

SANSONIA ITALICA RAFFI & TAVIANI, 1985, JUNIOR SYNONYM OF MARELEPTOPOMA MINOR (ALMERA & BOFILL, 1898). THE PRESENCE OF THE FAMILY PICKWORTHIIDAE IREDALE, 1917 IN THE EARLY PLIOCENE OF IBERIA

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Abstract In this paper we draw attention to the previously unnoticed synonymy between *Sansonia italica* Raffi & Taviani, 1985 and the senior synonym, *Mareleptopoma minor* (Almera & Bofill, 1898). A short history of the Almera & Bofill collection is given and the collection is located in the Museu de Ciències Naturals de Barcelona, Spain. The similarity between a group of Neogene *Mareleptopoma* species including, *M. minor*, *M. badenicum* Janssen, 2004, *M. kenneyi* (Ladd, 1966), and an as yet undescribed French Oligocene species is discussed. This group is probably Indo-Pacific in origin and migrated eastwards to the Paratethys and then to the Mediterranean. *Mareleptopoma minor* is an example of a Mediterranean Pliocene Tropical Survivor, which today occurs in the Mauritanian-Senegalese molluscan faunal province, following the southwards shift seen in many Early Pliocene Iberian gastropods.

Key words Gastropoda, Pickworthiidae, Pliocene, biogeography

INTRODUCTION

The family Pickworthiidae Iredale, 1917 consists of small to minute gastropods, living in the Paleocene to Recent tropical regions. Due to the tiny size of the shells they are rarely mentioned in the literature, especially in the fossil assemblages. Even in the Recent faunas, most species have been described since 1990 (Moolenbeek & Faber, 1984; Espinosa & Fernandez-Garcés, 1990; Espinosa & Fernandez-Garcés & Rolán, 1990; Rolán & Fernandez-Garcés, 1993; Kase, 1998a, b, c, 1999; Rolán & Rubio, 1999; Le Renard & Bouchet, 2003).

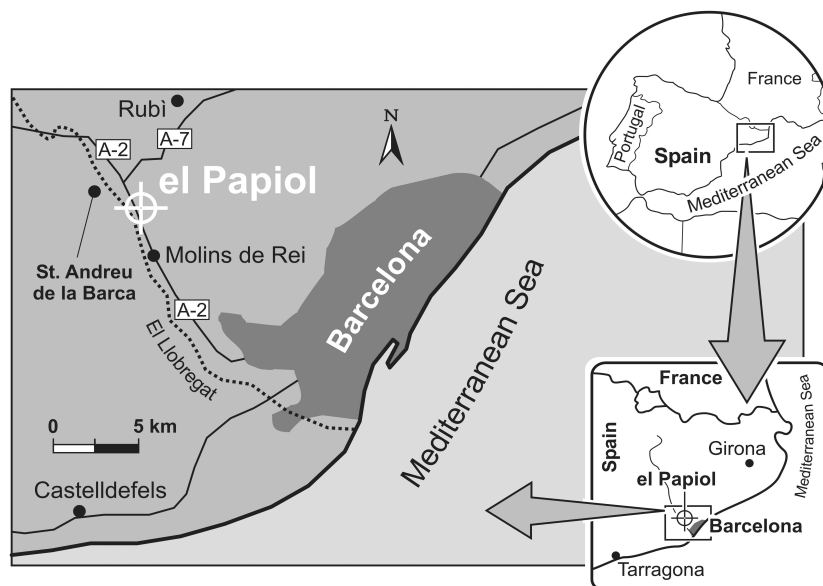
In the European Pliocene only one species has so far been described *Sansonia italica* Raffi & Taviani, 1985 from the Tabianian (= Zanclean) bathyal sediments of the Campore area in Italy. We have found numerous specimens of this same species in sievings from a shelly lens found in the Lower Pliocene, Zanclean locality of El Papiol, Baix Llobregat, Barcelona, northern Spain. The material comes from a quarry about 25 km southeast of Barcelona in the Southern Industrial Estate of El Papiol.

The quarry consists of bluish clays overlain by bluish-brown sandy clays with a sparse mollusc fauna, usually in a poor state of conservation. Shelly lenses are uncommon, this one was found

by a local collector, Mr Manuel Cervantes at the junction of the two layers. The lens is extremely rich in small gastropods, with some chiton plates and the odd bivalve preserved in a very fine, loose, sandy-clay matrix. There were no shells larger than 5 mm in the lens. The lens was excavated, the material sieved to 0.5 mm and examined under a binocular microscope. The fossil assemblage of this lens will be described and discussed in a subsequent paper (Landau in prep.).

GEOLOGICAL AND STRATIGRAPHICAL SETTING Civis (1977, 1982) considered the blue Pliocene marine sediments, which outcrop at Molins de Rey, to be relatively deep-water deposits from between 100-150 m water depth. Martinell & Marquina (1980), on the other hand, concluded that the clays represented a shallow-water littoral environment and further substantiated their conclusion by the finds of fossil squid and traces of small mammal footprints (Martinell & Marquina, 1984).

Gibert & Martinell (1992) distinguished six separate lithostratigraphic units within the Pliocene of Baix Llobregat. Our material comes from the 'Unitat d'argiles blaves' (Blue clay formation), deposited under tranquil conditions in less than 40 m water depth. This unit has the richest molluscan fossil assemblage.



Map 1 Geographical position of El Papiol

The scarcity of planktonic foraminifera in these marine sediments makes its chronostratigraphic assignment difficult. Civis (1975) considered the deposits Lower Pliocene based on the planktonic foraminifera. Suc & Cravatte (1982) dated them as lower Middle Pliocene based on pollen analysis. More recently Matías & Martinell (1984) placed the 'Unitat d'argiles blaves' (Blue clay formation) in the upper Lower Pliocene based on the calcareous nannoplankton. This chronostratigraphic position is supported by the molluscan assemblage, which is characteristically Lower Pliocene (Martinell, 1988).

We consider this fauna to belong to the biostratigraphic unit MPMU 1 (Mediterranean Pliocene Molluscan Units = MPMU), proposed by Raffi & Monegatti (1993) and further detailed in Monegatti & Raffi (2001). The authors distinguished four different faunal units within the Mediterranean Pliocene (Mediterranean Pliocene Molluscan Units = MPMU), MPMU 1 between 5.0 to 3.0 Ma, roughly equivalent to the Lower Pliocene (Zanclean + lower Piacenzian), the top of which was calibrated by the authors as 3-3.2 Ma (1993) later revised to 3 Ma (Monegatti & Raffi, 2001).

MOLLUSCAN FAUNA

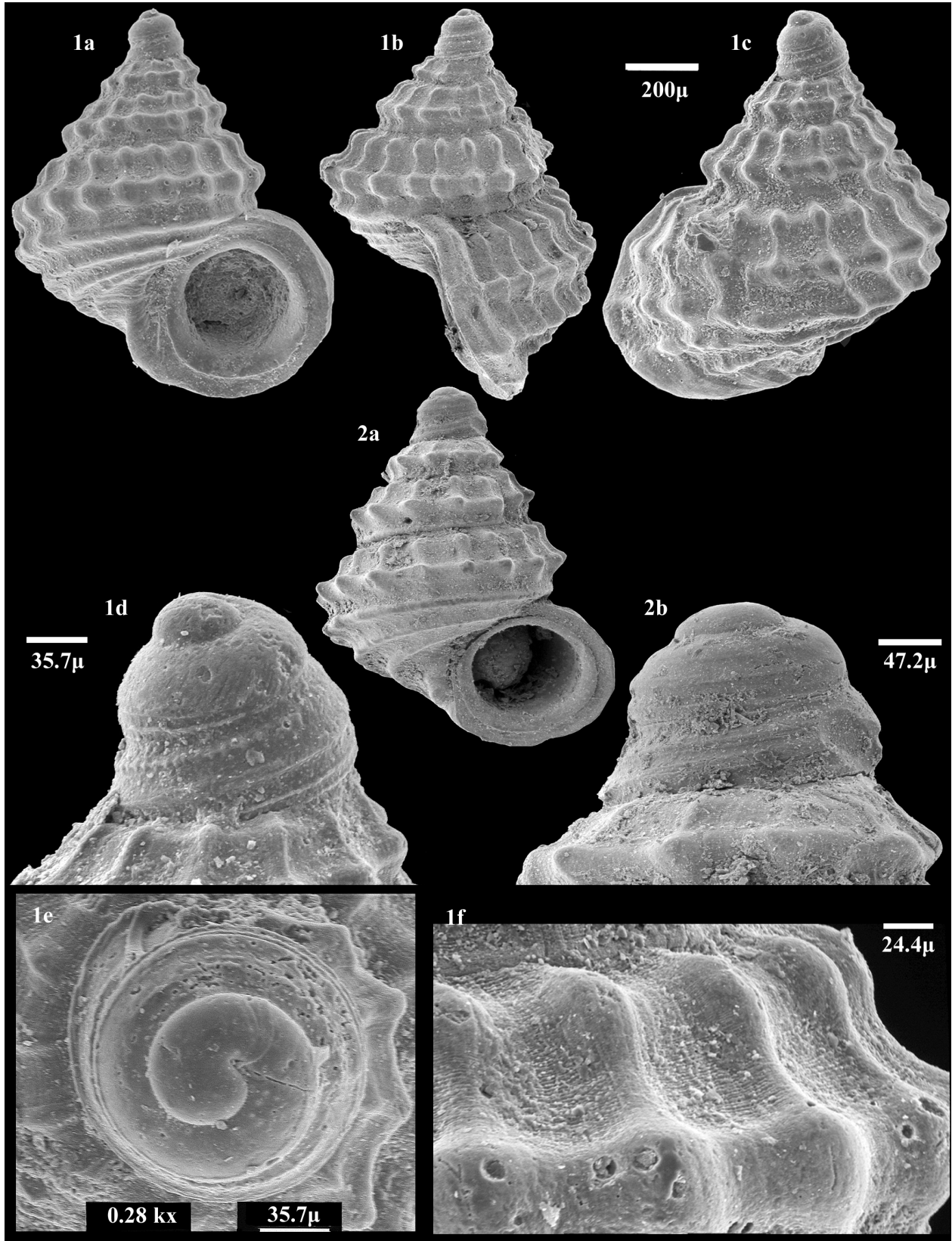
The Catalan Pliocene molluscan fauna has been revised in several publications by Martinell & Marquina (1980, 1981) and more recently by other Catalan researchers (Gili, 1990; Solsona,

1998, 1999). However, these works have all concentrated on the larger gastropod fauna. Most of the smaller shells, such as those described and recorded by Almera & Bofill (1898), have not been mentioned in more recent works.

The Almera & Bofill collection was accumulated during the last quarter of the 19th Century, as part of the preparation of the geological map of Catalonia. Artur Bofill was the project director, Jaume Almera, a priest, undertook the palaeontological studies.

Despite Almera being the founder of the Museu del Seminari Conciliar de Barcelona, an ecclesiastical institution, the collection was deposited in the Museu Geològic i Paleontològic de Barcelona, where it remains today. This is fortunate, as the Museu del Seminari Conciliar de Barcelona, which housed an important collection of Catalan fossils, was ravaged in 1936, during the Spanish Civil War, and in the ensuing disorder many of the fossils were removed and used to pave the nearby Balmes street. The Almera & Bofill collection of small Pliocene fossil shells was spared and transferred to the Museu Geològic i Paleontològic de Barcelona, today named Museu de Ciències Naturals de Barcelona, where it is found today. Incidentally, the Museu del Seminari Conciliar de Barcelona was re-established after the war and has grown again into one of the most important palaeontological museums in Spain.

Many of the records and new taxa described by Almera & Bofill (1898) are cited as originat-



Figs 1-2 1 *Mareleptopoma minor* (Almera & Bofill, 1898). El Papiol, Baix Llobregat, Barcelona, Spain. 'Unitat d'argiles blaves', upper Lower Pliocene. 2 *Mareleptopoma* sp. Abbese, Departement de Landes, France. Chattian, Upper Oligocene.

ing from the localities of Molins de Rei and Esplugues, both lying about 2 km south of El Papiol, and all three showing clearly the same palaeontological strata.

SYSTEMATIC PALAEOLOGY

SUPERFAMILY ?LITTORINOIDEA, Anon, 1834
 FAMILY PICKWORTHIIDAE Iredale, 1917
 Genus *Mareleptopoma* Moolenbeek & Faber,
 1984

Type species *Mareleptopoma karpatensis*
 Moolenbeek & Faber, 1984, by original designation.

Mareleptopoma minor (Almera & Bofill, 1898)
 Pl.1, fig. 1.

Danilia tinei var. *minor* Almera & Bofill, 1898: 90,
 pl. 6, fig. 17.

Sansonia italica Raffi & Taviani, 1985: 281, figs
 2-3.

Mareleptopoma italica (Raffi & Taviani) – Ardovini
 & Cossignani, 2004: 24, 89 unnumbered fig.

DISCUSSION:

Almera & Bofill (1898, p. 90, pl. 4, fig. 17) introduced the taxon *Danilia tinei* var. *minor*, by means of a figure with no description. The figure shows a very small shell, which is clearly not a *Danilia* Brusina, 1865. Although the figure shows a single spiral row of tubercles above the abapical suture and the scale bar suggests a shell about three times the size, the locality data and general resemblance to the specimen illustrated herein, suggested a member of the family Pickworthiidae.

We (J.F.) have examined the type material of *Danilia tinei* var. *minor* in the Museu de Ciències Naturals de Barcelona (holotype; catalogue number mgb11125) and confirm it to be conspecific with the material we found in the shelly lens from El Papiol. Unfortunately the shell is too small to photograph digitally and it was not possible to remove the type material for SEM photography. The shells illustrated in this work are deposited in the Museu de Ciències Naturals de Barcelona. Further specimens are deposited

in the Muséum national d'Histoire naturelle, Département Histoire de la Terre, Paris.

Raffi & Taviani (1985) described *Sansonia italica* from Tabianian (= Zanclean) bathyal sediments of the Campore area in Italy. Their specimens are somewhat abraded, but clearly conspecific. Described in the genus *Sansonia* Jousseau, 1892, the taxon is now transferred to *Mareleptopoma* Moolenbeek & Faber, 1984. The original generic diagnosis was modified by Le Renard & Bouchet (2003) and differs from *Sansonia* in including shells with a rissoiform rather than trochiform outline, more convex whorls, less thickened and less oblique apertural rim, narrow or obsolete umbilicus and a convex base sculptured with numerous concentric cords not forming a major keel at the periphery. The type genus *Pickworthia*, Iredale, 1917 has been synonymised with *Sansonia* (ICZN 1999, Art. 40.1). Reid (1998) placed the Pickworthiidae Iredale, 1917 in the superfamily Littorinoidea, although this allocation is not accepted by all (Le Renard & Bouchet, 2003).

Most species of Pickworthiidae are shallow water (Taviani & Sabelli, 1982; Fernandez-Garcés & Rolán, 1990; Rolán & Rubio, 1999) or shallow to moderately deep (Le Renard & Bouchet, 2003). Raffi & Taviani (1985, p. 238) postulated that their specimens of *Sansonia italica* found in Tabianian (= Zanclean) bathyal sediments of the Campore area in Italy, may have been transported from shallower environments. The presence of relatively numerous specimens in this shallow water assemblage from northern Spain and much fresher preservation than that illustrated by Raffi & Taviani would support this hypothesis.

The earliest occurrence of *Mareleptopoma* is from the Paleocene of Denmark (Bandel & Kowalke, 1997). One species occurs in the infralittoral Upper Oligocene, Chattian deposits of Abbese, Aquitaine (Pl. 1 Fig. 2; BL coll.), identified as *Alvania* (*Taramellia*) *kenneyi* Ladd, 1966 (Lozouet, 1986) or *Sansonia kenneyi* (Ladd, 1966) (Bandel & Kowalke, 1997). We also have three somewhat worn specimens of this species from the Lower Miocene of St-Paul-Lès-Dax (B.L. coll.), which may be reworked from older deposits. Although closely similar to *M. minor*, they are a distinct species. The French Oligocene shells have a more elongated teleoconch and although they have similar teleoconch sculptural elements consisting of two rows of tubercles, these are pointed rather

than rounded. The protoconch sculpture of the two species is also different.

Three species of *Mareleptopoma* have recently been described from the Middle Miocene Paratethys (Janssen, 2004). Of these *M. badenicum* Janssen, 2004 is the most similar, differing in having more numerous axial ribs and a greater number of spiral cords on the protoconch. Janssen (2004) suggested this species may be ancestral to *M. italica* (= *M. minor*).

Interestingly, *Alvania* (*Taramellia*) *kenneyi* Ladd, 1966 described from Middle-Late Miocene borehole samples from Eniwetok Atoll, Marshall Islands, Pacific Basin, which is also a *Mareleptopoma*, is very similar and seems to be phylogenetically linked. The figure is small (see Ladd, 1966) and the protoconch is not clearly seen. According to the description, the protoconch consists of 2.5 smooth whorls and no mention is made of the spiral sculpture. Several Recent Western Atlantic (*M. cubensis* Espinosa, Fernandez-Garcés & Rolán, 1990) Eastern Atlantic (*M. verdensis* Rolán & Rubio, 1999) and Pacific species (*M. drivasi*, *M. intermedia* and *M. pellucens* Le Renard & Bouchet, 2003) also have smooth or weakly sculptured protoconchs. We find no record of other species of Pickworthiidae with a global distribution and it is unlikely that they are conspecific with the French Oligocene shells.

PALAEOBIOGEOGRAPHIC IMPLICATIONS

Janssen (2004) noted the close similarity between *M. badenicum* and *M. kenneyi* and other Pickworthiidae occurring in the Early Badenian (Langhian) of the Paratethys, which seem to be much more closely related to Indo-Pacific taxa than to any of the extant western Atlantic Pickworthiidae. Connections between the Paratethys and the Indo-Pacific, which existed in the Early Badenian via Iran and India, made an extensive faunal exchange possible (Harzhauser, 2002; Janssen, 2004).

The presence of an undescribed species of *Mareleptopoma* in the Atlantic Late Oligocene of France suggests that the first migration predates the Miocene. During the Oligocene the Western Tethys Region covered the area of the modern Mediterranean and probably included also the European Atlantic coast up to the Bay of Biscay in the west and reached to Pakistan,

Somalia and Zanzibar in the east and the south, with a wide connection to the Indo-Pacific again allowing exchange of taxa (Harzhauser, 2002). In view of the much closer similarity between the European *Mareleptopoma* species and those in the Indo-Pacific, rather than the Atlantic, it is likely that this migration continued eastwards into the Mediterranean giving rise to *M. minor*.

During the Miocene one wide tropical European-West African Province extended from north-western France to Angola (ALVINERIE *et al.*, 1992). *Mareleptopoma*, like most gastropod families, disappeared from the Mediterranean during the Messinian Salinity Crisis, and repopulated the Mediterranean in the Early Pliocene from Atlantic stock.

Rolán (1991) reported *M. italica* (= *M. minor*) in the Recent fauna of the Cabo Verde archipelago, West Africa, in the tropical Mauritanian-Senegalese Recent molluscan faunal province. Monegatti & Raffi (2001) in their work on bivalves recorded species typical of MPMU 1 living along the West African coast south of latitude 20-22°N and called these species Mediterranean Pliocene Tropical Survivors (MPTSs). *Mareleptopoma minor* is an example of an MPTS within the gastropoda. Another example of a MPTS occurs in the El Papiol deposits, *Alvania fariae* Rolán & Fernández, 1990 (Landau in prep.), which also occurs further south in the Early Pliocene of Estepona, Málaga (Landau, Marquet & Grigis, 2004).

The genus is no longer present in the Mediterranean and is another example of the southward shift of Early Pliocene Iberian gastropods. This trend has already been recorded for other thermophilic gastropod taxa, e.g. *Solariella* (Silva, Landau & Martinell, 2000), *Alvania*, *Rissoina* (Landau, *et al.*, 2004), *Granulina* (La Perna, Landau & Marquet, 2002; La Perna, Landau & Silva, 2003), *Marginella*, *Dentimargo*, *Persicula* (Landau, La Perna & Marquet, 2006), which did not survive the climatic cooling in Europe during the Plio-Pleistocene and either migrated southwards or are now restricted to the southern part of their Pliocene distribution.

CONCLUSIONS

The localization of the Almera & Bofill collection in the Museu de Ciències Naturals de Barcelona

allowed us to examine the type specimen of *Danilia tinei* var. *minor* Almera & Bofill, 1898, and conclude it to belong to the Pickworthidae, conspecific with *Sansonia italica*, Raffi & Taviani 1985, which becomes a junior synonym.

Mareleptopoma minor no longer occurs in the Mediterranean, found today further south off the coasts of Cabo Verde, within the Mauritanian-Senegalese molluscan faunal province and is an example of a Mediterranean Pliocene Tropical Survivor.

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REFERENCES

- ALMERA J & BOFILL A 1898 Moluscos fósiles recogidos en los terrenos pliocenos de Cataluña. Descripciones y figuras de las formas nuevas y enumeración de todas las encontradas en dichos yacimientos. *Bolletín de la Comisión del Mapa Geológico de España* **24**: 1-222.
- ALVINERIE J, ANTUNES MT, CAHUZAC B, LAURIAT-RAGE A, MONTENAT C & PUJOL C 1992 Synthetic data on the paleogeographic history of Northeastern Atlantic and Betic-Rifian basin, during the Neogene (from Brittany, France, to Morocco). *Palaeogeography, Palaeoclimatology, Palaeoecology* **95**: 263-286.
- ARDOVINI R & COSSIGNANI T 2004 *West African Seashells (including Azores, Madeira and Canary Is.)*. L'Informatore Picentino, Ancona, 319pp.
- BANDEL K & KOWALKE TH 1997 Systematic value of the larval shell of fossil and modern Vanikoridae, Pickworthiidae and the genus *Fossarus* (Caenogastropoda, Mollusca). *Berliner geowissenschaftliche Abhandlungen* **E 25**: 3-29.
- CIVIS J 1975 *Estudio de los foraminíferos del Plioceno del NE de España*. Doctoral thesis (unpublished) University of Salamanca: 496 pp.
- CIVIS J 1977 Estudio de los foraminíferos pliocénicos de Papiol (Barcelona), significación, paleoecología y paleogeografía. *Studia Geologica Salmanticensia* **13**: 7-30.
- CIVIS J 1982 Microfauna del Plioceno de "La Plaça de les Bruixes" (Molins de Rei, Barcelona). *Acta Geologica Hispanica* **14** (1979): 385-390.
- ESPINOSA J & FERNANDEZ-GARCÉS R 1990 Una nueva especie antillana del genero *Sansonia* (Mollusca: Archeogastropoda). *Poeyana* **408**: 1-3.
- ESPINOSA J, FERNANDEZ-GARCÉS R & ROLÁN E 1990 *Mareleptopoma cubensis* n. sp., a new species from Cuba (Gastropoda Prosobranchia). *Basteria* **54**: 239-241.
- GIBERT JM & MARTINELL J 1992 Principales estructuras biogénicas el el Plioceno marino de la cuenca del Baix Llobregat (Catalunya). *Geogaceta* **12**: 104-105.
- GILI C 1990 *Els Nassariidae (Gastropoda, Prosobranchia) del Pliocè de la Mediterrània Occidental*. Doctoral thesis, University of Barcelona Col.l. Tesis Doc. *Microfitxades* **1412** (1992). University of Barcelona Publications, 563 pp.
- HARZHAUSER M, PILLER WE & STEININGER FF 1984 Circum-Mediterranean Oligo-Miocene biogeographic evolution – the gastropods point of view. *Palaeogeography, Palaeoclimatology, Palaeoecology* **183**: 103-133.
- ICZN 1999 *International Code of Zoological Nomenclature*. 4th ed. International Trust for Zoological Nomenclature, London, 306p.
- JANSSEN R 2004 The family Pickworthidae in the Middle Miocene of the Paratethys (Gastropoda: Caenogastropoda: Littorinoidea?). *Cour. Forschungsinstitut Senckenberg* **246**: 169-186.
- KASE T 1998a The family Pickworthiidae (Gastropoda: Caenogastropoda) from the Tropical Pacific submarine Caves: Four new species of *Sansonia*. *Venus* **57** (3): 161-172.
- KASE T 1998b The family Pickworthiidae (Gastropoda: Caenogastropoda) from the Tropical Pacific submarine Caves: Seven new species of *Microliotia*. *Venus* **57** (3): 173-190.
- KASE T 1998c The family Pickworthiidae (Gastropoda: Caenogastropoda) from the Tropical Pacific submarine Caves: Five new species of *Reynellona*. *Venus* **57** (4): 245-257.
- KASE T 1999 The family Pickworthiidae (Gastropoda: Caenogastropoda) from the Tropical Pacific submarine Caves: *Ampullosansonia* n. gen. and *Tinianella* n. gen. *Venus* **58** (3): 91-100.
- LANDAU BM & MARQUET R & GRIGIS M 2004 The Early Pliocene Gastropoda (Mollusca) of Estepona, Southern Spain. Part 2 - Orthogastropoda, Neotaenioglossa. *Palaeontos* **4**: 1-108.
- LANDAU BM, LA PERNA R & MARQUET R 2006 The

- Early Pliocene Gastropoda (Mollusca) of Estepona, Southern Spain. Part 10—Marginellidae, Cystiscidae. *Palaeontos* **9**: 22-60, 3 text figs, 2 tables, 12 plates.
- LA PERNA R, LANDAU B & MARQUET R 2002 *Granulina* (Gastropoda, Marginellidae) from the Pliocene of Málaga (southern Spain) with description of four new species. *Cainozoic Research* **1** (1-2): 111-120.
- LA PERNA R, LANDAU B & SILVA CM 2003 The genus *Granulina* (Gastropoda, Marginellidae) from the Atlantic Iberian Pliocene with description of a new species from Portugal. *Iberus* **21** (1): 35-42.
- LE RENARD J & BOUCHET P 2003 New species and genera of the family Picworthiidae (Mollusca, Caenogastropoda). *Zoosystema* **25** (4): 569-591.
- LOZOUET P 1986 *Les Gastéropodes prosobranches de l'Oligocène supérieur du Bassin de l'Adour (systématique, paléoenvironnements, paléoclimatologie, paléobiogéographie)*. Diplôme de l'E.P.H.E., 475pp.
- MARTINELL J & MARQUINA JM 1980 Señales de depredación en los Gastropoda procedentes de un yacimiento pliocénico de Molins de Rei (Barcelona). Implicaciones paleoecológicas. *Acta Geologica Hispanica* **13** (1978): 125-128.
- MARTINELL J & MARQUINA JM 1981 Malacofauna pliocénica de St. Vicenç dels Horts (Baix Llobregat, Barcelona). *Iberus* **1**: 9-22.
- MATÍAS I, & MARTINELL J 1984 Première contribution a la connaissance du Nannoplancton calcaire du Pliocène catalan. *Revue de Micropaléontologie* **27**: 43-53.
- MARTINELL J 1988 An overview of the marine Pliocene of N. E. Spain. *Géologie Méditerranéenne* **4**: 227-233.
- MARTINELL J & MARQUINA JM 1984 De la bathymetrie du Pliocene marin du Baix Llobregat (Barcelona, Espagne). *Paléobiologie continentale* **14**: 333-338.
- MONEGATTI P & RAFFI S 2001 Taxonomic diversity and stratigraphic distribution of Mediterranean Pliocene bivalves. *Palaeogeography, Palaeoclimatology, Palaeoecology*, Amsterdam **165**: 171-193.
- MOOLENBEEK RG & FABER MJ 1984 Studies of West Indian marine Mollusca. A new Gastropod genus and species from Bonaire, Netherlands Antilles. *Uitgaven natuurw. StudKring Suriname* **114**: 98-103.
- RAFFI S & MONEGATTI P 1993 Bivalve taxonomic diversity throughout the Italian Pliocene as a tool for climatic-oceanographic and stratigraphic inferences. Proc. 1st R.C.A.N.S. Congress, Lisboa, 1992. *Ciências da Terra* (UNL), Lisboa **12**: 45-50.
- RAFFI S & TAVIANI M 1985 *Sansonia italica* n.sp.: first evidence of *Sansonia* Jousseume, 1892 from the Mediterranean Pliocene (Gastropoda, Prosobranchia). *Archiv für Molluskenkunde* **115** (4-6): 279-286.
- ROLÁN E 1991 *Sansonia italica* Raffi & Taviani, 1985 primera cita para la fauna de Cabo Verde. *Noticiario SEM* **13**: 43.
- ROLÁN E & FERNÁNDEZ-GARCÉS R 1993 Descripción de dos nuevas especies del genero *Mareleptopoma* (Gastropoda, Prosobranchia) de Cuba. *Iberus* **11** (1): 57-60.
- ROLÁN E. & RUBIO F 1999 New information on the malacological fauna (Mollusca, Gastropoda) of the Cape Verde Archipelago, with the description of five new species. *Apex* **14** (1): 1-10.
- SILVA CM DA, LANDAU BM & MARTINELL JM 2000 The genus *Solariella* (Mollusca: Archaeogastropoda) from the Pliocene of Vale de Freixo, Portugal: Palaeobiogeographic and palaeoclimatic implications. *Contributions to Tertiary and Quaternary Geology* **37** (3-4): 57-65.
- SOLSONA M 1998 Paleobiologia dels Mesogasteròpodes del Pliocè del Mediterrani Nord-Occidental. *Doctoral thesis, Departamento d'Estratigrafia i Paleontologia, University of Barcelona*, 540pp.
- SOLSONA M 1999 Sistemàtica i descriptiva de les famílies Tonnidae, Ficidae i Cassidae (Tonnoidea, Gastropoda) del Pliocè del Mediterrani nord-occidental. *Butlletí de la Institució Catalana d'Història Natural* **67**: 69-90.
- SUC JP & CRAVATTE J 1982 Étude palynologique du Pliocène de Catalogne (Nord Est de l'Espagne). Apports a la connaissance de l'histoire climatique de la Méditerranée occidentale et implications chronostratigraphiques. *Paléobiologie continentale* **13**: 1-31.
- TAVIANI M & SABELLI B 1982 Origine et distribution du genre *Sansonia* (Gastropoda: Prosobranchia). *Malacologia* **22** (1): 545-546.

