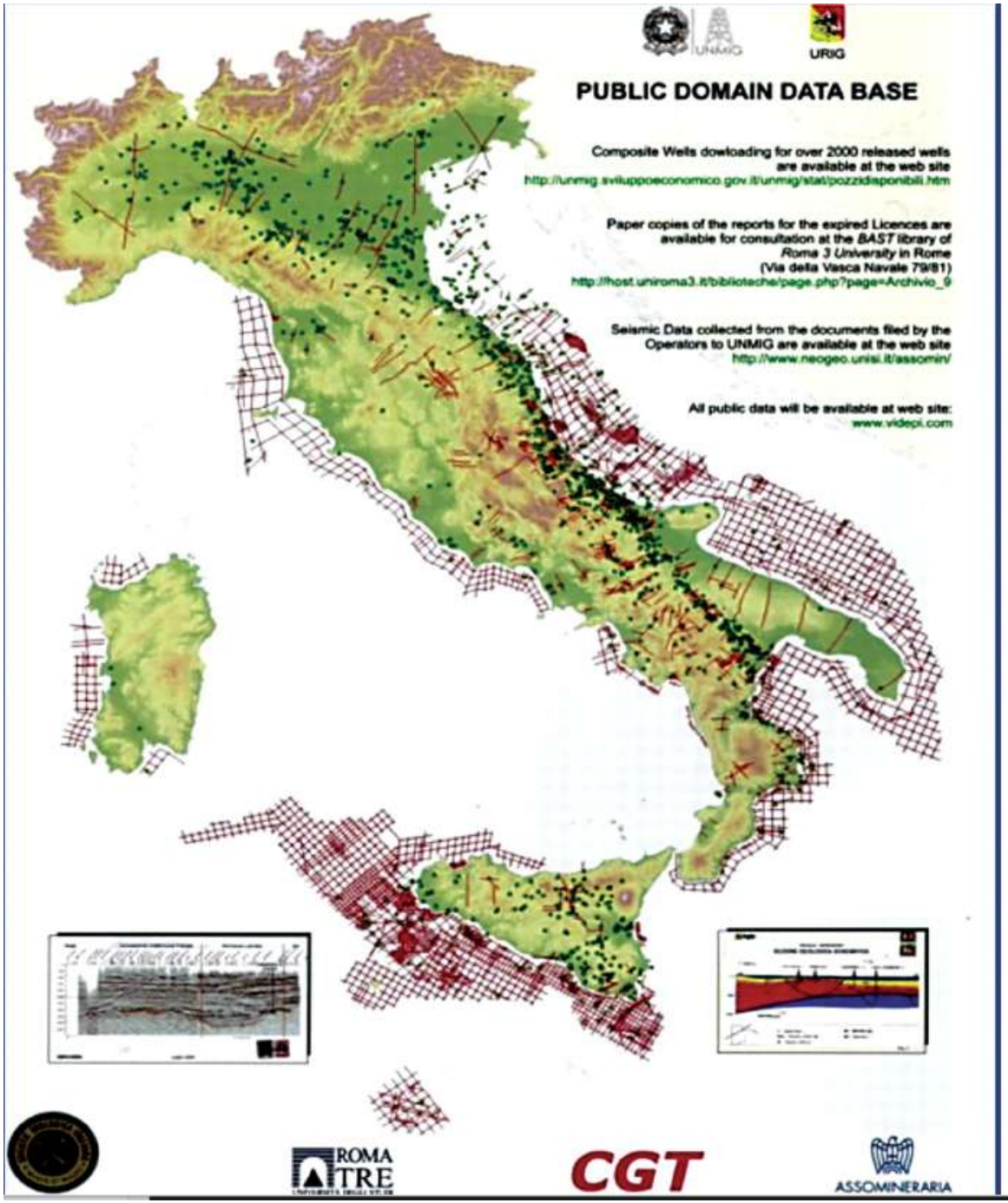




FRENCH (ECORS) - ITALIAN (CROP) COOPERATION -WESTERN ALPS (ALP-1/ALPI-1) -BALEARIC SEA (GULF OF LYON/SARDINIA, M-1)	**GERMAN (DEKORP) - AUSTRIAN (OEKORP) - - ITALIAN (CROP) COOPERATION** - EASTERN ALPS (TRANSALP)
SWISS (NPF-20) - ITALIAN (CROP) COOPERATION -CENTRAL ALPS (CROP-1, 2, 3 ,4 AND NPF-20 CONTINUATION TO NORTH)	**GREEK - ITALIAN (CROP) COOPERATION** - NE IONIAN SEA (EAST - EXTREMITIES OF M-34 & M-38)

CROP map

(Seismic profiles collected both onshore and offshore)



ViDEPI

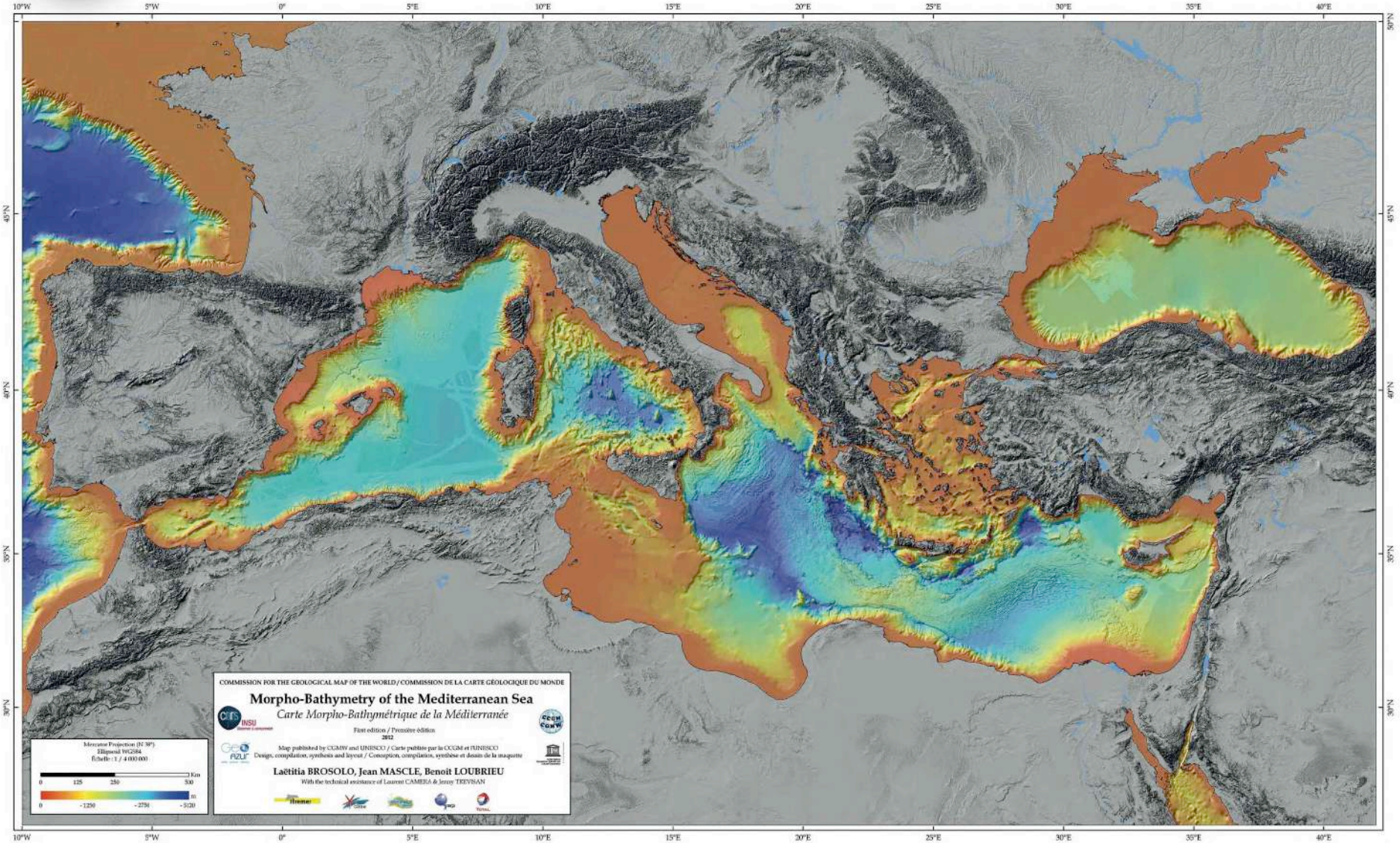
Visibilità dei dati afferenti all'attività di esplorazione petrolifera in Italia

http://unmig.sviluppoeconomico.gov.it/videpi/

OGS

, Italy

CCGM Morpho-Bathymetry of the Mediterranean sea



Légende

La cartographie systématique par bathymétrie multifaisceaux du bassin méditerranéen et de ses marges continentales, initiée dès le milieu des années 1990, a profondément modifié notre connaissance de la morphologie de la Mer Méditerranée ainsi que des différents processus géologiques actifs (sédimentaires, tectoniques, volcaniques, bio-géo-chimiques) qui contribuent au modelé du fond de mer.

Legend

The systematic swath bathymetric mapping of the Mediterranean Sea started in the mid nineties. This mapping has considerably modified our understanding of the morphology of the Mediterranean Sea and of the various active geological processes (sedimentary, tectonic, volcanic, bio-geochemical processes) which participate to the seafloor morphology.

Origine des données

Cette carte a été construite à partir de différents modèles numériques de terrain:

- Le MNT de base, à 500m, provient d'une compilation morpho-bathymétrique de la Méditerranée publiée par Loubrieu, B., Mascle,J. and Medimap group,(2005). « Morpho-bathymetry of the Mediterranean Sea », CIESM/IFREMER special publication.
Ce document se focalise sur la mise en commun de données bathymétriques multifaisceaux académiques acquises entre 1995 et 2007 par de nombreux instituts et laboratoires de recherches (http://www.ciesm.org/)
- Ce MNT a été complété par quelques données de bathymétrie multifaisceaux inédites provenant de l'IFREMER, du SHOM, de GEOAZUR, de l'OGS Trieste, de l'EMAR Bologne, du CMCR de l'Université de Hamburg ainsi, qu'au large de l'Egypte, par quelques données provenant de premières années de stratégie 3D d'origine industrielle (dont BP-Egypt, ENI, CMV). Quelques données complémentaires ont été extraites du site Web du programme européen EMODNET (www.emodnet-hydrography.eu/)
- Pour le golfe de Cadix la carte se fonde sur un MNT, également à 500m, provenant d'une compilation de diverses données de bathymétrie multifaisceaux publiée par Zitellini, N., Gracia, E., et al., (2009). « Bathymetry of the Gulf of Cadiz, North-East Atlantic: the Swim Multibeam compilation ». Earth and Planetary Sciences Letters, 280 15-50.doi: 10.1016/j.epsl.2008.12.005.
- Pour le Golfe de Gascogne un MNT à 1000m, extrait de Sibuet, J.C., Louërrier, B. , & al. (2004) « Carte bathymétrique de l'Atlantique nord-est et du Golfe de Gascogne : implications cinématiques », Bull. Soc. Géol. Fr., a été utilisé.
- En Mer noire les données de bathymétrie multifaisceaux proviennent du programme européen ASSEMBLAGE.
- Pour les domaines non encore cartographiés par bathymétrie multifaisceaux en Méditerranée (ou dont les données ne sont pas disponibles), et la Mer Noire, la carte a été complétée par un MNT à 1500 m provenant de l'atlas digital GEBCO (General

Data source

This map results from the compilation of the following DTMs and complementary data:

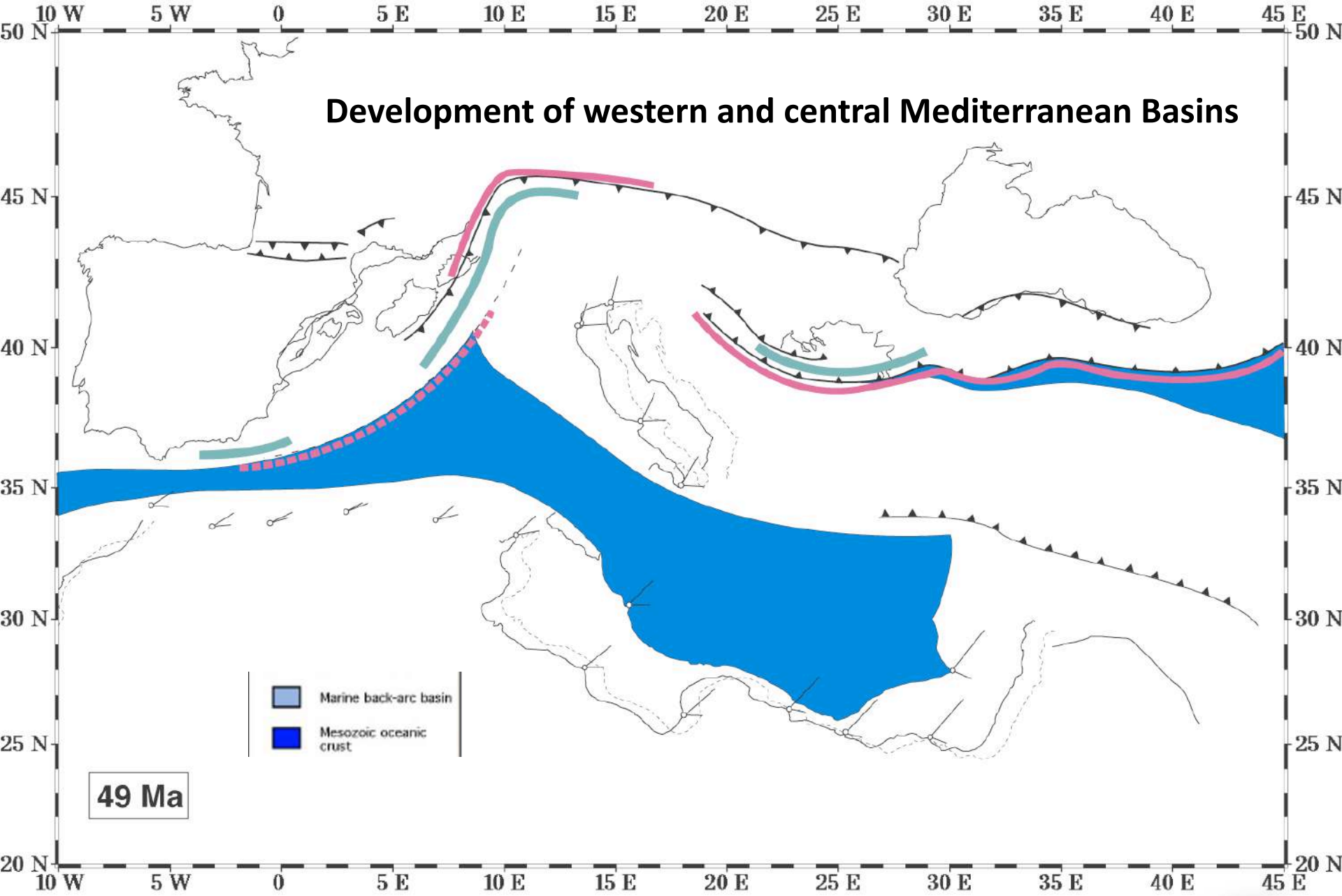
- The basic DTM is the one used for the Morpho-bathymetric compilation of the Mediterranean Sea published by Loubrieu,B., Mascle,J. and Medimap group, (2005). « Morpho-bathymetry of the Mediterranean Sea », CIESM/Ifremer special publication.
This compilation resulted from various DTMs from swath bathymetric data sets recorded between 1995-2007 by several European oceanographic laboratories and Institutes (see: http://www.ciesm.org/).
- This DTM has been completed by unpublished swath bathymetry data from IFREMER, SHOM, GEOAZUR, OGS-Trieste, EMAR-Bologna, CMCR- Hamburg and, off Egypt, by a few 3D seismic data first arrivals from Industry (BP-Egypt, ENI, CMV).
A few complementary data have been downloaded from the EMODNET European project portal (www.emodnet-hydrography.eu/).
- For the Gulf of Cadiz the compilation has benefited from a DTM at 500 m from various swath data published by Zitellini, N., Gracia, E., et a., (2009). « Bathymetry of the Gulf of Cadiz, North-East Atlantic: the Swim Multibeam compilation ». Earth and Planetary Sciences Letters, 280 15-50.doi: 10.1016/j.epsl.2008.12.005.
- For the Black Sea, the swath bathymetric data were obtained during the European project ASSEMBLAGE.
- For the Bay of Biscay a DTM at 1000m, from Sibuet, J.C., Louërrier, B. , & al. (2004) « Carte bathymétrique de l'Atlantique nord-est et du Golfe de Gascogne : implications cinématiques », Bull. Soc. Géol. Fr., has been used.
- For areas not yet mapped in details (or whose data are not yet available) in the Mediterranean Sea, and in the Black Sea a DTM, at 1500m, from the GEBCO atlas has been used to complete the map (General Bathymetric Chart of the Oceans.

- The present-day geological configuration of the Mediterranean region is the result of the creation and ensuing consumption of two major oceanic basins: the Paleotethys and the Neotethys.

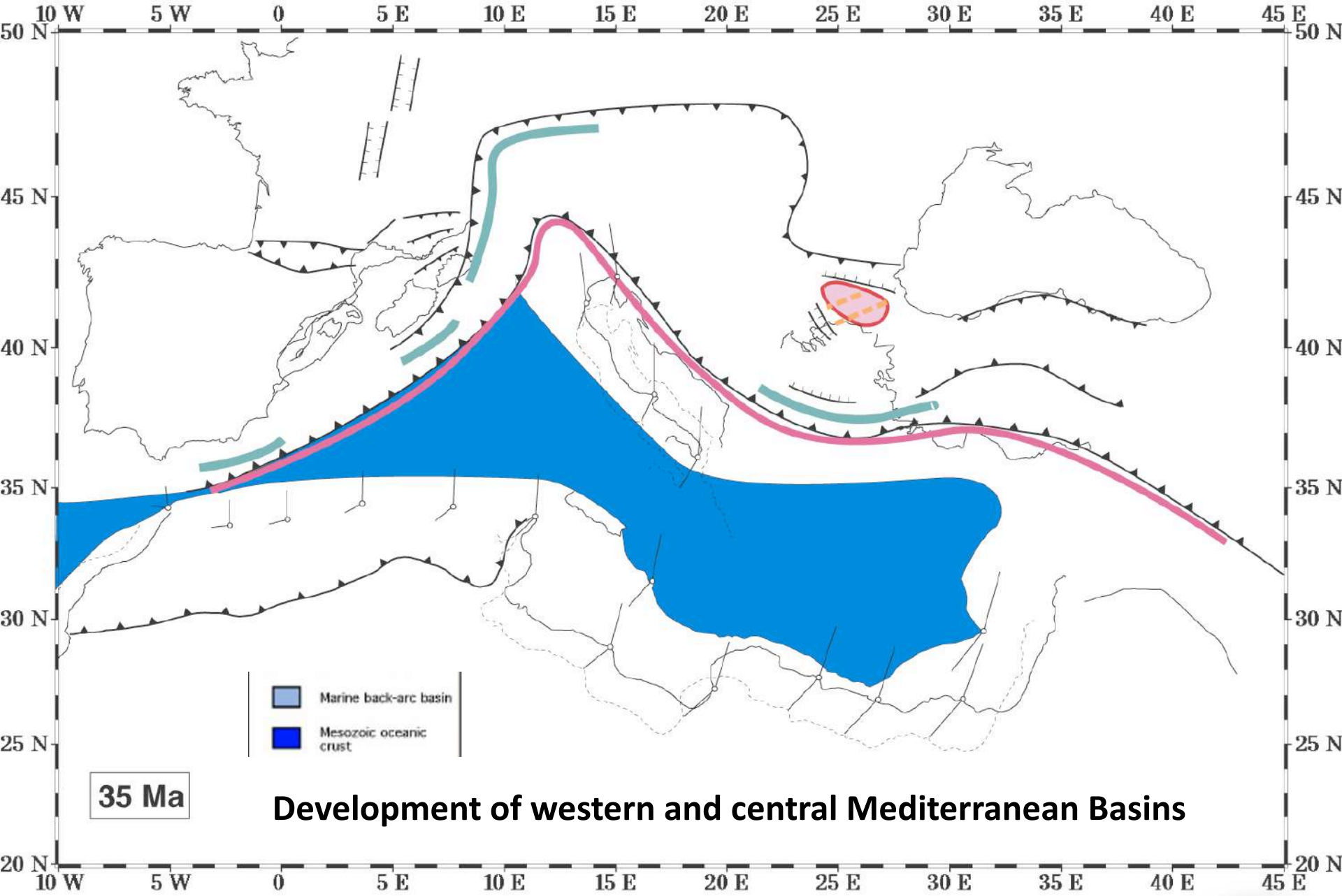
- The overall tectonic regime was (and it is) the regime of prolonged interaction between the Eurasian and the African-Arabian plates.

- The Mediterranean domain provides a present-day geodynamic analog for the final stages of a continent-continent collisional orogeny. Over this area, the oceanic lithospheric domains originally present between the Eurasian and African-Arabian plates have been subducted and partially obducted (ophiolitic terranes), except for the Ionian basin and the south-eastern Mediterranean.

- The modern marine basins of the Mediterranean Sea are variably floored by: (i) remnants of the Tethyan oceanic domains (Ionian, E Mediterranean); (ii) Neogene oceanic crust (Algero-Provençal basin and Tyrrhenian Sea); (iii) extended continental lithosphere (Alboran Sea, Valencia Trough, Aegean Sea), and (iv) thick continental lithosphere (Adriatic Sea).

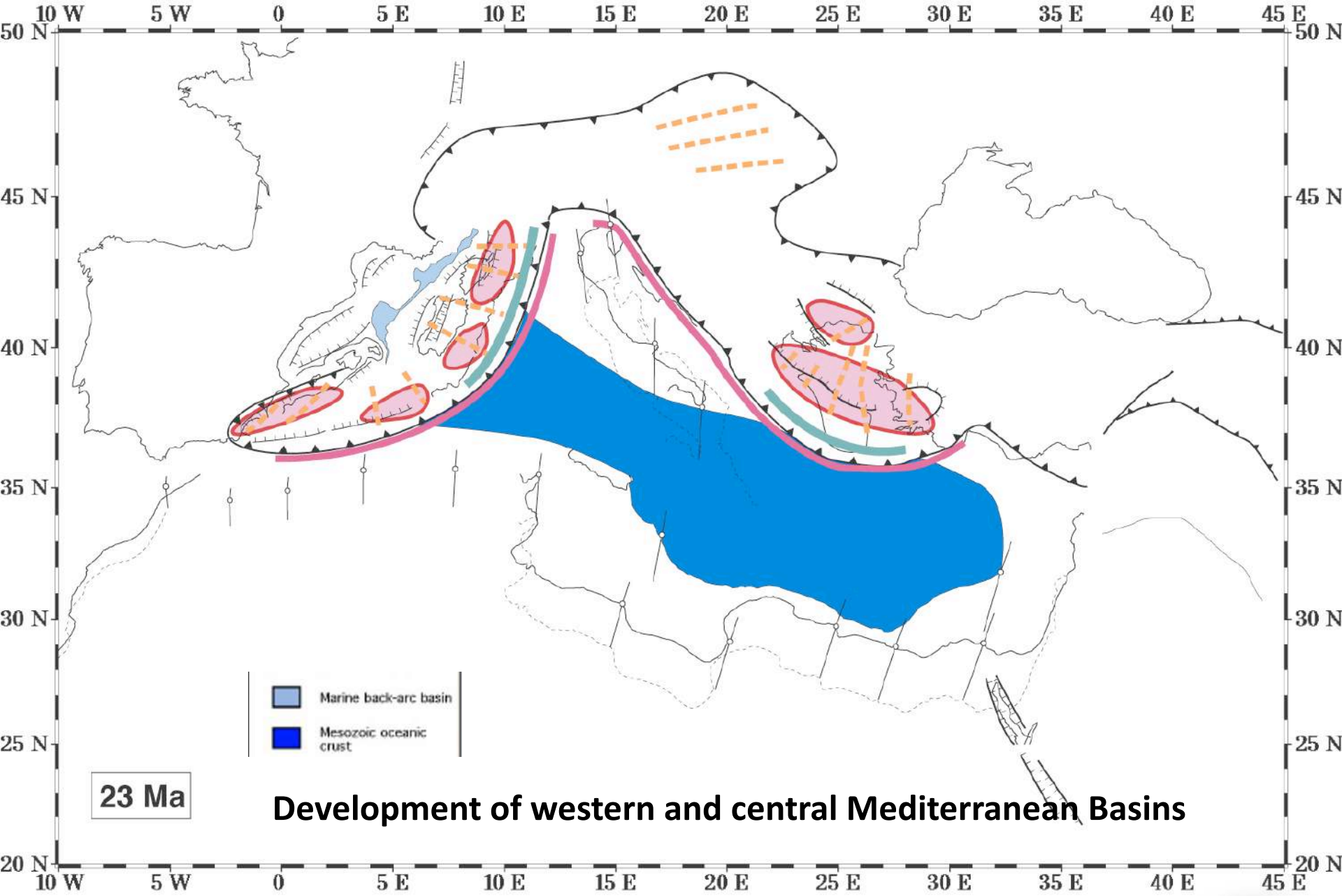


Jolivet et al., 2003., Kinematic data after Dewey et al.



Development of western and central Mediterranean Basins

Jolivet et al., 2003., Kinematic data after Dewey et al.



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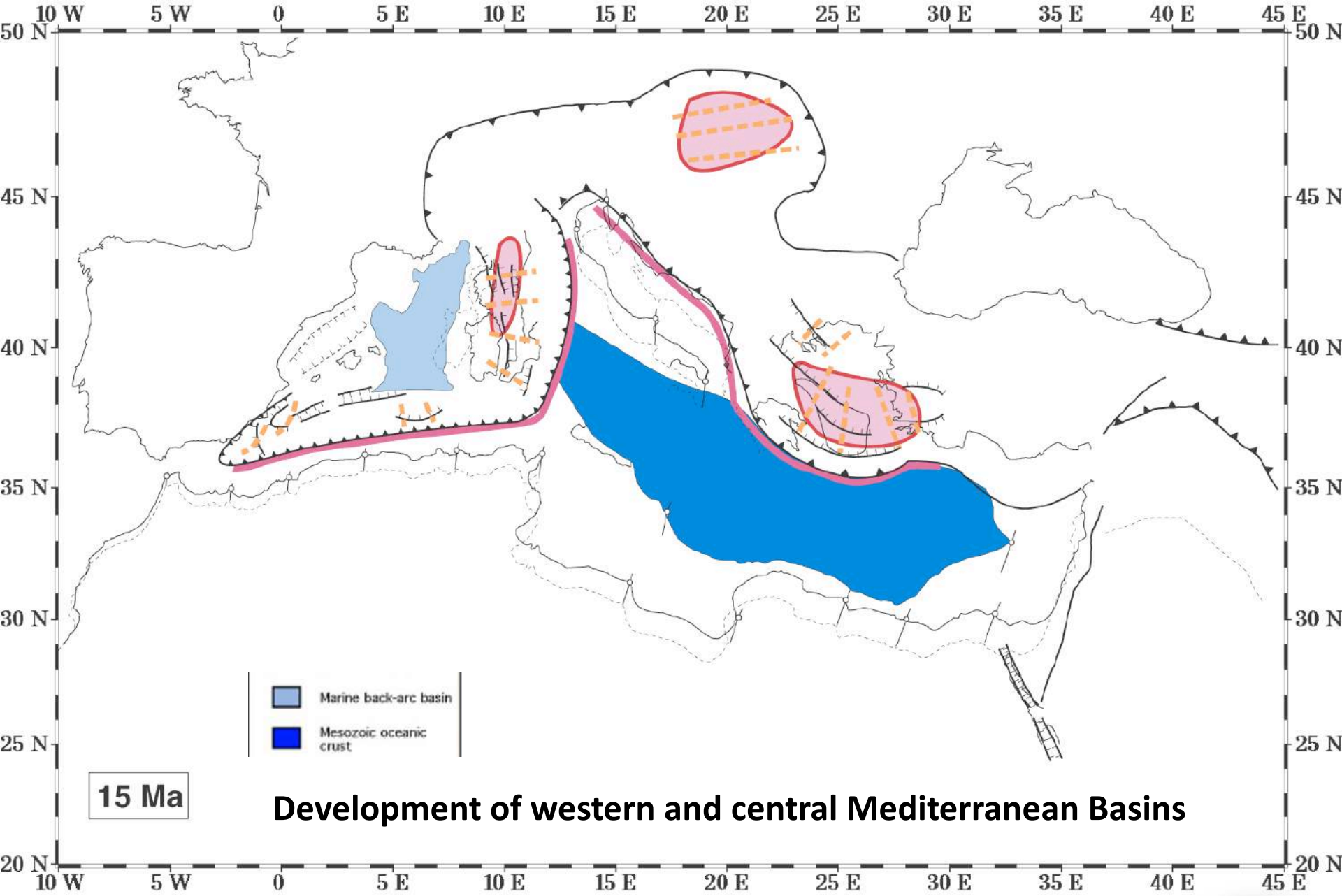

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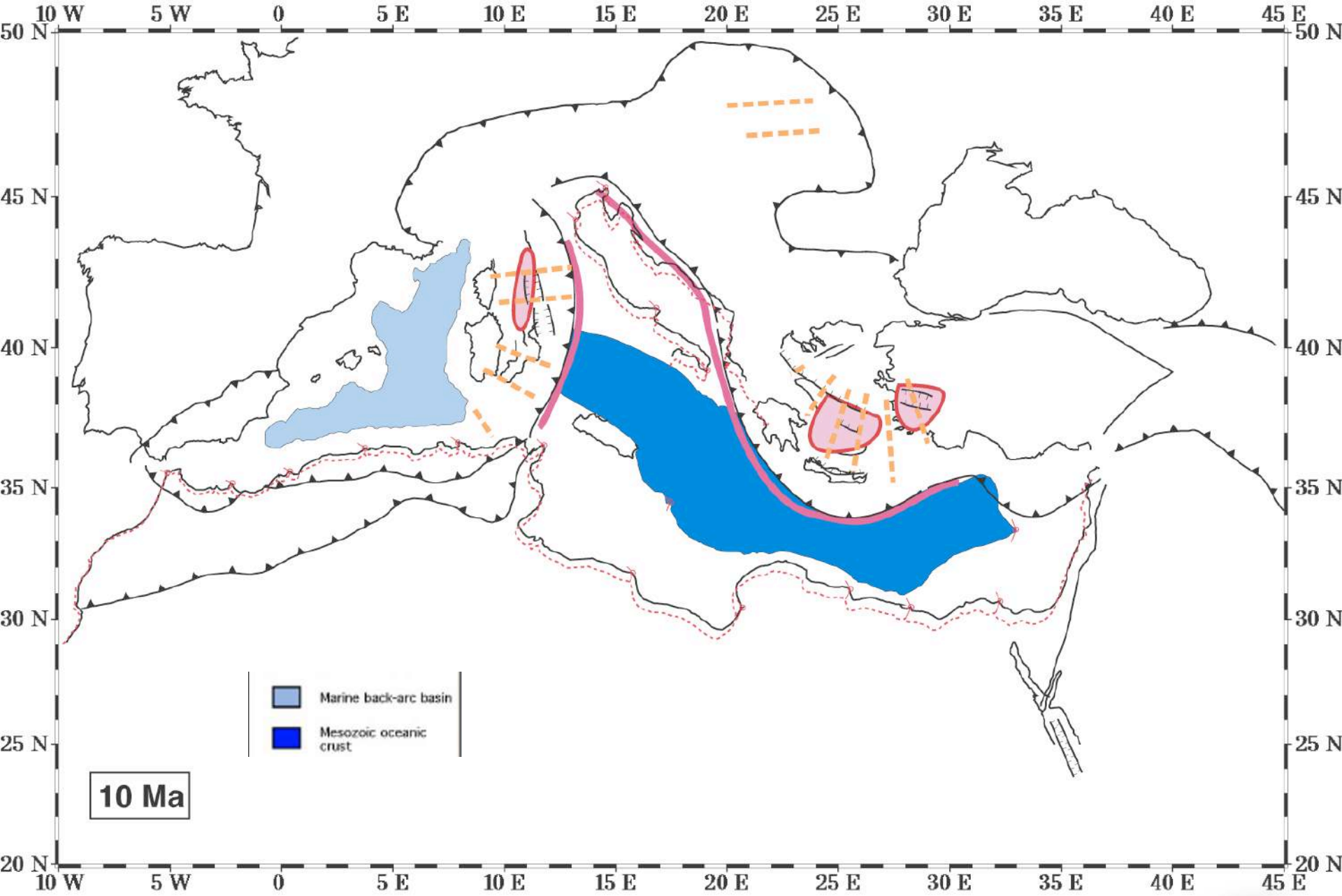
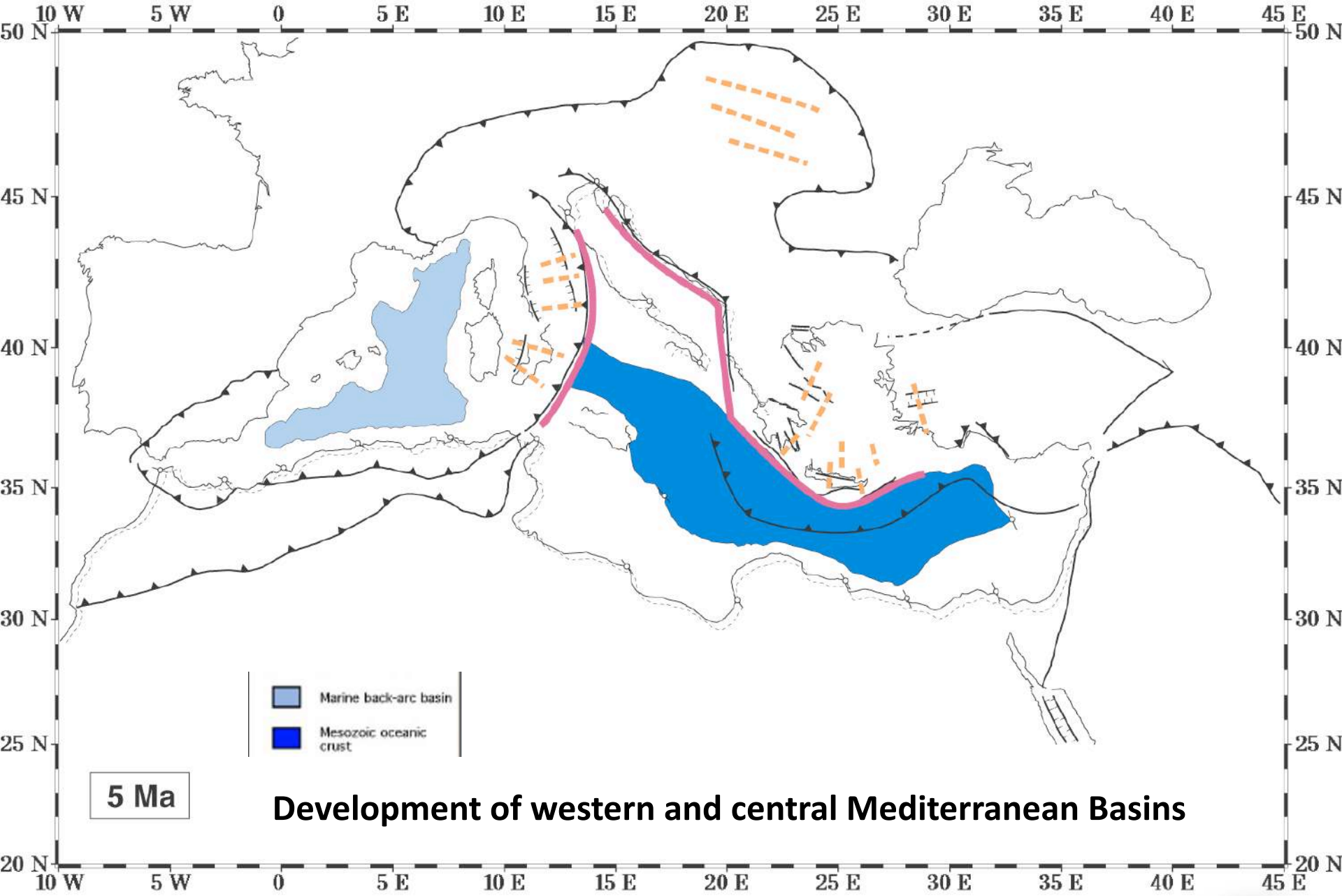


Jolivet et al., 2003., Kinematic data after Dewey et al.



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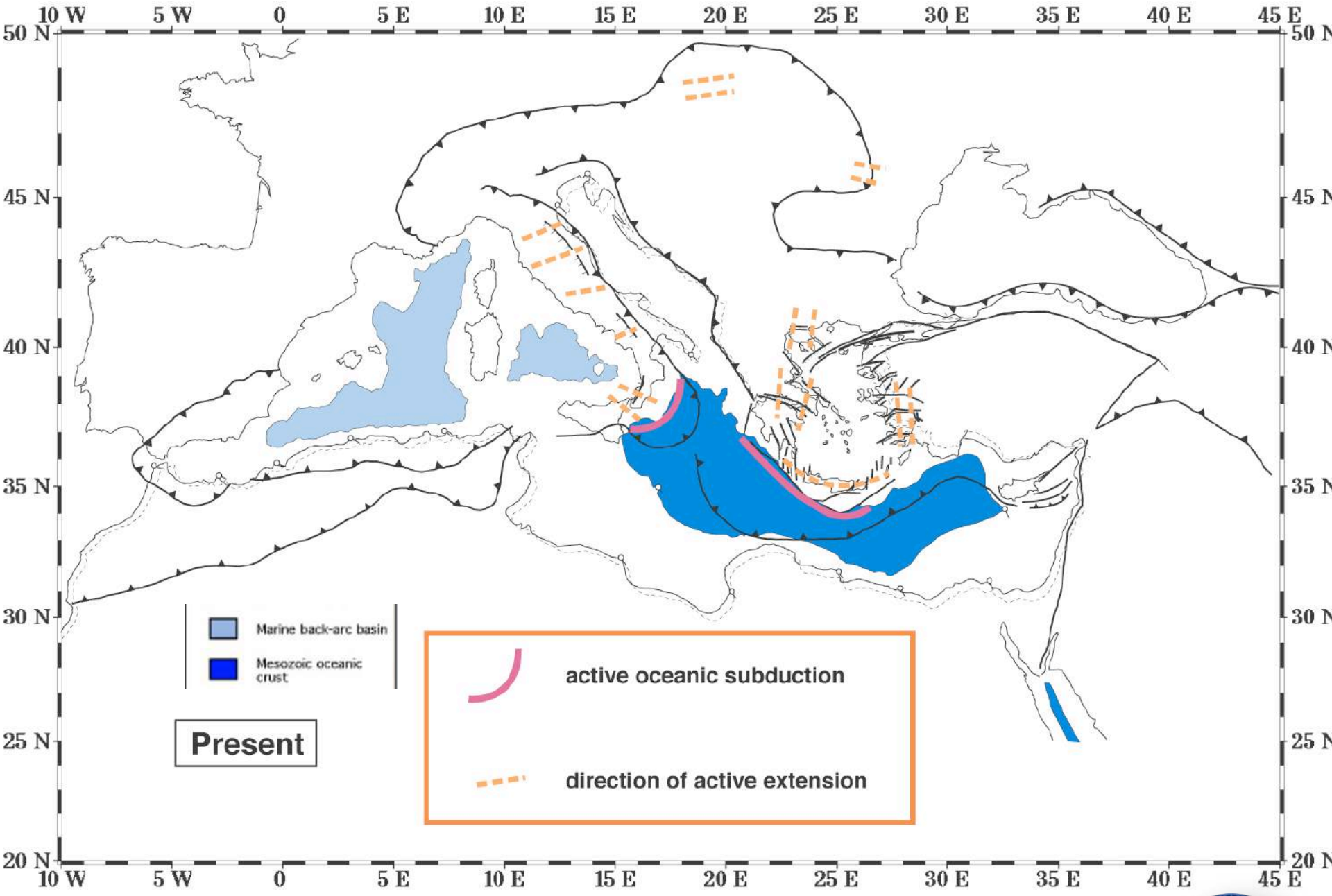
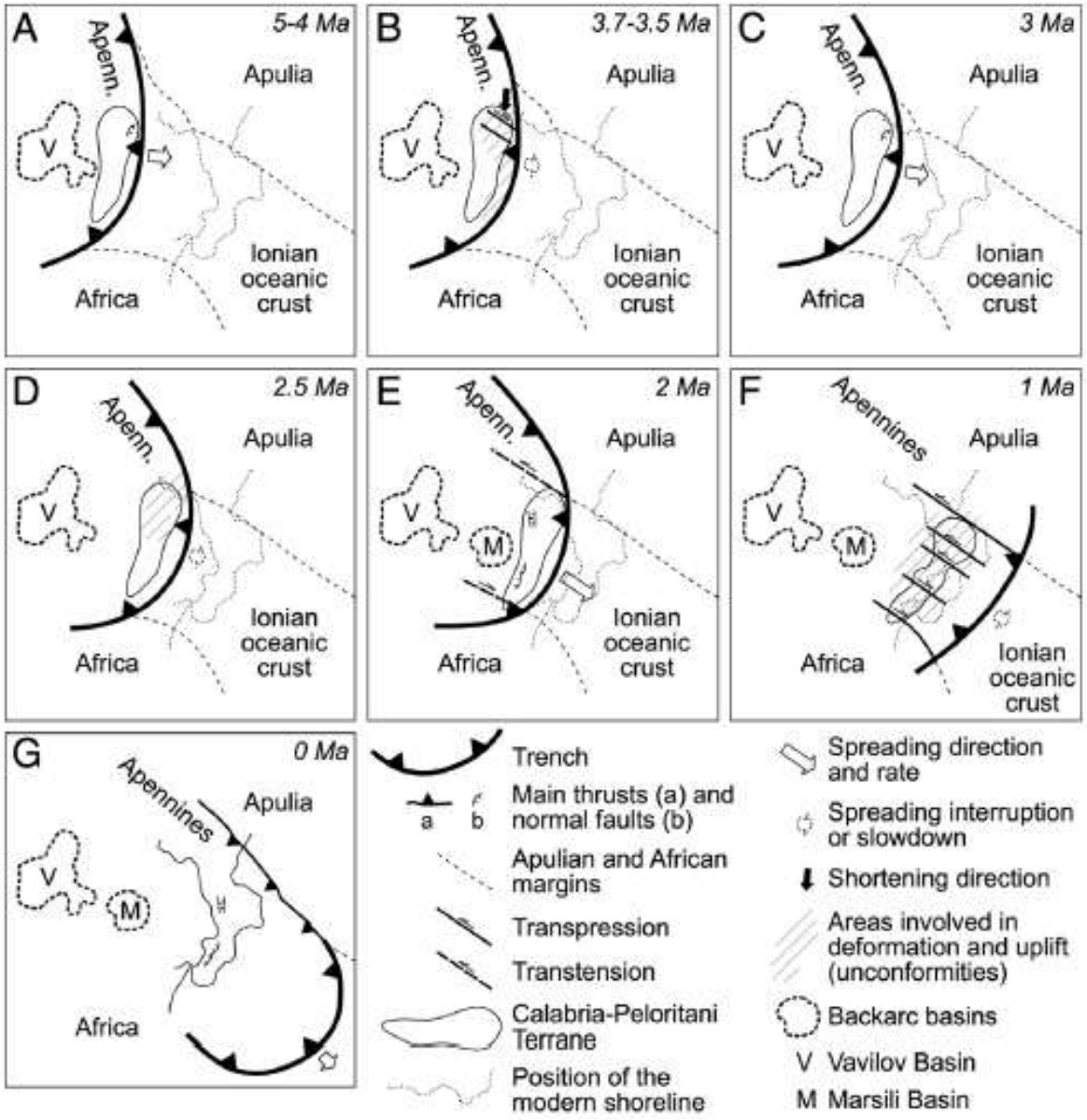


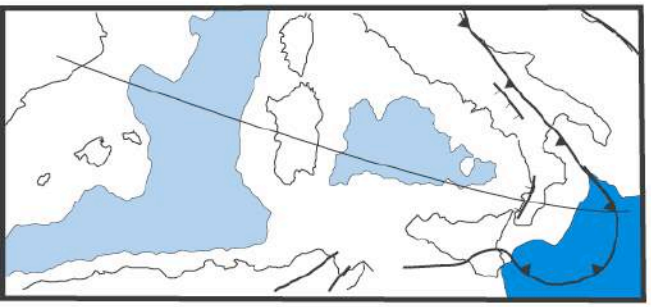
Jolivet et al., 2003., Kinematic data after Dewey et al.

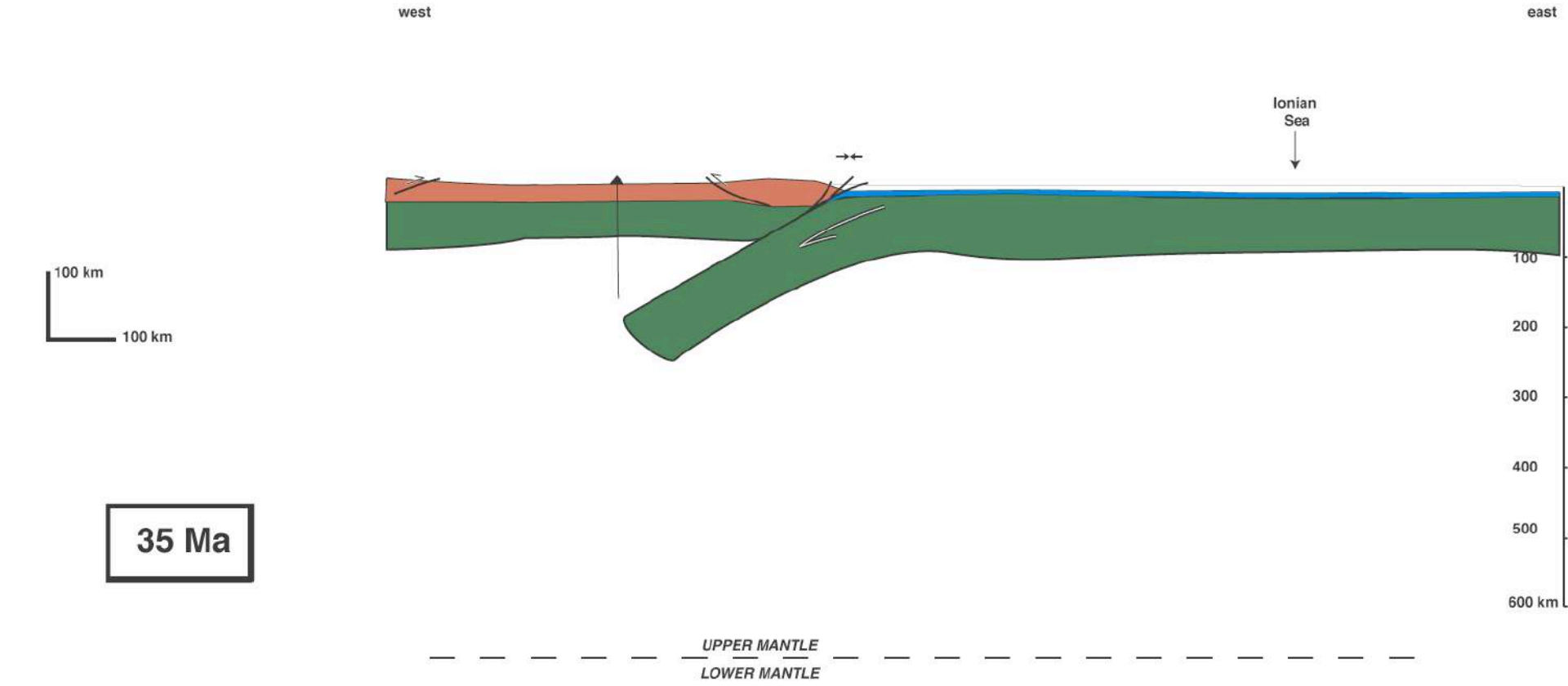
The Calabrian subduction

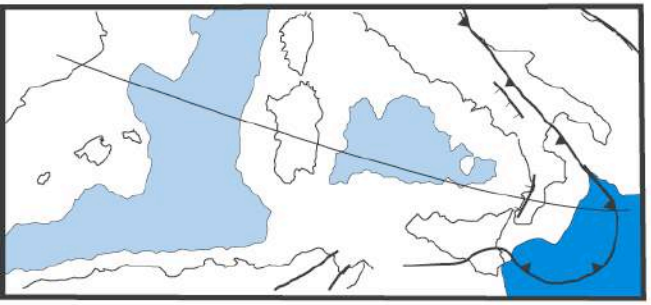


Zecchin et al 2015

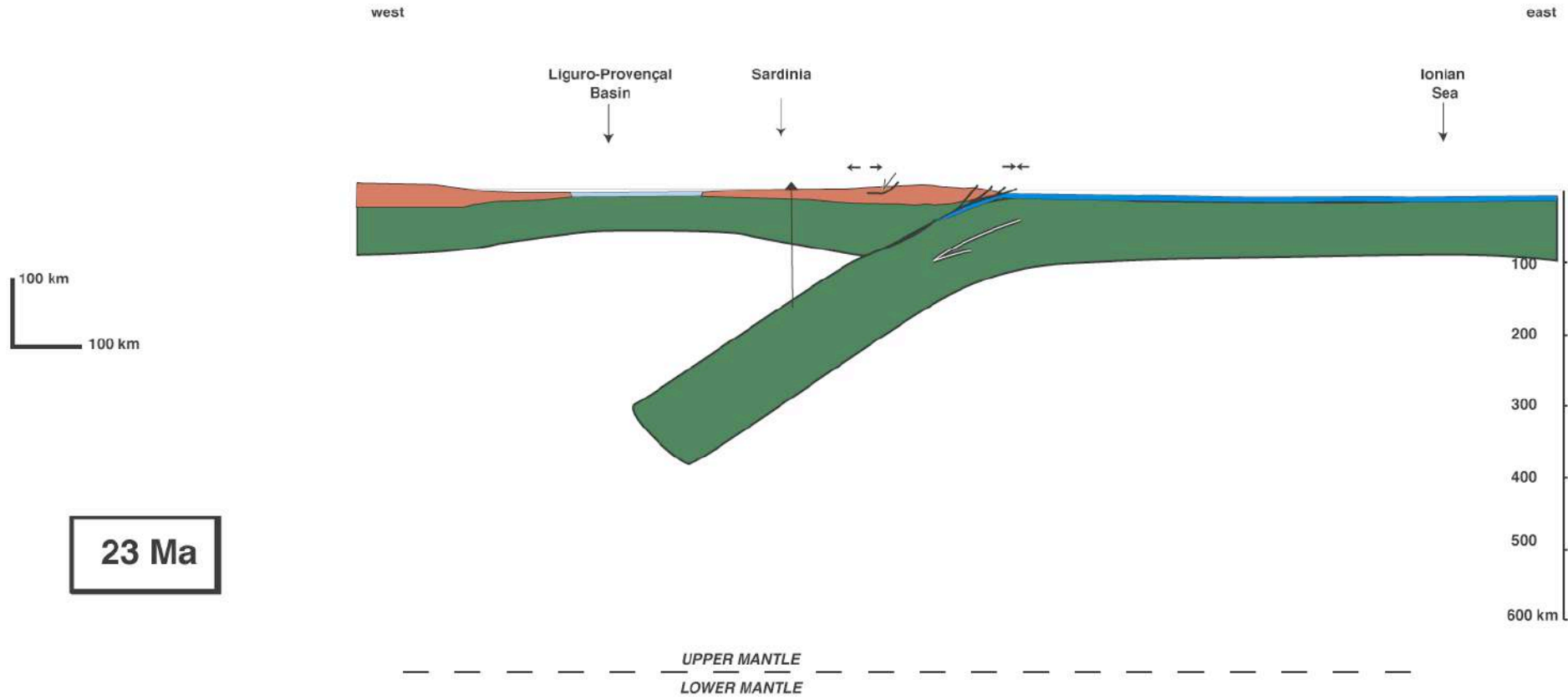
The subduction of the Ionian Sea



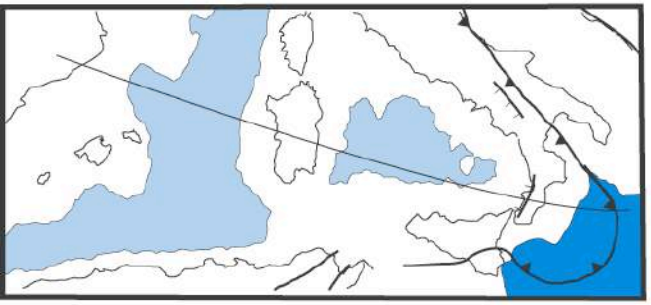


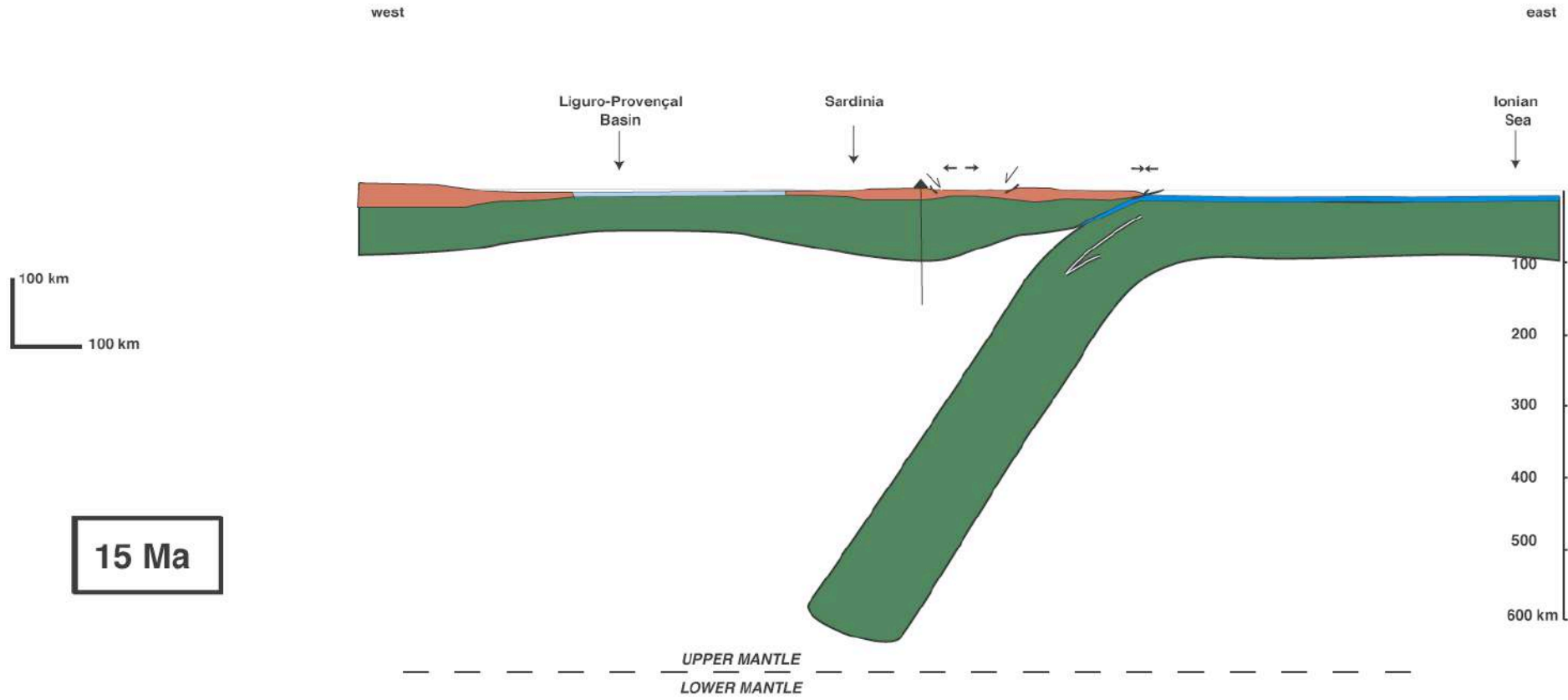


The subduction of the Ionian Sea

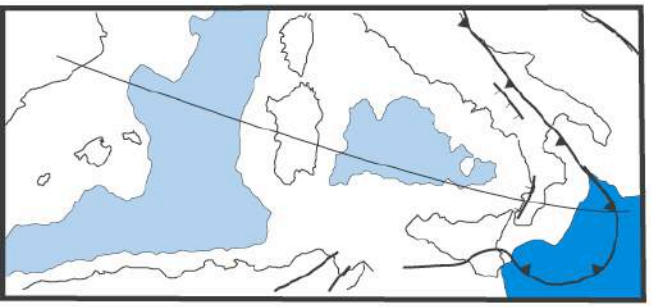


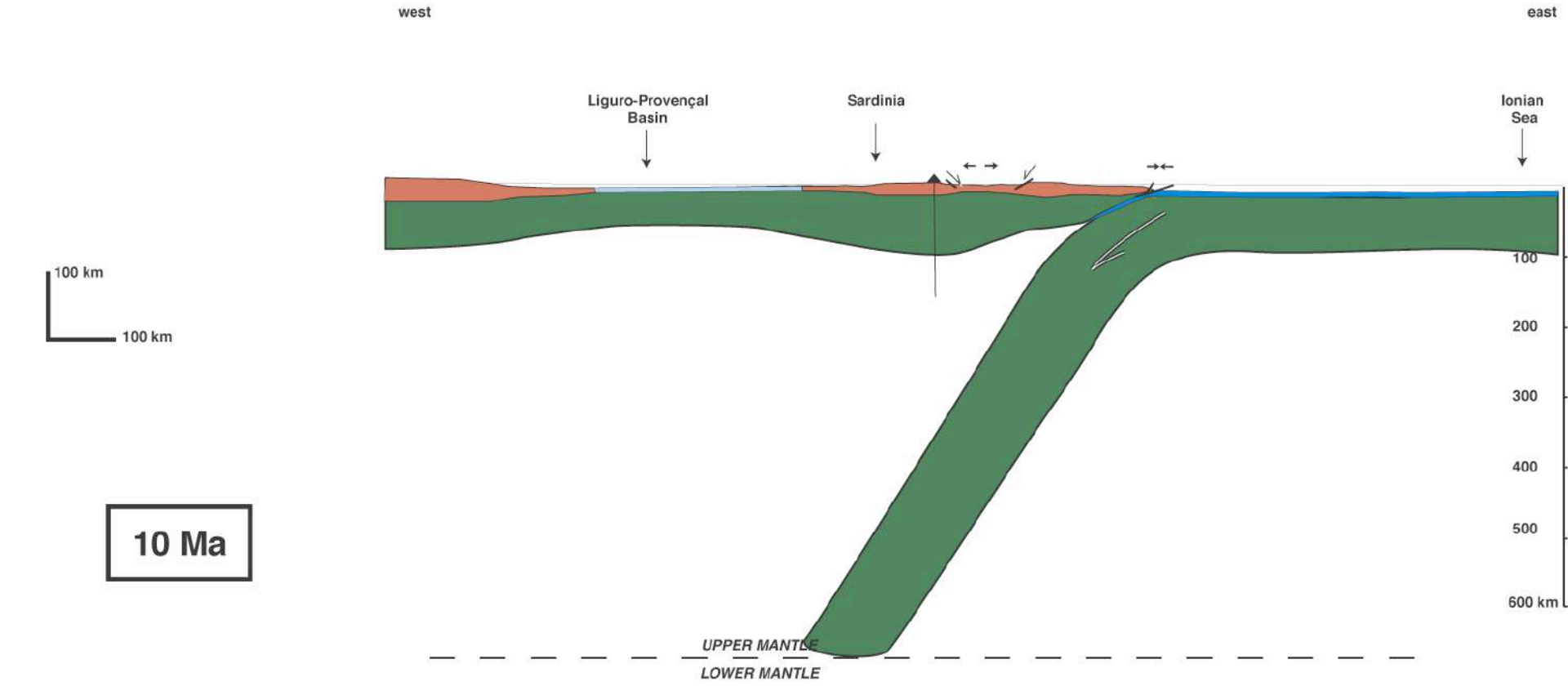
The subduction of the Ionian Sea



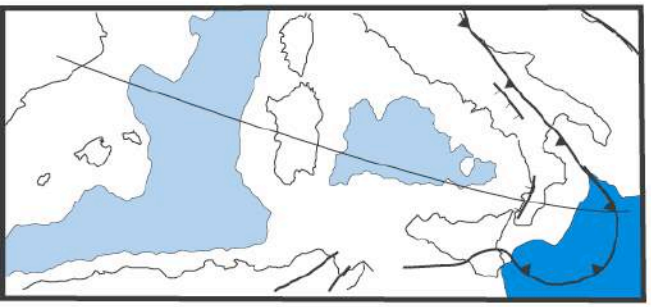


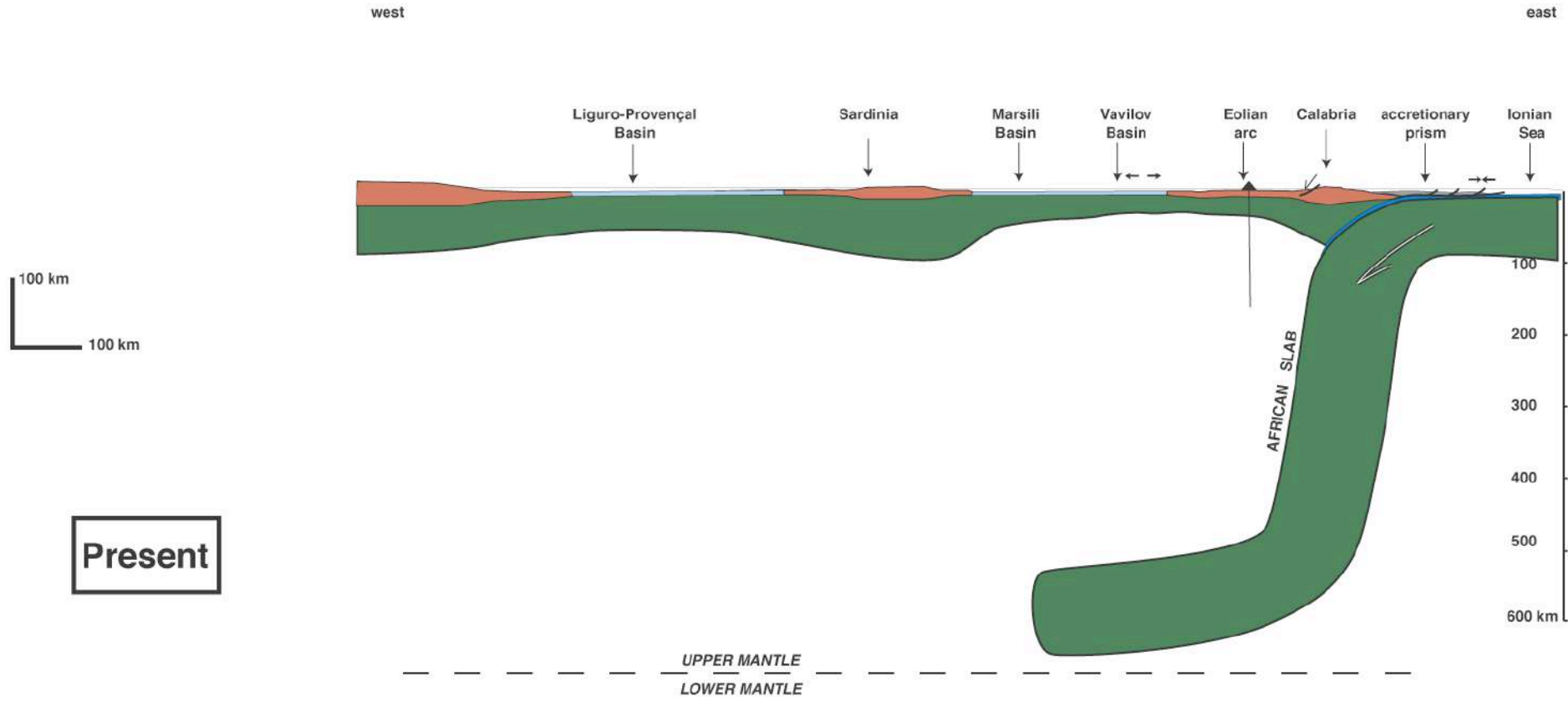
The subduction of the Ionian Sea





The subduction of the Ionian Sea

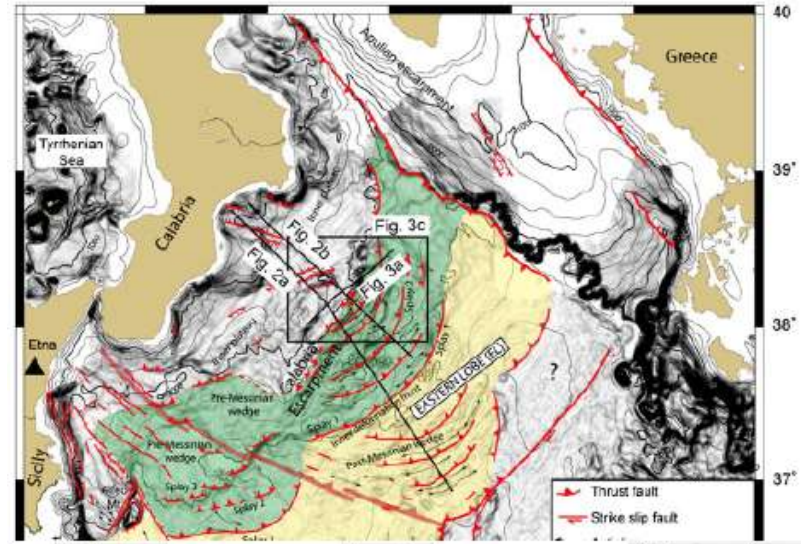


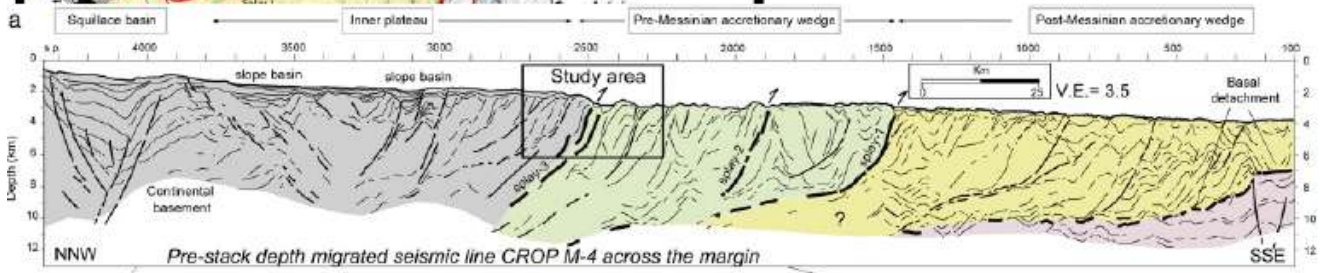


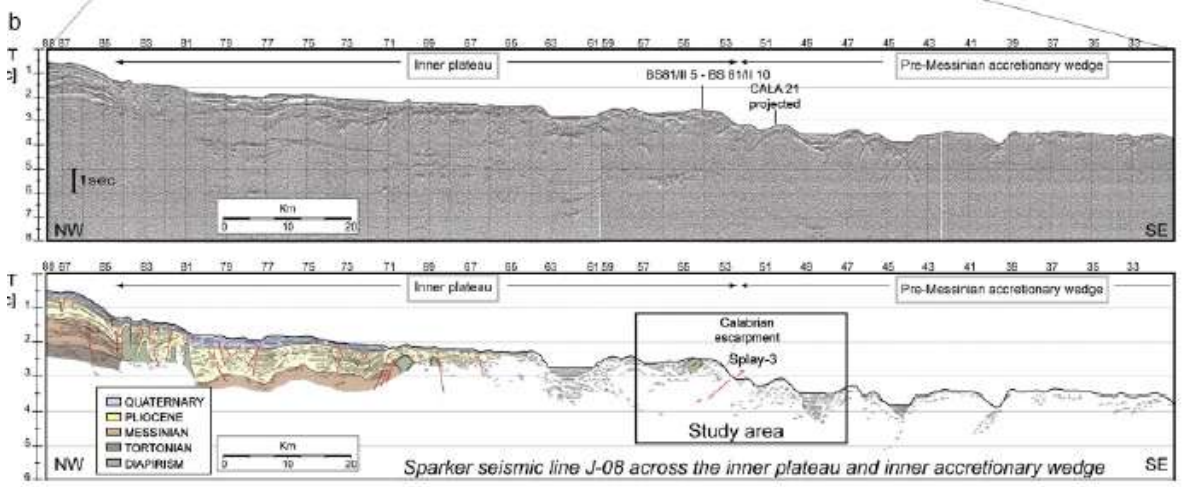
Present

Calabrian accretionary Prism

Deformation is related to an imbricate fan within the post-Messinian salt-bearing accretionary wedge (yellow domain), out-of-sequence thrust faults in the pre-Messinian wedge (green domain) and normal faults in the Inner plateau (gray domain).

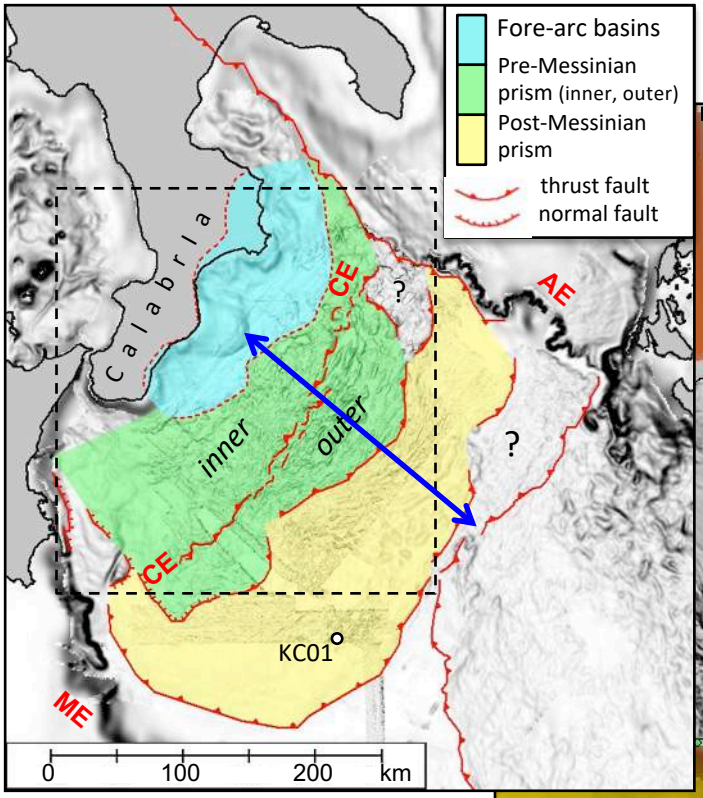






Polonia et al. 2011

Bathymetry of Calabrian accretionary prism



Calabrian Escarpment
up to 750 m high, 200 km long, 1st order feature of prism, separating inner plateau from steeper outer wedge

Ceramicola et al. 2014

Crotone Basin
Spartivento Basin
Madonna dello Ionio MVs
Sartori MV
Pythagoras MV
CE
AE
ME

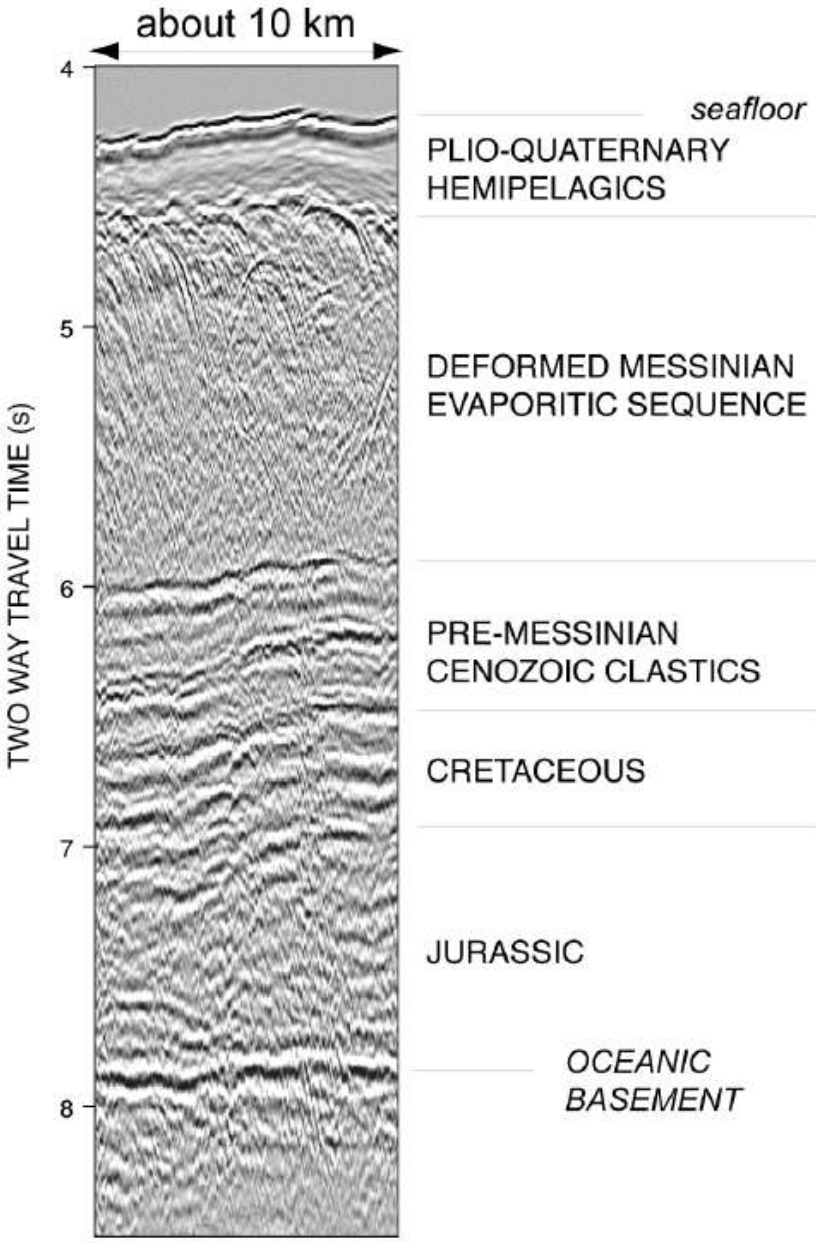
Cores
- of mud breccia
- (buried ≤.1.6 m) of hemipelagics

2,922 m
2,000 m
1,000 m
0 m
-1,000 m
-2,000 m
-3,000 m
-4,000 m
-4,359 m

0 km 50 km 100 km 150 km

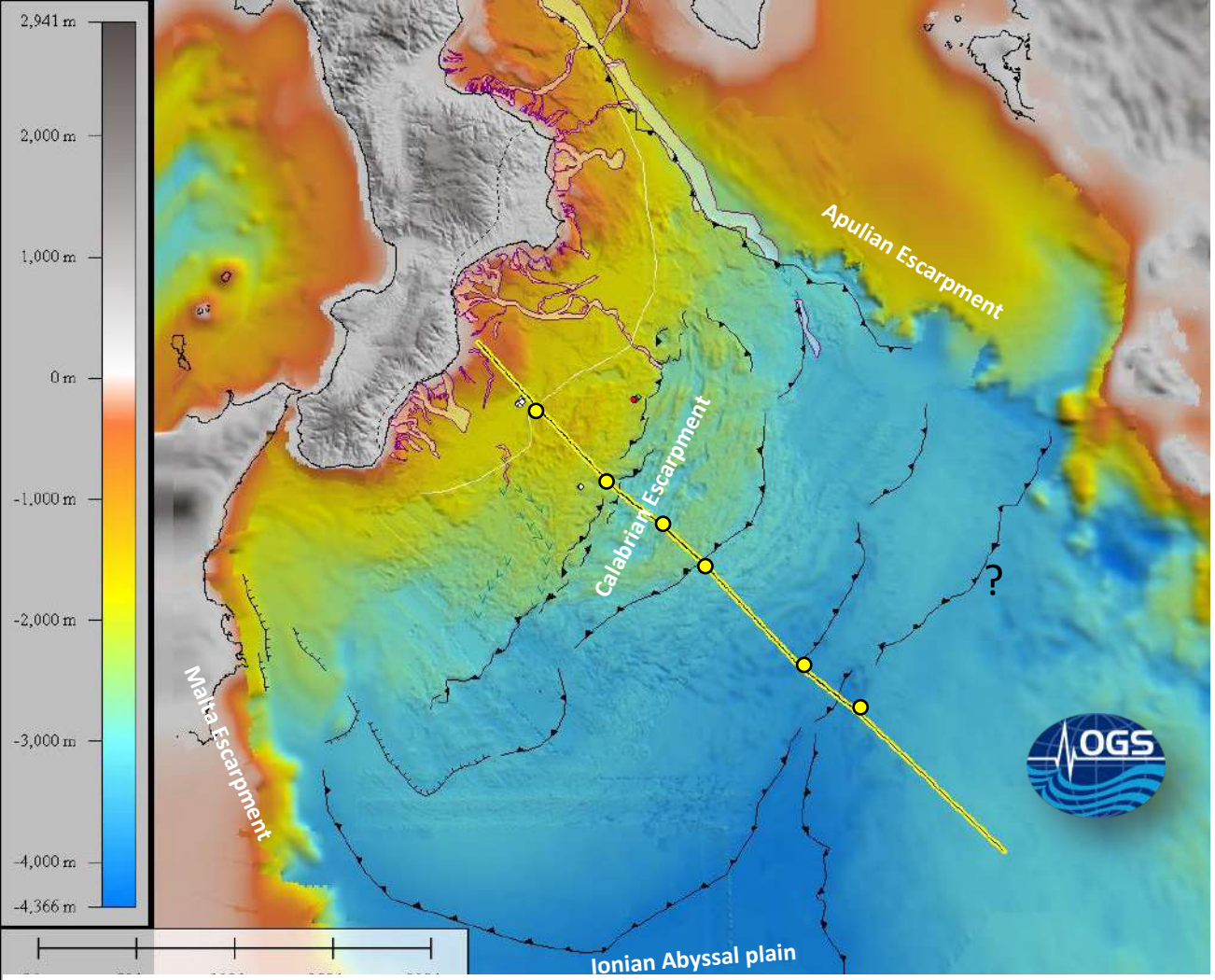
39° N
38° N
37° N
16° E
17° E
18° E

Seismic stratigraphy of the Ionian basin

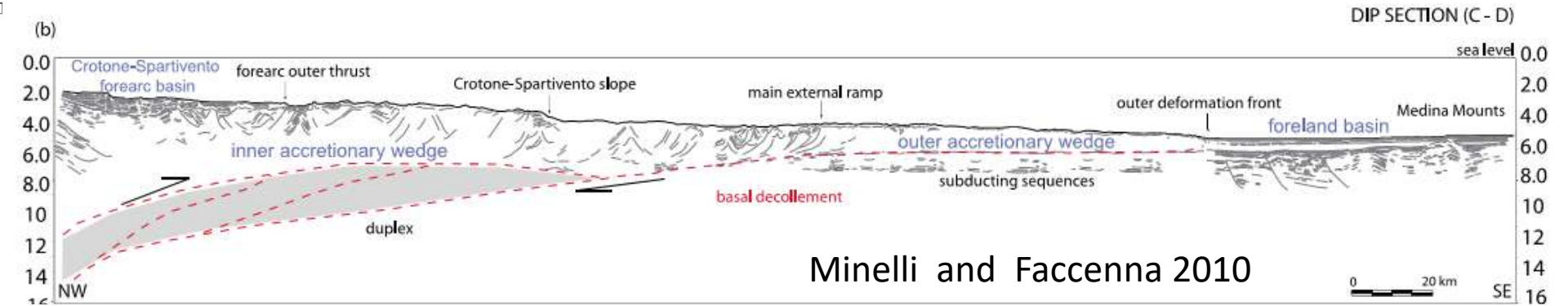


- As the last non-subducted sector of the Neo-Tethys ocean, the Ionian Sea turns out to be the oldest *in situ* ocean fragment of the world.
- It has been saved from subduction since locked within irregular S shaped continental margins of Africa and Eurasia.
- It is a 350 km wide x 600 km long abyssal plain lying at 3–4 km depth, locked between the continental platforms of northern Africa, Malta-Hyblean plateau, and Apulia, and active orogens of Calabria Arc and Hellenides.
- A thick package (5–7 km) of sediments overlying an extremely thin (8–11 km) crystalline crust.

THE IONIAN SEA

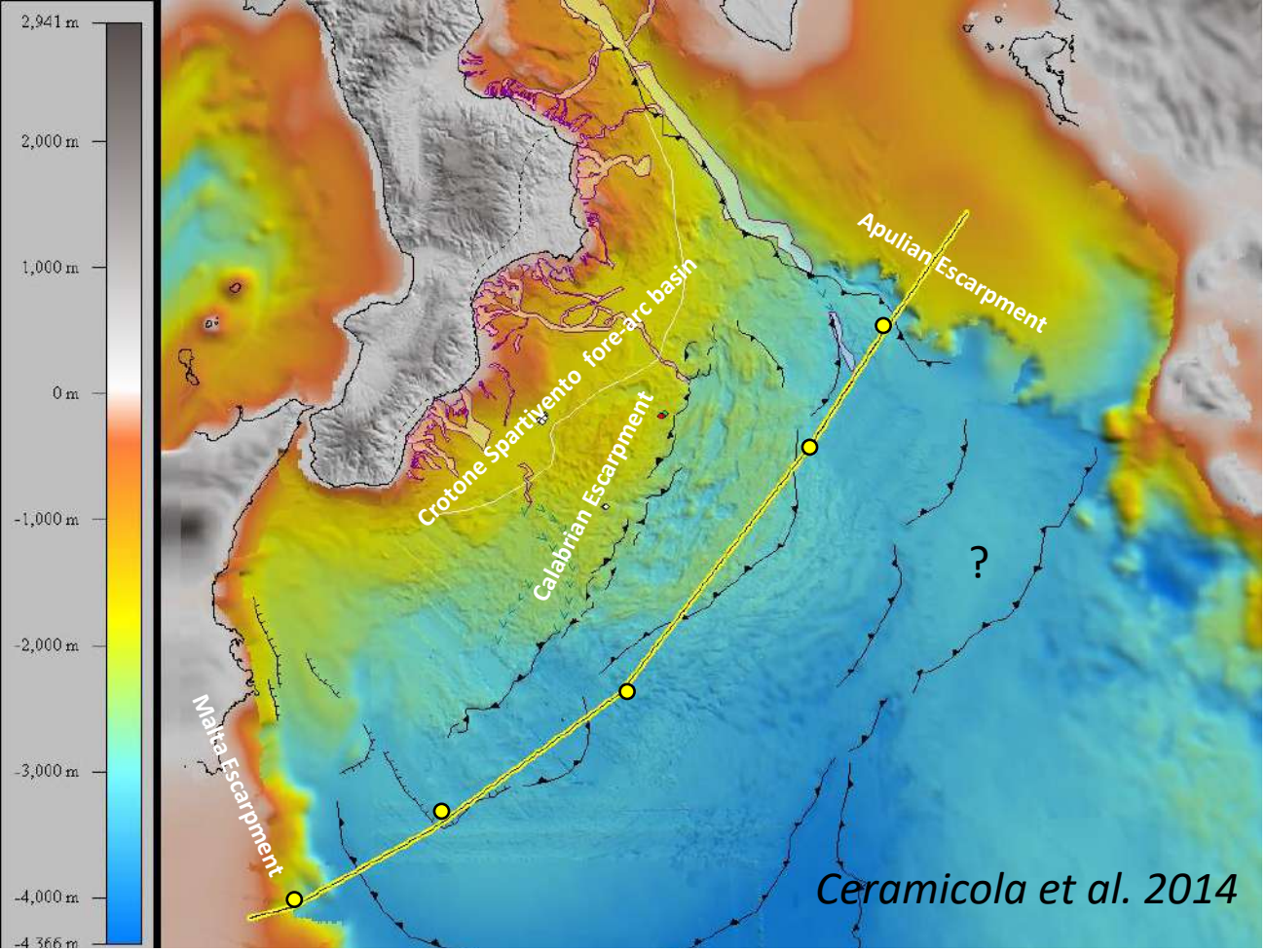


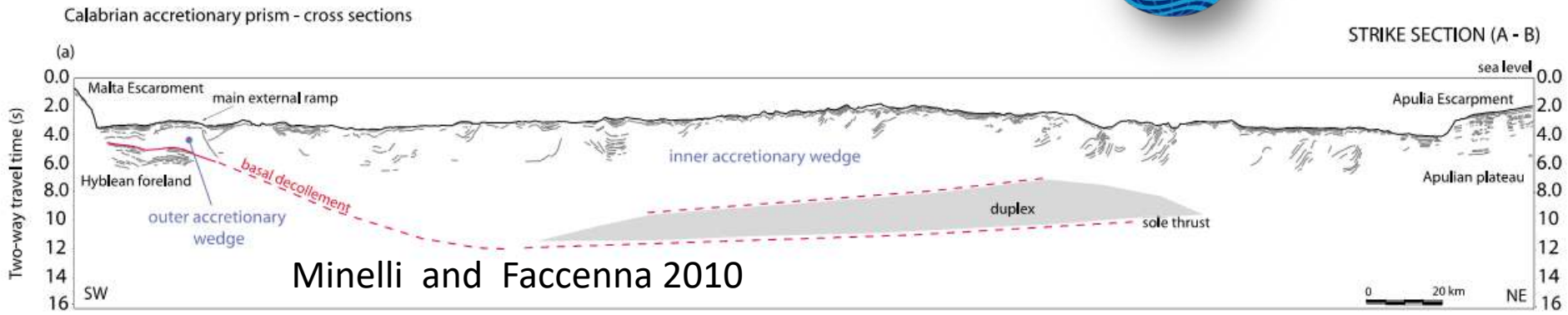
Ceramicola et al. 2014



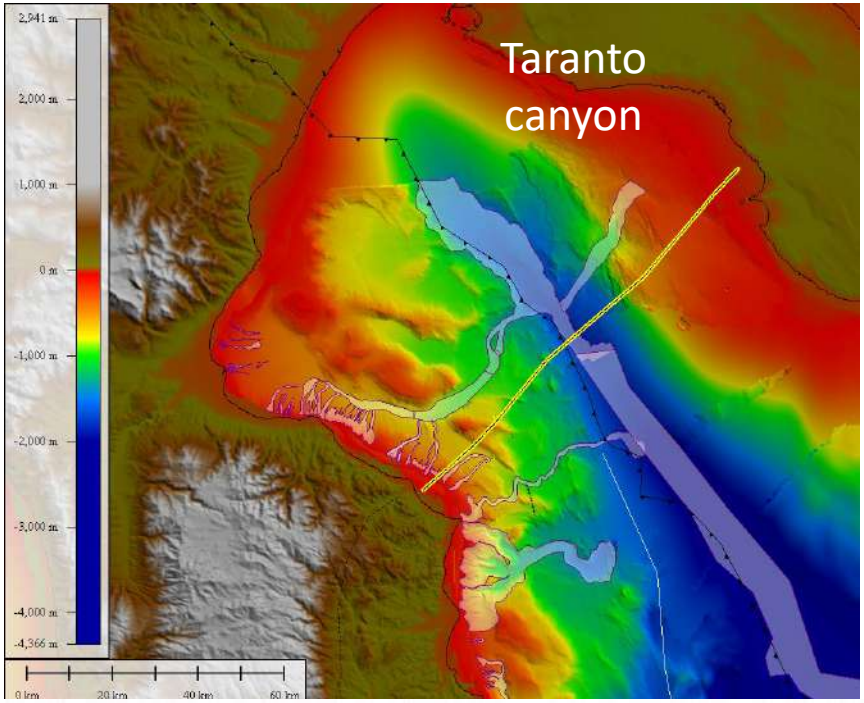
Minelli and Faccenna 2010

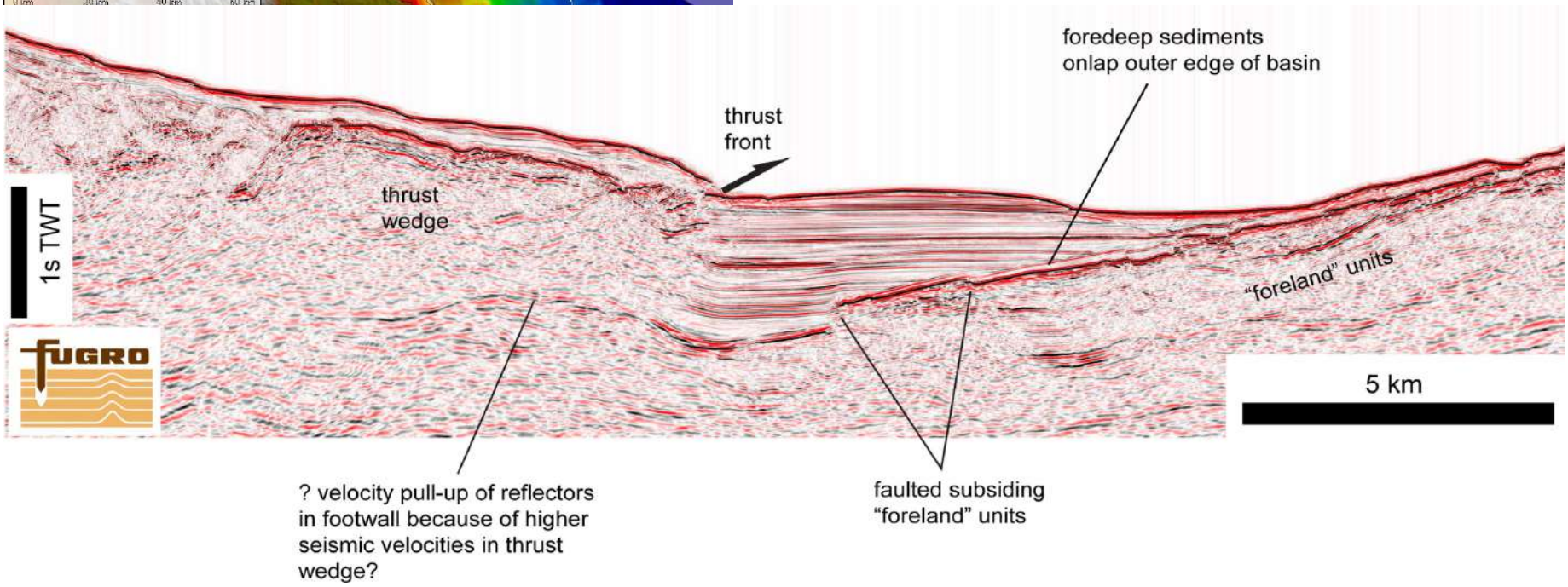
THE IONIAN SEA



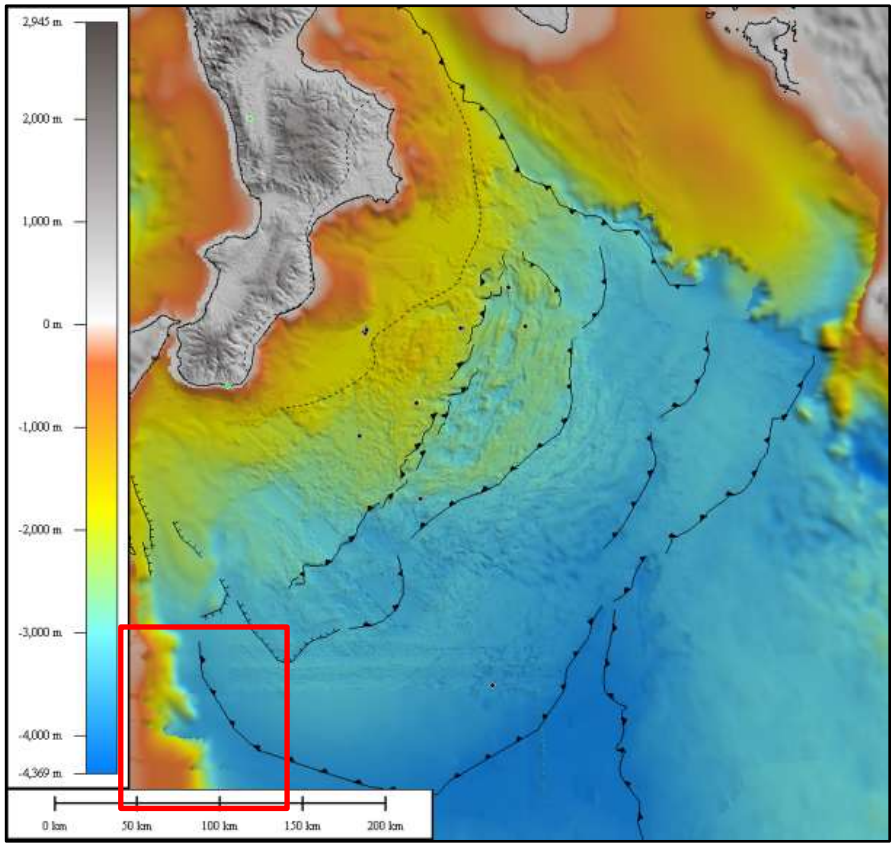


GULF OF TARANTO

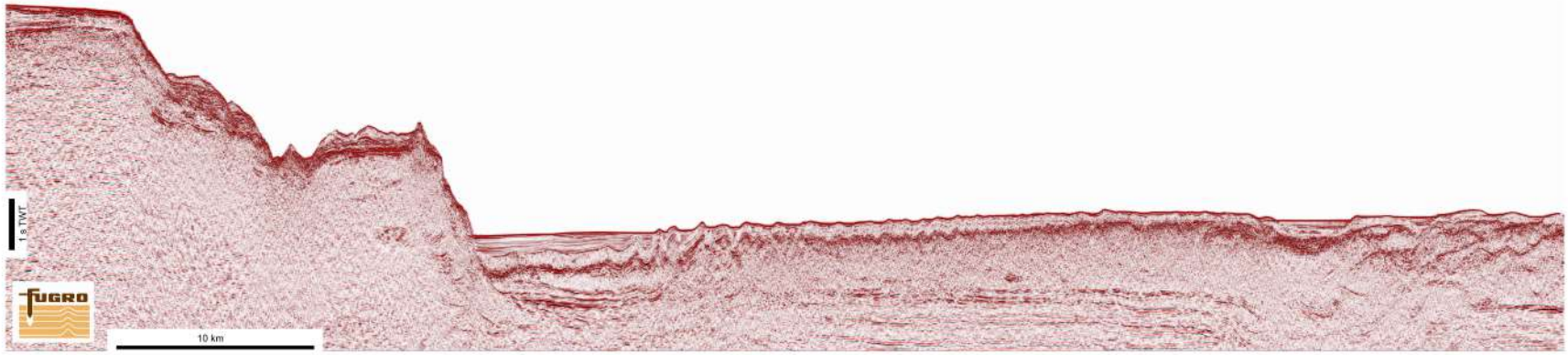




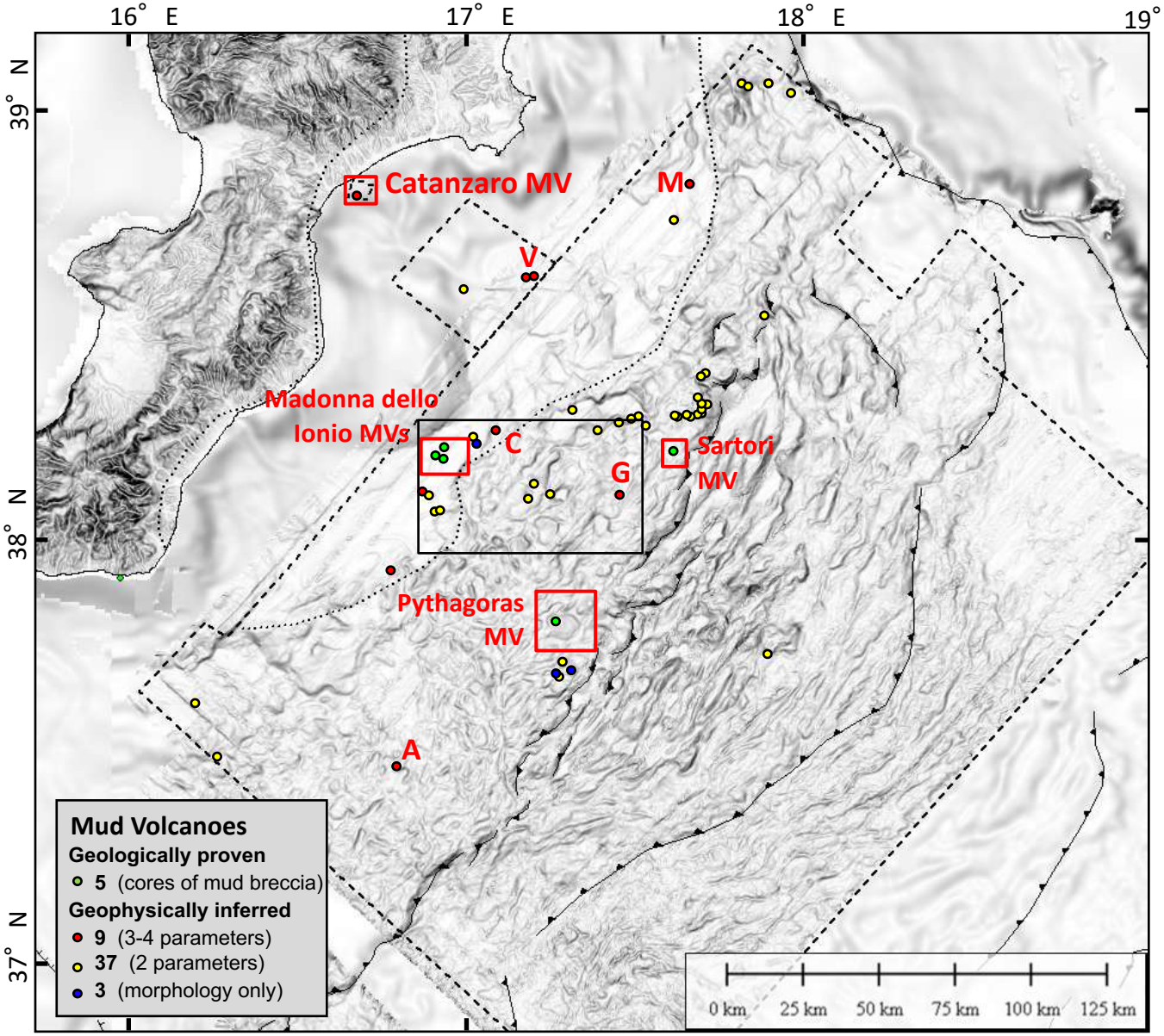
MALTA ESCARPMENT



Ceramicola et al. 2014



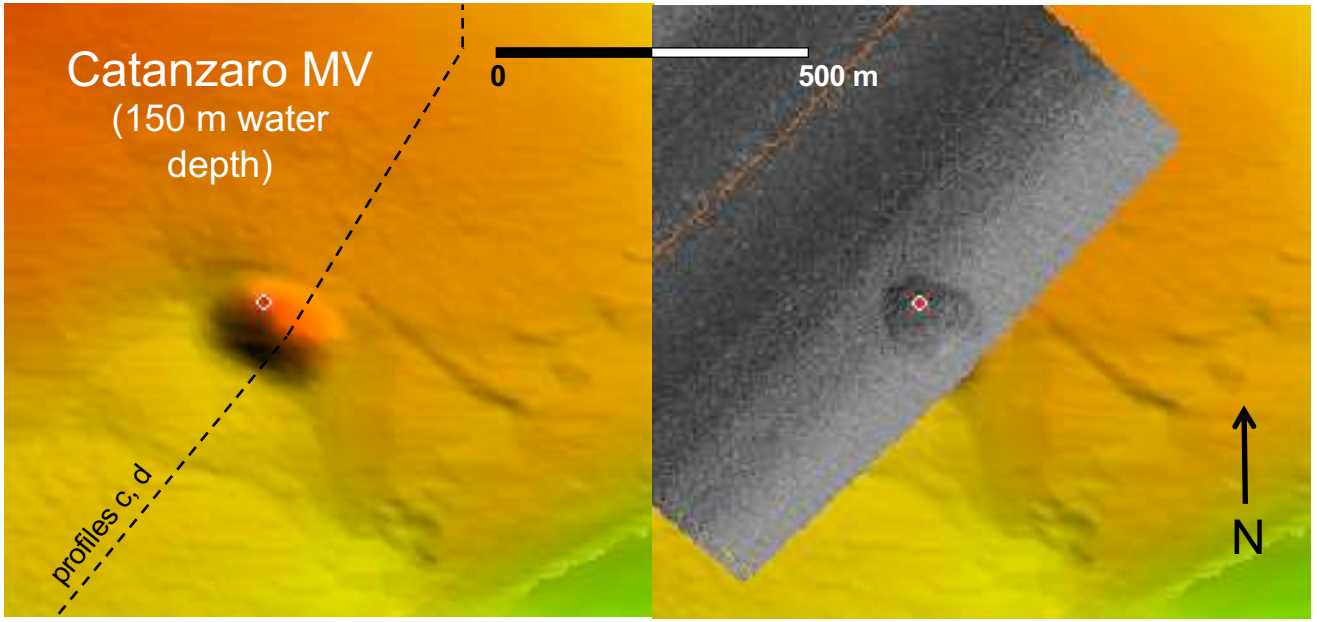
The Calabrian mud volcano province

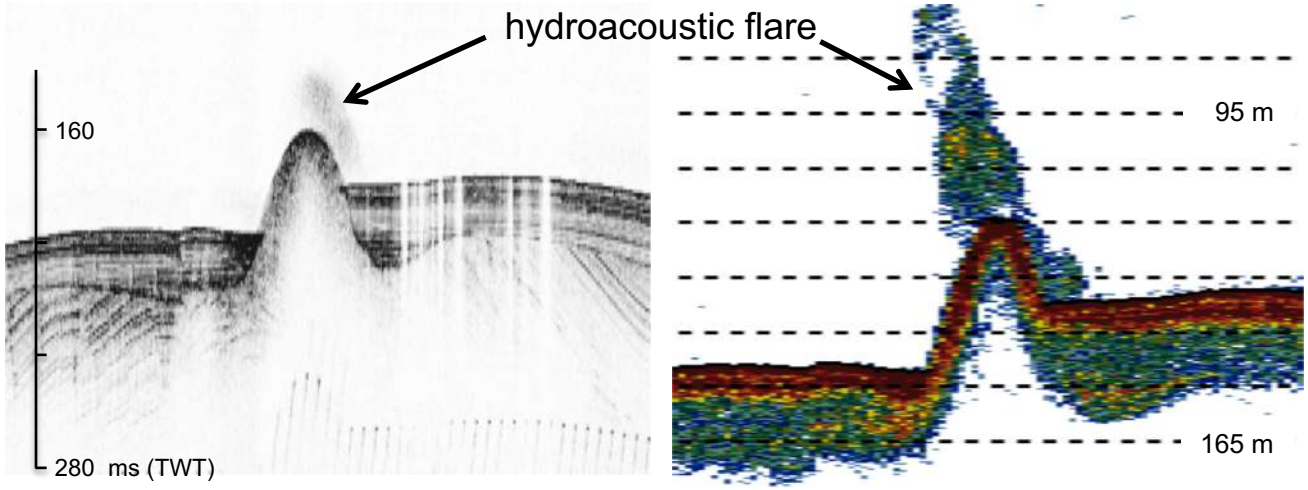


- **Seabed mapping** based on data acquired by OGS in 2005 and 2009
- At least 54 MVs (conservative criteria), all but one (possible) landward of Calabrian Escarpment
- 3 sites cored, others geophysically inferred

(*Ceramicola et al. 2014b*)

Multi-parameter geophysical evidence of mud volcanoes

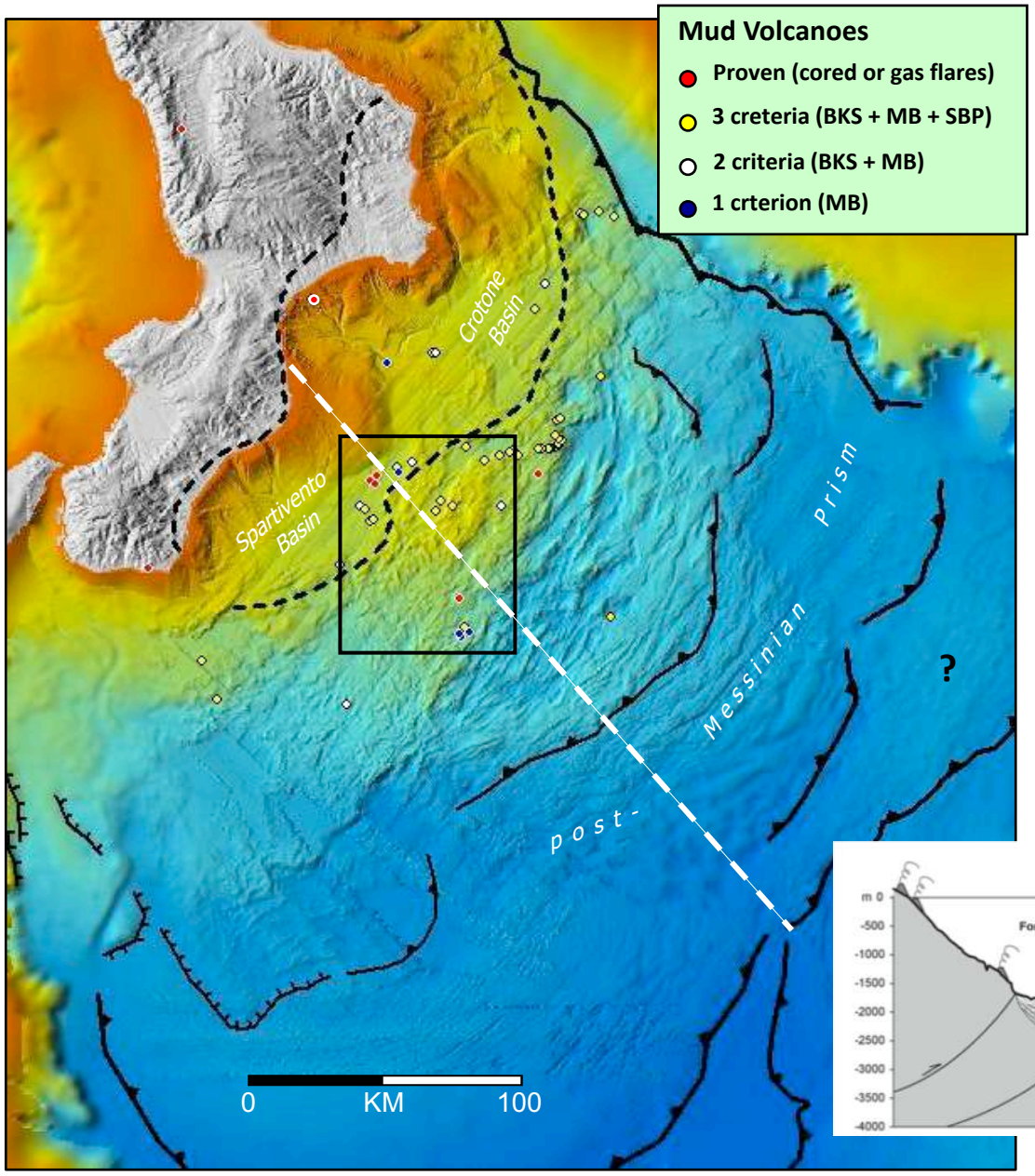




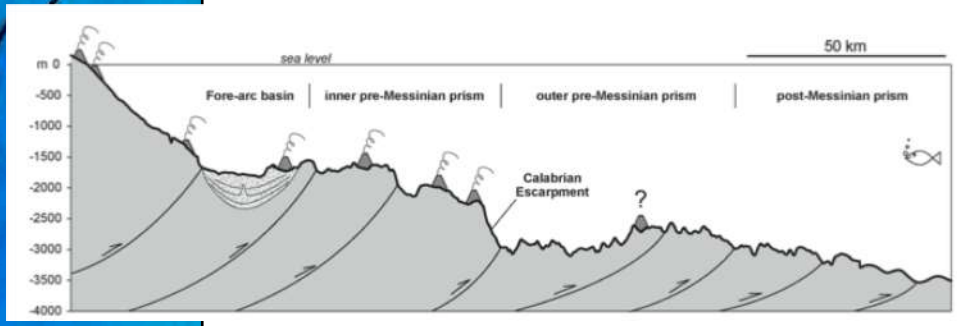
- 5 km off Calabrian coast, only MV in <1000 m water depth (100 kHz backscatter)
- Mud breccia extrusion above last glacial maximum unconformity **(19-23 ka BP)**
- Hydroacoustic evidence of gas venting to water column

Ceramicola et al. 2014b

Calabrian mud volcano province – in summary

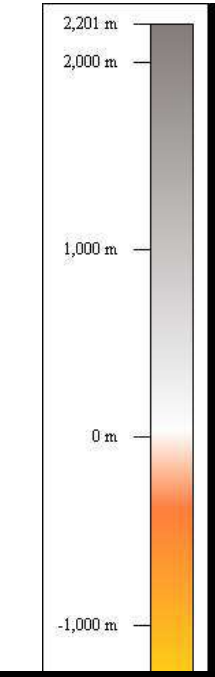


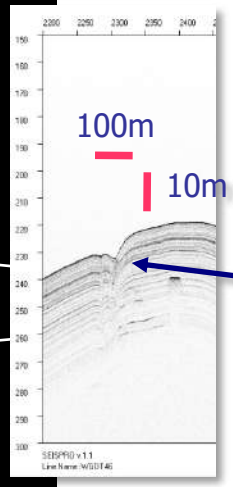
- At least 54 MVs (+ one on land)distributed across fore-arc basins (thin salt) and inner prism (no salt) – lower density than Med Ridge, fluid sources at depth
- Local influence of faults, none in centres of fore-arc basins (rising fluids blocked by salt or mud?)
- Seabed extrusion of mud breccias over last glacial to post-glacial cycle (50/53), ongoing gas seepage (3 sites)
- All but one possible MV landward of Calabrian Escarpment



Ceramicola, et al. (2014)

Fluid seepage





Pockmarks

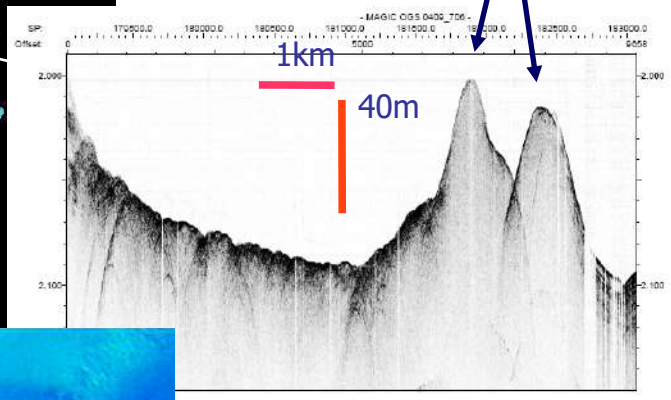
MARINE GEOHAZARDS ALONG THE ITALIAN COASTS
PROGETTO MAGIC

OGS

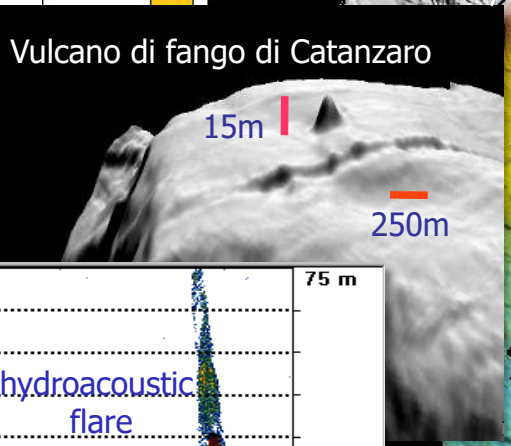
SW

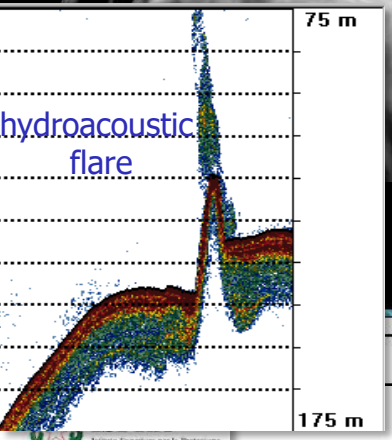
Vulcani di fango ?

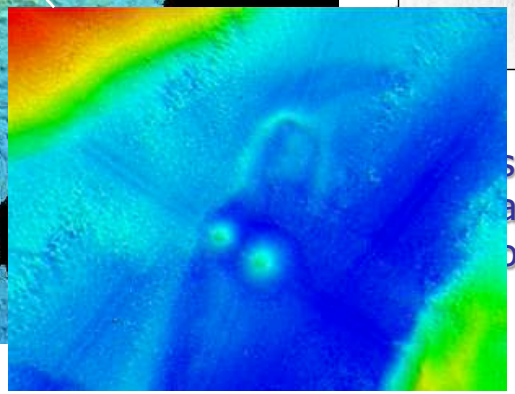
NE



Vulcano di fango di Catanzaro



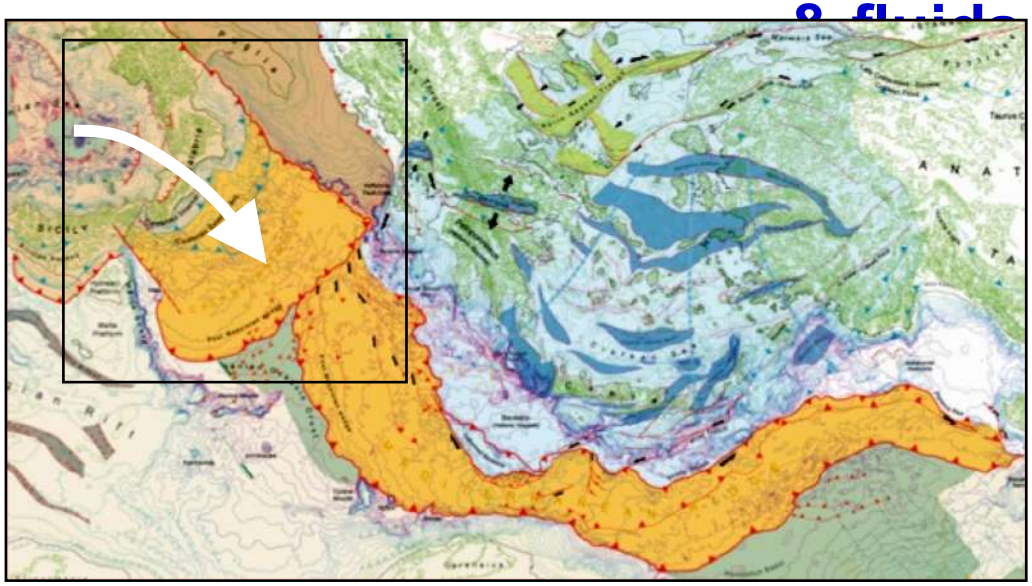




siti individuati nel
argine calabro ionico sottocosta,
olti di piu' sul prisma di accrezione

Ceramicola et al. 2014

Central and Eastern Mediterranean accretionary prisms & fluids



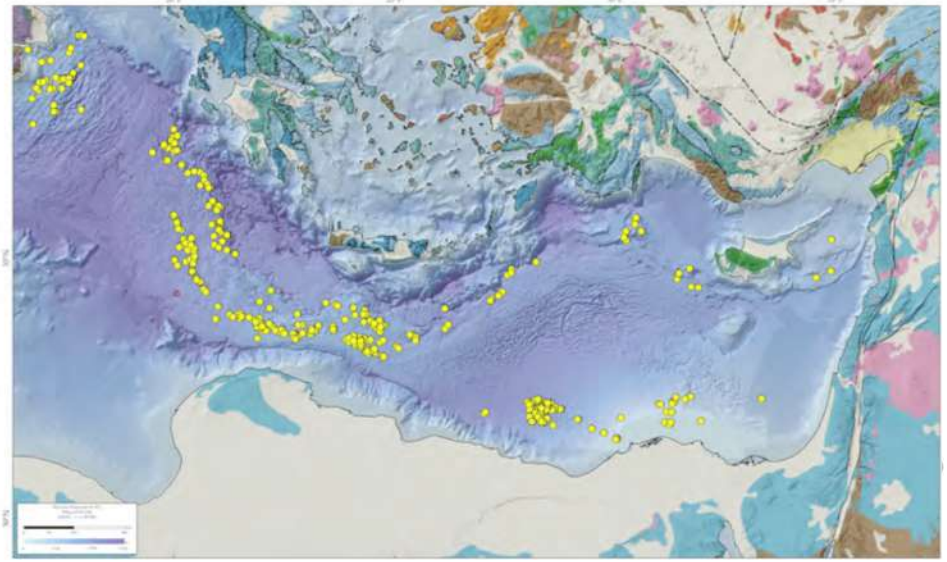
Chamot-Rooke et al. 2005

Mediterranean Ridge etc :

- MVs 1st identified from mud breccias over 30 years ago (Cita et al. 1981)
- Mud breccia extrusion for >1 Ma (ODP 164, 1996)
- Hundreds – highest abundance on Earth? (Kopf 2002)
- Tectonically-controlled crestal belt

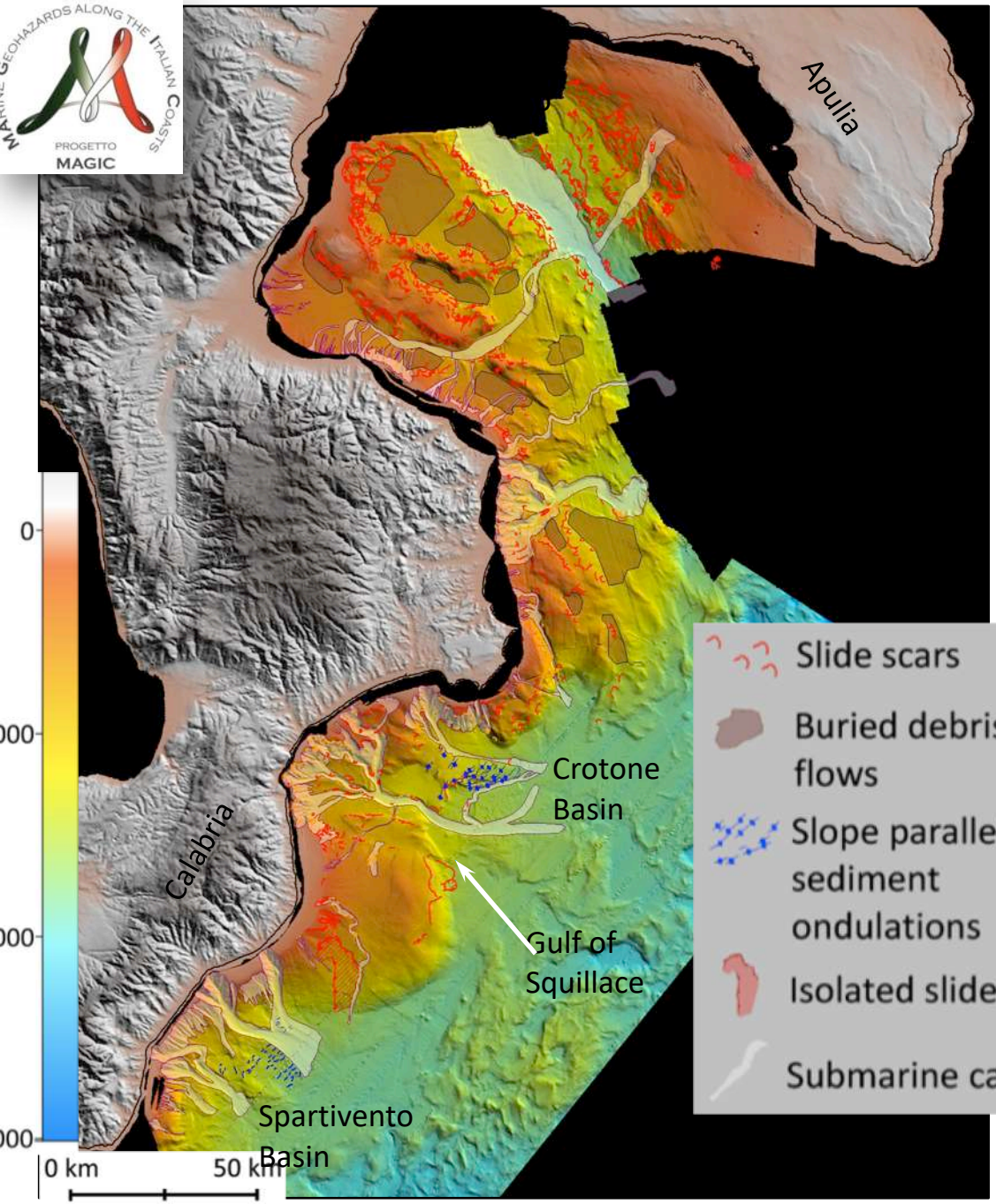
Calabrian 'arc' :

- Recent entry– rapid slab roll-back since the mid-Miocene c. 9 Ma → meets Med Ridge
- No seabed studies for >25 years since Rossi & Sartori (1981)
- Presence of long-lived mud volcanoes proven by OGS in 2005



Mascle et al. 2014

Mass movements along the Calabrian margin



1 Mass Transport Complexes (MTCs) in intra-slope basins (northern Calabrian margin)

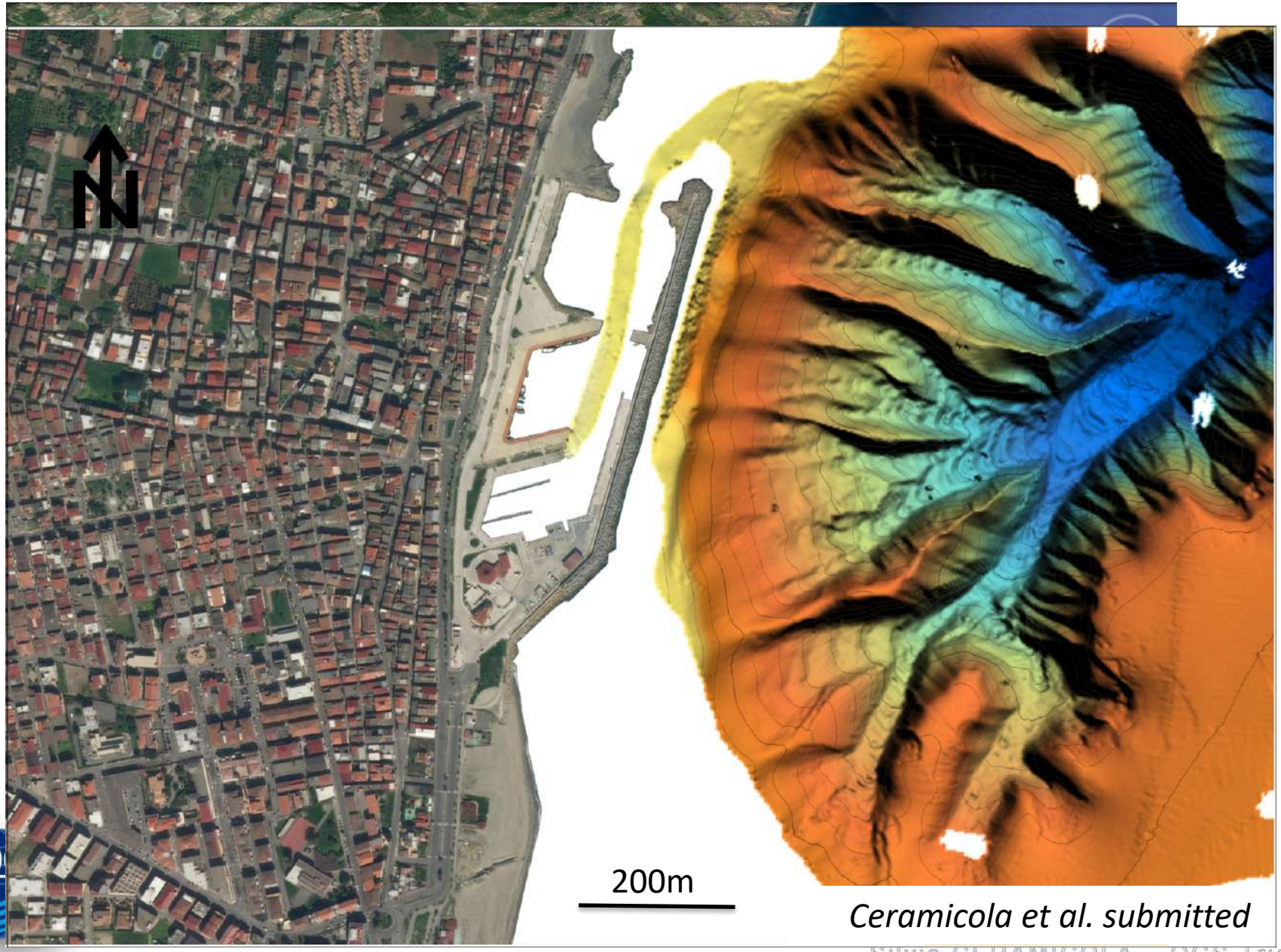
2 Isolated Slide Scars (ISSs) on open slopes (all margins)

3 Headwall & Sidewall Scarps in Submarine Canyons (HSC) (Calabrian margin)

4 Slope-Parallel Sediment Undulations (SPSU) (southern Calabrian margin)

Ceramicola et al. 2014a

Cirò marina submarine canyon and coastal hazard



Ceramicola et al. submitted

Cirò marina submarine canyon and coastal hazard

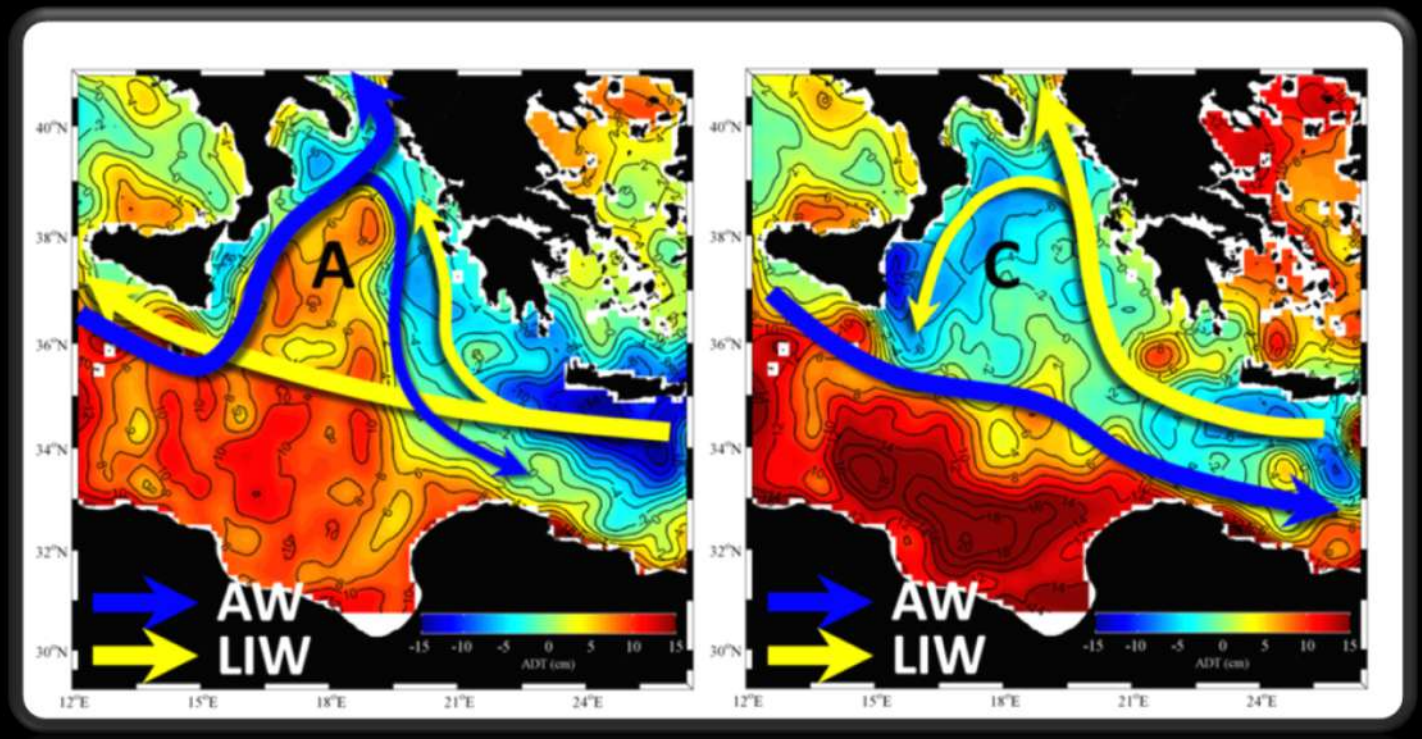
Adriatic-Ionian Bimodal Oscillating System (BiOs) (Gacic et al., 2010)

The Ionian Sea is the deepest regional sea of the Mediterranean and plays an important role in the intermediate and deep thermohaline cell of the Eastern Mediterranean (EMed) conveyor belt (Gacic et al.,2010)

In the 1950s it has been recognized that the Adriatic Sea, the northernmost basin of the Mediterranean Sea, exhibits substantial **quasi-decadal oscillations of its thermohaline properties**. The nature of the oscillations remained unknown till 2010, when they were related to circulation regimes of the adjacent northern Ionian Sea. Within the northern Ionian, circulation is either **cyclonic,** resulting in advection of highly-saline ultraoligotrophic waters from the Eastern Mediterranean, **or anticyclonic,** resulting in advection of less saline and nutrient-rich waters from the Western Mediterranean into the Adriatic. Type of water which is advected into the Adriatic subsequently influences density of the Adriatic dense waters generated through either wintertime cooling of shallow northern Adriatic shelf waters or through open ocean convection in the 1200 m deep Southern Adriatic Pit. Thus generated dense waters outflow from the Adriatic Sea, and, depending on their density, change vorticity of the northern Ionian Sea. This mechanism is known as the **Adriatic-Ionian Bimodal Oscillating System (BiOS).** A reversal of circulation in the Ionian Gyre from anticyclonic to cyclonic has been observed in the middle of 1997.

The vertical structure of a water column is formed by three layers : **dense and oxygenated waters**, mainly of Adriatic origin (in the **bottom layer**), **salty and warm waters** coming from the Levantine and Aegean basins (in the **intermediate layer**), relatively **fresh water of Atlantic origin (AW)** propagating toward the Levantine **basin over surface**

The Ionian Sea circulation ***reverses*** on decadal scale.
Accordingly, Atlantic Water path is deviated, generating
an ***alternate «dilution»*** of the
North Ionian and Adriatic Sea (A), or Levantine (C)



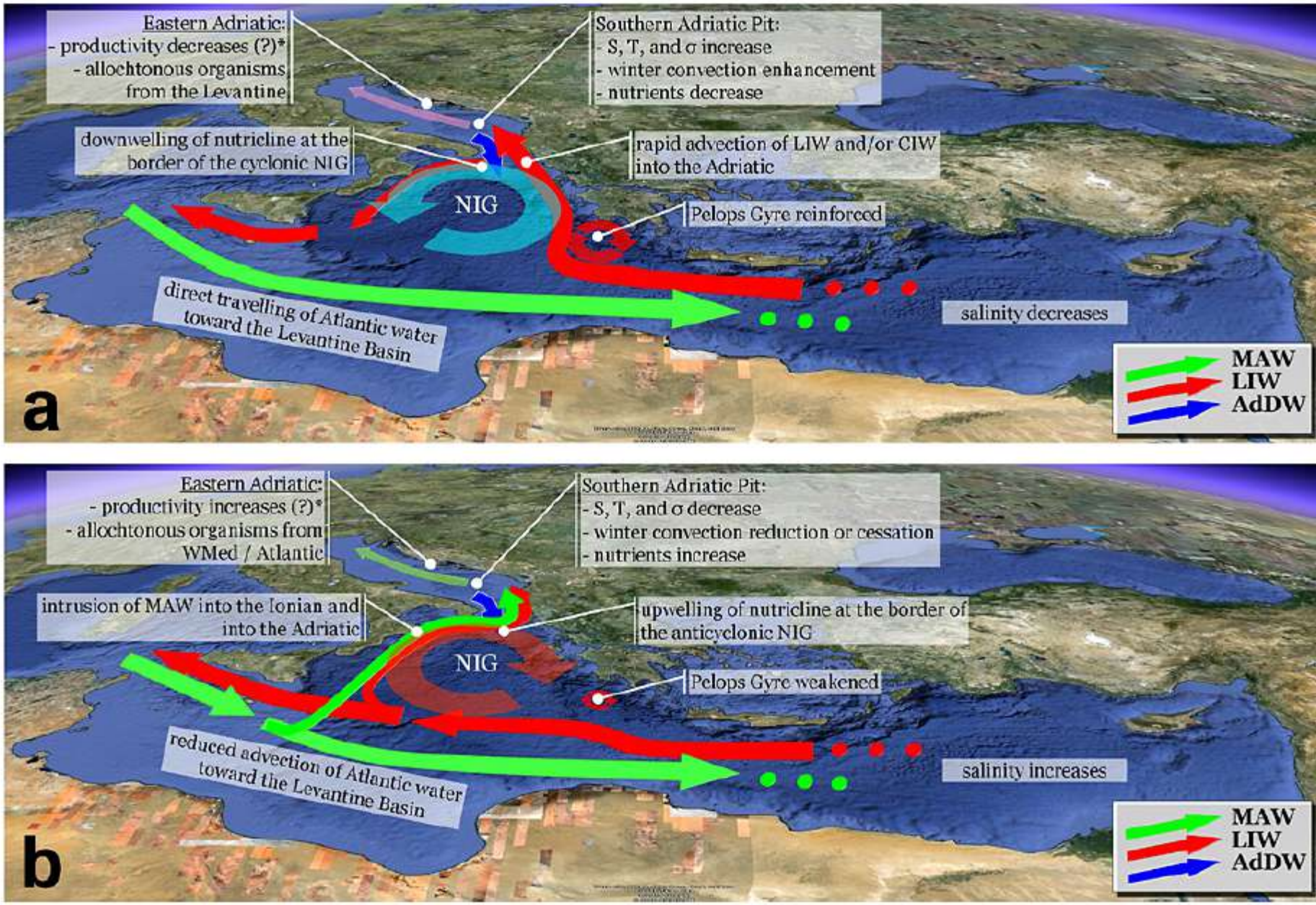
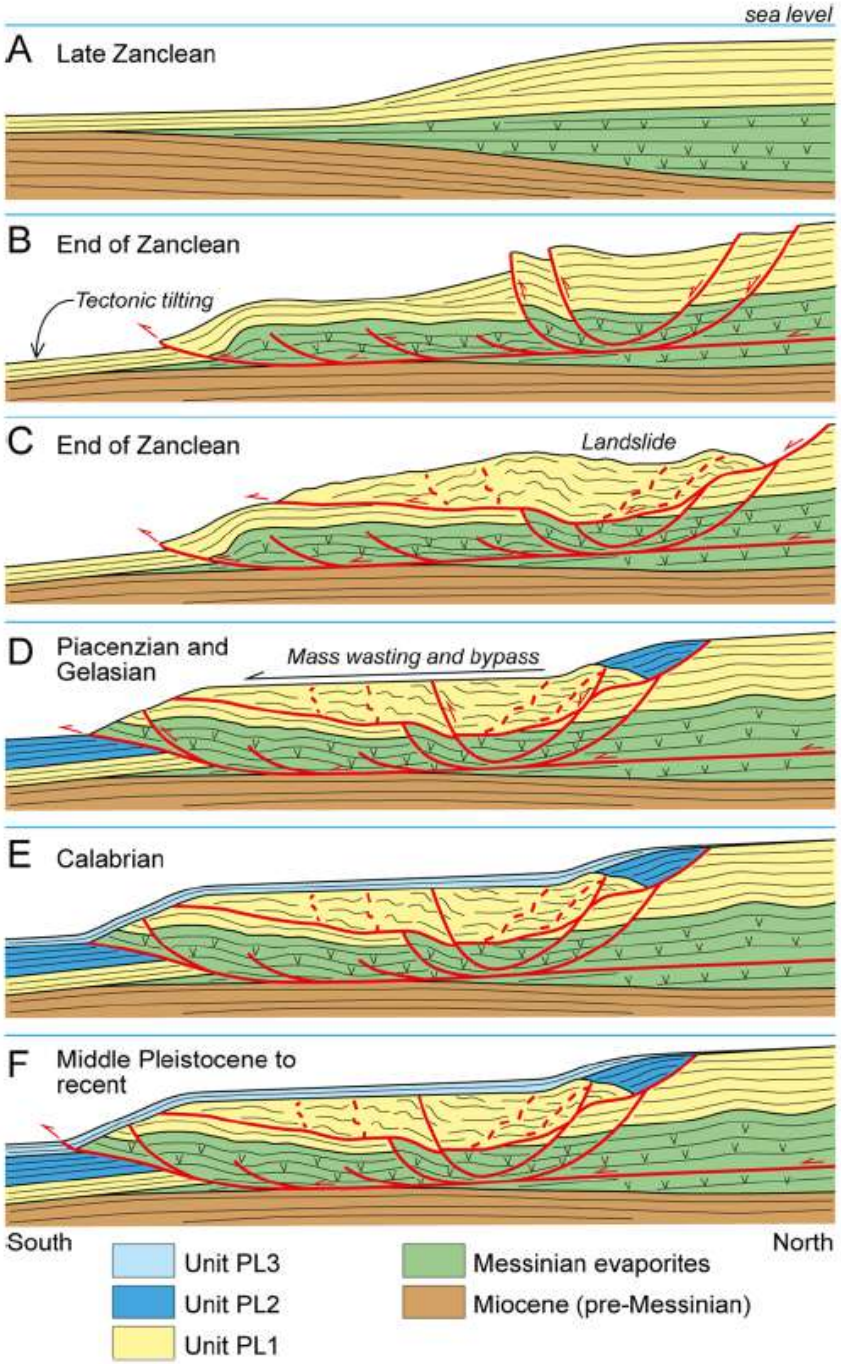
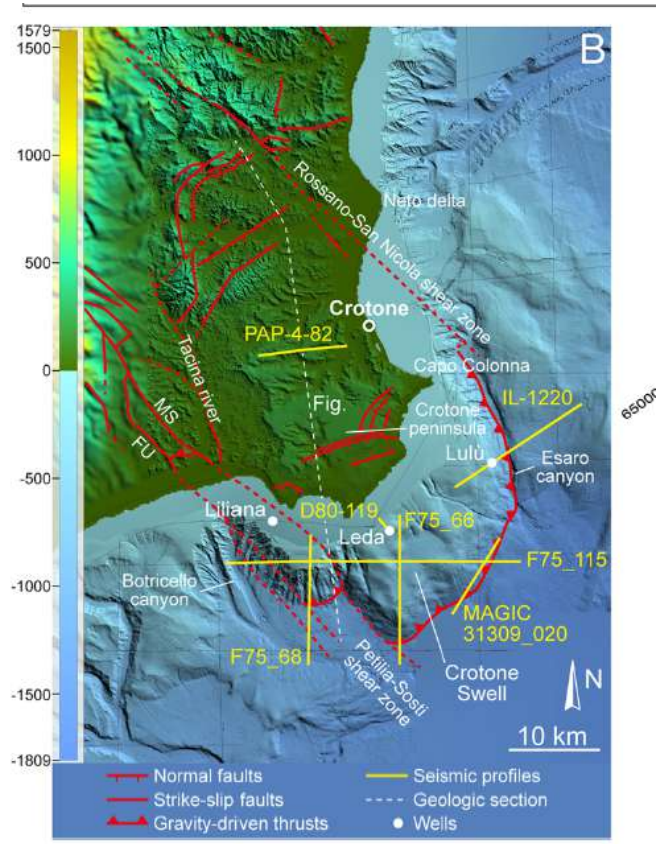


Fig. 5. Summary of the main characteristics of the Adriatic-Ionian BiOS and its impact on the area. **(a)** cyclonic NIG; **(b)** anticyclonic N
* For more detailed explanations, see main text (Sect. 4.2). For acronyms, see main text.

The Crotone Megaslide





Zecchin et al. 2018

Nuovi indizi sulla mega frana di Crotone

04/07/2018

Svelata da Ogs e Cnr la dinamica della frana che da milioni di anni coinvolge l'area costiera e marina a sud della città calabrese, interessando un'area di quasi 500 km^2 e uno spessore di circa 1,5 km. L'indagine, pubblicata su Scientific Reports, ha rivelato che l'evento è avvenuto in due fasi con dinamiche distinte, la prima risalente a circa 3,7 milioni di anni fa e la seconda iniziata circa 500.000 anni fa e tuttora in atto nell'area marina.

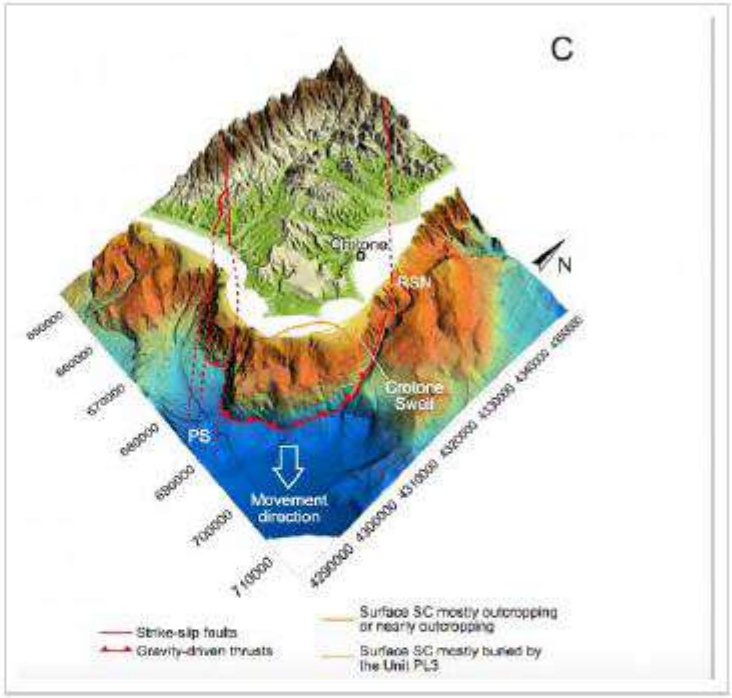


Fig. 1 Mappa del bacino di Crotone

Un gruppo di ricerca guidato dall'Istituto nazionale di oceanografia e di geofisica sperimentale (Ogs), in collaborazione con l'Istituto di scienze marine del Consiglio nazionale delle ricerche (Cnr-Ismar) di Venezia e con le Università di Padova, della Basilicata e della Calabria, ha fatto luce sull'origine del lento e imponente movimento franoso, definito dagli studiosi *megalandslide*, che da milioni di anni coinvolge il settore marino e costiero a sud di Crotone, interessando un'area di quasi 500 km^2 e uno spessore di circa 1,5 km. I risultati sono pubblicati su *Scientific Reports*, rivista del gruppo *Nature*.

Studi precedenti avevano già fornito indicazioni di un fenomeno di scivolamento massivo a scala regionale che coinvolge l'area marina crotonese e l'entroterra per qualche decina di chilometri, ipotizzando un lento movimento del bacino verso il mare. Con questo nuovo lavoro, attraverso diversi metodi di indagine geofisica - analisi di dati sismici, carotaggi profondi, nuovi rilievi morfo-batimetrici e satellitari - i ricercatori hanno ottenuto un'immagine più chiara e dettagliata del fenomeno. "Abbiamo scoperto che il *megalandslide* di Crotone è avvenuto in due fasi e con dinamiche differenti. La prima è stata innescata da un evento tettonico risalente a circa 3,7 milioni di anni fa ed è proseguita per almeno 1 milione di anni", afferma Massimo Zecchin, ricercatore dell'Ogs, coordinatore dello studio e

aratterizzata da uno scivolamento di massa verso mare (in
6,7 mm/anno, e da ulteriori franamenti molto rapidi ora sigillati da
irca 500.000 anni fa, e tuttora in atto nell'area marina, ha avuto una
ore marino della frana che generalmente non superano velocità di 1
biamo accertato che la mega frana scivola sopra una superficie di
abilmente impostata su uno strato di salgemma, che collega un
roterra con uno compressivo in quello sottomarino".

studiato i dati rilevati dai satelliti. "Nel settore di entroterra, le
le misure dei movimenti del suolo attuali ottenute dalle immagini
ilite dell'Agenzia spaziale italiana Cosmo-SkyMed e da registrazioni
ra gli autori dello studio. "L'analisi di questi dati ha evidenziato una
locali, ma non uno spostamento omogeneo con direzione verso
va invece nell'area marina".

ino e di entroterra farebbe escludere l'estensione attuale del
di Crotone, a differenza di quanto ritenuto in precedenza", precisa

no, attualmente molto lento verso sud-est, è un fenomeno naturale
per quanto riguarda la sicurezza della popolazione. Tuttavia,
ano di monitoraggio per controllarne l'evoluzione", concludono i

The Punta Stilo Swell

The Crotone (CS) and Punta Stilo (PSS) swells are two lobate-shaped submerged promontories with steeply-inclined flanks (up to 11°) and are located in the Crotone-Spartivento Basin (CSB) (Calabria region) (Fig. 1a,b,c). The CS corresponds to the downdip compressional domain of a large-scale gravitational collapse that has been involving the N sector of the CSB since Zanclean; it may be seen as a mega-mass-transport deposit and shows signs of activity at present (Fig. 1b) (Minelli et al., 2013; Guerricchio, 2015; Zecchin et al., 2018; Mangano et al., 2020). Conversely, the origin of the PSS, which is marked by slide scars and canyon incisions (Chiocci and Ridente, 2011; Ceramicola et al., 2014a and b; 2015), is still unknown (Fig. 1c).

The PSS is Chiocci and Ridente, 2011; Ceramicola et al., 2014a and b; 2015) shows a prominent lobate morphology and its seismo-stratigraphic succession is composed of various units of Serravallian to Pleistocene age (Fig. 2c,d). Our observations reveal that the PSS is the reflection of the Messinian compressional tectonics. Such tectonic phase is linked to a temporary pause of Calabrian Arc migration and caused the formation of the Upper Messinian Unconformity (Massari and Prosser, 2013). The Upper Messinian Unconformity (UMU) is observed to be folded, to truncate the underlying units of older ages and to be sealed by the Plio-Pleistocene succession. no evidence of slope instability events are recorded inside pre-dating mid-Pliocene units.

The CS is inferred to be the consequence of the mid-Pliocene RSSZ activity-linked compressional/transpressional event. The latter is supposed to have created uplift and promoted the onset of a large-scale slope failure, manifested by the evolution of the swell itself in the offshore area. At a regional-scale, the mid-Pliocene tectonic phase might be