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Biostratigraphic interpretation of Miocene holoplanktonic mollusc assemblages from Gargano and Salento (Puglia), Italy

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ABSTRACT - Samples collected in the early 1990s from localities in Salento and Gargano yield additional information on the assemblages of Miocene pelagic Mollusca. From the Gargano localities Crocifisso di Varano, Sannicola Varano, Sannicandro Garganico and Torre Mileto a total of 33 species are recorded from the Lago di Varano Formation, together unequivocally demonstrating a Langhian age (Pteropod Zone 18a). In Salento, Lecce area, two localities were sampled (Cursi and Melpignano), predominantly from a phosphorite rich horizon in the strongly glauconitic, so-called 'piromáfo' level in the upper part of the Pietra Leccese Formation, from which 31 species are now known, most of them indicating a Langhian age, but some only known from Serravallian (Pteropod Zone 19) or Tortonian (Pteropod Zone 20) rocks. Therefore the reworked character of the Lecce assemblages is acknowledged. The "piromáfo" deposit proper is not older than Tortonian. Pteropods from rocks underlying the "piromáfo" level do not show signs of reworking and yield exclusively species characteristic of Pteropod Zone 18a and are therefore considered to be *in situ* and of Langhian age.

Key words: Heteropoda, Pteropoda, biozonation, Langhian, Serravallian, Tortonian

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INTRODUCTION

Miocene assemblages of pelagic Gastropoda, predominantly so-called Pteropoda (= Thecosomata) have repeatedly been reported from two areas in the Italian province of Puglia, namely Gargano and Salento. Pteropods from Sannicola Varano in Gargano were described already by Checchia-Rispoli (1921), who recorded 14 pteropod species, seven of which were new to science, and who proposed a Langhian age for the assemblage. Sirna (1968) reinvestigated the Sannicola pteropod fauna, mentioning 15 species, two of which were introduced as new. Contrarily, he dated the fauna by means of foraminifera as Serravallian.

D'Alessandro et al. (1979) published a detailed study of the Gargano marine Neogene rocks, including all macrobiota, but with much attention paid to the pteropod assemblages of the Miocene Lago di Varano Formation. Their basic material of that group of gastropods was primarily from the same Sannicola Varano locality, but also some other outcrops of that unit in the same area (Posta di Milena, Masseria Palmieri) were sampled. They described 21 pteropod taxa and also recorded a single "heteropod" (= Gastropoda, Pterotracheoidea) species. These authors postulated a late Tortonian age for the pteropod-bearing deposits, mainly based on the known vertical distribution of various macrobiota.

D'Alessandro and Robba (1981) paid special attention to pteropod assemblages of the Puglia area in southern Italy, restricting themselves to the Cavolinioidea and focussing on two separate groups of localities, viz. near Lecce (outcrops of the Pietra Leccese Formation at Cursi and Melpignano), and revising in the same paper the Gargano pteropod material, published by D'Alessandro et al. (1979) and earlier authors from the Lago di Varano Formation. From Gargano 14 pteropod species were recorded and 20 from the five Lecce localities combined. They considered both the Lecce and Gargano pteropod assemblages to be reworked and indicative of a late Langhian-early/middle Serravallian time interval. The age of the deposits proper (bioclastic wackestones of the Lago di Varano Formation in Gargano, strongly glauconitic wacke- to packstones of the Pietra Leccese Formation in the Salento area) was considered to be of late Serravallian-middle/late Tortonian age on the basis of planktonic foraminifera.

Recently Janssen (2012a) published a study of heteropod and pteropod assemblages from the late Oligocene-Miocene deposits of Malta in which all holoplanktonic mollusc taxa referred to in the earlier Italian papers mentioned above were systematically revised and a short biostratigraphical interpretation of

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the Gargano and Salento assemblages was presented (Janssen, 2012a) in the context of a proposed biostratigraphical zonation based on pteropods.

In the present paper results of new material collected in the 1990s in both Italian areas are summarized and the biostratigraphical implications of the holoplanktonic mollusc assemblages are interpreted in more detail. From the Gargano and Lecce localities totals of 33 and 31 species respectively are recorded, three of which are Heteropoda. The considerably higher number of species, as well as of specimens, as compared to the earlier papers referred to above, is caused by sampling longer sections, by the number of samples, the sample sizes and inspection of the finer fractions as well.

A complete listing of recorded species from all localities is given in Tab. 1a and 1b, giving also the synonymies of earlier papers, based on Janssen (2012a), which makes a systematic description of species superfluous for the present paper.

GEOLOGICAL SETTING

Gargano

On the northern side of the predominantly Mesozoic, so-called "Promontorio Garganico" Neogene deposits are present (Fig. 1), unconformably overlying Jurassic and Cretaceous rocks that are quarried for "marble" on a large scale in between the villages of Apricena and Poggio Imperiale. Karst fissures in these limestones yield a beautiful washed-in Miocene terrestrial vertebrate island fauna, which has been sampled extensively in the 1970s by the then National Museum of Geology and Mineralogy (nowadays part of Naturalis Biodiversity Center) of Leiden, The Netherlands (Ballmann, 1973, 1976; Freudenthal, 1971, 1972, 1976, 1985; Butler, 1980; Willemsen, 1983; Leinders, 1984). Apart from these terrestrial deposits a sequence of marine sediments of Miocene and Pliocene age is found on top of the Mesozoic limestones and in some of the fissure fillings. Field observations of the various outcrops of Neogene marine sediments in the wide area around Apricena were made by van den Bosch (1970, unpublished). The stratigraphy of the area was extensively described by D'Alessandro et al. (1979) and summarized in D'Alessandro and Robba (1981). The present paper focusses on the fossil contents (predominantly pteropods) of marine Miocene calcarenites of the Lago di Varano Formation. On the basis of planktonic foraminifera D'Alessandro and Robba (1981) estimated the age of the formation as late Tortonian and considered the pteropod assemblages to be reworked.

Lecce area

Pteropods of several localities in the Lecce province were described by D'Alessandro and Robba (1981) from the Pietra Leccese Formation (Bosellini et al., 1999; Mazzei et al., 2009). They sampled five localities situated in between the villages of Cursi and Melpignano and gave a lithological description of an over 30 m high section (their figure 3) situated on the right side of the road from Cursi to Melpignano, about 500 m from the Cursi cemetery. Mazzei et al. (2009) recognized several hiatuses in this sequence and distinguished three separate levels, differing by an upward increasing glauconite content, together forming the Pietra Leccese Formation of Burdigalian, Langhian and early Tortonian age. On top of the upper, strongly glauconitic level and following a further hiatus, light coloured calcarenites of the Calcareniti di Andrano Formation of Messinian age are present (age assignments are after Mazzei et al., 2009). This succession can easily be recognized in the section measured by D'Alessandro and Robba (1981). The lower 25 m of their section consist of light yellowish, homogeneous calcarenites with an up-section slightly increasing glauconite component. In the upper part of the formation two distinctly different levels are indicated. The lower one of these, with a thickness of some 2.5 m, is separated by an obvious hiatus ("second hiatus" of Mazzei et al., 2009) with clear burrows into the top of the underlying rock, and with a strongly increased glauconite content. This level, the uppermost part of the Pietra Leccese Formation, is indicated as "piromáfo" and contains numerous phosphoritic concretions, many of which are bioclasts, concentrated at its base around a thin layer of bivalves, the "linea delle cozze".

On top of the glauconitic "piromáfo", and again separated by a distinct hiatus ("third hiatus" of Mazzei et al., 2009) a level of light yellowish, friable, non-glauconitic calcarenites is seen, up to 4 m thick, containing decalcified but not phosphatized macrofossils at its base. This latter part of the section belongs to the Calcareniti di Andrano Formation.

MATERIAL AND METHODS

For an inventory of the holoplanktonic mollusc assemblages two sections were measured and sampled, one at Sannicola Varano (Gargano) (Lago di Varano Formation) and one at Melpignano (Salento). The Sannicola section comprised almost 9.50 m. Eleven samples were collected, three levels were later bulk sampled because of important fossil contents. At Melpignano, at the time an active limestone quarry, a section with a height of 21 m was measured, the lower 19 m belonging to the Pietra Leccese Formation, the top 2 m to the Calcareniti di Andrano Formation. Eight samples were collected from the Pietra Leccese part of the section. Additionally random samples were collected from various other outcrops in Gargano and Salento, as described below.

Initially, fossil collecting was done visually, by inspecting matrix pieces with a watchmaker's lense. This, however, is very time-consuming and was soon replaced by treatment with diluted formic acid to dissolve the calcium carbonate and free the phosphoritic bioclasts. This method is extensively described in Janssen (2012a). Formic acid residues generally are > 0.10-0.15 mm and

Gargano and Salento localities revised list of species	Gargano, Sannicola Varano (Checchia-Rispoli, 1921)	Gargano, Sannicola Varano (Sirna, 1968)
Atlanta sp.	-	-
Protatlanta rotundata (Gabb, 1873)	-	-
Carinaria sp.	-	-
Heliconoides inflata (d'Orbigny, 1834)	-	-
Heliconoides tertiaria (Tate, 1887)	-	-
Heliconoides sp. (inflata/tertiaria)	-	-
Limacina valvatina (Reuss, 1867)	-	-
Limacina sp.	-	-
Praehyalocylis sp.	-	-
Styliola subula (Quoy and Gaimard,1827)	*Clio (Styliola) lamberti* Checchia-Rispoli (p. 10)	*Styliola lamberti* Checchia-Rispoli, 1921 (p. 420)
Creseidae sp.	-	-
Cuvierina paronai Checchia-Rispoli, 1921	*Cuvierina Paronai* Checchia-Rispoli (p. 6)	*Cuvierina paronai* Checchia-Rispoli, 1921 (p. 427)
Cuvierina curryi Janssen, 2005	-	-
Cuvierina grandis D'Alessandro and Robba, 1981	-	-
Cuvierina intermedia (Bellardi, 1873)	-	-
Clio aichinoi Checchia-Rispoli, 1921	*Clio (Clio) Aichinoi* Checchia-Rispoli (p. 21)	-
Clio bellardii Audenino, 1899	-	-
Clio distefanoi Checchia-Rispoli, 1921	*Clio (Clio) Distefanoi* Checchia-Rispoli (p. 20)	*Clio distefanoi* Checchia-Rispoli, 1921 (p. 421)
-	-	*Clio garganica* Sirna, 1968 (p. 421)
Clio pedemontana (Mayer, 1868)	*Clio (Clio) pedemontana* Mayer (p. 18)	-
Clio pulcherrima (Mayer, 1868)	*Clio (Clio) pulcherrima* Mayer (p. 19)	*Diacria sangiorgii* Scarsella, 1934 (p. 427)
Clio saccoi Checchia-Rispoli, 1921	*Clio (Clio) Saccoi* Checchia-Rispoli (p. 22)	*Clio saccoi* Checchia-Rispoli, 1921 (p. 422)
Clio sp. nov.	-	-
Cavolinia cookei Simonelli, 1895	-	-
Cavolinia gatti Janssen, 2012	-	-
Cavolinia pycna Jung, 1971	-	-
Cavolinia zamboninii Checcia-Rispoli, 1921	*Cavolinia Zamboninii* Checchia-Rispoli (p. 26)	*Cavolinia zamboninii* Checchia-Rispoli, 1921 (p. 428)
Diacrolinia aurita (Bellardi, 1873)	*Cavolinia Cerullii* Checchia-Rispoli (p. 24)	*Cavolinia Cerullii* Checchia-Rispoli, 1921 (p. 428)
Edithinella varanica (Sirna, 1968)	-	*Vaginella varanica* Sirna, 1968
Vaginella austriaca Kittl, 1886	*Clio (Vaginella) austriaca* Kittl (p. 13)	*Vaginella austriaca* Kittl, 1886 (p. 423)
		Vaginella calandrellii (Michelotti, 1847) (p. 423)
Vaginella gibbosa Audenino, 1899	*Clio (Vaginella) gibbosa* Audenino (p. 16)	*Vaginella gibbosa* Audenino, 1896 (p. 424)
Vaginella lapugyensis Kittl, 1886	*Clio (Creseis) spina* Reuss (p. 8)	*Creseis spina* Reuss, 1867 (p. 420)
	Clio (Vaginella) lapugyensis Kittl (p. 12)	*Vaginella lapugyensis* Kittl, 1886 (p. 425)
	var. *garganica* Checchia-Rispoli (p. 13)	
Vaginella sannicola Janssen, 1995	*Clio (Vaginella) depressa* Daudin (p. 15)	*Vaginella depressa* Daudin, 1800 (p. 424)
Sphaerocina formai (Audenino, 1899)	-	-
Cymbulia sp.	-	-
Peracle grebneffi Janssen 2012	-	-
Peracle sp.	-	-
Clione? ignota Janssen, 2012	-	-
Clione? imdinaensis Janssen, 2012	-	-
Clione? tumidula Janssen, 2012	-	-

Tab. 1a - Complete list of species recorded from all Gargano and Lecce localities, and their synonyms in earlier papers (1).

Gargano and Salento localities revised list of species	Gargano localities (D'Alessandro et al., 1979)	Gargano and Salento localities (D'Alessandro and Robba, 1981)
Atlanta sp.	-	-
Protatlanta rotundata (Gabb, 1873)	*Protoatlanta* sp. (p. 78)	-
Carinaria sp.	-	-
Heliconoides inflata (d'Orbigny, 1834)	-	-
Heliconoides tertiaria (Tate, 1887)	*Spiratella inflata* (d'Orbigny, 1836) (p. 82)	-
Heliconoides sp. (*inflata/tertiaria*)	*Spiratella inflata* (d'Orbigny, 1836) (p. 82)	-
Limacina valvatina (Reuss, 1867)	-	-
Limacina sp.	-	-
Praehyalocylis sp.	-	-
Styliola subula (Quoy and Gaimard,1827)	*Styliola lamberti* Checchia-Rispoli,1921 (p. 84)	*Styliola subula lamberti* (Checchi-Rispoli, 1921) (p. 617)
Creseidae sp.	-	-
Cuvierina paronai Checchia-Rispoli, 1921	*Cuvierina paronai* Checchia-Rispoli, 1921 (p. 89)	*Cuvierina paronai* Checchia-Rispoli, 1921 (p. 643)
Cuvierina curryi Janssen, 2005	-	*Cuvierina columnella urceolaris* (Mörch, 1850) (p. 645)
Cuvierina grandis D'Alessandro and Robba, 1981	-	*Cuvierina grandis* D'Alessandro and Robba, 1981 (p. 649)
Cuvierina intermedia (Bellardi, 1873)	-	*Cuvierina columnella urceolaris* (Mörch, 1850) (p. 645)
Clio aichinoi Checchia-Rispoli, 1921	*Clio aichinoi* Checchia-Rispoli, 1921 (p. 84)	*Clio aichinoi* Checchia-Rispoli, 1921 (p. 634)
Clio bellardii Audenino, 1899	-	*Clio bellardii* Audenino, 1897 (p. 634)
Clio distefanoi Checchia-Rispoli, 1921	*Clio distefanoi* Checchia Rispoliu, 1921 (p. 84)	*Clio distefanoi* Checchia-Rispoli, 1921 (p. 636)
	Clio garganica Sirna, 1968 (p. 84)	*Clio garganica* Sirna, 1968 (p. 638)
Clio pedemontana (Mayer, 1868)	*Clio* cf. *pedemontana* (Mayer, 1868)(p. 85) ??	-
Clio pulcherrima (Mayer, 1868)	*Clio pulcherrima* (Mayer, 1868) (p. 85)	*Clio pulcherrima* (Mayer, 1868) (p. 641)
Clio saccoi Checchia-Rispoli, 1921	*Clio saccoi* Checchia-Rispoli, 1921 (p. 85)	*Clio saccoi* Checchia-Rispoli, 1921 (p. 642)
Clio sp. nov.	-	*Clio pedemontana* (Mayer, 1868) (p. 641)
Cavolinia cookei Simonelli, 1895	*Cavolinia zamboninii* Checchia-Rispoli, 1921 (p. 91)	*Cavolinia cookei* Simonelli, 1895 (p. 656)
Cavolinia gatti Janssen, 2012	-	*Cavolinia aurita* (Bellardi, 1873) (p. 654)
Cavolinia pycna Jung, 1971	-	-
Cavolinia zamboninii Checchia-Rispoli, 1921	-	-
Diacrolinia aurita (Bellardi, 1873)	*Cavolinia cerullii* Checchia-Rispoli, 1921 (p. 91)	*Cavolinia audeninoi* Vinassa de Regny, 1898 (p. 651)
Edithinella varanica (Sirna, 1968)	*Vaginella* cf. *varanica* Sirna, 1968 (p. 89)	*Vaginella varanica* Sirna, 1968 (p. 633)
Vaginella austriaca Kittl, 1886	*Vaginella austriaca* Kittl, 1866 (p. 85)	*Vaginella austriaca* Kittl, 1886 (p. 620)
-	*Vaginella calandrellii* (Michelotti, 1847) (p. 87)	*Vaginella rotundata* Blanckenhorn, 1889 (p. 628)
-	*Vaginella* sp. (p. 89)	*Vaginella rzehaki* Kittl, 1886 (p. 631)
Vaginella gibbosa Audenino, 1899	*Vaginella gibbosa* Audenino, 1896 (p. 88)	*Vaginella rzehaki* Kittl, 1886 (p. 631)
Vaginella lapugyensis Kittl, 1886	*Creseis spina* Reuss, 1867 (p. 84)	*Vaginella lapugyensis* Kittl, 1886 (p. 627)
	Vaginella lapugyensis Kittl, 1886 (p. 88)	-
Vaginella sannicola Janssen, 1995	*Vaginella* aff. *depressa* Daudin, 1800 (p. 86)	*Vaginella eligmostoma* Tate, 1887 (p. 623)
Sphaerocina formai (Audenino, 1899)	-	-
Cymbulia sp.	-	-
Peracle grebneffi Janssen 2012	*Spiratella andrussowi* (Kittl, 1886) (p. 82)	-
Peracle sp.	-	-
Clione? ignota Janssen, 2012	-	-
Clione? imdinaensis Janssen, 2012	-	-
Clione? tumidula Janssen, 2012	-	-

Tab. 1b - Complete list of species recorded from all Gargano and Lecce localities, and their synonyms in earlier papers (2).

are fractionated with a set of standard sieves, and each fraction was subsequently analysed qualitatively for holoplanktonic molluscs. For most samples the remaining residues, always containing abundant foraminifera and other microfossils, are kept in the RGM collections (Rijksmuseum van Geologie en Mineralogie, nowadays part of Naturalis Biodiversity Center, Leiden, The Netherlands).

DESCRIPTION OF LOCALITIES

Gargano (all Lago di Varano Formation)

Among the many Gargano localities described and sampled by van den Bosch (1970) was a site at Sannicola Varano, indicated as "abandoned limestone quarry opposite Casa Fara". The light yellowish calcarenitic sample from this place contained abundant pteropod fossils in phosphoritic internal mould preservation. It was soon found out that this was the same outcrop area as sampled by Checchia-Rispoli (1921) and Sirna (1968), and later was one of the localities studied by D'Alessandro et al. (1979). The holoplanktonic mollusc samples underlying the latter paper are now housed in Dipartimento di Scienze della Terra "A. Desio", Università degli Studi, Milano, and are included herein.

Fieldwork in Gargano by the present author took place at several occasions in the early 1990s and consisted of extensive sampling of the Sannicola Varano 'opposite Casa Fara' locality, where a detailed section of the most important fossil locality, in one of three abandoned small limestone quarries, was measured and sampled. Also several further outcrops in the same area, all belonging to the Lago di Varano Formation, were sampled, see description of localities below. Specimens are housed in the collections of Naturalis Biodiversity Center (Leiden, The Netherland) (RGM registration numbers).

Crocifisso di Varano

Outcrop on East bank of Lago di Varano. A thin bed of white, compact calcarenites of the Lago di Varano Formation is present on top of Mesozoic carbonates. A sediment sample was collected c. 0.50 m above the base of the Miocene carbonates. Although fossils were barely visible in the matrix macroscopically, the residue yielded many mainly small phosphatized fossils, among which some heteropods and abundant pteropods.

Sannicola Varano

Natural outcrops and three small, abandoned limestone quarries with a depth of c. 10 m are present on the hillside opposite Casa Fara. The approximate position of the outcropping Lago di Varano Formation and the three quarries relative to Casa Fara is given in figure 2. The outcrop area is shown in figure 3. A simplified survey of the local stratigraphy is given in figure 4.

Sannicola Varano 1

This first sample, collected by M. van den Bosch in 1970, kept in the RGM collections, was treated with formic acid in 2002, the fossils from the residue are integrated with specimens collected visually by M. van den Bosch in 1970. Among the pteropods the species *Edithinella varanica* and *Vaginella sannicola* are commonly represented.

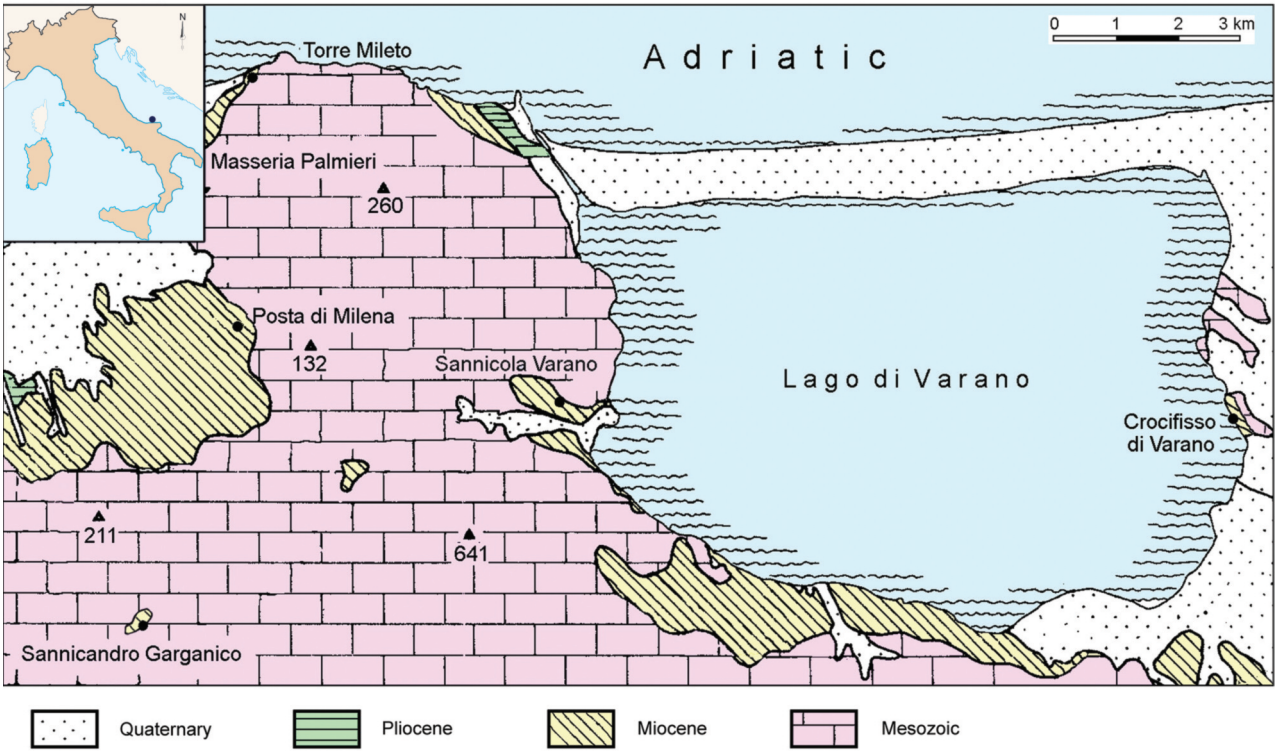

Fig. 1 - Geological sketch and collecting sites in Gargano (modified after D'Alessandro et al., 1979).

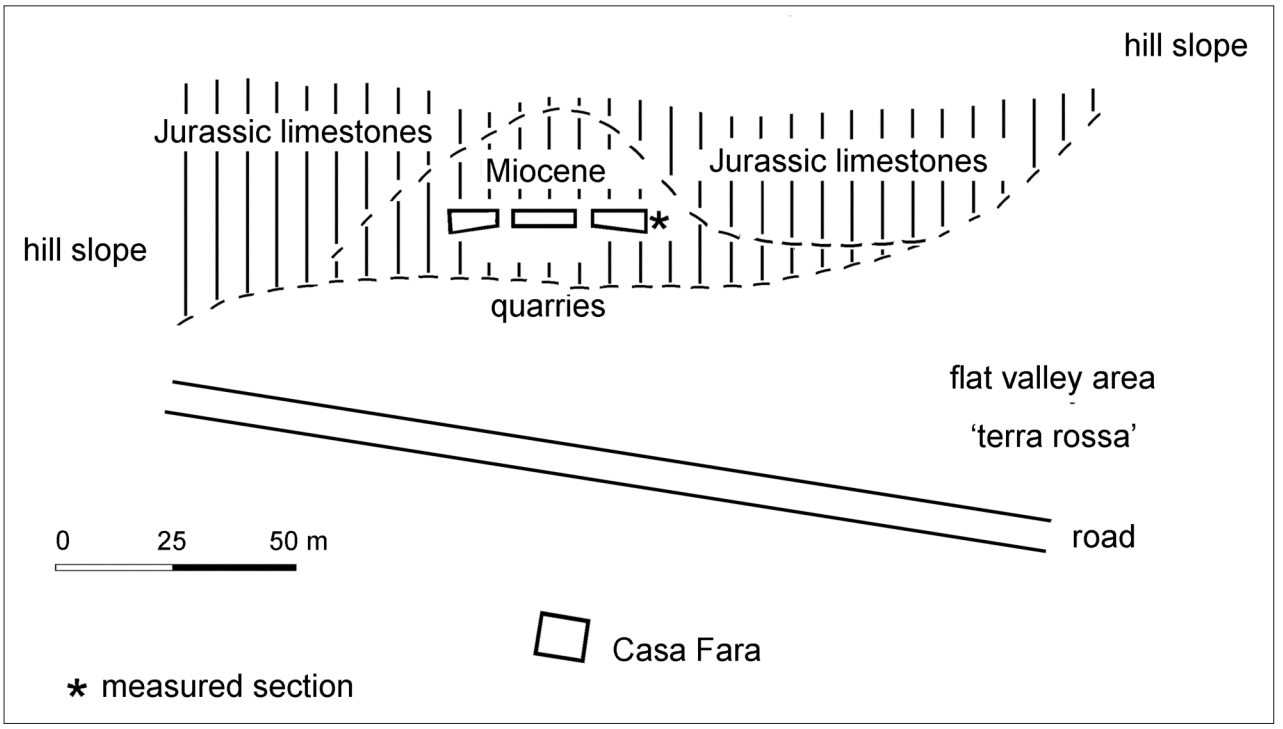

Fig. 2 - Sannicola Varano, approximate position of three small abandoned quarries opposite Casa Fara and location of measured section.

Fig. 3 - Sannicola Varano, Lago di Varano Formation, natural outcrop area on hill side opposite Casa Fara, October 1992.

Sannicola Varano 2

The above mentioned sample collected by M. van den Bosch, because of the high number of holoplanktonic molluscs, initiated further sampling at this locality more than 20 years later. Visual collecting from a quarry debris infill and a sediment sample collected at the same time, treated with formic acid, yielded an extensive collection, inclusive of heteropods and pteropods in a variety of

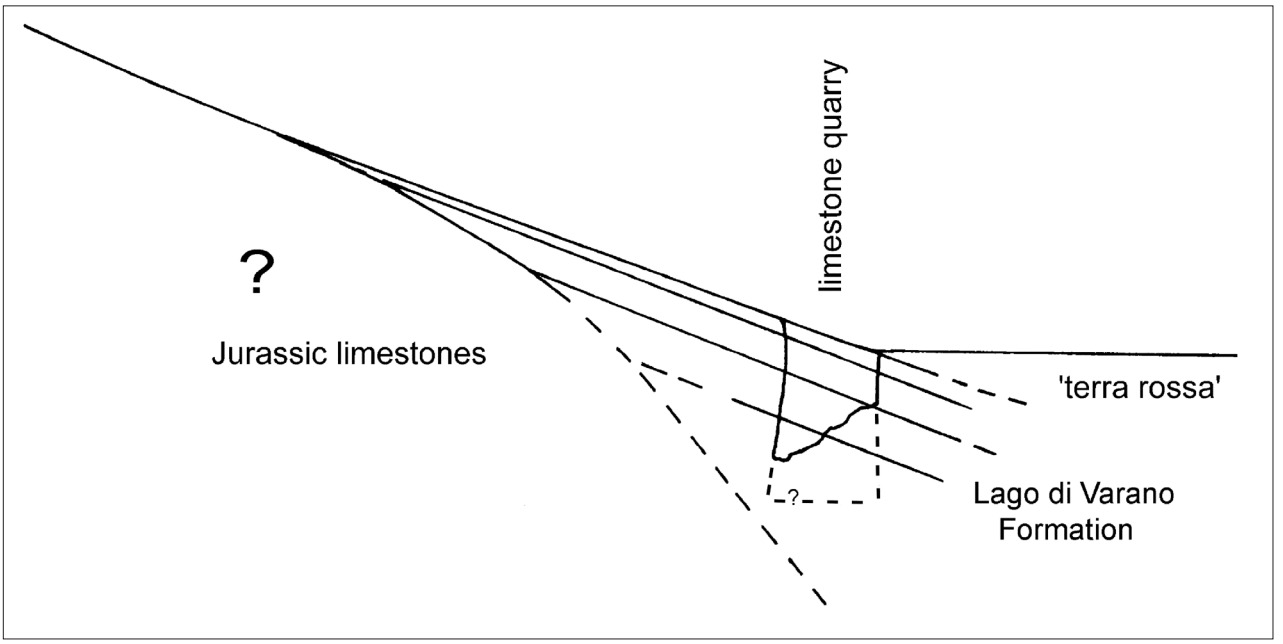

Fig. 4 - Sannicola Varano. Simplified stratigraphic scheme.

COLLECTIONS:	MILANO		LEIDEN																
localities: / species	San Nicola Varano	Masseria Palmireri	Crocifisso di Varano	San Nicola Varano 1	San Nicola Varano 2	San Nicola Varano 3-1	San Nicola Varano 3-2	San Nicola Varano 3-3	San Nicola Varano 3-4	San Nicola Varano 3-5	San Nicola Varano 3-6	San Nicola Varano 3-7	San Nicola Varano 3-8	San Nicola Varano 3-9	San Nicola Varano 3-10	San Nicola Varano 3-11	Sannicandro Garganica	Torre Mileto
Atlanta sp.	-	-	-	1, 7p	2, mp	12p	-	2, mp	11p	20p	3p	25p	20p	3p	7p	1, 45p	4, 14p	1p
Protatlanta rotundata	3	-	7p	1, 2p	1	-	-	35p	1, 3p	-	-	-	-	-	-	1	-	-
Carinaria sp.	-	-	1p	-	10p	-	-	21p	-	-	-	-	-	-	-	1	12p	1p
Heliconoides inflata	-	-	-	1?	-	-	-	5?	-	-	-	-	-	-	-	2	-	-
Heliconoides tertiaria	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Heliconoides sp.	-	-	80	m	m	30	m	m	m	m	35	m	m	m	m	m	m	7
Limacina valvatina	1	-	m	m	m	m	m	m	m	m	m	m	m	m	m	m	m	50
Creseis cf. *spina*	-	-	3	28	40	13	-	m	m	m	65	65	m	m	7	66	m	-
Hyalocylis sp,	-	-	-	-	-	-	-	-	5	-	-	-	-	-	-	-	-	-
Styliola subula	57	-	4	m	m	-	1	m	m	m	6	4	4	17	5	m	m	4
Cuvierina paronai	81	-	4	40	m	-	2p	19, 12p	32, 3p	2, 20p	1	-	-	3p	-	m, mp	m	-
Clio aichinoi	1	-	-	3	3	-	-	11	5	-	-	-	-	-	-	2	-	-
Clio bellardii	-	-	-	1	3	-	-	-	-	-	1	-	-	-	-	5	8	-
Clio distefanoi	m	-	1	8	m	-	1	m	m	17	1	-	-	-	-	m	--	-
Clio pedemontana	-	-	-	-	1?	-	-	-	-	-	-	-	-	-	-	-	-	-
Clio pulcherrima	20	-	1	30	m	-	1p	10	6, 2p	2	-	-	1	-	1	12, 4p	m, 30p	-
Clio saccoi	13	-	1	7	53	-	-	21	-	-	-	-	-	-	-	11	15	-
Cavolinia cookei	2	-	-	-	4	-	-	-	-	-	-	-	-	-	-	8	8	-
Cavolinia pycna	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-
Cavolinia zamboninii	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Diacrolinia aurita	7	-	1	6	m	-	-	8, 15p	9	1	-	-	-	-	-	6, 35p	11	-
Edithibella varanica	-	1	-	m	-	-	-	-	-	-	-	-	-	-	-	8	m	-
Vaginella austriaca	m	7	50	m	m	-	10	m	m	40	12	25	7	25	22	m	m	55
Vaginella gibbosa	m	-	2	10	m	-	-	m	m	-	-	-	-	-	-	7	-	-
Vaginella lapugyensis	69	-	22	20	m	1	4	m	m	m	11	10	8			35	4, 1p	12
Vaginella sannicola	-	-	-	m	-	-	-	-	-	1	-	-	-	2	5	m	m	-
Cymbulia sp.	-	-	1	2	22	1	3	10	9	3	3	2	50	20	-	16	3	-
Peracle grebneffi	1	-	-	-	5	1	-	3	1	-	-	-	-	-	-	-	4	-
Peracle sp.	-	-	-	1	2					-	-	-	-	-	-	-	-	-
Gleba ? sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	-
Clione? *ignota*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-
Clione? *imdinaensis*	-	-	-	7	5	1	1	4	9	2	5	14	-	26	6	m	-	-
Clione? *tumidula*	-	-	-	16	2	-	-	4	2	-	-	-	-	-	-	16	-	-

Tab. 2 - Specification of holoplanktonic molluscs from Gargano localities. Numbers of specimens recorded per sample, for the Milano collection differing, sometimes considerably, from the originally published numbers. That material on the one hand apparently is not complete, and, on the other hand, samples seem to be enlarged after earlier publications. p = protoconch(s); m = > 100.

species (26 taxa). The specimens usually occur dispersed in the sediment, but occasionally also in small concentrations (lumachelles), and do not show any sign of abrasion by reworking. Curiously enough, however, the pteropod species *Edithinella varanica* and *Vaginella sannicola*, so common in the 1970 sample Sannicola Varano 1, appeared to be completely absent, and the question arose if the 1970 sample had been collected at another nearby locality. A closer look at the exposed section (see Sannicola Varano 3, below) demonstrated later that especially *V. sannicola* is almost exclusively present in the top levels. The quarry debris therefore must originate from a lower level, which indeed seems quite logical.

Sannicola Varano 3

A joint visit in October 1992 to this locality with M. van den Bosch did not reveal the exact position of his 1970 sample, but it could be established that his material, because of the abundant presence of the pteropods *Edithinella varanica* and *Vaginella sannicola* must, at least partly, have been collected from the top level corresponding with samples Sannicola 3-9 to 11, as described below. A section along the easternmost quarry wall (Figs. 5 and 6), comprising almost 9.50 m, was measured. The sediments show a dip of 20.5° S, which agrees with the slope of the Jurassic rocks underlying the Miocene calcarenites. The local distribution of these Miocene rocks at this place is very restricted (Fig. 2): in E-W direction only some 150-200 m and uphill just for some tens of metres. On the valley side the sediments probably are continuous, but they are covered by so-called "terra-rossa", a Quaternary valley-fill. Level nr. 11 is the top level of the Miocene limestone all over its extension.

Fig. 5 - Sannicola Varano, easternmost small abandoned quarry with Lago di Varano Formation exposed, October 1992.

Eleven samples, all of them consisting of yellowish-white, friable bioclastic wackestones, locally nodular or containing calcareous algae and usually (apart from the top level) without macroscopically visible bioclasts, each c. 1-1.5 kg, were taken from this section (as indicated in figure 6). All samples yielded a phosphoritic residue, containing abundant globigerinid foraminifera (not collected, but remaining residues are housed in the RGM collections), and most of them also contained small quantities of glauconite. Because of the results three levels (samples Sannicola Varano 3-3, -4 and -11) were bulk sampled a year later. All holoplanktonic molluscs were isolated from the residues and their numbers are specified in table 2.

Sannicandro Garganico

Temporary outcrop (Fig. 7) on the Superstrada Garganica, 2.3 km E of Sannicandro exit, collected June 1992 and September 1993. This occurrence of Miocene rocks of the Lago di Varano Formation, not indicated on the map in D'Alessandro et al. (1979, Fig. 1), was accessible because of construction works on the superstrada. Exposed were c. 5-6 m very light-yellowish to whitish, fine-grained calcarenites with small dispersed phosphoritic concretions, mainly bioclasts. Collecting was done visually in the outcrop, and a sediment sample of 25 kg was treated with formic acid. The residue of this latter sample was c. 275 g, the coarser fractions existing predominantly of the pteropod *Vaginella austriaca*. Finer fractions yield abundant very small benthic molluscs (mainly larval shells), many juvenile limacinid pteropods, planktonic foraminifera, and some glauconite grains. The holoplanktonic mollusc assemblage consists of 20 species. Non-phosphatized benthic organisms, such as calcitic pectinids, ostreids or echinoids, are virtually absent. None of the fossils show signs of abrasion by transport and no concentration of fossils in lumachelles or otherwise was observed.

Torre Mileto

Small outcrop near Masseria de Sorgente (Fig. 1). Lago di Varano Formation, collected June 1992. Light yellowish calcarenite outcropping in arable field, with some small phosphoritic fossils macroscopically visible. A sediment sample of c. 2 kg was treated with formic acid. Residue only 3.5 g, but relatively rich in fossils.

In table 2 the pelagic Mollusca from the Gargano samples are specified. Specimens studied by D'Alessandro et al. (1979), restudied by D'Alessandro and

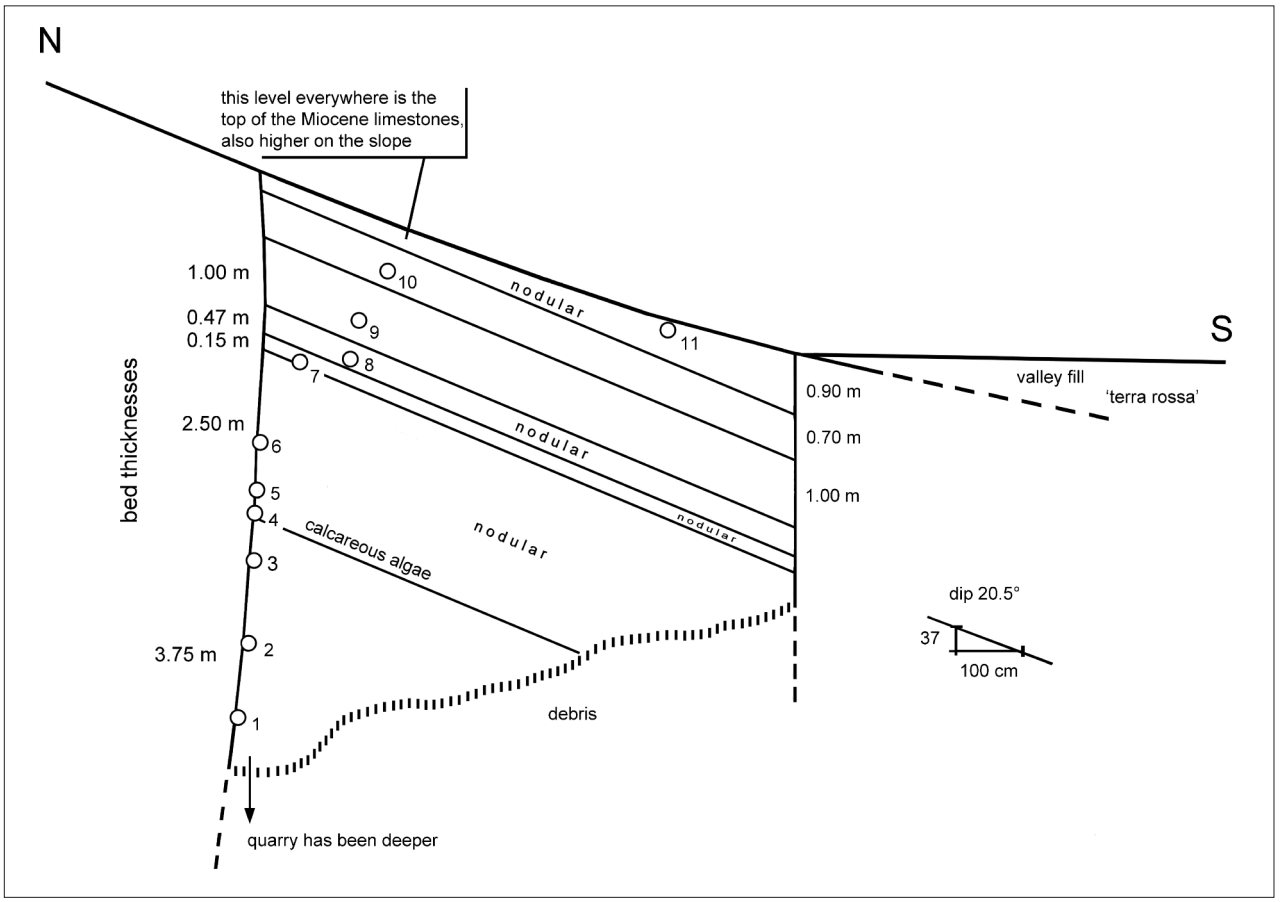

Fig. 6 - Sannicola Varano 3. Section measured along the easternmost quarry wall with location of samples Sannicola Varano 3-1 to 3-11. Section measured October 1992 by M. van den Bosch and A.W. Janssen.

Fig. 7 - Outcrop of Lago di Varano Formation on Superstrada Garganica near Sannicandro.

Robba (1981) and included herein, are housed in the Milano collection, reidentified and labelled by the present author in 2012. As far as recognisable illustrated specimens were curated separately.

Lecce area (Pietra Leccese Formation)

In 1992 two localities (Fig. 8) in the Lecce area were sampled, viz. at Cursi (D'Alessandro and Robba's locality Cursi 2) and Melpignano (locality "Melpignano 5" of D'Alessandro and Robba, 1981). The results are comparable with those of the said authors. The only difference found was that in the strongly glauconitic "piromáfo" level of the Pietra Leccese the very fossiliferous phosphorite concentration around the "linea delle cozze" is not present at the base of the 2 m unit, but in its middle part.

Formic acid residues from the calcarenites below the "piromáfo" level invariably yielded fine-grained phosphoritic material and fossils, mainly abundant globigerinid foraminifers, but inclusive of usually small to very small molluscs in internal mould preservation. From these residues all holoplanktonic molluscs were collected and identified. Unlike the material from the "piromáfo" level these specimens show no abrasion as a result of transportation and do not appear to be reworked.

The fossil material discussed by D'Alessandro and Robba (1981) originates exclusively from phosphorite concentrations in the "piromáfo" level, around the "linea delle cozze". Their basic material is housed in the Milano collection and was reviewed for the present study. After reidentification and labelling the material was returned to Milano. As far as possible specimens illustrated in the earlier papers were curated separately.

Cursi RGM

Abandoned limestone quarry along northern side of road from Cursi to Melpignano (Fig. 8). Sampled was a phosphoritic bed or "pocket" (Fig. 9) in the glauconitic "piromáfo" level. The "linea delle cozze", a thin level with pectinids, was not very evident at this locality. Sample size 5.410 g, June 1992, treated with formic acid. Residue c. 1.750 g, yielding abundant fossil specimens in internal mould preservation, inclusive of numerous pteropods, many with clear abrasion as a result of transportation. Fractions smaller than 1 mm yielded some foraminifera and bony fish skeleton parts, but virtually no molluscs.

Melpignano RGM

Active quarry (Fig. 10) along southern side of road to Cursi, close to Melpignano. Section with a height of 21 m, measured June 1992 (Fig. 11). This approximately is locality Melpignano 5 of D'Alessandro and Robba (1981). Level of reference is the base of the glauconitic, so-called "piromáfo" level (Fig. 11).

Macroscopically, small and rare dispersed phosphorite concretions, including some fossils are mainly seen in between 5 and 9 m below the base of the glauconitic "piromáfo" level. The boundary between the latter and the underlying calcarenites is sharp and testifies to a

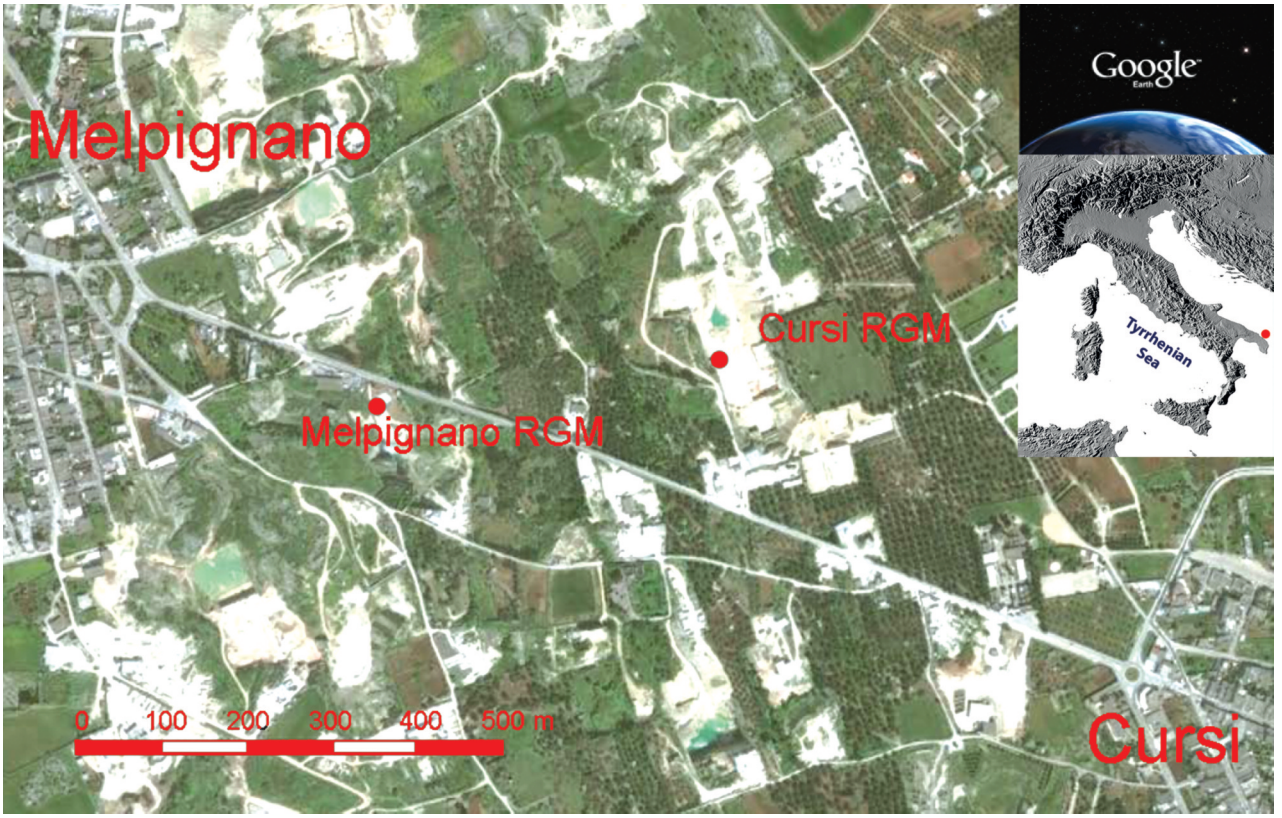

Fig. 8 - Outcrops between Melpignano and Cursi (Google Earth picture 21.04.2010), with indication of the RGM collecting sites.

Fig. 9 - Cursi RGM, fossiliferous pocket in "linea delle cozze" (Pietra Leccese Formation, "piromáfo"), 13 June 1992.

Fig. 10 - Melpignano, overview of active quarry, 15 June 1992.

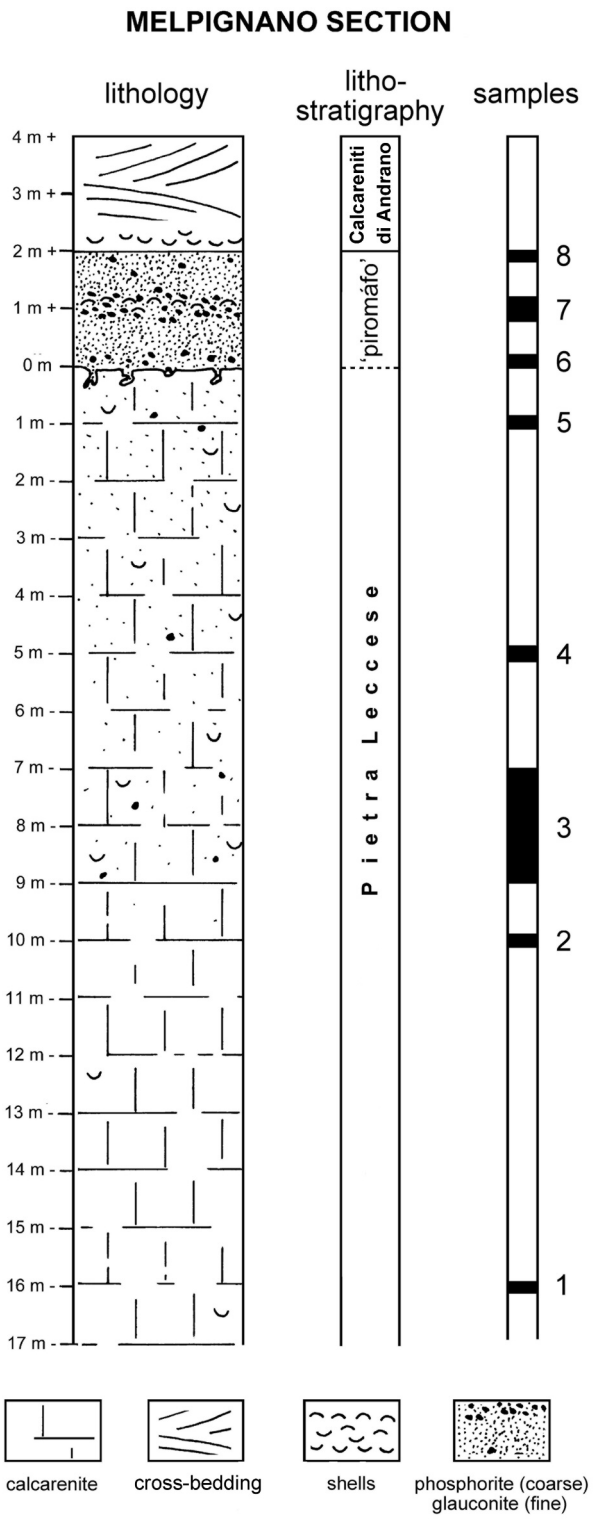

Fig. 11 - Melpignano RGM, section measured June 15, 1992.

period of erosion and non-deposition, as is clear from the glauconite-filled burrows penetrating from the boundary into the top of the underlying unit. Above this boundary the glauconite contents of the sediment suddenly increases considerably and dispersed phosphorite concretions, including many fossils, become abundant, with a culmination in the middle of this 2 m thick level, around the "linea delle cozze". The boundary with the overlying 2 m thick (but incomplete) Calcareniti di Andrano is again sharp, but no burrows are present here. This top level includes soft and friable yellowish wacke- to packstones without any visible glauconite and showing clear cross-beddings. At the base of this unit abundant internal moulds of benthic molluscs are present (not collected).

Melpignano RGM 1

Sample from 16 m below base of glauconitic "piromáfo" level. Sample size c. 150 g, treated with formic acid. Residue 3 g, consisting of very fine phosphoritic material and small skeletal parts of bony fishes. Few holoplanktonic molluscs, all juvenile to very juvenile. Not collected were numerous foraminifera, mainly globigerinids, and some very small echinoderm fragments.

Melpignano RGM 2

Sample from 10 m below base of glauconitic "piromáfo" level. Sample size c. 150 g, without visible phosphorites, treated with formic acid. Residue 7 g, consisting of very fine phosphatized material, including numerous foraminifera, mainly globigerinids, and few holoplanktonic molluscs.

Melpignano RGM 3

Sample from 7-9 m below base of glauconitic "piromáfo" level. In this interval some larger (up to 8 mm) phosphoritic fossils were visually collected from the sediment in the outcrop. A sediment sample of 400 g was treated with formic acid. Residue c. 9 g, for the greater part consisting of very fine phosphoritic material. Numerous foraminifera, mainly globigerinids (not collected), rather many holoplanktonic Mollusca. Some larger pectinids in a not phosphatized state of preservation were collected from the exposed rock, for museum's collection purpose only.

Melpignano RGM 4

Sample from 5 m below base of glauconitic "piromáfo" level. At this depth very few phosphoritic fossils were visible in the sediment, as well as some calcitic fossils. A sample of 500 g yielded a residue of 12 g, for the greater part consisting of very fine (< 125 μm) phosphoritic material. Numerous foraminifera, mainly globigerinids (not collected), strikingly many bryozoa, mainly isolated zooecia of lunulitiform species. The residue yielded furthermore small benthic gastropods and scaphopods, and some holoplanktonic gastropod species, among which especially the common occurrence of *Sphaerocina formai*, an index fossil for pteropod zone 18a (Langhian), is interesting (most of these were collected visually from this interval in the quarry).

Melpignano RGM 5

Sample from 1 m below base of glauconitic "piromáfo" level. Hardly any fossils were macroscopically visible in the matrix, that on the other hand contained a considerable number of glauconite grains. A sediment

sample of 400 g was treated with formic acid. Residue c. 10 g, for the greater part consisting of very fine (< 125 μm) phosphoritic material. Numerous foraminifera, mainly globigerinids (not collected). The residue additionally yielded very few small benthic gastropods and scaphopods, and some holoplanktonic gastropod species.

Melpignano RGM 6

Sample from the base of the glauconitic "piromáfo" level. No macroscopically visible fossils in the sediment, but with a sudden and considerable increase of glauconite. A sediment sample of 400 g was treated with formic acid. Residue c. 14 g, for the greater part consisting of very fine (< 125 μm) phosphoritic material, glauconitic grains and numerous foraminifera (mainly globigerinids). The residue yielded furthermore a few small benthic gastropods and scaphopods, and some holoplanktonic gastropod species.

Melpignano RGM 7

Sample from c. 1 m above the base of the glauconitic "piromáfo" level. Phosphorite concentration around the so-called "linea delle cozze", a continuous thin line of shells, mainly pectinids and some ostreids. Sample size c. 15 kg. The weight of the residue after formic acid treatment was 8.6 kg, c. half of which in the fraction < 0.5 mm, almost exclusively consisting of glauconitic grains. The coarser fractions contain abundant fossils, predominantly pteropoda, but also many benthic fossils (such as gastropods, bivalves, solitary corals etc..), all in phosphoritic internal mould preservation. In some cases also the original aragonite of the shells is replaced by phosphorite, resulting in specimens in which the surface ornament is retained. Some specimens show distinct abrasion from being transported. The fraction < 0.5 mm yielded virtually no fossils, apart from foraminifera and small bony fish skeleton parts. Some non-phosphatized fossils (pectinids and ostreids) were collected from the "linea delle cozze", as items for the RGM museum's collection.

Melpignano RGM 8

Sample from 2 m above base of glauconitic "piromáfo" level. Some coarser phosphorites were visible in the sediment. Sample size c. 0.5 kg. The weight of the residue after formic acid treatment was 220 g, of which the fraction < 0.5 mm was 205 g, almost exclusively consisting of glauconite and yielding virtually no fossils, apart from some globigerinid foraminifera and small bony fish skeleton parts. Some terebratulid brachiopods occurred in a non-phosphatized state.

In table 3 the pelagic mollusca from the Salento samples are specified. Specimens studied by D'Alessandro and Robba (1981), are housed in the Milano collection, included herein and reidentified and relabelled by the present author in 2012. As far as recognisable illustrated specimens were curated separately. Figures in table 3 represent the actual number of specimens present in the collections.

BIOSTRATIGRAPHIC INTERPRETATIONS AND CONCLUSIONS

The identification of all pelagic gastropods recorded herein is based on the descriptions presented in Janssen (2012a), where in most cases discussions on the Italian material published by earlier authors are also given (revisions are summarized in table 1a-b). The genus assignment in the present paper of several Gymnosomata is changed, as they were introduced in violation of ICZN rules in 'open generic nomenclature' as Genus Clionidarum. A validation of these taxa, transferring them to *Clione*?, is published in Janssen (2012b).

Apart from a single specimen (*Clio* sp. nov. in table 3) all species occurring in the Gargano and Salento samples are present in the Maltese rocks as well. In figure 12 the known vertical ranges of all taxa identified to species level enables an age assignment for both the Gargano and Salento assemblages, partly contradicting, partly acknowledging earlier age interpretations. Only those occurrences that are identified to species level are included in the range chart, as taxa in open nomenclature give no reliable indication about ages.

From the complete Gargano material from the Lago di Varano Formation (Tab. 2) 33 taxa are listed, 25 of which are identified to species, 8 had to remain in open nomenclature. Of the 25 identified species recorded from the Sannicola samples some have long ranges, such as *Heliconoides inflata* or *Styliola subula*, but very striking is the fact that all 25 species are known to occur in Pteropod Zone (PZ) 18a, of Langhian age, and many of them are even restricted to that zone (Fig. 12). This inevitably leads to the conclusion that the Gargano holoplanktonic mollusc assemblages are of Langhian age and the original opinion of Checchia-Rispoli (1921) is demonstrated here to be correct. For the more complete assemblages from Crocifisso di Varano and Sannicandro Varanico exactly the same conclusion can be drawn.

Some of the lowermost samples of the Sannicola 3 section yielded only few species on the basis of which an age assignment is difficult, but species indicating PZ 18, of late Burdigalian age, are absent. The same is true for the smaller samples from the Torre Mileto and Masseria Palmieri localities. Therefore all sampled rocks in the Gargano area are here considered to be of Langhian age and the pelagic mollusc assemblages are not reworked.

In the Maltese sequence a subdivision of PZ 18a (present in the Upper Globigerina Limestone Member) into four subzones was possible (Janssen, 2012a, Fig. 63), but these subzones cannot be recognized in the Italian localities. This acknowledges the interpretation that the Maltese subdivision is of local importance only.

From the "piromáfo" phosphorite concentrations in the Pietra Leccese Formation at localities Cursi and Melpignano in Salento a total of 31 species was recorded (Tab. 3), six of which had to remain in open nomenclature. From the 25 taxa identified to species level 21 show a similar vertical distribution in PZ 18a as

COLLECTIONS:	MILANO					LEIDEN								
localities / species	Cursi 1	Cursi 2	Cursi 2A	Cursi 4	Melpignano 5	Cursi RGM	Melpignano RGM 1	Melpignano RGM 2	Melpignano RGM 3	Melpignano RGM 4	Melpignano RGM 5	Melpignano RGM 6	Melpignano RGM 7	Melpignano RGM 8
Atlanta sp.	-	-	-	-	-	1	1	-	13p	-	-	-	-	-
Protatlanta rotundata	-	-	-	-	-	-	-	-	-	-	-	-	7	-
Heliconoides sp.	-	-	-	-	-	-	40	30	m	50	5	1	2	-
Limacina valvatina	-	-	-	-	-	-	2	-	8	-	18	-	-	-
Limacina sp.	-	-	-	-	-	-	1	-	1	-	-	-	-	-
Styliola subula	-	-	7	9	2	6	-	-	-	-	-	-	79	-
Creseidae sp.	-	-	-	-	-	-	5	2	3	-	-	-	-	-
Cuvierina curryi	3	4	43	90	m	41	-	-	-	-	-	-	50	-
Cuvierina grandis	3	3	9	m	m	66	-	-	-	-	-	-	m	1
Cuvierina intermedia	-	-	-	-	-	8	-	-	-	-	-	-	28	-
Cuvierina paronai	26	30	m	m	m	m	-	-	-	-	1	-	m	5
Clio aichinoi	-	-	-	1	-	-	-	-	-	-	-	-	-	-
Clio bellardii	-	-	1	5	4	3	-	-	-	1	-	-	2	-
Clio distefanoi	-	-	4	-	12	4	-	-	-	-	-	-	11	-
Clio pulcherrima	-	-	3	-	6	1	-	-	-	-	-	-	5	-
Clio saccoi	-	3	14	19	50	22	-	-	-	-	-	-	43	-
Clio sp. nov.	-	-	-	-	1	-	-	-	-	-	-	-	-	-
Cavolinia cookei	2	-	21	26	42	13	-	-	-	-	1	-	41	1
Cavolinia gatti	-	1	14	20	56	27	-	-	-	-	-	-	63	-
Cavolinia zamboninii	-	-	-	-	-	1	-	-	-	-	-	-	2	-
Diacrolinia aurita	-	-	2	6	22	3	-	-	1	-	-	-	14	-
Edithinella varanica	2	4	38	71	m	25	-	-	-	-	-	-	67	1
Vaginella austriaca	m	m	m	m	m	m	-	-	m	m	4	30	m	37
Vaginella gibbosa	16	30	m	m	m	m	-	-	-	6	-	-	m	-
Vaginella lapugyensis	7	9	m	m	m	50	1	-	3	-	-	5	93	1
Vaginella sannicola	1	2	m	91	m	33	-	-	-	-	-	-	m	-
Sphaerocina formai	-	-	-	-	-	-		-	12	36	-	-	1	-
Cymbulia sp.	-	-	-	-	-	-	1p	-	-	-	-	-	-	-
Peracle grebneffi	-	-	-	-	-	-	-	-	1	-	-	-	-	-
Clione? ignota	-	-	-	-	-	-	1p	-	-	-	-	-	-	-
Clione? imdinaensis	-	-	-	-	-	-	-	1p	2p	-	-	-	-	-

Tab. 3. Distribution and numbers of holoplanktonic mollusc specimens from the various Salento samples in the Milano and Leiden collections. Numbers for the Milano collection are those actually present, sometimes differing from numbers published earlier. p = protoconch(s); m = > 100.

at Gargano, but to date four species are unknown in that biozone. These are three *Cuvierina* species, of which *C. curryi* and *C. grandis* are restricted to PZ 19 of Serravallian age, whereas *C. intermedia* is known from the Serravallian and continues into PZ 20 (Tortonian) and even into the early Pliocene. Therefore these three species together indicate an origin from Serravallian rocks at the most. Finally, the species *Cavolinia gatti* is exclusively known from PZ 20 of Tortonian age. Together these data indicate that the Cursi and Melpignano "piromáfo" pteropod assemblages are mixed and reworked from deposits of Langhian to Tortonian age, implying that the age of the deposit proper is Tortonian at the most, which agrees well with the age estimate given by Mazzei et al. (2009). This definitely endorses the conclusion of D'Alessandro and Robba (1981) concerning the Cursi and Melpignano faunae being reworked.

The assemblages collected from the lower parts of the Pietra Leccese calcarenites, underlying the "piromáfo" horizon (samples Melpignano RGM 1 to 5), on the contrary, did not show any sign of transportation and yielded exclusively species known from PZ 18a, among which a common presence of the index species *Sphaerocina formai* in samples Melpignano RGM 3 and 4. Therefore I consider these rocks to be *in situ*, and of Langhian age, which also agrees well with the interpretation given by Mazzei et al. (2009).

The conclusions given here are exclusively based on the quite well-known Mediterranean distributions of

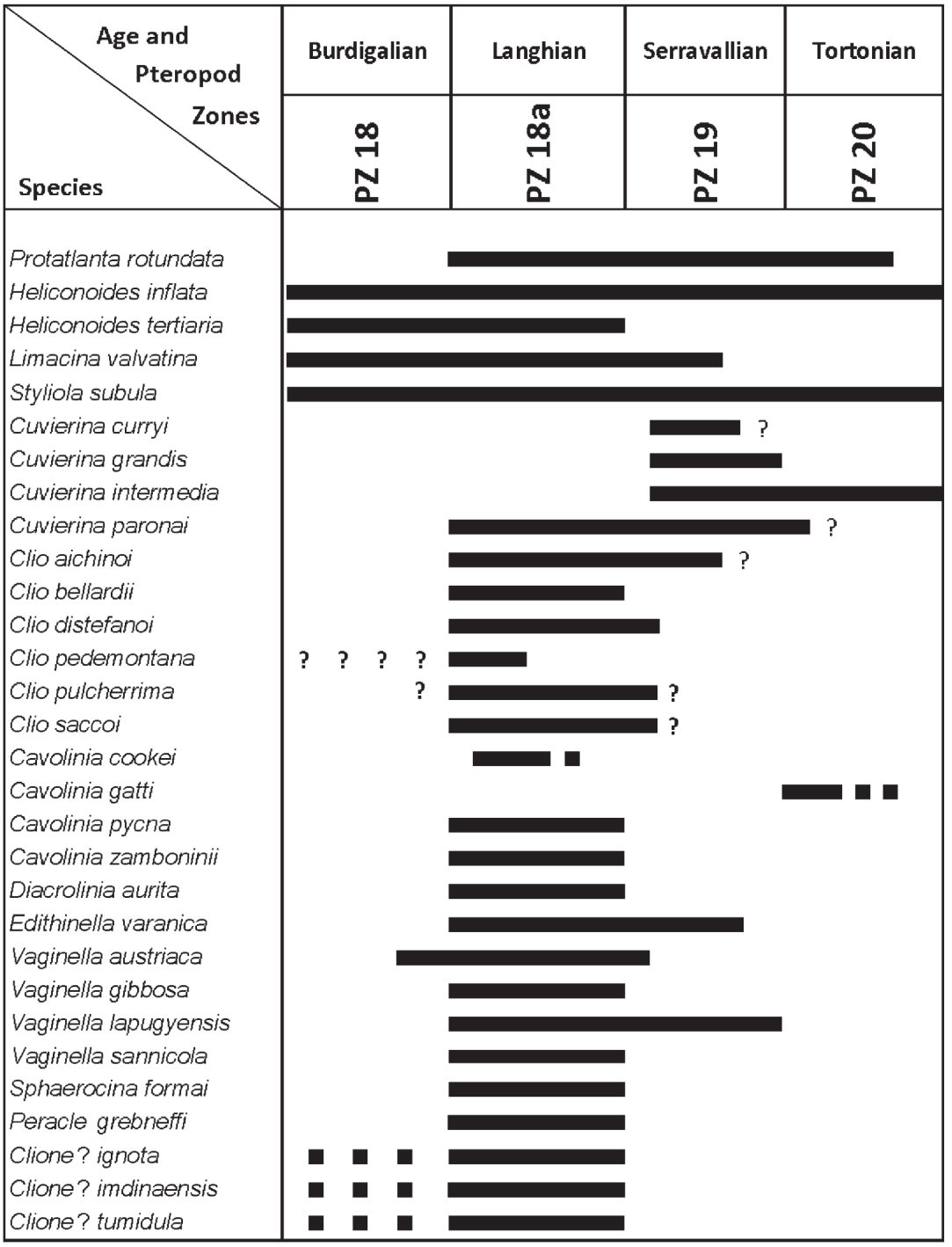

Fig. 12 - Known ranges of holoplanktonic gastropods identified to species level, from the Gargano and Salento samples.

holoplanktonic molluscs. Especially for the Gargano localities discrepancies in age assignments by application of mainly planktonic foraminifera, as applied in earlier papers, should be reconsidered in the light of more modern biostratigrapical interpretations of that group of microfossils.

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