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The Messinian Erosion Surface along the Eastern Sardinian Margin, Western Tyrrhenian: New Insights from Very High-Resolution Seismic Data (METYSS4)

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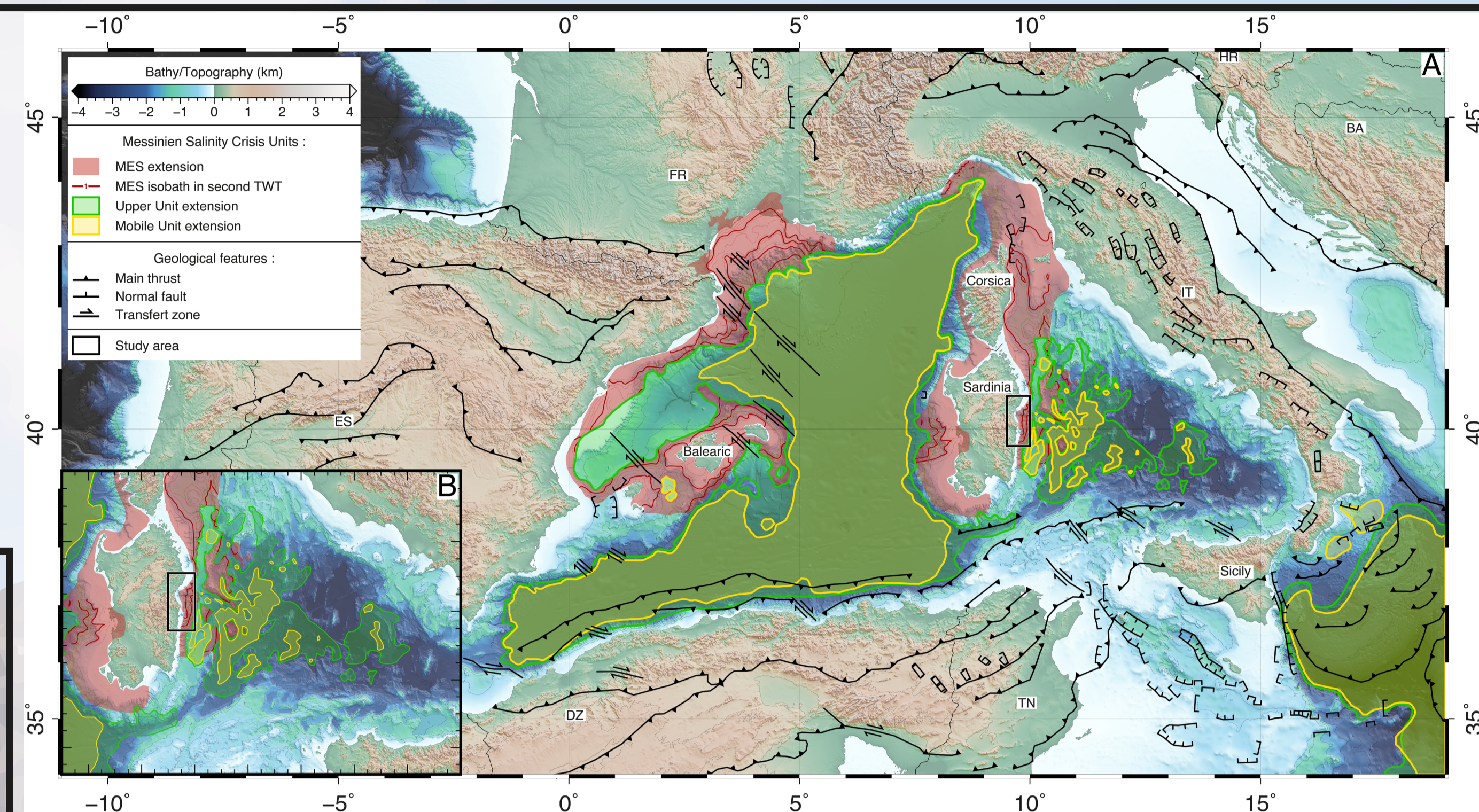
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1 - Introduction

The Eastern Sardinia margin consists in a hyper-extended rifted margin, located in the western Tyrrhenian Sea. This young back-arc basin (late Neogene) is related to the eastward migration of the Apennine-Calabria subduction from middle Miocene to Pliocene times (Jolivet and Faccenna, 2000; Romagny et al., 2020). The end of the rifting phase occurred during the late Tortonian. This area was affected by strong erosion during the Messinian Salinity Crisis (MSC, 5.96 - 5.33 Ma; Hsü et al., 1977) on the continental platform and slope and the deposits of evaporite series (MU and UU) associated with the sea level drop (> 1500

m) [Figure 1.A]. The Messinian Erosion Surface (MES) has already been studied in large fluvial systems (Lofi et al., 2005; Lofi, 2011, 2018; Tassy et al., 2014; Garcia-Castellanos et al., 2020) but not in small and diffuse drainage systems input like in the Gulf of Orsei (East-Sardinia) [Figure 1.B]. The MES was identified in the Cedrino Valley (Giresse et al., 2015), which flows into the Gulf and the East-Sardinia Basin (Lymer et al., 2018a, 2018b) but the relationship between onshore and offshore structures was never studied in this area. The «METYSS 4» cruise provided new very high-resolution seismic data on the continental shelf, allowing us to study this blind spot between onshore and offshore geology.



2 - Objectives of this study

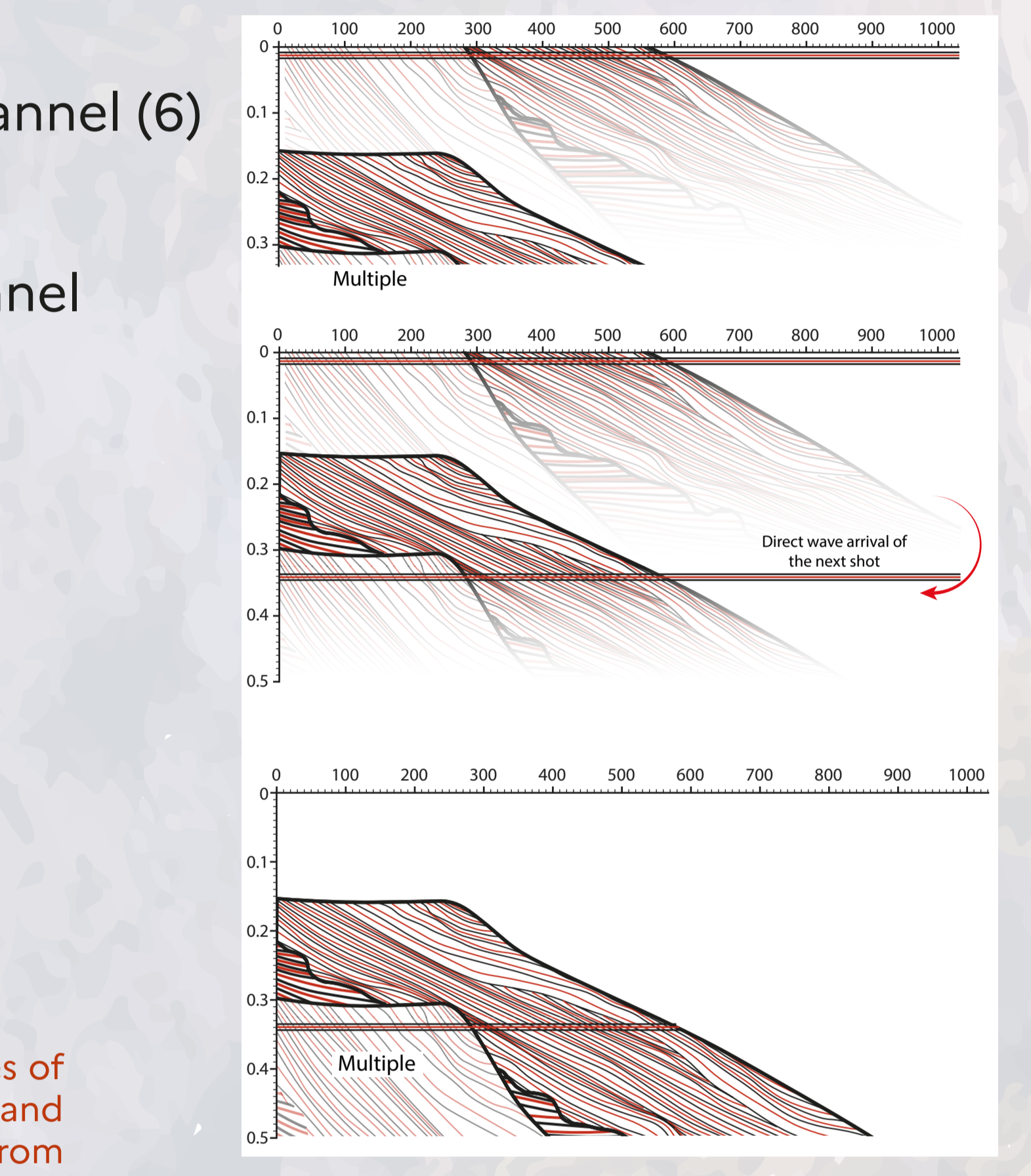
The aim of this study is to provide a new detailed map of the MES in order to: (1) characterize the Messinian fluvial network around the Gulf of Orsei; (2) compare it with the current hydrographic network; (3) establish the link between the continental MES and the offshore deepest units; (4) constrain the role of the Messinian topography and drainage network on the distribution of the Plio-Quaternary (PQ) deposits and subsequent present morphology of the margin.

3 - Dataset and processing

METYSS 1 - 3 (2009 - 2011): Air-gun, multichannel (6)
 • 53 seismic profiles (2 400 km) [Figure 3.1.A]

METYSS 4 (2019): Sparker, 300 J, single channel
 • 286 seismic profiles (2 030 km) [Figure 3.1.B]
 • Average spacing: 1 500 m

Processing (METYSS 4):
 • Bandpass filter (150, 500, 1 000, 1 500 Hz)
 • Mute of the water column
 • Divergence spreading correction
 • Migration in the T-K domain (Stockwell, 1999)



Improving investigation depth (Figure 3.2):
 • Developpement of «SeeDeeper» original method (Sylvain et al., in prep).
 • Seismic trace may end where there still is signal of interest (short shot intervals : 0.333/0.533 ms) and at greater water depths (continental slope, canyons...).

• Use of the signal receive on the trace n+1 to increase investigation depth.

• Copying raw data and concatenating the copied data under raw data with a shift of 1 shot point.

• Bandpass filter (150, 500, 1000, 1500 Hz).

• Water column mute.

4 - Interpretation of erosion surfaces

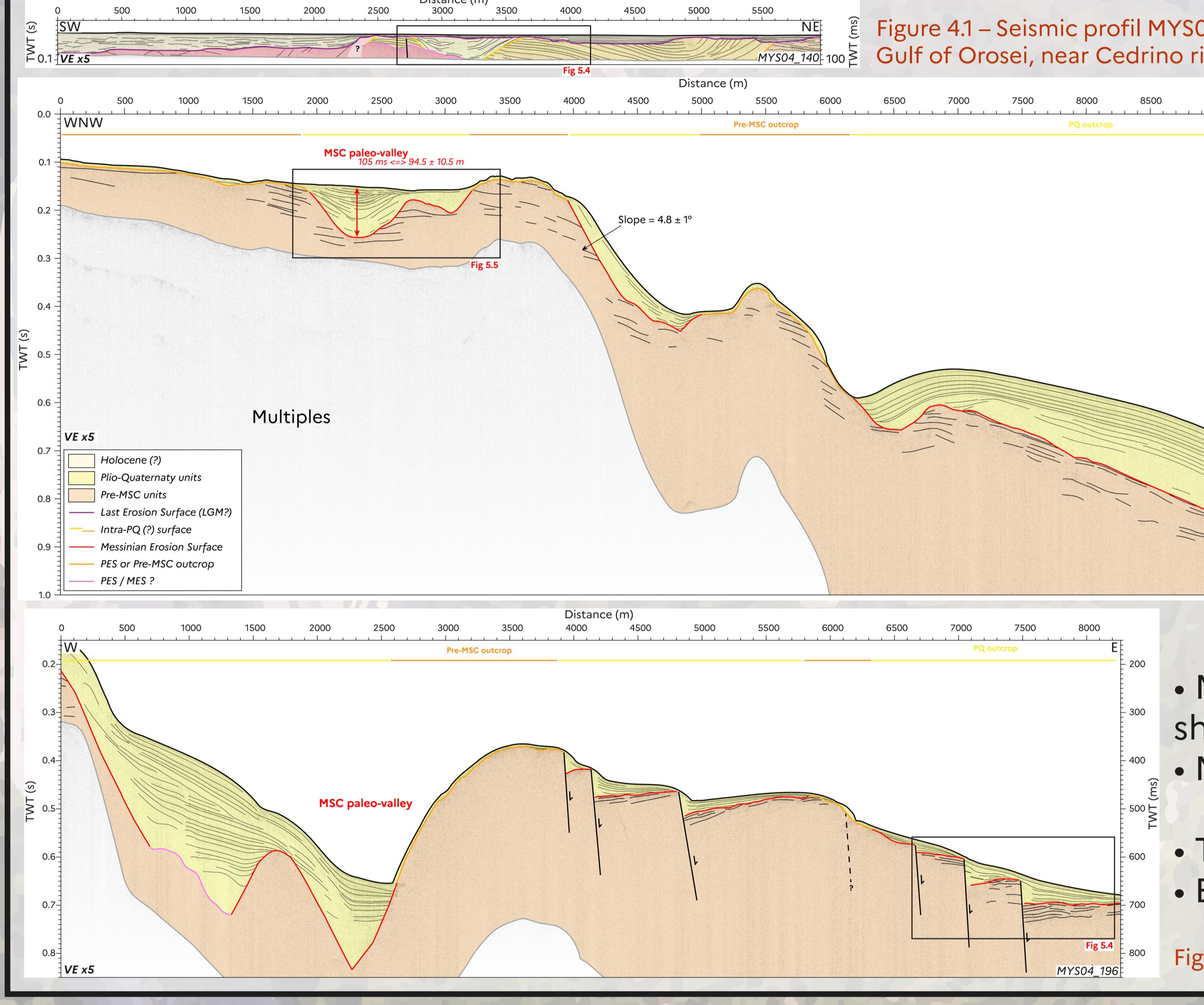


Figure 1 – (A) Regional map of the Western Mediterranean. (B) Map of the Tyrrhenian Sea. MSC units were compiled from Lofi et al., 2005; Sage et al., 2005; Maillard et al., 2006, 2020; Cornée et al., 2008; Lofi, 2011, 2018; Tassy et al., 2014; Thinon et al., 2016; Garcia-Castellanos et al., 2020. Geological features were compiled from Mascle et al., 2012; Romagny et al., 2020. Topography and bathymetry are extracted from the GMRT database (Becker et al., 2009).

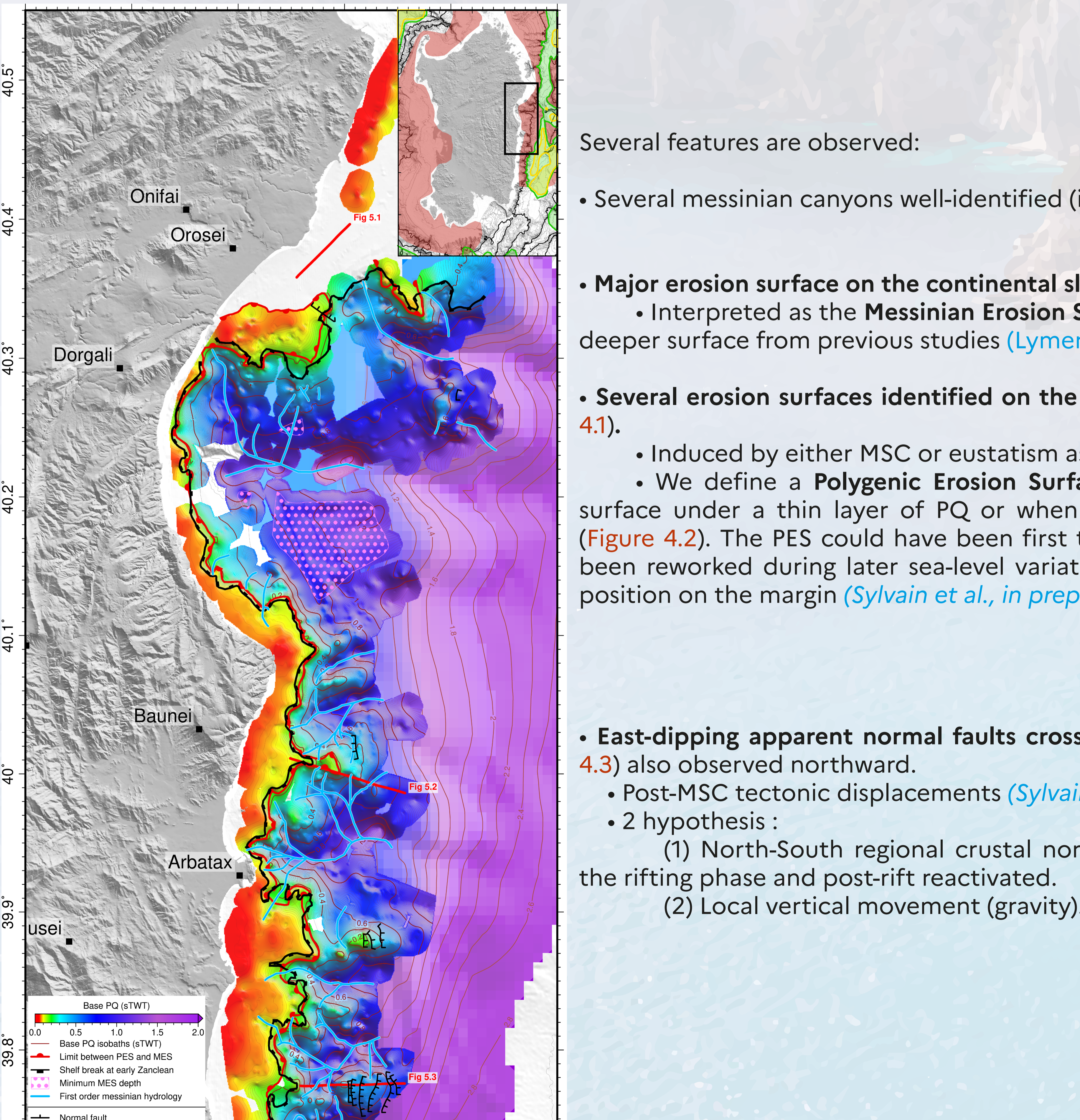
• MES from the continental shelf to the slope.
 • Continental shelf incised by Messinian paleo-valley.

• Topographic high preserved (Figure 4.2).
 Characterized by a seismic facies of high amplitude, medium frequency, and semi-continuous reflectors.

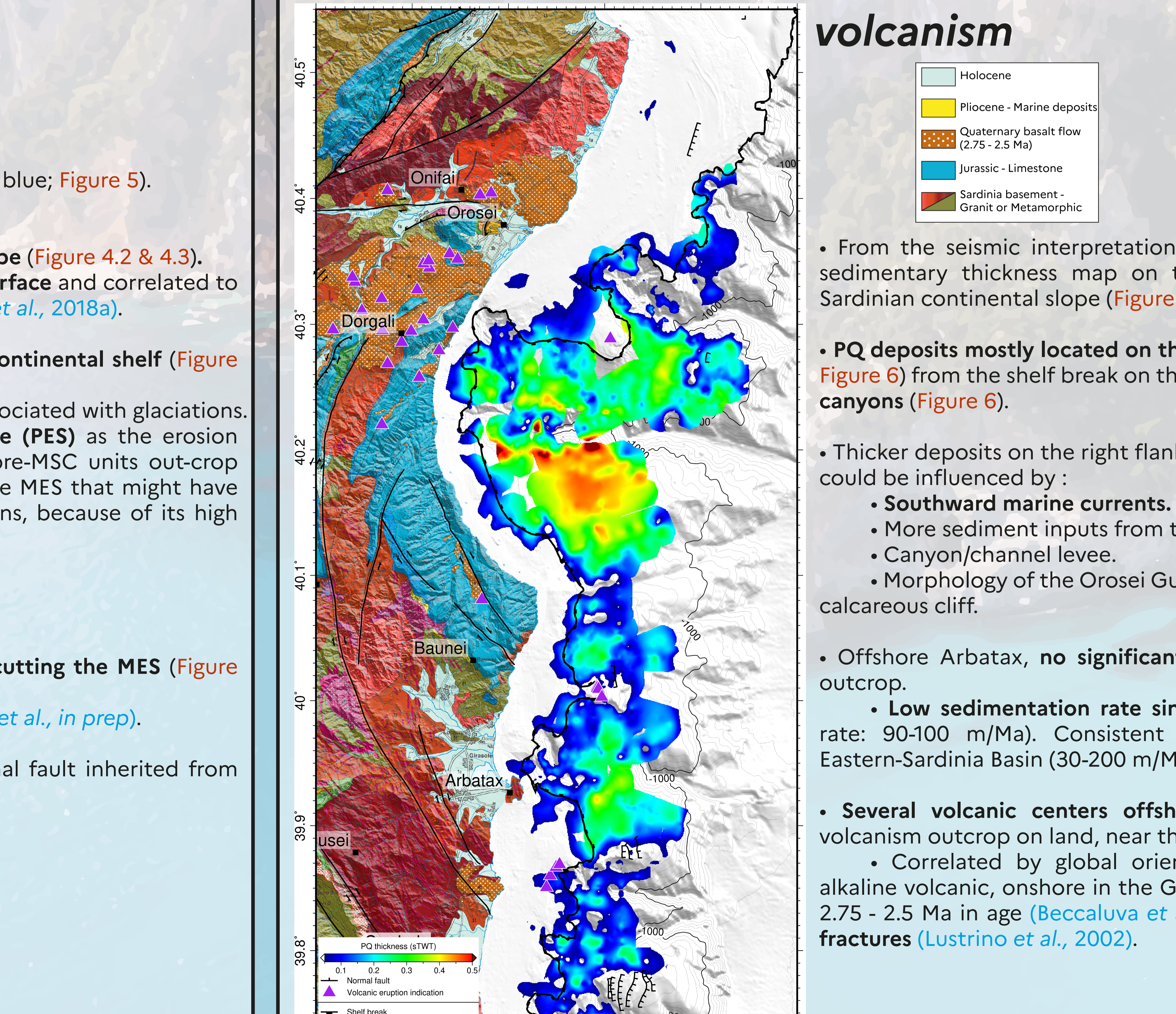
• MES observed from the continental shelf to the slope.
 • Messinian paleo-valley.

• Topographic high preserved
 • East-dipping normal faulting.

5 - Distribution of the Messinian Erosion Surface



6 - Plio-Quaternary sediments deposits and volcanism



Several features are observed:

- Several messinian canyons well-identified (in blue; Figure 5).
- Major erosion surface on the continental slope (Figure 4.2 & 4.3).
 • Interpreted as the Messinian Erosion Surface and correlated to deeper surface from previous studies (Lymer et al., 2018a).
- Several erosion surfaces identified on the continental shelf (Figure 4.1).
 • Induced by either MSC or eustatism associated with glaciations.
 • We define a Polygenic Erosion Surface (PES) as the erosion surface under a thin layer of PQ or when pre-MSC units outcrop (Figure 4.2). The PES could have been first the MES that might have been reworked during later sea-level variations, because of its high position on the margin (Sylvain et al., in prep).
- East-dipping apparent normal faults cross-cutting the MES (Figure 4.3) also observed northward.
 • Post-MSC tectonic displacements (Sylvain et al., in prep).
 • 2 hypothesis :
 (1) North-South regional crustal normal fault inherited from the rifting phase and post-rift reactivated.
 (2) Local vertical movement (gravity).

• From the seismic interpretation, we propose a Plio-Quaternary sedimentary thickness map on the upper part of the Eastern Sardinian continental slope (Figure 6).

• PQ deposits mostly located on the continental slope (Figure 4.2 & Figure 6) but also on the interfluvial and the sides of the canyons (Figure 6).

• Thicker deposits on the right flank of the Orsei Canyon. This area could be influenced by :
 • Southward marine currents.
 • More sediment inputs from the Cedrino River.
 • Canyon/channel levee.
 • Morphology of the Orsei Gulf and occurrence of the emerged calcareous cliff.

• Offshore Arbatax, no significant PQ deposits → pre-MSC units outcrop.
 • Low sedimentation rate since the MSC (maximum average rate: 90-100 m/Ma). Consistent with previous studies on the Eastern-Sardinia Basin (30-200 m/Ma; Giresse et al., 2014).

• Several volcanic centers offshore identified in front of the volcanism outcrop on land, near the coastline.
 • Correlated by global orientation (N-S to NE-SW) as the alkaline volcanic, onshore in the Gulf of Orsei dated late Pliocene 2.75 - 2.5 Ma in age (Beccalova et al., 1983) associated with crustal fractures (Lustrino et al., 2002).

7 - Discussion and perspectives

• We are able to map morphological features of Messinian times (Figure 5) to compare with actual ones (Figure 7).

• Setting up of the canyons during the MSC (?).
 • First-order MSC hydrologic network presents strong similarity to present-day.
 • Arbatax and Orsei Canyon are more meandering today than during Messinian.

• We show a spatial evolution of the shelf break → progradation of the margin.
 • Occurrence of vertical motion of the shelf off the Orsei Gulf or only filling by an important sedimentation (aggradation)?
 • The Orsei Canyon is closer to the coastline now → erosional process at the head of the canyon. This could require further exploration of this area to prevent coastline erosion hazards.

• Strong similarity between present-day and Messinian submarine river suggests no important deformation at regional scale since 5 Ma. However, we can observe local indications of small amplitude tectonic deformation corresponding to small-scale displacements along normal faults.

• This study is the first step to conclude on our objectives. We are going to focus on the link between onshore observation (Giresse et al., 2015) and deepest offshore studies (Lymer et al., 2018; Maillard et al., 2020). The results will be integrated to understand at local and larger scale the tectonic framework from the opening of the Tyrrhenian basin to present deformation.

Figure 5 – Detailed map of the Messinian Erosion Surface on the Eastern Sardinia continental shelf and slope. The previous MES map from (Lymer et al., 2018) is represented by only annotated contour and lower resolution grid.

Figure 6 – Plio-Quaternary thickness map on the Eastern Sardinia continental shelf. Geological map from (Carmignani et al., 2016). Submarine spring location from (De Waele et al., 2009; Romano et al., 2018; Nicod, 2022).

Figure 7 – Comparison between actual and messinian morphological features on today bathymetry.

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