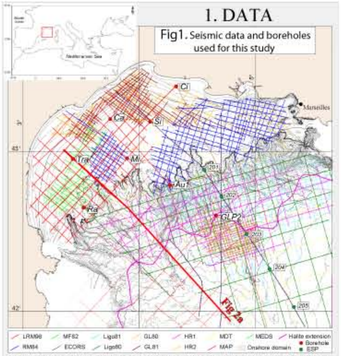
Messinian Events: View from the Provence Basin (Gulf of Lion, Western Mediterranean)

* francois.bache@upmc.fr

Bache, F.*[1]; Gorini, C.[1]; Olivet, JL.[2]; Rabineau, M.[3]; Aslanian, D.[2]; Suc, JP.[4]

1. iSTeP. UMR 7193 CNRS/Université Pierre et Marie Curie. Paris. France
2. Ifremer. Géosciences Marines. Plouzané. France
3. IUEM. Domaines océaniques. UMR 6538 CNRS/Université de Brest. Plouzané. France
4. Laboratoire PaléoEnvironnements et PaléobioSphère (UMR 5125 CNRS/Université Claude Bernard-Lyon 1

1. DATA



One of the major asset of this study has been the large amount of data collected in the area for both industrial and academic purposes. A partnership with Total gave us access to an exceptional set of conventional and high-resolution seismic reflection data from the coast to the deep domain. Seismic interpretation has been performed using the principles of seismic stratigraphy (Vail et al., 1977). We identified seismic units based on terminations and configurations of seismic reflections generated by sedimentary strata. The large coverage of seismic data enabled us to map these units in 3D in the entire Gulf of Lion. Further data were obtained from the logs of nine industrial boreholes that sampled the sedimentary cover down to the substratum. A detailed micropaleontological study (Cravatte et al., 1974) provided informations on the stratigraphy and depositional environments of the Miocene, Pliocene and Quaternary successions in four wells (Mistral1, Sirocco1, Autan1 and Tramontane1). The Ecors programme (De Voogd et al., 1991) provided three general seismic sections across the entire margin, completed by a series of ESP (Expanding Spread Profiles) (Pascal et al., 1993). ESP data were used to obtain propagation velocities from which it was possible to evaluate the thickness of the series from the seismic data (time-depth conversion), thus giving access to volumes of particular units.

2. EROSIONAL AND SALINITY CRISES

We illustrate our interpretation of the Messinian evolution of the Provençal Basin in Figures 4a and 4b. Following an initial and limited Messinian regression (Clauzon et al., 1996) (Figs 9a and 10a), we recognize four major phases.

The first phase is marked by a major detrital event, underlying the lowermost evaporite and related to the major drop in the Mediterranean sea level (yellow areas in Figs. 2a, b, c). The Miocene shelf thus became a centre of active erosion (Fig. 2b) producing the surface at the base of Messinian units (Figs. 2a, b). We attribute its prominence to the major phase of drawdown, and the first indication of the Messinian Crisis. Our interpretation means that this major pre-evaporite episode in the central basin therefore cannot correspond to the evaporite sequences in the marginal basins. This phase corresponds to the major sediment transfer of the Messinian Crisis, which built detrital wedges of thickness as much as 1000 m at the outlet of the Messinian rivers, and in the order of 800 m in the basin (Fig. 2c, d). The huge phase of erosion affects the Rhône Valley and the continental shelf as soon as these domains are subaerialy exposed. During this first phase, the supply of oceanic water (i.e. the input of salt and thus its concentration) is not sufficient for precipitate thick evaporites in the central basin (visible at the seismic resolution). This scenario precludes the assumption that central basin evaporites partly deposited before the major phase of erosion (Krijgsman et al., 1999; Krijgsman and Meijer, 2008).

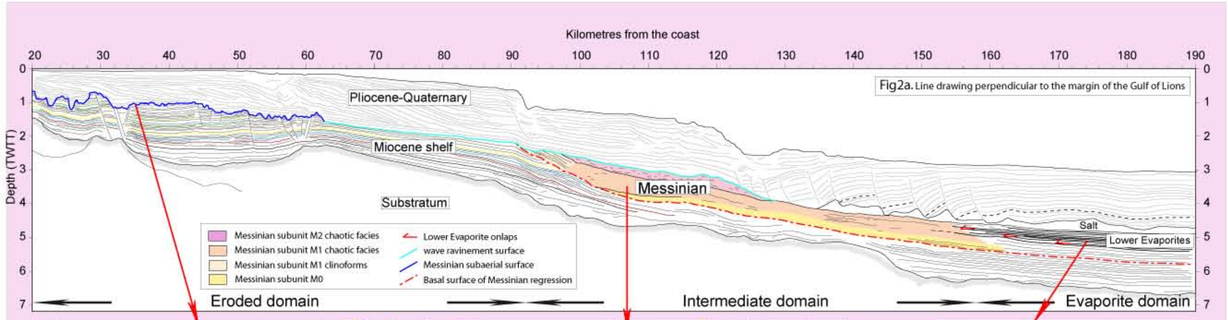
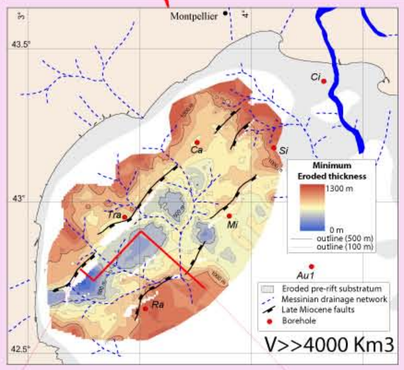


Fig2a. Line drawing perpendicular to the margin of the Gulf of Lions



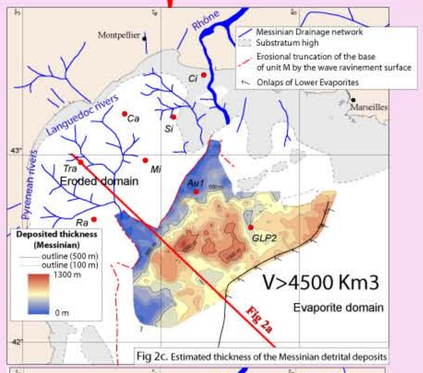


Fig 2c. Estimated thickness of the Messinian detrital deposits

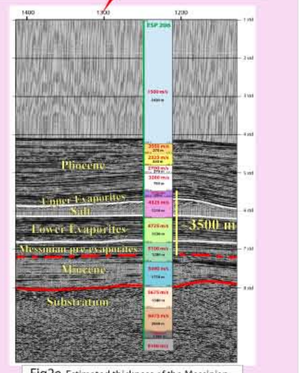


Fig2e. Estimated thickness of the Messinian units in the basin

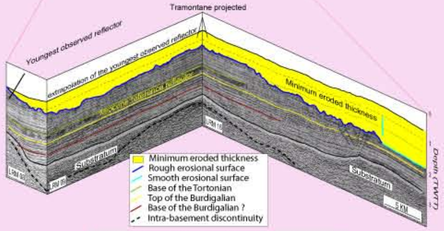


Fig 2b. Estimated thickness of the Miocene sediments eroded during the Messinian Event

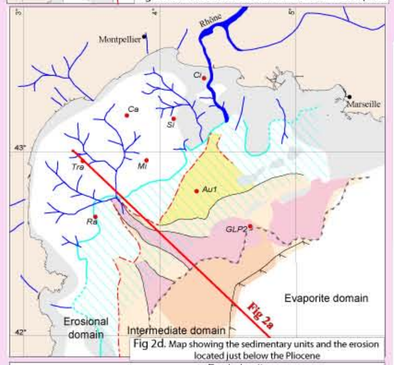


Fig 2d. Map showing the sedimentary units and the erosion located just below the Pliocene

The second phase (Figs. 4a and 4b) corresponds to a strong change in the sedimentary regime as shown by the onlaps of the sediments during this phase (LU1) onto the underlying layer (Fig. 2a). As the sea drawdown progresses, sedimentation evolves from the first detrital event (phase 1) to a massive salt deposition (at the top of LU1 unit) resulting from the continuous input of marine waters within the almost desiccated basin. The corresponding seismic facies is comparable to that of the Upper Evaporites facies comprising of halites, gypsum, anhydrite, lacustrine mud and marls with clastics reworked from the margin. Therefore, we attributed LU1 to the onset of evaporite/detrital deposition in the central Provençal Basin. These "Lower Evaporites" present a thickness of ~1500 m (Fig. 2e), much higher than what was assumed previously (500 to 600 m) (Montadert et al., 1978; Lofi et al., 2005).

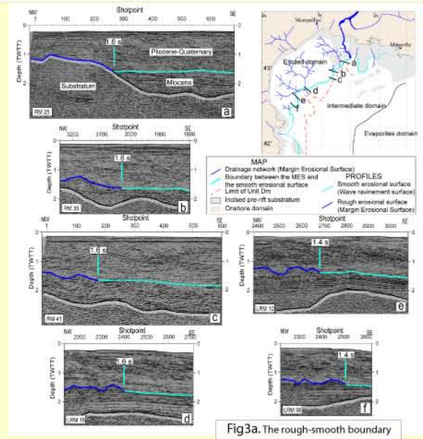


Fig3a. The rough-smooth boundary

3. REFLOODING

The third and the fourth phases correspond to a two-step trangression at the end of the crisis. An initial relatively slow sea level rise (Figs 4a and 4b) permitted the development of a transgressive surface with smooth topography (light blue line) identified previously on seismic profiles. These flatten the top of regressive prisms and represent the limit between Messinian and Pliocene deposits (Figs. 3a, b). During this relatively slow landward migration of the Messinian shoreline, the continuous action of waves and tides smoothed the reliefs of the Messinian erosional surface. This interpretation is supported by the presence of 30m of azoic sand at the top of the evaporites in the GLP2. This unit, described by Gorini (1993), could correspond to the transgressive sand from the upstream marine abrasion by wave ravinement. The fourth phase corresponds to the Zanclean rapid reflooding (Hsü et al., 1973a; Clauzon and Cravatte, 1985; Pierre et al., 1998; Blanc, 2002; Lofi et al., 2005) and has been precisely dated at 5.33 Ma (Hilgen and Langereis, 1993; Van Couvering et al., 2000; Lourens et al., 2004). It is clearly marked by the transition between two morphologies (rough and smooth), at a constant two-way traveltime/depth of 1.6 seconds over the entire shelf (Fig. 3a). Up to this two-way traveltime depth, the irregular 'rough' or badland topography (of MES) illustrates the Messinian paleogeography as it was at the end of the Messinian erosional period (Figs. 3a and 3b, in dark blue). This rapid reflooding implies a cessation of the action of waves, which has preserved badland morphologies. The change in morphology corresponds therefore to the transition between a subaerial erosion (rough morphology) and a submarine erosion (smooth morphology). In this scenario, the 1.6 second limit corresponds to the position of the paleoshoreline at 5.33 Ma and is an appropriate marker for subsidence studies. We therefore quantify an average amount of subsidence of ~300 m/My at this point for the last 5.33 My. This value is consistent with the value calculated using Plioquaternary geometries on the shelf (Rabineau et al., 2006).

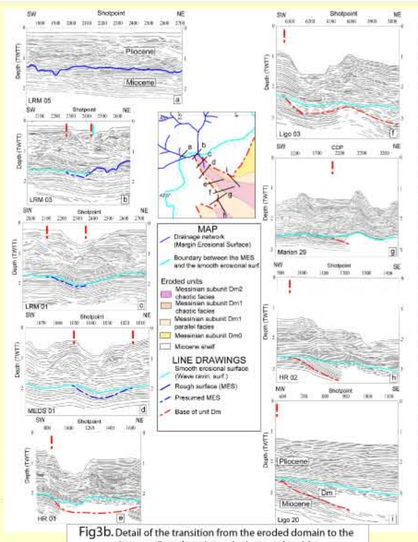


Fig3b. Detail of the transition from the eroded domain to the intermediate domain on the Languedoc side

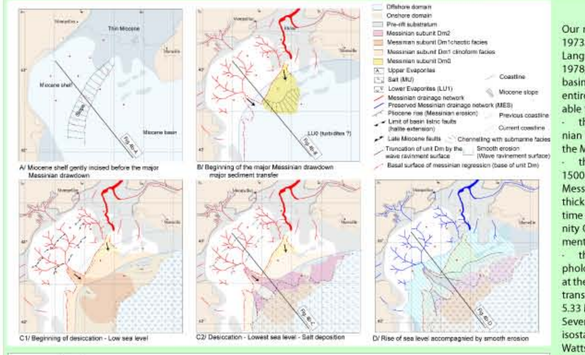


Fig 4a. Paleogeographic synthesis of the observations made over the entire Gulf of Lion margin

4. CONCLUSION

Our results support the deep-desiccated evaporite basin hypothesis (Hsü et al., 1973a): thick detrital deposits at the outlet of the Messinian Rhône and Messinian Languedocian and Pyrenean rivers are, as would be expected (Ryan and Cita, 1978; Clauzon, 1982), present at the transition between the Miocene shelf and basin. On the basis of depositional geometries, studied for the first time over the entire margin and down to the central basin of the Western Mediterranean, we are able to underscore the following points:

- the evidence of a pre-evaporite phase corresponding to a prominent "Messinian Erosional Crisis" responding to the major Messinian drawdown (~1500 m) of the Mediterranean seawater.
- the probable presence of a "Lower Evaporites" series (with a thickness up to 1500 m) located below the salt sequence. This implies that the total thickness of Messinian deposits in the basin should as much as 3500 m (including the salt). This thickness also implies that the depth of the basin was already significant at the time of their deposition. The basin was gradually filled during the Messinian Salinity Crisis. This infilling would have had a significant effect on the vertical movements of the basin.
- the characteristics of the final discontinuity surface and of two types of morphology (rough and smooth) provides evidence of the basin being resubmerged at the end of the Messinian Crisis. This refilling was first moderate accompanied by transgressive ravinement and later rapid (so as to "preserve" the paleoshoreline at 5.33 My and the Margin Erosion Surface).

Several authors have tried to study the subsidence in the Provençal Basin and the isostatic readjustments related to the Messinian Crisis (Ryan, 1976; Steckler and Watts, 1980; Burrus and Audebert, 1990). The view that we outline provides new fodder for the study of subsidence of the Provençal Basin and better understanding its structural evolution.

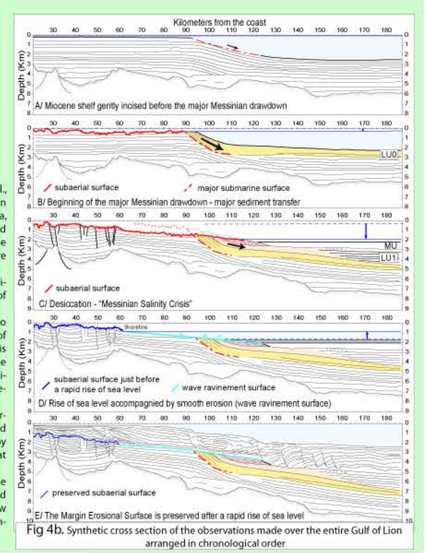


Fig 4b. Synthetic cross section of the observations made over the entire Gulf of Lion arranged in chronological order