

Late Messinian Lago-Mare deposits of the island of Mallorca (Western Mediterranean). Implications on the MSC events



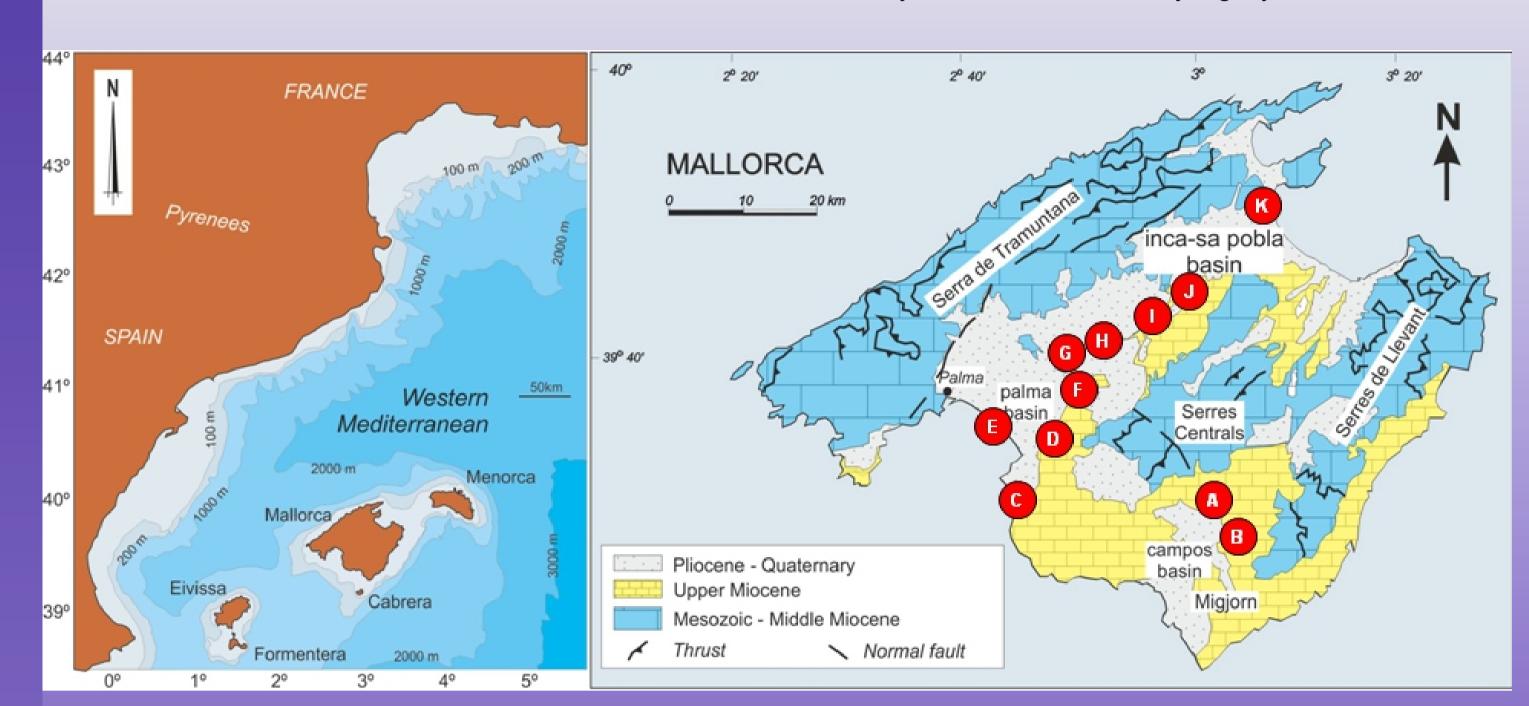


Guillem Mas and Joan J. Fornós

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

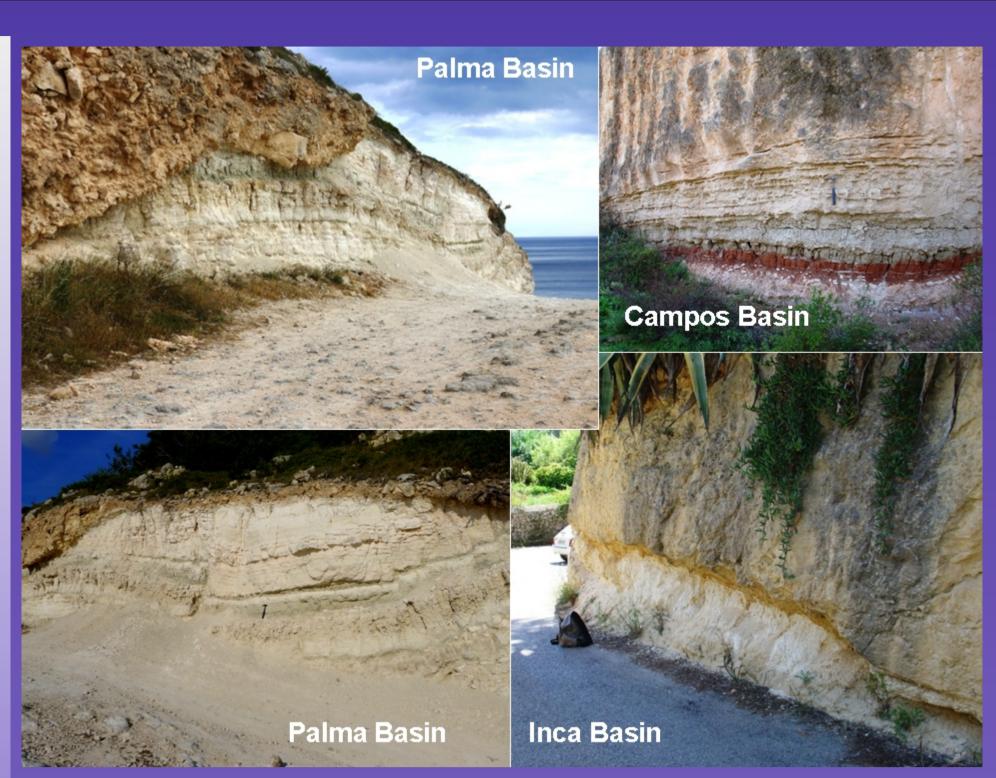
Introduction

The island of Mallorca (Balearic Islands) constitutes the most important emerged segment of the so-called Balearic Promontory, which in turn constitutes the north-eastern prolongation of the external zones of the Betic Range (south-eastern Spain) into the Mediterranean Sea and the southern margin of the so-called Valencia Trough. The island is characterized by ranges of folded and thrusted Mesozoic to Middle Miocene rocks that are flanked by areas covered with only slightly deformed Late Miocene to Pleistocene sedimentary rocks.



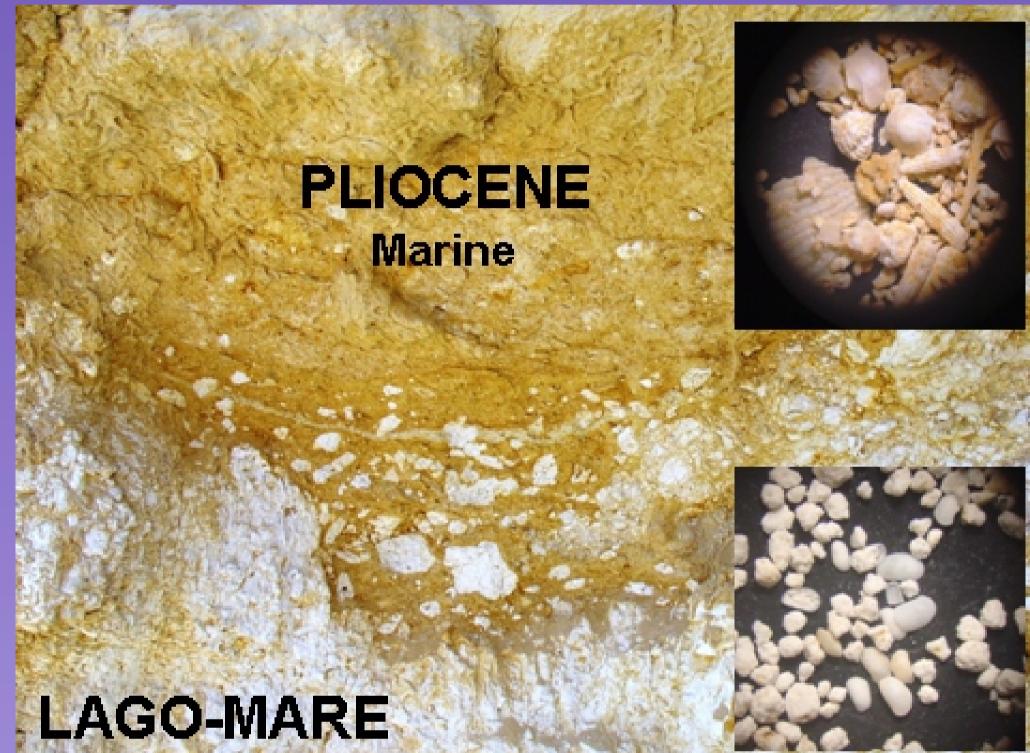
The Neogene basins of Mallorca provide an adequate record to illustrate the sequence related to the Messinian Salinity Crisis events and may serve to test various debated scenarios (Mas and Fornos, 2011, 2012). The island of Mallorca has been relatively stable in terms of vertical movements since the Miocene.

In these basins, the Messinian and Pliocene stratigraphic record shows four main stratigraphic units and two major unconformities. The Reef Unit (Late Tortonian-Messinian) documents the pre-crisis marine sedimentation. This unit is limited at the top by the intra-Messinian unconformity, representing a subaerial erosive phase related to a first major sea-level fall. The evaporitic marginal episode is characterized by the Terminal Carbonate Complex (Esteban, 1979), which changes basinward into massive selenite gypsum (Upper Evaporite). The post-evaporitic deposits (latest Messinian) are characterized by lacustrine sedimentation, related to the Lago-Mare episode. At the top of the Lago-Mare Unit there is the end-Messinian unconformity, caused by a second major sea-level fall. Over this unconformity lie the Pliocene Units (Early Pliocene), represented by marine deposits that mark a transgression, and the subsequent end of the Messinian Salinity Crisis.



General overview of Lago-Mare outcrops in different mallorcan basins

Palaeontology assemblages



Lago-Mare record

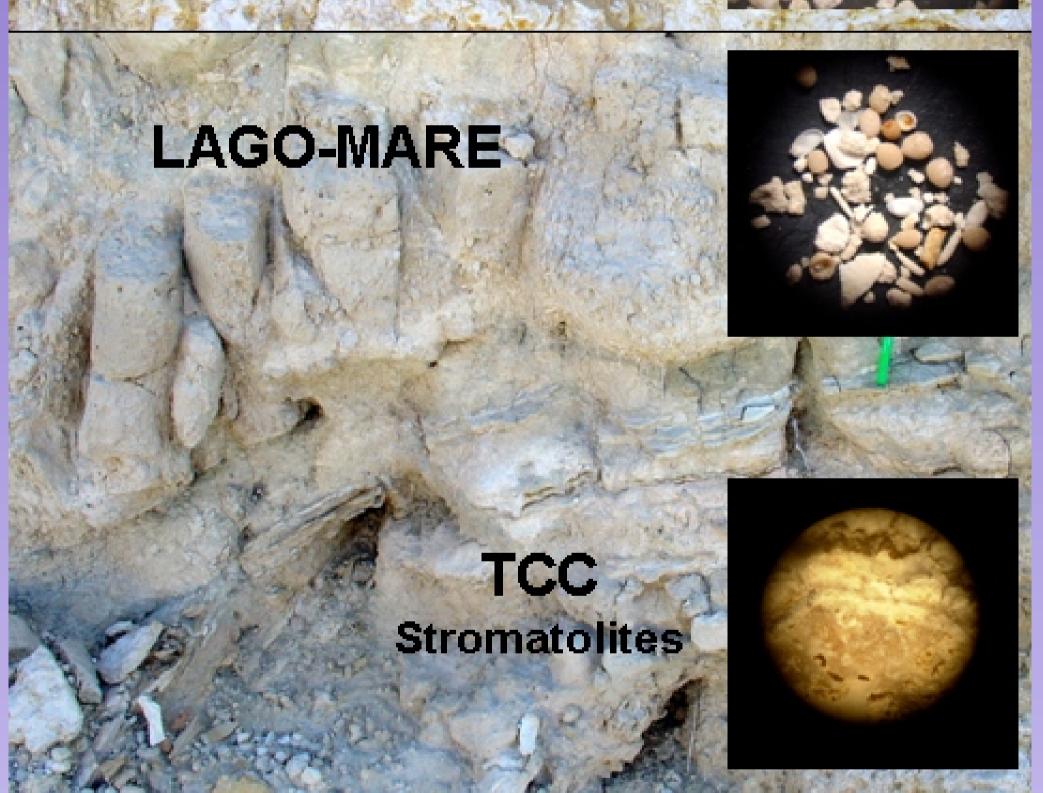
Lago-Mare records (outcrops and borehole cores) are widely distributed in the four main basins of the island of Mallorca (Campos, Palma, Inca and Alcúdia-Sa Pobla basins) and usually do not exceed a few (5-6) meters thick.

The sediments belonging to the Lago-Mare Unit comprise the strata deposited above the uppermost TCC-Upper Evaporite facies and below the marine Pliocene. This unit is composed of marls and sandy-marls lacustrine deposits with brackish to freshwater faunal assemblages and paleosoils.

They contain (i) plant remains: charophyte oogones (Chara spp.), Microcodium; (ii) Paratethyan bivalves: Dreissena (Pontodreissena) ex gr. D. (P.) rostriformis (Deshayes, 1838), Lymnocardium adriaticum Gillet, 1969, Euxinicardium subodessae (Sibzov, 1877), Pseudocatillus cf. P. pseudocatillus (Barbot de Marny, 1869), Prosodacnomya sp., Limnocardiinae indet.; (iii) non-marine prosobranch gastropods from the families Hydrobiidae (cf. Saccoia sp.), Neritidae (Theodoxus sp.), Melanopsidae (Melanopsis sp.), Thiaridae (Melanoides sp.); (iv) scarce pulmonata gastropods (Planorbidae indet. cf. Hippeutis sp., Helicidae-Higromidae indet.); (v) ostracods wiht Parathethyan affinities: Cyprideis agrigentina Decima, 1964, Tyrrhenocythere pontica (Livental in Agalarova et al., 1961), Loxoconxa spp., Ilyocypris sp.; (vi) insect ichnites, (vii) scarce fish remains (scale and bones) and (viii) scarce reworked benthic foraminifera (Ammonia, Elphidium, Miliolids). Of the molluscs (with the exception of ostracods), normally only the cast is preserved.

This is a typical Paratethyan affinity Lago-Mare assemblage from elsewhere in the Mediterranean basins, from Cyprus to Malaga (Rouchy and Caruso, 2006; Orszag-Sperber, 2006; Esu, 2007; Guerra-Merchán et al., 2010).

In some Son Segui antiform outcrops (site G), coinciding with the most superior part of the TCC and the base of the Lago-Mare deposits, marly and calcareous deposits appear with brackish to restricted marine fauna and vegetal remains (leaves). These contain abundant littoral foraminifera (Elphidium sp., Ammonia sp.), ostracods, echinoderm spines, bivalves (Anadara sp., Lucinidae, Cardidae), gastropods (Potamididae cf. Timpanotonus sp.) and fish remains (bones and scales), that probably correspond to an initial phase of brackish conditions (pre Lago-Mare facies).



				Litl	holo	gy	Stru	uctur	es	Biva	lves			Gast	rope	ods			Os	trac	ods					
Basin	Site / Locality	Z (m)	P (m)	Fine marls/clay	Sandy marls	Micro-pebbles	Paleosoils	Desiccation cracks	Rootlets	Dreissena	Limnocardiinae	Hydrobiidae	Melanopsis	Melanoides	Theodoxus	Potamididae	Planorbidae	Pulmonata	Cyprideis	Tyrrhenocythere	Гохосопха	llyocypris	Benthic foraminifera	Charophyte	Insect (traces)	Pisces
CAMPOS	(Porreres)	120	>3	٧	٧	٧	٧	٧	٧	٧	٧	٧	٧	٧					٧	٧	٧		٧	٧		
	B Cova des Fum cave (Campos)	65	>2	٧	٧							٧							٧	٧	٧			٧		
PALMA	C Ses Olles cliff (Llucmajor)	40	5	٧	٧				٧	٧	٧	٧							٧	٧			٧	٧	٧	
	D Can Ramis quarry (Llucmajor)	52	5	٧	٧					٧	٧	٧	٧	٧	٧			٧	٧	٧			٧	٧	٧	٧
	(Palma)	-118	8-20	٧							٧															
	(Palma)	-80	6-30		٧	٧				٧	٧	٧							٧	٧	٧	٧		٧		٧
INCA	G Son Seguí antiform (Sta. Maria)	305	?	٧						٧	٧	٧				٧			٧					٧		V
	(H) Es Rafal trough (Santa Eugènia)	196	?	٧	٧					٧	٧	٧	٧	٧	٧		٧		٧	٧	٧		٧	٧	٧	
	(Sencelles)	112	>2	٧							٧	٧							٧	٧						
ALCÚDIA	(LLubí)	59	>3	٧	٧					٧	٧	٧	٧	٧					٧					٧		
	(Alcúdia)	-311	6	٧								٧							٧	٧				٧		

Discussion and Conclusions

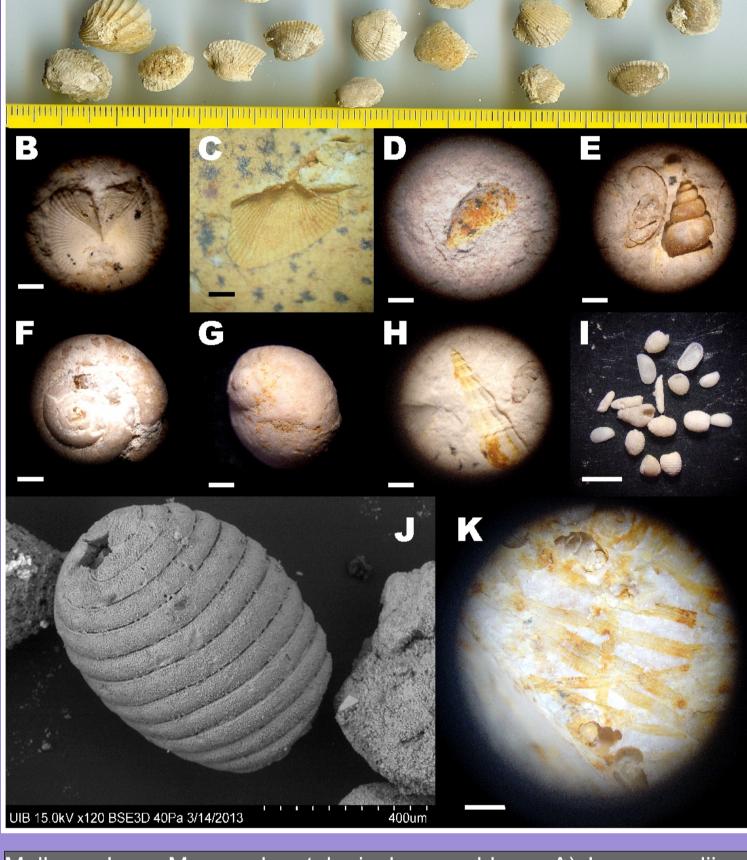
The recovered mollusc assemblage is a typical Lago-Mare taxa association; there is practically no variation in their composition throughout their distribution in the Mediterranean, including the presence of small bivalves such as Lymnocardiinae and Dreissenidae (fresh water mussels) and pulmonate and prosobranch gastropods of a hypo-oligohaline character. Dreissena ex gr. rostriformis is a species of unequivocal Paratethyan origin (Archambault-Guezu, 1976) which had a wide distribution in the Mediterranean during the latest Messinian and which appears in the majority of mollusc assemblages of the Lago-Mare facies. The Paratethyan immigrants disappeared from the Mediterranean 5.33 Ma ago (Nevesskaja et al., 2001), when open marine conditions were re-established at the beginning of the Pliocene.

The presence of ostracods of the genus Tyrrhenocythere, in combination with species of the genus Cyprideis and the family Loxoconchidae ("Cyprideis-Loxoconxidae-Tyrrhenocythere assemblage", Grossi et al., 2008) indicates a body of shallow oligonaline water (probably no more than 10-15 m deep).

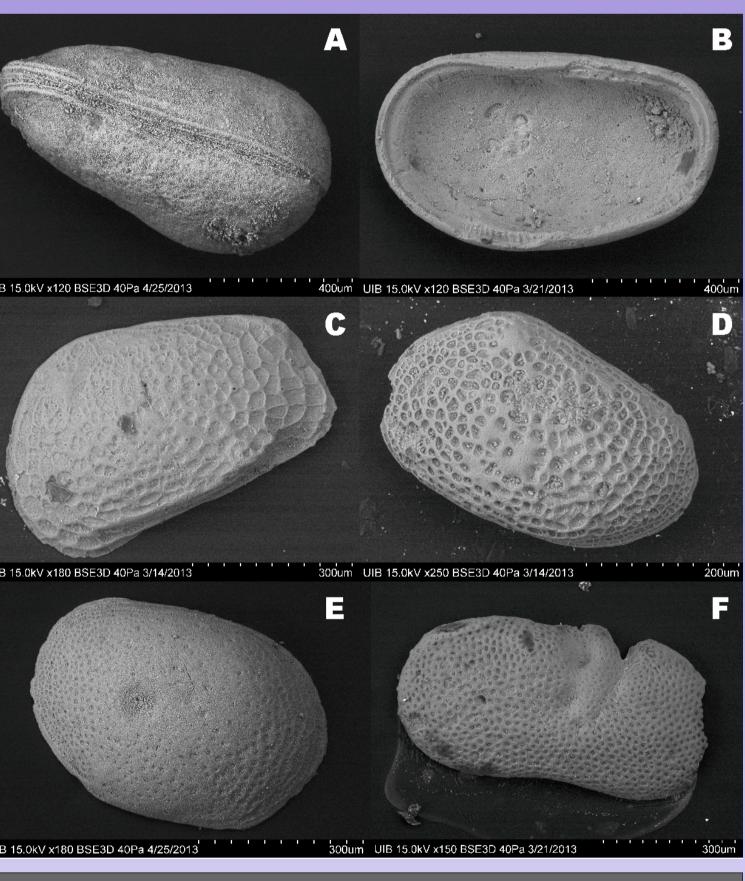
In Mallorca, the Lago-Mare deposits appear in a single episode, with a sudden but not erosional transition from the TCC-Upper Evaporite to Lago-Mare beds. No major discontinuity between these two units is observed. Evaporite deformation and dissolution may have affected the geometry (brecciation, fracturing, and gliding) of both TCC and Lago-Mare depositional sequences. Subsequently, a new major erosion surface develops on top of Lago-Mare deposits, sometimes resulting in their complete erosion that may also affect the TCC deposits. No planktonic foraminifera are known, suggesting that normal marine conditions were

not present during the deposition of the Lago-Mare unit. Finally, the Pliocene marine deposits abruptly and extensively overlie the end-Messinian erosion surface, which forms the Mio-Pliocene boundary in the basins. Thus, the Lago-Mare unit constitutes a marker bed, since both evaporites in the basinward area and the TCC in the margins are covered with brackish and fresh water deposits of the Lago-Mare unit, with no apparent erosion surface separating them. However, deeper-platform and basinal equivalents of the TCC are the massive gypsum of the depocentre (Upper Evaporite).

Central Mallorca Age Mallorca Margins Events Mediterranean Depocentres series Bourillot et al., 2010 Erosion Salinity (%) Water level 0 30-40 130 300 **QUATERNARY** Plistocene **Palma Siltstones Eolianites** 2,58 N glatiatons Calcisiltites & Pliocene PLIOCENE Calcarenites 5,33 Calcarenites TES Normal marine 5,42 Lago-Mare Lago-Mare Lago-Mare **Terminal Carbonate Upper evaporites** Gypsum & marls Complex 5,55 MESSINIAN Lower evaporites 5,96 BES / TRU MSC start Reef Unit Reef Unit Pre-evaporitic 7,24 T/M boundary **TORTONIAN**



Mallorca Lago-Mare paleontological assemblage: A) Lymnocardiinae (scale in cm), B) Lymnocardium adriaticum Gillet, 1969, specimen with articulated valves; C) *L. adriaticum;* D) *Dreissena* ex gr. *D. rostriformis* (Deshayes, 1838); E) *D. rostriformis* & Hydrobiidae (cf. *Saccoia*); F pulmonate gastropod (Helicidae-Higromidae); G) Theodoxus sp.; H Melanoides sp.; I) charophyte oogones, ostracods (Cyprideis) & faecal pellets; J) charophyte oogone; K) charophyte stems (Chara sp.). Scale bar = 2 mm, except J) = 400 um.



Mallorca Lago-Mare typical ostracods: A) & B) *Cyprideis agrigentina* Decima, 1964; C) *Tyrrhenocythere pontica* (Livental in Agalarova et al. 1961); D) & E) *Loxoconxa* spp.; F) *Ilyocypris* sp.

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