

<i>Bollettino della Società Paleontologica Italiana</i>	33 (3), 1994	ISSN 0375-7633	299-339	2 pls.	Modena, Dicembre 1994
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Planktonic foraminiferal biostratigraphy of the middle Miocene in Italy

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KEY WORDS – Planktonic foraminifera, Biostratigraphy, Stratotypes, Middle Miocene, Italy.

ABSTRACT – A planktonic foraminiferal biostratigraphy is presented for eight Italian sedimentary successions of the middle Miocene. The study areas include the type area of the Langhian Stage (Bormida valley, Southern Piedmont), the type area of the Serravallian Stage (Scrvia valley, south-eastern Piedmont), the Marche region and Sicily.

In the interval between the FAD of *Praeorbulina glomerosa sicana* and the FAD of *Globigerinoides obliquus extremus* 7 planktonic foraminiferal biozones and 8 subzones have been recognized. They allow detailed subdivisions and correlations of the studied sedimentary bodies.

The historical stratotype of the Langhian Stage (Cessole composite section) is biostratigraphically bracketed by the FAD of *P. glomerosa sicana* and the FAD of *Orbulina universa*.

The FAD of *O. universa* lies 45 metres below the base of the commonly accepted Serravallian stratotype in the Serravalle Scrivia section.

The first appearances of *P. glomerosa sicana* and *O. universa* are easily recognizable events which provide valuable biostratigraphical criteria for correlation of the lower boundaries of the Langhian and Serravallian stratotypes, as historically fixed.

RIASSUNTO – [Biostratigrafia a foraminiferi planctonici del Miocene medio italiano] – Otto successioni stratigrafiche italiane di età medio-miocenica sono state studiate nel loro contenuto in foraminiferi planctonici. Sono state campionate le seguenti sezioni: 1) Bricco del Moro e 2) Cessole nella Val Bormida di Millesimo (AT); 3) Serravalle Scrivia (AL); 4) Gavi (AL); 5) S. Maroto nei pressi di Camerino (MC); 6) il Trave nei pressi di Ancona; 7) Case Pelacani (Palazzolo Acreide - SR) e 8) Pozzallo (RG) nell'area iblea; 9) M. Giammoia nella Sicilia centrale. Le sezioni 1) e 2) rappresentano la successione stratotipica del Piano Langhiano. Le sezioni 3) e 4) interessano la successione stratotipica del Piano Serravalliano.

Lo studio biostratigrafico ha consentito una dettagliata suddivisione dei corpi sedimentari indagati ed agevoli correlazioni tra aree diverse. Nell'intervallo compreso tra il bioorizzonte di comparsa evolutiva di *Praeorbulina glomerosa sicana* ed il bioorizzonte di comparsa evolutiva di *Globigerinoides obliquus extremus* sono state riconosciute 7 biozone a foraminiferi planctonici. Alcune di esse sono ulteriormente suddivise in subzone (complessivamente 8). Lo schema zonale impiegato è, in parte, nuovo. La risoluzione biostratigrafica raggiunta è elevata nel Langhiano e nella parte inferiore del Serravalliano; è minore nel Serravalliano medio e superiore a causa delle mutate condizioni climatiche e paleogeografiche.

Lo stratotipo storico del Langhiano (sezione di Cessole) risulta compreso tra il bioorizzonte di comparsa di *Praeorbulina glomerosa sicana* ed il bioorizzonte di comparsa di *Orbulina universa*. La comparsa di *O. universa* è stata riconosciuta circa 45 metri sotto la base dello stratotipo, comunemente accettato, del Piano Serravalliano (limite inferiore delle Arenarie di Serravalle nella sezione di Serravalle Scrivia). Tale evento biostratigrafico sembra essere quello che consente la migliore correlazione, mediante i foraminiferi planctonici, del limite inferiore di detto stratotipo.

INTRODUCTION

The Miocene Series is currently divided into six stages introduced during the past century and now widely accepted (Berggren *et al.*, 1985; Haq & Van Eysinga, 1987; Haq *et al.*, 1988; Cowie & Bassett, 1989; Harland *et al.*, 1990). Four of them have their type area in Italy (Langhian, Serravallian, Tortonian and Messinian).

Despite the common use of these Stages, their definition is far from being satisfactory. By tradition, stage boundaries were established on the basis of lithofacies variations, and the proposals of stratotype sections for Miocene Stages were greatly influenced by this practice until the sixties of the present century. Consequently, most of the proposed stratotypes do not seem to be proper, clear and precise standards for definition of the

chronostratigraphic units. Moreover, the biostratigraphic data presently available for many type sections are conflicting in several aspects (see Berggren *et al.*, 1985; Iaccarino, 1985; Berger, 1992). A thorough revaluation of the matter in order to rigorously define the Miocene Stages, is urgently required.

This reasoning suggested a reappraisal of the Langhian and Serravallian historical stratotypes. The planktonic foraminifers of the type sections were studied with the aim of precisely recording time-significant biostratigraphic events.

To attain a better understanding of the biostratigraphical problems of the middle Miocene, the researches were extended to other Italian sedimentary successions of the same age. The main objectives were to control the succession of the planktonic foraminiferal events in different

geological contexts and test the possibilities of recognizing and correlating these events over a sufficiently large area.

STUDY AREAS

I have studied planktonic foraminiferal assemblages from eight stratigraphic successions chosen as representative of the Italian (Mediterranean) middle Miocene.

The selected areas are (Text-fig. 1):

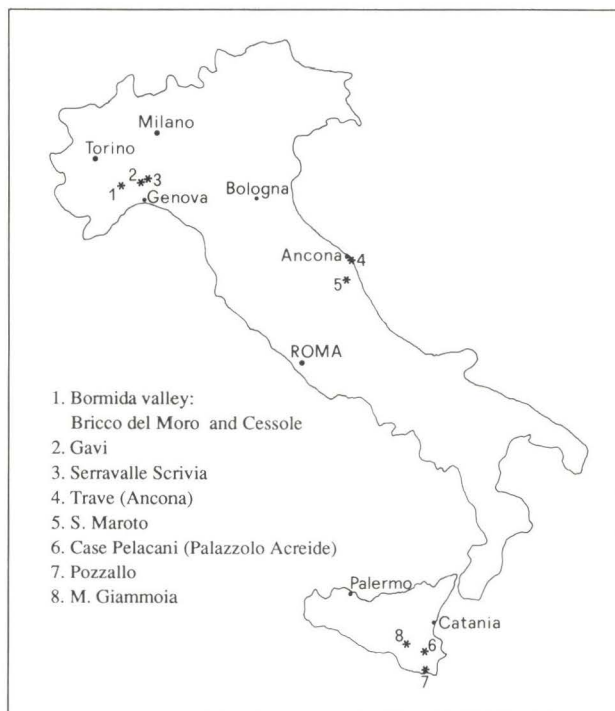
- The Langhe region (Bormida di Millesimo valley) near Cessole (Asti Province), type area of the Langhian Stage (Pareto, 1865).

- The Scrivia and Lemme valleys, between Serravalle Scrivia and Gavi (Alessandria Province), type area of the Serravallian Stage (Pareto, 1865).

- The inner Marche region around Camerino («Camerino Basin») and the neighbourhood of Ancona on the Adriatic coast.

- The Hyblean Plateau in eastern Sicily.

- Central Sicily (so-called «Caltanissetta Basin»).



Text-fig. 1 - Geographical locations of the studied sections.

ADOPTED PLANKTONIC FORAMINIFERAL ZONATION

The studied sedimentary bodies have been divided into biostratigraphic units in accordance

with a planktonic foraminiferal zonal scheme summarized here (Tab. 1). This scheme derives from a critical evaluation of the existing literature (see, for example, Iaccarino & Salvatorini, 1982; Iaccarino, 1985; Bizon, 1979; Borsetti *et al.*, 1979; etc.) taking into account the results of the present study.

The employed biostratigraphic units are listed below from oldest to youngest:

1) *Globigerinoides trilobus* Interval Zone (Iaccarino & Salvatorini, 1982).

2) *Praeorbulina* Lineage Zone: interval from the horizon of the first evolutionary appearance of *Praeorbulina glomerosa sicana* to the horizon of the first evolutionary appearance of *Orbulina suturalis*. The Zone is subdivided into the following subzones:

2.1) *Praeorbulina glomerosa sicana* Lineage Subzone: interval from the lower boundary of the *Praeorbulina* Zone to the horizon of the first evolutionary appearance of *P. glomerosa curva*.

2.2) *Praeorbulina glomerosa curva* Lineage Subzone: interval from the upper boundary of the preceding Subzone to the horizon of the first appearance of *P. glomerosa circularis*.

2.3) *Praeorbulina glomerosa circularis* Lineage Subzone (Iaccarino & Salvatorini, 1982).

3) *Orbulina suturalis* - *Globorotalia peripheroronda* Concurrent Range Zone (Iaccarino & Salvatorini, 1982). The Zone is subdivided into three subzones as follows:

3.1) *Orbulina suturalis* Lineage Subzone (Iaccarino & Salvatorini, 1982).

3.2) *Orbulina universa* Lineage Subzone (Iaccarino & Salvatorini, 1982).

3.3) *Globorotalia praemenardii* - *Globorotalia peripheroronda* Concurrent Range Subzone (Iaccarino & Salvatorini, 1982).

4) *Globoquadrina altispira* Interval Zone: interval from the horizon of the local disappearance, in the Mediterranean, of *Globorotalia peripheroronda* to the horizon of the appearance of *Paragloborotalia partimlabiata*.

5) *Globigerinoides subquadratus* Interval Zone: interval from the horizon of the appearance of *P. partimlabiata* to the horizon of the first evolutionary appearance of *Globigerina nepenthes*. The unit is subdivided into the following subzones:

5.1) *Paragloborotalia partimlabiata* Interval Subzone: interval from the horizon of the appearance of *P. partimlabiata* to the horizon of the appearance of *Globigerina decoraperta*.

5.2) *Globigerina decoraperta* Interval Subzone: interval from the top of the preceding Subzone to the biohorizon of the evolutionary appearance of *G. nepenthes*.

6) *Globigerina nepenthes* - *Paragloborotalia*

Blow, 1969	Bolli, 1966; Bolli & Saunders, 1985	Cati <i>et al.</i> , 1968	Cita & Premoli Silva, 1971-1973; in Cita, 1976	Bizon, 1979	Borsetti <i>et al.</i> , 1979	Iaccarino & Salvatorini, 1982; Iaccarino, 1985	Martinotti, 1981-1990	present work	biohorizons (FO: First Occurrence - LO: Last Occurrence)
N16	<i>Globorotalia humerosa</i>	<i>Globorotalia menardii</i>	<i>Globorotalia acostaensis</i> <i>Globorotalia merotumida</i>	<i>Globorotalia humerosa</i>	<i>Globorotalia merotumida</i>	<i>Globigerinoides obliquus extremus</i>		<i>Globigerinoides obliquus extremus</i>	<i>Globigerinoides obliquus extremus</i> FO
	<i>Globorotalia acostaensis</i>			<i>Globorotalia acostaensis</i>		<i>Neogloboquadrina acostaensis</i>			
N15	<i>G.lia menardii</i>		<i>G.lia linguaensis</i> <i>G.des obliquus</i>	<i>G.lia menardii</i>	<i>Globigerinoides obliquus</i>	<i>G.lia menardii</i> s.l.		<i>G.des obliquus</i>	<i>Neog.drina acostaensis</i> FO <i>Parag.lia mayeri</i> LO
N14	<i>Globorotalia mayeri</i>	<i>G.des obliquus</i>	<i>Globigerina drury</i> <i>Globigerina nepenthes</i>	<i>Globorotalia mayeri</i>	<i>Orbulina universa</i>	<i>Globorotalia siakensis</i> <i>Globigerinoides obliquus</i>	<i>Globorotalia mayeri</i>	<i>G.na nepenthes</i> <i>Parag.lia mayeri</i>	<i>Globigerina nepenthes</i> FO <i>Globigerina decoraperta</i> FO
N13	<i>G.des ruber</i>					<i>Globigerinoides subquadratus</i>	<i>Globigerinoides ruber</i>	<i>G.des subquadratus</i> <i>Globigerina decoraperta</i> <i>Parag.lia partimlabiata</i>	<i>Parag.lia partimlabiata</i> FO
N12	<i>Globorotalia fohsi robusta</i> <i>Globorotalia fohsi lobata</i>	<i>Globoquadrina altispira</i> <i>Globorotalia miozea</i>	<i>Orbulina universa</i>			<i>Globoquadrina altispira altispira</i>		<i>Globoquadrina altispira</i>	
N11	<i>Globorotalia fohsi fohsi</i>								
N10									
N9	<i>Globorotalia fohsi peripheroronda</i>	<i>O.suturalis</i>	<i>O.suturalis</i>	<i>Globorotalia fohsi peripheroronda</i>	<i>O.suturalis</i>	<i>suturalis periphe- roronda</i> <i>praemenardii</i> <i>O. universa</i> <i>O. suturalis</i>	<i>G.lia fohsi peripheroronda</i>	<i>suturalis periphe- roronda</i> <i>praemenardii</i> <i>O. universa</i> <i>O. suturalis</i>	<i>Globorotalia peripheroronda</i> LO <i>Globorotalia praemenardii</i> FO <i>Orbulina universa</i> FO <i>Orbulina suturalis</i> FO
N8	<i>Praeorbulina glomerosa</i>	<i>Praeorbulina glomerosa</i> s.l.	<i>Praeorbulina glomerosa</i>	<i>Praeorbulina</i>	<i>Praeorbulina glomerosa</i> s.l.	<i>P. glomerosa circularis</i> <i>Praeorbulina glomerosa sicana</i>	<i>Praeorbulina glomerosa</i>	<i>Praeorbulina</i> <i>P. glomerosa circularis</i> <i>P. glomerosa curva</i> <i>P. glomerosa sicana</i>	<i>P. glomerosa circularis</i> FO <i>P. glomerosa curva</i> FO <i>P. glomerosa sicana</i> FO
N7	<i>Globigerinatella insueta</i>	<i>Globigerinoides bisphericus</i> <i>Globoquadrina dehiscens</i>	<i>Globigerinoides bisphericus</i> <i>Globigerinoides trilobus</i>	<i>Globigerinoides bisphericus</i> <i>Globigerinoides trilobus</i>	<i>Globigerinoides sicanus</i> <i>Globigerinoides trilobus</i>	<i>Globigerinoides trilobus</i>		<i>Globigerinoides trilobus</i>	

Tab. 1 - Comparison of the planktonic foraminiferal zonal scheme used in the present work with major Mediterranean schemes and the zonations of Blow (1969) and Bolli (1966) / Bolli & Saunders (1985).

mayeri Concurrent Range Zone: interval from the horizon of the appearance of *G. nepenthes* to the horizon of the disappearance of *Paragloborotalia mayeri*.

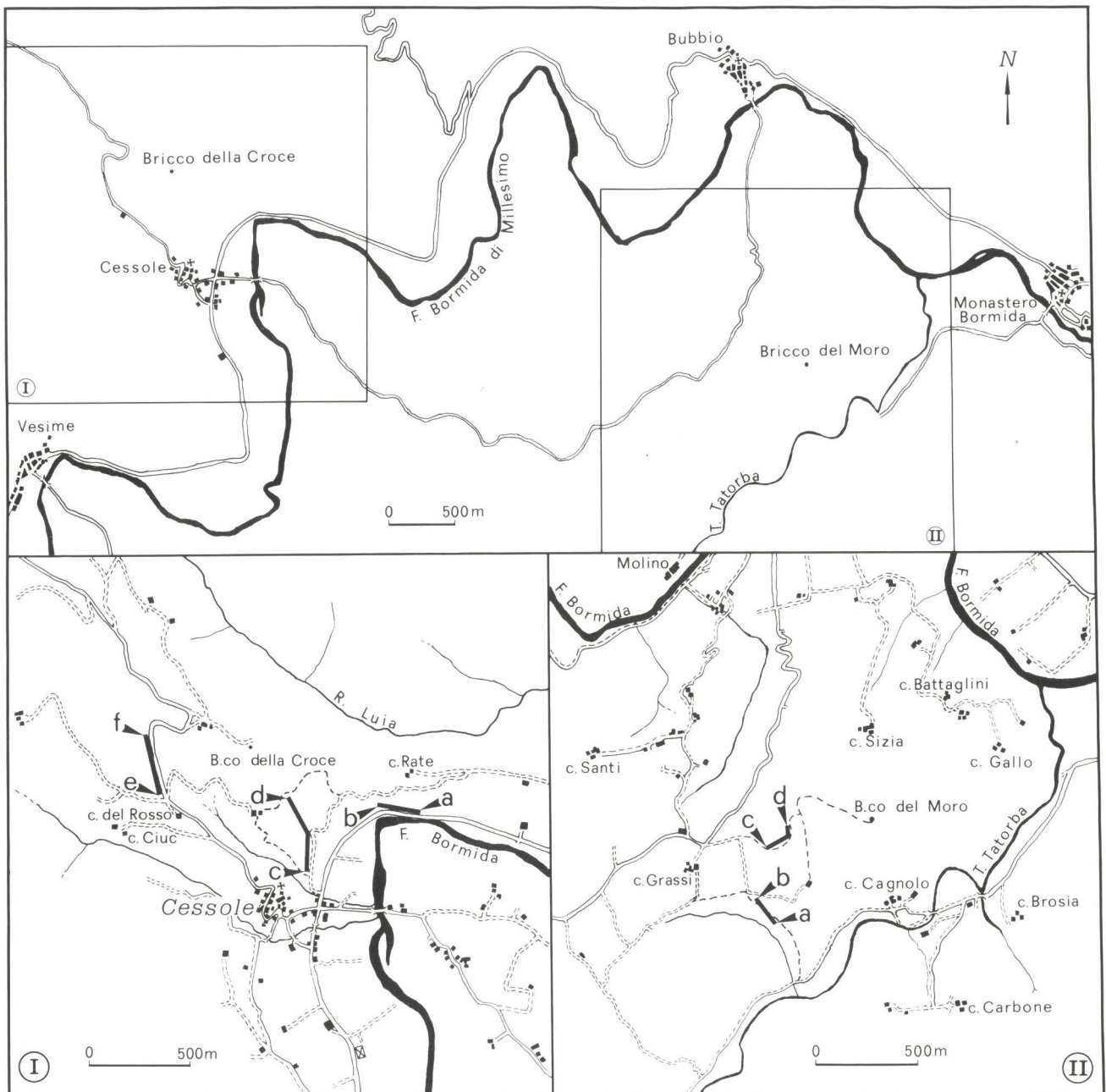
7) *Globigerinoides obliquus* Interval Zone: interval from the horizon of the disappearance of *P. mayeri* to the horizon of the appearance of *Neogloboquadrina acostaensis*.

8) *Neogloboquadrina acostaensis* Interval Zone (Iaccarino & Salvatorini, 1982).

9) *Globigerinoides obliquus extremus* Interval Zone (Iaccarino & Salvatorini, 1982).

THE LANGHIAN TYPE AREA: THE «LANGHE» NEAR CESSOLE (ASTI)

Stratigraphical setting. A thick succession of mainly siliciclastic deposits make up the well-known «stratigraphical landscape» of the «Langhe» region in



Text-fig. 2 - Location of the Bricco del Moro and Cessole sections (From the IGM Carta d'Italia, scale 1:25.000, Sheet 81 I NO Bubbio).

BURDIGALIAN		LANGHIAN	
<i>G. trilobus</i>	<i>Praeorbulina</i>	<i>Praeorbulina</i>	<i>Praeorbulina</i>
	<i>glomerosa sicana</i>		
CORTEMILIA Formation		CESSOLE Formation	
Stage		Biozone	
Subbiozone		Formation	

LANGHIAN STRATOTYPE (lower part)
according to Cita & Premoli Silva, 1960a

Lithology:

silty, sandy marl

sand and sandstone

<i>G. des bisphericus</i>	
<i>P. glomerosa sicana</i>	
<i>G. lia peripheroronda</i>	
<i>G. lia praescitula</i>	
<i>Parag. lia mayeri</i>	
<i>G. drina langhiana</i>	

Text-fig. 3 - Lithological log of the Bricco del Moro section and ranges of selected planktonic foraminiferal species.

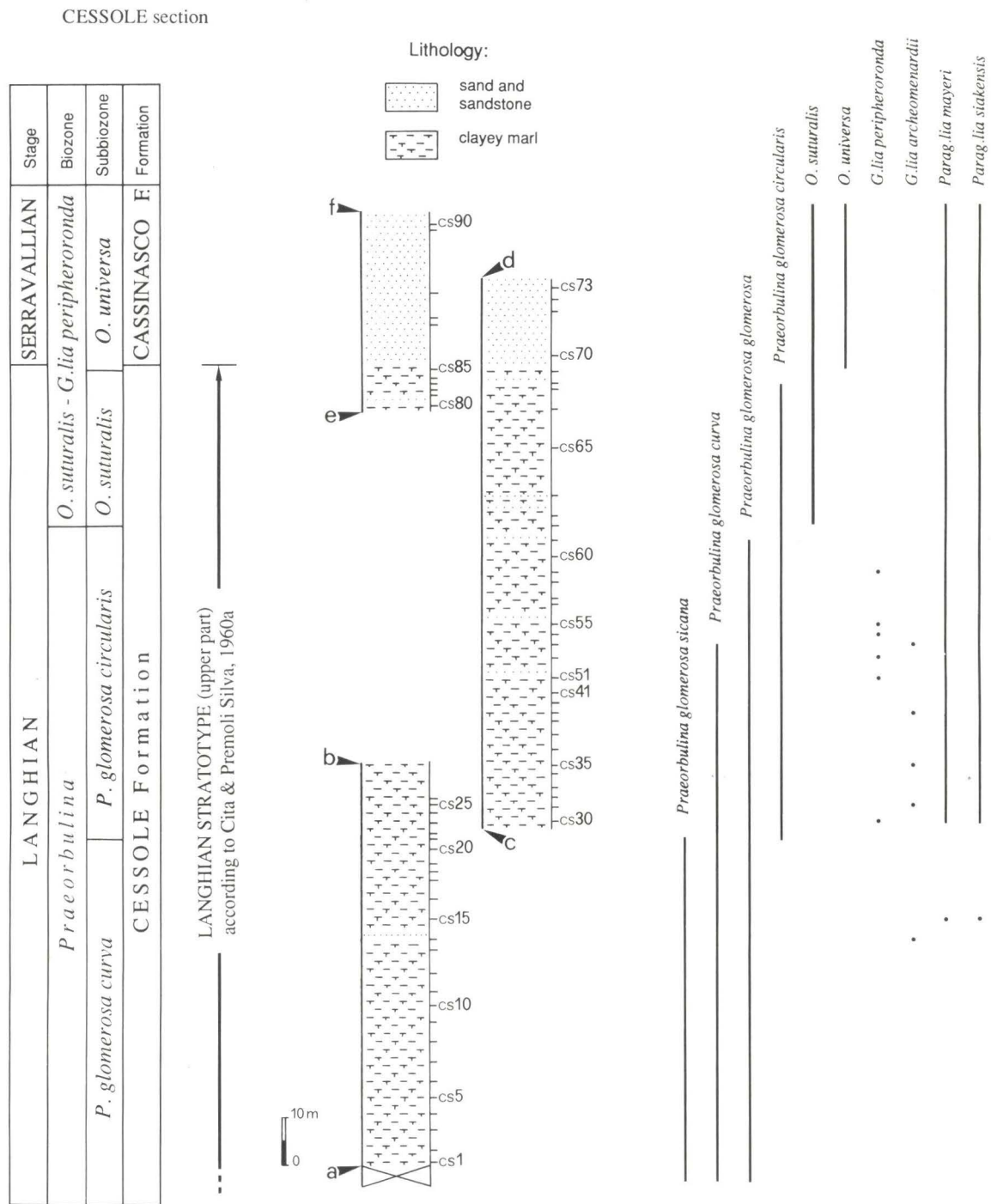
southern Piedmont. These Oligocene to Miocene deposits accumulated in the southern-central part of a large Cenozoic episutural basin (*sensu* Bally & Snelson, 1980), the so-called «Tertiary Piedmont Basin» (Sacco, 1890; Gelati, 1968; Lorenz, 1969; Gelati & Gnaccolini, 1982 e 1988; Gelati *et al.*, 1993; Gnaccolini *et al.*, 1992; etc.). Bormida valley is an important part of the Langhe.

According to Gelati (1968), the lower to middle

Miocene of the Bormida valley can be divided into three main lithostratigraphic units listed below in ascending stratigraphic order:

1) The Cortemilia Formation (Gelati, 1968) formed by rhythmic alternations of sands or sandstones and marls.

2) The Cessole Formation (Vervloet, 1966; Gelati, 1968) composed of clayey marls with irregular intercalations of thin-bedded sands and sand-



Text-fig. 4 - Lithological log of the Cessole section and ranges of selected planktonic foraminiferal species.

stones («marne a pteropodi» = «pteropod marls» Auctt.).

3) The Cassinasco Formation (Vervloet, 1966; Gelati, 1968) composed of thick-bedded coarse-grained sands and sandstones with irregular intercalations of thin-bedded silty marls.

The last two units are partially heteropic.

The «marne a pteropodi» of the Cessole Fm. are considered a shelf-margin or slope hemipelagic deposit on the basis of sedimentological (Gnaccolini, 1960; 1967; 1968) and paleontological (Premoli Silva, 1960; Oertli, 1961; Robba, 1971) evidence.

The Cortemilia Fm. and Cassinasco Fm. are currently interpreted as basin plain turbidite

Bricco del Moro section																															
samples:	BMG31	BMG32	BMG33	BMG34	BMG35	BMG36	BMG37	BMG38	BMG39	BMG40	BMG3	BMG4	BMG5	BMG6	BMG7	BMG8	BMG9	BMG10	BMG11			BMG15	BMG16	BMG17	BMG18	BMG19	BMG20	BMG21	BMG22	BMG23	BMG24
species:																															
1. <i>Globigerina praebuloides</i>	x	x	x	x	x		x				x	x	x	x	x		x	x	x			x	x	x	x	x	x	x	x		x
2. <i>Globigerina druryi</i>	x	x	x	x	x	x	x	x	x		x				x	x			x			x	x		x	x					x
3. <i>Globigerinoides trilobus</i>	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x			x	x	x	x	x	x	x	x		x
4. <i>Globigerinoides bisphericus</i>	x	x	x	x	x	x	x	x	x	x		x			x	x	x	x	x			x	x	x	x	x					x
5. <i>Globorotalia praescitula</i>	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x			x	x	x	x	x	x				x
6. <i>Globoquadrina baroemouensis</i>	x	x	x	x	x	x	x	x	x	x	x	x	x			x	x	x	x	x		x	x	x	x	x	x	x	x		x
7. <i>Turborotalita cf. quinqueloba</i>	x	x	x	x	x	x	x		x	x					x	x		x	x					x	x	x	x		x		x
8. <i>Globigerinella obesa</i>	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x					x	x		x	x			N	x
9. <i>Globoquadrina langhiana</i>	x	x		x	x	x	x	x			x	x	x			x	x	x	x	x			x	x	x	x	x	x		R	x
10. <i>Globoquadrina dehiscens</i>		x						x	x	x	x					x	x	x												R	x
11. <i>Globigerinita glutinata</i>		x			x	x		x	x	x		x				x	x							x	x						R
12. <i>Globigerinella praesiphonifera</i>			x	x												x															A
13. <i>Paragloborotalia continuosa</i>				x			x						x	x	x		x						x	x	x						B
14. <i>Globoquadrina larmei</i>					x								x		x	x	x	x					x				x	x			
15. <i>Praeorbulina glomerosa sicana</i>						x				x		x	x		x	x	x						x	x	x	x	x	x			x
16. <i>Praeorbulina transitoria</i>						x					x			x	x	x								x	x	x	x				x
17. <i>Globorotalia peripheroronda</i>							x				x					x	x	x	x						x						
18. <i>Globigerina woodi</i>								x			x																x		x		x
19. <i>Globigerinoides subquadratus</i>																x															
20. <i>Paragloborotalia mayeri</i>											x				x	x	x	x						x		x					
ZONE	<i>G. trilobus</i>					<i>Praeorbulina</i>																									
SUBZONE						<i>Praeorbulina glomerosa sicana</i>																									
STAGE	Burdigalian															Langhian															

Tab. 2 - Occurrence of planktonic foraminifera in the samples of the Bricco del Moro section.

deposits (Gnaccolini, 1968; Casnedi, 1983; Caprara *et al.*, 1985).

In describing the Langhian Stage for the first time, Pareto (1865) mentioned the area surrounding Acqui Terme and Bistagno, in the Bormida valley, as typical of his new Stage. About a century later, Cita & Premoli Silva (1960a) proposed as Langhian Stratotype the stratigraphic succession exposed near Cessole, in the Bormida di Millesimo valley. The stratotype, as described by the authors, consists of the Cessole Fm. outcropping near its type locality (see Cita & Blow, 1969, fig. 4; Cita, 1967 and 1971). The stratotype boundaries were never precisely designated; they were taken as roughly coincident with the limits of the Cessole Fm.. The upper limit (Cessole/Cassinascio boundary) is rather sharp and easily detectable in the field, while the lower one (Cortemilia/Cessole transition) is gradational and poorly exposed in the Langhian type area.

Biostratigraphical studies on the section include those of Cita & Premoli Silva (1960a, 1968); Cita & Blow (1969), Martini (1968, 1971) and Bossio *et al.* (1992). Cita & Premoli Silva (1960a, 1968) reported the first occurrence of *Praeorbulina glomerosa curva*

in the lower part of the Cessole Formation (Bricco del Moro section) and the last occurrence of *Praeorbulina* in the uppermost part of the proposed Langhian stratotype (Cessole section). Cita & Blow (1969) assigned the upper part of the Cessole Formation (and the upper boundary of the Langhian stratotype) to Blow's (1969) Zone N10 (see also Ryan *et al.*, 1974). Iaccarino (1985) disagreed with this last statement. She argued that the Langhian/Serravallian boundary, in the Langhian type section, falls within Blow's Zone N9 and approximates the first occurrence of *Orbulina universa*.

THE BRICCO DEL MORO AND CESSOLE SECTIONS

The measured and sampled stratigraphic sections are located near the Bricco del Moro hill and on the outskirts of Cessole (Asti Province). The study area is represented in Text-fig. 2.

The Bricco del Moro section (Text-fig. 3) straddles the transition from the Cortemilia Fm. to the Cessole Fm.. It substantially corresponds to the upper part of Vervloet's (1966) section IIc (Map II). It fairly well matches the middle and upper part of the

Cessole section (interval a-b)																											
samples:	CS1	CS2	CS3	CS4	CS5	CS6	CS7	CS8	CS9	CS10	CS11	CS12	CS13	CS14	CS15	CS16	CS17	CS18	CS19	CS20	CS21	CS22	CS23	CS24	CS25	CS26	
species:																											
1. <i>Globigerina praebulloides</i>	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
2. <i>Globigerina woodi</i>	x		x		x	x		x	x	x											x	x	x	x	x	x	
3. <i>Turborotalita cf. quinqueloba</i>	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
4. <i>Globigerinoides trilobus</i>	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
5. <i>Globigerinoides bisphericus</i>	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	
6. <i>Globigerinoides subquadratus</i>	x					x					x	x	x	x	x	x											
7. <i>Globigerinella obesa</i>	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	
8. <i>Globigerinella praesiphonifera</i>	x		x	x	x	x	x	x	x	x	x			x	x	x	x		x	x		x	x		x	x	
9. <i>Praeorbulina glomerosa sicana</i>	x	x	x		x								x		x	x	x					x					
10. <i>Praeorbulina glomerosa curva</i>	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x			x						
11. <i>Praeorbulina glomerosa glomerosa</i>	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x		x	x	
12. <i>Praeorbulina transitoria</i>	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
13. <i>Globorotalia praescitula</i>	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
14. <i>Globoquadrina dehiscens</i>	x		x	x	x	x	x	x	x	x	x				x	x				x			x			x	
15. <i>Globoquadrina langhiana</i>	x	x	x	x	x	x	x	x	x	x	x			x	x		x			x		x	x	x	x	x	
16. <i>Globoquadrina baroemouensis</i>	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
17. <i>Globoquadrina altispira</i>	x	x	x	x		x				x	x	x		x							x	x	x	x	x	x	
18. <i>Globoquadrina larmei</i>			x	x		x	x	x		x	x		x	x													
19. <i>Globigerina druryi</i>							x	x				x	x	x		x											
20. <i>Paragloborotalia continuosa</i>									x						x								x		x	x	
21. <i>Globigerina falconensis</i>												x		x	x												
22. <i>Globorotalia archeomenardii</i>														x											x		
23. <i>Paragloborotalia mayeri</i>															x								x	x	x	x	
24. <i>Paragloborotalia siakensis</i>															x								x	x	x	x	
25. <i>Praeorbulina glomerosa circularis</i>																	cf	cf		cf	x	x			x	x	
26. <i>Globorotalia peripheroronda</i>																											
27. <i>Orbulina suturalis</i>																											
28. <i>Orbulina universa</i>																											
ZONE	Praeorbulina																										
SUBZONE	P. glomerosa curva																				P. glom. circularis						
STAGE	Langhian																										

Tab. 3a - Occurrence of planktonic foraminifera in the samples of the Cessole section (interval a-b).

Bricco del Moro section described by Cita & Premoli Silva (1960a), that is to say the lower portion of the proposed Langhian stratotype (Premoli Silva, 1993, written communication).

The Cessole section (Text-fig. 4) largely corresponds to that described by Gelati (1968, p. 913). The sampling route is approximately the same as Gelati's in the lower part; it slightly differs in the upper part in order to sample better exposures and avoid tectonic duplications. The measured section consists of three segments which easily correlate in the field. It represents the middle and upper part of the proposed Langhian Stratotype (Bricco della Croce section of Cita & Premoli Silva, 1960a) and includes the Cessole/Cassinascio boundary (upper boundary of the stratotype).

Biostratigraphy. The samples collected in the Cor-

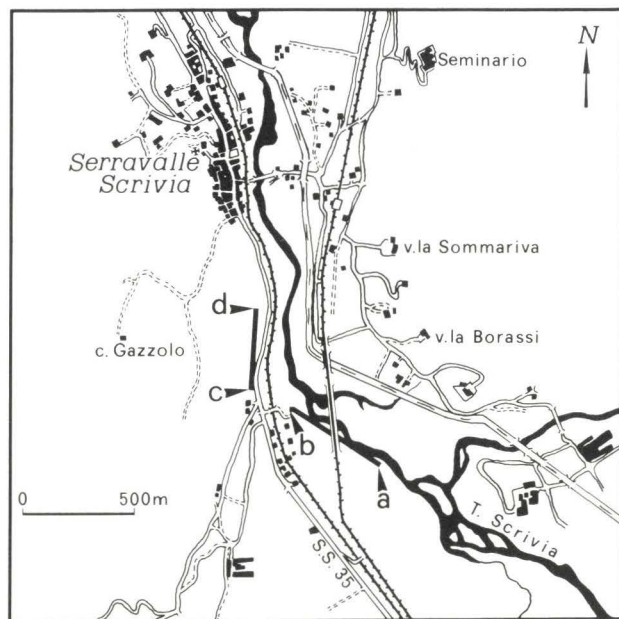
temilia Fm. and in the basal part of the Cessole Fm. (Bricco del Moro section, Text-fig. 3) as well as those from the Cassinascio Fm. (upper part of the Cessole section, Text-fig. 4) yielded low-diversity, poorly preserved foraminiferal assemblages. On the other hand, the samples from the typical «marne a pteropodi» of the Cessole Fm. (Cessole section, see Text-fig. 4) yielded abundant planktonic foraminifera, which are relatively well preserved although recrystallization of the tests is always observed.

The species occurrences in the collected samples are shown in Tab. 2 (Bricco del Moro section) and Tab. 3a-3b (Cessole section). The most significant biostratigraphic data are summarized below.

In the Bricco del Moro section *Praeorbulina glomerosa sicana* first occurs in the uppermost part of the Cortemilia Formation (sample BMG36) around

Cessole section (interval c-d)																														(Interval e-f)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																										
samples:		CS30	CS31	CS32	CS33	CS34	CS35	CS36	CS37	CS38	CS39	CS40	CS41	CS51	CS52	CS53	CS54	CS55	CS56	CS57	CS58	CS59	CS60	CS61	CS62	CS63	CS64	CS65	CS66	CS67	CS68	CS69	CS70	CS71	CS72	CS73	CS80	CS81	CS82	CS83	CS84	CS85	CS86	CS87	CS88	CS89	CS90																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																									
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1. <i>Globigerina praebulloides</i>		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																												

Tab. 3b - Occurrence of planktonic foraminifera in the samples of the Cessole section (intervals c-d and e-f)



Text-fig. 5 - Location of the Serravalle section (From the IGM Carta d'Italia, scale 1:25.000, sheet 70 II SE Serravalle).

sixty metres below the base of the Cessole Formation.

The lower part of the Cessole section (Tab. 3a) yielded a planktonic foraminiferal assemblage with *P. glomerosa sicana*, *P. glomerosa curva*, *P. glomerosa glomerosa* and is assigned to the *P. glomerosa curva* Subzone. Going up the stratigraphic succession, the first occurrences of *P. glomerosa circularis* (in sample CS21), of *Orbulina suturalis* (in sample CS62) and of *Orbulina universa* (in sample CS85) were successively recorded.

The first occurrence of *O. universa*, that marks the base of the *O. universa* Subzone, was recognized in sample CS85, which was taken below the boundary between the Cessole Fm. and the overlying Cassinasco Fm. It immediately follows the last occurrence of *P. glomerosa circularis*.

A gap exists between the top of the Bricco del Moro section and the bottom of the Cessole section. It corresponds to a part of the *P. glomerosa sicana* Subzone plus part of the overlying *P. glomerosa curva* Subzone. This interval is poorly exposed in the Langhian type area.

Praeorbulina glomerosa curva was not found in the lower part of the Cessole Formation (Bricco del Moro section).

In the studied sections, the Cessole Formation («Marne a pteropodi» Auctt.) ranges from above the horizon of the first occurrence of *P. glomerosa sicana* to the horizon of the first occurrence of *O. universa*.

I recognized the former around sixty metres below the base of the Formation and the latter close to the Cessole - Cassinasco boundary.

Similar results have been reached by Bossio *et al.* (1992).

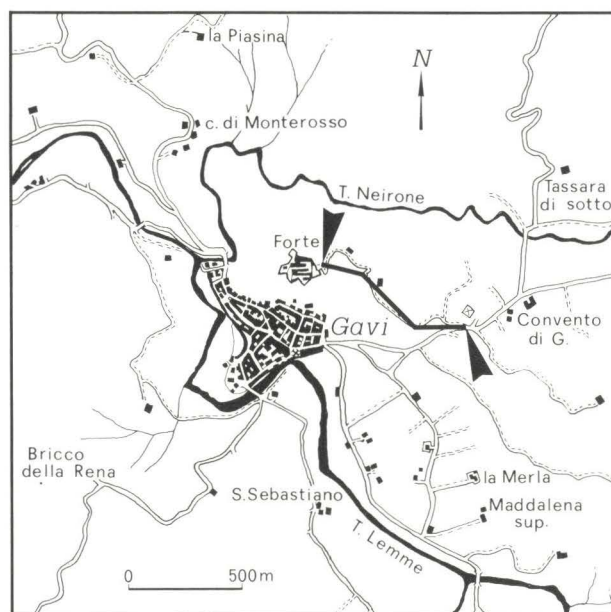
THE SERRAVALLIAN TYPE AREA: THE SCRIVIA AND LEMME VALLEYS

Stratigraphical setting. The Scrivia and Lemme valleys are located in the eastern part of the Tertiary Piedmont Basin. The local stratigraphic succession is well known having been studied for more than a century (Pareto, 1865; Mayer, 1877; Sacco, 1890; Lorenz, 1969; Andreoni *et al.*, 1981; Casnedi, 1983; Caprara *et al.*, 1985; Ghibaudo *et al.*, 1986; etc.). The Miocene stratigraphic succession of the area is similar to that of the Bormida valley in its lower part; it significantly differs in the upper part.

The lithostratigraphic units commonly recognized are the following, from bottom to top:

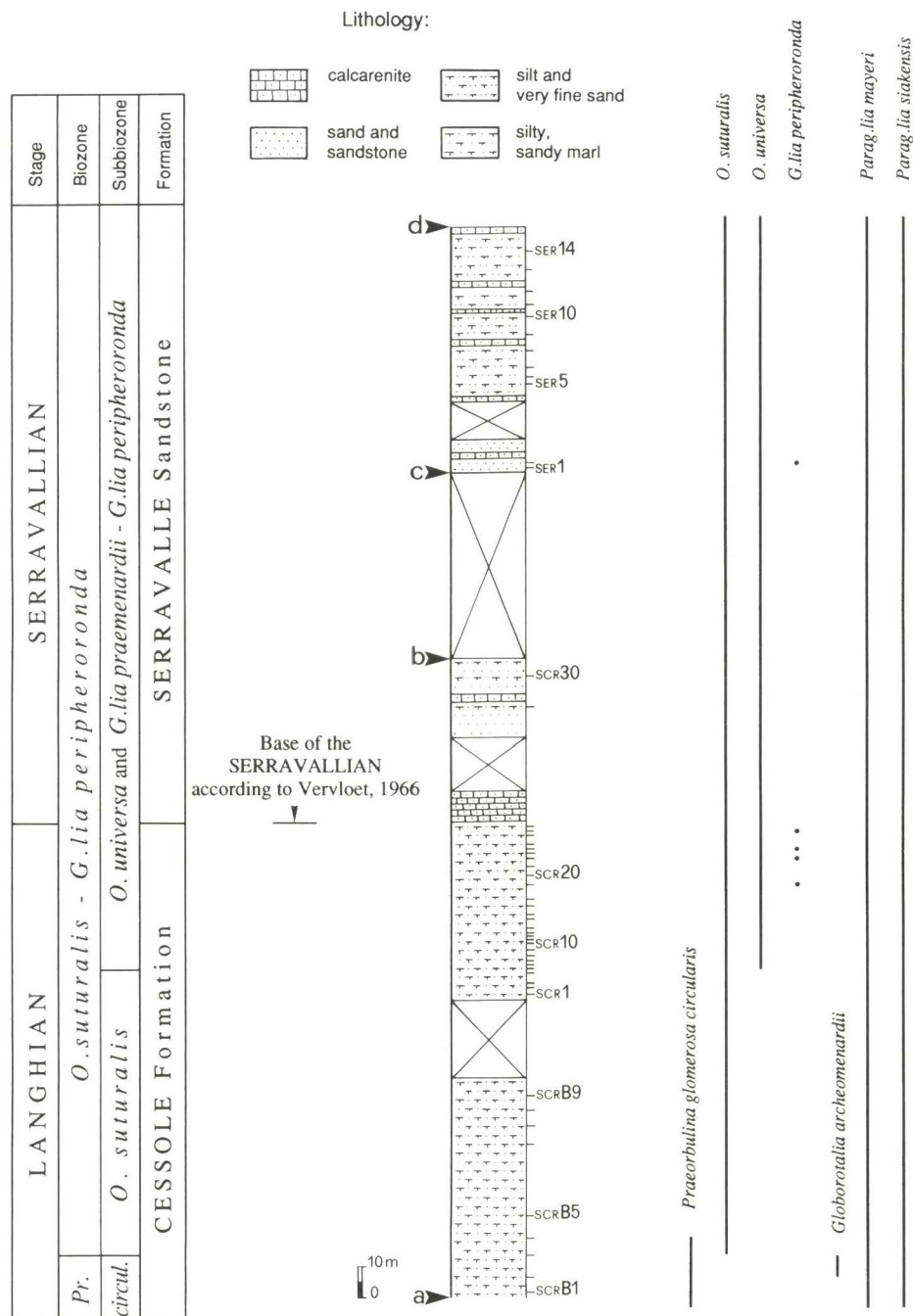
1) The Costa Areaa Formation (Vervloet, 1966; Andreoni *et al.*, 1981; Ghibaudo *et al.*, 1986), which is lithostratigraphically correlatable with the Cortemilia Fm. of the Langhe area (Gelati & Gnaccolini, 1988). The age is Burdigalian-early Langhian.

2) The Cessole Formation, composed of clayey and silty marls, associated with siltstones and fine-grained sandstones; it presents a higher content of siliciclastic material than in the type area. The age is Langhian.



Text-fig. 6 - Location of the Gavi section (From the IGM Carta d'Italia, scale 1:25.000, sheet 70 II SO Gavi).

SERRAVALLE section

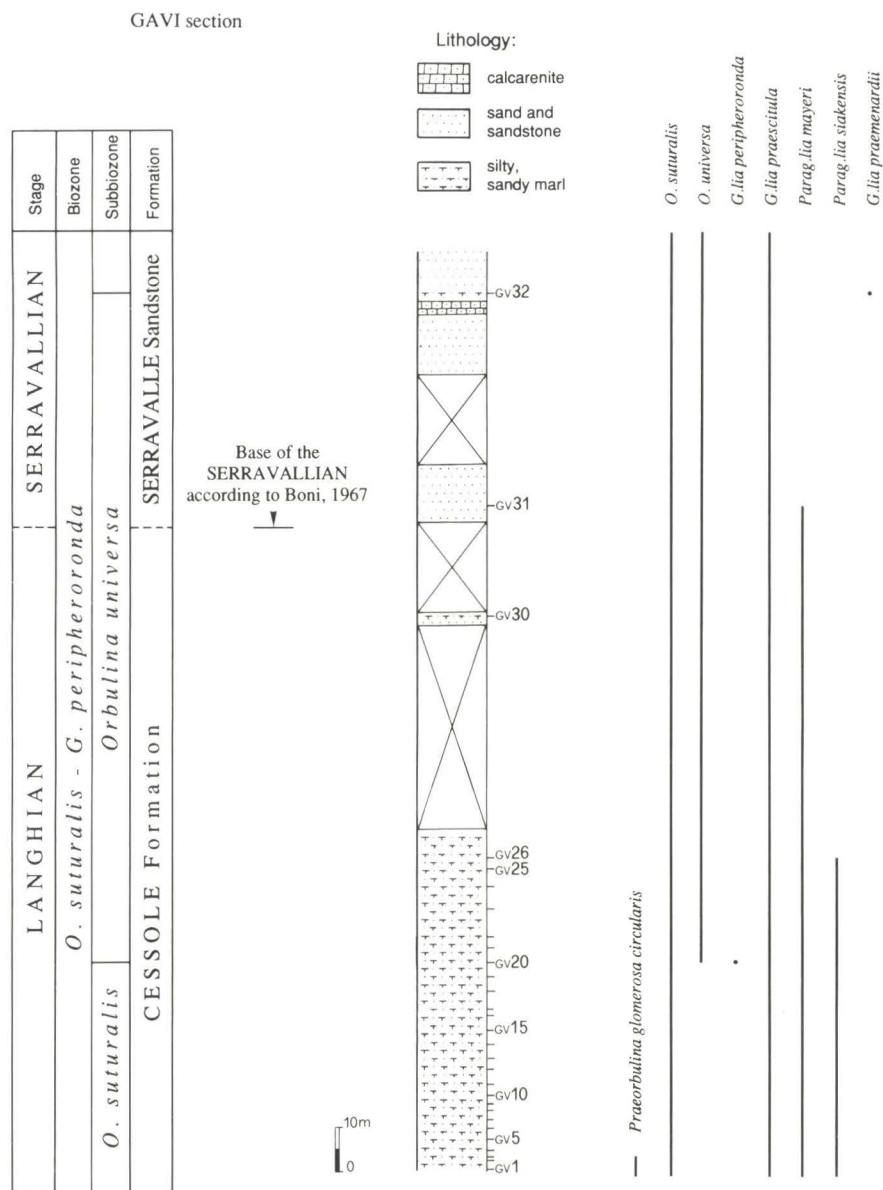


Text-fig. 7 - Lithological log of the Serravalle section and ranges of selected planktonic foraminiferal species.

3) The Serravalle Sandstone (Boni, 1967a) formed by fine- to coarse-grained, mainly bioclastic sandstones, siltstones and silty marls.

4) The S. Agata Fossili Marl (Beatrizotti *et al.*, 1965; Boni, 1967b) composed of silty and sandy marls with intercalations of fine-grained sands and

sandstones. Large bodies of resedimented conglomerates are locally present. The S. Agata Fossili Marl exposed in the Rio Mazzapiedi near Castellania (some ten kilometres NNE of Serravalle) forms the historical stratotype of the Tortonian Stage (Gianotti, 1953; Cita *et al.*, 1966).



Text-fig. 8 - Lithological log of the Gavi section and ranges of selected planktonic foraminiferal species.

The sands and sandstones outcropping near Serravalle Scrivia (Alessandria) were indicated by Pareto (1865) as representative of his Serravallian Stage. Following the original indication of Pareto, Vervloet (1966) proposed as Serravallian stratotype precisely the type section of the Serravalle Formation (= Serravalle Sandstone) exposed on the banks of the Scrivia river near Serravalle. The lower boundary of the Serravalle Formation is the lower boundary of Vervloet's stratotype. Another section, in the neighbourhood of Gavi (Alessandria), was proposed by Boni (1967a) as type of the Stage in place of that of Vervloet (Boni & Selli, 1971).

Previous biostratigraphical studies on the two sections include those of Vervloet (1966), Boni (1967), Cita & Blow (1969), Foresi (1992). Cita & Blow (1969) assigned the base of the Serravalle Formation to Blow's Zone N10 and proposed «to define biostratigraphically the Serravallian as coincident with the base of Zone N11». Iaccarino (1985) rejected this proposal and assumed that the Serravallian lower boundary, which is approximated by the first occurrence of *O. universa*, falls within Zone N9. Foresi (1992) recorded the first occurrence of *O. universa* below the Serravallian stratotype.

Serravalle section																																																		
samples:	SCR1	SCR2	SCR3	SCR4	SCR5	SCR6	SCR7	SCR8	SCR9	SCR10	SCR11	SCR12	SCR13	SCR14	SCR15	SCR16	SCR17	SCR18	SCR19	SCR20	SCR21	SCR22	SCR23	SCR24	SCR25	SCR26	SCR27	SCR28	SCR29	SCR30	SER1	SER2	SER3	SER4	SER5	SER6	SER7	SER8	SER9	SER10	SER11	SER12	SER13	SER14						
	species:																																																	
1. <i>Praeorbulina glomerata circularis</i>	x	x	x	x																																														
2. <i>Globigerina praebulloides</i>	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x																														
3. <i>Turborotalia quinqueloba</i>	x	x	x	x	x	x	x	x	x																																									
4. <i>Globigerinoides trilobus</i>	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		
5. <i>Globigerinella obesa</i>	x	x	x	x	x	x	x	x	x																																									
6. <i>Globorotalia praescitula</i>	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x																		
7. <i>Paragloborotalia mayeri</i>	x	x	x	x	x	x	x	x	x	x	x	x	x	x																																				
8. <i>Paragloborotalia siakensis</i>	x	x	x	x	x	x																																												
9. <i>Globoquadrina dehiscens</i>	x	x																																																
10. <i>Globoquadrina baroemouensis</i>	x	x	x	x	x																																													
11. <i>Paragloborotalia continuosa</i>	x																																																	
12. <i>Globoquadrina altispira</i>																																																		
13. <i>Globorotalia archeomenardii</i>																																																		
14. <i>Globoquadrina langhiana</i>																																																		
15. <i>Globigerina druryi</i>																																																		
16. <i>Globigerina woodi</i>																																																		
17. <i>Globigerinella praesiphonifera</i>																																																		
18. <i>Orbulina suturalis</i>																																																		
19. <i>Globigerinita glutinata</i>																																																		
20. <i>Globigerinoides subquadratus</i>																																																		
21. <i>Orbulina universa</i>																																																		
22. <i>Globoquadrina larmei</i>																																																		
23. <i>Globorotalia peripheroronda</i>																															</																			

Tab. 4 - Occurrence of planktonic foraminifera in the samples of the Serravalle section.

Gavi section																																
samples:	GV1	GV2	GV3	GV4	GV5	GV6	GV7	GV8	GV9	GV10	GV11	GV12	GV13	GV14	GV15	GV16	GV17	GV18	GV19	GV20	GV21	GV22	GV23	GV24	GV25	GV26	GV30	GV31	GV32			
species:																																
1.Praeorbulina transitoria	x	x																														
2.Praeorbulina glomerosa circularis	x	x	x																													
3.Globigerinella praesiphonifera	x								x								x															
4.Globoquadrina langhiana	x	x	x	x	x	x	x	x	x		x	x		x		x	x		x	x												
5.Globoquadrina larmeu	x	x	x				x		x				x	x		x	x					x	x									
6.Globigerina praebuloides	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x		
7.Globigerina woodi	x	x	x		x		x		x		x		x		x	x	x		x			x							x			
8.Turborotalita quinqueloba	x	x	x		x	x	x	x	x		x		x		x		x		x	x	x	x		x	x	x	x	x	x	x		
9.Globigerinoides trilobus	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		
10.Globigerinella obesa	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x		x	x	x	x	x	x	x	x	x	x	x	x		
11.Orbulina suturalis	x	x	x	x		x	x	x	x	x	x	x			x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		
12.Globorotalia praescitula	x	x	x		x		x	x	x	x	x	x	x		x	x	x		x	x	x	x	x	x	x	x	x	x		x		
13.Paragloborotalia mayeri	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x			
14.Paragloborotalia siakensis	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x					
15.Paragloborotalia continuosa	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x		x			x		
16.Globoquadrina dehiscens	x	x	x	x				x	x	x	x		x		x	x	x													x		
17.Globoquadrina baroemoenensis	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x				x	x		
18.Globoquadrina altispira	x				x											x		x														
19.Globigerina falconensis			x								x																					
20.Globigerina druryi			x								x																			x		
21.Globigerinoides subquadratus					x		x									x														x		
22.Orbulina universa																				x			x			x	x	x	x	x		
23.Globorotalia peripheroronda																				x												
24.Globorotalia praemenardii																														x		
ZONE	Orbulina suturalis - Globorotalia peripheroronda																															
SUBZONE	Orbulina suturalis																				Orbulina universa											
STAGE	Langhian																															Ser.

Tab. 5 - Occurrence of planktonic foraminifera in the samples of the Gavi section.

THE SERRAVALLE AND GAVI SECTIONS

Two sections have been measured and sampled:

1) South of Serravalle, in the Scrivia river and along highway SS 35, close to the village of Libarna (Text-fig. 5);

2) on the eastern outskirts of Gavi (Text-fig. 6).

The former section (Text-fig. 7) corresponds to the lower and middle part of Vervloet's section IVD (Map IV); it straddles the boundary between the Cessole Fm. and the Serravalle Sandstone (= Precipiano Formation and Serravalle Formation respectively of Vervloet, 1966). On the Scrivia left bank, nearly one kilometre south of Serravalle and immediately downstream of the railway viaduct across the river, the stratigraphic boundary between the Cessole Fm. and the Serravalle Sandstone crops out: yellow arenaceous calcarenites of the Serravalle Sandstone overlie, with a sharp contact, grey silty marls, pertaining to the Cessole Fm. The lower part

of the studied section was sampled starting some tens of metres upstream of the railway bridge and following the left bank of the Scrivia; it spans the upper part of the Cessole Fm. and the lowermost beds of the Serravalle Sandstone. The upper part of the section was sampled in the steep scarp along the Serravalle-Arquata Scrivia road.

The Gavi section was described by Boni (1967a) as Serravallian type section and was visited by the members of the Committee on Mediterranean Neogene Stratigraphy during the IV Congress held in Bologna (1967). The stratigraphic interval sampled for the present study (Text-fig. 8) corresponds to the lower part of Boni's section. It spans the upper part of the Cessole Fm. and the basal part of the Serravalle Sandstone, here represented by medium-to coarse-grained, cross-bedded sands and sandstones. The sampling was performed in the disused quarry located near the cemetery of Gavi and along the steep road to the «Forte». Only two samples

were collected in the basal part of the Serravalle Sandstone because the local lithofacies is unsuitable for micropaleontological sampling.

Biostratigraphy. The microfossil assemblages of the studied samples are generally of low abundance and diversity. The preservation of the foraminifers (and of rare ostracods) is rather poor. The tests are encrusted and recrystallized.

The planktonic foraminiferal species occurrences in the samples are shown in Tab. 4 (Serravalle section) and Tab. 5 (Gavi section).

For the Serravalle section (Text-fig. 7; Tab. 4) the most meaningful data are summarized below.

- The first occurrence of *O. suturalis* (base of the *O. suturalis* Subzone) was recorded in sample SCRB3.

- *O. universa* was first recognized in sample SCR5 and I have drawn the lower boundary of the *O. universa* Subzone at level SCR5. This level is around 45 metres below the base of the Serravalle Sandstone.

- *Globorotalia peripheroronda* was observed as scattered in the upper part of Cessole Fm. and in the lower part of the Serravalle Sandstone.

It is worth noting that *Globorotalia praemenardii* was not detected in the Serravalle section and *Globorotalia peripheroronda* is extremely rare. Hence I failed to recognize the upper limit of the *O. universa* Subzone (lower boundary of the *G. praemenardii* - *G. peripheroronda* Subzone) and the upper limit of the *O. suturalis* - *G. peripheroronda* Zone. Generally speaking, no significant biohorizon was recognized in the Serravalle Sandstone.

I obtained similar results from the Gavi section study (Tab. 5). The following data are of significance:

- *P. glomerata circularis* was recorded in the three lowest samples;

- *O. suturalis* was continuously recorded from the base of the section;

- *O. universa* was first recognized in sample GV20;

- *G. peripheroronda* was detected in only one sample (GV20);

- *G. praemenardii* occurs in sample GV32.

Consequently, the base of the Serravalle Sandstone in the Gavi section (base of the Serravallian according to Boni, 1967a) falls in the *O. universa* Subzone and it is biostratigraphically bracketed by the first occurrence datums of *O. universa* and *G. praemenardii*. These results are in agreement with Boni (1967a, fig. 17).

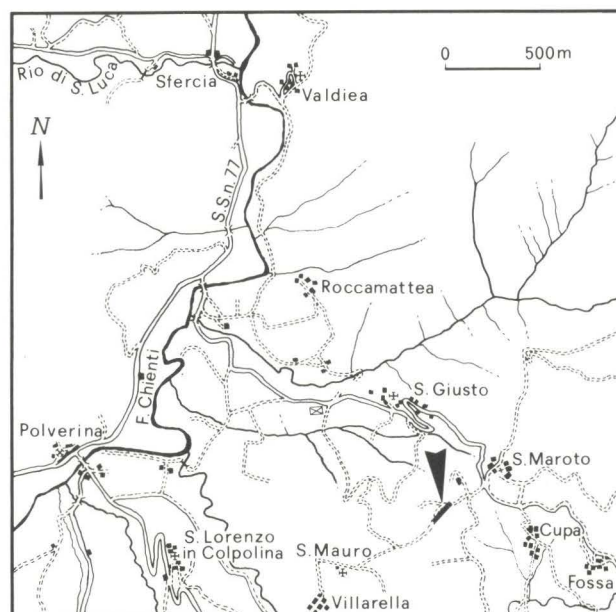
Summing up, it results that the first occurrence of *O. universa* is the most useful planktonic

foraminiferal event recognizable near the lower boundary of the Serravalle Sandstone (proposed lower boundary of the Serravallian Stage) both in the Serravalle and Gavi sections. The appearance of *G. praemenardii* in the lower part of the Serravalle Sandstone (Gavi section) probably approximates the first evolutionary appearance of the species. However, the lineage from *Globorotalia archeomenardii* to *G. praemenardii* is not documented in the sections studied; the evolutionary transition is not precisely detectable. Moreover *G. praemenardii* was not recorded in the Serravalle section. So the first evolutionary appearance horizon of *O. universa* seems to be more suitable for widespread correlation.

It must be stressed that the depositional environment of the Serravalle Sandstone was clearly not favourable for recording time-significant planktonic foraminiferal assemblages. Deep-dwelling species, such as *G. praemenardii* (Keller, 1985; Gasperi & Kennett, 1993), are exceedingly rare or lacking throughout the Sandstone (as well as in the upper part of the Cessole Fm.). Hence, a detailed biostratigraphic zonation and a careful correlation of the Serravalle Sandstone are greatly hampered.

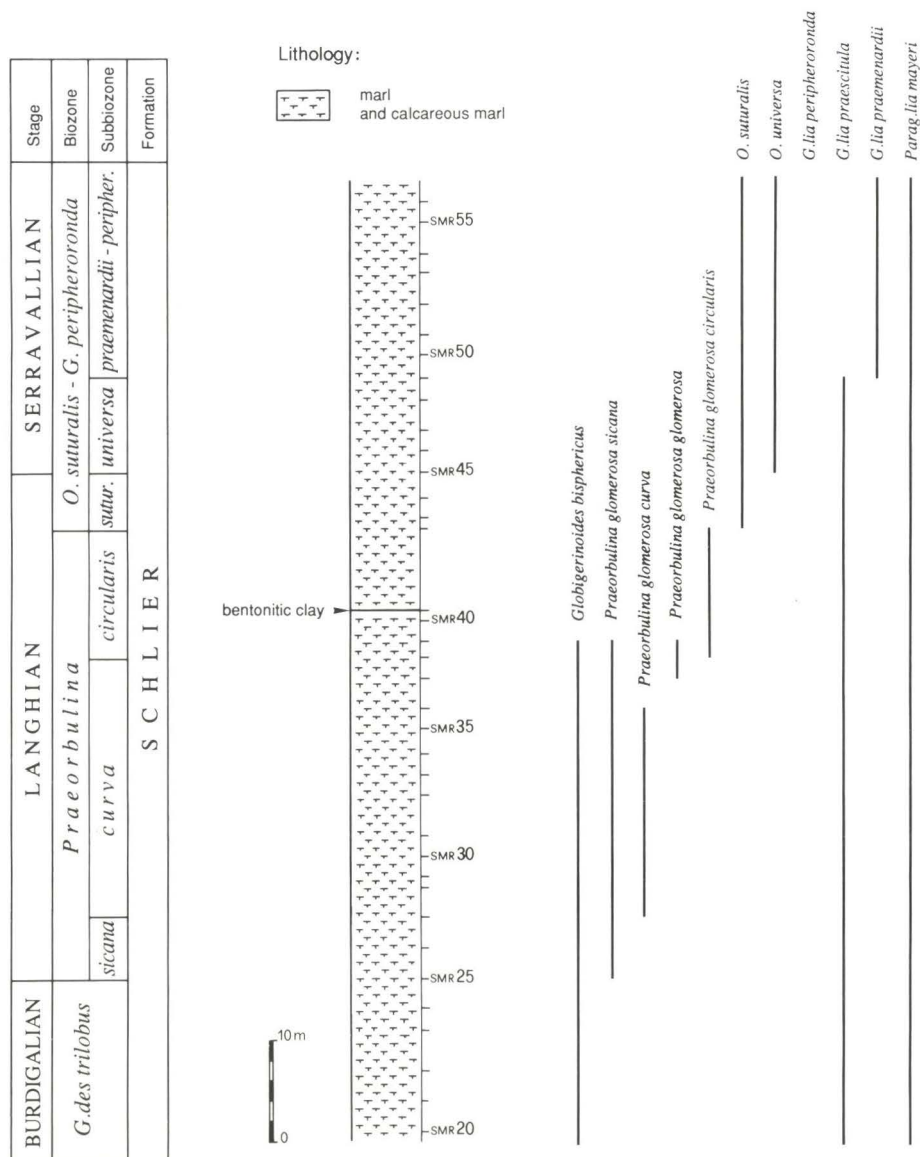
THE MIDDLE MIOCENE OF THE MARCHE REGION

Stratigraphical setting. The stratigraphic succession of the Marche region consists of a thick, continuous, mostly pelagic, fossiliferous sequence ac-



Text-fig. 9 - Location of the S. Maroto section (From the IGM Carta d'Italia, scale 1:25,000, sheet 124 III NE Polverina).

S. MAROTO section



Text-fig. 10 - Lithological log of the S. Maroto section and ranges of selected planktonic foraminiferal species.

accumulated on the Adriatic-Apulian continental margin (Apenninic Foreland) from the Jurassic to the Miocene (Selli, 1954; Crescenti *et al.*, 1969; Centamore *et al.*, 1980; Centamore & Deiana, 1986; Centamore & Micarelli, 1991; etc.).

The Lower and Middle Miocene are made up of hemipelagic deposits commonly referred to two informal lithostratigraphic units: the Bisciaro formation (limestones and cherty limestones interbedded with marls and calcareous marls) and the Schlier formation (marls and calcareous marls, with intercalations of volcanoclastic layers and volcanic-derived clays). The age of the Schlier is Burdigalian

to Tortonian (Burdigalian to Messinian in the eastern part of the region, beyond the so-called Marchean ridge; Cantalamessa *et al.*, 1986).

The Middle Miocene stratigraphic succession of the Marche region has been studied in two sections: 1) the S. Maroto section, located in the so-called «Camerino inner basin» (Calamita *et al.*, 1979); 2) the Trave section, on the coast near Ancona.

THE SAN MAROTO SECTION

The section was traced near the locality of S. Maroto (Pieveboggiana Commune, Macerata Provin-

S. Maroto section																																						
samples:	SM20	SM21	SM22	SM23	SM24	SM25	SM26	SM27	SM28	SM29	SM30	SM31	SM32	SM33	SM34	SM35	SM36	SM37	SM38	SM39	SM40	SM41	SM42	SM43	SM44	SM45	SM46	SM47	SM48	SM49	SM50	SM51	SM52	SM53	SM54	SM55	SM56	
species:																																						
1.Globigerinoides bisphericus	x	x	x	x	x	x	x		x	x	x				x		x	x		x																		
2.Globoquadrina langhiana	x	x	x	x					x	x	x	x	x		x				x	x	x																	
3.Globorotalia praescitula	x	x			x	x	x	x		x	x		x	x	x	x	x	x	x	x						x					x							
4.Globigerina praebulloides	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x				x	x	x		x	x	x	x	x	x		x	x	
5.Globigerinoides trilobus	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
6.Paragloborotalia mayeri	x	x	x									x	x	x	x					x	x		x										x	x	x	x	x	
7.Globoquadrina baroemouensis	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x					x	x	x	x	x	x	x		x	x	x	x	
8.Praeorbulina transitoria		x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x					x	x										
9.Globigerina woodi		x					x	x																														
10.Globigerinoides subquadratus		x						x																				x								x	x	x
11.Globigerinella obesa		x		x	x	x	x	x		x	x	x	x			x	x	x	x	x	x					x	x			x	x	x	x			x	x	
12.Globorotalia peripheroronda		x																											x									
13.Paragloborotalia continuosa		x	x	x				x			x	x			x	x				x	x					x								x	x	x	x	
14.Globoquadrina larmei		x	x			x	x	x																														
15.Turborotaliia quinqueloba				x															x	x	x																	
16.Globoquadrina dehiscens				x								x							x	x	x															x	x	
17.Globigerinella praesiphonifera						x						x																										
18.Praeorbulina glomerosa sicana						x	x	x	x	x	x	x	x	x	x	x	x	x		x																		
19.Praeorbulina glomerosa curva								x			x	x	x	x	x	x	x																					
20.Paragloborotalia siakensis												x	x	x	x				x	x	x	x												x	x	x	x	
21.Praeorbulina glomerosa glomerosa																			x	x	x																	
22.Praeorbulina glomerosa circularis																				x	x	x	x	x														
23.Globigerina druryi																				x																		
24.Orbulina suturalis																											x	x	x	x	x	x	x	x	x	x	x	x
25.Orbulina universa																											x	x										
26.Globigerina falconensis																																						
27.Globorotalia miozea																																						
28.Globorotalia praemenardii																																						
29.Globoquadrina altispira																																						
ZONE	G. trilobus					Praeorbulina																			O. suturalis - G. peripheroronda													
SUBZONE						sicana	curva										circularis	suturalis	universa		praemenardii-peripheroronda																	
STAGE	Burdigalian					Langhian																			Serravallian													

Tab. 6 - Occurrence of planktonic foraminifera in the samples of the S. Maroto section.

ce). The area is represented in Text-fig. 9. Along the dirt road from S. Maroto to S. Mauro the stratigraphic succession consists of the Scaglia Cinerea formation (marls, Oligocene in age), the Bisciario and the Schlier (see Calamita *et al.*, 1979 for more details). The studied section, 95 metres thick (Text-fig. 10), was measured in the middle-lower part of the Schlier, which crops out continuously. A thin bed of bentonitic clay occurs at level SM41.

Biostratigraphy. Usually the collected samples yielded abundant, poorly preserved foraminifers. However, the microfossil preservation varies from sample to sample. The tests are always recrystallized, sometimes they are greatly encrusted and partially etched. In the most difficult cases, species identification is greatly hampered.

The species occurrences in the studied samples are reported in Tab. 6. The most significant data are summarized below:

- *P. glomerosa sicana* was recorded from sample SM25 to sample SM39.
- *P. glomerosa curva* was first recognized in sample SM27 and its last occurrence is in sample SM36.
- *P. glomerosa glomerosa* was found in samples SM37, SM38, SM39.
- *P. glomerosa circularis* was recorded from sample SM38 to sample SM42.
- In sample SM42 *O. suturalis* was first recorded.
- *O. universa* was found from sample SM45 upwards.
- The first recognized occurrence of *G. praemenardii* is in sample SM49.
- *G. peripheroronda* was sporadically detected in the sampled interval.

It follows that the biostratigraphic units of the adopted zonal scheme are all recognizable in the section up to the *G. praemenardii* - *G. peripheroronda* Subzone.

It seems that a hiatus exists in the stratigraphic succession between sampling levels SM36 and SM37 because *P. glomerosa glomerosa* first occurs in sample SM37 with highly evolved specimens close to the descendant subspecies (*circularis*). *P. glomerosa circularis* was first recorded in the subsequent sample and the *P. glomerosa glomerosa* local range results as exceedingly short.

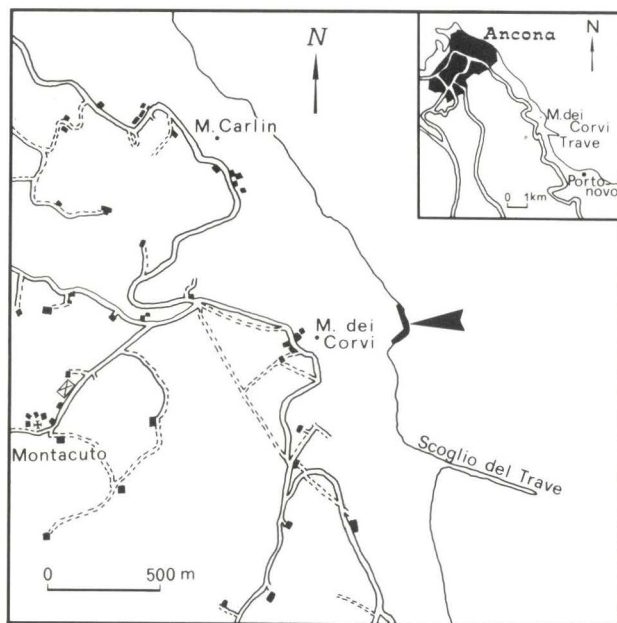
THE TRAVE SECTION

The stratigraphic succession being considered crops out on the cliff along the seashore South of Ancona (between the Town and Monte Conero; see Text-fig. 11).

The sequence comprises, from North to South

and in ascending stratigraphic order: 1) the Bisciario, exposed on the southern outskirts of Ancona; 2) the Schlier; 3) Messinian plastic clays, which contains gypsum lenses, sand levels and arenaceous bodies, locally very thick («Trave» rock). The stratigraphic succession is not continuously exposed. It is affected by tectonic accidents and is locally covered by landslides.

The section (Text-fig. 12) has been traced in the middle-upper part of the Schlier that crops out some hundreds of metres north of the «Trave» rock, near a fisherman's shack. It consists of a rhythmic alternation of marls and calcareous marls. Dark, brown or black, shales with a moderate to high organic carbon content repeatedly intercalate in the succession (see Coccioni *et al.*, 1992; Krüge *et al.*, 1992; Bromley & D'Alessandro, 1992 for more details). A thin biotite-rich bed (Livello Ancona, as nominated by Coccioni *et al.*, 1992) occurs in the upper part of the sampled interval. According to Deino & Montanari (1992), $^{40}\text{Ar}/^{39}\text{Ar}$ radiometric dating of biotite crystals yielded an age of 11,3 Ma BP.

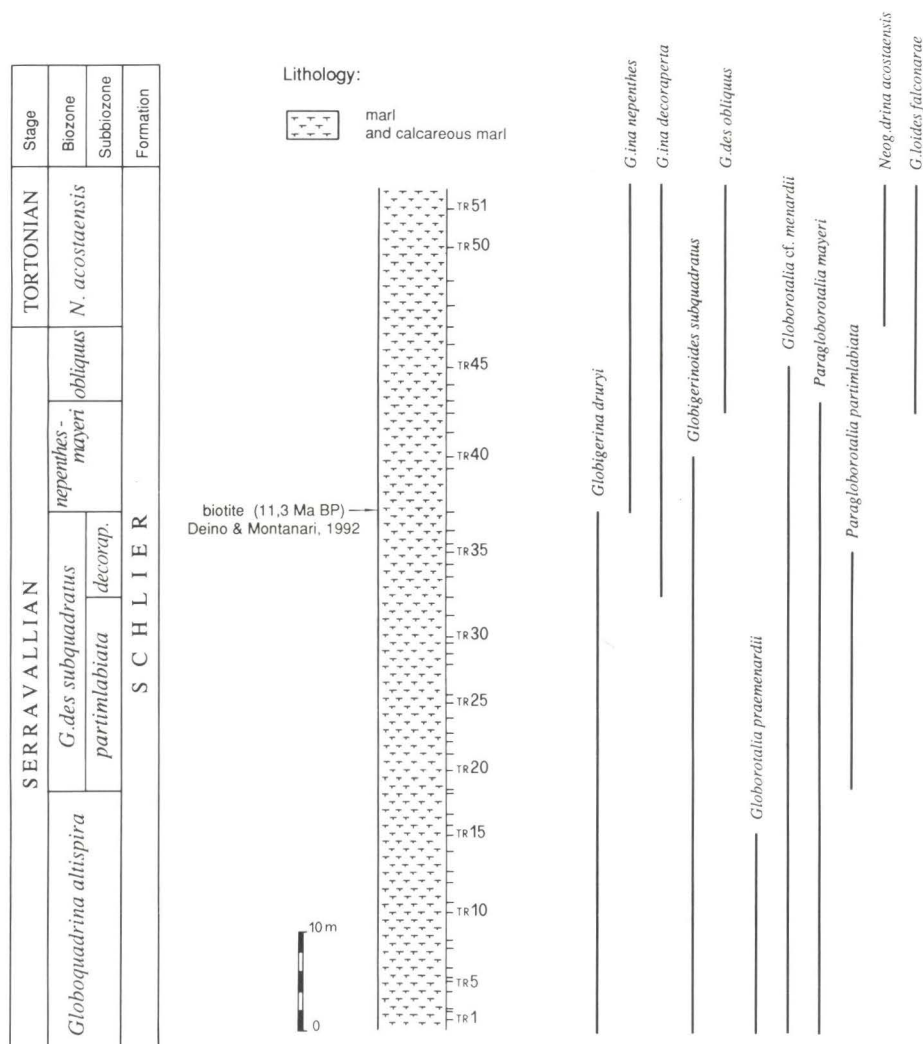


Text-fig. 11 - Location of the Trave section (From the IGM Carta d'Italia, scale 1:25.000, sheet 118 IV NO Ancona).

Biostratigraphy. The washing residues of the sampled marls contain abundant planktonic foraminifers. Microfossils are poorly to moderately preserved, always recrystallized.

The occurrences of the identified species in the studied samples are shown in Tab. 7. The most

TRAVE section



Text-fig. 12 - Lithological log of the Trave section and ranges of selected planktonic foraminiferal species. The lower limit of the Tortonian Stage has provisionally been taken as coincident with the first occurrence horizon of *N. acostaensis*.

meaningful biostratigraphic events are listed below.

- The first occurrence of *Paraglobobulimina partimlabiata* (that marks the lower limit of the *Globigerinoides subquadratus* Zone) is in sample TR19;

- The first occurrence of *Globigerina decoraperta* is in sample TR32;

- The first occurrence of typical specimens of *Globigerina nepenthes* is in sample TR38, immediately below the biotite-rich bed, dated at 11,3 MaBP.

- The last occurrence of *Globigerinoides subquadratus* is in sample TR40;

- *Paraglobobulimina mayeri* was last recovered in sample TR43;

- The first occurrence of *Neoglobobulimina*

acostaensis (that marks the lower limit of the homonym zone) is in sample TR47.

THE HYBLEAN PLATEAU

Stratigraphical setting. The Hyblean Plateau, in south-eastern Sicily, is an upraised, weakly deformed block structurally pertaining to the African (or Adriatic) Foreland of the Central Mediterranean (Pelagian Block of Burollet *et al.*, 1978). It is made up of an unfolded marine sedimentary succession – and associated volcanites – that spans from Mesozoic to Quaternary. However, the bulk of the outcropping rocks is Oligocene to Miocene in age (Grasso & Lentini, 1982; Pedley, 1981; Carbone *et al.*, 1989 and references therein).

Trave section																																																						
samples:	TR1	TR2	TR3	TR4	TR5	TR6	TR7	TR8	TR9	TR10	TR11	TR12	TR13	TR14	TR15	TR16	TR17	TR18	TR19	TR20	TR21	TR22	TR23	TR24	TR25	TR26	TR27	TR28	TR29	TR30	TR31	TR32	TR33	TR34	TR35	TR36	TR37	TR38	TR39	TR40	TR41	TR42	TR43	TR44	TR45	TR46	TR47	TR48	TR49	TR50	TR51			
species:																																																						
1.Globorotalia praemenardii	x						x	x							x																																							
2.Globigerina druryi	x		x	x		x	x			x	x			x	x	x	x	x	x	x	x								x		x			x		x	x																	
3.Paragloborotalia siakensis	x			x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x					x	x	x	x	x	x	x	x	x	x			x		x															
4.Paragloborotalia mayeri	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x			x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x						
5.Globorotalia cf. menardii	x						x	x								x	x	x	x										x		x			x	x	x	x	x																
6.Globoquadrina baroemouensis	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x																															
7.Globigerina praebulloides	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x					x	x			x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x							
8.Globigerina falconensis	x	x																	x																																			
9.Turborotalia quinqueloba	x			x	x	x		x	x	x	x	x	x	x	x	x	x	x																																				
10.Globigerinoides trilobus	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		
11.Globigerinella obesa	x	x	x	x	x	x			x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x																										
12.Orbulina universa	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		
13.Orbulina suturalis	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		
14.Paragloborotalia continuosa	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x			x		x			x		x	x	x	x	x	x	x			x	x	x	x	x	x	x	x	x	x	x	x	x	
15.Globigerinita glutinata	x				x	x	x	x	x	x	x	x	x	x	x	x	x	x	x											x		x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
16.Globoquadrina dehiscens				x	x	x		x						x	x	x	x		x	x																																		
17.Globigerinopsis agasayensis					x														x																																			
18.Globigerinoides subquadratus					x			x		x				x	x	x	x	x	x																																			
19.Globigerina woodi					x	x		x									x	x																																				
20.Globoquadrina altispira globosa					x																																																	
21.Globoquadrina altispira							x																																															
22.Paragloborotalia partimlabiata																																																						
23.Globigerina decoraperta																																																						
24.Clavatorella sturani																																																						
25.Globigerina nepenthes																																																						

Tab. 7 - Occurrence of planktonic foraminifera in the samples of the Trave section.

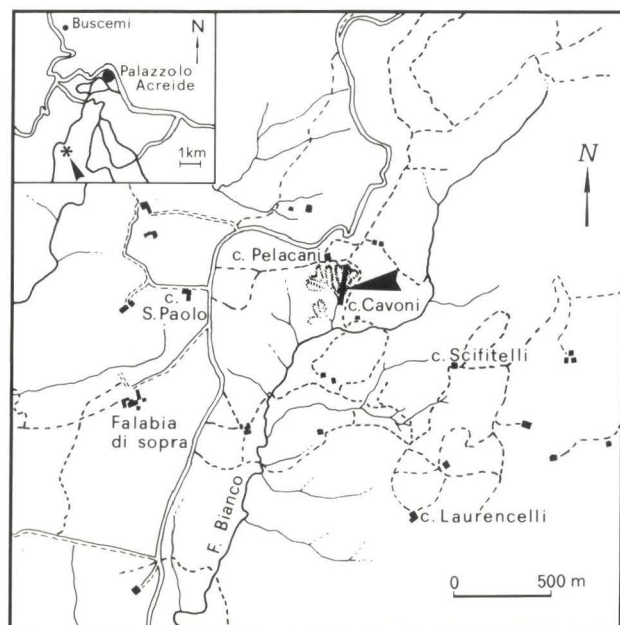
In the western Hyblean sector the Miocene Series mainly consists of three lithostratigraphic units, as defined by Rigo & Barbieri (1959). They are:

1) The Ragusa Formation formed by alternating marls and fine-grained limestones, sometimes cherty limestones, passing up to resedimented calcarenites with macrofossils. The age is late Oligocene - early Miocene.

2) The Tellaro Formation made up of clays and marls, with intercalated alternations of limestones and marls, volcanoclastic lenses and huge bodies of submarine basic lavas. The age is middle-late Miocene.

3) The Palazzolo Formation that consists of calcarenites and calcareous marls, middle to late Miocene in age.

The Palazzolo Fm. is partly heteropic of the Tellaro Fm..



Text-fig. 13 - Location of the Case Pelacani section (From the IGM Carta d'Italia, scale 1:25.000, sheet 273 II SE Palazzolo Acreide).

THE CASE PELACANI SECTION

The section spans the upper part of the Tellaro Fm. that crops out in the upper Tellaro valley south of Palazzolo Acreide, that is to say in the type area of the Formation (see Rigo & Barbieri, 1959; Romeo & Sciuto, 1989). It was measured and sampled in the badlands near Case Pelacani (Text-fig. 13). The sampled section (Text-fig. 15) roughly corresponds to the middle part of the Fiume Bianco section of Romeo & Sciuto (1989).

Biostratigraphy. The clayey marls of the Tellaro Fm. yielded rich, very well-preserved fossil assemblages. Besides abundant planktonic and benthonic foraminifers, ostracods are quite common. Benthonic foraminiferal assemblages (De Santis, 1993) and ostracods (Miculan, in progress) indicate deposition in an upper slope, well oxygenated environment.

The most meaningful biostratigraphic data resulting from the study of planktonic foraminiferal assemblages are as follows (see Tab. 8):

- *P. partimlabiata* is present in the lowermost sample; the species continues through the section up to sample CP7.

- *G. decoraperta* first occurs in sample CP7.

- *G. nepenthes* appears in sample CP13 along with the last specimens of *G. druryi* and *G. subquadratus*. The latter species disappears in sample CP14.

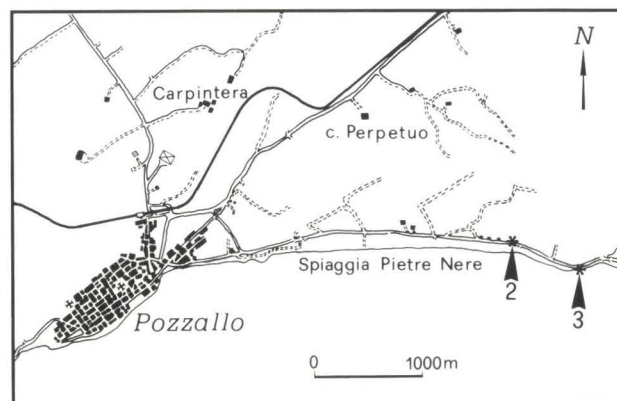
- The last occurrence of *P. mayeri* was detected in sample CP22.

- In the upper part of the *P. mayeri* range rare specimens of *G. obliquus* first occur. The species become common immediately above the level of the last occurrence of *P. mayeri*.

- *Globorotaloides falconarae* is present from sample CP22 upwards.

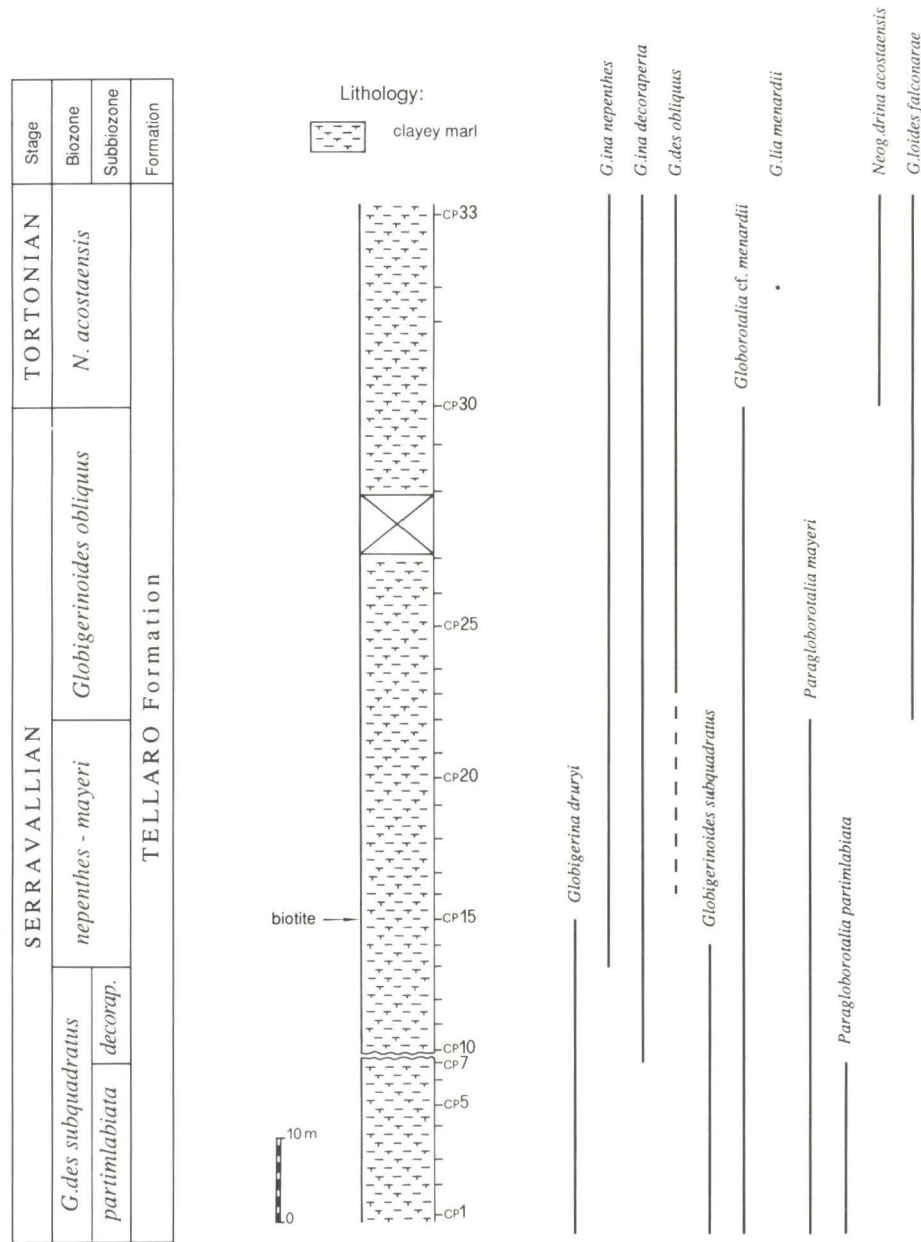
- *Neogloboquadrina acostaensis* first occurs in sample CP30.

It is noteworthy that the first occurrence of *G. decoraperta* and the last occurrence of *P. partimlabiata* have been recorded in the same sample (CP7). In other stratigraphic successions considered in the present work (M. Giammoia and Trave sections) *P. partimlabiata* disappears in the upper part of the *G. decoraperta* Subzone, in agreement with data from the literature (Salvatorini & Cita, 1979; Iac-



Text-fig. 14 - Location of the Pozzallo section (From the IGM Carta d'Italia, scale 1:25.000, sheet 276 II SE Pozzallo).

CASE PELACANI section



Text-fig. 15 - Lithological log of the Case Pelacani section and ranges of selected planktonic foraminiferal species. As in fig. 12, the lower limit of the Tortonian Stage has provisionally been taken as coincident with the first occurrence horizon of *N. acostaensis*.

carino, 1985; etc.). It follows that a great part of the two species concurrent range (lower *G. decoraperta* Subzone) probably lacks in the Case Pelacani section.

THE POZZALLO SECTION

A short composite section was sampled in the lower part of the Tellaro Formation cropping out along the seashore near Pozzallo (Ragusa). The study area is represented in Text-fig. 14.

Along the southern margin of the Hyblean plateau, the Tellaro Formation consists of whitish/ grey or cream microfossil-rich marls and calcareous marls.

The presence in the microfossil assemblages of psycrospheric ostracods (*sensu* Benson, 1975), such as *Agrenocythere hazelae* van den Bold, *Bythoceratina vandenboldi* Ruggieri and *Bythoceratina aviformis* Ruggieri, indicates deep bathyal conditions (an ostracod fauna from the Tellaro Fm., approximately

Case Pelacani section																																		
samples:	CP1	CP2	CP3	CP4	CP5	CP6	CP7	CP10	CP11	CP12	CP13	CP14	CP15	CP16	CP17	CP18	CP19	CP20	CP21	CP22	CP23	CP24	CP25	CP26	CP27	CP28	CP29	CP30	CP31	CP32	CP33			
species:																																		
1.Globorotalia miozea	x					x																												
2.Paragloborotalia partimlabiata	x	x	x	x	x	x	x																											
3.Globigerinoides subquadratus	x	x	x	x	x	x	x	x	x	x		x																						
4.Globigerina druryi	x	x	x	x	x			x	x			x	x	x																				
5.Paragloborotalia siakensis	x			x	x	x	x	x	x	x		x	x	x																				
6.Paragloborotalia mayeri	x	x		x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x													
7.Turborotalita quinqueloba	x					x	x		x	x			x	x	x	x		x	x				x	x	x		x				x	x		
8.Globigerinoides trilobus	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		
9.Globigerinella obesa	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x		x				x	x	x	x	x	x	x	x		x	x		
10.Orbulina suturalis	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		
11.Orbulina universa	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		
12.Paragloborotalia continuosa	x			x	x	x	x	x	x	x		x	x	x				x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		
13.Globoquadrina baroemoenensis	x	x	x	x	x	x	x	x	x	x	x	x	x			x					x			x	x	x		x				x		
14.Globoquadrina altispira	x				x			x				x									x											x		
15.Globigerina praebulloides		x	x	x	x	x	x	x		x	x	x	x				x				x			x	x	x		x						
16.Globoquadrina dehiscens		x	x							x														x	x	x	x		x					
17.Globigerinita glutinata		x	x		x	x		x	x	x	x	x	x	x		x	x	x	x	x	x		x	x	x		x	x	x		x	x		
18.Globorotalia cf. menardii			x	x	x	x	x	x	x	x			x	x	x	x	x		x	x		x		x	x	x	x	x						
19.Globigerinopsis agasayensis			x		x		x						x	x	x			x						x	x	x	x	x						
20.Globigerina woodi				x						x		x			x	x	x	x	x	x		x			x	x		x	x			x	x	
21.Globigerina parabulloides					x				x	x	x	x		x	x	x	x	x	x					x	x	x	x			x				
22.Globigerinita uvula					x					x			x			x			x					x			x							
23.Clavatorella sturani						x																												
24.Globigerina decoraperta							x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x			x	x		
25.Globigerina foliata										x	x														x									
26.Sphaeroidinellopsis disjuncta											x														x		x	x				x		
27.Globigerina nepenthes											x		x	x	x	x		x	x			x		x	x	x	x	x	x			x	x	
28.Globigerinoides bulloideus													x	x	x	x		x	x	x	x	x	x	x	x	x		x			x	x		
29.Globigerinoides obliquus														x*		x*	x*	x*		x*		x	x	x		x	x	x	x		x	x		
30.Globorotalia scitula															x															x		x		
31.Globigerina falconensis																	x	x	x											x				
32.Globorotaloides falconarae																				x	x	x		x	x	x	x				x	x		
33.Globorotalia linguaensis																											x	x	x			x		
34.Globigerinoides bollii																												x				x		
35.Neogloboquadrina acostaensis																										cf	cf	x			x	x		
36.Globorotalia menardii																															x			
37.Globoquadrina altispira globosa																																x		
ZONE	Globigerinoides subquadratus										G. nepenthes - P. mayeri										Gl.des obliquus										acostaensis			
SUBZONE	P. partimlabiata										decoraperta																							
STAGE	Serravallian																																	Tortonian
x* = the species is rare in the sample																																		

x* = the species is rare in the sample

Tab. 8 - Occurrence of planktonic foraminifera in the samples of the Case Pelacani section.

coeval with those of the studied samples was described by Ruggieri, 1960).

Biostratigraphy. The washing residues yielded abundant, highly diversified, and well preserved foraminiferal assemblages. Besides foraminifers, ostracods are quite common.

The planktonic foraminiferal occurrences in the investigated sections are shown in Tab. 9. The most

noticeable data are summarized below.

At the base of partial section 3 (see Text-fig. 16), *P. glomerosa sicana*, *P. glomerosa curva*, *P. transitoria* are present among the other species.

P. glomerosa glomerosa ranges from sample PZ38 upwards.

In partial section 2 the lowermost samples yielded *O. suturalis*, *P. mayeri*, *P. siakensis*, *G. baroemuenensis*, etc.

Pozzallo section																										
samples:	PZ31	PZ32	PZ33	PZ34	PZ35	PZ36	PZ37	PZ38	PZ39	PZ40	PZ41	PZ42	PZ43	PZ44												
species:																										
1. <i>Globigerinoides bisphericus</i>	x																									
2. <i>Praeorbulina sicana</i>	x	x	x	x	x	x	x	x	x																	
3. <i>Praeorbulina glomerosa curva</i>	x	x	x	x	x	x	x	x	x	x	x	x														
4. <i>Praeorbulina transitoria</i>	x	x	x	x	x	x		x	x		x	x														
5. <i>Globigerina praebuloides</i>	x	x	x	x	x	x	x	x	x	x	x	x	x	x												
6. <i>Globigerina druryi</i>	x				x					x	x		x													
7. <i>Globigerinoides trilobus</i>	x	x	x	x	x	x	x	x	x	x	x	x	x	x												
8. <i>Globigerinoides subquadratus</i>	x		x		x	x	x	x	x	x	x															
9. <i>Globorotalia praescitula</i>	x			x	x	x		x		x			x	x												
10. <i>Globoquadrina dehiscens</i>	x	x	x		x	x	x		x	x	x	x	x	x												
11. <i>Globoquadrina langhiana</i>	x		x	x	x	x	x		x		x			x												
12. <i>Globoquadrina baroemouensis</i>	x	x	x	x	x	x	x	x	x	x	x	x	x	x												
13. <i>Globigerinita glutinata</i>	x	x	x	x	x	x		x	x	x	x		x													
14. <i>Globigerinella obesa</i>	x	x		x	x		x			x	x	x														
15. <i>Turborotalita cf. quinqueloba</i>				x							x															
16. <i>Praeorbulina glomerosa glomerosa</i>								x	x	x	x	x	x	x												
17. <i>Paragloborotalia mayeri</i>									x		x	x	x													
18. <i>Globoquadrina altispira</i>										x																
19. <i>Globigerinella praesiphonifera</i>										x				x												
20. <i>Paragloborotalia siakensis</i>											x		x	x												
21. <i>Paragloborotalia continuosa</i>											x		x													
22. <i>Globigerinita uvula</i>											x															
23. <i>Globorotalia peripheroronda</i>													x													
24. <i>Globorotalia archeomenardii</i>														x												
25. <i>Globigerina woodi</i>																										
26. <i>Orbulina suturalis</i>																										
27. <i>Orbulina universa</i>																										
ZONE	<i>Praeorbulina</i>														<i>O. suturalis</i> - <i>G. peripheroronda</i>											
SUBZONE	<i>Praeorbulina glomerosa curva</i>														<i>Orbulina suturalis</i>											
STAGE	Langhian														Langhian											

Tab. 9 - Occurrence of planktonic foraminifera in the samples of the Pozzallo section.

Zwann & Gudjonson (1986). Two subsections have been measured and sampled (Text-figs. 17 and 18). The first (segment a-b) spans the lower part of the «marne a globigerine» immediately above the «argille scagliose variegate». The second (segment c-d) ranges from the base of the «calanco» up to a level some tens of metres above the path across the outcrop.

Partial section a-b approximately corresponds to the interval of Romeo's (1969) Cenozona B and to the Giammoia 1 section of Theodoridis (1984). Partial section c-d matches Theodoridis' Giammoia 2 section and partially overlaps the lowermost part of the section studied by Colalongo *et al.* (1980).

In the lower part of the stratigraphic succession being considered (segment c-d), immediately above sampling level MGB6, a thin volcanic ash layer occurs. This layer, already described by Romeo (1969;

see Carveni *et al.*, 1982 for more details), yielded fresh crystals of biotite suitable for K-Ar radiometric dating (Odin *et al.*, 1995).

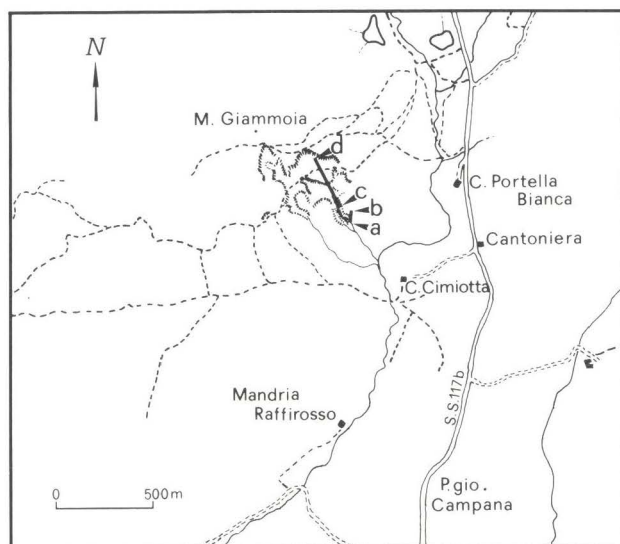
Biostratigraphy. The collected samples yielded rich, highly diversified, and very well-preserved planktonic foraminiferal assemblages. However, foraminiferal tests are often recrystallized and present calcite overgrowth inside the chambers.

The species occurrences in the section are reported in Tab. 10a-10b. The most meaningful data are summarized below.

- In the basal part of the a-b interval the foraminiferal assemblages are characterised by *P. glomerosa sicana*, *P. siakensis*, *P. mayeri*, *G. bisphericus*.

- *P. glomerosa curva* first occurs in sample MGA4.

- In the c-d interval, the lowermost samples



Text-fig. 17 - Location of the M. Giammoia section (From the IGM Carta d'Italia, scale 1:25.000, sheet 272 I SE Passo di Piazza).

yielded *O. universa*, *G. peripheroronda*, *G. praemenardii* among the other species. This association indicates the *G. praemenardii* - *G. peripheroronda* Subzone.

- *G. peripheroronda* ranges up to sample MGB5.

- *P. partimlabiata* was first recorded in sample MG6 with the last specimens of *G. praemenardii*. As a consequence the *G. altispira* Zone spans a very short interval between MGB5 level and the unconformity immediately above level MGB7.

- *G. decoraperta* first occurs in sample MG14.

- The last occurrence of *G. subquadratus* is in sample MG18.

- *G. nepenthes* first occurrence is in sample MG19.

- The last occurrence of *P. mayeri* is in sample MG27.

- The following sample contains *N. acostaensis*, *G. menardii* and specimens referred to as *Pulleniatina* cf. *primalis*. It results that the *N. acostaensis* Zone rests on the *G. nepenthes* - *G. mayeri* Zone.

- *Globigerinoides obliquus extremus* first occurs in sample MG68.

Summarising, the following points deserve special attention:

1) There is a gap between interval a-b and interval c-d.

2) Two main lacunae are detectable in the stratigraphic succession represented by section c-d. The lowest one is marked in the outcrop by an unconformity, bracketed by levels MGB7 and MG6 (see Text-fig. 18). It cancels most of the *G. altispira*

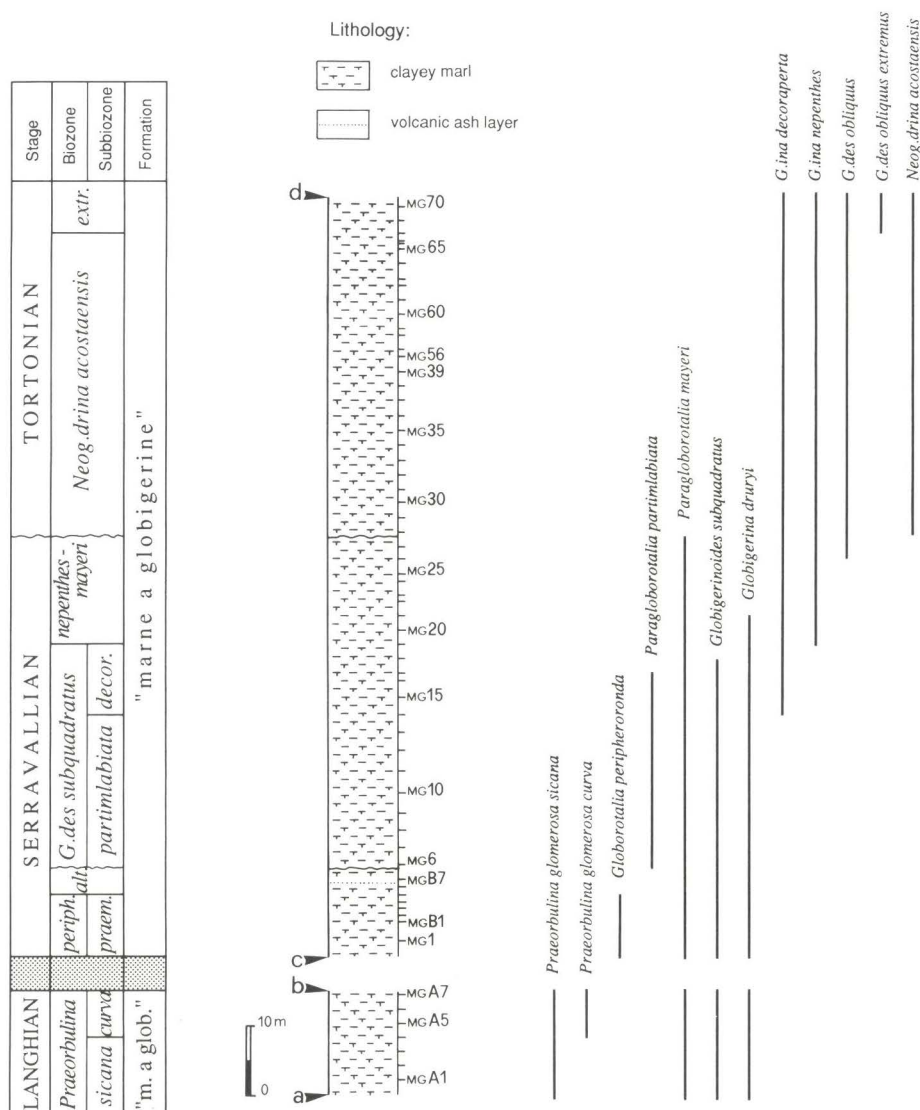
Zone and the lower part of the *P. partimlabiata* Subzone. The highest hiatus has been recognized between levels MG27 and MG28. The missing interval spans from the *G. nepenthes* - *P. mayeri* Zone to the *N. acostaensis* Zone.

This stratigraphic interpretation is markedly discordant with those of Zachariasse & Spaak (1983), Theodoridis (1984) and Van der Zwann & Gudjonson (1986). In their opinion the M. Giammoia succession would be continuous from the lower Serravallian to the Messinian. As a matter of fact, Zachariasse & Spaak (1983, fig. 2) reported the first occurrence of *P. partimlabiata* immediately above the disappearance of *G. peripheroronda*, in good agreement with the results of the present study. According to the most qualified literature (Ruggieri & Sprovieri, 1970; Giannelli & Salvatorini, 1972 and 1975; Salvatorini & Cita, 1979; Iaccarino & Salvatorini, 1982; Iaccarino, 1985; etc.) there is a significant time lag between the disappearance of *G. peripheroronda* and the first appearance of *P. partimlabiata*. This conclusion is supported by the results of the present research. As the two events are closely associated in the M. Giammoia section, we have to admit a hiatus in the succession.

M. Giammoia section (interval a-b)						
samples:	MGA1	MGA2	MGA3	MGA4	MGA5	MGA6
species:						
1. <i>Globigerinoides bisphericus</i>	x			x	x	
2. <i>Praeorbulina glomerosa sicana</i>	x	x	x	x	x	
3. <i>Praeorbulina transitoria</i>	x	x	x	x	x	
4. <i>Globoquadrina langhiana</i>	x	x	x	x		x
5. <i>Globorotalia praescitula</i>	x	x	x	x	x	x
6. <i>Globigerinoides subquadratus</i>	x	x		x	x	x
7. <i>Globigerina druryi</i>	x			x	x	
8. <i>Paragloborotalia siakensis</i>	x	x	x	x	x	x
9. <i>Paragloborotalia mayeri</i>	x	x		x	x	x
10. <i>Globoquadrina baroemouensis</i>	x	x	x	x	x	x
11. <i>Globigerina praebuloides</i>	x	x	x	x	x	x
12. <i>Globigerinoides trilobus</i>	x	x	x	x	x	x
13. <i>Globigerinella obesa</i>	x	x		x	x	
14. <i>Paragloborotalia continuosa</i>	x	x	x	x	x	x
15. <i>Globoquadrina dehiscens</i>	x	x				x
16. <i>Globoquadrina altispira</i>	x					
17. <i>Globigerinita glutinata</i>	x	x		x		
18. <i>Praeorbulina glomerosa curva</i>				x	x	x
ZONE	Praeorbulina					
SUBZONE	sicana		curva			
STAGE	Langhian					

Tab. 10a - Occurrence of planktonic foraminifera in the samples of the M. Giammoia section (interval a-b).

M. GIAMMOIA section



Text-fig. 18 - Lithological log of the M. Giammoia section and ranges of selected planktonic foraminiferal species.

The second stratigraphic gap had already been recognized by Romeo (1969).

These considerations seriously undermine the stable isotope stratigraphy proposed by Van der Zwann & Gudjonson (1986, see also Chamley *et al.*, 1986) for the M. Giammoia section. The Dutch authors recognized a maximum $\delta^{18}\text{O}$ value near the last occurrence of *G. peripheroronda* and interpreted it as recording the well-known mid-Miocene cooling episode (Savin *et al.*, 1975; Shackleton & Kennett, 1975; Savin *et al.*, 1981; Miller *et al.*, 1987; Miller *et al.*, 1991; Woodruff & Savin, 1991; etc.). In my opinion, the sharp $\delta^{18}\text{O}$ increase that takes place in the M2-M3 oxygen isotope Zones of Miller *et al.* (1991) is not recorded in the M. Giammoia suc-

cession because the corresponding interval is locally missing. The $\delta^{18}\text{O}$ decrease that follows the Serravallian maximum in the Van der Zwann & Gudjonson's curve may tentatively be correlated with the lower part of oxygen isotope Zone M4 (Miller *et al.*, 1991). It is worth noting that Zone M4 correlates with Blow's zones N12-N13. According to Salvatorini & Cita (1979) *P. partimlabiata* appears in zone N12.

COMPARISON WITH OTHER MIOCENE PLANKTONIC FORAMINIFERAL ZONATION

The biostratigraphic scheme adopted in the present work easily correlates with previous ones

[illegible]

Tab. 10b - Occurrence of planktonic foraminifera in the samples of the M. Giammoia section (interval c-d).

Tab. 10b - Occurrence of planktonic foraminifera in the samples of the M. Giammoia section (interval c-d).

proposed for the Mediterranean region (Iaccarino & Salvatorini, 1982; Iaccarino, 1985; Borsetti *et al.*, 1979; Bizon, 1979; etc.) from which it substantially derives (see Tab. 1). In particular, it is very similar to that of Iaccarino & Salvatorini (1982) re-proposed by Iaccarino (1985) without significant changes for the interval considered in the present research.

The planktonic foraminiferal zonation here employed differs from that of Iaccarino & Salvatorini in the points listed below.

1) The *P. glomerosa* s.l. Zone of Iaccarino & Salvatorini (herein renamed *Praeorbulina* Zone) is subdivided into three subzones instead of two; following a firmly established biostratigraphical tradition (Bolli, 1966; Bolli & Saunders, 1985; Stainforth *et al.*, 1975; Bizon, 1979; Borsetti *et al.*, 1979 among others) the first appearance of *P. glomerosa curva* is here recognized as a meaningful, easy correlatable, time-significant event and is used to mark the lower boundary of the homonym Subzone. Iaccarino & Salvatorini (op. cit.) maintain that *P. glomerosa curva* Blow is a junior synonym of *Globigerinoides sicana* De Stefani; I do not share this opinion (see Taxonomic Notes for more details).

2) The *Globorotalia siakensis* Zone of Iaccarino & Salvatorini, which ranges over an exceedingly long stratigraphic interval, has been split up into three distinct zones: these roughly correspond to the subzones of the cited authors.

3) The *Globigerinoides subquadratus* Zone, as considered in the present paper, ranges up to the biohorizon of the evolutionary appearance of *G. nepenthes* (from *G. druryi*) and differs from the homonym Subzone of Iaccarino & Salvatorini that spans up to the biohorizon of disappearance of *Globigerinoides subquadratus* [= *G. ruber sensu* Bolli & Saunders, 1985; nec *G. ruber* (d'Orbigny)]. According to my data the *G. subquadratus* last occurrence slightly follows the first appearance of *G. nepenthes*. I have chosen the second event to mark the biostratigraphic boundary because I believe that an evolutionary event can be taken as synchronous

over long distances more confidently than a taxon disappearance. Hence it must be preferred for correlation tasks.

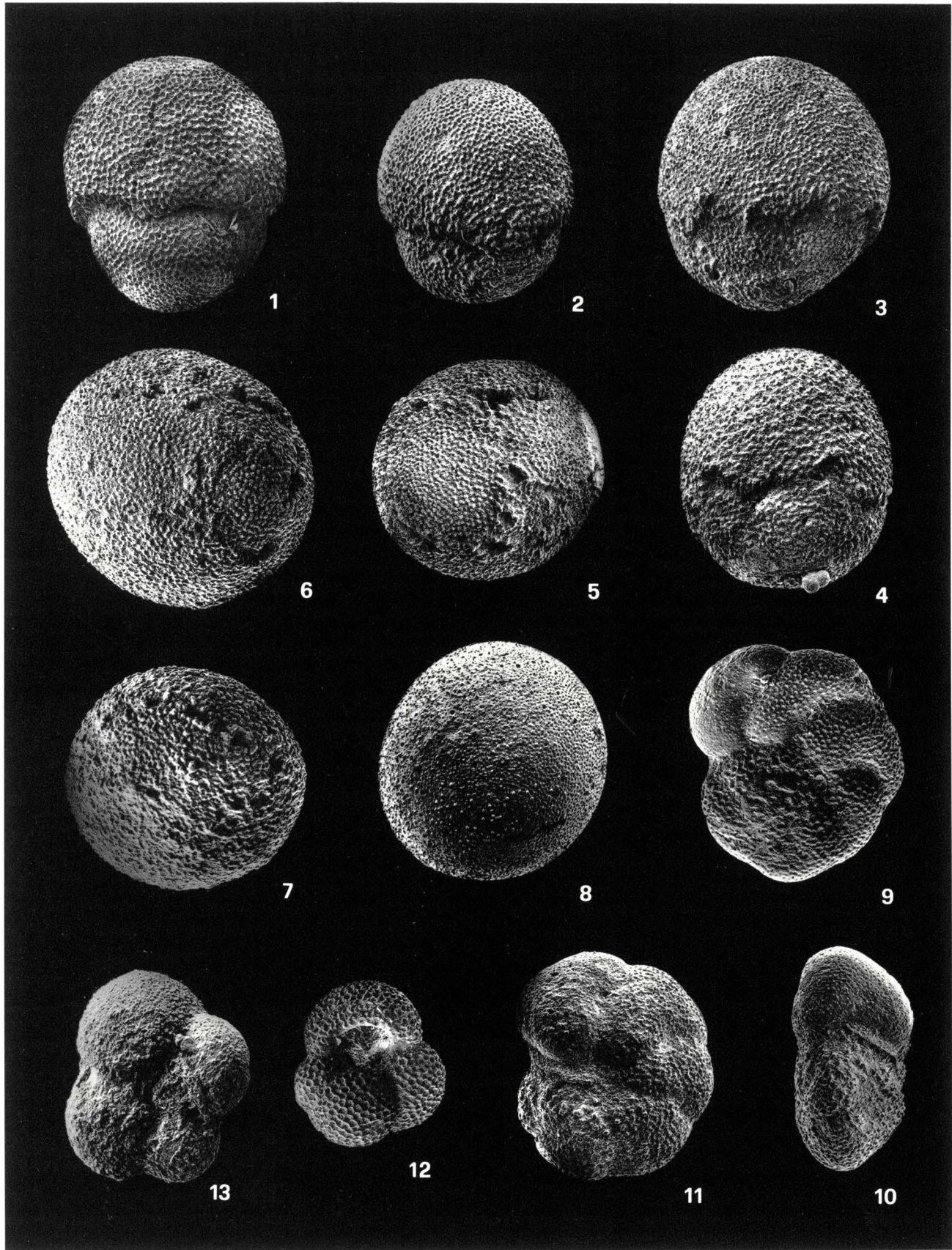
4) The *G. subquadratus* Zone is subdivided into two subzones bounded by the horizon of the first appearance of *G. decoraperta*.

5) The *Globorotalia menardii* Zone, as defined by Bolli (1966) and employed by Iaccarino & Salvatorini, has been renamed *Globigerinoides obliquus* Zone for two reasons: a) typical specimens of *G. menardii* do not seem to be present in this interval; they occur in upper levels; b) the stratigraphic record of the *G. menardii* is rather discontinuous in the Mediterranean; on the contrary, *G. obliquus* is always common throughout the zone. The *G. obliquus* Zone, as here understood, slightly differs from the *G. obliquus* Zone of Borsetti *et al.* (1979) whose lower boundary is marked by the first common occurrence of *G. obliquus* (not first occurrence as previously reported). As Martinotti (1990) pointed out, the massive increase of *G. obliquus* that stratigraphically occurs above the disappearance of *G. subquadratus* and below the last occurrence of *P. mayeri* is an important, easily detectable event in the Mediterranean area. The abrupt «explosion» of the species was clearly triggered and controlled by ecological factors, hence must be considered with caution for time-correlation. However, this event seems to be consistently synchronous in the entire Mediterranean and useful for local correlation.

Correlation of the present scheme with other reference foraminiferal zonations, like those of Blow (1969), Bolli (1966), Bolli & Saunders (1985), developed for tropical regions, presents several problems. In particular, correlation is easy and precise in the Langhian and lower Serravallian (*Praeorbulina* and *O. suturalis* - *G. peripheroronda* Zones of the present work; zones N8 and N9 of Blow's zonal scheme). It turns difficult in the middle Serravallian (*G. altispira* and *G. subquadratus* Zones; Blow's zones N10 to N13). In the upper Serravallian

EXPLANATION OF PLATE 1

- Figs. 1-2 - *Praeorbulina glomerosa sicana* (De Stefani). Side view of two different specimens, M. Giammoia, sample MGA1, X90.
 Figs. 3-5 - *Praeorbulina glomerosa curva* (Blow). Pozzallo, sample PZ41. 3) Side view, X90. 4) Side view, X90. 5) Spiral view, X90.
 Fig. 6 - *Praeorbulina glomerosa glomerosa* (Blow). Pozzallo, sample PZ41, spiral view, X90.
 Fig. 7 - *Praeorbulina glomerosa circularis* (Blow). S. Maroto, sample SMAR38, spiral view, X90.
 Fig. 8 - *Orbulina universa* d'Orbigny. M. Giammoia, sample MG34, X90.
 Figs. 9-11 - *Globorotalia peripheroronda* Blow & Banner. M. Giammoia, sample MGB1. 9) Spiral view, X120. 10) Side view, X120. 11) Umbilical view, X120.
 Fig. 12 - *Globigerina decoraperta* Takayanagi & Saito. M. Giammoia, sample MG34, umbilical view, X120.
 Fig. 13 - *Globigerina praebulloides* Blow. Topotype of «*Globigerina bollii*» Cita & Gelati. Cessole, sample CS45, umbilical view, X90.
 (SEM-photos by P. Ferrieri)



- lower Tortonian the first evolutionary appearances of *G. nepenthes* and *N. acostaensis* mark biohorizons which are easily recognizable both in the Mediterranean and in the tropical-subtropical regions. They can be assumed synchronous throughout.

This situation reflects variations in the spatial distribution of the planktonic bioprovinces caused by global climatic changes (Cifelli, 1976; Sancetta, 1978; Haq, 1980; Thunell & Belyea, 1982; Kennett *et al.*, 1985; Wright & Thunell, 1988; etc.). As a consequence of the contraction of the tropical-subtropical biogeographic province due to the steepening of latitudinal temperature gradients, important planktonic foraminiferal lineages (e.g. the *G. peripheroronda* - *Globorotalia fohsi* lineage) disappeared from the middle latitudes during the Serravallian (Bolli, 1964; Cita, 1976; Martinotti, 1981; etc.). The Mediterranean last occurrence of *G. peripheroronda* approximately marks the inception of a climatic cooling trend (Savin *et al.*, 1975; Shackleton & Kennett, 1975; Demarcq, 1984; Suc, 1986; Miller *et al.*, 1987; etc.) and progressive isolation of the Mediterranean basin from the world ocean (According to Steininger & Rögl, 1984, marine connections between the present-day Mediterranean area and the Indo-Pacific Ocean ceased to exist in the early Serravallian.). Since that time, a high proportion of the species employed for the low latitude zonal schemes are restricted to tropical water masses.

Correlation of the last Mediterranean occurrence of *G. peripheroronda* with that of low latitudes is rather doubtful. I agree with Martinotti (1981) in considering that *G. peripheroronda* disappears in the Mediterranean before its complete extinction in the oceans and immediately before the first appearance of *G. peripheroacuta* (that marks the N9/N10 boundary in Blow's (1969) zonal scheme).

As for the upper Serravallian biostratigraphy, the position of the last appearance horizon of *P. mayeri* is still open to question. Whether the species disappears before, in coincidence with or after the

first appearance of *N. acostaensis* is a matter of debate. In passing, I note that the range of morphologic variation of *P. mayeri* and its relationship with closely related taxa, such as *P. siakensis*, are also debated (for example, see Bolli & Saunders, 1982; Iaccarino, 1985; etc.). My opinion is that a stratigraphic interval without *P. mayeri* does exist in the Mediterranean successions below the first appearance of *N. acostaensis*. In this interval *P. mayeri* is absent throughout or, at least, exceedingly rare. Therefore, the last occurrence of the species (maybe the last common occurrence) before the appearance of *N. acostaensis* marks a useful biohorizon, suitable for correlation in the Mediterranean area. However, it seems hazardous to draw the biohorizon as world-wide synchronous; in other words, the oceanic and Mediterranean records are not precisely the same and both have to be independently evaluated.

In conclusion, I note that the planktonic foraminiferal zonal scheme employed in the present study proved useful in correlating different significant stratigraphic successions. The achieved resolution is very good in the interval between the FAD (First Appearance Datum) of *P. glomerosa sicana* and the FAD of *O. universa*. Some more work is needed in the lower-middle Serravallian (*G. altispira* Zone), a time span unfavourable to the development of widespread time-significant correlation biohorizon. In this time interval, an event deserves special attention as potentially useful for correlation: the first appearance of the species here referred to as *Globorotalia* cf. *menardii* (see Taxonomic notes). This promising event has to be tested in suitable stratigraphic successions before complete validation.

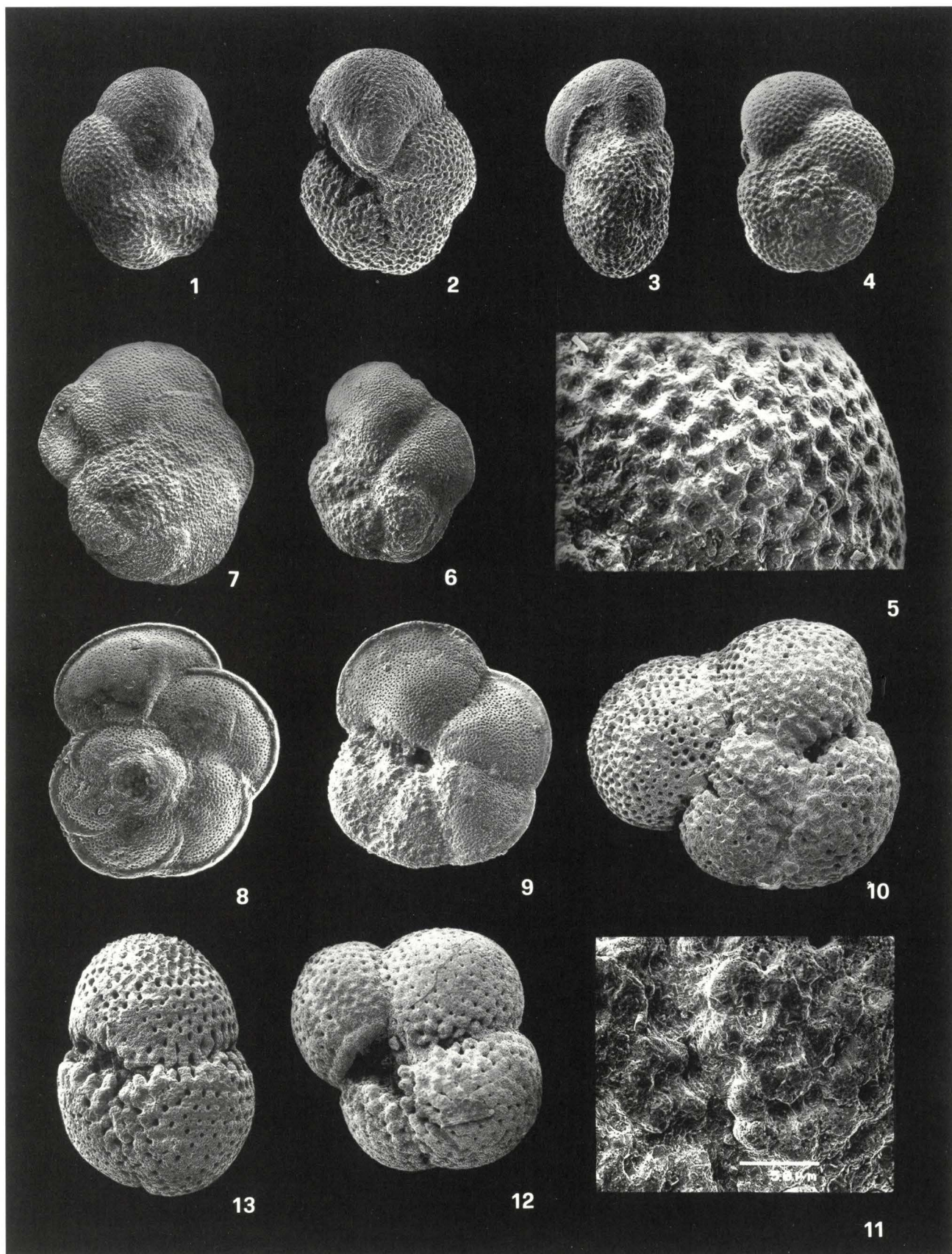
CONCLUSIONS

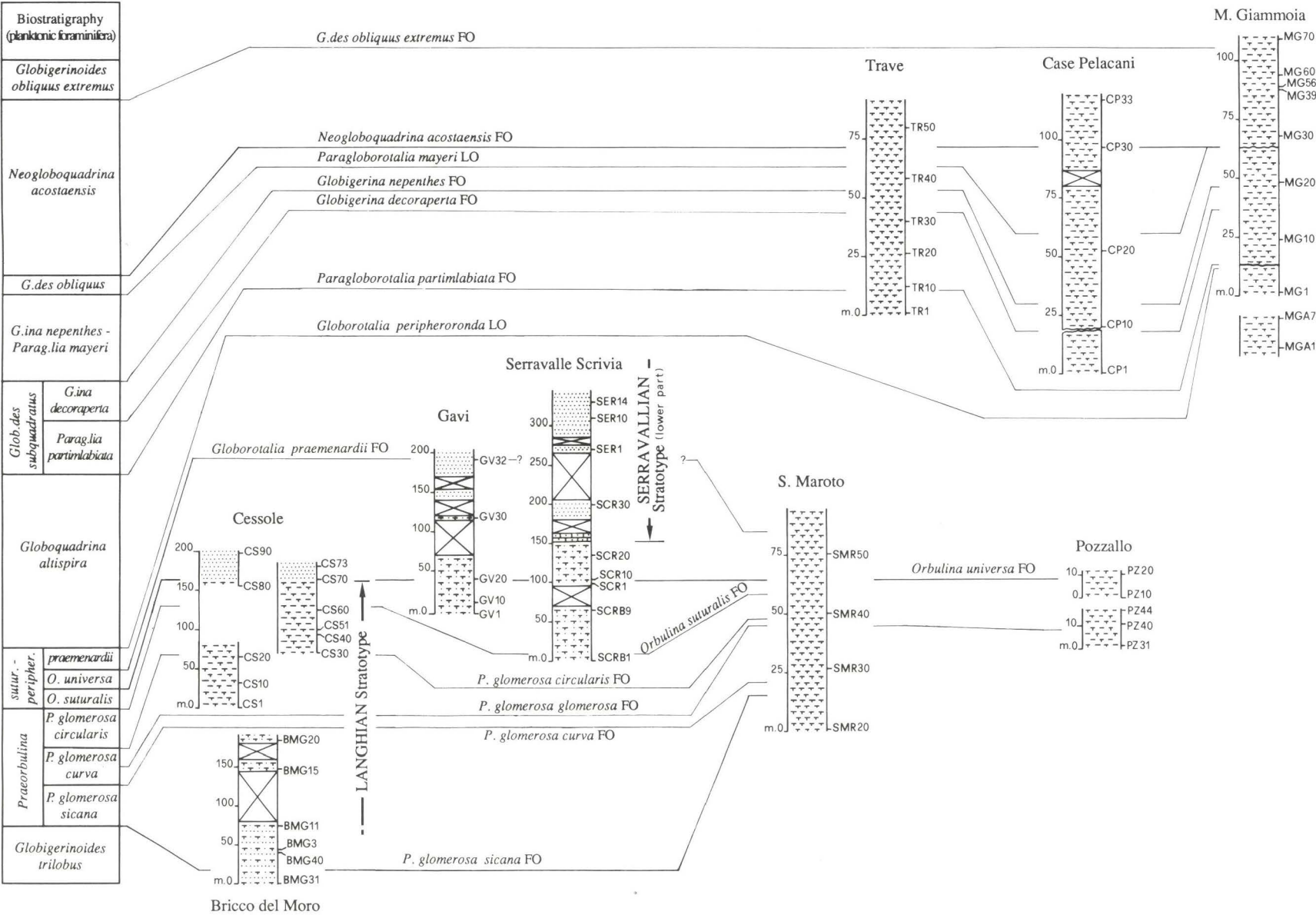
The planktonic foraminiferal biostratigraphy of the historical Langhian and Serravallian stratotypes has been revised. The stratotypes have been com-

EXPLANATION OF PLATE 2

- Figs. 1-5 - *Paragloborotalia partimlabiata* (Ruggieri & Sprovieri). M. Giammoia, sample MG10. 1) Umbilical view, X120. 2) Umbilical view, X120. 3) Oblique view, X120. 4) Spiral view, X120. 5) Detail of the specimen of fig. 4, penultimate chamber, X600.
 Figs. 6-7 - *Globorotalia praemenardii* Cushman & Stainforth. M. Giammoia, sample MGB1. 6) Umbilical view, X60. 7) Spiral view, X60.
 Figs. 8-9 - *Globorotalia* cf. *menardii* (Parker, Jones & Brady). Case Pelacani, sample CP27. 8) spiral view, X90. 9) Umbilical view, X90.
 Figs. 10-13 - *Sphaeroidinellopsis disjuncta* (Finlay). Case Pelacani, sample CP33. 10) Spiral view, X90. 11) Detail of the specimen of fig. 10, X3300. 12) Umbilical view, X90. 13) Umbilical view, X90.

(SEM-photos by P. Ferrieri)





Text-fig. 19 - Biostratigraphic correlation of the studied sections.

pared with five middle Miocene marine successions from different Italian areas.

The main results of the biostratigraphical study of the stratotypes are as follows:

– In the Bricco del Moro section (lower part of the historical Langhian stratotype - Cita & Premoli Silva, 1960a) the lower limit of the Cessole Formation («marne a pteropodi» Auctt.) is around sixty metres above the first occurrence of *Praeorbulina glomerosa sicana*. This lithostratigraphic boundary (Cortemilia/Cessole boundary) was assumed as the lower limit of the Langhian stratotype. Taking into account the high sedimentation rate of the Cortemilia Fm. (mainly turbidite sandstones) it seems that the first occurrence horizon of *P. glomerosa sicana* approximates the base of the historical Langhian stratotype rather well. No other planktonic foraminiferal event useful for correlation has been recognized in the Bricco del Moro section.

– In the Cessole section, the upper limit of the Cessole Formation (upper boundary of the historical Langhian stratotype) is close to the first occurrence horizon of *Orbulina universa*.

– In the Serravalle section the lower limit of the Serravalle Sandstone (lower boundary of the Serravallian stratotype proposed by Vervloet, 1966) is around 45 metres above the first occurrence horizon of *O. universa*. The immediate phyletic predecessor of *O. universa* (*O. suturalis*) is common in the beds below the first occurrence of the species.

The evolutionary appearance of *O. universa* seems to be the most reliable planktonic foraminiferal event for correlating the lower boundary of the Serravallian stratotype, as historically fixed.

TAXONOMIC NOTES

Globigerina bollii Cita & Premoli Silva, 1960 (Pl. 1, fig. 13)

1960 *Globigerina bollii* CITA & PREMOLI SILVA, pp. 119-126, Tav. 1.

Cita & Premoli Silva (1960b) described *Globigerina bollii* on the basis of material from the Langhian stratotype (Bricco della Croce section). Studying the Cessole section, I found numerous specimens referable to this taxon. They are characterized by the shape, dimensions and ornamentation of the last chamber. This is always smaller than the penultimate one and is more finely pitted than the remaining part of the test. In my opinion, the mentioned characters are not species specific and the small last chamber of *G. bollii* is anomalous (kummerform *sensu* Berger, 1969), probably developed during gametogenesis (see Hemleben *et al.*, 1989). *G.*

bollii is disregarded as a valid species and is considered as a junior synonym of *Globigerina praebulloides* Blow. It is worth noting that typical individuals of Blow's species always co-occur with the *G. bollii* morphotypes.

Globigerinoides trilobus Reuss, 1850

Globigerinoides quadrilobatus Auctt. (nec *Globigerina quadrilobata* d'Orbigny)

Globigerinoides sacculifer (Brady, 1877)

The specimens commonly referred to these taxa are all regarded here as phenotypic variations of a single species (Hemleben *et al.*, 1987), which is named *G. trilobus*. Reuss' name has priority over that of Brady.

I share the opinion that the lectotype of *Globigerina quadrilobata* d'Orbigny, 1846 selected by Banner & Blow (1960) does not represent the species erected by d'Orbigny, which is a true *Globigerina* (Todd, 1961; Bandy, 1964; etc.), and it is not valid.

Praeorbulina glomerosa (Blow) *sicana* (De Stefani, 1952) (Pl. 1, figs. 1-2)

Praeorbulina glomerosa (Blow) *curva* (Blow, 1956) (Pl. 1, figs. 3-5)

According to Iaccarino & Salvatorini (1982) *P. glomerosa curva* (Blow) is a junior synonym of *Globigerinoides sicana* De Stefani. As a matter of fact the holotypes of the taxa are clearly diverse (see Jenkins *et al.*, 1981); *P. glomerosa sicana* and *P. glomerosa curva* are two morphologically distinct and successive stages of the *Praeorbulina* lineage which are of great biostratigraphic utility. In my opinion, they have not to be lumped together.

Globorotalia cf. *menardii* (Pl. 2, figs. 8-9)

The specimens here referred to as *G. cf. menardii* have intermediate morphology between *Globorotalia praemenardii* Cushman & Stainforth and *Globorotalia menardii* (Parker, Jones & Brady). They differ from the individuals of the first species in possessing limbate intercameral sutures on the spiral side. They are distinguished from *G. menardii* specimens in the test morphology; in spiral view, the chambers are more elongated and less rounded than in typical specimens of *G. menardii*.

Globorotalia ex gr. *cultrata sensu* Cita *et al.*, (1978) is referred to the present form.

Globorotalia cf. *menardii* is potentially a useful biostratigraphic index for the middle-upper Serravallian. Its stratigraphic range has to be carefully checked. It seems that it appeared in the lower Serravallian (Blow's zone N11 according to Cita *et al.*, 1978).

Orbulina bilobata (d'Orbigny)

Following Stainforth *et al.*, (1975) and Hemleben *et al.* (1989) I include the bilobate form within *Orbulina universa*.

ACKNOWLEDGEMENTS

I would like to thank: profs. M. L. Colalongo and S. Sartoni (Bologna University) for their advice and support during the course of this work (and for their patience); prof. R. Barbieri (Bologna University) for critically reading the typescript; prof. G. Ruggieri (Palermo University) for information on the Pozzallo section; prof. I. Premoli Silva (Milano University) for providing unpublished data about the Bricco del Moro section; drs. F. Pontoni (Iesi) and P. Sandroni (Ancona) for information on the Trave section; P. Ferrieri (Bologna University) for the SEM micrographs.

TAXONOMIC REFERENCES

- The planktonic foraminiferal species recognized in this work are listed below. The genera are arranged in systematic order, following Loeblich & Tappan (1988). The original publications are given for all the identified taxa. In square brackets are references to specimens here illustrated.
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- Globigerina parabulloides* Blow, 1959 - Blow, 1959, Bull. Amer. Pal., 39 (178), pp. 179-180, pl. 10, figs. 46a-c.
- Globigerina foliata* Bolli, 1957 - Bolli, 1957, U.S. Nat. Mus. Bull., 215, p. 111, pl. 24, figs. 1a-c.
- Globigerina falconensis* Blow, 1959 - Blow, 1959, Bull. Amer. Pal., 39 (178), p. 177, pl. 9, figs. 40-41.
- Globigerina woodi* Jenkins, 1960 - Jenkins, 1960, Micropaleontology, 6 (4), p. 352, pl. 2, fig. 2a-c.
- Globigerina apertura* Cushman, 1918 - Cushman, 1918, U.S. Geol. Surv. Bull., 676, p. 57, pl. 12, figs. 8a-c.
- Globigerina druryi* Akers, 1955 - Akers, 1955, J. Paleont., 29 (4), p. 654, pl. 65, fig. 1a-c.
- Globigerina nepenthes* Todd, 1957 - Todd, 1957, U.S. Geol. Surv. Prof. Paper, n. 280-H, p. 301, pl. 78, figs. 7a-b.
- Globigerina decoraperta* Takayanagi & Saito, 1962 - Takayanagi & Saito, 1962, Sci. Rep. Tohoku Univ., ser. 2 (geol.), Spec. Vol. 5, p. 85, pl. 28, figs. 10a-c (*Globigerina druryi decoraperta*). [Pl. 1, fig. 12].
- Globigerinella obesa* (Bolli, 1957), U.S. Nat. Mus. Bull., 215, p. 119, pl. 29, figs. 2-3 (*Globorotalia*).
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- Globigerinoides bulloideus* Crescenti, 1966 - Crescenti, 1966, Geol. Rom., 5, p. 43, text-fig. 8 (3-3a) and 9.
- Globigerinoides trilobus* (Reuss, 1850) - Reuss, 1850, K. Akad. Wiss. Wien, 1, p. 374, pl. 47, figs. 11a-d (*Globigerina triloba*).
- Globigerinoides bisphericus* Todd, 1954 - Todd, 1954, in Todd, Cloud, Low & Schmidt, Amer. Journ. Science, 252 (11), pp. 681-682, pl. 1, fig. 1a-c.
- Globigerinoides bollii* Blow, 1959 - Blow, 1959, Bull. Amer. Pal., 39 (178), pp. 189-191, pl. 10, figs. 65a-c.
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- Praeorbulina glomerosa* (Blow) *curva* (Blow, 1956) - Blow, 1956, Micropaleontology, 2 (1), pp. 64-65, pl. 1, figs. 9-14 (*Globigerinoides*). [Pl. 1, figs. 3-5]
- Praeorbulina glomerosa* (Blow) *circularis* (Blow, 1956) - Blow, 1956, Micropaleontology, 2 (1), p. 65, pl. 2, figs. 3-4 (*Globigerinoides*). [Pl. 1, fig. 7]
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(manuscript received August 2, 1993
accepted July 15, 1994)

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