RIFTING AND POST-RIFT REACTIVATION OF THE EASTERN SARDINIAN MARGIN (WESTERN TYRRHENIAN BACK-ARC BASIN) EVIDENCED BY THE MESSINIAN SALINITY CRISIS MARKERS AND SALT TECTONICS

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1. SCIENTIFIC AIMS

The offshore-onshore project METYSS-METYSAR aims at getting a better understanding of the Miocene-Pliocene relationships between crustal tectonics, salt tectonics, and sedimentation along the East-Sardinian margin, Tyrrhenian Basin (**Figure 1**). In this key-area, the Tyrrhenian back-arc basin underwent recent rifting (9-5 Ma), pro parte coeval with the **Messinian Salinity Crisis** (**MSC**, 5.96-5.33 Ma), sea-floor spreading starting during Pliocene times, and post-rift reactivation. Thereby, the Tyrrhenian basin and the East-Sardinian margin are excellent candidates for studying the mechanisms of extreme lithospheric stretching and thinning, the role of pre-existing structural fabric during and after rifting, the reactivation of a passive margin and the associated deformation and sedimentation patterns during the MSC.

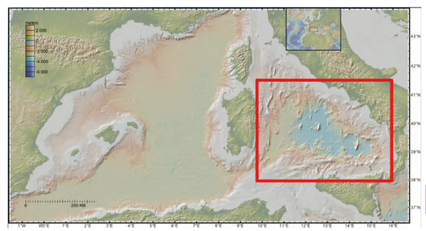


Figure 1. Bathymetric map of the Mediterranean (from GeoMapApp) showing the study area (red rectangle).

2. GEOLOGICAL SETTING

The Tyrrhenian Sea is a Neogene back-arc basin that opened by continental rifting and oceanic spreading related to the eastward migration of the Apennine subduction system from middle Miocene to Pliocene times, linked to the progressive retreat of subducting African slab during convergence between Africa and Europe. Rifting of the southern Tyrrhenian Sea occurred during Serravallian-Tortonian and Messinian times, starting possibly as early as the Langhian, and was followed by sea-floor spreading in a few small deep basins from c. 5 Ma to present-day (Kastens et al., 1988; Mascle and Rehault, 1990; Jolivet and Faccenna, 2000; Sartori et al. 2001; 2004; Doglioni et al., 2004; Carminati et al., 2012) (**Figure 2**).

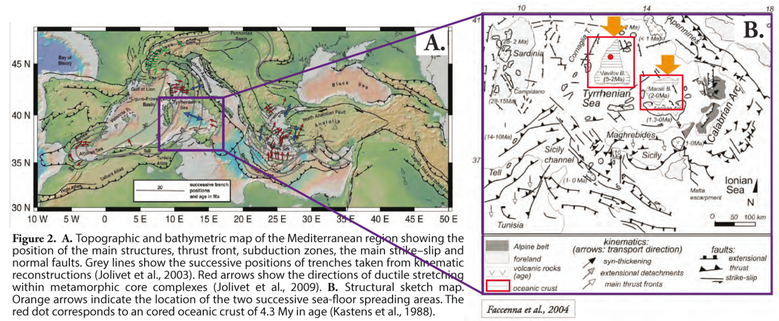


Figure 2. A. Topographic and bathymetric map of the Mediterranean region showing the position of the main structures, thrust front, subduction zones, the main strike–slip and normal faults. Grey lines show the successive positions of trenches taken from kinematic reconstructions (Jolivet et al., 2003). Red arrows show the directions of ductile stretching within metamorphic core complexes (Jolivet et al., 2009). **B.** Structural sketch map. Orange arrows indicate the location of the two successive sea-floor spreading areas. The red dot corresponds to an cored oceanic crust of 4.3 My in age (Kastens et al., 1988).

3. DATA SET

The data set comprises 2400 km of new high-resolution seismic profiles acquired onboard the R/V "Téthys II" (METYSS 1-2009 and 3-2011) and 4 field trips in the Orosei area (**Figure 4**).

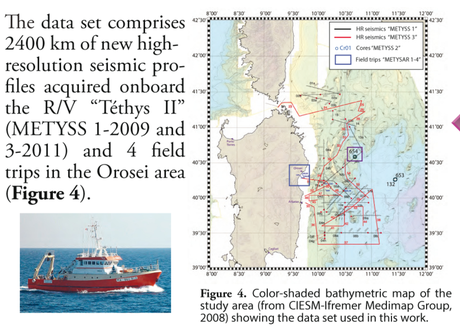


Figure 4. Color-shaded bathymetric map of the study area (from CIESM-Ifremer Medimap Group, 2008) showing the data set used in this work.

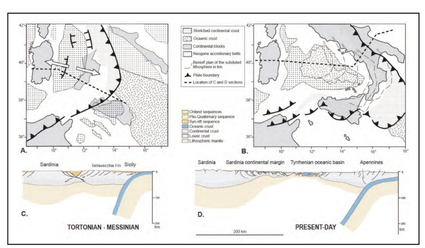


Figure 3. Geodynamic setting of the Tyrrhenian Sea. A: Geodynamic map reconstruction during Tortonian-Messinian times (6.5-5.3 Ma) (modified from Jolivet et al., 2006). The dotted bold black line shows the location of cross section C. B: Present-day geodynamic map showing the distribution of the oceanic domains and zones of stretched continental crust (modified from Jolivet et al., 2006; Faccenna et al., 2005). Dotted grey lines represent the depth of the Benioff zone, top of the descending Ionian slab (Sartori et al. 2004). The dotted bold black line shows the location of cross section D. C. and D: Schematic cross sections, respectively for Tortonian-Messinian and Present-Day times (modified from Sartori et al., 2001 and 2004; Spakman and Wortel, 2004; Jolivet et al., 2006).

4. METHODS

We use **the MSC seismic markers and the deformation of viscous salt and its brittle overburden** as proxies to better delineate the timing of rifting and post-rift reactivation, and especially to quantifying vertical and horizontal movements **(Figure 5).**

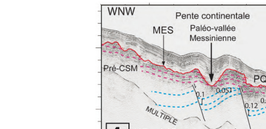
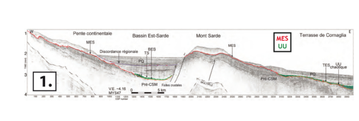


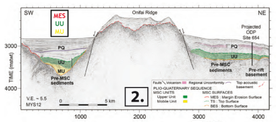
Figure 5. Idealized schematic cross section for the western Mediterranean basin, illustrating the geometric organization of the MSC seismic markers in the offshore domain if no salt movement had occurred (Lofi et al., 2011a and 2011b). MSC: Messinian Salinity Crisis, MES: Margin Erosion Surface, BES: Bottom Erosion Surface, BS: Bottom Surface, TES: Top Erosion Surface, TS: Top Surface, UU: Upper Unit, MU: Mobile Unit, LU: Lower Unit, CU: Complex Unit (Lofi et al., 2011).

5. RESULTS

A. MSC SEISMIC MARKERS

5.1. PRE-MSC RIFTING





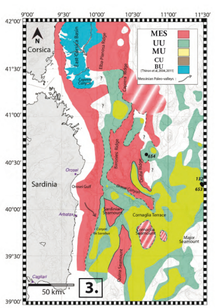


Figure 7. 1. "METYSS 3" seismic profile (location in yellow on **Figure 6**) illustrating the relationships between the MES and UU on the East-Sardinia Basin. **2.** "METYSS 1" seismic profile (location in black on the middle insert) illustrating the relationships between the MES and Messinian Units (UU and MU) on the Cornaglia Terrace. **3.** Distribution map of the MES, UU and MU.

The distribution map of the Messinian Erosion Surface (MES) and of the Messinian units (Upper and Mobile Units) testify for the existence of a rifted basin already created by the time of the Messinian Salinity Crisis. It demonstrates therefore **major pre-MSC rifting over the whole domain** (**Figure 7**).

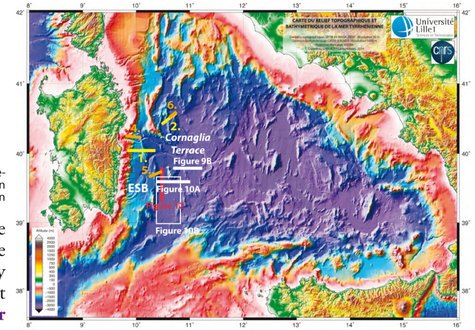
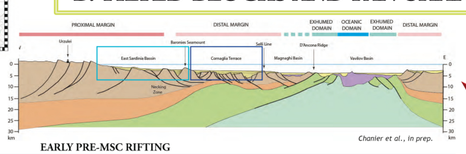


Figure 6. Bathymetric and topographic map of the Tyrrhenian Basin and surroundings areas. The yellow, orange, white and red lines show the location of the "METYSS" seismic profiles illustrated in the RESULTS section. ESB: East-Sardinia Basin.

B. TILTED BLOCKS AND FAN-SHAPED SEDIMENTS



Our seismic data surprisingly showed that there are no clues for Messinian syn-rift sediments along the East-Sardinia Basin and Cornaglia Terrace, hence **no evidence for rifting after Late Tortonian times** (**Figure 8**).

Figure 8. "METYSS " seismic profiles (location in orange on **Figure 6**) illustrating the tilted blocks and associated fan-shaped sediments (**in blue**) resulting from a pre-MSC rifting. We can notice that rifting stops earlier westward, i.e. in the East-Sardinia Basin. **Dashed pink lines** correspond to post-rift pre-MSC sequences (4 and 5). Further East, on the Cornaglia Terrace (6), there is no pre-MSC post-rift sequence, UU corresponding the the first post-rift unit.

A. SALT TECTONICS

In un-confined basins, such as on **Figures 9 and 10**, **salt tectonics is huge**. There is apparently no basal slope of regional scale below salt. Moreover, no salt-related extensional structures, such as upslope normal faults, are visible along the basement highs that could attest for gravity gliding (**Figure 11A**). We therefore conclude that, there, the main driving process for generating salt structures (mainly diapirs) is local gravity spreading related to differential sediment loading (Figure 11B), or downbuilding (Figure 11C). Moreover, **salt tectonics starts very early, during the UU deposition**, suggesting an early differential sedimentary overload, even weak. It also means that diapirs are created by extensional process (Gaullier and Vendeville, 2005).

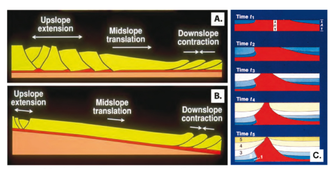


Figure 11. A. Gravity spreading. B. Gravity gliding. Salt is in red, sedimentary cover is in yellow (Vendeville, 2005). C. Down-building (Vendeville, pers. comm., from Barton, 1933).

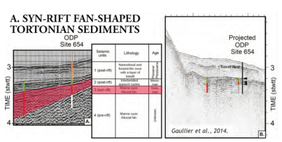


Figure 9. Examples of fan-shaped sediments due: A. To crustal tectonics, i.e. rifting; B. To thin-skinned tectonics, i.e. diapirism.

Because salt tectonics can create fan-shaped geometries in sediments, syn-rift deposits have to be carefully re-examined in order to decipher the effects of crustal tectonics (rifting) and thin-skinned salt tectonics (**Figure 9**).

5.2. POST-RIFT DEFORMATION

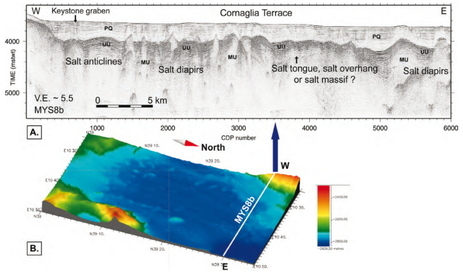


Figure 10. A: Part of seismic line MYS08b (Location on Figure 6) illustrating intense salt tectonics and various associated salt structures in an un-confined basin, on the Cornaglia Terrace. B: Color shaded multibeam bathymetric close up showing salt-related sea-floor deformation with isolated or aligned salt diapirs. The location corresponds to the white rectangle on Figure 6. Bathymetric data are modified from CIESM-IFREMR MediMap Group et al. (2008).

B. POST-RIFT REACTIVATION EVIDENCE BY SALT TECTONICS

Our data show that there is no evidence for rifting processes after Late Tortonian times. Nevertheless, widespread deformation occurs during the Pliocene and is therefore attributed to **post-rift reactivation. This post-rift tectonics is characterized not only by normal faulting but also by contractional structures** (**See Chanier et al., this meeting**). **Some Pliocene vertical movements have been evidenced by discovering localized gravity gliding of the salt and its Late Messinian (UU) and Early Pliocene overburden. To the South of the study area, crustal-scale southward tilting triggered along-strike gravity gliding of salt and cover recorded by upslope extension and downslope shortening (Figure 12).**

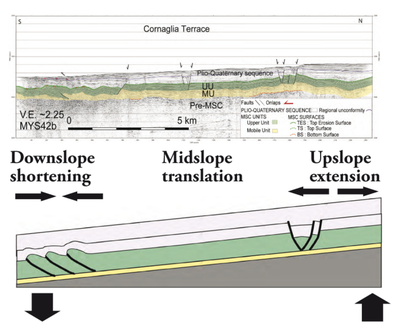


Figure 12. Example of late gravity gliding due to crustal vertical movement.

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Cited references: see the annex sheet.