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Plio-Pleistocene sedimentary facies and their evolution in centre-south-eastern Sicily: a working hypothesis

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Abstract. This paper examines the distribution and evolution of the Plio-Pleistocene sedimentary facies in centre-south-eastern Sicily, especially around Enna, Licata and Caltagirone. Sectors occur in this region (Caltanissetta-Enna-Centuripe, Pietraperzia-Barrafranca-Piazza Armerina-Butera, S. Michele di Ganzaria-Caltagirone-Niscemi, Licata-Gela) where, in relation to the late Zanclean-Piacenzian / Selinuntian period, the sedimentary succession has different lithostratigraphic characteristics.

The area studied belongs to the Caltanissetta Basin, which is a paleogeographical-sedimentary unit. From the Late Miocene to the Quaternary period it consisted of a dynamic foredeep basin between the Hyblean Foreland and the Apennine-Maghrebian Trust front. Between the Early Pliocene and Early Pleistocene periods this front advanced about 50 km southwards and south-eastwards.

The Plio-Quaternary lithostratigraphic sequence is mainly represented by 11 units: Zanclean Trubi Fm, Pliocene Argille Brecciate Fm. (Pliocene Brecciated Clays-AB IV, V), Enna Marls of the late Zanclean-Piacenzian, Centuripe Sandstones and Capodarso Calcarenites of the late Zanclean-Piacenzian, Geracello Clayey Marls of the Piacenzian-Selinuntian, Piazza Armerina Sands of the Piacenzian-Selinuntian, Mt. S. Giorgio Marly Clays of the Selinuntian, Caltagirone-Niscemi Sands of the Selinuntian, Terraced sediments of the Middle-Late Pleistocene, Present day sediments.

There are three clear unconformities in the sequence, excluding the one at the base of the quaternary terraced deposits. The first, of late Zanclean age, is located above the Trubi Fm., and developed immediately after the beginning of the Enna Marls sedimentation; it has a synsedimentary character and developed in a marine environment without emergence. The second, of late Piacenzian age, lies at the base of the Geracello Clayey Marls, while the third (Selinuntian), is located at the base of the Mt. S. Giorgio Marly Clays. Minor unconformities, probably of glacio-eustatic origin, are locally present.

The lithostratigraphic, geometric and tectonic elements suggest that the Plio-Pleistocene geological evolution in the area examined is mainly tied to a large sedimentary episode which developed between the Zanclean and the Selinuntian with facies progradation to the South and South-East. A possible scheme of interpretation could be the one proposed by Grasso et al. (1997, 1998) and Lickorish et al. (1999) for the Licata area, which predicted the southward tectonic migration of the sedimentary basins without particular emergence. In this development the eustatic variations of the sea level show a clear effect on the borders of the basins.

The peculiarities of the first two areas mentioned (Caltanissetta-Enna-Centuripe, Pietraperzia-Barrafranca-Piazza Armerina-Butera) belong to two episodes of the sedimentary basin during its southward migration between late Zanclean and Selinuntian times. The other two areas, between Caltagirone and Licata, lying close to the front of the Gela Nappe, record a further movement of the basin towards the South and South-East.

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1 Introduction

In the south-eastern area of central Sicily (Fig. 1), up to the western Hyblean border, prevalently Plio-Quaternary sediments outcrop. The paleogeographical evolution has been characterised, since the Miocene, by the emergence of both the Madonie-Nebrodi-Peloritani ranges and the central part of the Hyblean mountains. The first corresponds to the Miocene Apennine-Maghrebian thrust belt, the second to the northern sector of the Pelagian Foreland (Ben Avraham et al., 1990).

After Messinian evaporite deposition, there was a return to fully marine conditions with the sedimentation of Zanclean pelagic carbonates. This unit, in the main part of the Mediterranean area, presents a homogeneous lithology (marly limestones and calcareous marls containing an Zanclean planktonic foraminifer association) showing conditions of variable bathymetry but becoming deeper with time.

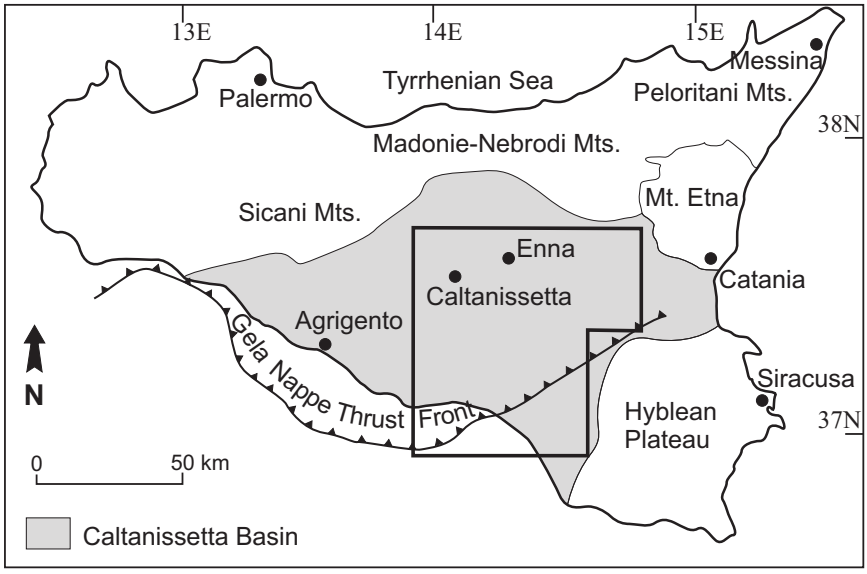

Fig. 1. Geographical map and location of the study area (Fig. 2).

Afterwards, between the late Zanclean-Piacenzian and the Selinuntian, the evolution of the sedimentary facies is associated with tectonic-eustatic influence. These changes caused the space-time alternation of pelitic and arenitic facies. The evolution of these facies is sometimes interpreted as due to the occurrence of different sedimentary cycles correlated also to tectonic events (Roda, 1966, 1967a, 1967b, 1968). Among these events, the south-east translation of the sediments with the substratum via movement of the Gela Nappe had important consequences for the evolution of the succession.

The aim of this study is to propose a working hypothesis on the basis of field analysis and already published data, synthetically outlining the lithological characteristics, the stratigraphic-geological setting and the tectonic-structural evolution of the Plio-Quaternary succession, in the area between Enna-Caltanissetta-Licata and Caltagirone-Niscemi. Also for the chrono-biostratigraphic aspects we referred to some published studies, integrating with the direct check. The results of the analysis show some areas characterised by almost uniform lithostratigraphic elements and structural evidence. The sedimentary series, the vertical and lateral migration of the facies and the paleogeographical evolution of each area, have been reconstructed. We also attempt a preliminary correlation of the different areas and their evolution in time.

2 Geological and Structural setting

The study area, located between the southern part of the Maghrebian-Apennine Chain and the western part of the Hyblean Foreland, belongs to the Caltanissetta Basin (Fig. 1). In geological literature, the dynamic-structural interpretation of this basin, which represents a Late Miocene-Quaternary paleogeographical unit, has changed in time. From about the 1960's (Ogniben, 1960, 1969) until the first structural models for the Italian area (C. N. R., 1975), this unit was considered as a postorogenic sedimentation association following the Miocene paroxystic phase responsible for the formation of the thrust belts in the Mediterranean area.

In contrast, since the early 1980's (Catalano and D'Argenio, 1982; C.N.R., 1983; Bianchi et al., 1989; Ben Avraham et al., 1990; Lentini et al., 1990, 1996; Butler et al., 1992, 1995; Catalano et al., 1993, 1996; Lickorish et al., 1999), as previously suggested by Beneo (1958), Rocco (1959), Roda (1967a), the orogenesis in the Sicilian area has considered as persisting until the Quaternary (Gela Nappe), although with a lesser intensity than during the previous phases, with compressive-translative and synchronous rotational movements (Catalano et al., 1977; Grasso et al., 1987). The consequence is that the foredeep basin area between the Maghrebian-Apennine Chain and the Hyblean Foreland, evolved in time and space with the advancing Chain front. According to literature, this front is located a few kilometers north of Caltanissetta-Enna-Centuripe (Figs. 1, 2) in the Late Tortonian. In the Early Quaternary it is located near the Gela-Caltagirone-Ramacca alignment (Fig. 2); a forward movement of about 50 km to the south-east is therefore recognised, with a consequent reduction of the foreland domain.

It seems that this forward movement did not occur continuously but through several events which brought about the gradual reduction of the foredeep. From the Late Miocene to the Quaternary therefore, different paleogeographical structural units (Satellite Basins) sometimes considered "piggy-back" basins (Catalano et al., 1993; Vitale, 1996; Lentini et al., 1991) often complexly interrelated, interacted together in the centre-eastern Sicilian area. Their location is often only approximate because it is difficult to define the precise boundaries.

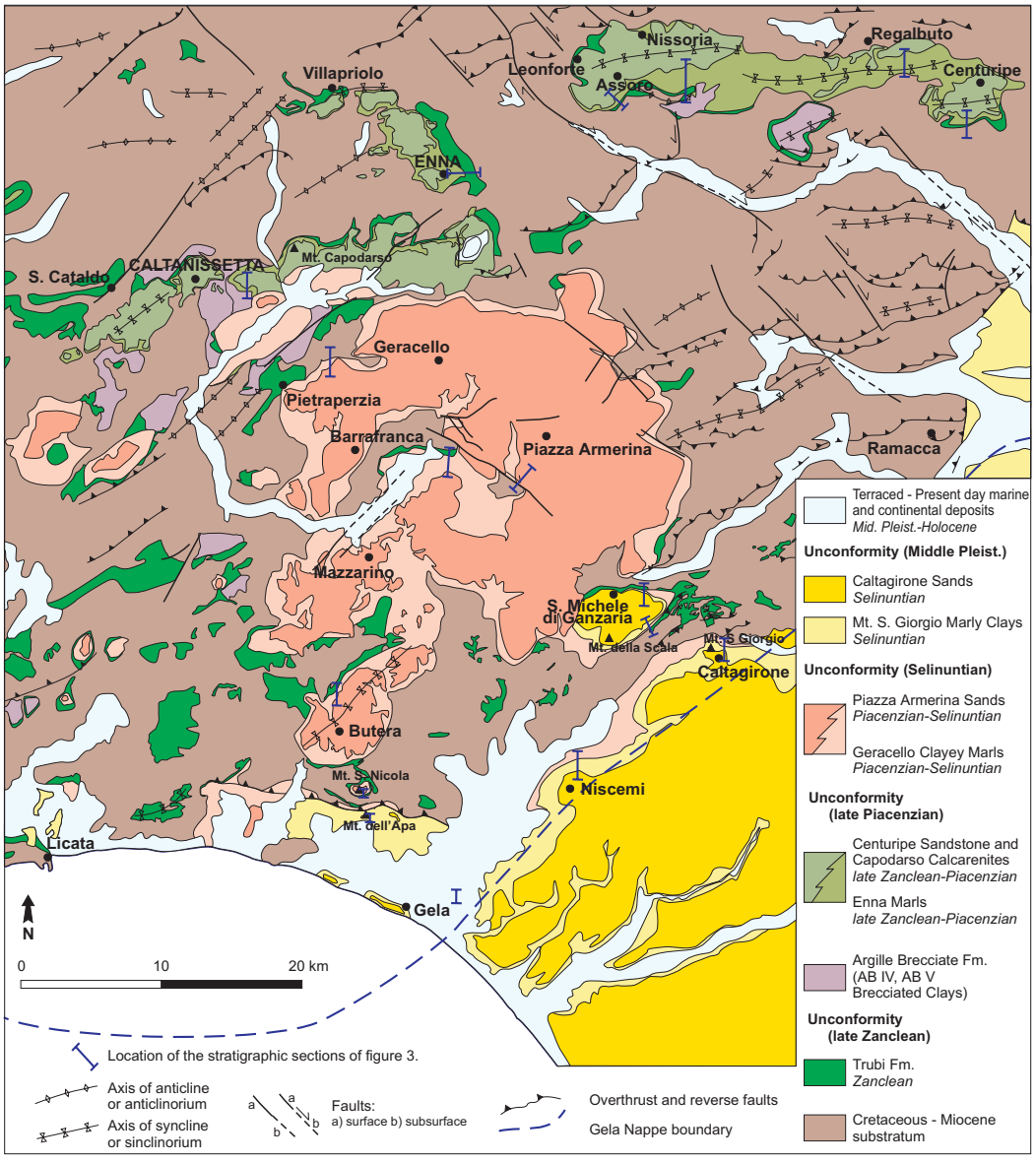

Fig. 2. Geological schematic map of the Plio-Pleistocenic lithostratigraphic units in the examined area. The tectonic elements are partially from Lentini et al. (1996) mod.

3 Plio-Pleistocene lithostratigraphic units

The stratigraphic succession exposed in centre-eastern Sicily (Fig. 2) consists, from bottom to top, of the following informal lithostratigraphic units:

– Trubi Fm. Marly limestones and calcareous marls with Globigerinidae prevalently of pelagic-neritic environment, white, heavily fractured normal to the bedding. They often contain yellow-reddish ferruginous concretions, and grade upwards into an alternation of grey marls and white marly limestones. Their age is Zanclean, the upper part may sometimes (Mt. S. Nicola-Rio et al., 1994) extend into early Piacenzian. Locally, between this Formation and the Messinian terms, a sandy-arenaceous conglomeratic level is present (Arenazzolo).

– Argille Brecciate Fm. (Brecciated Clays-AB IV, V according to Ogniben, 1953, 1954). Grey-dark brown brecciated clays with diverse clasts including rare lenses a few meters thick of marly limestones or calcareous marls similar to Trubi Fm., and white marls. These blocks are considered olistostromes of tectono-gravitational (Ogniben, 1953, 1954; Rigo De Righi, 1957) or tectono-diapiric (Monaco and Tortorici, 1996) origin. They are considered marine, but, for the top levels, it is not possible to exclude a continental genesis.

– Enna Marls. Marls and grey-blue clayey marls, calcareous, white towards the base and yellow silt towards the top. Southwards their age gradually changes

from late Zanclean to Gelasian-Selinuntian and they occupy the lithostratigraphic interval known elsewhere as Monte Narbone Formation, with reference to a deep marine environment of 500–1300 meters according to Rio et al. (1994). They often lie unconformably above Trubi Fm. and sometimes on the older units. East of Enna (Assoro-Centuripe) they tend to be less calcareous. North of Centuripe they lie above Oligo-Miocenic terrains with transgressive arenitic-ruditic basal level (0–70 m). Close to the old coast line they gradually develop into Centuripe-Capodarso arenites.

– Centuripe Sandstones and Capodarso Calcarenites (Late Zanclean-Piacenzian). They show stratigraphic continuity with the Enna Marls and quick heteropy, often within very small distances, among themselves. On the northern slope of the Centuripe hill these pliocenic sandstones and quartz sands are superimposed with stratigraphic continuity on the Enna Marls, while on the southern slope there is a big lens (0–400 meters) of a clayey marly and silty-arenaceous interbedded alternation. In the western part there are yellow bioclastic calcarenites (Capodarso Calcarenites) on the Enna Marls. These two littoral units outcrop together along a curved area, about 4 km wide, extending from Centuripe to Caltanissetta and also in other areas. Immediately to the south of Caltanissetta-Enna-Nissoria-Regalbuto (Fig. 2) they have a regressive attitude, while northwards they are superimposed transgressively on the oligo-miocenic terms. This unit shows a maximum thickness of 300 m decreasing to the South and South-East. In the Capodarso area this formation is referred to Middle Pliocene, because of the heteropy with the upper level of the Enna Marls, by Roda (1967b), to the same age by Catalano et al. (1993) and to Early Gelasian by Vitale (1996).

– Geracello Clayey Marls. Clayey marls, marly clays and silty marls. They are considered transgressive by Roda (1968) because they present a basal sand-gravelly level and sometimes lie unconformably on older units. They are Piacenzian in age to the north, while southwards they are Selinuntian in age, belonging to the Mt. Narbone Fm. (Rio et al., 1994). Sometimes they exceed a thickness of 300 m.

– Piazza Armerina Sands (Piacenzian-Selinuntian). Yellow sands with arenaceous levels, locally conglomerates, in stratigraphic continuity with the Geracello Clayey Marls and showing a diachronous relationship of heteropy with the same. Their maximum thickness is over 250 m (Piazza Armerina).

– Mt. St. Giorgio Marly Clays (Selinuntian). They outcrop from Mt. St. Giorgio (Caltagirone) to Licata, along the valley of the Maroglio river and along the present day coastal area. In outcrops they rest unconformably, through a sandy silty level (50–200 cm), on marly clays or on clayey marls referable to the Mt. Narbone Fm. (Rio et al., 1994) aged from Piacenzian to Selinuntian.

– Caltagirone Sands (Selinuntian). Littoral yellow silty sands with arenaceous lenses, in stratigraphic continuity with the Mt. St. Giorgio Marly Clays, passing in the upper part to sands, gravels and red conglomerates, probably of continental origin, associated to travertine levels. The thickness ranges from between 100 and 270 m in the Caltagirone-Niscemi area to more than 400 m near St. Michele di Ganzaria, with a marked reduction towards the area of Gela (less than 40 m in Mt. dell'Apa). Such variations in thickness, together with their age, suggest relationships of lateral heteropy with the Mt. St. Giorgio argillaceous sediments.

– Terraced sediments. Near the present day coastline marine arenites and rudites of the Middle-Late Pleistocene occur. These belong to various levels of terraces located up to a height of 80 m. Between Gela and Niscemi various levels of continental terraces are present, at the same height as the marine ones. The series closes with marine and continental Present day sediments.

4 Plio-Pleistocene facies areal distribution

In the area examined, relatively to the late Zanclean/Selinuntian interval, four sectors with different lithostratigraphic characteristics were observed. These give precise temporal and space information on the facies evolution. Some of them correspond to paleogeographical units. The relative lithostratigraphic sequences are illustrated in Fig. 3 which also shows, as in Fig. 4, the correlation elements. In the whole area the Mio-Early Pliocene substratum shows constant lithostratigraphic and structural characteristics and almost everywhere, except the area of Mt. St. Nicola, to the north of Gela, (Channel et al., 1992; Rio et al., 1994), the late Zanclean unconformity between Trubi Fm. and Enna Marls is observable.

4.1 Caltanissetta-Enna-Centuripe (First Area)

In the late Zanclean this area corresponded to the northern margin of the Caltanissetta Basin and was located between the southern front of the Maghrebian-Apennine Chain, mainly characterized by uplift in the Pliocene age, and the foredeep, where subsidence prevailed at the same time.

The outcropping lithostratigraphic pliocenic sequence presents a complete sedimentary cycle which was involved during the late Zanclean in a tectonic event responsible for the aforesaid unconformity between Enna Marls and Trubi Fm. It probably represents a synsedimentary event because it is not possible to observe any coeval emergence in the zone. Locally, the same event, controlled in places by submarine elevated structures, influenced the direct superposition of Enna Marls on the Miocene substratum. Sometimes the geometry of the facies is altered by this tectonic event, with a considerable variation in thickness.

The Leonforte-Centuripe area is characterised by a Pliocene lithostratigraphic sequence with frequent lateral het-

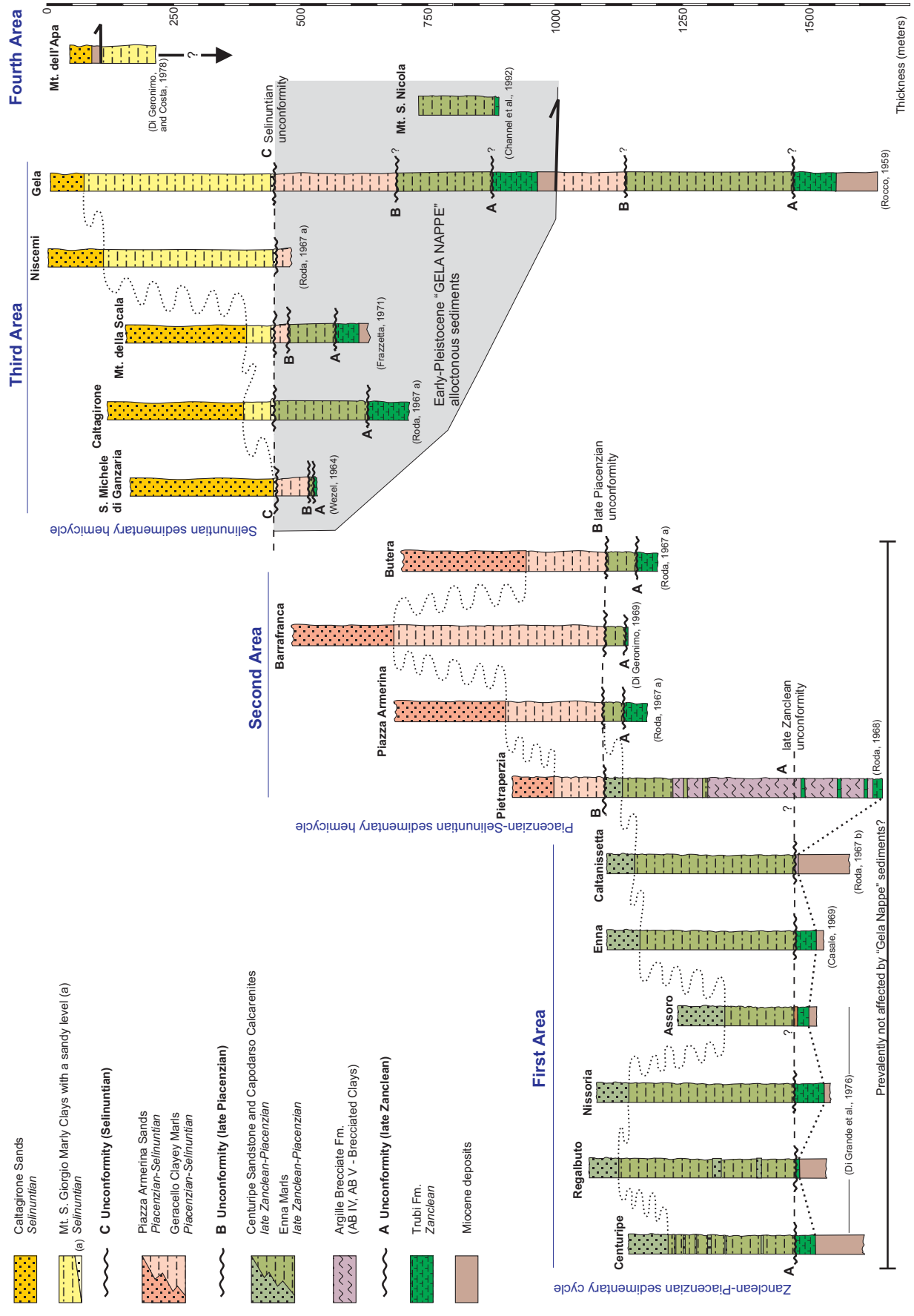

Fig. 3. Correlation between stratigraphic sections known in literature correlated with the main Plio-Pleistocenic unconformities (A, B, C).

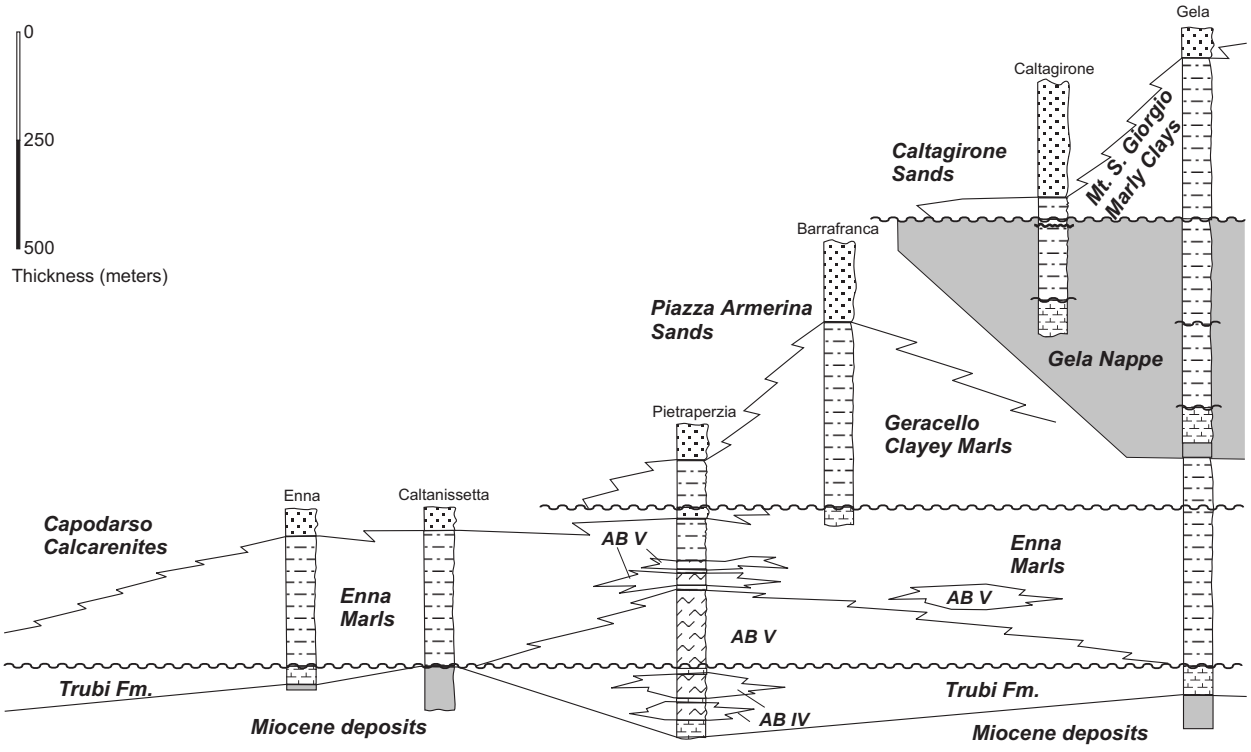

Fig. 4. Correlation among the plio-pleistocenic lithostratigraphic units on the basis of Fig. 3 elements. In agreement with Ogniben, 1953, 1954 the abbreviation AB corresponds to the Argille Brecciate Fm. (Brecciated Clays) and similarly AB IV corresponds to those associated with the Trubi Fm., and AB V to those associated with Enna marls.

eropies. The succession, emerging along the southern flank (Di Grande et al., 1978; Carbone et al., 1990; Lentini et al., 1991), consists of Trubi Fm. (0–70 m) sometimes overlapped by Argille Brecciate Fm. (Brecciated Clays-AB IV according to Ogniben, 1953, 1954), Enna Marls (50–400 m), superimposed with unconformity and containing thin levels of Argille Brecciate Fm. (Brecciated Clays-AB V according to Ogniben, 1953, 1954), and Centuripe Sandstones (100–300 m). In the eastern part an additional argillaceous-marly-arenaceous-silty alternation is present (Di Grande et al., 1978; Carbone et al., 1990). To the north, the Enna Marls are replaced by the Centuripe Sandstones, and are superimposed, directly or through a basal conglomerate, on Oligo-Miocenic units.

The distribution of the Pliocene units along the Leonforte-Centuripe ridge therefore suggests the presence, up to the late Zanclean-Piacenzian, of a paleocoastline with East-West direction close to Nissoria-Regalbuto and a rapidly deep basin, as is shown by the quick heteropy between arenitic and argillaceous sediments and by the thickness of the latter. The synsedimentary unconformity between Trubi Fm. and Enna Marls (Fig. 3: A unconformity) is associated with erosion and the deformation of the Trubi Fm., increase of the bathymetry of the basin and, moreover, a depression of all the ridge with consequent "transgressive" northward prograded position of the Centuripe and Capodarso Fms. basal levels.

The Pliocene sequence shows a single complete sedimentary cycle and the regressive hemicycle is generally strongly represented. Possible smaller unconformities observed within it (Catalano S., pers. comm.) suggest secondary sedimentary episodes.

Between Enna and beyond Caltanissetta, the Pliocene succession shows a sedimentological and structural setting similar to the Leonforte-Centuripe one, but with a larger calcareous sedimentary component. Besides the late Zanclean unconformity, smaller unconformities are observable at various levels, especially in the Capodarso Fm. (Vitale, 1996). At M. Sabbucina some lenses of Brecciated Clays are interbedded in the Capodarso Fm. It is not possible to exclude that in this area the Piacenzian marine regression was quite complex with local transgressive episodes in a general regressive tendency.

4.2 Pietraperzia-Barrafranca-Piazza Armerina-Butera (Second Area)

Located in the centre of the study area, it is characterised by arenitic facies (Piazza Armerina-Butera Sands), prevalently superimposed with stratigraphic continuity on pelitic facies (Geracello Clayey Marls). The age of the arenites here is Piacenzian-Selinuntian and the underlying argillaceous sediments are more recent than in the previous area. The thickness and the correlations are indicated in Figs. 3, 4.

Near Barrafranca and Piazza Armerina two synsedimentary unconformities are present, associated with two hiatuses. The older, sometimes covered by Argille Brecciate Fm. (Brecciated Clays-AB IV), is late Zanclean in age. The younger lies between Piacenzian and Piacenzian-Gelasian sediments. Also in this area the pelitic sediments are more widespread towards the South and East, with considerable variations and deepening of the facies in the same direction.

4.3 St. Michele di Ganzaria-Caltagirone-Niscemi (Third Area)

This area is characterised by the superposition of Selinuntian sediments (Mt. St. Giorgio Marly Clays and Caltagirone-Niscemi Sand) on the more southerly advanced front of the Plio-Quaternary Allochthon (Gela Nappe). Around Caltagirone this basal surface with unconformity is seen to lie upon different levels of the Piacenzian-Gelasian (Malatesta and Torrente, 1954; Ruggieri, 1958; Roda, 1967a), by the absence of continental erosion and by the lack of recognisable transgressive facies at the contact. The local outcropping succession is shown in Figs. 3, 4.

Also in this area the generalised absence of some stratigraphic levels, recognised within the Piacenzian-Gelasian sediments, and a marked unconformity, confirm (according to Beneo, 1958; Ogniben, 1960; Roda, 1967a, 1971; Lickorish et al., 1999) a translation of the Mio-Pliocene sediments to the East and South, with a revival of deep sedimentation in the Selinuntian.

To the south-west of Caltagirone, in the areas with depressed morphology, terraced fluvial deposits lie above a variety of sediments of the sequence. These are at the same height as the Middle-Late Pleistocene terraced marine deposits of the Gela-Licata coastal zone. Other portions of the Pleistocene marine terraces are present in the depression of Caltagirone river.

4.4 Licata-Gela (Fourth Area)

Near Licata-Gela the youngest sedimentary levels involved in the Apennine-Maghrebian Front are present. In comparison with the previous area, this is characterised by the increment of pleistocenic argillaceous facies and by the presence of Quaternary compressive structures which involve also the postorogenic deposits of the Gela Nappe. Current official cartography (Carta Geol. d'Italia, 1955), Di Grande and Muzzicato (1986), Grasso et al. (1995) recognised the continuity over 20 km of a reverse fault, which immediately to the north of Gela leads the Miocene over Selinuntian units. Considering the sediments involved and not involved, they can be dated as late as about the terminal Selinuntian age.

In the Mt. dell'Apa area, Di Geronimo and Costa (1978) observe a regressive sandy-clay sequence with a thickness of 150 m. Alloctonous Messinian evaporitic deposits are interbedded between clays and sands. This situation can be linked to a revival of the Gela Nappe, during the Selinuntian.

Terraced marine deposits of the Middle-Late Pleistocene are also present in this area. They are not affected by any tectonic movements.

An important stratigraphic and structural element, for their bulk and rapid formation (Ogniben, 1 954; Monaco and Tortorici, 1996), are the considerable bodies of Argille Brecciate Fm. (AB IV-Brecciated Clays) at the level of the late Zanclean unconformity (Grasso et al., 1997, 1998).

5 Plio-Pleistocene tectonics

The Pliocene terrains distribution and their vertical and lateral relationships make it possible to recognise compressive, extensive and transcurrent tectonic structures in the examined area (Fig. 2). The areas described correspond to zones with a different stratigraphic and structural significance.

After normal marine conditions resumed in the Zanclean, the first tectonic episode, common to every area, involved the development of a general unconformity at the contact of the same Trubi Fm. with the Enna Marls. It was a synsedimentary episode, which caused basin deepening and early postdepositional sediment dislocation.

In general the overthrusts (Fig. 2), which are a signal of the southerly migration of the Apennine-Maghrebian front, mainly involve terrains older than the Piacenzian. Their outcrops are prevalently covered by younger Piacenzian-Quaternary formations. They have an East-West trend in the northern part and NE-SW in the southern one. Close to the Hyblean area the latter orientation still prevails. It shows a possible evolutionary link between the Apennine-Maghrebian Chain and the Hyblean Foreland.

Such tectonic episodes, which could be ascribed to the early Piacenzian, have remarkable intensity in the whole area and their reactivation episodes are mainly responsible for the structural set around the Plio-quaternary sedimentary basins. In the contiguous foreland area (Hyblean Plateau) the tensional evolution became most intense during the Piacenzian tectonic phase (Ghisetti e Vezzani, 1981; Grasso, 1993; Di Grande, 1997) and is linked to extensive basic eruptive activity (Beccaluva et al., 1993; Schmincke et al., 1997).

In the first area (Caltanissetta-Centuripe) the most recent outcropping terrains involved in the tectonics are of the late Zanclean-Piacenzian age, so the respective structures are younger. The upper chronological limit is uncertain. The compressive tectonic controlled the development in this area, from East to West (Fig. 2), of the Leonforte-Centuripe Sinclinorium, which shows an axis made of three tracts sharply aligned East-West, the Villapriolo Sinclinorium (Mt. Giulfo – Mt. Corvo) with the same axial direction, the Capodarso Monocline with East-West orientated axis, and the Caltanissetta-S. Cataldo Sinclinorium with NE-SW orientation. There are 5 major anticlinal structures with a mainly NE-SW axial orientation.

In the same Caltanissetta-Centuripe area there are normal, reverse and transcurrent faults (Lentini et al., 1996) (Fig. 2). The first are mainly present in the calcarenite

blocks of the late Zanclean-Piacenzian; among the second the M. Sacchitello reverse fault is very evident, connected to a overturned anticline, and located immediately SW of Enna, where the Zanclean-Piacenzian terrains are also involved. In this case too the chronological relationship between the two kinds of fault is not clear. The main dextral transcurrent line, observed with an NW-SE direction, runs East from Enna where it dislocates pre-Pliocene terrain.

In the second area, apart from the overthrust described above, the tectonic elements involve younger terrain, up to the Selinuntian in age, and therefore their chronological limits (upper and lower) are more recent. The more important compressive structures are the Butera Sinclinorium, with a NE-SW direction, and the Piazza Armerina Monocline, which shows maybe a soft synclinal structure. There are normal, reverse and transcurrent faults (Lentini et al., 1996); the principal one is located between Piazza Armerina and Barrafranca (Fig. 2).

Locally just to the North from Piazza Armerina, neptunean dykes are present, aligned along pre-existing extensive fault lines (Antolini, 1958).

In the third area the most important tectonic element is the buried front of the Gela Nappe and the corresponding smaller structures. The Caltagirone-Niscemi highland and the S. Michele di Ganzaria area are involved in intense and extensive tectonic movement. On the basis of the units involved, the age of all the structures is Quaternary without doubt.

Around the Gela zone (the fourth area) the main structural element, apart from the buried front of the Gela Nappe, is the wide overthrust, extending for about twenty kilometres and overthrusting Mio-Pliocene terrains on to the Selinuntian. Its age could be ascribed to the Selinuntian as it does not affect the marine terraces of the Middle-Late Pleistocene (Grasso et al., 1997, 1998). Another structural event is the reactivation of the Gela Nappe, which controlled the interfingering at Mt. dell'Apa of Miocene deposits in the Pleistocene ones during the Selinuntian.

Along the western margin of the Hyblean area Plio-Quaternary tectonics are well developed. The activity is mainly linked to the Middle-Pliocene tectonic phase (Ghisetti and Vezzani, 1980), showing a prevalently NE-SW direction, sometimes with transcurrent characteristics (Grasso, 1993; Di Grande, 1997).

6 Elements for discussion

The lithostratigraphic sequence and the geometric relationships between the formations show the following evolutive elements:

- There are three clear unconformities in the sequence (A, B, C in Fig. 3) excluding the one at the base of the quaternary terraced deposits. The first (A), of late Zanclean age, is located on the Trubi Fm., and developed immediately after the beginning of Enna Marl sedimentation. The second (B), of late Piacenzian age, is associated with the base of the Geracello Clayey Marls in contact with the various underlying units; the third (C) is at the base of the Mt. S. Giorgio Marly Clays and is Selinuntian in age (Figs. 2, 3).

- Minor discordances are visible in the whole series, first in the upper part of the Enna Marls near Centuripe (Catalano S.: pers. comm.) and between Caltanissetta and Centuripe, in the Capodarso Calcarenites and Centuripe Sandstones. In the Capodarso area, Catalano et al. (1993) and Vitale (1996) report that the deposition of some beds was controlled by eustatic processes. Other minor unconformities, with characteristics similar to the Caltanissetta-Centuripe ones, are located in the sands of the Piazza Armerina-Butera area.

- During the entire period under consideration the area studied shows a complete sedimentary cycle of the Zanclean-Piacenzian age, enhanced by a single synsedimentary tectonic event, and two regressive hemicycles could be detected, occurring respectively in the Piacenzian-Selinuntian and Selinuntian (Figs. 2, 3).

- There is no field evidence of a true transgression, with continental erosion, among the three sedimentary episodes referred to, while the start of the second and third hemicycles is principally characterised by basal discordances in marine environments.

- The Plio-Quaternary facies distributions have a NE-SW trend, while they become gradually more recent towards the South and South-East.

- The arenitic sediments remain prevalently on the argillaceous ones, even if it is possible to observe reciprocal heteropies to the South.

- The only provable Plio-Pleistocene transgression relative to the Southern coastal stretch is demonstrated by terraced marine sediments of Middle-Late Pleistocene age.

- In the Pliocene age, a production at various levels of clayey-breccia bodies (Argille Brecciate Fm.-AB III, IV, V) of varying dimensions, must have modified the geometry of the sedimentary basins.

- The bathyal facies of the more recent levels involved in the Gela Nappe are similar to the sediments lying on it. It is possible to assume a lowering of the basin towards East and South and a bathymetric reset by the translated terrains.

7 Conclusions: paleogeographic evolution

In conclusion a comparative study of the elements discussed suggests, as a working hypothesis, that the geological evolution of the area examined is tied to a single large regressive sedimentary episode which occurred mainly from Piacenzian

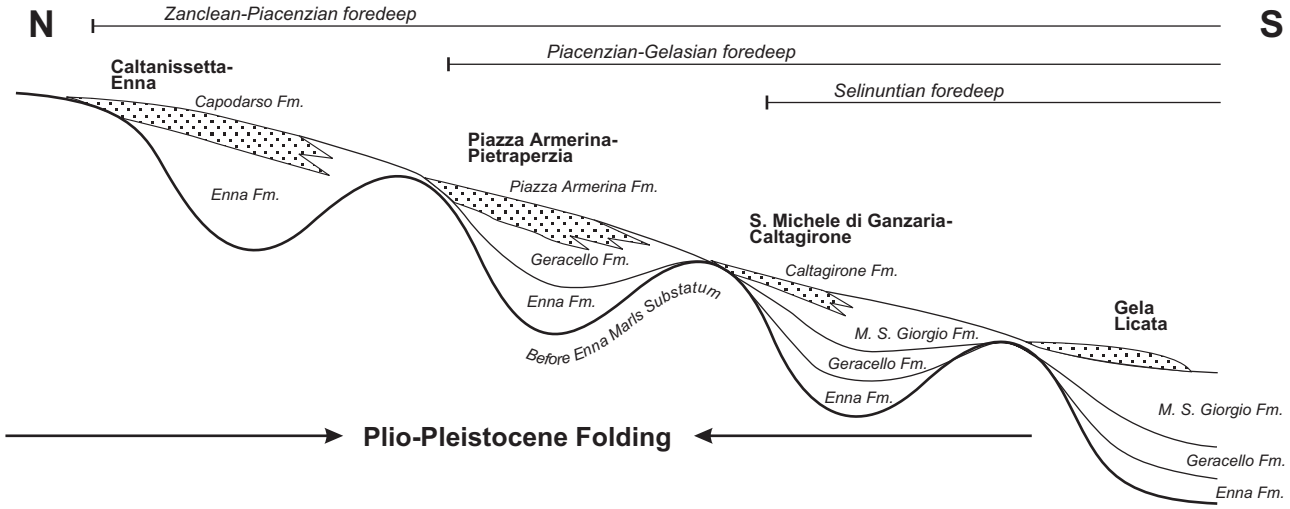

Fig. 5. Evolutionary hypothesis of the Plio-Pleistocenic sedimentary facies in the examined area using, with modifications, the schema proposed by Grasso et al. (1997, 1998) and Lickorish et al. (1999) for the Licata area. Their progradation is related to the various deformation events which affected the sedimentary basin. The use of the scheme is founded on the facies and age of the examined units.

to Selinuntian age with facies progradation towards the South and South-East. A possible evolving scheme (Fig. 5), could be the one proposed by Grasso et al. (1997, 1998) and Lickorish et al. (1999) for the Licata area, which foresees the tectonic migration of the sedimentary basins to the South without substantial emergence. The glacio- eustatic variations of the sea level have a secondary character in this evolution but show the clearest effects on the basin margins. The first two areas (Caltanissetta-Centuripe and Piazza Armerina-Butera) developed two clear episodes of southward migration of the sedimentary basin during Piacenzian-Selinuntian times. The other two areas, between Caltagirone and Licata, associated with the front of the Gela Nappe, record a further movement of the basin towards the South and South-East.

The lithostratigraphic, geometric, tectonic and eustatic elements suggest an evolution summarised in the following episodes:

– In the late Zanclean, at the end of the Trubi Fm. sedimentation, a tectonic episode resulted in the deepening of the sedimentary basin with deformation and synsedimentary erosion. Bathyal sedimentation of the Enna Marls followed. In this context the direct superposition, with unconformity, of these marls on the units older than Zanclean may be explained by sudden tectonism of the bathyal environment and associated uplift.

– In the late Zanclean the production of a large body of clayey-breccia (Argille Brecciate Fm. (Brecciated Clays-AB IV), associated with the uplifting of the northern and north-western portion of the basin, contributed to the facies migration towards the South and South-East, with sedimentation of the Geracello Marly Clays and the Piazza.

– In the Piacenzian, in the southern and north-eastern part of the basin, the arenitic facies (Centuripe Sandstones and Capodarso Calcarenites) provide evidence of a marine regression, while towards the North and North-West the same facies, owing to eustatic and tectonic oscillations, appear transgressive from late Zanclean.

– These conditions remained till the Selinuntian, when a sudden deepening of the southern and eastern margin of the foredeep, together with orogenic reactivation from the North, caused migration towards the South and East of the recently deposited terrains over the substratum (Gela Nappe). The occasionally observed hiatus in the Late Pliocene argillaceous sediments (Di Geronimo, 1969) may be an early signal of this event.

– In the Selinuntian bathyal sedimentation recommenced intermittently and the Gela Nappe was reactivated; this event was followed, in the Selinuntian, by a general regression.

– Just after the Selinuntian, the uplift commenced at a speed that can be calculated as about 0.2 mm/year (Cosentino and Gliozzi, 1988).

– During the Middle and Late Pleistocene there were various momentary sea level fluctuations with relative effects preserved up to the level of 80 m above the present day sea level.

– Further marine withdrawals, linked to area uprising, have continued up to the Present day.

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