

The Messinian Salinity Crisis Record in the Palma Basin (Mallorca, Balearic Islands, Western Mediterranean)

Guillem Mas and Joan J. Fornós

Karst and Littoral Geomorphology Research Group, Universitat de les Illes Balears, Mallorca (masgornals@gmail.com)

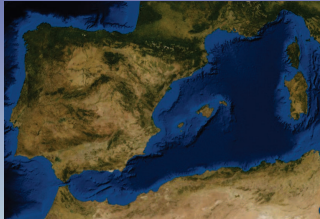
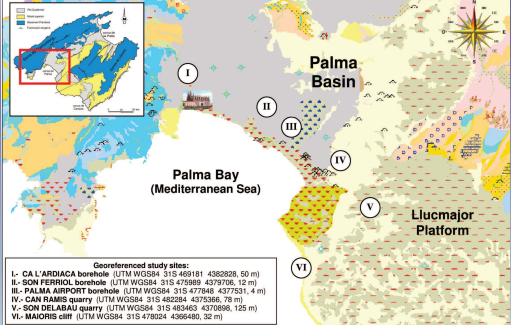
Introduction

The island of Mallorca (Balearic Islands) constitutes the most important emerged segment of the so-called Balearic Promontory, which constitutes the North-eastern prolongation of the external zones of the Betic Cordillera (East Spain) into the Mediterranean Sea and the southern margin of the so-called Valencia Through.

The neogene Palma basin, located in the SW of the island of Mallorca, is limited by the NW for the reliefs of the Tramuntana Range, by SE the Lluçmajor Platform, on the NE by the Marratxí anticline-like reliefs and the SW by the Palma Bay. The basin responds to half-graben developed over an extensional stress field active until Quaternary times. It outcrops mainly post-Alpine materials largely covered by Quaternary deposits.

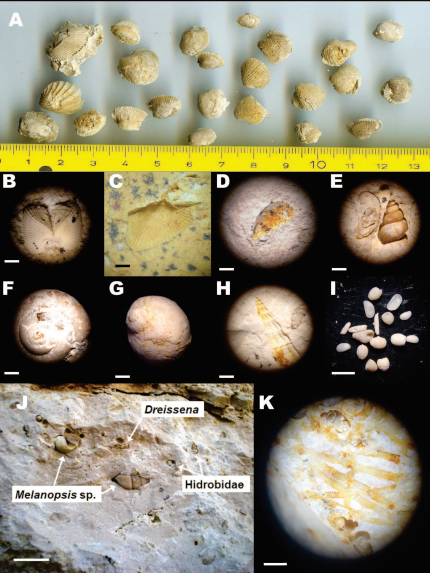
During the Messinian Salinity Crisis (MSC) the desiccation of the Mediterranean caused the deposition of thick evaporites in the deep basins and the emergence of its margins. Onshore, in the marginal (or peripheral) basins, evaporite deposits and erosional surfaces also exist and their nature, position and timing are still debated (Rouchy & Caruso, 2006; CIESM, 2008). Some authors correlate the marginal evaporites with the deep Mediterranean lower evaporites and the Terminal Carbonate Complex (TCC, Esteban, 1979, 1996) with the upper evaporites (Rouchy & Saint Martin, 1992; Bourillot et al., 2010), while others maintain that the marginal evaporites are partly coeval with the TCC (Esteban, 1999; Cornée et al., 2002, 2003; Lu, 2006).

The neogene Palma basin was poorly studied in relation to the new MSC scenario. In this study six georeferenced sedimentological sections (representative outcrops, quarry sections and boreholes), located along an East-West basin transect, are analysed in order to reconstruct a MSC tentative scenario. The main discontinuities, stratigraphic geometries and facies changes were characterized in terms of major surfaces, lateral correlation and vertical facies organization.



	QUATERNARY	PLIOCENE
	Sant Jordi Sandstone	
	Coquina	
	Amusium Calcilit.	LAGO - MARE
	Microbialites	
	Mud-dominated	REF. UNIT
	Halimeda beds	
	Slope - open platform clinobeds	

PALMA BASIN LAGO-MARE FAUNAL ASSEMBLAGES



A) *Lymnocyprina* (scale in cm), B) *Lymnocyprina adriaticum* Gillet, 1969, specimen with articulated valves; C) *L. adriaticum*; D) *Dreissena* ex gr. *D. rostriformis* (Deshayes, 1838); E) *D. rostriformis* & *Hydrobiidae* (cf. *Saccia*); F) pulmonate gastropod (*Hydrobiidae-Hydrobiidae*); G) *Tridacna* sp.; H) *Melanopsis* sp.; I) charophyte oogones, ostracods (*Cypridae*) & faecal pellets; J) *Melanopsis* sp.; *Dreissena* sp. & *Hydrobiidae*; K) charophyte stems (*Chara* sp.). Scale bar = 2 mm, except J) = 10 mm.

Discussion

In the Palma basin, the base of the TCC overlaps marginwards the eroded and karstified Top Reef Unconformity (TRU), that constitutes a major erosion surface (BES - Bottom Erosion Surface).

Along the north-western margins of the Palma basin, coinciding with the base of the main reliefs, the TCC unit grades into fan-delta marls and conglomerates (derives from the close reliefs denudation) which also overlie the TRU.

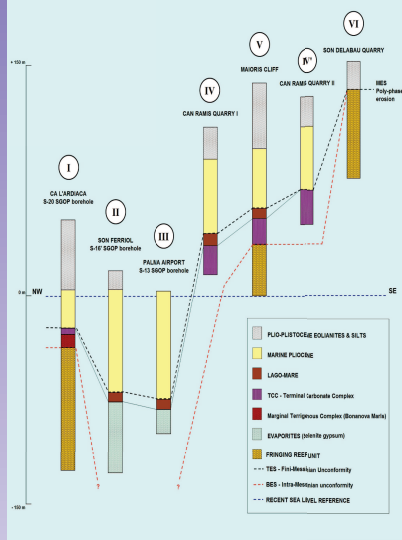
The TCC deposits change basinward into evaporites. Thus, in this basin, the Messinian evaporites (massive selenite gypsum and sapropels in the basinward areas) are coeval with the TCC (oolites and microbialites in the marginward part).

The TCC unit shows abundant desiccation cracks but no any major intra-erosion surface.

The Lago Mare unit constitutes a marker bed, since both, evaporites in the basinward areas and TCC in the margins, are roofed directly by continental deposits of the Lago Mare unit.

Synsedimentary evaporite deformation and dissolution may have affected the geometry (brecciation, fracturing and gliding) of TCC and Lago Mare deposited sequences.

At the beginning at Zanclean, an abrupt and wide marine flooding overlies a new erosion surface (M/P boundary) in the basin.



Conclusions

In relation to the manifestations of the crisis of salinity in the Mediterranean marginal (or peripheral) basins, the section of the Palma basin illustrates the following sequence of events:

- 1) pre-evaporitic or pre-crisis marine sedimentation represented by the Reef Unit;
- 2) first fall of sea level and erosion recorded by an intra-Messinian discontinuity (MES or TRU);
- 3) sedimentation for a sin-evaporitic episode, represented by the materials for the Terminal Carbonate Complex (TCC) and evaporites;
- 4) lacustrine post-evaporitic sedimentation corresponding to the Lago Mare Unit;
- 5) second fall in sea level recorded by the fini-Messinian discontinuity (TES - Top Erosion Surface); and
- 6) re-flooding of the basin and marine sedimentation post-crisis, characterized by the Son Mir Calcsiltites and Sant Jordi Calcarentes Pliocene units.

Assuming the desiccated deep basin model, either discontinuities (intra- or fini-Messinian) may represent the major fall of sea level which caused the precipitation of evaporites in the abyssal plains of the Mediterranean. Tentatively we propose that is the intra-Messinian discontinuity (BES or TRU), taking into account that the second discontinuity (TES) occurs once the Lago Mare episode (considered a fini-Messinian post-evaporitic unit) that post-dates both the TCC and evaporites) is ended.

References
 Bourillot, R., Vennin, E., Rouchy, J.M., Blanc-Valleron, M.M., Caruso, A., Durlet, C. (2010). The end of the Messinian Crisis in the western Mediterranean: Insights from the carbonate platforms of south-eastern Spain. *Sedimentary Geology*, 229, 224-253.
 CIESM (2008). The Messinian Salinity Crisis from mega-deposits to microbiology. A consensus report. Executive Summary. Almeria (Spain), 7-10 November 2007. Briand, F. (ed.), CIESM Workshop Monographs, 33, 7-28.
 Cornée, J.J., Roger, S., Münch, P., Saint Martin, J.P., Feraud, G., Conesa, G., Pezrea-Saint Martin, S. (2002). Messinian events: new constraints from sedimentological investigations and new ⁴⁰Ar/³⁹Ar ages in the Neilla - Nadar Basin (Morocco). *Sedimentary Geology*, 151, 127-147.
 Cornée, J.J., Mallard, A., Conesa, G., García, F., Saint Martin, J.P., Sage, F., Münch, P. (2003). Onshore to offshore reconstruction of the Messinian erosion surface in Western Sardinia, Italy: Implications for the Messinian salinity crisis. *Sedimentary Geology*, 210, 45-60.
 Esteban, M. (1979). Significance of the upper Miocene coral reefs of the Western Mediterranean. *Palaogeography, Palaeoclimatology, Palaeoecology*, 29, 169-188.
 Esteban, M. (1996). An overview of Messinian basins from Mediterranean areas: general trends and facies models. In: Franseen, E.K., Esteban, M., Ward, W.C., Rouchy, J.M. (Eds.), Models for Carbonate Stratigraphy from Miocene Reef Complexes of Mediterranean Regions. Concepts in Sedimentology and Paleontology, SEPM, Tulsa, Oklahoma, USA, pp. 3-53.
 Lu, F.H. (2006). Lithofacies and water-body record of Messinian evaporites in Nijar Basin, SE Spain. In: Rouchy, J.M., Suc, J.P., Ferrandini, J. (eds.), The Messinian salinity crisis re-visited. *Sedimentary Geology*, 188-189, 115-130.
 Pomar, L., Marzo, M., Barón, A. (1983). El Terciario de Mallorca. In: Pomar, L., Obrador, J., Fornós, J., Rodríguez-Pérez, A. (eds.), El Terciario de las Baleares (Mallorca - Menorca). Guía de las excursiones. X Congreso Nacional de Sedimentología. Memoria 1983. Grupo Español de Sedimentología, pp. 21-44.
 Rouchy, J.M., Saint Martin, J.P. (1992). Late Miocene events in the Mediterranean as recorded by carbonate-evaporite relations. *Geology*, 20, 629-632.
 Rouchy, J.M., Caruso, A. (2006). The Messinian salinity crisis in the Mediterranean basin: A reassessment of the data and an integrated scenario. *Sedimentary Geology*, 189-190, 35-67.

The upper Miocene - Pliocene succession in the Palma Basin

The marginal-peripheral neogene Palma basin (Mallorca) shows Late Tortonian to Plio-Pliocene deposits and displays four formations, from bottom to top:

- prograding reefal carbonates, changing basinward into bioclastic facies with abundant coralline algae (rhodoliths, pavements), *Halimeda* beds and molluscs (Tortonian-Messinian fringing Reef Unit, Pomar et al., 1983);
- transgressive-regressive muddy, microbiolite and oolite-dominated beds (Terminal Carbonate Complex, TCC, Esteban, 1979) which locally suffered important diagenetic processes (strongly recrystallized, dolomite), changing basinward into massive selenite gypsum and sapropels (marginal evaporite). This unit grades landward, along the north-western margins of the basin, into fan-delta marls and conglomerates (Marginal Terrigenous Complex or Bonanova Marls);
- lacustrine deposits, with brackish to freshwater faunal assemblages: charophyte oogones (*Chara*), paratethyan bivalves (*Dreissena*, *Lymnocyprina*), gastropods (*Hydrobiidae*, *Neritidae*, *Melanopidae*, *Thiuridae* and *Pulmonata*), ostracods (*Cypridae*) and scarce reworked benthic foraminifera (*Ammonia*, *Ephidium*) (Lago Mare Unit);
- yellowish calcisiltites with abundant *Amusium* and planktonic foraminifera (Son Mir Calcsiltites, Pomar et al., 1983). It ranges vertically and marginwards to yellowish bioclastic limestones (near-shore, coquina) and eolian calcarenites (Sant Jordi Calcarentes, Pomar et al., 1983) (transgressive-regressive Pliocene unit).

	Representative study sites		Paleontological record
	Majoris cliff	Can Ramis quarry	
PLIOCENE Open marine <i>Amusium</i> calcisiltites and calcarenites with molluscs, equinoids, planktonic and benthonic foraminifera			
TES Erosion Top erosion surface M/P boundary. Conglomerates at base. Marine and reworked lacustrine faunas			
LAGO-MARE Oligo-mesohaline Marls and sandy marls whit paratethyan bivalves, gastropods, ostracods and charophytes			
TCC Hypersaline ? Microbialites & tidalites (oolites with flaser tidal marks) whit abundant fish debris			
BES / TRU Erosion Top Reef Unconformity The TCC overlaps the eroded <i>Halimeda</i> beds (Reef Unit)		Not outcrop	

