Bollettino della Società Paleontologica Italiana - Vol. 14, n. 2, 1975, pp. 177-196, pls. 1-5, 4 text-figs.

Planktonic foraminifera of the Upper Miocene from some Italian sections and the problem of the lower boundary of the Messinian

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(manuscript received January 7, 1976)

ABSTRACT — The results of a biostratigraphical study of Upper Miocene sediments in order to identify the lower boundary of the Messinian on the basis of planktonic foraminifera are reported. A number of sections from different Italian regions has been sampled and studied. This study of planktonic foraminifera has allowed a sufficiently detailed zonation for the interval under discussion which predates the onset of the « salinity crisis ».

The recognized biostratigraphic units are as follows, from bottom to top:

1 - Globorotalia acostaensis acostaensis *Zone*

1a - Globorotalia continuosa *Subzone*
1b - Globigerinoides obliquus extremus *Subzone*
1c - Globorotalia suterae *Subzone*

2 - Globorotalia conomiozea *Zone*

2a - Globorotalia mediterranea *Subzone*
2b - Globigerina multiloba *Subzone*

A remarkable faunistic change is recorded in all the sections studied at the boundary between the G. acostaensis acostaensis *Zone and the* G. conomiozea *Zone. It is, in fact, at this level that the appearance of various species of Globorotalias such as* G. conomiozea, G. mediterranea, G. saheliana, G. saphoae, *and forms very close to* G. miozea sphericomiozea *occurs.*

This event, at least in the Mediterranean basin, allows the recognition of the zonal boundary even in the absence of the marker. G. conomiozea *is a taxon, biostratigraphically well defined, with a widespread geographical distribution. Its first appearance seems to be the best element in order to recognize the closest levels to the Tortonian-Messinian boundary.*

In this way, the Authors take into consideration the possibility, according to the recommendations of the International Subcommission on Stratigraphic Classification of I.U.G.S., to emend the Tortonian and Messinian stages and to place the boundary between these coincident with the lithological level in which the first appearance of G. conomiozea *occurs.*

RIASSUNTO — (I FORAMINIFERI PLANCTONICI DEL MIOCENE SUPERIORE DI ALCUNE SEZIONI ITALIANE E IL PROBLEMA DEL LIMITE INFERIORE DEL MESSINIANO) — *In questo lavoro vengono riportati i risultati di uno studio biostratigrafico condotto su sedimenti del Miocene superiore allo scopo di identificare il limite inferiore del Messiniano sulla base dei foraminiferi planctonici.*

Al fine di impostare il problema su dati provenienti da un'area quanto più vasta possibile sono state campionate e studiate numerose sezioni ubicate in diverse regioni italiane; esse sono da nord a sud le seguenti: 1) sezione del Mussotto (Piemonte); 2) sezione di Rio Mazzapiedi-Castellania (Piemonte), sezione-tipo del Tortoniano; 3) sezione di S. Agata Fossili (Piemonte); 4) sezione di Pietralacroce (Marche); 5) sezione di Cropalati (Calabria); 6) sezione di Capodarso (Sicilia), sezione-tipo della parte inferiore del Messiniano; 7) sezione di Falconara (Sicilia).

Lo studio dei foraminiferi planctonici ha permesso di riconoscere per questo intervallo stratigrafico una zonazione sufficientemente dettagliata. Le unità biostratigrafiche distinte sono le seguenti a partire dal basso:

1 - Zona a Globorotalia acostaensis acostaensis

1a - Sottozona a Globorotalia continuosa
1b - Sottozona a Globigerinoides obliquus extremus
1c - Sottozona a Globorotalia suterae

2 - Zona a Globorotalia conomiozea

2a - Sottozona a Globorotalia mediterranea
2b - Sottozona a Globigerina multiloba

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Le suddette unità biostratigrafiche sono brevemente descritte nel loro contenuto in foraminiferi planctonici. In particolare viene messo in evidenza un notevole cambiamento faunistico, comune a tutte le sezioni studiate, in coincidenza del limite fra la Zona a Globorotalia acostaensis acostaensis *e la zona a* G. conomiozea. *E' a questo livello infatti, che si verificano le comparse, oltre a quella di* G. conomiozea, *di varie altre specie di Globorotalie quali* G. mediterranea, G. saheliana, G. saphoae *e forme molto vicine a* G. miozea sphericomiozea. *Questo evento, almeno nel bacino del Mediterraneo, rende possibile il riconoscimento del limite inferiore della zona a* G. conomiozea *anche in assenza del marker.*

G. conomiozea *è un taxon biostratigraficamente ben definito con un'ampia distribuzione geografica. La sua comparsa sembra l'elemento più valido per riconoscere i livelli più prossimi al limite Tortoniano-Messiniano.*

Gli Autori, pertanto, prendono in considerazione la possibilità, in accordo con le raccomandazioni della « International Subcommission on Stratigraphic Classification » dell'I.U.G.S. e previa discussione e approvazione da parte di una Commissione Geologica Internazionale, di emendare i piani Tortoniano e Messiniano e di porre il limite tra questi in corrispondenza del livello litologico nel quale si osserva la comparsa di G. conomiozea.

INTRODUCTION

The present research has been undertaken in connection with the Italian program on Geodynamics with special reference to the geodynamic significance of the terminal Miocene salinity crisis in the Mediterranean. The Authors were entrusted to study biostratigraphically the problem of the lower boundary of the Messinian in order to identify and correlate this boundary on the basis of planktonic foraminifera.

Such a necessity was due, amongst other things, to the fact that the definition of the Messinian made by Selli (1960) is mainly based on paleoenvironmental considerations. As a consequence the stage and in particular its base cannot be recognized in areas outside the Mediterranean.

In order to investigate the problem on a regional basis, several sections were sampled. These are from different Italian regions, from Piedmont to Sicily (Fig. 1). They include the Capodarso section where the lower part of the Messinian neostratotype has been defined (Selli, 1960) and the Rio Mazzapiedi-Castellania section, the stratotype of the Tortonian (Gianotti, 1953). Besides these sections, which will be discussed in more detail later, data deduced from the examination of samples from other localities have been taken into consideration, in particular from the S. Gaudenzio (Marche), Monte Giammoia (Sicily) and Monte S. Nicola (Sicily) sections, known after papers of Borsetti et alii (1975), Romeo (1969 a) and Catalano & Sprovieri (1971) respectively.

LOCATION AND LITHOSTRATIGRAPHIC OUTLINE OF THE SECTIONS
(Figs. 1-2)

The lithology of the sections investigated is very schematically represented in Fig. 2. As these sections have already been described in previous papers, only a brief description is given here. From N to S, the sections are as follows:

MUSSOTTO SECTION (PIEDMONT) — A composite section has been sampled in an area that extends in E-W direction along the edge of the hills which form the northern border of the the Tanaro plain between Mussotto and Biglini near Alba. The three main parts of the section in stratigraphic succession are located near the quarry in front of the Mussotto furnace, immediately to the west of the village of Scaparone, and along the southern side of the hill of q. 317 respectively. In this section (for a detailed lithological description see Sturani, 1973, 1975; Sturani & Sampò, 1973) thirty-six samples were collected below the gypsum, at more or less regular intervals. Altogether a thickness of about 190 meters was sampled, represented by a thin basal part (MU 1 - MU 3) of homogeneous clayey pelites alternating with laminated varved pelites followed (MU 4 - MU 34) by a close rythmic alternation of fine graded sands, bioturbated silty pelites and laminated clayey-silty pelites (Unit 1 of Sturani, 1973), followed again (MU 35 and MU 36) by silty clays and thinly laminated silts with some intercalations of calcareous beds (Unit 2 of Sturani, 1973).

RIO MAZZAPIEDI - CASTELLANIA SECTION (PIEDMONT) — The sampling was carried out along the river bed in correspondance with the Tortonian type-section described by Gianotti (1953), starting from the alternations of sandstones and sands (Unit 2 of Gino, 1953). Unfortunately, the present conditions of exposure do not allow either detailed observations or accurate sampling, especially in the terminal part of the section. Altogether twenty-five samples were collected at irregular intervals: fairly close in the alternation of sandstones and sands (RM 1 - RM 16) and in the lower part of the overlying clayey marls (RM 7 - RM 16), where almost continuous outcrops exist; less frequent and more irregularly spaced in the upper part of the section up to the evaporites, where the outcrops become sporadic and limited in extension.

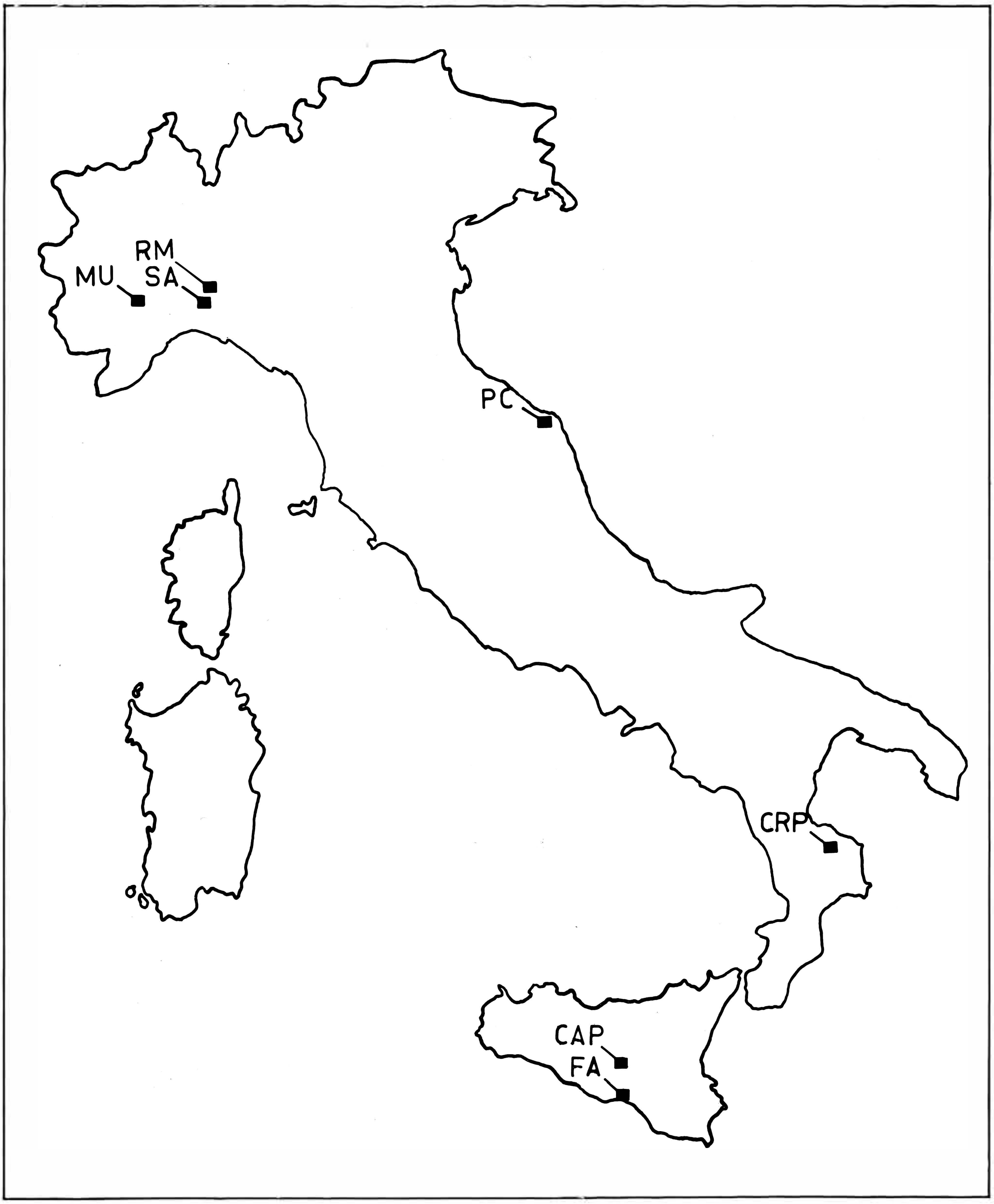


Fig. 1 - Position of the studied stratigraphic sections:

MU - Mussotto section (Piedmont); RM - Rio Mazzapiedi-Castellania section (Piedmont) (type-section of the Tortonian); SA - S. Agata Fossili section (Piedmont); PC - Pietralacroce section (Marche); CRP - Cropalati section (Calabria); CAP - Capodarso section (Sicily) (type-section of the Lower Messinian); FA - Falconara section (Sicily).

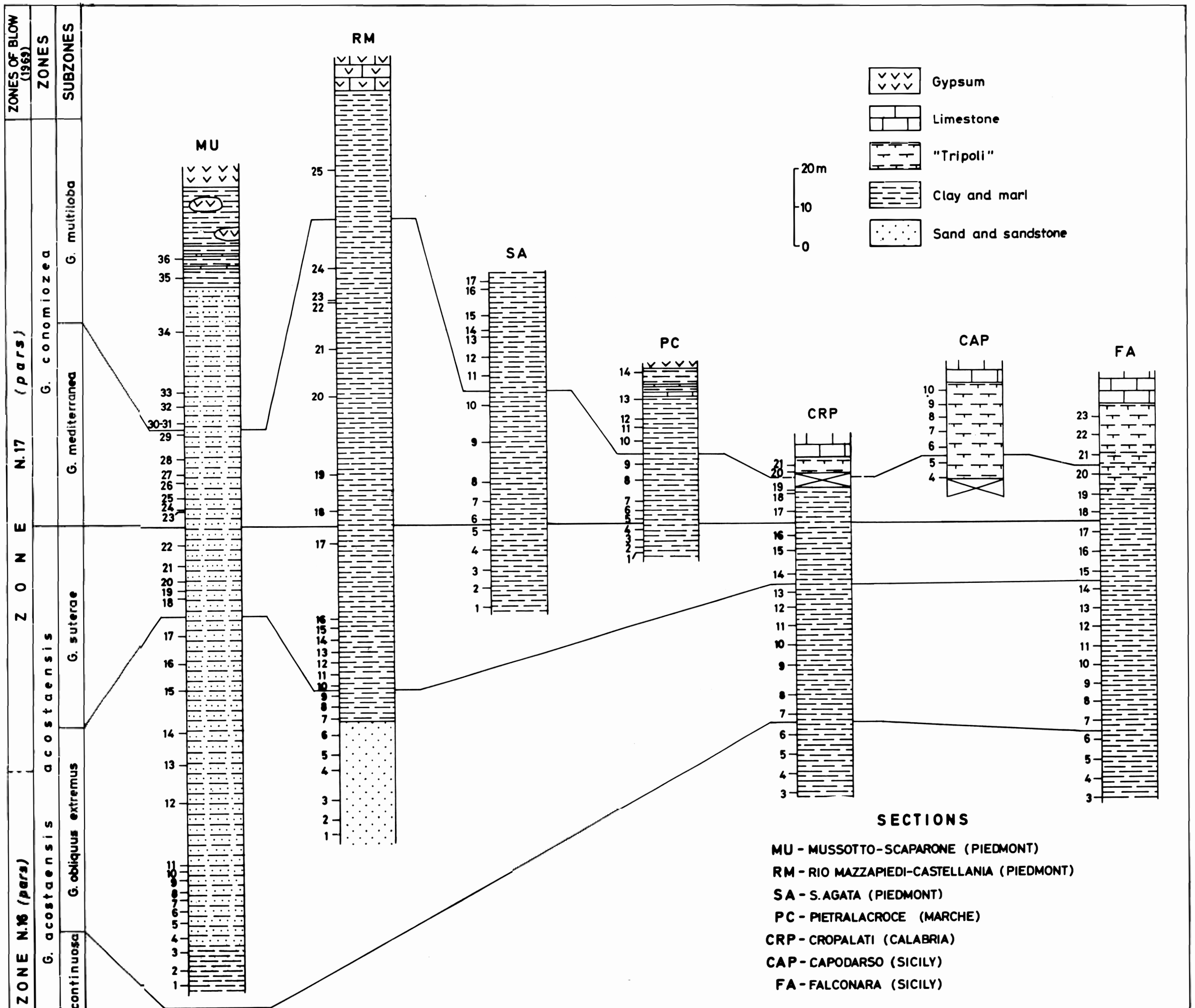

ZONES OF BLOW (1969)
ZONES
SUBZONES
ZONE N.16 (pars)
ZONE N.17 (pars)
G. acostaensis
G. acostaensis
G. conomiozea
G. continuosa
G. obliquus extremus
G. suterae
G. mediterranea
G. multiloba
MU
RM
SA
PC
CRP
CAP
FA
20m
10
0
Gypsum
Limestone
"Tripoli"
Clay and marl
Sand and sandstone
SECTIONS
MU - MUSSOTTO-SCAPARONE (PIEDMONT)
RM - RIO MAZZAPIEDI-CASTELLANIA (PIEDMONT)
SA - S. AGATA (PIEDMONT)
PC - PIETRALACROCE (MARCHE)
CRP - CROPALATI (CALABRIA)
CAP - CAPODARSO (SICILY)
FA - FALCONARA (SICILY)

Fig. 2

Fig. 3 shows the approximate position of our samples and of those of Cita et alii (1965) in the critical interval. Both samplings are compared with the succession of Gino's units (1953), retaining his thicknesses as valid.

S. Agata Fossili Section (Piedmont) — The section is located less than 1 km from Rio Mazzapiedi near the Village of S. Agata and along a « calanco » which runs from the bottom of the valley almost as far as the road to Bavantore.

The sampling was carried out to integrate the incomplete one from the upper part of the Rio Mazzapiedi-Castellania section. An almost continuous outcrop does in fact exist along this « calanco » and the transition from blue marls to tobacco-coloured marls is clearly shown. Seventeen samples were collected at regular intervals from a thickness of approximately 90 meters. The interval between samples SA 1 and SA 11 is represented by grey-blue marls; slightly above sample SA 11 the marls tend to become darker and contain intercalations of tobacco-coloured marls. This latter lithotype becomes dominant from sample SA 16 on.

Pietralacroce Section (Marche) — The section is located near Ancona along the road that leads to Pietralacroce from Belvedere di Portonovo. This section has been described by Carloni & Ceretti (1967) in the Guide book to the Excursions of the IV Congress on Mediterranean Neogene Stratigraphy (p. 141, text-fig. 38).

The sampled interval, from which fifteen samples were collected, has a thickness of approximately 45 meters and includes the terms from i) to b) of the above mentioned figure. The lithology can be summarized as follows: at the base, whitish calcareous marls (*Schlier*), then ash-grey to dark-grey marls or clays, more or less silty or sandy with intercalations of laminated grey marls, and, limited to the terminal part, of limestones.

Cropalati Section (Calabria) — The section is located in the area of Cropalati (Cosenza province) described by Ogniben (1962) and recently re-examined by Di Nocera et alii (1974). The sampling was carried out mainly on the excellent outcrops existing on the eastern side of the trail which crosses the saddle between Cropalati and Cozzo Marcello (see fig. 1 of Ogniben, 1962). Nineteen samples (from CRP 3 to CRP 21) were collected from a thickness of 85 meters at more or less regular intervals. Samples CRP 3 - CRP 19 come from the « argilloso-marnosa » Formation (Ogniben, 1962) while the samples CRP 20 and CRP 21 have been collected in the « Tripoli » Formation whose contact with the underlying formation is masked by a detrital covering of limited vertical extension. The « Calcare di base » Formation starts approximately 2 meters above the sample CRP 21.

Capodarso Section (Sicily) — The lower part of the Messinian neostratotype (Selli, 1960) has been designated in this section. Unfortunately, the present outcrop conditions are very different from those indicated by Selli (1960) because of an extensive landslide (see also Catalano & Sprovieri, 1971 and Cita et alii, 1973).

In the part still uncovered to the east of the landslide, seven samples were collected (CAP 4 - CAP 10) at stratigraphic intervals of about 3 meters (the whole sampled thickness is about 23 meters). The lowest sample (CAP 4) comes from grey marls which outcrop for a very limited thickness, while the others were collected in the overlying « Tripoli ». Sample CAP 10 comes from about 2 meters below the « Calcare di base ». The samples collected west of the landslide in the silty clays immediately overlying the « argille brecciate » were not taken into consideration since it is impossible to specify exactly the thickness which separates them from CAP 4 because of both the detrital covering and the remarkable differences in the dipping of the layers (Catalano & Sprovieri, 1971; Cita et alii, 1973).

Falconara Section (Sicily) — The section is located near a « calanco » on the southern side of M. Cantigaglione, about 3.5 km to the NW of Castello di Falconara on the southern coast of Sicily, and coincides exactly with that studied by Catalano & Sprovieri (1971).

The section, including 21 samples (FA 3 - FA 23) collected at intervals of about 5 meters, starts in grey clays with intercalations of thin sandy levels, approximately 15 meters above the contact with the underlying allochthonous sediments. Towards the top (from FA 19) the clays turn into alternations of diatomites and diatomitic marls. The uppermost sample is located about 3 meters below the « Calcare di base ». The thickness of the sampled interval is about 100 meters.

BIOSTRATIGRAPHY

The study of the planktonic foraminiferal assemblages from the described sections allowed us to recognize a succession of biostratigraphic events on the basis of which it has been possible to define a sufficiently detailed zonation for the studied interval.

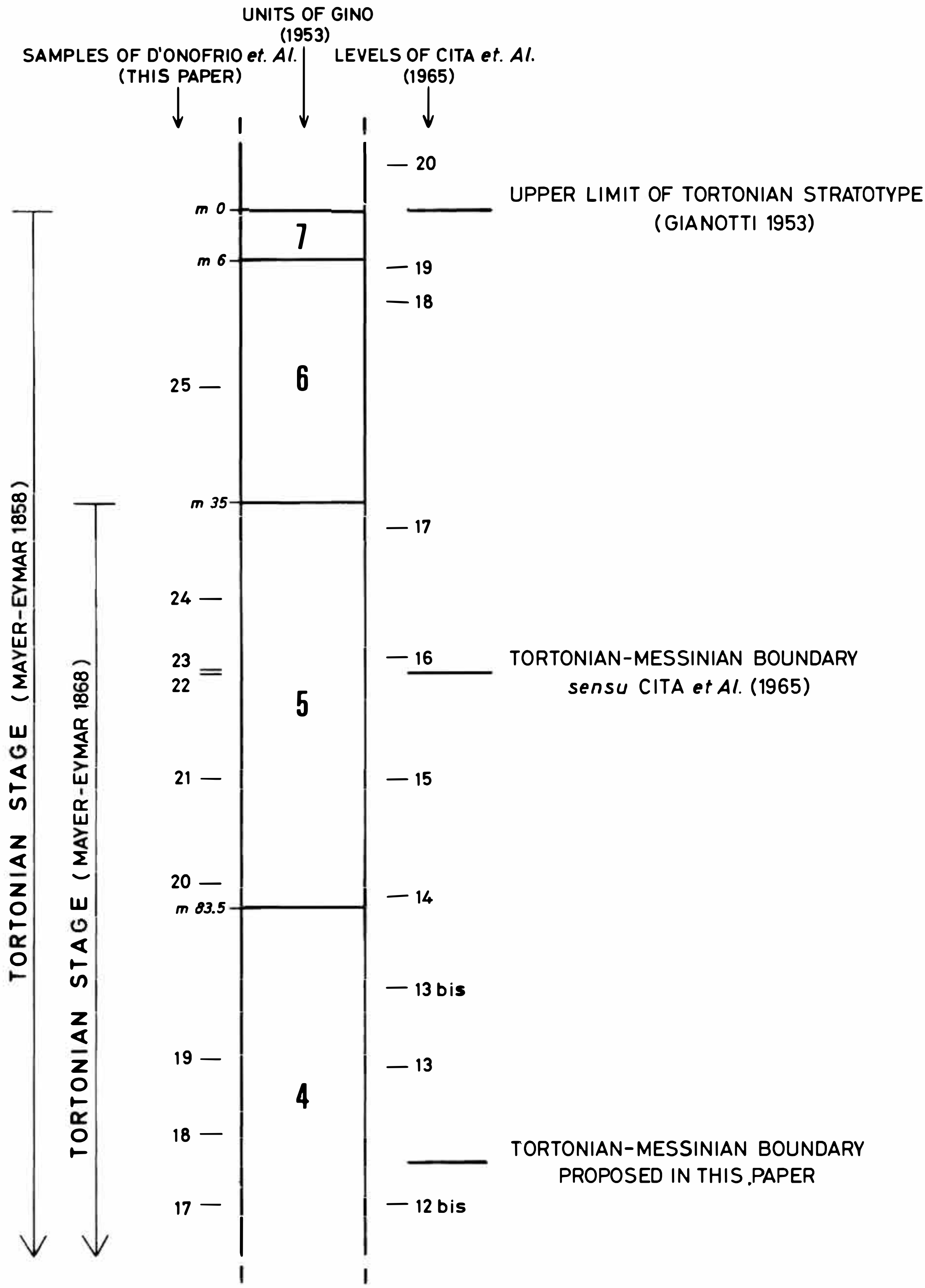

UNITS OF GINO
(1953)
SAMPLES OF D'ONOFRIO et. Al.
(THIS PAPER)
LEVELS OF CITA et. Al.
(1965)
20
UPPER LIMIT OF TORTONIAN STRATOTYPE
(GIANOTTI 1953)
m 0
7
m 6
19
18
25
6
m 35
17
24
23
22
16
TORTONIAN-MESSINIAN BOUNDARY
sensu CITA et Al. (1965)
5
21
15
20
m 83.5
14
13 bis
19
13
4
18
TORTONIAN-MESSINIAN BOUNDARY
PROPOSED IN THIS PAPER
17
12 bis
TORTONIAN STAGE (MAYER-EYMAR 1858)
TORTONIAN STAGE (MAYER-EYMAR 1868)

Fig. 3

	ZONES	SUBZONES	DATUM PLANES
MESSINIAN	*Globorotalia conomiozea*	*Globigerina multiloba*	
			G. multiloba
		Globorotalia mediterranea	G. nicolae
			G conomiozea G. saheliana G. mediterranea G. saphoae
TORTONIAN	*Globorotalia acostaensis acostaensis*	*Globorotalia suterae*	G. exserta
			G. suterae
		Globigerinoides obliquus extremus	
			G. obliquus extremus
		Globorotalia continuosa	
			G. acostaensis acostaensis
	Orbulina s.l.		

Fig. 4

It was preferable to define a new zonation for the interval relative to the Upper Miocene instead of following the zonal scheme proposed by Cati et alii (1968) for the Mediterranean area, which, in the light of recent biostratigraphic studies, is considered mostly out-of-date.

The zonal scheme includes (see Fig. 4) two biostratigraphic units (*Globorotalia acostaensis acostaensis* and *Globorotalia conomiozea* Zones) which replace (pro parte) the *G. menardii* Zone of Cati et alii (1968).

The practical application of this zonal scheme to the studied sections is shown in Fig. 2. The biostratigraphic units are defined and described as follows from bottom to top:

1 - *Globorotalia acostaensis acostaensis* Zone

Its lower boundary is defined by the first appearance of the zonal marker and its upper boundary by the first appearance of *Globorotalia conomiozea*. Three subzones can be recognized as follows:

1a - *Globorotalia continuosa* Subzone. The lower boundary is defined by the first appearance of *G. acostaensis acostaensis* and the upper one by the first appearance of *Globigerinoides obliquus extremus*. The subzone is represented almost entirely only in the Falconara section; in fact in the lowest sample (FA 3), *G. acostaensis acostaensis* is associated with *G. continuosa* (from which it evolves). Numerous transitional specimens are observed.

Important biostratigraphic events recorded in the subzone include the disappearance of *Globorotalia lenguaensis* and the first appearance of *G. merotumida*. It is also necessary to point out the high frequency of *G. continuosa*, *Globorotaloides falconarae*, *Globigerina decoraperta*, *G. falconensis*, *G. praebulloides praebulloides*, *Globigerinoides obliquus obliquus*, *Orbulina* spp.. The following taxa are present sporadically: *Globorotalia miozea conoidea*, *Globoquadrina* gr. *altispira*, *G. dehiscens dehiscens*, *Sphaeroidinellopsis* spp., *Candeina nitida praenitida*, *Hastigerina siphonifera siphonifera*, *Globigerina nepenthes*, *G. woodi woodi* (frequent in some levels).

1b - *Globigerinoides obliquus extremus* Subzone. The lower boundary is defined by the first appearance of *Globigerinoides obliquus extremus* and the upper one by the first appearance of *Globorotalia suterae*. The disappearance of *Globorotalia continuosa* and *Globorotaloides falconarae* and the first appearance of *Globorotalia acostaensis humerosa* and *G.* cf. *tumida plesiotumida* within the subzone are to be noted.

The following taxa are generally frequent: *Globorotalia acostaensis acostaensis*, *G.* gr. *cultrata*, *G.* gr. *scitula*, *Globigerina bulloides bulloides*, *G. decora-*

PLATE 1
(SEM illustrations)

Fig. 1a, b, c - *Globorotalia lenguaensis* BOLLI (x 150).
a: umbilical view; b: lateral view; c: spiral view.
G. acostaensis acostaensis Zone; *G. continuosa* Subzone;
Falconara section, sample FA 3.

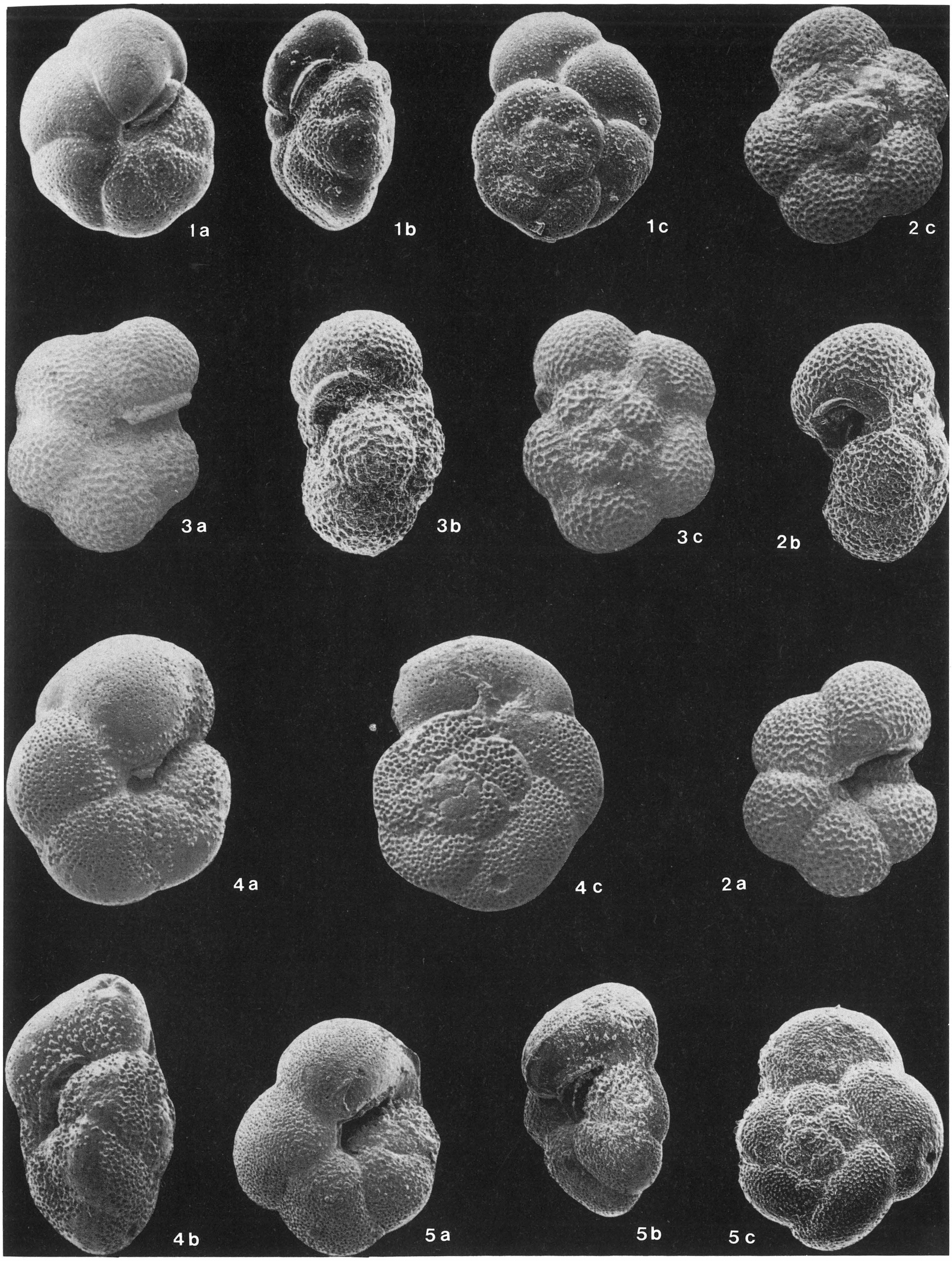
Fig. 2a, b, c - *Globorotalia acostaensis humerosa* TAKAYANAGI & SAITO (x 120).
a: umbilical view; b: lateral view; c: spiral view.
G. acostaensis acostaensis Zone; *G. obliquus extremus* Subzone;
Mussotto section, sample MU 12.

Fig. 3a, b, c - *Globorotalia acostaensis humerosa* TAKAYANAGI & SAITO (x 120).
a: umbilical view; b: lateral view; c: spiral view.
G. acostaensis acostaensis Zone; *G. obliquus extremus* Subzone;
Mussotto section, sample MU 13.

Fig. 4a, b, c - *Globorotalia suterae* CATALANO & SPROVIERI (x 140).
a: umbilical view; b: lateral view; c: spiral view.
G. acostaensis acostaensis Zone; *G. suterae* Subzone;
Falconara section, sample FA 15.

Fig. 5a, b, c - *Globorotalia suterae* CATALANO & SPROVIERI (x 105).
a: umbilical view; b: lateral view; c: spiral view.
G. acostaensis acostaensis Zone; *G. suterae* Subzone;
Falconara section, sample FA 16.

The foraminifera figured in the Plates 1-5 are deposited in the micropaleontological Laboratory of Geological Institute of Pisa University.


1 a
1 b
1 c
2 c
3 a
3 b
3 c
2 b
4 a
4 c
2 a
4 b
5 a
5 b
5 c

perta, *G. falconensis*, *G. praebulloides praebulloides*, *G. woodi woodi*, *Globigerinoides obliquus obliquus*, *G. obliquus extremus*, *G. bollii*, *G.* gr. *quadrilobatus*, *G. bulloideus*, *Orbulina* spp.; *Globorotalia miozea conoidea*, *Globigerina digitata praedigitata*, *Hastigerina siphonifera siphonifera*, *Sphaeroidinellopsis* spp., *Globoquadrina* gr. *altispira*, *Candeina nitida praenitida* are present sporadically.

1c - *Globorotalia suterae* Subzone. Its lower boundary is defined by the first appearance of *G. suterae* and the upper one by the first appearance of *G. conomiozea*. *Globorotalia exserta* first appears and *Globigerina woodi woodi* disappears in its lower part. The subzone is characterized by an exceptional frequency, in all the sections, of Globorotalias of the *G. suterae* - *G. exserta* group. The keeled Globorotalias of the *G. cultrata* group present, instead, a certain frequency only in the lower part and in general tend to decrease remarkably towards the top. The following species are more or less constantly frequent: *Globorotalia acostaensis acostaensis*, *G. acostaensis humerosa*, *Globigerina bulloides bulloides*, *G. decoraperta*, *Globigerinoides obliquus obliquus*, *G. obliquus extremus*, *G. bollii*, *G.* gr. *quadrilobatus*, *G. bulloideus*, *Orbulina* spp.; *Hastigerina pelagica*, *Globoquadrina* gr. *altispira*, *Sphaeroidinellopsis* spp., *Globigerina digitata praedigitata* are scattered, while *Globigerina nepenthes*, *G. falconensis*, *G. parabulloides*, *Hastigerina siphonifera siphonifera* are present more constantly.

2 - *Globorotalia conomiozea* Zone

The lower boundary is defined by the first appearance of the zonal marker. The upper boundary is not biostratigraphically definable due to the absence of foraminiferal assemblage from a certain level on. Two subzones have been defined as follows:

2a - *Globorotalia mediterranea* Subzone. The lower boundary is defined by the first appearance of the zonal marker and the upper one by the appearance of *Globigerina multiloba* (2).

This biostratigraphic interval is generally easily recognizable, even in the absence of *Globorotalia conomiozea* because it is characterized, usually from the base, by the occurrence of some species of Globorotalias which are absent in the underlying interval. Among these, *Globorotalia mediterranea*, *G. saheliana* and *G. saphoae* and forms very close to *G. miozea sphericomiozea* are particularly significant. *Globorotalia nicolae* appears in the middle-upper part of the subzone. In general the following species are frequent throughout the interval: *Globorotalia acostaensis acostaensis*, *G. acostaensis humerosa*, *Globigerina bul-*

(2) An accurate check, based on the direct examination of the holotype and of the paratypes of *Globigerina multiloba*, allowed us to ascertain that the taxon, if correctly interpreted, has a much more limited vertical distribution than that reported by various Authors (see for example: Blow (1969), Cita & Blow (1969); Catalano & Sprovieri (1971); Brönnimann & Resig (1971), Ryan et alii (1975).

PLATE 2

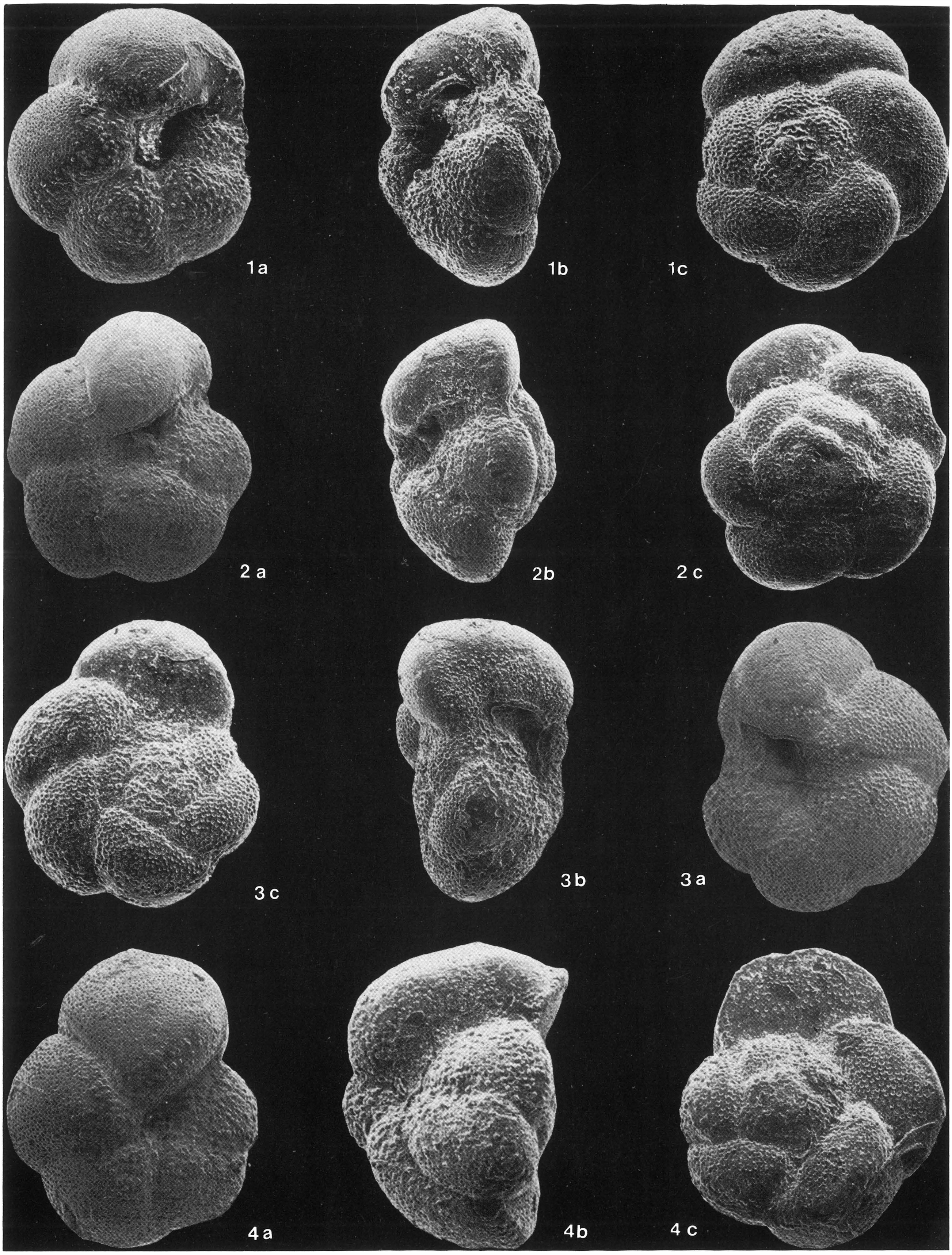
(SEM illustrations)

Fig. 1a, b, c - *Globorotalia suterae* CATALANO & SPROVIERI (x 120).
a: umbilical view; b: lateral view; c: spiral view.
G. acostaensis acostaensis Zone; *G. suterae* Subzone;
Falconara section, sample FA 16.

Fig. 2a, b, c - *Globorotalia exserta* ROMEO (x 110).
a: umbilical view; b: lateral view; c: spiral view.
G. acostaensis acostaensis Zone; *G. suterae* Subzone;
Falconara section, sample FA 16.

Fig. 3a, b, c - *Globorotalia exserta* ROMEO (x 110).
a: umbilical view; b: lateral view; c: spiral view.
G. acostaensis acostaensis Zone; *G. suterae* Subzone;
Falconara section, sample FA 16.

Fig. 4a, b, c - *Globorotalia saheliana* CATALANO & SPROVIERI (x 115).
a: umbilical view; b: lateral view; c: spiral view.
G. conomiozea Zone; *G. mediterranea* Subzone;
Falconara section, sample FA 18.


1a
1b
1c
2 a
2b
2 c
3 c
3 b
3 a
4 a
4b
4 c

loides bulloides, *G. decoraperta*, *Globigerinoides obliquus obliquus, G. obliquus extremus, G. bollii, Orbulina* spp.; instead rich populations of *Globorotalia suterae, G. exserta* and *G. miotumida miotumida* are present only in the lowermost part of the subzone. *Hastigerina pelagica, Globigerina digitata praedigitata. Globoquadrina* gr. *altispira, Sphaeroidinellopsis* spp., *Globigerinoides mitra* (the last exceptionally abundant in some levels of the Mussotto section) occur sporadically. In the upper part of this subzone there is a general and more or less gradual impoverishment in the benthonic foraminiferal assemblages; levels with planktonic fauna showing a more or less high degree of specialization (essentially *Orbulina*, *Globigerinoides* or *Globigerina* faunas) are not infrequent.

2b - *Globigerina multiloba* Subzone. The lower boundary is coincident with the appearance of *G. multiloba.* The upper boundary, as observed in the discussion of the zone, is not biostratigraphically definable. The subzone is characterized by an impoverished foraminiferal assemblage often with very specialized benthonic and planktonic microfaunas. Among the forms which may be so frequent as to display sometimes real oligotypical assemblages, *Globigerina quinqueloba, G. multiloba, G. bulloides bulloides, G. decoraperta*, *Globigerinoides* gr. *obliquus*, *Orbulina* spp., are to be noted. Throughout the interval *Globorotalia* gr. *scitula* is rare and, with few exceptions, the keeled forms are absent.

As a conclusion we must underline the fact, common to all the studied sections, that a considerable change in the planktonic foraminiferal assemblages occurred during the Tortonian. Such a faunistic renewal is particularly evident at the boundary between the *Globorotalia acostaensis acostaensis* Zone and the *G. conomiozea* Zone, where the almost simultaneous appearance of some keeled Globorotalias is recorded.

THE TORTONIAN-MESSINIAN BOUNDARY

The Messinian stage was erected by Mayer in 1867, and later precised by the same Author (Mayer, 1868). Neverthless, inexactitudes and uncertainties occur in Mayer's definitions so that Selli (1960), entrusted by the C.M.N.S. (Vienna, 1959), re-examined the problem. As a conclusion, the Author proposed a neostratotype which could be used as a reference for the Messinian stage.

It was therefore evident that in order to accomplish our assigned task it would be necessary to recognize, in the neostratotype section itself, paleontological elements suitable for a biostratigraphical definition of the lower boundary of the Messinian. However, as previously observed, the conditions of the Capodarso section are so different from the Selli's description (1960) as not to allow to collect a set of samples suitable to our purpose.

Owing to the objective impossibility to recognize the paleontological features of the lower boundary of the Messinian in its neostratotype section, we hold it convenient to face this problem through the paleontological characterization of the upper boundary of the Tortonian in its type-section, keeping in mind Mayer's concepts (1868) as well as Selli's definition, according to which the Messinian is « l'intervallo di tempo com-

PLATE 3

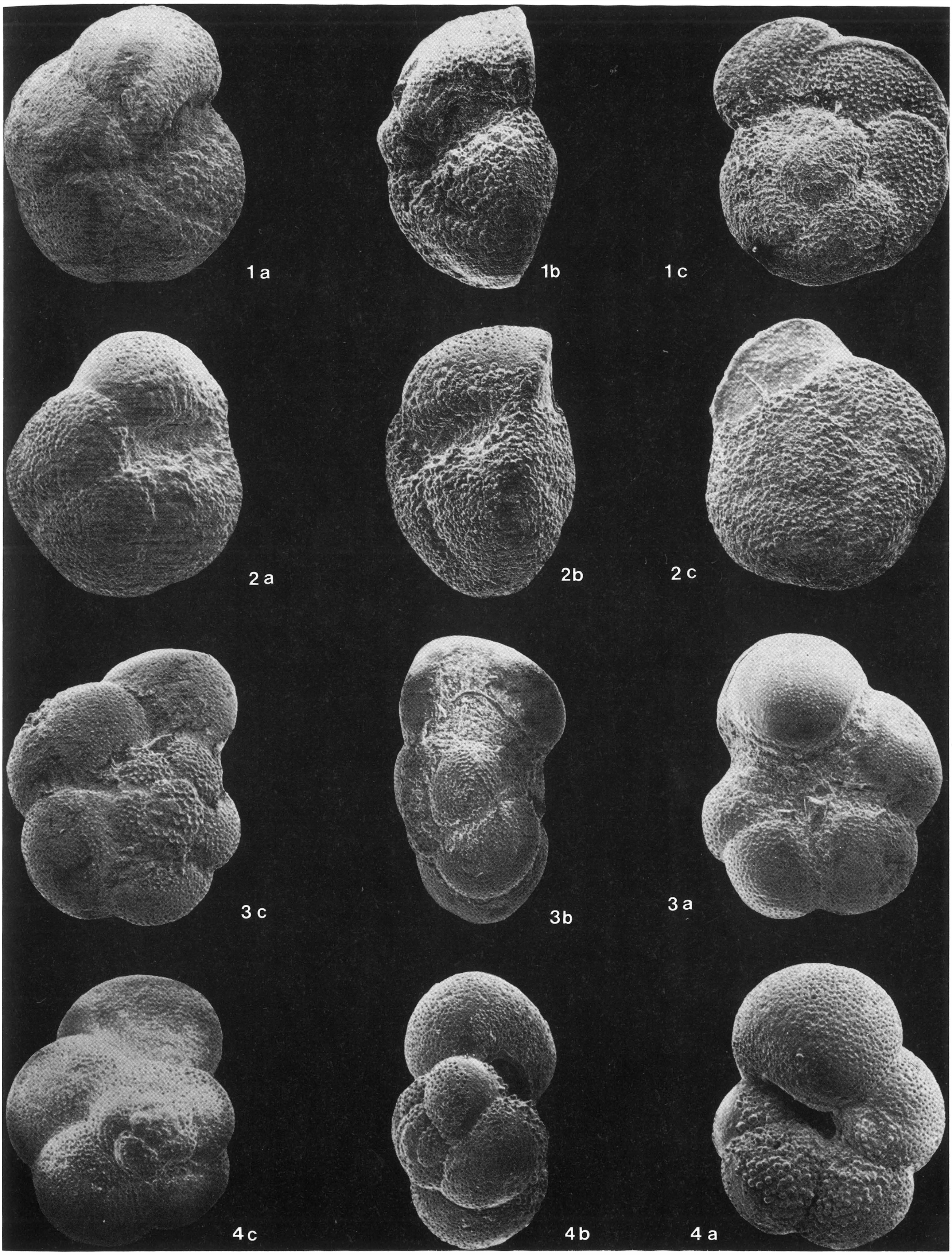
(SEM illustrations)

Fig. 1a, b, c - *Globorotalia saheliana* CATALANO & SPROVIERI (x 120).
a: umbilical view; b: lateral view; c: spiral view.
G. conomiozea Zone; *G. mediterranea* Subzone;
Falconara section, sample FA 18.

Fig. 2a, b, c - *Globorotalia saphoae* BIZON (x 120).
a: umbilical view; b: lateral view; c: spiral view.
G. conomiozea Zone; *G. mediterranea* Subzone;
S. Gaudenzio section, sample n. 106b.

Fig. 3a, b, c - *Globorotalia nicolae* CATALANO & SPROVIERI (x 125).
a: umbilical view; b: lateral view; c: spiral view.
G. conomiozea Zone; *G. mediterranea* Subzone;
S. Gaudenzio section, sample n. 116.

Fig. 4a, b, c - *Globorotalia nicolae* CATALANO & SPROVIERI (x 125).
a: umbilical view; b: lateral view; c: spiral view.
G. conomiozea Zone; *G. mediterranea* Subzone;
S. Nicola section, sample n. 1.


1 a
1b
1 c
2 a
2b
2 c
3 c
3b
3 a
4 c
4 b
4 a

preso fra il Tortoniano (strati di Tortona) e il Pliocene (strati di Tabiano) . . . » (1960, p. 28).

The Tortonian was defined by Mayer (1858) who intended to include in this stage all the marls underlying the evaporites. That is all the *Cerithium rubiginosum* marls outcropping in the area among Stazzano, S. Agata Fossili and Rio Bocca d'Asino. This definition was later modified when Mayer (1868) ascribed the « Marne a Cerizi » to the Messinian and placed the upper boundary of the Tortonian at the top of the *Pleurotoma* and *Ancillaria* upper layers (Stazzanin). The stratotype was proposed by Gianotti in the Rio Mazzapiedi - Castellania section and described by Gino only in 1953. Gianotti's proposal agrees with Mayer's first definition and includes tobacco-coloured « Marne a Cerizi » in the Tortonian.

This stratotype was later re-examined by Cita et alii (1965) who, following the description of the Messinian neostratotype which had meantime been made by Selli (1960), thought it advisable to keep to Mayer's definition (1868) of the Tortonian.

However, from the comparison between their stratigraphic column and the thicknesses given for the Units by Gino (1953) and Gianotti (1953) it comes that, placing the Tortonian- Messinian boundary at the level 16, a thickness of sediments underlying the tobacco-coloured « Marne a Cerizi » and belonging to Gino's Unit 5 is also included in the Messinian (Fig. 3).

In a later paper, Cita & Blow (1969, p. 583, Fig. 9), although maintaining the Tortonian-Messinian boundary in agreement with the same stratigraphic level (level 16), include the whole of Gino's (1953) Unit 5 in the Messinian. These different interpretations led the present writers to try a biostratigraphic « evaluation » of the proposed boundaries.

(a) - The upper boundary of the Tortonian as proposed by Mayer in 1858 and accepted by Gianotti (1953) cannot be adequately defined as it is well known that there are no suitable biostratigraphic criteria, because the levels which immediately underlie the evaporites are exceptionally poor, if not completely barren.

(b) - The boundary as placed by Cita et alii (1965), corresponds to a drastic faunal impoverishment. In our samples which correspond to the same stratigraphic level (RM 22 and RM 23) we also recorded the same impoverishment. However, this event is not considered as a valid element even in the Mediterranean basin in order to recognize and/or correlate this boundary, since it is too much controlled by local environmental factors. Such a biostratigraphically defined boundary cannot be identified in extra-mediterranean areas.

(c) - The upper boundary of the Tortonian, sensu Mayer 1868, could not be identified in the field, as the base of the tobacco-coloured « Marne a Cerizi » in the Rio Mazzapiedi - Castellania section could not be detected owing to the very bad exposure of this part of the type-section. For this reason the thickness as given by Gino (1953) for this lithological unit (Unit 6) was retained. Only sample RM 25 (see Fig. 2) comes from this unit while samples RM 22, RM 23 and RM 24, where remarkable faunistic impoverishment was recognized, are from the underlying litho-

PLATE 4

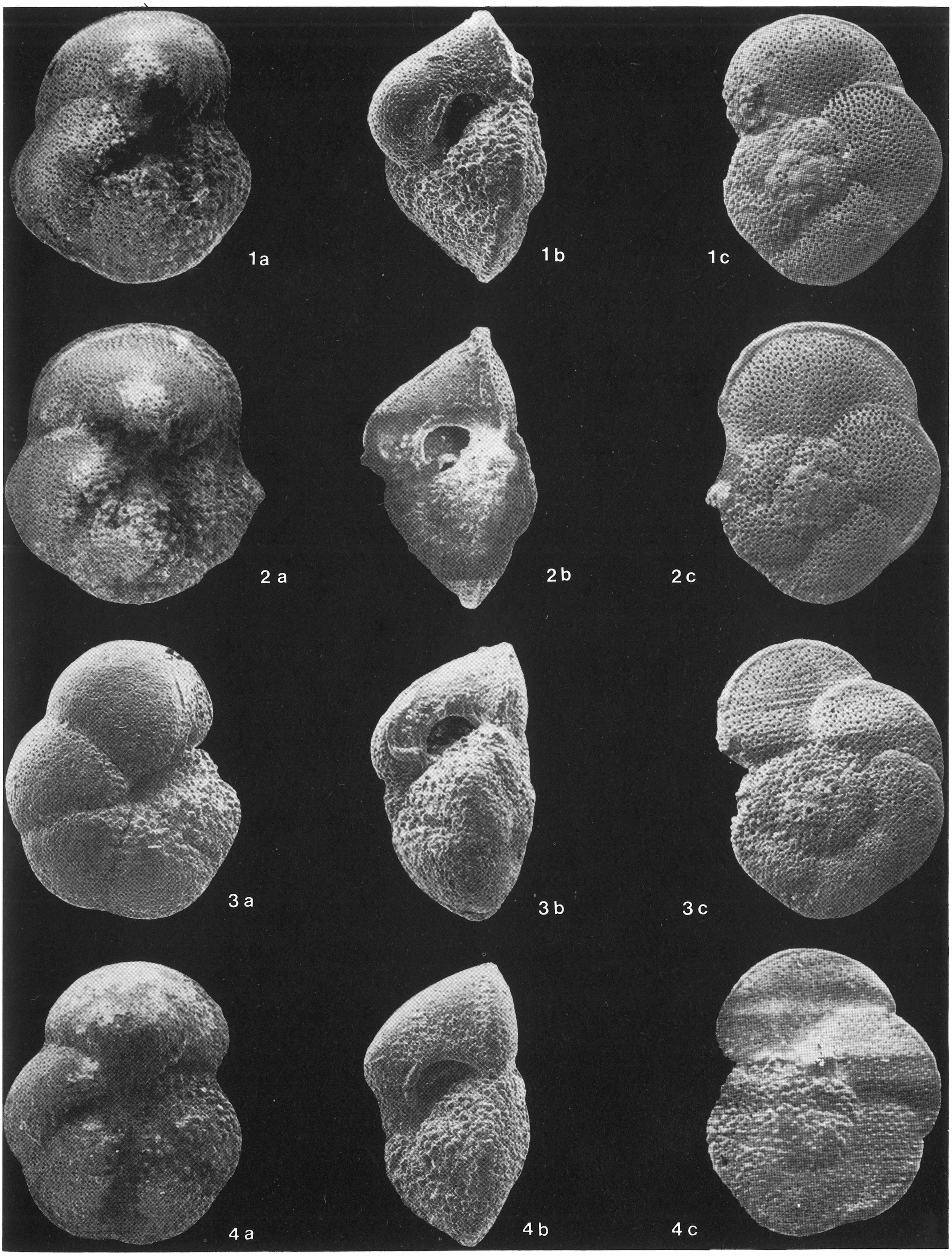
(SEM illustrations)

Fig. 1a, b, c - *Globorotalia conomiozea* KENNETT (x 135).
a: umbilical view; b: lateral view; c: spiral view.
G. conomiozea Zone; *G. mediterranea* Subzone;
Mussotto section, sample MU 26.

Fig. 2a, b, c - *Globorotalia conomiozea* KENNETT (x 135).
a: umbilical view; b: lateral view; c: spiral view.
G. conomiozea Zone; *G. mediterranea* Subzone;
Mussotto section, sample MU 26.

Fig. 3a, b, c - *Globorotalia mediterranea* CATALANO & SPROVIERI (x 105).
a: umbilical view; b: lateral view; c: spiral view.
G. conomiozea Zone; *G. mediterranea* Subzone;
S. Agata section, sample SA 6.

Fig. 4a, b, c - *Globorotalia mediterranea* CATALANO & SPROVIERI (x 105).
a: umbilical view; b: lateral view; c: spiral view.
G. conomiozea Zone; *G. mediterranea* Subzone;
S. Agata section, sample SA 6.


1a
1b
1c
2a
2b
2c
3a
3b
3c
4a
4b
4c

logical unit, still belonging to the Tortonian sensu Mayer 1868. The lower boundary of the tobacco-coloured marls is better exposed in the near S. Agata Fossili section where the first intercalations of this lithotype are observed a little above sample SA 11.

The only remarkable biostratigraphic event recorded very close to the lower boundary of the tobacco-coloured marls is the first occurrence of *Globigerina multiloba* (occurring from sample SA 11 in the S. Agata section and in sample RM 25 in the type-section), a taxon which is always present in the levels underlying the evaporites in the other sections investigated. This event is here considered too provincial as it was recorded only in the Mediterranean basin. As far as we know, this taxon if correctly understood, is not present in sediments outside the Mediterranean basin.

In conclusion, no particularly significant biostratigraphic event suitable for characterizing the Tortonian-Messinian boundary was recognized in correspondance to/or in proximity of any of the (a), (b), (c) boundaries.

It results from the above discussion that the first appearance of *G. conomiozea* is the most important biostratigraphic event which can be used to recognize the stage boundary under discussion. This event occurs at the apex of the previously mentioned faunistic change which, at least in the Mediterranean basin, makes it possible to recognize the lower boundary of *G. conomiozea* Zone even in the absence of the marker. *G. conomiozea* is an easily recognizable taxon, biostratigraphically well defined, with a widespread geographical distribution. Its first appearance seems to be the best element in order to recognize the closest levels to the Tortonian-Messinian boundary even in extra-Mediterranean areas.

Considering 1) that according to the recommendations of the International Subcommission on Stratigraphic Classification (Hedberg, 1971), stages boundaries must be selected in sequences of essentially continuous deposition, containing markers which are as favorable as possible for long-distance time-correlation; 2) that the appearance of *G. conomiozea* in the Tortonian stratotype occurs in a level only some tens of meters below its upper boundary, as proposed by Mayer (1968); 3) that this thickness, taking into account the high rate of sedimentation in these terrigenous deposits, corresponds to a very short time-interval, it is here proposed to take into consideration the possibility to emend the Tortonian and Messinian stages, and to place the boundary between these two stages coincident with the lithological level in which the first appearance of *G. conomiozea* occurs. In such a way we should have a coincidence between a stage boundary and a biostratigraphic event worldwide recognizable.

Moreover, the Tortonian-Messinian boundary would be so easily located in Blow's zonal scheme: it falls within the middle part of Zone N. 17, where the first appearance of *G. conomiozea* is documented (Blow, 1969; Berggren & Amdurer, 1973) (3).

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(3) There is some uncertainty in placing the N. 16/N. 17 boundary with respect to our zonal scheme. It is due to the fact that such a boundary is defined by the first appearance of *G. tumida plesiotumida*, a taxon characteristic of tropical assemblages, whose presence in the Mediterranean basin has not yet been documented carefully. However it is likely that this boundary falls within the *Globigerinoides obliquus extremus* Subzone, because in this interval the first appearance of *G. acostaensis humerosa* is recorded (according to Blow the first appearance of this taxon occurs just below the base of Zone N. 17).

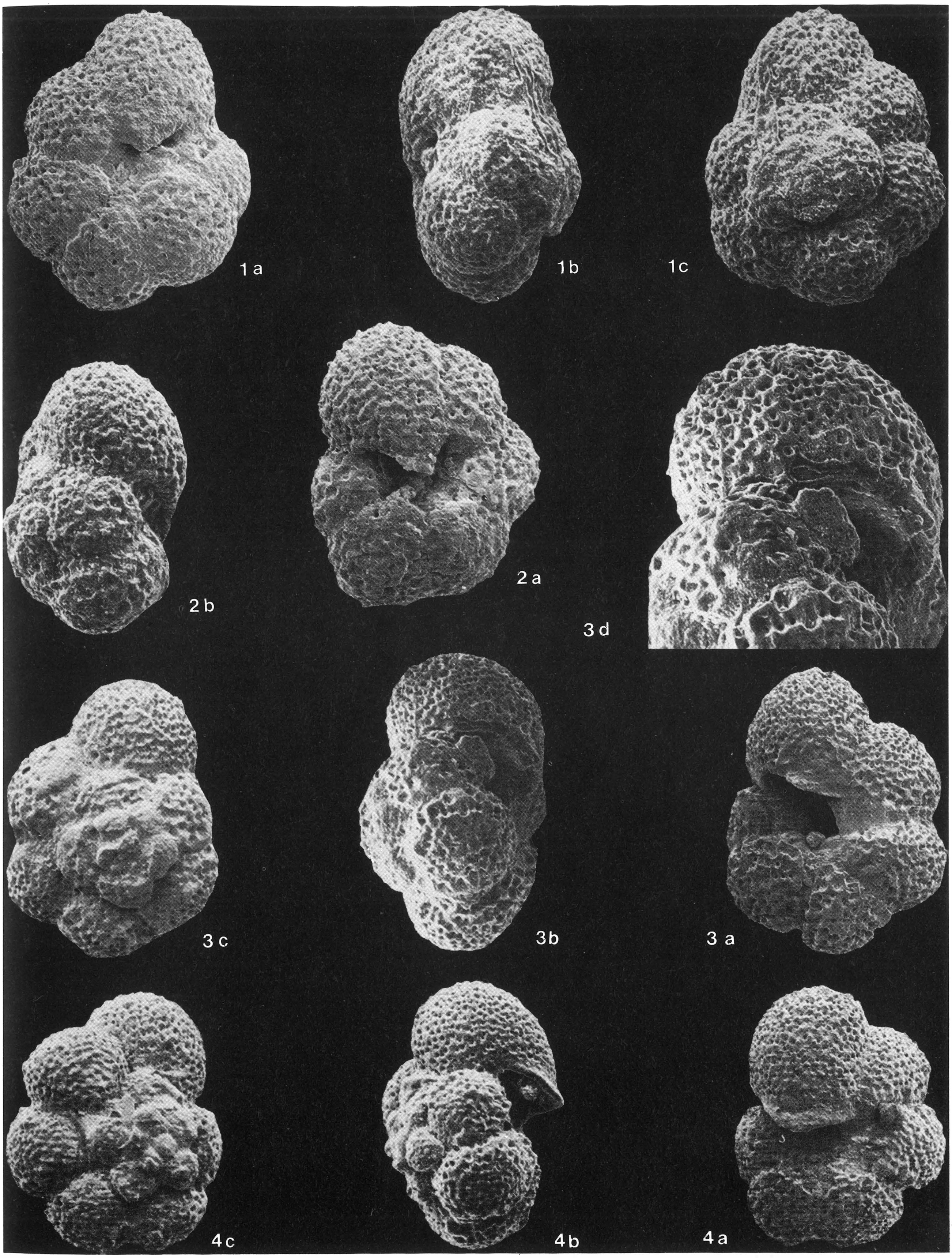
PLATE 5
(SEM illustrations)

Fig. 1a, b, c - *Globigerina multiloba* ROMEO (x 250).
a: umbilical view; b: lateral view; c: spiral view.
G. conomiozea Zone; *G. multiloba* Subzone;
Rio Mazzapiedi section, sample RM 25.

Fig. 2a, b - *Globigerina multiloba* ROMEO (x 250).
a: umbilical view; b: lateral view.
G. conomiozea Zone; *G. multiloba* Subzone;
Rio Mazzapiedi section, sample RM 25.

Fig. 3a, b, c, d - *Globigerina multiloba* ROMEO.
a: umbilical view; b: lateral view; c: spiral view (x 250).
d: particular of the test (x 450).
G. conomiozea Zone; *G. multiloba* Subzone;
Mussotto section, sample MU 34.

Fig. 4a, b, c - *Globigerina multiloba* ROMEO (x 225).
a: umbilical view; b: lateral view; c: spiral view.
G. conomiozea Zone; *G. multiloba* Subzone;
Mussotto section, sample MU 34.


1a
1b
1c
2b
2a
3d
3c
3b
3a
4c
4b
4a

Since such an emendation must be discussed, and eventually approved, by an international geological body, we prefer here only to propose such a possibility, whereas we repeat that the first appearance of *G. conomiozea* in the Tortonian stratotype is the actually most valid biostratigraphic event to recognize the closest levels to the top of the Tortonian.

Detailed analysis of some italian sections is in progress from a lithological, sedimentological, paleomagnetic and paleontological point of view in order to provide a better choice when a Tortonian-Messinian boundary stratotype will be defined according to the above discussed criteria.

ACKNOWLEDGEMENTS

We are grateful to A. Bossio, M.B. Cita, M.L. Colalongo, S. Sartoni, and G.B. Vai for the critical discussions and the valuable contributions during the various phases of the work. Many thanks to F. Russo for SEM photographs taken at the Institute of Paleontology (Modena University). This work is supported by Italian C.N.R., Committee 05, Research Grants n. 74.01858.05, n. 74.00939.05, n. 74.01474.05, n. 74.00938.05, n. 74.01479.05, and n. 74.01478.05.

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