Biogeographia vol. XXIV - 2003
(Printed October, 31st 2003)
Marine biogeography of the Mediterranean Sea: patterns and dynamics of biodiversity

Shaping the biogeography of the Mediterranean basin: one geologist's perspective

MARCO TAVIANI
Istituto di Scienze Marine-Sezione Geologia Marina, CNR,
via Gobetti 101, I-40129 Bologna (Italy)
e-mail: marco.taviani@bo.ismar.cnr.it

Key words: Mediterranean basin, paleobiogeography, geology.

SUMMARY

The present Mediterranean biogeography is the transitory result of climatic and geological events suffered by this semi-enclosed basin throughout its history. The potential consequences over stenoecious marine ecosystems of the late Miocene "Messinian Salinity Crisis" are discussed. In particular, postulated frankly-marine sanctuaries at the time of evaporite deposition and periodical intra-Messinian inundations are not considered sufficient in maintaining stenoecious ecosystems throughout the entire Messinian time. The biogeography of the Mediterranean deep-sea benthos is strongly affected by the geodynamic evolution of the basin and in particular by the post-Messinian establishment of a shallow sill (Gibraltar); since the Pleistocene at least, the sill acts as a filter biasing the flux of potential Atlantic deep-sea invaders. Finally, the Mediterranean basin boasts a remarkable history of deep-sea cold seep chemosynthetic ecosystems from the Oligocene up to Present. These peculiar biota, however, show a distinct evolution through time. The pre-Messinian ones are typically oceanic in affinity hosting, among other, large chemosynthetic bivalves (e.g. Calyptogena, Modiolus etc.) and tubeworms, while the post-Messinian and Modern ones are strongly impoverished. This trend is mainly controlled by the geological history of the Mediterranean region.

INTRODUCTION

In a recent paper I offered my personal perception of the history of the stenoecious marine benthic biota of the Mediterranean basin, Neogene to Present (Taviani, 2002). To my view, it was the interplay between global climatic signals and concomitant geodynamic evolution of the Tethys-Mesogean-Mediterranean basins (e.g., Biju-Duval et al., 1977; Krijgsman, 2002) that moulded the biogeography of the modern Mediterranean Sea. Arguments and data supporting this vision are reported in Taviani (2002) and are not repeated here.

However, one of the major issues for Mediterranean biogeographers was and is the significance of the late Miocene "Messinian Salinity Crisis" (MSC

hereafter) and its consequences over the biota. A widely shared view (with some opponents) endorses the concept that the MSC caused the extermination of the basin's marine stenoecious organisms. The obvious corollary of such view is to consider the post-MSC marine inundation as the real starting point of the Mediterranean biogeographic history by re-importing into the basin a fresh wave of Atlantic organisms (e.g. Taviani, 2002, with references therein).

In this paper I will comment again some open problems related to the MSC. Furthermore, I will discuss the biogeographic evolution of deep-sea normal and chemosynthetic ecosystems. Most of my reasoning will be conducted by using benthic molluscs as a particularly suitable biogeographic tracer (Taviani, 2002).

BACK AGAIN TO THE MESSINIAN SALINITY CRISIS AND ITS ACTION ON BIOTA

The problem represented by the MSC is yet far from being adequately understood as proven by the steady publication of papers still dealing with this issue. The rather evocative but perhaps simplistic scenario (heralded by the slogan "the Mediterranean was a desert") envisaged 30 and more years ago (Hsü et al., 1977) has been variously debated, refined, contrasted (e.g., Cita and McKenzie, 1986; Hsü, 1986; Busson, 1990; Benson and Rakic-El-Bied, 1991; Cita and Corselli, 1993; and many others).

Although in its intrinsic temporal brevity (< 1my, Krijgsman et al., 1999) the MSC was an astonishingly complex event. The Messinian includes a (1) pre-evaporitic phase, punctuated by high frequency anoxic events leading to peculiar deposits (euxinic marls and Tripoli, i.e. diatomaceous muds), partly coeval or followed by (2) precipitation of mainly sulphatic layers (gypsum beds of the "Lower Evaporites") beginning c. 5.96 Ma BP (Krijgsman et al., 1999); to follow is (3) the precipitation of the "Upper Evaporites" and the (4) late Messinian by the hypo-meso-haline continental environments of Lago-Mare (Ruggieri, 1967; Rouchy et al., 2001; Roveri et al. 2003).

Biogeographically the big question is: there were open marine connections between the Atlantic and the Mediterranean during the Messinian? And, if so, when, where and how far inside the basin were they resented?

For instance, benthic fauna from intra-evaporitic marly beds of Sorbas basin (Southeastern Spain) has been taken as an indication that the MSC was not such from a biological perspective (Saint-Martin et al., 2000). In particular, Néraudeau et al. (2001) suggest that the stenohaline echinoid *Brissopsis* may have survived the crisis in a marine *refugium* like the Alboran Sea. Benthic foraminiferal evidence from these same beds also suggests their intra-Messinian survival (Goubert et al., 2001). This postulated "Alboran sanctuary" may have acted as such during part only of the entire Messinian crisis, as admitted by Ben Moussa et al. (1988).

Thus, some authors agree that the westernmost part of the Mediterranean basin was at least temporarily under marine conditions at times during the MSC. The same does not hold necessarily true for the rest of the basin (Taviani, 2002).

The potential existence of one or more "marine sanctuaries" within the Mediterranean proper, evoked by some biogeographers (e.g., Di Geronimo, 1990), is still largely based on circumstantial arguments, not on ground-truth evidence. Furthermore, it is not yet demonstrated that *permanent* marine interconnections between the Atlantic Ocean and the Mediterranean Sea existed throughout the Messinian to support the extreme view that the latter did not suffer (at times at least of the complex Messinian history) one or more lethal biological crises.

A connection between the Atlantic Ocean and Mediterranean basins as east as Sicily was postulated by Butler et al. (1996) based on the recovery of frankly marine plankton within Early Messinian diatomaceous marls. This suggestion, however, was not substantiated by later research on these same beds (Sprovieri et al., 1996).

A further argument on this line not to be neglected, calls for the evaluation of the basin-scale impact of the post-evaporitic event known as "Lago-Mare", that imposed strong hypohaline conditions all over the Mediterranean, including its westernmost sectors as documented, among other, by the Messinian sequence of the Nijar basin, southeastern Spain (Fortuin and Krijgsman, 2003), ODP cores in both the Western and Eastern Mediterranean (Cita et al., 1990; Blanc-Valleron et al., 1998) and outcrop evidence in Cyprus (Krijgsman et al., 2002)

In summary, I am still convinced that overall the MSC imposed intolerable conditions, on a basin scale, capable to jeopardize the stenoecious benthic marine realm.

The re-flooding and, therefore, the re-colonization of the entire basin was a rapid event (Ryan, Hsü et al., 1973; McKenzie et al., 1999; Iaccarino et al., 1999; Fortuin and Krijgsman, 2003) taking place at the beginning of the Pliocene, if not already during the latest Messinian (Steffahn and Michalzik, 2000). From a strict biogeographic perspective the implication is again that the real renewing of the Mediterranean benthos is accompanied by this inundation from the Atlantic Ocean.

THE DEEP-SEA BIOTA

In the past, the biogeography of the deep-sea Mediterranean benthos has been largely deduced from speculations upon the affinity of the present Mediterranean stocks more than on exhaustive paleontological data (e.g., Ekman, 1953; Pérès and Picard, 1960, 1964; Pérès 1967, 1989; Zibrowius, 1980; Raffi and Taviani, 1984; Fredj and Laubier, 1985; Por and Dimentman, 1985, 1989; Allouc, 1987;

Bouchet and Taviani, 1989, 1992a,b). A reverse to this approach took place in the last decade or so, especially because of the appearance of detailed taxonomic studies of Italian Plio-Pleistocene bathyal assemblages (Tabanelli, 1993; Di Geronimo et al., 1997; Di Geronimo and La Perna, 1996, 1997; Corselli, 2001). Some of these contributions were sensitive to the origination of the Mediterranean deep-sea faunas with respect to those of the adjacent Atlantic Ocean.

Based on the latest Pleistocene-Recent Mediterranean deep-sea mollusc fauna, Bouchet and Taviani (1992a) proposed the concept that a significant share of the recent Mediterranean deep-zoobenthos derived largely by the continuous meroplanktic larval influx from mother-populations in the Atlantic Ocean. This option is not accepted in his extreme terms by Di Geronimo and co-workers (e.g. Di Geronimo et al., 2001) who observe that this model does not account for the observed existence of a conspicuous stock of deep-sea organisms provided with either direct or lecithotrophic development, although this coexistence was already highligthed by Bouchet and Taviani (1992a). The Quaternary deep-sea benthos of the Mediterranean basin may, therefore, result from a stock of Atlantic organisms likely derived from ?pre-Pleistocene invasions when a deeper Gibraltar corridor connected the two basins plus a continuous larval influx from the Atlantic. Emig and Geistdoerfer (2004) predict that the Mediterranean will become an important center of evolution of deep-sea organisms, a view supported from data on deep-sea protobranchs (La Perna, 2004).

RISE AND DECLINE OF DEEP-SEA CHEMOSYNTHETIC COMMUNITIES IN THE MEDITERRANEAN BASIN

A decade ago it has been realized that the Mediterranean basin hosted ocean-like chemosynthetic communities with megafauna exploiting hydrogen sulphide and hydrocarbon enriched fluids (Taviani, 1994). These communities punctuated the history of the basin since the Oligocene at least up to Present (e.g., Conti and Fontana, 1998; Taviani, 2001). Late Miocene (Tortonian) cold-seep paleo-communities show strong taxonomic similarities with Modern hydrocarbon seep setting the northern Gulf of Mexico slope and West Africa. Noteworthy is the presence of chemosynthetic sulfide- (?*Calyptogena*, *Solemya*, large lucinids, tubeworms, *Beggiatoa*-like bacteria) and /or hydrocarbon-based (?*Bathymodiolus*, *Thalassonerita*) invertebrates (Taviani, 1994, 2001). Pliocene to recent deep-sea chemosynthetic macrofaunal communities are taxonomically impoverished and host *Vesicomya*, *Solemya* and smaller lucinids (Taviani et al., 1997; Corselli and Basso, 1996; Taviani, 2001; Salas and Woodside, 2002). A trend is apparent showing a significant decline of such quasi-oceanic seep

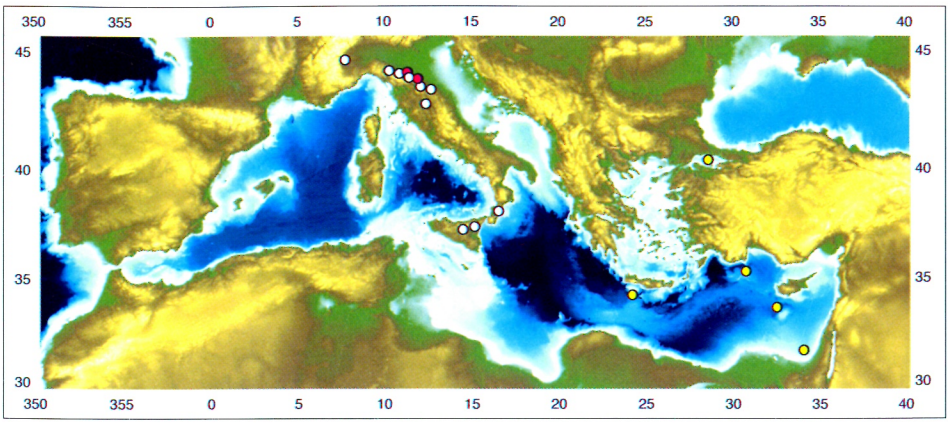

Fig. 1 - Physiographic map of the Mediterranean basin showing location of known occurrences of deep-sea cold-seep communities Neogene to Present. White circles = Miocene; red circles = Pliocene; yellow circles = Recent.

communities with the beginning of the Pliocene, a possible consequence of diminishing propitious structural scenarios linked to the Apennine orogeny, coupled with the onset of a shallow sill at Gibraltar and the postulated Messinian biological extermination (Taviani, 2001, 2002). At present, deep-sea chemosynthetic communities including both microbial and macrofaunal organisms (small mytilids, lucinaceans, and vesicomyids) are located at various sites of the Eastern Mediterranean basin, including the Nile delta fan, Eratosthenes Seamount, Napoli Dome and other mud volcanoes and fault zones in the Marmara Sea (Fig. 1).

ACKNOWLEDGEMENTS

The present article is part of an invited talk presented to the 34th Congress of the Italian Biogeographic Society (S.I.B.) held in Ischia, 21-25 October 2002; my warmest thanks to Valerio Sbordoni for his kind invitation to present the talk as well as to Marco Oliverio for his support. I thank Andrea Argnani, Cesare Corselli, Italo Di Geronimo, Marco Oliverio, Pietro Renda, Franco Ricci Lucchi, Gian Battista Vai for useful discussion about issues on Mediterranean paleogeography. I am indebted with Alessandro Remia for his help in preparing the bathymetric map and with Alessandro Ceregato for editorial work.

This is IGM scientific contribution n. 1407.

REFERENCES

ALLOUC J. 1987 - Les paléocommunautés profondes sur fond rocheux du Pléistocène méditerranéen. Description et essai d'interprétation paléeocologique. Geobios, **20**: 241-263.

BEN MOUSSA A., BREBION PH., LAURIAT-RAGE A., DEMARCQ G. 1988 - Intérêt paléobiologique des mollusques messiniens de Melilla (NE Maroc). Rev. Paleobiol., 7: 335-358.

BENSON R.H., RAKIK-EL-BIED K.R. 1991 - The Messinian parastratotype at Cuevas del Almanzora, Vera Basin, SE Spain: refutation of the deep-basin, shallow-water hypothesis?. Micropaleontology, **37**: 289-302.

BIJU-DUVAL B., DERCOURT J., LE PICHON X. 1977 - From the Tethys Ocean to the Mediterranean seas: a plate tectonic model of the evolution of the western Alpine system. In: B. Biju-Duval, L. Montadert (eds.), Structural History of the Mediterranean Basins, International Symposium, Editions Technip, Paris: 143-164.

BLANC-VALLERON M.-M., ROUCHY J.-M., PIERRE C., BADAUT-TRAUTH D., SCHULER M. 1998 - Evidence of Messinian nonmarine deposition at Site 968 (Cyprus lower slope). In: A.H.F. Robertson, K.C. Emeis, C. Richter, A. Camerlenghi (eds.), Proc. ODP, Scientific Results, **160**: 437-445.

BOUCHET P., TAVIANI M. 1989 - Atlantic deep-sea gastropods in the Mediterranean: new findings. Boll. Malacol., **2**: 137-148

BOUCHET P., TAVIANI M. 1992a - The Mediterranean deep-sea fauna: pseudopulations of Atlantic species? Deep-Sea Res., **39**: 169-184.

BOUCHET P., TAVIANI M. 1992b - La colonizzazione dei bacini a soglia. Il caso del Mar Mediterraneo. Lav. Soc. Malacol. It., Parma, **24**: 120-130.

BUSSON G. 1990 - Le Messinien de la Mediterranée: vingt ans après. Géologie de la France, voll. 3-4: 3-58.

BUTLER R.W.H., PEDLEY H.M., MANISCALCO R., GRASSO M., MCCLELLAND E., FINEGAN B. 1996 - The significance of Messinian occurrences of *Globorotalia margaritae* and *Globorotalia puncticulata* in Sicily. Terra Nova, **8**, 59-64.

CITA M.B. 1973 - Mediterranean evaporite: paleontological arguments for a deep-basin desiccation model. Messinian events in the Mediterranean, Koniklijke Nederlandse Akademie van Wetenshappen, Amsterdam: 206-228.

CITA M.B., CORSELLI C. 1993 - Messiniano: vent'anni dopo. Mem Soc. Geol. It., **49**: 145-164.

CITA M.B., MCKENZIE J.A. 1986 - The terminal Miocene event. A.G.U., Mesozoic and Cenozoic Oceans, Geodynamics Series, vol. 15: 123-140.

CITA M.B., SANTAMBROGIO S., MELILLO B., ROGATE F. 1990 - Messinian paleoenvironments: new evidence from the Tyrrhenian Sea (ODP Leg 107). In: Kastens K.A., Mascle J. et al. (eds.), Proc. ODP, Sci. Results, 107, College Station TX (Ocean Drilling Program): 211-228.

CONTI S., FONTANA D. 1998 - Recognition of primary and secondary Miocene lucinid deposits in the Apennine chain. Mem. Sci. Geol., **50**: 101-131.

CORSELLI C. 2001 - Change and diversity: the Mediterranean deep corals from the Miocene to the Present. In: F.M. Faranda, L. Gugliemo, G. Spezie (eds.), Mediterranean Ecosystems: Structures and Processes, Springer-Verlag Italia: 361-366.

CORSELLI C., BASSO D. 1996 - First evidence of benthic communities based on chemosynthesis on the Napoli mud volcano (Eastern Mediterranean). Mar. Geol., **132**: 227-239.

DI GERONIMO I. 1990 - Biogeografia dello zoobenthos del Mediterraneo: origine e problematiche. Oebalia, Suppl., **16**: 31-49.

DI GERONIMO I., LA PERNA R. 1996 - *Bathyspinula excisa* (Philippi, 1844) (Bivalvia, Protobranchia): a witness of the Plio-Quaternary history of the deep Mediterranean benthos. Riv. It. Paleont. Strat., **102**: 105-118.

DI GERONIMO I., LA PERNA R. 1997 - Pleistocene bathyal molluscan assemblages from southern Italy. Riv. It. Paleont. Strat., 103: 389-426.

DI GERONIMO I., D'ATRI A., LA PERNA R., ROSSO A., SANFILIPPO R., VIOLANTI D. 1997 - The Pleistocene bathyal section of Archi (Southern Italy). Boll. Soc. Paleont. It., **36**: 189-212.

DI GERONIMO I., ROSSO A., LA PERNA R., SANFILIPPO R. 2001 - Deep-sea (2501,550m) benthic thanatocoenoses from Southern Thyrrenian Sea. In: Faranda F.M., Guglielmo L., Spezie G. (eds.) Mediterranean Ecosystems: Structures and Processes, Springer, Berlin, Heidelberg, ch. 36: 277-287.

EKMAN S. 1953 - The Mediterranean-Atlantic fauna and the Sarmatic fauna. Zoogeography of the Sea. Chapter 5: 81-99.

EMIG C.C., GEISTDOERFER P. 2004 - The Mediterranean deep-sea fauna: historical evolution, bathymetric variatios and geographic changes. Carnets de Geologie/Notebooks on Geology, Article 2004/01 (CG2004_A01_CCE-PG): 1-10.

FORTUIN A.R., KRIJGSMAN W. 2003 - The Messinian of the Nijar Basin (SE Spain): sedimentation, depositional environments and paleogeographic evolution. Sedim. Geol., **160**: 213-242.

FREDJ G., LAUBIER L. 1985 - The deep Mediterranean benthos. In: M. Moraitou-Apostopoulou, V. Kiortsis (eds.), Mediterranean Marine Ecosystems, NATO Conference Series, Plenum Press, New York-London, vol. 8: 109-145.

GOUBERT E., NERAUDEAU D., ROUCHY J.-M., LACOUR D. 2001 - Foraminiferal record of environmental changes: Messinian of the Los Yesos area (Sorbas Basin, SE Spain). Palaeogeogr. Palaeoclimatol. Palaeoecol., 175: 61-78.

HSÜ K.J. 1986 - Unresolved problem concerning the Messinian salinity crisis. Giorn. Geol., ser. 3ª, 47 (1985): 203-212.

HSÜ K.J., MONTADERT L., BERNOULLI D., CITA M.B., ERICKSON A., GARRISON R.E., KIDD R.B., MELIERES F., MÜLLER C., WRIGHT R. 1977 - History of the Mediterranean salinity crisis. Nature, **267** (5610): 399-403.
IACCARINO S., CASTRADORI D., CITA M.B., DI STEFANO E., GABOARDI S., MCKENZIE J.A., SPEZZAFERRI S., SPROVIERI R. 1999 - The Miocene-Pliocene boundary and the significance of the earliest Pliocene flooding in the Mediterranean. Mem. Soc. Geol. It., **54**: 109-131.
KRIJGSMAN W. 2002 - The Mediterranean: *Mare Nostrum* of Earth Sciences. Earth Planet. Sci. Lett., **205**: 1-12.
KRIJGSMAN W., HILGEN F.J., RAFFI I, SIERRO F.J., WILSON D.S. 1999 - Chronology, causes and progression of the Messinian salinity crisis. Nature, **400**: 652-655.
KRIJGSMAN W., BLANC-VALLERON M.-M., FLECKER R., HILGEN F.J., KOUWENHOVEN T.J., MERLE D., ORSZAG-SPERBER F., ROUCHY J.-M. 2002 - The onset of the Messinian salinity crisis in the Eastern Mediterranean (Pissouri Basin, Cyprus). Earth Planet. Sci. Lett., **194**: 299-3 10.
LA PERNA R. 2004 - The identity of *Yoldia micrometrica* Seguenza, 1877 and three new deep-sea protobranchs from the Mediterranean (Bivalvia). J. Nat. Hist., **38**: 1045-1057.
MCKENZIE J.A., SPEZZAFERRI S., ISERN A. 1999 - The Miocene-Pliocene boundary in the Mediterranean Sea and Bahamas: implications for a global flooding event in the earliest Pliocene. Mem. Soc. Geol. It., **54**: 93-108.
MONTENAT C., BIZON G., BIZON J.J., CARBONNEL G., MULLER C., RENEVILLE J. DE 1976 - Continuité ou discontinuité de sédimentation marine Mio-Pliocène en Méditerranée Occidentale, l'example du basin de Vera (Espagne Meridionale). Rev. Inst. Franc. Pétr., **31**: 613-663.
MÜLLER D.W., HSÜ K.J. 1987 - Event stratigraphy and paleoceanography in the Fortuna basin (southeast Spain): a scenario for the Messinian salinity crisis. Paleoceanography, **2**: 679-686.
NÉRAUDEAU D., GOUBERT E., LACOUR D., ROUCHY J.-M. 2001 - Changing biodiversity of Mediterranean irregular echinoids from the Messinian to the Present-Day. Palaeogeogr. Palaeoclimatol. Palaeoecol., **175**: 43-60.
PÉRÈS J.-M. 1967 - The Mediterranean benthos. Oceanogr. Mar. Biol. Ann. Rev., **5**: 449-533.
PÉRÈS J.-M. 1989 - History of the Mediterranean biota and the colonization of the depths. In: F.D. Por (ed.), The Legacy of Tethys, Monographiae Biologicae, Kluwer, Dordrecht, vol. 63: 198-232.
PÉRÈS J.-M., PICARD J. 1960 - Origine, distribution et modifications recentes du peuplement de la Mer Méditérranee. Rec. Tr. Stat. Mar. Endoume, **3**: 29-33.
PÉRÈS J.-M., PICARD J. 1964 - Nouveau manuel de bionomie benthique de la Mer Méditerranée. Rec. Tr. Stat. Mar. Endoume Bull., **14**: 120 pp.
POR F.D., DIMENTMAN C. 1985 - Continuity of Messinian biota in the Mediterranean basin. In: D.J. Stanley, F-C. Wezel (eds.), Geologic Evolution of the Mediterranean Basin, Springer-Verlag: 545-556.
POR F.D., DIMENTMAN C. 1989 - The legacy of Tethys. An aquatic biogeography of the Levant. Monographiae Biologicae, Kluwer, Dordrecht, **63**: 214 pp.
RAFFI S., TAVIANI M. 1984 - An outline of the late Tertiary to Recent history of the Mediterranean deep-sea mollusks faunas. Int. Coll. On Mediterranean Neogene Marine Megafaunal Palaeoenvironments and Biostratigraphy, Ann. Geol. Pays Hellen., **32**: 257-261.
ROUCHY J.-M., ORSZAG-SPERBER F., BLANC-VALLERON M.-M., PIERRE C., RIVIERE M., COMBOURIEU-NEBOUT N., PNAYIDES I. 2001 - Paleoenvironmental changes at the Messinian-Pliocene boundary in the eastern Mediterranean (southern Cyprus basins): significance of the Messinian Lago-Mare. Sedim. Geol., **145**: 93-117.
ROVERI M., MANZI V., RICCI LUCCHI F., ROGLEDI S. 2003 - Sedimentary and tectonic evolution of the Vena del Gesso basin (Northern Apennines, Italy): implications for the onset of the Messinian salinity crisis. Geol. Soc. Am. Bull., **115**: 387-405.
RUGGIERI G. 1967 - The Miocene and later evolution of the Mediterranean sea. In: C.G. Adams, D.V. Ager (eds.), Aspects of Tethyan Biogeography, Londson, Systematic Association Publication, pp. 283-290.
RYAN W.B.F., HSÜ K.J. et al. 1973 - Initial Reports of the Deep Sea Drilling Project, Washington, US Govt. Printing Office, vol. 13, 1447 p.
SAINT-MARTIN J.-P., NERAUDEAU D., LAURIAT-RAGE A., SECRETAN S., GOUBERT E., BABINOT J.F., BOUKLI-HACENE S., POUYET S., LACOUR D., PESTREA S., CONESA G. 2000 - La faune interstratifiée dans les gypses messinienns de Los Yesos (Bassin de Sorbas, SE Espagne): implications paléoenvironmentales. Geobios, **33**: 637-649.
SALAS C., WOODSIDE J. 2002 - *Lucinoma kazani* n.sp. (Mollusca: Bivalvia): evidence of a living benthic community associated with a cold seep in the Eastern Mediterranean Sea. Deep-Sea Res., **49**: 991-1005.
SPROVIERI R., DI STEFANO E., CARUSO A., BONOMO S. 1996 - High resolution stratigraphy in the Messinian tripoli Formation in Sicily. Palaeopelagos, **6**: 415-435.
STEFFAHN J., MICHALZIK D. 2000 - Significance of post-evaporitic ('Messinian Salinity Crisis') foraminiferal assemblages in some 'distal' Neogene basins of SE Spain: preliminary results of latests Miocene/earliest Pliocene (?) environmental reconstruction. IV Congreso del Grupo Español del Terciario, Geotemas, **1**: 213-215.
TABANELLI C. 1993 - Osservazioni ed ipotesi sulle malacofaune plioceniche della Romagna. Quad. Studi Nat. Romagna, **2**: 1-20.
TAVIANI M. 1994 - The "Calcari a Lucina" macrofauna reconsidered: Miocene deepsea faunal oases from Miocene-age cold vents in the Romagna Apennine, Italy. GeoMar. Letters, **14**: 185-191.

TAVIANI M. 2001 - Fluid venting and associated processes. In G.B. Vai, I.P. Martini (eds.), Anatomy of an Orogen: the Apennines and Adjacent Mediterranean Basins, Kluwer Academic Publishers: 351-366.
TAVIANI M. 2002 - The Mediterranean benthos from late Miocene up to present: ten million years of dramatic and geologic vicissitudes. Biol. Mar. Medit., 9: 445-463.
ZIBROWIUS H. 1980 - Les Scléractiniaires de la Méditerranée et de l'Atlantique Nord-occidental. Mém. Inst. Océanogr., Monaco, **11**: 1-284.