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STRATIGRAPHIC AND PALEOENVIRONMENTAL OBSERVATIONS ON THE TERRAVECCHIA FORMATION IN THE SALEMI–CASTELVETRANO BASIN (WESTERN SICILY)

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Riassunto. Nel presente studio sono state esaminate le caratteristiche della Formazione Terravecchia, soprattutto per l'aspetto biostratigrafico, in un'area compresa fra Trapani, Alcamo, Menfi e Mazara del Vallo, corrispondente grosso modo al bacino di Salemi–Castelvetrano della Sicilia sud–occidentale. Della formazione sono stati soprattutto controllati età e ambiente di deposizione. L'indagine è stata condotta su campioni di 6 pozzi Agip e su campioni di superficie.

La Formazione Terravecchia è composta da depositi molassici prodotti dallo smantellamento dell'orogene settentrionale siciliano e accumulatisi in bacini di avanfossa, quali quelli di Salemi–Castelvetrano e Caltanissetta. Dalle associazioni microfaunistiche rinvenute è risultato che la Formazione Terravecchia si è deposta durante un lungo ciclo sedimentario del Serravalliano superiore / Tortoniano inferiore – Messiniano superiore. La sedimentazione, però, non è stata sempre continua: un'interruzione alquanto generalizzata è avvenuta fra il Serravalliano superiore ed il Tortoniano inferiore, oscillando entro questo intervallo di tempo da luogo a luogo in accordo, sembra, con i caratteri fisiografici del bacino e con la entità degli apporti. L'ambiente di deposizione varia considerevolmente da nord a sud, passando da condizioni fluvio–deltizie a quelle proprie di bacino non molto profondo. Tutti i dati ottenuti, integrati con analoghi dati di letteratura, hanno permesso un tentativo di ricostruzione dell'evoluzione paleogeografica del bacino di Salemi–Castelvetrano dal Serravalliano s.l. al Messiniano preevaporitico.

Summary. The Sicilian Miocene silico–clastic sediments usually known as Terravecchia Formation have been studied with the aim of specifying the age and depositional environment of the formation by micropaleontologic observations. The study area was the Salemi–Castelvetrano basin, grossly spread between Trapani and Alcamo, at north, and Menfi and Mazara del Vallo, at south, in the southwestern part of Sicily. The study was performed both on ditch and core samples of 6 named Agip wells and on surface samples.

The Terravecchia Formation consists of molassic deposits supplied by erosion of the Sicilian Northern Mount System and sedimented southwards in foredeeps, such as those of Salemi–Castelvetrano and Caltanissetta. The microfaunal assemblages found indicate that the Terravecchia Formation accumulated during the Late Serravallian/Early Tortonian – Late Messinian. The sedimentation, however, was not continuous throughout this time. An important and rather generalized sedimentation gap took place during the Late Serravallian and the Early Tortonian. Such sedimentation gap shifts within this time interval from place to place appearingly in accordance with the basin's physiographic features and with

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the sediment supply. The biologic content, as well as the sedimentologic and lithologic features of the Terravecchia Formation in these western areas denote a marked transition of its depositional environment, north to south, from fluviatile to epibathyal marine conditions.

A tentative reconstruction has been made of the paleogeographic and paleobathymetric evolution of the Salemi–Castelvetrano basin throughout the Serravallian s.l. and the preevaporitic Messinian.

Introduction.

The Terravecchia Formation was formalized by Schmidt di Friedberg et al. (1960), based on what reported by Flores (1959). It is composed of several Miocene silico–clastic outcropping and subsurface sediments. Usually the Terravecchia Formation deposits represent a thorough sedimentary cycle; its top and bottom are often erosive and the formations on which it lies differ from place to place.

The initial transgressive phase is generally followed by a regressive one that sometimes tops with the Gessoso–Solfifera Formation beds. The transition to the latter can either be abrupt or gradual, marked, in this case, by a slow increase of evaporitic crystals.

The lithology varies greatly, ranging from marls and/or shales, sometimes silty or silty–sandy or with more or less micaceous and/or sandstone intercalations, to more or less graded sands or sandstones, poligenic conglomerates, with variable amounts of sandy and/or argillaceous matrix, olistostrome sediments and, occasionally, calcarenites and calcirudites. Generally, these main constituents occur without a strictly defined order within the formation's sequences. Seemingly, the thickness is very uneven, ranging from 200 to 2000–2500 m, with average of about 600–800 m.

Several Authors (Flores, 1959; Schmidt di Friedberg et al., 1960; Ogniben, 1954, 1960; Ogniben & Vezzani, 1975; M. Rigo & Barbieri, 1959; Marchetti, 1960; Amore, 1969; Schmidt di Friedberg, 1962; Ruggieri, 1966a; Romeo, 1968; Roda, 1971; Colalongo et al., 1979; Catalano & Sprovieri, 1971; Magné, Mascle & Mongin, 1972; Desio, 1973; Di Stefano & Catalano, 1978; Catalano & Montanari, 1979; Mascle, 1979; Catalano, 1979) assigned different names and ages to these sediments; but opinions seem growing more consistent with time. As a matter of fact, most Authors today refer to the Sicilian «postorogenic» or «neoautochthonous» terrigenous beds as to the Middle–Late Tortonian – Early Messinian «Terravecchia Formation». Because of its transition to the Gessoso– Solfifera Formation, the upper chronologic limit of the Terravecchia Formation is well defined; but the same is not true for its base.

From literature, the sedimentation environment ranges, southwards, from fluviatile – fluvio–deltaic to shelf, slope and, at last, shallow basin depositional conditions. This is reflected by a remarkable grain size reduction, north to south, from conglomerates and sands, becoming more and more argillaceous, to shales and/or marls free or almost free from coarser elements.

Therefore, two were the main aims of this research:

1) to determine the age and the depositional environment of the Terravecchia Formation within the Salemi–Castelvetrano basin;

2) to tentatively reconstruct the physiographic evolution of the Salemi–Castelvetrano basin throughout the Serravallian s.l. and the preevaporitic Messinian.

Both age and depositional environment were mainly deduced by micropaleontologic analyses. The tentative reconstruction of the physiography of the Salemi–Castelvetrano basin during the Middle–Late Miocene was obtained by plotting on maps the sedimentation depths that resulted from the comparison of a great deal of data (biologic, petrographic and sedimentologic evidences, sediment thickness, geologic setting and tectonic evolution of the area and data from literature).

The Salemi–Castelvetrano foredeep approximately stretches from Trapani – Alcamo to Menfi – Mazara del Vallo. The type–locality of the Terravecchia Formation is represented by the northern flank of Cozzo Terravecchia, 7 km north of S. Caterina Villarmosa, in the outskirts of Caltanissetta (Flores, 1959). The type–section is located along the southern flank of Cozzo Gracello and the Imera river valley, NW of Scillato (Schmidt di Friedberg et al., 1960).

Previous studies.

Literature is very poor relevantly to the postorogenic sediments of south–western Sicily. Neglecting works such as those of Baldacci (1886), Checchia Rispoli (1911) or Trevisan and di Napoli Alliata (1937), remarkable, but old by now, most generical data about Tertiary deposits of the Salemi–Castelvetrano basin can be drawn by Marchetti (1960), Schmidt di Friedberg (1962), Ogniben (1960, 1963), Ruggieri (1966a), Mascle (1970, 1979), Desio (1973), Ogniben & Vezzani (1975), etc. Among the most recent studies we have Catalano & D'Argenio (1978) and Catalano (1979), the former with stratigraphic–structural data relevant to the whole western Sicily and, the latter, rich in stratigraphic, sedimentologic and paleoenvironmental data of all the postorogenic deposits of central and western Sicily.

Further news about the sediments now grouped into the Terravecchia Formation can be drawn by Ogniben (1954), Crescenzi & Gaffurini (1955), Rigo M. & Barbieri (1959), Marchetti (1960), Romeo (1968), Truillet (1968), Ruggieri et al. (1969), Amore (1969), Catalano & Sprovieri (1971), Roda (1971), Magné, Mascle & Mongin (1972), Di Stefano & Catalano (1978), Catalano & Montanari (1979), Catalano (1979).

Geologic setting.

The geologic history of Sicily consists of a preorogenic and of a postorogenic phase. During the former, the paleogeography of the island was characterized by a block structure morphology, with alternated Horsts and Grabens delimited by E–W trending normal fault systems originated by intense Jurassic extensional tectonics linked with the opening of Central Tethys.

Such structural setting affected the sedimentary patterns with a remarkable alternation of deep and shallow depositional environments dominated by carbonatic sediments with very reduced terrigenous influxes. Further sedimentary evolution witnessed the accumulation of Tertiary flysch deposits that caped some of the sequences of these original domains.

The collision of the northern, European Plate with the southern, African Plate within the Mediterranean area closed the Tethys Ocean, overthrowing the previous settings and triggering the Alpine Orogenesis. So the second phase of the geologic history of Sicily began.

The orogenic compressional wave reached the island between Late Eocene and Langhian times, deforming the original domains and giving rise to nappe structures that glided, one on the other, towards south. The parossistic phase of Alpine Orogenesis in Sicily took place during Middle–Late Serravallian and Early Tortonian times.

The new paleogeographic landscape of Sicily during the Middle Tortonian was characterized, from N to S, by a) an uplifting, E–W trending mount system, made of a pile of allochthonous sheets, composed of Mesozoic–Tertiary deposits; b) a foredeep system in which molassic sediments, originated by the erosion of the northern mountain chain, settled down; c) a stable foreland area, not subjected to crustal shortening processes.

The western Salemi–Castelvetrano, as well as the Central Sicily Caltanissetta basins, formed the Neogenic foredeep system in which the Terravecchia Formation sedimented.

Well and sampled sections.

This study was mostly carried out on the micropaleontologic content of core and ditch samples of 6 named Agip wells (Marinella 1, Campobello 1, Gazzera 1, Mazara del Vallo 1, Lippone 1, Biddusa 1) located within the parallels of Marinella, at south, and Marsala, at north. The data so achieved were then compared and integrated with those of samples collected from outcropping sections scattered within the Salemi–Castelvetrano basin (Diga al Lago della Trinità, Monte Baronia, Ca' di Marchese, S. Cipirello) and from others located in the type–locality and the type–section areas of the Terravecchia Formation (Resuttano, Cozzo Gracello–Imera River, Ca' Pestavecchia).

Lithostratigraphic outline

Only few notes are here given to better visualize the lithologic–sedimentologic features of the Terravecchia Formation, as well as its relations with eventual over– and underlying formations.

Well Marinella 1.

Formations recovered:

Ribera Fm. –	Agrigento Member	0– 674 m
	– Narbone Member	674–1028 m
	– Trubi Member	1028–1100 m
Gessoso–Solfifera Fm.		1100–1125 m
Terravecchia Fm.		1125–1401 m (total depth)

The well was bottomed within the Terravecchia Formation marly shales, at 1401 m of depth; nothing can thus be said about the substratum of the formation. The lithology of the Terravecchia Formation is quite uniform: five cores drilled through it are characterized by greyish–green, hard, slightly silty marly shales. The transition to the Gessoso–Solfifera evaporitic deposits is gradual, marked by a progressive enrichment of the shales in gypsum and anhydrite crystals.

Well Campobello 1.

Formations recovered:

Quaternary conglomerates	0– 30 m
Terravecchia Fm.	30–853 m
Langhian–Early Serravallian sandstones, shales and marls	853–960 m
Cretaceous limestones	960–967.5 m (total depth)

The Miocene argillaceous sediments are comprised between two erosional surfaces. The lithology is as follows:

960–853 m	sandstone
853– 30 m	shales and marls, sometimes silty, with few rare, thin sandy intercalations; between 320 m and 200 m very rare, gravel–size elements occur.

Four cores drilled through this section display grey–green, hard, uniform shales and/or marls.

Well Gazzera 1.

Formations recovered:

Terravecchia Fm.	100– 719 m
Hybla Fm.	719– 792 m
Busambra Fm.	792– 905 m
Giardini Fm.	905– 992 m
Taormina Fm.	992–1320 m (total depth)

No report was found relevantly to the first 100 m of this well. The base of the Terravecchia Formation is erosive; it directly overlies the Early Cretaceous Hybla Formation beds. It is composed of shales, sometimes sandy, with sand intercalations that grow thicker (from 1 ÷ 5 m to 30 ÷ 40 m thick) and more frequent upwards. The sand is granulometrically very fine. The shaly levels among the sand banks are 5 to 60 m thick. Seven cores and seven side wall cores of the Terravecchia sediments recovered grey–green, or, at times, ash grey marly shales that turn silty or even slightly sandy towards the upper part of this section.

Well Mazara del Vallo 1.

Formations recovered:

Quaternary shales	0– 20 m
Terravecchia Fm.	20–1255 m
Serravallian marls and shales	1255–1482 m
Oligocene limestones	1482–1490 m (total depth)

The transition to the Quaternary deposits is not marked by any distinct surface. The lower portion of the Miocene deposits is here represented by marls, sometimes calcareous. The marls pass upwards to shales, silty at times, with rare thin intercalations of sand and sandstone. From 585 m to the top an alternance of sometimes slightly cemented, argillaceous sand banks, 30 ÷ 50 m thick, and more or less sandy shales, 60 ÷ 90 m thick, occurs.

Only one core was collected in these sediments: it displays a fine grained sand with more or less sandy shale intercalations.

Well Lippone 1.

Formations recovered:

Quaternary shales, gravels and sands	0– 18 m
Terravecchia Fm.	18–1301 m
Serravallian marls, shales, silty and sandy shales	1301–1416 m
Oligocene–Triassic limestones and dolomitic limestones	1416–2583 m (total depth)

The Miocene deposits display the following composition:

1) from 1416 m to 1332 m – marls;
2) from 1332 m to 656 m – silty shales (30 + 90 m thick) and shales (190 ÷ 360 m thick);
3) from 656 m to 18 m – shales, marly shales, silty shales and shales with thin sand intercalations.

Eleven cores were drilled through this portion; they recovered greenish to yellowish, sometimes hard and/or silty marls, and dark, grey and grey–green, at times nodular or scaley or silty shales.

Well Biddusa 1.

Formations recovered:

Quaternary sandy shales and conglomerates	0– 20 m
Pliocene shales, marls, sands and conglomerates	20– 977 m
Terravecchia Fm.	977–2500 m (total depth)

The well was bottomed within the Terravecchia Formation, so the features of its base, as well as its substratum, are unknown.

The transition towards the Pliocene deposits is very gradual. The oldest Pliocene sediments cannot be discriminated on sole lithological basis.

Three main sedimentologic units can here be distinguished within the Terravecchia Formation:

1) from 2500 m to 2170 m grey–green, hard shales;
2) from 2170 m to 2111 m sand–sandstone banks (10 ÷ 40 m thick) subdivided by shale intercalations, alternated with dark, grey–green clays, slightly sandy at times (80 to 230 m thick);
3) from 2111 m to 977 m sandy–conglomeratic banks (10 ÷ 40 m thick) subdivided by shale beds.

Nine cores were drilled through the lower part of the formation. They show dark grey–green, hard shales, sometimes silty and/or slightly micaceous or with rare sandstone levels.

Diga al Lago della Trinità section.

The outcropping section is 22–24 meters thick. It is made of an alternance of sand banks (50÷60 cm thick at the bottom, 40 ÷ 50 cm upwards) and clay levels (40÷50 cm thick at the bottom, 70 ÷ 80 cm upwards). The sand banks disappear at the top. The clays are silty–sandy, reddish–grey in colour. The sands are fine grained, yellowish, slightly cemented and graded; they display Tb and Tc Bouma levels. The sediments are plane bedded and no evident erosional surface can be detected.

On the top of this sequence Quaternary calcarenites occur. The base is not exposed.

Monte Baronia section.

Two members can be recognized, from the bottom:

Member 1. It is represented by reddish or yellowish sands with dispersed pebbles. Upwards, an alternance of greyish sandy shale levels, 5 to 20 cm thick, and sand beds, 30 to 40 cm thick, occurs. This member is about 275 m thick.

Member 2. Directly on the sands at the top of Member 1 lie coarse, yellowish, stratified organic limestones, with beds 30 ÷ 50 cm thick or more. Upwards, these limestones pass to greyish, evaporitic limestones with beds 10 to 20 m thick. This member is about 130 m thick.

No other lithologic unit occurs over the second member. The base of the section is not exposed.

Ca' di Marchese section.

It is composed of well bedded sands and sandstones about 1 – 1.2 m thick, with frequent, more or less silty and/or sandy clay lenses about 20 cm thick.

The sands are yellowish, medium to fine grained, normal graded and not much cemented. Ta, Tb and Tc Bouma levels can often be recognized; the Tb level is predominant, Tc is frequent, Ta is rare.

Clay chips are common and erosional surfaces and channels can be detected, as well as massive beds. Many of the erosional surfaces occur at the top of the clay lenses; others distinguish a sand bank from another. The clay lenses are dark, grey or green and show many thin, plane silty and silty–sandy yellowish laminations. The clay is generally plastic, but sometimes crumbly.

At the base of this outcrop, a polymict conglomeratic level occurs, rich in sandy matrix and about 1 m thick. Elements are composed of Mesozoic limestones and quartzitic sandstones.

Outcropping thickness approximately 47 m. Top and bottom not exposed.

S. Cipirello section.

Greenish–grey and grey–bluish marls, with typical «soapy» cleavage. The outcrop is very bad, as it is mostly covered by marly material washed down by meteoric processes.

Sampled thickness, about 3 m; whole thickness unknown. Top and bottom not outcropping.

Resuttano section.

Poorly sorted, non or weakly cemented, massive sands, with rare, thin plane laminations. Rare, thin, very sandy clay lenses occur.

Exposed thickness about 11 m. Top and bottom not outcropping.

Cozzo Gracello–Imera River section.

This is the type–section of the Terravecchia Formation. It represents a complete transgressive cycle, in which 6 members may be distinguished, namely:

Member 1. Massive sands. About 150 m thick.

of quartzitic sandstones. Mesozoic and Paleogenic limestones, granites and metamorphites.

Foresets, due to braided river bar prograding, are also recognizable, specially towards the top of this member. Both bed thickness and granulometry decrease upwards. The transition to the following member is gradual, marked by a sand/conglomeratic alternance. The colour is generally reddish–brown. Whole thickness about 360 m.

Member 3. Generally coarse grained quartzitic sands, with frequent fine grained sand and conglomeratic and microconglomeratic levels. Erosional channels, plane laminations, planar and trough cross–bedding structures occur.

Erosional channels and other kinds of erosional surfaces, marked by poligenic, well rounded conglomerates (rarely larger than 10 cm in diameter) are frequent. These channels are filled with trough cross bedded sands that thin upwards, often passing to very discontinuous clay intercalations rich in plant remains. The sand banks have most variable thicknesses, possibly higher than 1.5 m. Sometimes some typical point bar sequences are recognizable.

The member as a whole displays a remarkable granulometric fining upwards gradation, with gradual transition to the overlying member. Whole thickness about 130 m.

Member 4. Very fine grained, slightly clayey sandstone banks, just distinguished one another by thin, sandy clay joints. The banks are few tens of centimeters thick, wavy or planar bedded, with weakly dipping laminations ($5^\circ \div 10^\circ$) cut by erosional surfaces with low angle cross bedded sandstones that represent small erosive channel fillings. Vertical bioturbations can somewhere be noted. The sandstones are well cemented and have variable amounts of argillaceous matrix. Whole thickness about 15–20 m.

Member 5. Grey–green marly shales with very thin (2–3 cm) reddish silt/fine sand intercalations. These latter are more regular and more evident in the lower part of the member, becoming instead very difficult to distinguish, or even thoroughly disappearing, upwards. They appear again very close to the top of the member. These silty/sandy intercalations dip $5^\circ - 10^\circ$ towards W–NW. The shales are crumbly. Thickness about 250 m.

The transition to the following member is abrupt, marked by an erosional surface.

Member 6. Thick, planar bedded conglomerates, made of poligenic (limestones and sandstones) and heterometric (gravel to cobble size) elements. Abundant sandstone matrix. Frequent erosional pockets infilled with sand.

The banks seem massive. Thickness about 60 m.

Ca' Pestavecchia section.

In the first tens of meters from the outcropping base the section is composed of slightly silty shales that pass to shales upwards. The latter show a weak enrichment in evaporitic crystals towards the top. The transition to the overlying Gessoso–Solfifera Formation is abrupt.

The outcropping thickness is about 105 m. The base is not exposed.

Biostratigraphy

The reference zonal scheme here followed is basically the one proposed by Borsetti et al. (1979), although modified in some parts in order to better represent the peculiar Neogene Sicilian foraminiferal assemblages and to make it more suitable for bore–hole micropaleontologic analyses. Therefore, relatively to the Tortonian Stage, the biozones introduced by Borsetti et al. (1979) were substituted by those proposed by Colalongo et al. (1979); furthermore, concerning the Late Langhian/Serravallian interval, the *Orbulina universa* Zone and the *O. suturalis* Zone were grouped together in a generic *Orbulina* spp. Zone because caving, in well ditch samples, does not allow to discriminate the two zones.

The zonal scheme results as follows, from bottom to top:

1) *Praeorbulina* spp. Zone, characteristic of the Early Langhian;

2) *Orbulina* spp. Zone, that ranges from the Late Langhian to the whole Serravallian;

3) *Globorotalia acostaensis* Zone, that embraces the whole Tortonian. This biozone comprises three subzones, namely *Globorotalia continuosa* Subzone, *Globigerinoides extremus* Subzone and *Globorotalia suterae* Subzone;

4) *Truncorotalia conomiozea* Zone, that ranges throughout the whole Messinian. This zone comprises two subzones, namely *Globorotalia mediterranea* Subzone and *Globigerina multiloba* Subzone;

5) *Sphaeroidinellopsis* spp. Zone, that characterizes the very beginning of the Pliocene;

6) *Globorotalia margaritae* Zone, within the Early Pliocene;

7) *Globorotalia puncticulata* Zone, characteristic of the late Early Pliocene.

These are the only biozones effectively or potentially represented in the sediments here studied. For full description of the biozones, the reader should refer to the works mentioned above (1).

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(1) In some of the sequences biozones or sub–biozones are indicated with an interrogation mark. In such rock bodies the zonal or subzonal marker was not found; though other characteristic taxa that are usually recovered with those particular markers occur as well.

Some of the biostratigraphic boundaries in the wells were hard to resolve because of a sometimes too scanty core sampling, bad or poor faunal preservation and strong faunal reworking. Thus, sampling was improved by examining ditch samples of the intervals between the cores, although, as well known, ditch samples are highly affected by faunal caving.

Figures 1–13 show the distribution and the abundance of age–diagnostic taxa in the wells and outcropping sections here studied; in few cases bathymetrically significant benthic foraminifers are reported as well. Most of the microfaunas found in these samples are not well preserved except those of wells Marinella 1 and Campobello 1 and of S. Cipirello and Ca' Pestavecchia sections. Furthermore, in some cases the microfaunal assemblages are composed of very small specimens.

Some Globorotalias were plotted in the figures as a group. In particular, those indicated as *Globorotalia* gr. *menardii* are characterized by very low trochospire, more or less lobulate equatorial periphery, lenticular axial profile with acute and marked keeled margin, 5 to 7 chambers in the last whorl, petaloid to crescentic on spiral side and triangular on umbilical side, umbilicus narrow, interiomarginal slit–shaped extraumbilical–umbilical aperture, bordered by a lip, smooth surface densely perforate, somewhat pustulose around the umbilicus, arcuate raised sutures on spiral side, radial to slightly curved and depressed sutures on umbilical side.

Seemingly, those called *Globorotalia* gr. *scitula* have low trochospire and test about equally biconvex or slightly umbilico–convex, 4 to 5 chambers in the last whorl, equatorial periphery subcircular, to pentagonal, slightly lobulate, axial profile angular to subangular or sometimes even rounded, sutures very strongly recurved on spiral side, almost straight, radial, depressed on umbilical side, elongate crescentic chambers, very narrow or even closed umbilicus, interiomarginal, extraumbilical–umbilical, slit–shaped aperture, bordered by a rim or a lip and typical smooth surface.

Very few benthic taxa are here believed age–diagnostic. As well known, in bore–hole stratigraphy last occurrence of taxa is far more useful than first occurrence. Few already formalized markers were found in the Terravecchia Formation sediments: *Bolivina miocenica* and *Brizalina arta*, which are not known to range in Pliocene sediments, *Bulimina echinata* and *Brizalina mutinensis*, typical Messinian markers and *Anomalinoides ornatus*, *Bolivina cistina* and *B. leonardii*, all characteristic Pliocene taxa.

Besides these, few other benthic species were acknowledged to have a peculiar distribution: *Spiroplectammina carinata* was noticed to be rather common in the Tortonian beds and very scarce or more often totally lacking in the Messinian ones, *Uvigerina barbatula* was never recovered in sediments more recent than the Tortonian and *Heterolepa mexicana, Anomalinoides pseudogrosserugosus* and *Uvigerina auberiana attenuata* were never found to range beyond the Serravallian.

A brief description of the biozones and sub–biozones represented in each well and sampled outcrop follows. The occurrences of biozonal and sub–biozonal markers as well as of other significant planktic and/or benthic species are emphasized. A general description of the microfaunal assemblages as a whole and of the inorganic fraction of each interval are also included.

Well Marinella (Fig. 1).

Truncorotalia conomiozea Zone – *Globorotalia mediterranea* Subzone: from 1125 m to 1180 m. Early Messinian.

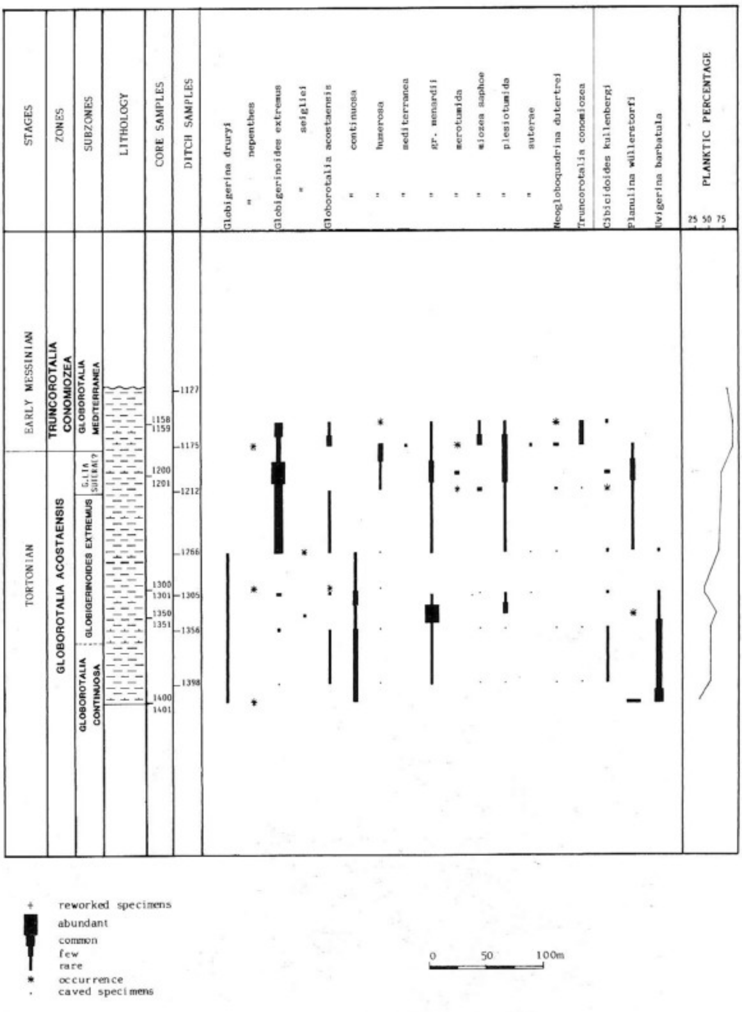


Fig. 1 – Occurrence of selected species in samples from well Marinella 1.

The microfaunal assemblage is very rich in the lower–middle part of this interval and turns very poor in the upper. Also preservation worsens upwards. Specimens are usually reduced in size. No age–diagnostic benthic foraminifers were recovered within this interval.

The inorganic fraction is composed of very abundant gypsum and anhydrite crystals, abundant argillaceous elements, scarce to very scarce pyrite, very scarce quartz. Carbonaceous fragments are present as well, ranging from scarce to abundant.

Globorotalia acostaensis Zone – *Globorotalia suterae* ? Subzone: from 1180 m to 1214 m. Late Tortonian.

Globorotalia acostaensis, G. humerosa, G. miozea saphoe and *Neogloboquadrina dutertrei* are the most diagnostic species. All but *Globorotalia humerosa* are only present in the lower levels of this interval. The subzonal marker was not found here; therefore, this interval is tentatively referred to the *Globorotalia suterae* Subzone. Age–diagnostic benthic foraminifers lack in this portion. The microfaunal assemblage is very rich and well preserved, but specimens are still rather small in most levels.

The inorganic fraction is represented by abundant anhydrite crystals, argillaceous elements and carbonaceous fragments; gypsum, pyrite and glauconite are scarce, while quartz and arenaceous granules are very scarce.

Globorotalia acostaensis Zone – *Globigerinoides extremus* Subzone: from 1214 m to 1367 m. Late – Middle Tortonian.

Globigerinoides extremus, Globorotalia acostaensis, G. continuosa and *G. plesiotumida* are the most indicative planktic forms. *Uvigerina barbatula* mostly characterizes the benthic microfaunal assemblage. Very rich and usually well preserved microfaunal assemblage.

Abundant argillaceous elements and pyrite, scarce carbonaceous fragments and very scarce glauconite compose the inorganic fraction.

Globorotalia acostaensis Zone – *Globorotalia continuosa* Subzone: from 1367 m to 1401 m. Early Tortonian.

Globorotalia acostaensis, G. continuosa and *G.* gr. *menardii* are the most significant taxa within this interval. Very rich microfaunal assemblage; preservation good to fair.

The inorganic fraction consists of abundant argillaceous elements, abundant to very scarce glauconite, abundant pyrite and scarce carbonaceous fragments.

Well Campobello 1 (Fig. 2).

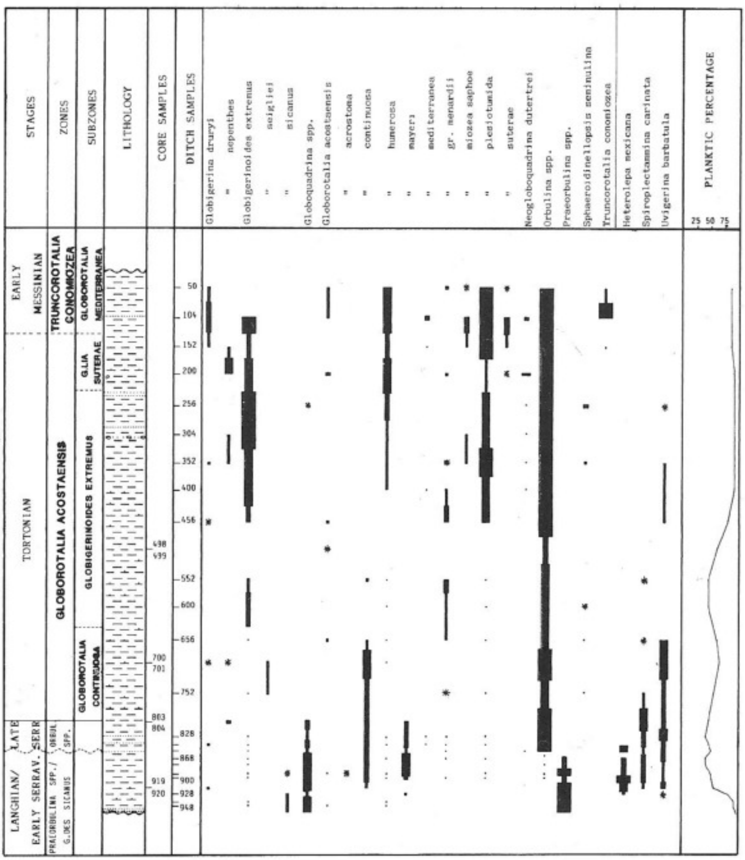
Truncorotalia conomiozea Zone – *Globorotalia mediterranea* Subzone: from 30 m to 130 m. Early Messinian.

No age–diagnostic benthic foraminifers can be reported. Poor, but very well preserved microfaunal assemblage.

Very abundant quartz, very scarce to abundant pyrite, scarce to abundant calcite and scarce glauconite compose the inorganic fraction.

Globorotalia acostaensis Zone – *Globorotalia suterae* Subzone: from 130 m to 230 m. Late Tortonian.

The zonal and subzonal markers, as well as *Neogloboquadrina dutertrei* are the most diagnostic taxa. Rich microfaunal assemblage in the lower half of this interval and poor in the upper half. Good preservation.



The inorganic fraction is represented by very abundant quartz, very scarce pyrite, scarce micas and from scarce to abundant calcite.

Globorotalia acostaensis Zone – *Globigerinoides extremus* Subzone: from 230 m to 646 m. Late – Middle Tortonian.

Globigerinoides extremus, Globorotalia acostaensis, G. continuosa, G. humerosa, G. miozea saphoe, G. plesiotumida and *Sphaeroidinellopsis seminulina* are the noteworthy species of this interval. Among the benthic foraminifers *Spiroplectammina carinata* and *Uvigerina barbatula* are to be reported. Poor microfaunal assemblage, that increases in abundance upwards. Preservation fair to good towards the upper levels.

The inorganic fraction is composed of very abundant argillaceous elements, scarce to very abundant quartz, abundant to very scarce pyrite, scarce to abundant calcite, scarce micas and scarce to very scarce carbonaceous fragments. Very abundant to very scarce arenaceous granules occur between 456 m and 499 m.

Globorotalia acostaensis Zone – *Globorotalia continuosa* Subzone: from 646 m to 801 m. Early Tortonian.

Globigerinoides seigliei, Globorotalia acostaensis, G. continuosa and *G.* gr. *menardii* are the most significant taxa. Microfaunal assemblage generally poor, but very rich in the second core, at 700–701 m: fair preservation.

Very abundant arenaceous elements, abundant pyrite, scarce quartz, calcite and carbonaceous fragments characterize the inorganic fraction.

Orbulina spp. Zone: from 801 m to 853 m. Late Serravallian.

Globoquadrina spp., *Globorotalia mayeri* and *Orbulina* spp. are the most characterizing taxa. *Orbulina universa* dominates this assemblage, followed by *Globigerinoides trilobus* and *Orbulina suturalis* that are common in most levels. Together with *Spiroplectammina carinata* and *Uvigerina barbatula*, another characterizing benthic species must be reported, *Heterolepa mexicana.* Microfaunal assemblage poor in the lowermost part of the interval, much richer upwards. Preservation good in most levels.

The inorganic fraction is composed of very abundant to scarce argillaceous elements, very scarce quartz and glauconite, very abundant calcite and abundant to scarce pyrite.

– U n c o n f o r m i t y –

Orbulina spp./ *Praeorbulina* spp. Zones: from 853 m to 960 m. Early Serravallian/Langhian.

Caving and faunal reworking do not allow sure dating of this interval. *Globigerinoides sicanus, Globoquadrina* spp., *Globorotalia acrostoma, G.*

continuosa, G. mayeri and *Praeorbulina* spp. are the most indicative taxa. *Globigerinoides altiaperturus, G. quadrilobatus, G. trilobus* and *Praeorbulina glomerosa* are the most frequent species recovered in this interval. Very rich microfaunal assemblage; excellent preservation.

The inorganic fraction is represented by most variable amounts of argillaceous elements, very scarce pyrite, quartz and glauconite, very abundant to very scarce calcite and scarce carbonaceous fragments.

Well Gazzera 1 (Fig. 3).

Truncorotalia conomiozea Zone – *Globorotalia mediterranea* Subzone: from 100 m to 365 m. Early Messinian.

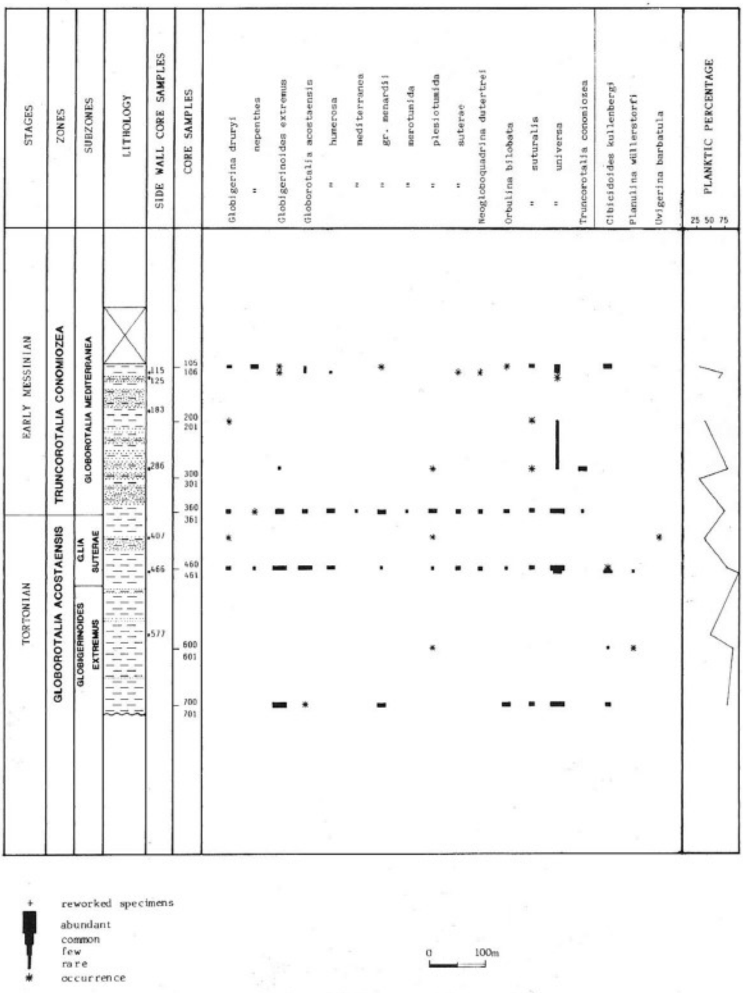


Fig. 3 – Occurrence of selected species in samples from well Gazzera 1.

No age–diagnostic benthic foraminifers were recovered within this interval. Poor and generally badly preserved microfaunal assemblage.

The inorganic fraction is composed of very abundant quartz and most variable amounts of argillaceous elements, calcite, micas and carbonaceous fragments. Glauconite is very scarce and pyrite occurs only in the first core, at 105–106 m.

Globorotalia acostaensis Zone – *Globorotalia suterae* Subzone: from 365 m to 490 m. Late Tortonian.

Globorotalia acostaensis, G. suterae and *Neogloboquadrina dutertrei* are the diagnostic planktic species. *Uvigerina barbatula* occurs in the upper half of this interval. Very rich microfaunal assemblage, well preserved in the lower levels, very badly in the upper ones.

Very abundant to scarce quartz and argillaceous elements and scarce pyrite and carbonaceous fragments characterize the inorganic fraction.

Globorotalia acostaensis Zone – *Globigerinoides extremus* Subzone: from 490 m to 719 m. Late – Middle Tortonian.

The most indicative species are *Globigerinoides extremus, Globorotalia acostaensis* and *G. plesiotumida.* No significant benthic foraminifers occur. The microfaunal assemblage is very rich in the lower levels and turns very very poor upwards. Also preservation strongly worsens towards the upper levels.

The inorganic fraction consists of very abundant argillaceous elements, variable amounts of arenaceous granules and quartz; calcite, pyrite, glauconite and carbonaceous fragments are very scarce.

Well Mazara del Vallo 1 (Fig. 4).

Truncorotalia conomiozea Zone – *Globorotalia mediterranea* Subzone: from 20 m to 585 m. Early Messinian.

One specimen of *Uvigerina barbatula* (reworked?) was found at 550 m. The microfauna is very very poor, or even totally lacking in some levels, and strongly deteriorated, from the top of this interval down to about 550 m; under this depth abundances grow a little higher and preservation is fair.

The inorganic fraction is represented by very abundant quartz and very scarce glauconite; arenaceous granules, calcite, pyrite and carbonaceous fragments occur in most variable amounts. Scarce argillaceous elements and abundant micas are present in the core drilled at 570–571 m.

Globorotalia acostaensis Zone – *Globorotalia suterae/Globigerinoides extremus* Subzones: from 585 m to 1255 m. Late – Middle Tortonian.

The two subzones could not be distinguished.

Globigerinoides extremus, Globorotalia acostaensis, G. humerosa, G. merotumida, G. plesiotumida, G. suterae and *Neogloboquadrina dutertrei* are the most diagnostic taxa. *Spiroplectammina carinata* occurs in the low part of the interval. Poor to very poor microfaunal assemblage; preservation fair in the lower levels, very bad in the upper ones.

Very abundant quartz, abundant calcite and pyrite, generally scarce arenaceous granules, abundant to scarce carbonaceous fragments and very abundant argillaceous elements (the latter in the samples of the very base of this interval) characterize the inorganic fraction.

– U n c o n f o r m i t y –

Orbulina spp. Zone: from 1255 m to 1482 m. Early Serravallian (Late Langhian?).

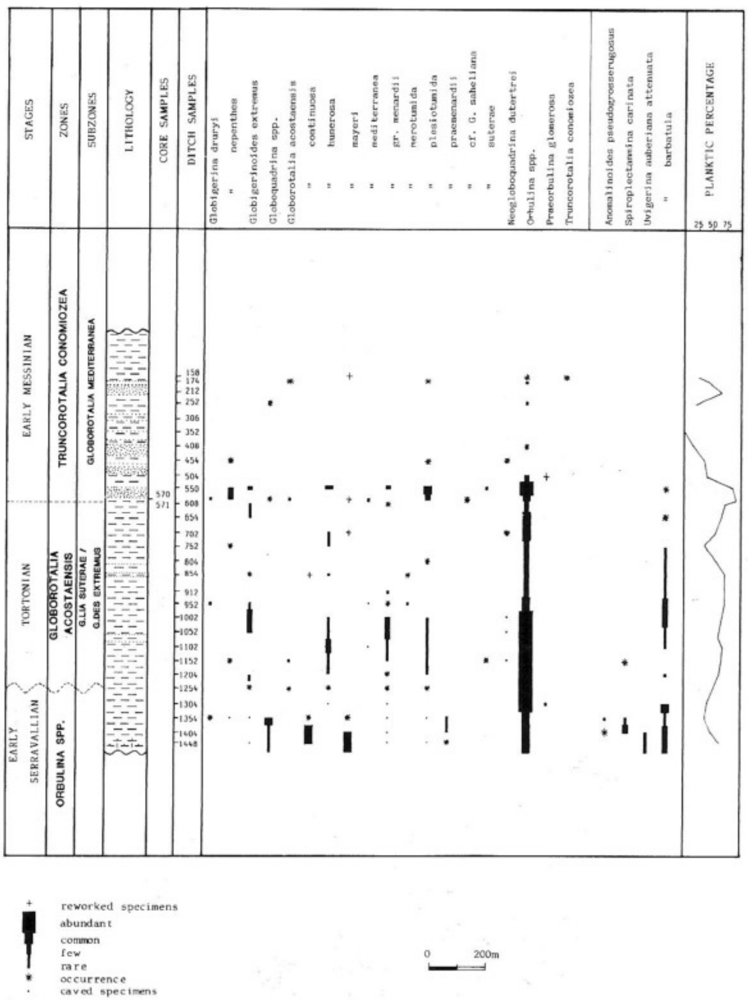


Fig. 4 – Occurrence of selected species in samples from well Mazara del Vallo 1.

Globoquadrina spp., *Globorotalia continuosa*, *G. mayeri*, *G. praemenardii*, *Orbulina* spp. and *Praeorbulina glomerosa* characterize this interval. *Globigerinoides immaturus* and *G. trilobus* dominate this assemblage. Besides *Uvigerina barbatula* and *Spiroplectammina carinata*, *Anomalinoides pseudogrosserugosus* and *Uvigerina auberiana attenuata* occur in this interval. Very rich microfauna, except in the uppermost levels where a strong reduction of the abundance was observed. Preservation is fair.

The inorganic fraction is represented by variable amounts of argillaceous elements and arenaceous granules and very scarce to scarce quartz and pyrite.

Well Lippone 1 (Fig. 5).

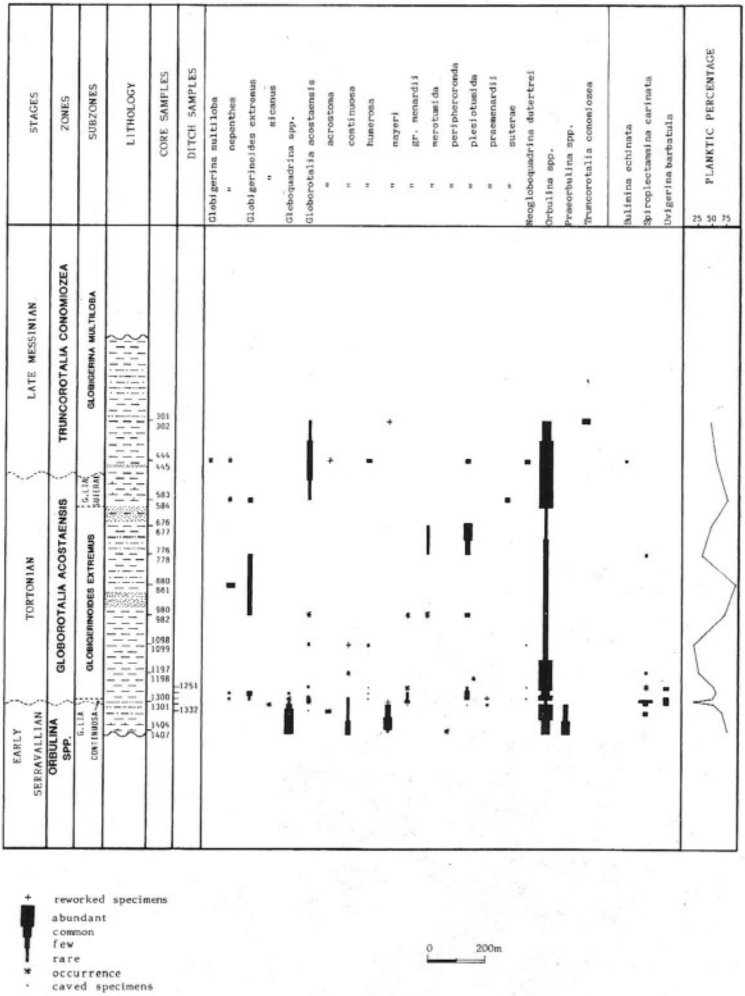


Fig. 5 – Occurrence of selected species in samples from well Lippone 1.

Truncorotalia conomiozea Zone – *Globigerina multiloba* Subzone: from 18 m to 492 m. Late Messinian.

Bulimina echinata occurs with rare specimens. Rich microfaunal assemblage in the lower portion of this interval; it grows poor upwards. Preservation generally fair.

Very abundant quartz and calcite, scarce to very scarce argillaceous elements, abundant to very scarce micas, very scarce glauconite and scarce to abundant carbonaceous fragments compose the inorganic fraction.

– U n c o n f o r m i t y –

Globorotalia acostaensis Zone – *Globorotalia suterae* Subzone: from 492 m to 603 m. Late Tortonian.

No indicative benthic foraminifers occur in this interval. Very rich and unusually well preserved microfaunal assemblage.

The inorganic fraction is made of scarce argillaceous elements and very scarce pyrite and micas.

Globorotalia acostaensis Zone – *Globigerinoides extremus* Subzone: from 603 m to 1291 m. Late – Middle Tortonian.

Globigerinoides extremus, Globorotalia acostaensis, G. continuosa, G. humerosa, G. merotumida and *G. plesiotumida* are the diagnostic taxa found in this portion. *Spiroplectammina carinata* and *Uvigerina barbatula* occur in this interval. Very rich microfaunal assemblage, well preserved in the upper levels, fairly to very badly preserved in the middle–lower ones.

The inorganic fraction consists of very abundant argillaceous elements, very scarce micas (limitedly to the upper levels of this interval), very scarce to scarce glauconite, pyrite, calcite and carbonaceous fragments and generally scarce to abundant or very abundant quartz.

Globorotalia acostaensis Zone – *Globorotalia continuosa* Subzone: from 1291 m to 1301 m. Early Tortonian.

Globorotalia acostaensis, G. continuosa and *G.* gr. *menardii* characterize this interval. *Globigerinoides trilobus* dominates this assemblage. Generally rich microfaunal assemblage. Preservation is good in the middle levels and worsens both upwards and downwards.

Very scarce calcite, pyrite, glauconite and carbonaceous fragments, scarce quartz and very abundant argillaceous elements compose the inorganic fraction.

– U n c o n f o r m i t y –

Orbulina spp. Zone: from 1301 m to 1416 m. Early Serravallian (Late Langhian ?).

Globigerinoides sicanus, Globoquadrina spp., *Globorotalia acrostoma, G.*

continuosa, *G. mayeri*, *G. peripheroronda*, *G. praemenardii*, *Orbulina* spp. and *Praeorbulina* spp. are the most characterizing taxa. *Globigerina foliata* and *Globigerinoides trilobus* dominate this assemblage. Microfauna usually very rich, well preserved in the lowest levels and more or less deteriorated in the middle and upper ones.

The inorganic fraction is made of very abundant argillaceous elements and very scarce quartz, calcite, pyrite (present at the very base of this interval), micas, glauconite and carbonaceous fragments.

Well Biddusa 1 (Fig. 6).

The upper part of this portion of the drilled sequence, from 306 m to 977

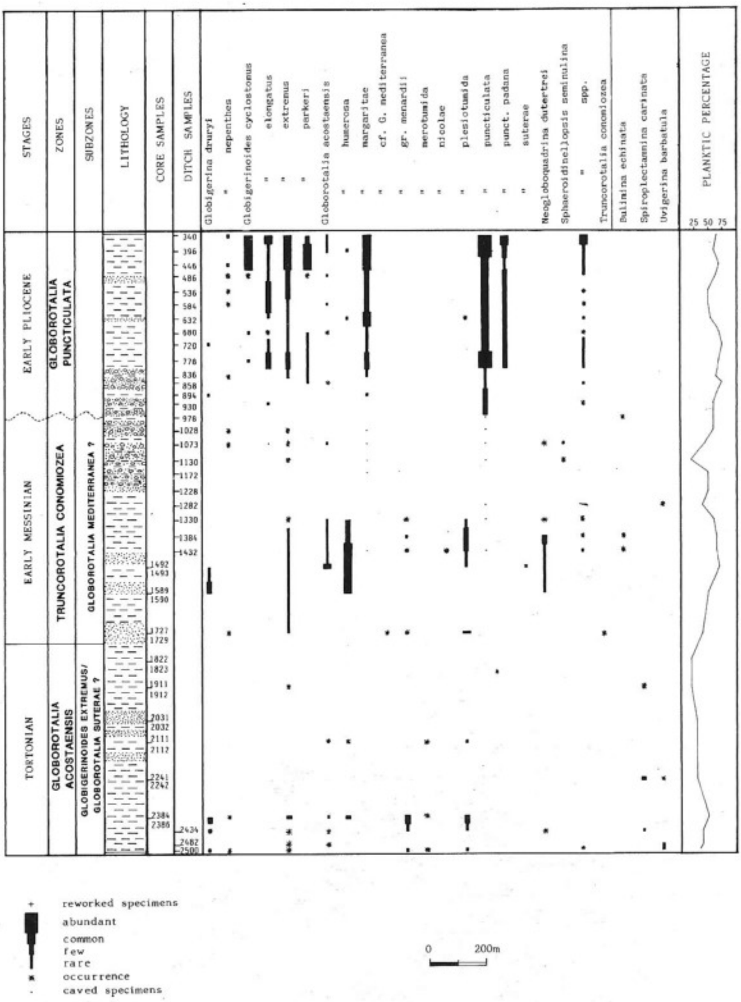


Fig. 6 – Occurrence of selected species in samples from well Biddusa 1.

m, was originally assigned to the Tortonian in the internal stratigraphic report issued by the Agip laboratories in the late fifties. This dating derived by electric log pattern correlation with nearby wells. And, as a matter of fact, by the sole lithologic viewpoint, these sediments are most similar to the immediately underlying ones; yet no Miocene taxon was found in this interval, and, instead, a rich Early Pliocene assemblage was recovered.

Globorotalia puncticulata Zone: from 306 m to 977 m. Early Pliocene.

Globigerinoides cyclostomus, G. elongatus, G. parkeri, Globorotalia margaritae, G. puncticulata, G. puncticulata padana and *Sphaeroidinellopsis* spp. particularly characterize this interval. Few typical Pliocene benthic foraminifers occur, such as *Anomalinoides ornatus, Bolivina cistina* and *B. leonardii.* Microfaunal assemblage usually very poor, but sometimes rich or even very rich (e.g. in the uppermost levels, between 350 m and 400 m). Most variable preservation.

Very abundant quartz, very abundant (in the lower part of the interval) to very scarce arenaceous granules, scarce calcite, pyrite and bituminous aggregations, very scarce glauconite, micas and gypsum (both in the lowermost levels), scarce argillaceous elements and very scarce limonite concretions compose the inorganic fraction.

– U n c o n f o r m i t y –

Truncorotalia conomiozea Zone – *Globorotalia mediterranea* ? Subzone: from 977 m to 1757 m. Early Messinian.

The zonal marker occurs only in the third core, at 1727–1728 m, while the subzonal marker was not found with certainty. Yet, in its place, again in the third core, a $5^1/_2$ chambered, keeled specimen with flat spiral side and strongly inflated umbilical side was recovered; it was called *Globorotalia* cf. *G. mediterranea* because of its reduced number of chambers, closer umbilicus and lower aperture with respect to the holotype. Other diagnostic species in this interval are *Globorotalia nicolae* and *G. juanai. Bulimina echinata* and *Uvigerina barbatula* (only one specimen, perhaps reworked, at 1282 m) occur in these sediments. Very poor microfaunal assemblage in the middle and upper levels, rich to poor in the lower ones. Bad to very bad preservation. Microfossils generally reduced in size.

Very abundant arenaceous granules, abundant to very abundant quartz, abundant to scarce argillaceous elements and glauconite (the latter limitedly to the lowermost levels), very scarce to abundant gypsum crystals, scarce calcite, scarce to very scarce pyrite and micas, very scarce to scarce carbonaceous fragments and bituminous aggregations and very scarce limonitic concretions characterize the inorganic fraction.

Globorotalia acostaensis Zone – *Globorotalia suterae* ?/*Globigerinoides extremus* Subzones: from 1757 m to 2500 m. Late – Middle Tortonian.

The two subzones could not be distinguished. *Globorotalia suterae* was not found. *Globigerinoides extremus, Globorotalia acostaensis* and *G. humerosa* represent the most indicative planktic taxa. *Spiroplectammina carinata* characterizes this interval, together with *Uvigerina barbatula.* This microfaunal assemblage is poor to very poor upwards. Preservation is very very bad.

The inorganic fraction is represented by very abundant to very scarce argillaceous elements, abundant to very abundant micas (upper levels), scarce arenaceous granules (lower levels), scarce to very abundant quartz, scarce to

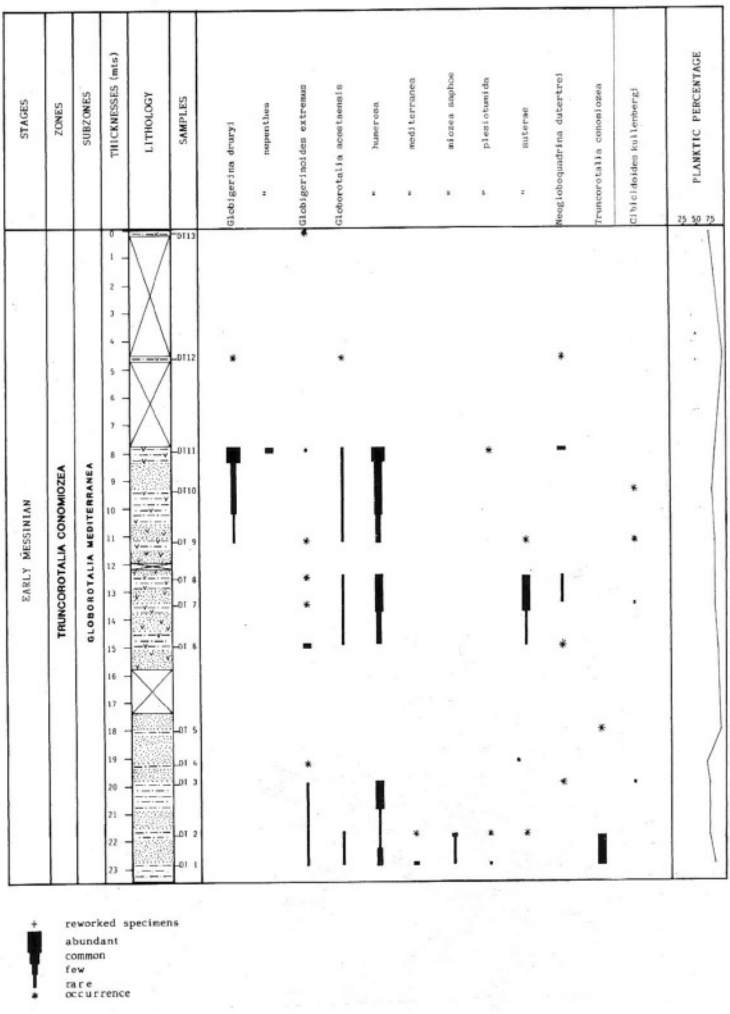


Fig. 7 – Occurrence of selected species in samples from Diga al Lago della Trinità section.

abundant calcite, very scarce pyrite, scarce limonitic concretions and very scarce carbonaceous fragments (lower levels).

Diga al Lago della Trinità section (Fig. 7).

The microfaunal assemblages found in these sediments are referable to the *Truncorotalia conomiozea* Zone – *Globorotalia mediterranea* Subzone. Therefore, the whole sequence results sedimented during the Early Messinian. No age –diagnostic benthic foraminifers were found within this interval.

Rich to poor microfaunal assemblages (very poor in DT 4 and DT 12).

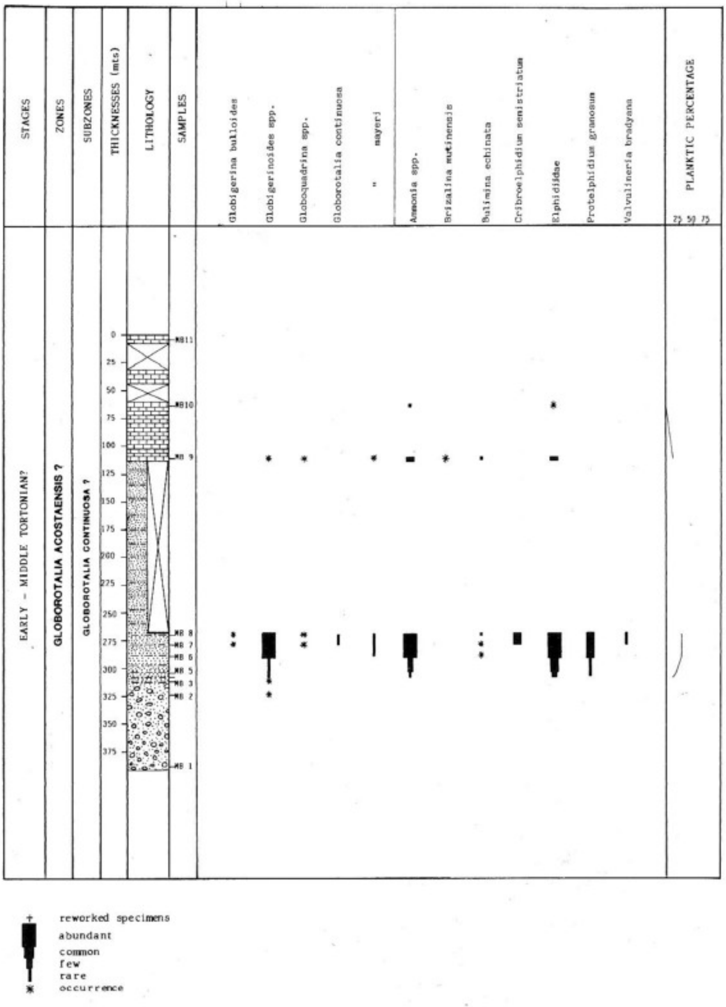


Fig. 8 – Occurrence of selected species in samples from Monte Baronia section.

Preservation generally good, but fair to bad in DT 4, DT 5, DT 12 and DT 13. Specimens are usually rather small.

Very abundant quartz, abundant calcite, scarce to very abundant arenaceous granules, abundant to scarce micas (limitedly to DT 11, DT 12 and DT 13), scarce to very scarce limonitic concretions, very scarce to very abundant gypsum and abundant anhydrite crystals and very scarce glauconite and carbonaceous fragments compose the inorganic fraction.

Monte Baronia section (Fig. 8).

The trivial microfauna present in the sediments that compose this sequence did not allow sure dating. This was made even harder by the occurrence of quite an amount of Early–Middle Miocene species mixed up with rare to sporadic more recent taxa. As a matter of fact, the most significant species here recovered are *Globigerina bulloides, Globorotalia acrostoma, G. mayeri* and, among the benthic foraminifers, *Brizalina mutinensis.* The latter is known to straddle the Tortonian/Messinian boundary; however, it is represented by only one specimen in sample MB 9, at the base of the upper limestone that composes the second member of this sequence. Therefore, we cannot tell whether this occurrence is effective or due to contamination. Nevertheless, the limestones could be supposed sedimented during Late Miocene times.

The sediments of the lower, first member are even more problematic. *Globigerina bulloides* is barely present with two specimens, one in MB 7 and the other in MB 8. These two samples bear also rare specimens of *Globorotalia continuosa* and *G. mayeri*, while *G. acrostoma* is common. By literature, *Globigerina bulloides* is never reported in sediments older than the Tortonian. Therefore, if its occurrence is not the result of contamination, it should be concluded that *Globorotalia acrostoma* and *G. mayeri* are reworked, and that, because of the presence of *G. continuosa*, the sequence sedimented during Early to Middle Tortonian times. *Globigerinoides trilobus* is the only abundant planktic species recovered in few levels of the second member. On the whole, the microfaunal assemblage of this section is very poor and bad preserved.

The inorganic fraction consists of very abundant quartz and calcite, scarce to abundant arenaceous granules and limonitic concretions and abundant to scarce or very scarce micas. Limitedly to the lower member, also abundant argillaceous elements, very scarce to scarce glauconite and scarce to abundant carbonaceous fragments must be reported.

Ca' di Marchese section (Fig. 9).

Also this section like that of Monte Baronia was quite hard to date, mostly because of the presence of a larger amount of reworked Cretaceous, Paleogene and Early–Middle Miocene species. In this case, however, unlike Monte Baronia section, rare diagnostic taxa, such as *Globigerinoides extremus, Globorotalia acostaensis, G. continuosa, G. plesiotumida* and *Sphaeroidinellopsis seminulina*, referable to the lower part of the *Globigerinoides extremus* Subzone, point out that the sedimentation took place during the Middle Tortonian. *Uvigerina barbatula* also characterizes these sediments. The microfaunal assemblages are poor to very bad preserved.

Very abundant arenaceous granules and quartz, very scarce to scarce carbonaceous fragments and very scarce to scarce gypsum and anhydrite crystals (in the upper samples, from CM 11 to CM 17) make up the inorganic fraction. Scarce dolomite occurs in CM 15.

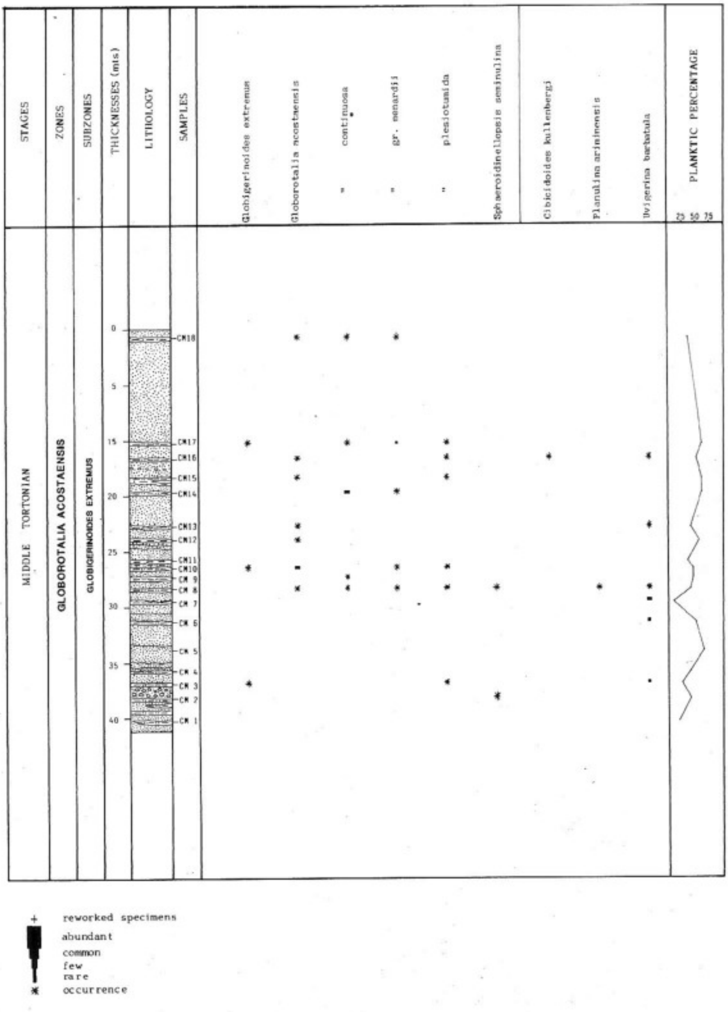


Fig. 9 – Occurrence of selected species in samples from Ca' di Marchese section.

S. Cipirello section (Fig. 10).

According to Ruggieri and Sprovieri (1970), these marls represent the top–most sediments of the local paleoautochthonous sequence. They were assigned by the two Authors to the Middle–Late Miocene (Serravallian–Middle Tortonian). Unfortunately, as acknowledged by the Authors themselves, the exposure is very bad, very reduced and discontinuous, because of the extremely chaotic structural setting of the area that resulted from the overthrust of the Sicilid Complex sediments and the following superimposition of the Pliocene extensional tectonics.

In order to compare the features of these marls with those of the neo-

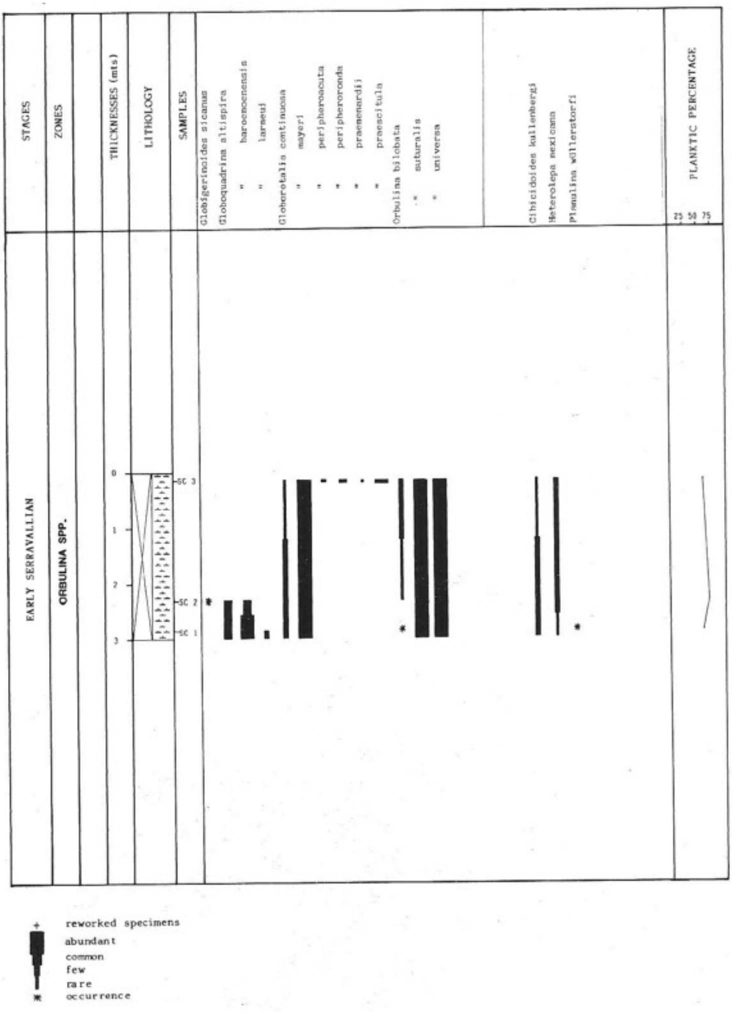


Fig. 10 – Occurrence of selected species in samples from S. Cipirello section.

autochthonous sediments of the Terravecchia Formation, a sampling was carried out in the S. Cipirello Marls outcropping areas indicated by Ruggieri and Sprovieri. The exposures found were far worse than described by the Authors and only three samples could be collected. These bear a typical Late Langhian–Early Serravallian assemblage, characterized by *Globigerinoides sicanus, Globoquadrina* spp., *Globorotalia continuosa, G. mayeri, G. peripheroacuta, G. peripheroronda, G. praemenardii, G. praescitula* and *Orbulina* spp., referable to the lower part of the *Orbulina* spp. Zone.

Globigerinoides quadrilobatus, G. ruber, G. trilobus, Globorotalia gr. *scitula, Orbulina suturalis* and *O. universa* are the most frequent taxa. *Heterolepa*

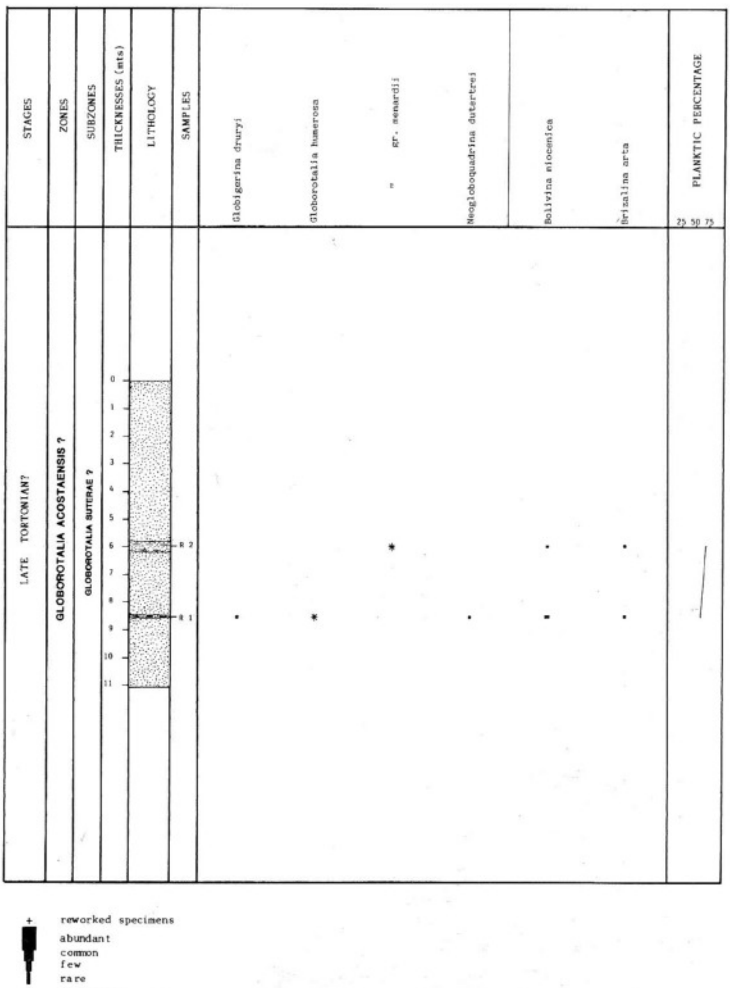


Fig. 11 – Occurrence of selected species in samples from Resuttano section.

mexicana characterizes the benthic assemblage. The microfaunal assemblage is very rich and excellently preserved.

The inorganic fraction consists of very abundant argillaceous elements, scarce calcite and pyrite and very scarce glauconite, limonitic concretions and carbonaceous fragments.

Resuttano section (Fig. 11).

The two samples collected from this outcrop bear a very rich microfaunal assemblage though devoid of highly indicative forms. The only noteworthy planktic taxa are *Globorotalia humerosa, G.* gr. *menardii* and *Neogloboquadrina dutertrei*, while, among the benthic foraminifers *Bolivina miocenica* and *Brizalina arta* can be mentioned. The range of all these species straddles the Tortonian/Messinian boundary; therefore, the age of sedimentation can't be exactly specified. The lack of suitable nearby sections or boreholes did not allow any kind of lithologic correlation either.

Since *Neogloboquadrina dutertrei* appears within the Late Tortonian *Globorotalia suterae* Subzone, the Resuttano outcrop is tentatively referred to this time interval, although this arbitrary attribution is acknowledged to be fully questionable.

Fair preservation. The inorganic fraction is composed of very abundant quartz, abundant calcite and micas and scarce carbonaceous fragments.

Cozzo Gracello–Imera River section (Fig. 12).

This very interesting transgressive sequence displays a complete, gradual transition from continental, fluvial deposits to marine sediments, as evidenced by the macroscopic sedimentologic features of the following beds. Microscopically, the lower samples, from GI 1 to GI 10, are thoroughly barren of fossils, while a rich microfaunal assemblage suddendly appears in GI 11 and then characterizes all the following samples, although with most variable abundances. These microfaunas are dominated by benthic species; planktic foraminifers, when present, are few and represented by trivial taxa.

Among the numerous benthic forms, *Bulimina echinata* and *Spiroplectammina carinata* are particularly distinctive. The former occurs in GI 22, while the latter ranges from GI 17 to GI 20. Since *Bulimina echinata* marks the Messinian Stage and *Spiroplectammina carinata* is here believed to characterize the Tortonian, as elsewhere mentioned, this section results straddling the Tortonian/Messinian boundary, the transition taking place between samples GI 20 and GI 22.

The most representative planktic species are *Globigerinoides extremus, G. seigliei, Globorotalia humerosa* and *Neogloboquadrina dutertrei*, all forms that range from Tortonian to Messinian times.

The microfaunal assemblages are rich in samples GI 11, GI 15 to GI 23 and GI 26, poor to very poor elsewhere. Preservation is bad in the lowermost samples and improves upwards.

The inorganic fraction consists of very abundant quartz, very abundant to scarce or abundant arenaceous granules, very abundant calcite, variable amounts of carbonaceous fragments, scarce pyrite and argillaceous elements, scarce to very scarce gypsum and/or anhydrite crystals (in samples GI 16, GI 18, GI 19, GI 21 and GI 22), abundant or very abundant limonitic concretions (from GI 21 upwards) and very scarce glauconite (only in GI 24).

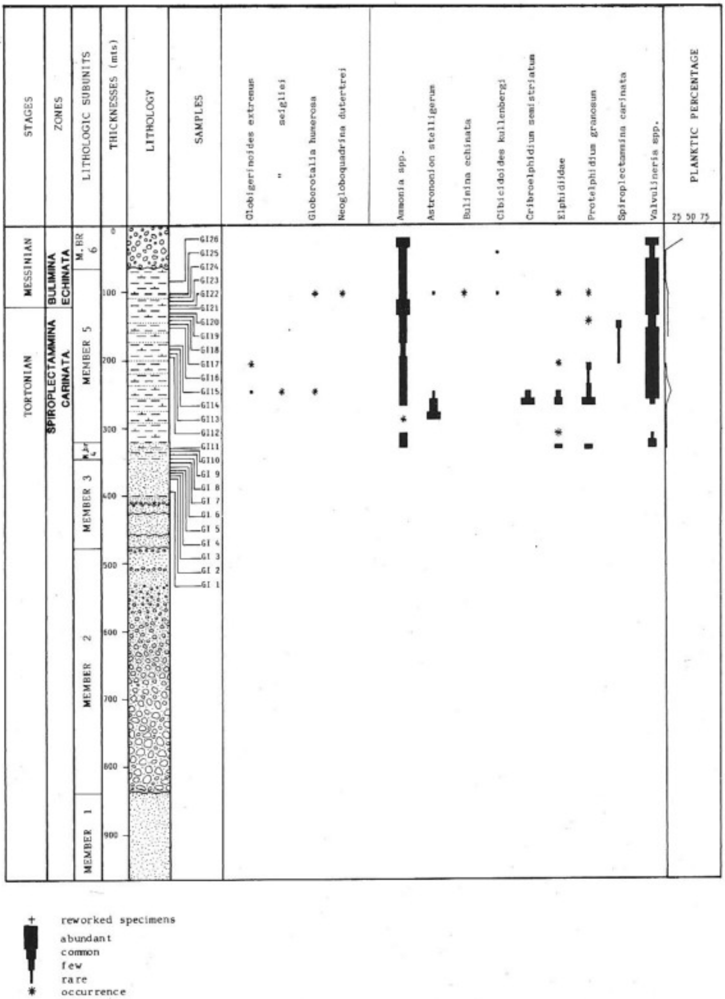


Fig. 12 – Occurrence of selected species in samples from Cozzo Gracello–Imera River section.

Ca' Pestavecchia section (Fig. 13).

The microfaunal assemblages recovered are referable to the *Truncorotalia conomiozea* ? Zone – *Globigerina multiloba* Subzone. Therefore, the whole sampled sequence results sedimented during the Middle–Late Messinian.

The most diagnostic planktic species is *Globigerina multiloba* (common in CP 3, occurrence in CP 4); the zonal marker was not found in these samples. The attribution to the Messinian was further inferred from the occurrence of *Brizalina multinensis*, but most of all from *Bulimina echinata*. The microfaunal assemblages are poor and usually composed of small specimens; preservation is

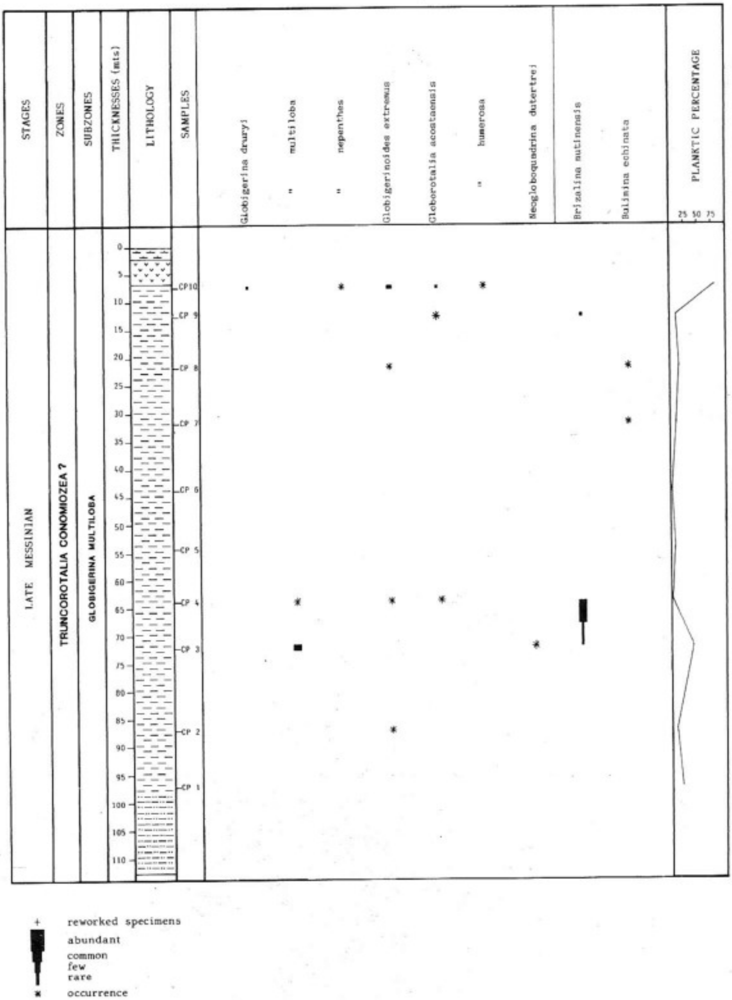


Fig. 13 – Occurrence of selected species in samples from Ca' Pestavecchia section.

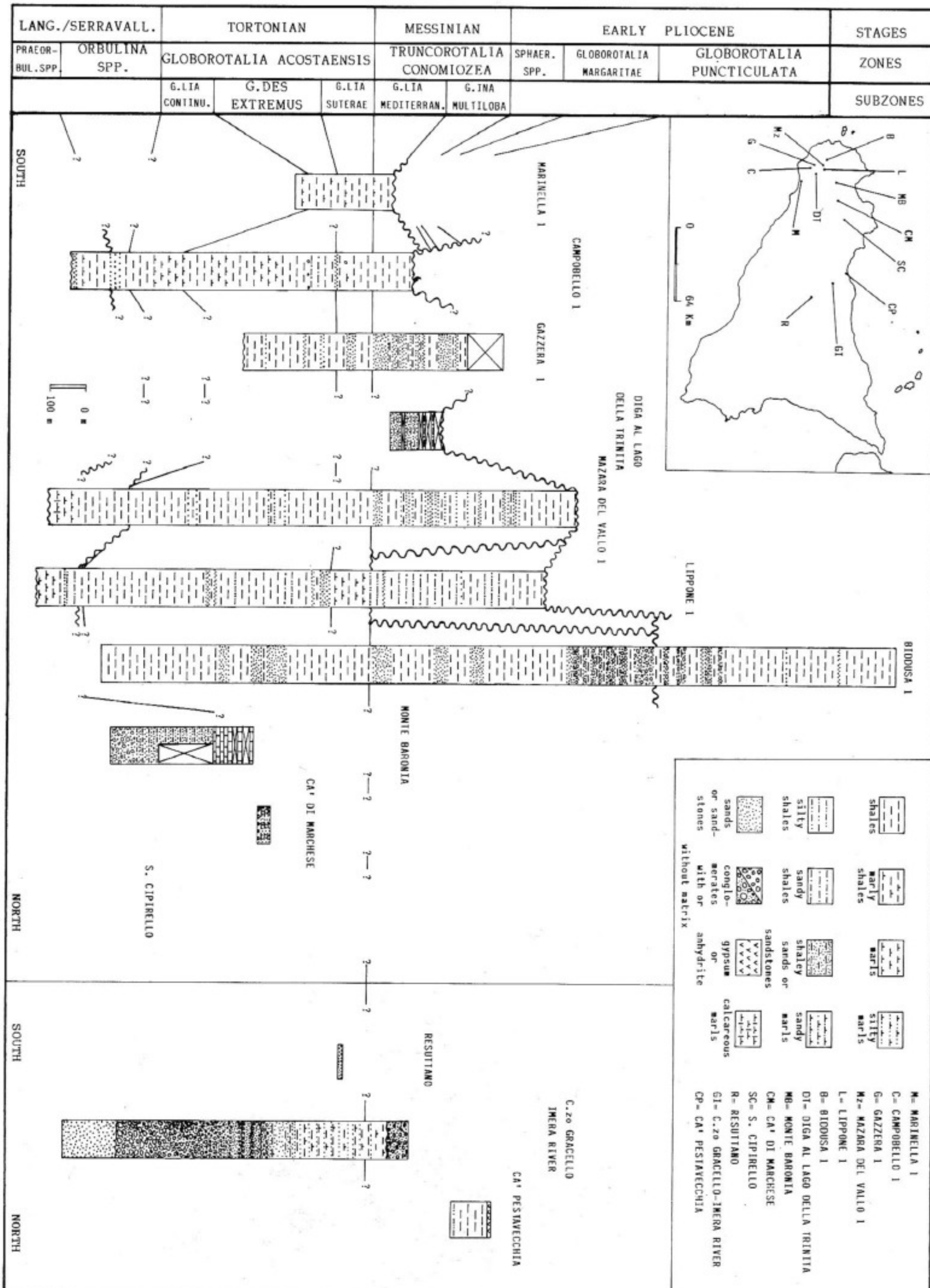


Fig. 14 – Correlation chart of Neogene subsurface and outcropping sequences of western and central–northern Sicily, for the most part referable to the Terravecchia Formation.

variable in the lower half of the sequence, good in the upper. A very rich and diversified macrofauna characterizes these sediments.

Abundant to very abundant gypsum, very abundant anhydrite crystals (in CP 10), abundant to very abundant argillaceous elements, arenaceous granules, quartz and calcite, variable amounts of micas, abundant carbonaceous fragments, very scarce to scarce glauconite, scarce to abundant pyrite, abundant to scarce limonitic concretions and very abundant dolomite (in CP 5) compose the inorganic fraction.

Paleoenvironmental considerations

The average sedimentation depths here proposed are the result of the comparison of several different parameters, such as occurring benthic foraminiferal assemblages, relative planktic percentages, lithologic/sedimentologic features, rock body thicknesses and composition of the macrofauna and inorganic fraction in the washed samples.

The reference works for the paleobathymetric interpretation of the benthic foraminiferal assemblages have been Berggren & Haq (1976), Caralp, Lamy & Pujos (1970), Murray (1971, 1973), Cita & Zocchi (1978) and Wright (1978). Relatively to other environmental factors (temperature, salinity, oxygenation, turbidity etc.) the main reference works have been Loeblich et al. (1957), Loeblich & Tappan (1964) and Phleger & Parker (1951). The paleodepths computed were each time compared with all the parameters over mentioned, in order to test their consistency. And this particularly dealing with the well ditch samples, as the long time range of most benthic species rarely allowed to tell whether eventually reworked or, even worse, caved specimens occurred. For this, the planktic percentages and the possible occurrence of deep habitat indicators in ditch samples were rarely thought trustworthy, relying mostly on the closest core sample data.

The bathymetric zonation here used is as follows:

inner shelf	0–50 m
outer shelf	50–180 ÷ 200 m
upper epibathyal	180 ÷ 200 – 500 ÷ 700 m
lower epibathyal	500 ÷ 700 – 1300 ÷ 1500 m

The main benthic assemblages here used to estimate paleobathymetry were:

Nonion sp., *Cancris* sp., *Textulariidae*, that mostly characterize the shelf environment as a whole; in particular *Elphidium* spp., *Ammonia* spp., *Florilus* spp., *Cribroelphidium semistriatum* and *Protelphidium* spp. range at inner shelf depths, while *Valvulineria* spp., *Amphicoryna scalaris, Astrononion stelligerum, Melonis soldanii, Cassidulina* spp, *Haplophragmoidinae, Cassidulina* *neocarinata, Brizalina spathulata* are characteristic of the outer shelf.

The epibathyal environment as a whole is suggested by the occurrence of *Bulimina aculeata, Pullenia bulloides, Melonis* spp. and *Heterolepa floridana*; in particular *Brizalina dilatata, Cibicides refulgens, Bolivina albatrossi, Siphonina reticulata, Pyrgo* sp., *Sphaeroidina bulloides, Martinottiella communis, Uvigerina striatissima, Cibicidoides italicus, Planulina ariminensis, Cyclammininae, Anomalinoides flinti, A. helicinus* and *Oridorsalis umbonatus* dwell at upper epibathyal depths, while *Bulimina* cf. *B. inflata, Planulina wuellerstorfi* and *Cibicidoides kullenbergi* range at lower epibathyal depths.

No mesobathyal marker was found in these sediments.

Lower epibathyal conditions of about 800 ÷ 1000 m of depth are suggested by the occurrence of deep sea dwelling benthic assemblages, mainly characterized by *Planulina wuellerstorfi, Cibicidoides kullenbergi* and *Bulimina* cf. *B. inflata*. Such assemblages were met in the Lower Serravallian beds of wells Mazara del Vallo 1, Lippone 1 and of S. Cipirello section, in the Tortonian sediments of all the wells and of Resuttano section and in the Messinian deposits of all the wells and of Diga al Lago della Trinità section.

The turbiditic Tortonian sediments of Ca' di Marchese section probably accumulated in the upper part of a lower epibathyal environment, at about 600 to 800 m of depth, as can be inferred from the extreme scarcity of deep dwelling taxa.

The whole Messinian Ca' Pestavecchia section laid down in an upper epibathyal environment, as suggested by the high frequency of *Bulimina aculeata* and by the occurrence of *Siphonina reticulata* and *Pyrgo* sp.

A typical shelf microfauna (*Astrononion stelligerum, Valvulineria bradyana, Elphidium* spp., *Ammonia beccarii, Cribroelphidium semistriatum, Protelphidium granosum, Textulariidae, Florilus* spp., *Cancris* sp.) characterizes all the samples of Monte Baronia section.

Few, local, more or less intense regressive and transgressive episodes took place in different times.

The lower part of the Langhian/Lower Serravallian section of well Campobello 1 deposited in an upper epibathyal environment, as can be inferred from the occurrence of *Siphonina reticulata, Heterolepa floridana, Sphaeroidina bulloides, Martinottiella communis, Uvigerina striatissima* and *Anomalinoides helicinus.* A slight sea bottom deepening took place when the topmost Langhian/Lower Serravallian levels laid down and this sinking increased even more during the Late Serravallian and the Early–Middle Tortonian, stabilizing, from then on, at lower epibathyal depths.

In the lower part of the Tortonian beds of well Gazzara 1 a slight and brief regressive episode seems inferable from an upward disappearance of the typical deep taxa and from quite an increase of upper epibathyal forms.

A similar, gradual upward rarefaction of deep dwelling taxa was observed also in the Messinian beds of well Mazara del Vallo 1, but upper epibathyal species do not occur in this case. This could indicate that the sea bottom approached the upper depth limits of most of the deep taxa, ranging from about 600 to 800 m.

Two regressive events can be emphasized by the analysis of the benthic microfaunas of well Lippone 1, the first at the time when the uppermost Lower Serravallian deposits sedimented and the other during the Latest Tortonian. The latter surely went on along the whole Messinian, as the Upper Messinian sediments of this well bear common *Planulina ariminensis* and rare *Bolivina albatrossi* together with a rich, shallow water assemblage reworked from the shelf environment. At the end of the Messinian the sedimentation depth probably ranged at about 500 ÷ 600 m.

A striking regressive episode, however, is recorded by the Early Messinian assemblages of well Biddusa 1. All the deep taxa that occur in the Tortonian beds of this well disappear, replaced, at first, by few to sporadic *Uvigerina striatissima, Cyclammininae, Anomalinoides flinti, A. helicinus, Planulina ariminensis, Brizalina dilatata, Oridorsalis umbonatus, Martinottiella communis, Cibicidoides italicus* and *Pullenia bulloides* and then only by rare to sporadic *Ammonia beccarii, Valvulineria complanata, Cassidulina laevigata, Trifarina bradyi, Protelphidium tuberculatum, Textulariidae* and *Elphidiidae*. At about 780 m subsidence increased again as testified by the reappearance of sporadic to few specimens of typical upper epibathyal species, followed, at about 590 m, by lower epibathyal markers.

The lowermost levels of Diga al Lago della Trinità section settled down in an upper epibathyal environment, at about 300 + 500 m of depth, as suggested by the occurrence of common *Planulina ariminensis* and by the absence of any other deeper taxa. Upwards, a strong deepening results by the sporadic occurrence of rare *Cibicidoides kullenbergi*.

Most of this section laid down in a lower epibathyal environment, as mentioned far above. A regression interested this area when the topmost beds accumulated; as a matter of fact, these sediments contain only upper epibathyal species.

At last, concerning Cozzo Gracello–Imera River section the top beds of the fifth member resulted being the only sure marine portion of this section. These provided fairly rich benthic assemblages that indicate, at first, a rapid sea bottom subsidence and then, in the topmost levels, an even more rapid sea regression. In the lowermost fauna bearing samples (GI 11–GI 15) *Valvulineria* spp., *Ammonia* spp., *Florilus* spp., *Astrononion stelligerum, Protelphidium granosum, Elphidium* spp., *Brizalina spathulata, Nonion* sp., *Cancris oblongus* and *Cribroelphidium* spp. are frequent; *Haplophragmoidinae* and *Textulariidae* are sporadic to common; *Cibicides refulgens* and *Bulimina aculeata* (which appears in GI 14) are rare to few; *Heterolepa floridana* is present with few specimens only in GI 11 and *Martinottiella communis* and *Amphicoryna scalaris* occur in GI 15. This assemblage suggests a sinking from an inner to an outer shelf environment and therefore sedimentation depths from 0 ÷ 50 m to about 150 m.

From GI 16 to GI 21 a further sea bottom sinking from 150 ÷ 200 m to about 500 ÷ 700 m of depth is inferred from a sudden appearance of *Melonis soldanii, M.* cf. *M. pompilioides* and *Cassidulina neocarinata* (that altogether suggest deepest shelf depths and shallowest bathyal depths), a high abundance of *Haplophragmoidinae* (indicative of deepest shelf depths) and a remarkable increase in abundance of *Cibicides refulgens* and *Heterolepa floridana.* This transgressive event tops in the following four samples (GI 22–GI 25) in which rare *Cibicidoides kullenbergi* occur, *Heterolepa floridana* becomes very abundant (this suggests 600 – 800 ÷ 900 m of depth) and *Melonis* spp. are more or less common. All this points out sedimentation depths of about 800 ÷ 1000 m.

The top sample, GI 26, lacks all these deep indicators and bears, instead, a faunal assemblage very similar to that of samples GI 11 –GI 15.

Usually, most of these regressive episodes are consistently marked by the occurrence or an increase of coarser intercalations which could indicate much closer source areas.

In the area of the wells there is a discrete increase in abundance and diversification of the benthic foraminiferal assemblages from south (Marinella 1) to north (Biddusa 1). Relying on the planktic foraminifers, the waters were probably temperate to warm, since warm–water indicators, such as *Orbulina universa, Globigerinoides ruber, G. sacculifer,* keeled Globorotalias, etc. tend to prevail on cooler markers (e.g. *Neogloboquadrina dutertrei*). Slightly cooler conditions seem inferable only from the microfaunas of wells Gazzera 1 and Biddusa 1 and Ca' di Marchese section.

Water salinity might have been high when the Tortonian–Messinian sediments of well Marinella 1 and the Messinian beds of well Biddusa 1 and of Diga al Lago della Trinità and Ca' Pestavecchia sections laid down, as can be inferred from the richness in evaporitic crystals and from the reduced dimensions of the fossil content. However, in well Biddusa 1 and Diga al Lago della Trinità section the evaporitic crystals appear worn and abraded, suggesting that they may be reworked consistently with the lithologic features of these sequences.

In Cozzo Gracello–Imera River section water salinity was normal during the Tortonian and probably slightly higher in the Messinian, relying on the scarce evaporitic crystals that occur at some levels. In the remnant parts of the sequence salinity was most likely normal.

Water turbidity was probably high in most of the areas because of the abundance of coarse–grained supply. Better conditions may infer for wells Marinella 1 and Campobello 1 and for S. Cipirello section, where coarse–

grained supply is rare and foraminifers, both planktic and benthic, are well developed.

The planktic percentage is often consistent with paleobathymetric observations seen so far. However, in the wells and in all the sequences composed of turbiditic sediments, such as Ca' di Marchese, for instance, the planktic percentage seems rather affected by resedimentation and/or caving.

Tentative reconstruction of the Terravecchia basin's evolution

On the base of both chronostratigraphic and paleobathymetric data, an extremely schematic reconstruction of the paleogeographic evolution of the Salemi–Castelvetrano basin and of western and central–northern Sicily in general, from the Serravallian s.l. to the Preevaporitic Messinian, was tentatively accomplished. This was made possible by integrating the here achieved data with any others from literature.

The reconstruction is summarized on four maps (Fig. 15) showing the main geologic events in the western areas during the Serravallian s.l., the Early Tortonian, the Middle–Late Tortonian and the Preevaporitic Messinian.

Serravallian s.l.

According to Giunta and Liguori (1972), during the Early Miocene the Trapanese domain was characterized by widespread pelagic argillaceous sediments suggestive of a rather deep and monotonous depositional environment. These sediments seem referable to the S. Cipirello Marls Auct., that the two Authors report in two sections located respectively at Monte Inici and at Montagna Grande.

The only Serravallian deposits recovered in the wells and sections here studied are those of wells Campobello 1, Mazara del Vallo 1, Lippone 1 and S. Cipirello section. The sedimentation depths of these beds were actually the same or very similar in the Mazara del Vallo 1, Lippone 1 and S. Cipirello areas, while they were shallower in the Campobello 1 area. This states for the probable existence of a paleohigh that could be responsible for the discontinuity of the Serravallian sediments in well Campobello 1.

Concerning central–northern Sicily, Catalano and Montanari (1979) report the occurrence of Serravallian–Lower Tortonian clayey–sandy marls of the S. Cipirello Fm.; they also talk about a connection between the Trapanese and the eastern, adjacent Sicani areas in a unique basin characterized by terrigenous–carbonatic supplies.

Thus, during the Serravallian, facies progressively evened within the Trapanese and the Sicani domains, with a generalized deposition of more or less clayey and, at times, silty–sandy deep sea marls.

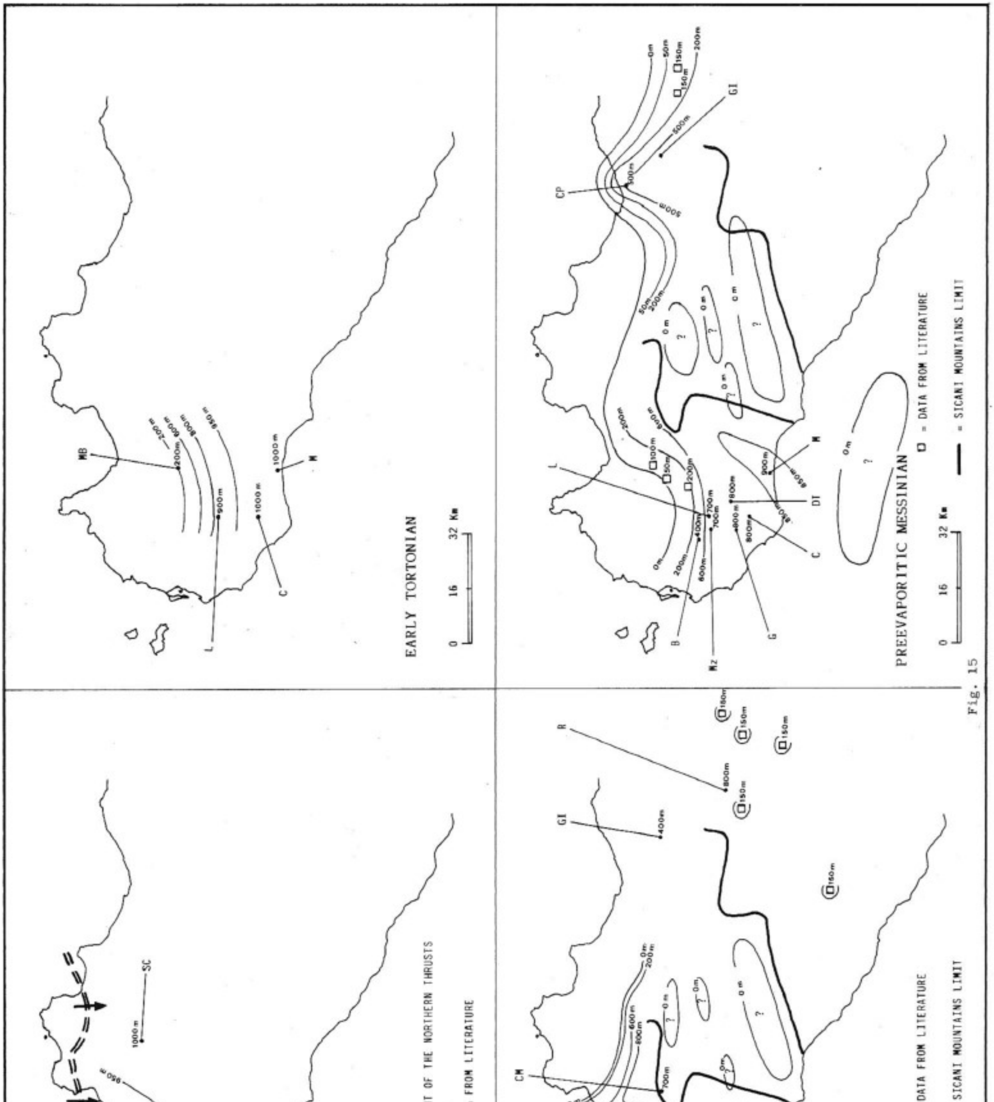


Fig. 15 — Tentative reconstruction of the physiographic evolution of western Sicily throughout the Middle–Late Miocene.

Throughout the Langhian and Early Tortonian a strong compressional event affected these areas. The deformation of the northern domains gave rise to allochthonous units that slided southwards. Several of these allochthonous sheets plunged into the subsiding Trapanese area; so, it is ever since these times that the Trapanese domain attained foredeep characteristics.

Early Tortonian.

The crustal contractions in the western areas, as well as in many other parts of Sicily, reached their climax during the Late Serravallian and Early Tortonian. The deformation of the Salemi–Castelvetrano basin sea floor became more and more intense. The northern borders of the basin underwent a severe uplifting, while the southern areas furtherly sank.

In the central–northern areas some Trapanese allochthonous units, already outlined at the end of the Serravallian, overthrusted the deposits of the Sicani area. These strong tectonic modifications caused a general starvation of many previous sedimentation sites; as a matter of fact, the Upper Serravallian and Lower Tortonian sediments are poorly represented or totally lacking in most of the wells and sections here studied, as well as in other onshore or offshore Sicilian areas. This sedimentation gap is also reported in many Tunisian sections.

Early Tortonian sediments were only found in wells Marinella 1, Campobello 1, Lippone 1 and in Monte Baronia section, although the age of deposition of the latter is doubtful.

Middle–Late Tortonian.

The complex morphology of the Salemi–Castelvetrano basin during the Middle–Late Tortonian was probably inherited, with slight differences, from that attained during the Late Serravallian and Early Tortonian, although the latter is very hard to reconstruct because of the scanty data available. The sea bottom deformation gradually wore out during this time and sedimentation started again in most areas.

A relative high, that already existed in the Campobello 1 – Gazzera 1 area during the Serravallian, was restored in the southwesternmost part of the basin. The basin's deepest belt bordered the northern, eastern and southern flanks of this paleohigh, stretching then towards NE. This is inferred from the paleobathymetric data of wells Marinella 1, Mazara del Vallo 1 and Lippone 1 and from what can be found in literature (deep sea shales are reported in a SW–NE trending belt from Marinella 1 towards the present day Gibellina, Poggioreale, Salaparuta, Partanna and S. Ninfa areas).

Towards the north, a steep slope led to the broad emerged areas of the then just formed Northern Mount System. Such a transition is testified by the occurrence of coarser and coarser sediments and by faunal assemblages characteristic of progressively shallower environments. Fluvial sediments are present at the foot of the northern chain.

While in these western areas no remarkable horizontal translations occurred in this time (only local slumps and other restricted gravitational events are reported in literature), the orogenic southward migrating compressional wave reached the Sicani domain giving rise to several tectonic scales that overlapped one another towards south, overthrusting, at last, the deposits of the nearby Saccense domain.

This peculiar tectonic history and the kind and distribution of Tortonian sediments (shales, sandy shales, sands and conglomerates) induce to believe that few emersed WSW–ENE elongated areas, separated by narrow and shallow arms of sea, existed in these times in the Sicani domain. These areas were probably the emerged tops of some of the overmentioned tectonic scales. The distinct tectonic behaviour of the Trapanese with respect to the Sicani area seems due to the existence of transversal lineaments across the Northern Mount System which favoured differential displacements (Catalano & D'Argenio, 1978).

The Salemi–Castelvetrano basin was thus delimited, at north, by the broad emerged areas of the Northern Mount System, through which a narrow channel, in the area of today's Castellamare Gulf, represented the only connection with the northern sea, and at east, by the just then forming Sicani Mountains. At south and at west the Salemi–Castelvetrano basin comunicated with the open sea respectively through an outlet in the Sciacca–Castelvetrano and in the Marsala areas.

At last, much more at east, in the Cozzo Gracello, Caltavuturo, Sclafani Bagni and Serra Tignino, Valledolmo and Vallelunga areas sandstone and conglomeratic sediments prevail. Sporadic patch reefs occur at Villadoro, Portella del Landro, Villapriolo, Capodarso and Grotte (Catalano, 1979).

According to Catalano, the Caltanissetta parallel represents an ideal limit between a northern domain, characterized by generally coarse–grained sediments, among which also pelagic marls or shales occasionally occur, and a southern domain, in which shales decidedly prevail. This gross subdivision is also valid within the Salemi– Castelvetrano basin: shaley sediments dominate in the southernmost areas (Marinella 1, Campobello 1, Gazzera 1, Mazara del Vallo 1), while sandy shales, sands (Lippone 1, Biddusa 1, Ca' di Marchese) and, at last, conglomerates become more and more frequent northwards, that is, towards the supplying areas. Thicknesses grow consistently towards north as well.

A weak marine regression began during the Late Tortonian; it became more intense during the Messinian topping at last with the deposition of the evaporitic beds of the Gessoso–Solfifera Formation. This regression is clearly denoted by a generalized seaward progradation of the shallower litho– and biofacies.

Preevaporitic Messinian.

The Messinian sea withdrawal called for a generalized widening of the already emerged areas and, instead, for a shrinking of the deepest environments and of the various sea arms seen in the Middle–Late Tortonian. In the northern border of the Salemi–Castelvetrano basin, for instance, the previously emerged areas merged closing the channel of the Castellamare Gulf and giving rise to a continuous E–W stretched continental area, whereas at south only a remnant of the Tortonian deepest belt occurred, stretched NNE–SSW along what today is the Belice valley.

Catalano (1979), founding on the presence of reefs, suggests the occurrence of a probably emerged foreland area off the present day southwestern coast. The overmentioned continental area, that limited the Salemi–Castelvetrano basin at north, continued towards east at least till beyond Cefalú. This is testified by the presence of shallow water sediments and patch–reefs both in the Baucina–Ciminna and in the Petralia–Gangi areas, while in between, at Ca' Pestavecchia, some kind of a gulf existed, since deeper Messinian deposits occur.

Conclusions

By a chronological point of view, the here studied deposits sedimented between the Langhian–Earliest Serravallian and the Early Pliocene (Fig. 14). However, sedimentation was not continuous throughout this long time lapse. An important and rather generalized sedimentation gap took place during the Late Serravallian and the Early Tortonian, shifting within this time interval from place to place in accordance with the basin's physiographic features and with the sediment supply. In the well Campobello 1, the unconformity occurs between the (Langhian?) Lower Serravallian and the Upper Serravallian deposits, while in the wells Mazara del Vallo 1 and Lippone 1 the sedimentation gap took place during the Late Serravallian and the Early Tortonian. As a matter of fact, the sediments of this age are totally missing or are only few meters thick in those two wells.

Other evident hiatuses were found in the wells Lippone 1, where Upper Tortonian deposits come in direct contact with Upper Messinian beds, and Biddusa 1, in which there is an abrupt transition from Lower Messinian to Lower Pliocene sediments. The former concerns a very short lapse of time.

The lack of Lower Messinian sediments in well Lippone 1 is probably not due to a supply interruption, but to the removal of already accumulated deposits. As a matter of fact, a slope environment most probably existed, during the Latest Tortonian and the Early Messinian, in the area in which well Lippone 1 was drilled. Furthermore, the Upper Messinian sediments of this well do not belong to a new sedimentary cycle. Therefore the Upper Messinian deposits of well Lippone 1 do pertain to the Terravecchia Formation. On the contrary, the hiatus of well Biddusa 1 spans a longer time interval. The Lower Messinian beds of this well close with a marked regression. The overlying Lower Pliocene deposits clearly start a new sedimentary cycle, with shallow marine sediments that rapidly pass, upwards, to lower epibathyal deposits. Therefore the Lower Pliocene beds of well Biddusa 1 do not belong to the Terravecchia Formation.

On the whole, after the main interruption during the Late Serravallian/Early Tortonian, the sedimentation seems to have been continuous up till the Late Messinian. It can therefore be concluded that the Terravecchia Formation is a typical, postorogenic molassic deposit. It accumulated during the long Upper Serravallian/Lower Tortonian – Upper Messinian sedimentary cycle, that began with the parossistic event of the Alpine Orogenesis in Sicily and ended with the great Messinian sea withdrawal.

The S. Cipirello Marls represent the most recent deposits of the sedimentary cycle that immediately precedes the Alpine orogenic event. Therefore this formation ranges in age from the Serravallian to the Early Tortonian. The sedimentation of these marls probably continued in some protected parts of the western basin, where previous preorogenic conditions temporarily maintained. Elsewhere the oldest deposits of the postorogenic Terravecchia Formation already began to accumulate. The marly beds that underlie the main Serravallian/Early Tortonian unconformity in the wells Campobello 1, Mazara del Vallo 1 and Lippone 1 could most likely be ascribed to the S. Cipirello Marls.

Concerning the sedimentation environment of the Terravecchia Formation it was substantially the same as that reported in literature for the same kind of sediments from the Caltanissetta basin. As a matter of fact, a marked transition from fluviatile down to lower epibathyal marine deposits of about 1000 m of depth or more can be evidenced, from north to south, in the Salemi–Castelvetrano basin, by sedimentologic, lithologic and biologic features.

The physiographic reconstruction of the Salemi–Castelvetrano basin during the Serravallian s.l. is very incomplete because of the scarce available data. Except for a relative high in the southernmost areas, in this time the Salemi–Castelvetrano basin displayed rather uniform depositional conditions. In the Early Tortonian, the definitive arrival of southward gliding allochthonous sheets originated by the deformation of the northern domains deeply modified the original setting. A gently dipping slope connected the most probably emerged northern areas with the southern deep sea ones. Such a slope still existed in the Middle–Late Tortonian. It contoured a northern, this time surely emerged area that represented the northwestern border of the basin. Another emerged area stretched in a WNW–ESE trend was represented by the just formed Palermo Mountains. These two emerged areas were separated by a channel approximately stretched in today's Castellamare Gulf. Also the Sicani Mountains allochthonous sheets were piling one on the other towards south, thus forming the eastern flank of the Salemi–Castelvetrano basin. A weak sea floor relief probably existed in the Gazzera–Campobello area. At last, during the Messinian the generalized sea withdrawal caused an expansion of the previous Tortonian isopic facies and the closure of the Castellamare Gulf channel. The southern border of the Salemi–Castelvetrano basin was probably represented by an emerged area in today's Sciacca offshore.

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ABUNDANT ○ = COMMON + = FEW ▪ = RARE ✱ = OCCURRENCE P = PLIOCENE M = MESSINIAN T = TORTONIAN S = SERRAVALLIAN L

SELECTED MICROFAUNAL SPECIES AND MACROFAUNA / WELLS SECTIONS	PESTAVECCHIA	IMERA RIVER	ZO GRACELLO -	RESUTTANO	CIPIRELLO	A' di MARCHESE	MONTE BARONIA	di LAGO TRINITÀ	BIDDUSA 1			LIPPONE 1			MAZARA DEL VALLO 1			GAZZERA 1		AMPOBELLO 1			MARINELLA 1	
Globigerina bulloides	+	✱	○	▪		▪	✱	+	▪	+	▪		○	+		○	○	○	▪		○	○	○	●
" druryi	▪			▪	▪	▪		○	▪	▪	▪	▪	+	+	✱	▪	▪	▪	▪	▪	▪	+	▪	
" foliata	▪	✱	✱	▪		▪	▪	▪	✱			○	▪	▪		○		▪	▪	▪	+	▪	+	▪
" multiloba	+													✱										
" nepenthes	✱							○	✱	✱	▪		+	✱		✱	▪	▪	○	+	+		✱	✱
" woodi	▪	▪	✱	○		✱		+	▪	▪	▪	+	▪		▪	+	▪	○	+	▪	○	●	○	▪
Globigerinoides altiaperturus					○							▪			▪					○				
" cyclostomus											+													
" elongatus											+													
" extremus	▪	▪				✱		▪	▪	▪	+		+			▪	+	●	+		○	●	○	○
" immaturus	✱				+	✱					▪	○	+	▪	○	▪		+	✱	○	▪	+	▪	+
" parkeri											+													
" quadrilobatus	✱			▪	●	▪		●												●	○		+	●
" ruber				▪	●	▪	✱	+			▪	+	▪	✱	▪	▪				▪	▪	✱	○	▪
" sacculifer	✱				+			+	▪	▪	▪	▪	▪		▪	▪	▪	○	✱	▪	▪	+	▪	○
" seigliei		✱																			▪		✱	
" sicanus					✱							✱								▪				
" spp.							○					○												
" trilobus	+	▪	▪	○	●	○	○	○	+	▪	+	●	○	▪	●	○	▪	+	+	●	○	●	●	○
Globoquadrina altispira					○							▪	✱		✱					+	✱			
" baroemoenensis					●							+			○					○				
" larmeui					+							✱												
" spp.				▪		▪	✱					○	▪		+		✱			○				
Globorotalia acostaensis	▪					✱		▪	▪	+	▪		▪	▪		▪	▪	○	▪		▪	▪	▪	▪
" acrostoma							▪					+								✱				
" continuosa					+	▪	▪					+	▪		○					+	+		+	
" humerosa	✱	✱	✱	✱				○	▪	○	▪		▪	+		+	○	○	+		+	○		✱
" juanai										▪														
" margaritae											+													
" mayeri					●		▪					+			○					○				
" mediterranea								▪									▪		▪			+		▪
" cf. m. mediterranea										✱														
" gr. menardii				✱		✱			▪	▪			▪			▪	+	+	+		▪	▪	○	▪
" merotumida									✱				▪			▪			▪				▪	✱
" miozea saphoe								▪													▪	▪	○	▪
" nicolae										✱														
" peripheroacuta					+																			
" peripheroronda					○							✱												
" plesiotumida						✱		▪	▪	+	✱		+	+		▪	+	▪	+		○	●	▪	▪
" praemenardii					▪							▪			▪									
" praescitula					●																			
" puncticulata											○													
" punct. padana											+													
" cf. saheliana																	✱							
" gr. scitula				+	●	▪	▪	○	▪	+	+	▪	○	○	▪	+	+	○	+	▪	○	○	+	○
" suterae								+		▪				+		✱	▪	+	▪		▪	▪		▪
Neogloboquadrina dutertrei	✱		✱	▪				▪	✱	▪				+		✱	✱	+	▪		○	○	▪	▪
Orbulina bilobata					+			▪	▪	▪	▪	▪	▪	▪	▪	▪	▪	+	▪	+	▪	✱	+	▪
" suturalis	✱	▪	✱	▪	●	▪	▪	▪	▪	+	▪	○	▪	▪	○	▪	▪	+	▪	+	+	+	+	▪
" universa	▪	▪	✱	▪	●	▪		○	+	+	+	●	○	●	○	○	+	●	○	●	●	●	●	●
Praeorbulina glomerosa												+			▪					●				
" transitoria												+								○				
Sphaeroidinellopsis seminulina						✱				▪											▪			

											+			I					●					Praeorbulina glomerosa
											+								○					" transitoria
					*				I											I				Sphaeroidinellopsis seminulina
*								*	I	+		*	*		*	I	*						*	" spp.
							○		*				○			*		+			○		+	Truncorotalia conomiozea
+	+	○	○		+		*	I	I	I	*	*	I	I	I	I	I	○		I		*	I	Ammonia beccarii
○	○	○			+	○		+	I	I	*	*	I		I	I	I	+		I	I			" spp.
	I			I			*	*			*	I	*				I	*				I		Amphicoryna scalaris
				I	*		I	*	I		I	I	*	I	I		I	I	I	I		I	I	Anomalinoides flinti
				I			+	I	I	I	I	+		+	I	I	+	I	+	I	I	+	+	" helicinus
										I														" ornatus
											*			I										" pseudogrosserugosus
+	○	I			+	I		*										I						Astrononion stelligerum
									*			*	I											Bolivina albatrossi
										I														" cistina
										*														" leonardii
			I		I		+	I	I		*	I	I	I	I	I	I	*		I	*	I	+	" miocenica
	I		I	+	I			I	*		I	I	*	I	I	*	*		I	I		+		Brizalina arta
+	*	*		I	I	*	I	I	I	I		+	○	I	I	I	I	+	I	I	I	I	I	" dilatata
+						*																		" mutinensis
	I		*																					" spathulata
+	I	I	I	I	I	I		*			I	I	+	I		*		I	I	I		+		Bulimina aculeata
*		*				I			*				I											" echinata
			I	I	I		I	○	○		I	I	+	I	I	*	+	+	I	I	I	I	I	" cf. B. inflata
I	I			I	*	I		I	I	I	*	*		*	*		I	*	I	I		*		Cancris oblongus
+						I		*			*	*	I					*	I	I	*			" spp.
	I	I			*		+	I	○		+	+		+	I	I		I	+	+	I	I	+	Cassidulina laevigata
	I	○					*											I				+	*	" neocarinata
I	+	I	+		I	*	*			*								*			I	○		Cibicides refulgens
					*			I	I	I	I	I	I	*	I	*	+		I	I	+	I	I	Cibicidoides italicus
		I		+	*		I				I	I	+	+	I	I	+	○	+	+	I	I	I	" kullenbergi
○	○					○																		Cribroelphidium semistriatum
	*			I				+	I		I	+		+	+	I	I		I	I				Cyclammininae
○	+	*	+		+	○	I	*	*	I	I	I	+	+	I	I		I	I	I	+	I	I	Elphidiidae
+	○	I	●		+	+	*	I	I	*	I	I	I	I	*	I	I	*	*	*	*			Florilus spp.
	○	○						○	I		I	I			*				I					Haplophragmoidinae
I	+	○	I	+	I	*	I	I	I	I	I	+	I	+	I	I	+	I	+	+	I	○	I	Heterolepa floridana
				+							*								○					" mexicana
	*	I		+	I		I	I	I	I				+	I	*	I	I	+	I	I	I	I	Martinottiella communis
	I	+	I		I		I	*			I	I		*	I	*		I		I	*	+		Melonis soldanii
	●	○									I	I		*								+		" cf. M. pompilioides
	I																							Nonion sp.
*							I	+	I	I	*	I	+	I	I	*	+	I	*	I		*	*	Oridorsalis umbonatus
				I	*		+	I	+	+	I	I	+	I	I	I	+	I	I	+	+	+	+	Planulina ariminensis
				*	*			*	I		I	I		I	I	*	I		+	I		+	I	" wüllerstorfi
+	○	*			I	+							*											Protelphidium granosum
									*															" tuberculatum
	I	I	I	I	I	*	+	I	I	I	+	I	+	I	*	I	I	I	+	I	*	+	*	Pullenia bulloides
I																			*	*		*		Pyrgo sp.
*				+				I	I	I	I	+	I	+	+	I	+		+	I	I	+	*	Siphonina reticulata
	I	I	I	I	I	I	*	I	I	I	+	I	I	I	*		*	+	I	I		I	I	Sphaeroidina bulloides
	I			+				I			+	+		+	*				+	+				Spiroplectammina carinata
+	+	+	+	I		I	*	I	*	I	*	I		*	*			*	*	I		I		Textulariidae
*	*	I	*	*	*				I		*	*	+	*		*		*	*			I		Trifarina bradyi
														I										Uvigerina auberiana attenuata
					I			I	*		+	+		+	I	*	*		+	+		+		" barbatula
			I	○				○	+					○	I	I			+	I		+	*	" striatissima
+	+	●	I		*	I				I								*						Valvulineria bradyana

" barbatula						-			-	*		+	+		+	-	*	*		+	+		+	
" striatissima				-	O				O	+					O	-	-			+	-		+	*
Valvulineria bradyana	+	+	●	-		*	-				-								*					
" complanata	●	●	●	-		-		+	-	-		*	+	O				-	+		*			
Bryozoa	O	-					*	-	-	-	-		-		-	-	-			-	+	O	-	-
Corals																						*		
Crustacea	+						*																-	
Echinodermata	O	-	+		*	-	O	-	+	-	-	+	+		-	-	-	*	-		+	+	-	-
Fecal pellets	O																							
Fish teeth	-	*			*	*	*	*	-	-	-	*	*		*	*		●		-	-		-	-
Gastropoda	O	*				*	*					*	-		*	-	*			-	-	*		-
Ostracoda	O	-	+	*	-	-	-	-	*		-	-	-		*	*			*	-	-	-	+	
Otoliths	+											*	*			-	-				*		-	
Pelecypoda	●		+				-		-	-	*		-			-	*				+	O		+
Plant elements		*	-					-	-	-	-													
Scaphopoda	O										-												-	
Sponge spicules	*							*																*
STAGES	M	T	M	T	S	T	T?	M	T	M	P	S	T	M	S	T	M	T	M	S/L	T	M	T	M

PLATE 3

Fig. 1 – *Globigerina multiloba* Romeo. Spiral view. *Truncorotalia conomiozea* Zone; *Globigerina multiloba* Subzone. Ca' Pestavecchia section, sample CP 3; x 300.

Fig. 2 – *Globigerina multiloba* Romeo. Axial view. *Truncorotalia conomiozea* Zone; *Globigerina multiloba* Subzone. Ca' Pestavecchia section, sample CP 3; x 300.

Fig. 3 – *Globigerina multiloba* Romeo. Umbilical view. *Truncorotalia conomiozea* Zone; *Globigerina multiloba* Subzone. Ca' Pestavecchia section, sample CP 3; x 300.

Fig. 4 – *Globigerinoides extremus* Bolli & Bermúdez. Spiral view. *Globorotalia acostaensis* Zone; *Globorotalia suterae* Subzone. Well Campobello 1, ditch sample at 152 m; x 160.

Fig. 5 – *Globigerinoides extremus* Bolli & Bermúdez. Umbilical view. *Truncorotalia conomiozea* Zone; *Globigerina multiloba* Subzone. Ca' Pestavecchia section, sample CP 4; x 160.

Fig. 6 – *Globigerinoides seigliei* Bermúdez & Bolli. Umbilical view. *Globorotalia acostaensis* Zone; *Globigerinoides extremus* Subzone. Well Marinella 1, ditch sample at 1266 m; x 180.

Fig. 7 – *Truncorotalia conomiozea* Kennett. Spiral view. *Truncorotalia conomiozea* Zone; *Globorotalia mediterranea* Subzone. Well Campobello 1, ditch sample at 50 m; x 180.

Fig. 8 – *Truncorotalia conomiozea* Kennett. Axial view. *Truncorotalia conomiozea* Zone; *Globorotalia mediterranea* Subzone. Well Gazzera 1, side wall core sample at 286 m; x 180.

Fig. 9 – *Truncorotalia conomiozea* Kennett. Umbilical view. *Truncorotalia conomiozea* Zone; *Globorotalia mediterranea* Subzone. Well Gazzera 1, side wall core sample at 286 m; x 180.

Fig. 10 – *Globorotalia mediterranea* Catalano & Sprovieri. Spiral view. *Truncorotalia conomiozea* Zone; *Globorotalia mediterranea* Subzone. Well Campobello 1, ditch sample at 104 m; x 200.

Fig. 11 – *Globorotalia mediterranea* Catalano & Sprovieri. Axial view. *Truncorotalia conomiozea* Zone; *Globorotalia mediterranea* Subzone. Well Campobello 1, ditch sample at 104 m; x 160.

Fig. 12 – *Globorotalia mediterranea* Catalano & Sprovieri. Umbilical view. *Globorotalia acostaensis* Zone; *Globorotalia suterae/Globigerinoides extremus* Subzones. Well Mazara del Vallo 1, ditch sample at 952 m; x 160.

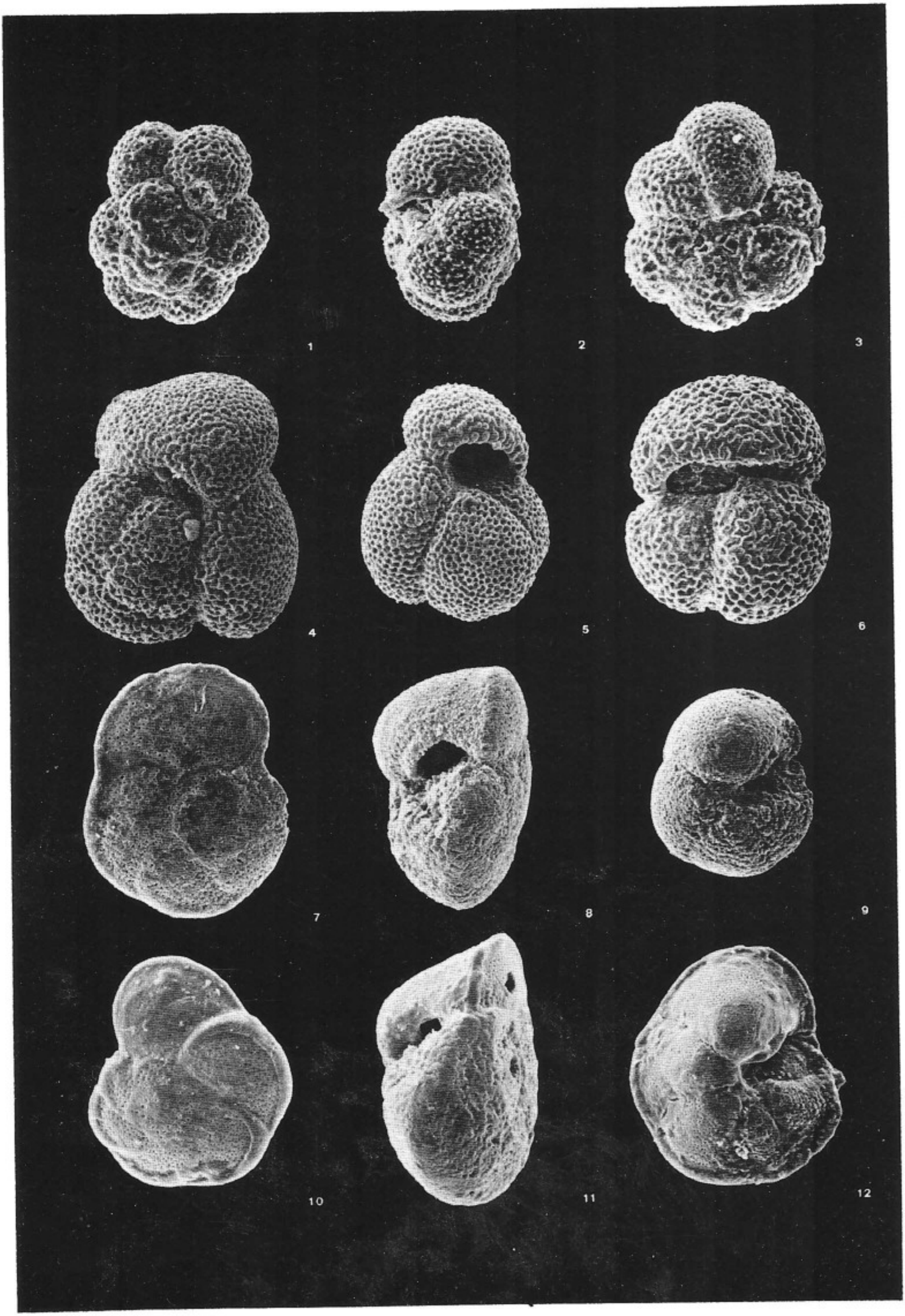
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PLATE 4

Fig. 1 – *Globorotalia suterae* Catalano & Sprovieri. Spiral view. *Truncorotalia conomiozea* Zone; *Globorotalia mediterranea* Subzone. Well Mazara del Vallo 1, ditch sample at 550 m; x 180.

Fig. 2 – *Globorotalia suterae* Catalano & Sprovieri. Umbilical view. *Globorotalia acostaensis* Zone; *Globorotalia suterae*/*Globigerinoides extremus* Subzones. Well Mazara del Vallo 1, ditch sample at 1152 m; x 180.

Fig. 3 – *Neogloboquadrina dutertrei* (d'Orbigny). Umbilical view. *Truncorotalia conomiozea* Zone; *Globorotalia mediterranea* Subzone. Well Gazzera 1, core sample at 105–106 m; x 180.

Fig. 4 – *Globorotalia mayeri* Cushman & Ellisor. Umbilical view. *Orbulina* spp. Zone. Well Campobello 1, ditch sample at 844 m; x 220.

Fig. 5 – *Globorotalia acostaensis* Blow. Spiral view. *Truncorotalia conomiozea* Zone; *Globorotalia mediterranea* Subzone. Well Marinella 1, core sample at 1158–1159 m; x 220.

Fig. 6 – *Globorotalia acostaensis* Blow. Umbilical view. *Truncorotalia conomiozea* Zone; *Globorotalia mediterranea* Subzone. Well Marinella 1, core sample at 1158–1159 m; x 220.

Fig. 7 – *Globorotalia continuosa* Blow. Umbilical view. *Globorotalia acostaensis* Zone; *Globigerinoides extremus* Subzone. Well Lippone 1, core sample at 1098–1099 m; x 240.

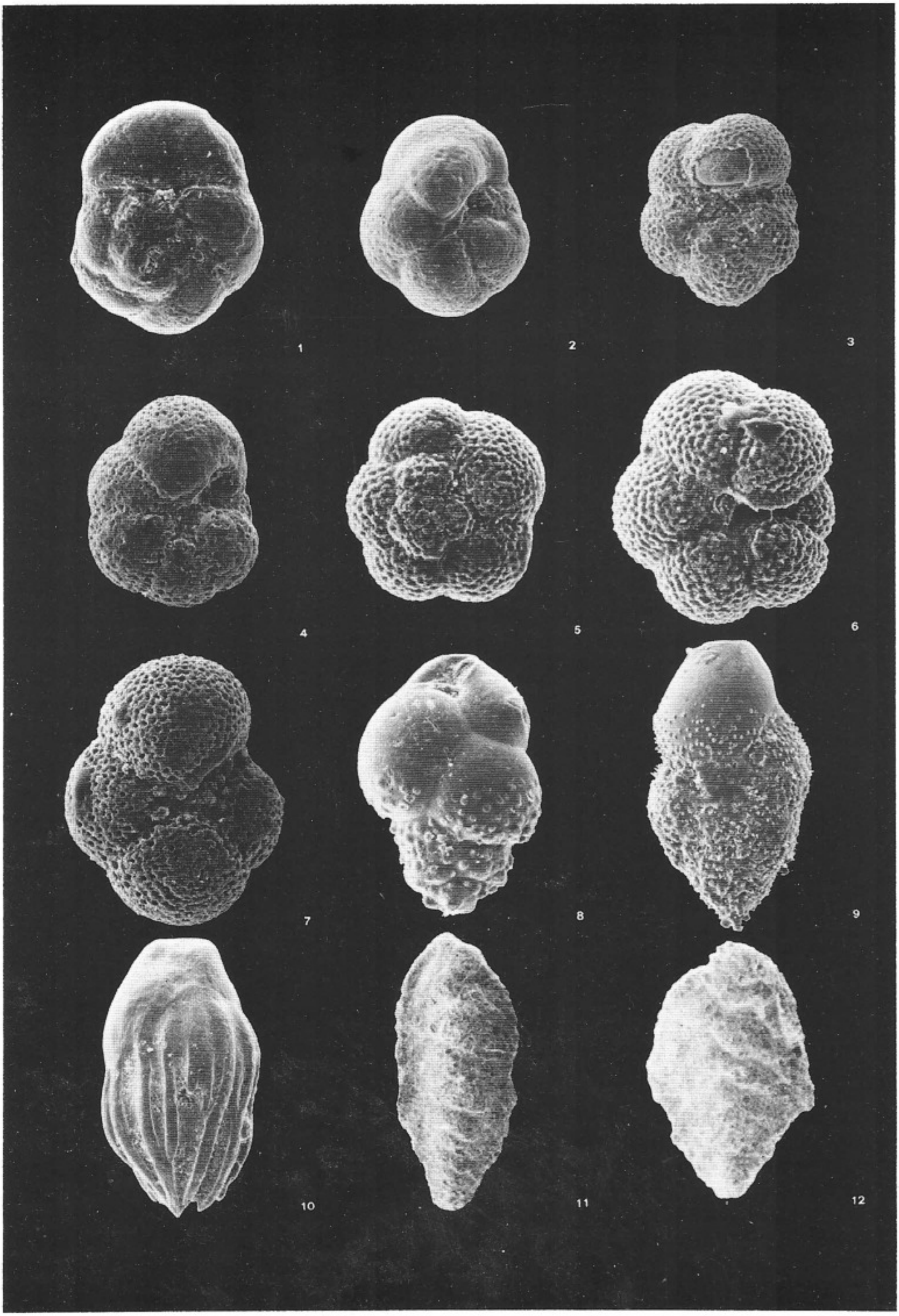
Fig. 8 – *Bulimina echinata* d'Orbigny. *Bulimina echinata* Zone. Cozzo Gracello–Imera River section, sample GI 22; x 240.

Fig. 9 – *Bulimina echinata* d'Orbigny. *Truncorotalia conomiozea* Zone: *Globigerina multiloba* Subzone. Cà Pestavecchia section, sample CP 8; x 180.

Fig. 10 – *Uvigerina barbatula* Macfadyen. *Globorotalia acostaensis* Zone; *Globigerinoides extremus* Subzone. Well Lippone 1, ditch sample at 1257 m; x 120.

Fig. 11 – *Spiroplectammina carinata* (d'Orbigny). *Globorotalia acostaensis* Zone; *Globigerinoides extremus* Subzone. Well Lippone 1, core sample at 1300–1301 m; x 50.

Fig. 12 – *Spiroplectammina carinata* (d'Orbigny). *Globorotalia acostaensis* Zone; *Globigerinoides extremus* Subzone. Well Lippone 1, core sample at 1300–1301 m; x 80.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