Rivista Italiana di Paleontologia e Stratigrafia	volume 103	numero 3	pagine 343-356	Dicembre 1997

NEW BIOSTRATIGRAPHIC DATA ON THE FRAZZANÒ FORMATION (LONGI-TAORMINA UNIT): CONSEQUENCES ON DEFINING THE DEFORMATION AGE OF THE CALABRIA-PELORITANI ARC SOUTHERN SECTOR

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Key-words: Oligocene, Early Miocene, Biostratigraphy, Tectonics, Frazzanò Flysch, Calabria-Peloritani Arc, Southern Italy.

Riassunto. È stato eseguito uno studio biostratigrafico, mediante foraminiferi e coccoliti, della Formazione del Flysch di Frazzanò, che rappresenta il termine più alto della successione stratigrafica dell'Unità di Longi-Taormina. Quest'ultima costituisce l'unità geometricamente più bassa della pila di falde a basamento cristallino dei Monti Peloritani, l'unica dell'intero settore meridionale dell'Arco Calabro-Peloritano nella quale siano stati riconosciuti terreni terziari. Sebbene indispensabile per porre un limite inferiore all'età della fase tettogenetica che ha portato all'impilamento delle falde dei Monti Peloritani, l'età del Flysch di Frazzanò non è ancora ben definita dal momento che solo Coltro (1967) riporta associazioni di foraminiferi pelagici dell'Eocene Superiore. Successivamente sono state proposte età comprese tra l'Eocene Medio e l'Oligocene, nessuna giustificata da nuovi dati biostratigrafici.

Il ritrovamento tra i nannofossili di alcuni taxa che compaiono a partire dall'Oligocene Superiore e dal Miocene Inferiore, ha permesso di attribuire un'età non più antica dell'Oligocene Superiore ai termini di passaggio tra la Formazione del Flysch di Frazzanò e la sottostante Formazione di Militello, ed un'età non più antica della base dell'Aquitaniano ai livelli sommitali della medesima formazione. Le associazioni ritrovate sono caratterizzate da un intenso rimaneggiamento, che porta alla netta prevalenza tra i coccoliti di forme cretacico-eoceniche ed al riconoscimento tra i foraminiferi solo di forme di età compresa tra il Cretacico Superiore e l'Eocene Superiore.

La fase tettogenetica responsabile dell'impilamento delle falde dei Monti Peloritani, pertanto, deve essere considerata di età non anteriore all'Aquitaniano.

Questi dati, peraltro coerenti con quelli riconosciuti nelle unità omologhe dei settori betico e rifano del Mediterraneo occidentale, rimettono in discussione l'attribuzione all'Oligocene Superiore dei livelli basali della Formazione di Stilo-Capo d'Orlando, che poggia in discordanza angolare su tutte le unità tettoniche del settore meridionale dell'Arco Calabro-Peloritamo suturandone i contatti e permette di porre un limite superiore all'età del loro impilamento.

Abstract. New biostratigraphic data on the Frazzanò Flysch Formation are presented. This unit is the topmost formation of the stratigraphic succession characterising the Longi-Taormina Unit, which in turn represents the lowest tectonic unit of the Peloritani Mountains and the only unit in the entire southern sector of the Calabria-Peloritani Arc in which cenozoic terrains have been recognised. The age of the Frazzanò Fm., which as yet has not been well defined, is essential to ascertain the time period during which the tectogenetic phase responsible for the superposition of the nappes in the Peloritani Mountains occurred. Coltro (1967) reported foraminiferal assemblages of Late Eocene age, but subsequently ages ranging between the Middle Eocene and the Oligocene have been proposed, none of them supported by new biostratigraphic data.

The identification of some coccolithid taxa which appear in the Late Oligocene and Early Miocene allowed us to attribute an age not older than Late Oligocene to the levels that mark the transition between the Frazzanò Fm. and the underlying Militello Formation, and an age not older than Early Aquitanian to the most recent beds of the Frazzanò Formation.

Therefore, the tectogenetic phase responsible for the superposition of the nappes in the Peloritani Mountains, very likely started during the Aquitanian.

While these data agree with the evolution of homologous units recognised in the Betic and Rifian sectors, they challenge the Late Oligocene age ascribed to the basal levels of the Stilo-Capo d'Orlando Formation, which lies unconformably over all the tectonic units of the Calabria-Peloritani Arc and provides a chronological upper limit to their overthrusting.

Introduction.

The Southern Apennine and the Sicilian Maghrebides represent two segments of the Africa-Adria-verging peri-Mediterranean Alpine orogenic belt. They consist of a series of nappes overthrust during the Miocene, mostly derived from Meso- to Cenozoic carbonate-rich covers of the Africa-Adria continental margin and, to a lesser extent, from oceanic crust and sedimentary cover of a branch of the Western Tethys (Guerrera et al., 1993; Bonardi et al., 1993; 1994; Spadea, 1994).

The Calabria-Peloritani Arc is interposed between the Southern Apennine and the Sicilian Maghrebides (Fig. 1). It is formed by a stack of Alpine nappes, both oceanic and involving a pre-Alpine crystalline basement,

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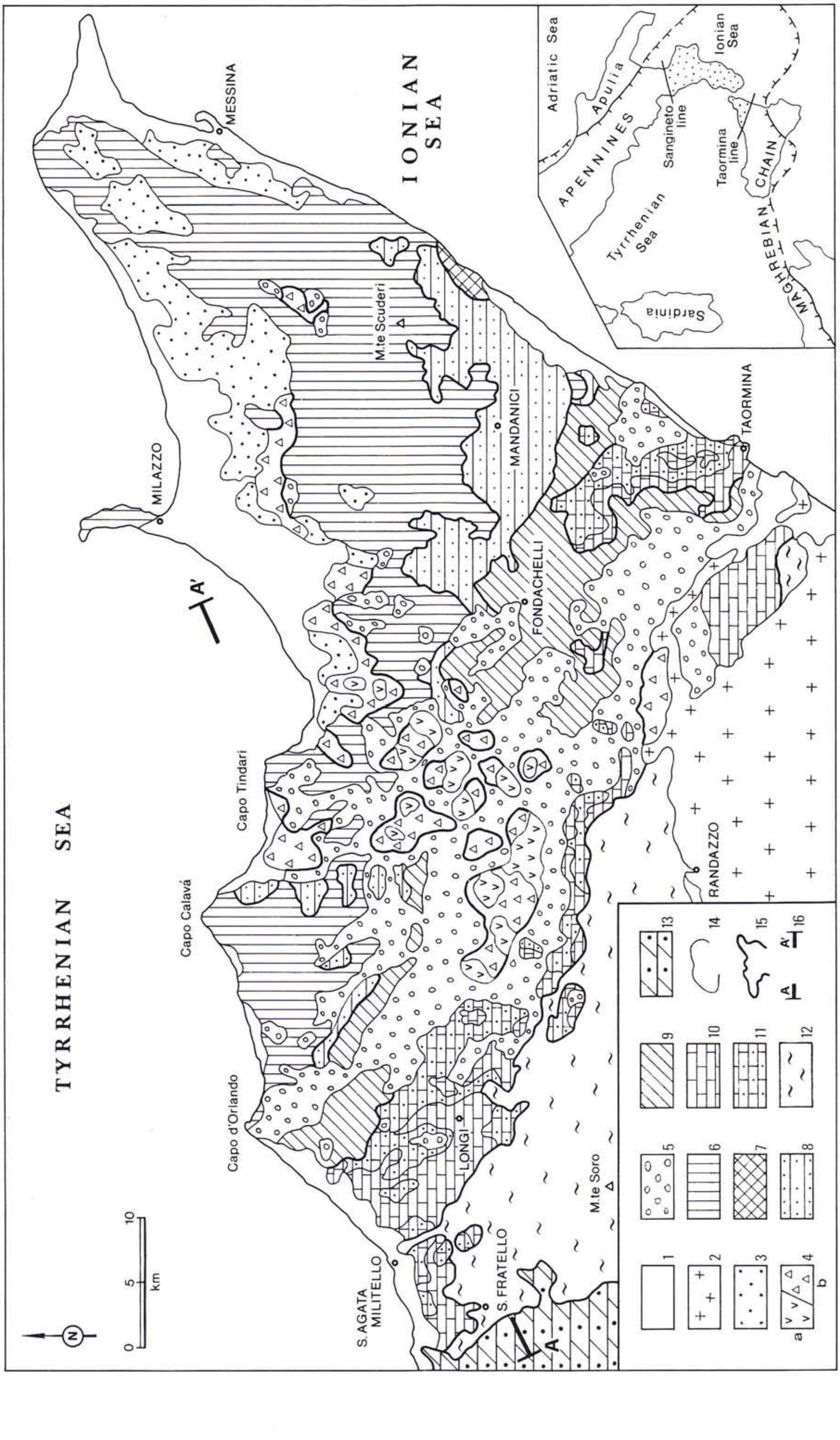
TYRRHENIAN SEA
IONIAN SEA
MESSINA
MILAZZO
M.te Scuderi
MANDANICI
TAORMINA
FONDACHELLI
Capo Tindari
Capo Calavá
Capo d'Orlando
LONGI
S.AGATA MILITELLO
S. FRATELLO
M.te Soro
RANDAZZO
A'
A
0 5 10
km
Adriatic Sea
Apulia
Ionian Sea
APENNINES
Sangineto line
Taormina line
Tyrrhenian Sea
Sardinia
MAGHREBIAN CHAIN
1
2
3
a 4 b
5
6
7
8
9
10
11
12
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14
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16

and represents, like the Algerian Kabylias and Moroccan Rif, an "exotic element" to the Apennine-Maghrebian Chain. The Arc is interpreted here as a fragment of the Europe-verging Eo-alpine orogenic belt, consisting of structural units from both oceanic and African continental crust, backthrust in the Miocene during the growth of the Africa-verging Apennine-Maghrebian thrust belt (Haccard et al., 1972).

The southern sector of the Calabria-Peloritani Arc (Bonardi et al., 1980; 1996 and references therein), lacks both ophiolitic terrains and the earlier deformation affecting the northern sector, which is Late Cretaceous-Paleogene in age. It is made of a stack of Alpine nappes, some consisting only of a pre-Triassic crystalline basement, and others containing a Meso-Cenozoic sedimentary cover as well. Among the latter, the Longi-Taormina Unit shows the most extensive and complete cover. Clastic deposits attributed to the Stilo-Capo d'Orlando Formation (Bonardi et al., 1980) lie unconformably on all the overthrust units, from the lowermost to the topmost. They suture the tectonic contacts between the units and are younger than the overthrusting of the nappes (Fig. 1, and 2).

The age of the tectogenetic phase during which the nappes were overthrust is still controversial. It is necessarily bracketed by the age of the youngest strata involved in the nappes formation (Frazzanò Fm. in the Longi-Taormina Unit) and the oldest deposits lying unconformably on the nappes stack (Stilo-Capo d'Orlando Formation). However, the ages proposed for these formations range from Middle Eocene to Early Miocene. Since the 1960's, French researchers (Truillet, 1968; Grandjacquet & Mascle, 1978; Courme & Mascle, 1988, and references therein) considered this tectogenetic event as Ypresian-Lutetian in age, whereas most authors suggested an Oligocene age. Only Guerrera et al. (1993), taking into account data from the Betic-Rifian Arc, proposed an Early Miocene deformation for the Peloritanian Domain.

Bonardi et al. (1996) pointed out that existing data can only delimit the age of this tectogenetic phase to the interval between the Eocene-Oligocene boundary and the Early Miocene. In the Frazzanò Formation, in fact, only Coltro (1967) recognised Upper Eocene microfaunas. Afterwards, Eocene, Eocene-Oligocene and Oligocene ages were proposed, however none of these age estimates are supported by biostratigraphic data (Tab. 1). As for the Stilo-Capo d'Orlando Fm. (Tab. 1), Truillet (1968) specified a Late Oligocene-Langhian age on the basis of foraminiferal assemblages. Similarly, Late Oligocene ages for the calcareous levels at the base of the Stilo-Capo d'Orlando Fm (Afchain, 1966; Bonardi et al., 1971) and Aquitanian-Langhian ages (Bonardi et al., 1971) for the overlying siliciclastic and pelitic deposits were recognised in the eastern Serre. Guerrera & Wezel (1974) were the first to find lower Aquitanian taxa about 35 m from the base of the formation in Sicily. Afterwards, a regional study by Bonardi et al. (1980) recognised foraminifera and nannofloras which, according to the present biostratigraphic scales, indicate a Burdigalian age for the basal levels (Zones N5 of Blow, 1969; upper part NN2 of Martini, 1971; CN 1-2 of Okada & Bukry, 1980) and a Langhian age for the upper ones (zones N8-N9 of Blow, 1969; NN5 of Martini, 1971; CN4 of Okada & Bukry, 1980). Later, the Stilo-Capo d'Orlando Fm. was considered Lower Miocene in age only in a few studies (Giunta et al., 1992; Guerrera et al., 1993; Bonardi et al., 1996). On the contrary, an Oligocene age for the base of the unit has been often re-proposed both in regional studies, and in more detailed studies supported by biostratigraphic data (Tab. 1). Only the Early Oligocene-lower Burdigalian age suggested by Weltjie (1992) seems incompatible with both the thickness of the formation and the sedimentation rate characterising the recognised facies (Cavazza, 1989; Cavazza & De Celles, 1993; Patterson et al., 1995).

In the present paper, new biostratigraphic data on the Frazzanò Fm. allow us to date both the deformation of the southern domains of the Calabria-Peloritani Arc and its orogenic evolution.

The Longi-Taormina Unit.

This tectonic unit and its equivalents represent an element common to other sectors of the Maghrebian Chain (Kabylias and Rif) and to the Betic Cordillera ("Chaîne bordière" or "Dorsale Calcaire"; Durand Delga, 1980; Bouillin et al., 1986; 1992). In all of these areas they constitute the most external crystalline units overriding the "Flysch" Domain Units.

This unit lies in tectonic contact on the "Flysch di Monte Soro" Maghrebian Unit in northeastern Sicily,

Fig. 1 - Geological sketch of the Peloritani Mountains (modified after Bonardi et al., 1997. In the square the Calabria-Peloritani Arc is dotted). 1) Recent to Upper Pliocene essentially clastic deposits. 2) Etna Volcanics. 3) Lower Pliocene-upper Tortonian mostly clastic deposits. Calabria-Peloritani Arc Southern Sector: 4) Floresta Calcarenites (a; Langhian) and "Antisicilide Complex" (b; Paleogene-Cretaceous variegated shales); 5) Stilo-Capo d'Orlando Formation (Lower Miocene); 6) Aspromonte and Mela Units (Pre-Triassic); 7) Mandanici Unit (Cretaceous-Paleozoic); 8) Alì Unit (Cretaceous-Upper Paleozoic); 9) Fondachelli Unit (Cretaceous-Paleozoic); 10) Longi-Taormina Unit sedimentary cover (Aquitanian-Upper Triassic); 11) Longi-Taormina Unit basement (Paleozoic). Maghrebian Chain: 12) Sicilide Units (Monte Soro and Troina-Tusa Units; Lower Miocene-Cretaceous); 13) External (Panormide and Imerese) Units (Middle Miocene-Middle Triassic). 14) Stratigraphic contacts; 15) Tectonic contacts. 16) Cross-section of figure 2.

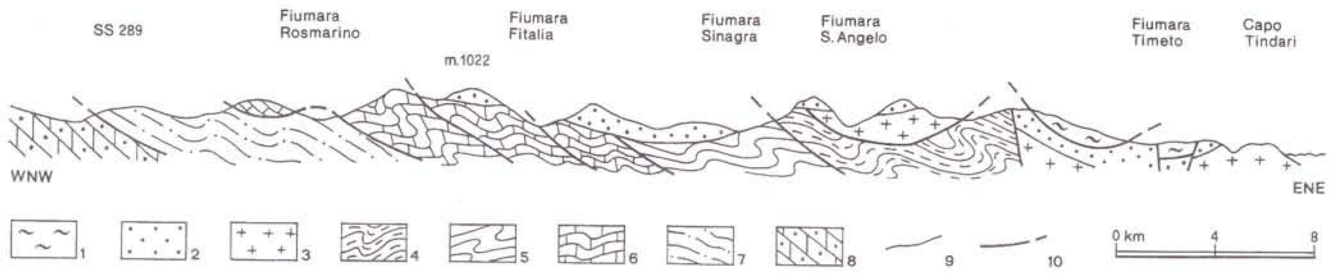


Fig. 2 - Schematic section across the northwestern Peloritani Mountains, from Capo Tindari to the Longi area. Calabria-Peloritani Arc: 1) Floresta calcarenites and "Antisicilide" Variegated Shales Nappe; 2) Stilo-Capo d'Orlando Formation; 3) Aspromonte and Mela Units; 4) Mandanici Unit; 5) Fondachelli Unit; 6) Longi-Taormina Unit. Maghrebian Chain; 7) Sicilide Units; 8) External Units. 9) Stratigraphic contacts; 10) Tectonic contacts.

defining the southern boundary of the Calabria-Peloritani Arc (Taormina Line). It crops out in a NW-SE oriented belt, about 10 km wide, from Sant'Agata di Militello, on the Tyrrhenian coast, to Taormina on the Ionian coast (Fig. 1). The widest outcrops are located near coastal areas, whereas these terrains are covered by the Stilo-Capo d'Orlando Fm. in the central sector and crop out again only near Francavilla di Sicilia, Roccella Valdemone and Floresta (Fig. 1). In all of these areas, the outcrops are subdivided into several tectonic slices (Fig. 2 and 3), also involving the pre-Alpine crystalline basement. The geometry and the tectono-sedimentary evolution of these slices are very much debated (Truillet, 1968; Duée, 1969; Lentini, 1975; Bonardi et al., 1976; Arnone et al., 1979; Bouillin et al., 1992). Recent detailed structural studies reported that a thin-skinned thrust structure (Nigro, 1995) was generated along numerous detachment surfaces, which also affected the single sedimentary successions. Lithologically, the crystalline basement, although not yet well studied, appears similar in each slice, and is composed of very low to low grade metamorphics interbedded with basic to acidic metavolcanics. The age of this basement may be placed between the Cambrian-Tremadocian boundary and the Early Carboniferous.

The sedimentary cover displays varied lithological characters and thicknesses in the different slices. Fig. 3 shows the stratigraphic columns in the Galati Mamertino-Sant'Agata di Militello area according to Arnone et al. (1979).

The oldest strata of the sedimentary successions are Upper Triassic fluvial "Verrucano-type" deposits, followed by a few meters of Hettangian greyish continental and marine sandstones, and by neritic carbonates, which rapidly evolve to pelagic limestones. Tithonian up to Oligocene strata include uniform bathyal plain facies, characterised by "maiolica-type" and "scaglia-type" sediments (Militello Formation; Ogniben, 1960). The renewal of tectonic activity during the Paleogene is recorded by the presence of carbonatoclastic sediments and olistoliths ("klippen sédimentaires" of French Authors) within the uppermost part of the Militello Formation. The sequence is capped by the siliciclastic sandy-conglomeratic turbidites of the Frazzanò Formation.

The Frazzanò Formation.

The Frazzanò Fm. (Ogniben, 1960) is known only from outcrops of the Longi-Taormina Unit located near the Tyrrhenian coast, where it occurs as the lowest tectonic element (Longi slice; Fig. 3). The gradual stratigraphic transition to the underlying Militello Formation may be seen in only a few areas due to tectonic detachments. Strata of the Frazzanò Fm. usually are affected by strong tectonic deformations, resulting in folded and fractured beds.

Nigro & Puglisi (1993) studied the formation in detail, subdividing it into a sandy-pelitic lower portion, followed by dominantly turbiditic sandstones and conglomeratic strata, the latter characterised by prevalent plutonic clasts in the lower portion and by abundant extrabasinal carbonate clasts in the upper portion. The sandstones are quartzose-feldspatic containing abundant metamorphic and ancient carbonate lithic grains. The formation is 300-400 m-thick.

Ogniben (1960, 1961) considered the Frazzanò Formation to be essentially Oligocene in age, based on unspecified globigerinids, and hypothesised a Late Eocene age for the lower part of the formation and the tectonic elision of higher Lower Miocene levels. An Upper Eocene age for the lower levels was confirmed by Coltro (1967) in the only work to date that indicates the presence of foraminiferal assemblages. Subsequently, ages ranging from the Middle Eocene (Truillet, 1968) to the latest Oligocene (Guerrera et al., 1993) have been suggested, though not supported by new biostratigraphic data. Table 1 summarises previously proposed ages for the Frazzanò Formation.

Stratigraphic sections.

Two composite stratigraphic sections of the Frazzanò Formation were studied, in which the stratigraphic transition to the Militello Formation was preserved.

AUTHORS	FRAZZANÒ FORMATION	STILO-CAPO d'ORLANDO FORMATION
Ogniben (1960; 1961)	Upper Eocene-Lower Miocene	Oligocene-Lower Miocene
Afchain (1966)	----------------	OLIGOCENE-LOWER MIOCENE (F)
Coltro (1967)	UPPER EOCENE (F)	--------------
Truillet (1968)	Middle Eocene	UPPER OLIGOCENE-LANGHIAN (F)
Duée (1969)	Middle-Upper Eocene	OLIGOCENE-LOWER MIOCENE (F)
Ogniben (1969)	Eocene/Oligocene boundary	Oligocene-Lower Miocene
Bonardi et al. (1971)	----------------	UPPER OLIGOCENE-LANGHIAN (F)
Ogniben (1973)	Eocene/Oligocene boundary	Upper Oligocene-Lower Miocene
Guerrera & Wezel (1974)	----------------	LOWER MIOCENE (F)
Lentini (1975)	Upper Eocene	Oligocene-Miocene
Lentini & Vezzani (1975)	Upper Eocene-Oligocene	Upper Oligocene-Lower Miocene
Amodio Morelli et al. (1976)	Eocene-Oligocene	Upper Oligocene-Lower Miocene
Bonardi et al. (1976)	Eocene-Oligocene	--------------
Grandjacquet & Mascle (1978)	----------------	Oligocene-Burdigalian
Lentini & Vezzani (1978)	Eocene-Oligocene	--------------
Arnone et al. (1979)	Eocene-Oligocene	--------------
Bonardi et al. (1980)	----------------	BURDIGALIAN-LANGHIAN (F, N)
Broquet et al. (1984)	----------------	Oligocene-Miocene
Bouillin (1986)	----------------	Upper Oligocene-Lower Miocene
Bouillin et al. (1986)	Eocene	Upper Oligocene-Lower Miocene
Meulenkamp et al. (1986)	----------------	UPPER OLIGOCENE-BURDIGALIAN (F)
Puglisi (1987)	Upper Eocene-Oligocene	Lower Miocene
Courme & Mascle (1988)	----------------	UPPER OLIGOCENE-BURDIGALIAN (F, N)
Giunta (1991)	----------------	Lower Miocene
Giunta et al. (1992)	Oligocene	Lower Miocene
Weltjie(1992)	Upper Eocene-Lower Oligocene	LOWER OLIGOCENE-MIDDLE BURDIGALIAN(D)
Caliri et al.(1993)	----------------	UPPER OLIGOCENE-LOWER MIOCENE (N)
Guerrera et al. (1993)	Uppermost Oligocene	Burdigalian
Nigro & Puglisi (1993)	Upper Eocene-Lower Oligocene	Oligocene-Miocene
Keziran et al. (1994)	----------------	UPPER OLIGOCENE-BURDIGALIAN (F, N)
Lentini et al. (1994)	----------------	UPPER OLIGOCENE-LOWER BURDIGALIAN (N)
Lentini et al.(1995)	Upper Eocene-Lower Oligocene	UPPER OLIGOCENE-LOWER MIOCENE (N)
Nigro (1995)	----------------	OLIGOCENE-BURDIGALIAN (F, N)
Patterson et al. (1995)	----------------	UPPERMOST OLIGOCENE-BURDIGALIAN (IS)
Catalano & Di Stefano (1996)	----------------	UPPER OLIGOCENE-LOWER MIOCENE (N)
Bonardi et al. (1997)	Eocene/Oligocene boundary	Lower Miocene
Cavazza et al. (1997)	----------------	UPPERMOST OLIGOCENE-BURDIGALIAN (IS)

Tab. 1 - Ages of the Frazzanò Formation and Stilo-Capo d'Orlando Formation according to different Authors. The ages supported by biostratigraphic data are capitalized (F = Foraminifera; N = Calcareous Nannoplankton; D = Dinoflagellates; IS = Isotopic Stratigraphy).

The first section (Fig. 4) was measured and sampled in the Iria-Valle Bruca area (4 km south of Sant'Agata di Militello; Topographic map of Italy, Tav. 252 III SE Sant'Agata di Militello). In this area the terrains of the Longi-Taormina Unit are strongly deformed by numerous thin thrust sheets which preclude finding a continuous section. All the terrains, from the Liassic limestones to the Frazzanò Formation dip towards the western quadrants, between N 240° and N 330°.

We sampled the lower part of the section along the track which originates after the bend along the road to Iria, at an altitude of 446 m a.s.l. There, the section includes the transition between the Militello and Frazzanò Formations and consists of 4 m of reddish and greyish marls and silty marls, representing the uppermost portion of the Militello Formation, followed by 8 m of sandy-silty marls with interbedded thin sandstone strata (Fig. 4; Log 1). The succession dips N 240°.

The second part of the section was sampled immediately north of Valle Bruca, along the road for Sant'Agata di Militello, between houses located at an altitude of 352 and 355 m a.s.l. This part includes 10 m of sandstone beds, 10-20 cm- thick, with thin and discontinuous silty-pelitic levels, dipping N 300° (Fig. 4; Log 1).

The uppermost part of the section is located downwards along the same road, originating at the branch to San Giovanni. At this point, 225 m of a succession dipping N 330° were measured. The lower beds consist of 150 m of turbidite sandstones and 4 conglomerate levels, 1-2 m-thick. The sandstone beds show erosional boundaries and range from 20 cm to 1 m in thickness. The overlying beds include 25 m of sandy-conglomeratic turbidites and 50 m of conglomerates, characterised by clasts 6-10 cm in size, mostly composed of extrabasinal carbonate (Fig. 4; Log 1).

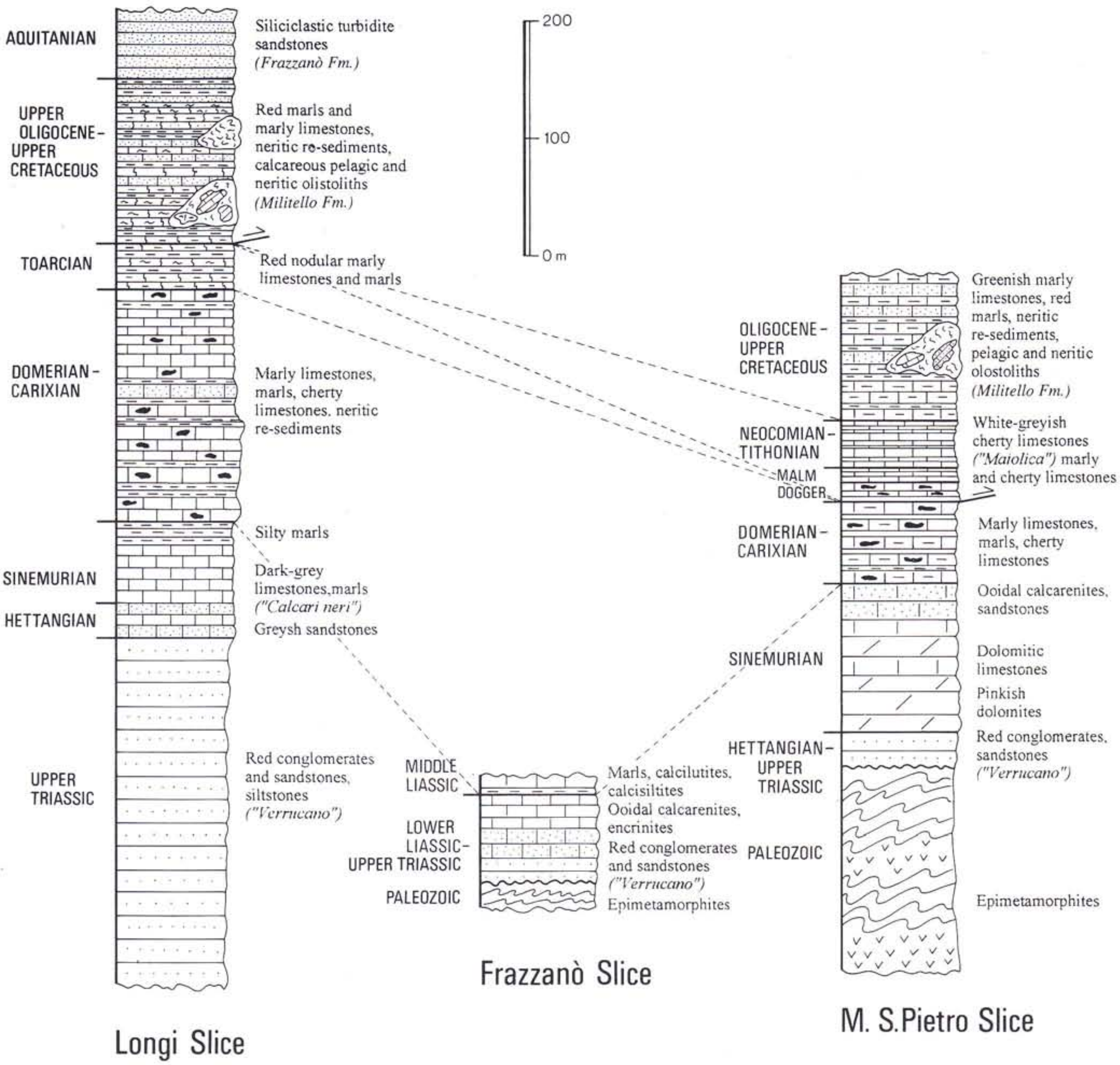
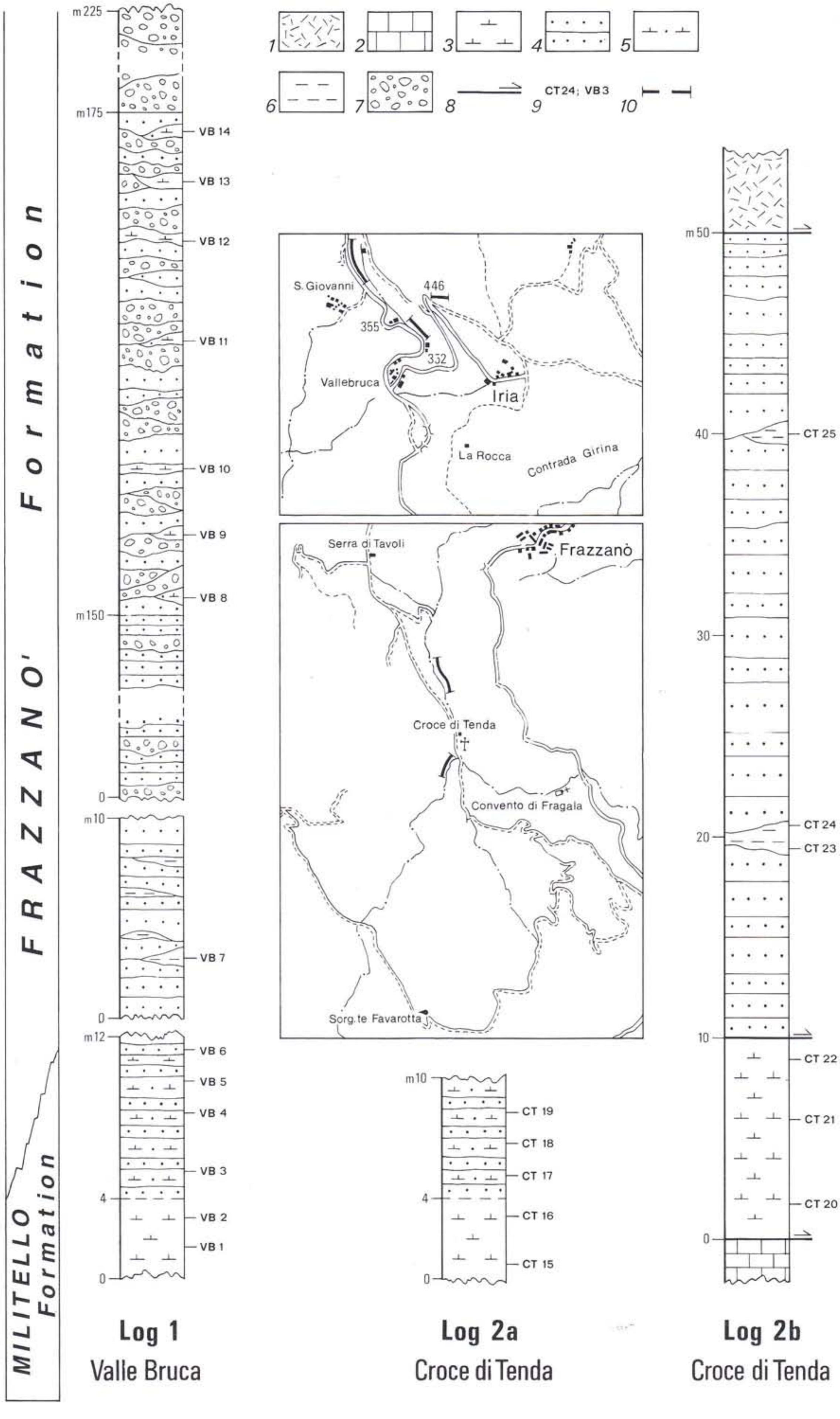


Fig. 3 - Stratigraphic successions of the Longi-Taormina Unit in the Galati Mamertino-Sant'Agata di Militello area (after Arnone et al., 1979; ages modified).

The second stratigraphic section (Fig. 4) was measured in the Croce di Tenda-Convento di Fragalà area (1 km south of Frazzanò village; Topographic map of Italy, Tav. 252 II SO Galati Mamertino).

We sampled the top of the Militello Fm. along the track from Croce di Tenda to Sorgente Favarotta (Fig. 4; Log 2a). This succession is composed of 4 m of reddish and yellow-greenish marls, followed by 6 m of marls with a few thin sandstone strata, dipping N 25°. We also sampled at another site, nearly 250 m northwards along the new road (not indicated on the map), from Croce di Tenda to Frazzanò village (Fig. 4). There a fault separates the Liassic carbonates ("Medolo facies" Auct.) from the Militello Formation, composed of nearly 10 m of reddish and yellowish marls, followed by the Frazzanò Formation. The latter unit consists of 40 m of sandstones, with a few thin microconglomerate beds, and only two pelitic levels (Fig. 4; Log 2b). The entire succession, from the "Medolo" to the Frazzanò Formation, dips N 20°.

Fig. 4 - Stratigraphic sections from the Iria-Valle Bruca and Croce di Tenda areas: 1) Epimetamorphites; 2) Limestones; 3) Marls; 4) Sandstones; 5) Sandy and silty marls; 6) Pelites and silty pelites; 7) Conglomerates; 8) Tectonic contacts; 9) Samples; 10)Trace of the sampled sections.


FRAZZANO' Formation
MILITELLO Formation
CT24; VB3
S. Giovanni
446
355
332
Vallebruca
Iria
La Rocca
Contrada Girina
Serra di Tavoli
Frazzanò
Croce di Tenda
Convento di Fragala
Sorg.te Favarotta
VB 1
VB 2
VB 3
VB 4
VB 5
VB 6
VB 7
VB 8
VB 9
VB 10
VB 11
VB 12
VB 13
VB 14
CT 15
CT 16
CT 17
CT 18
CT 19
CT 20
CT 21
CT 22
CT 23
CT 24
CT 25
Log 1
Valle Bruca
Log 2a
Croce di Tenda
Log 2b
Croce di Tenda

PLANKTONIC FORAMS	IRIA-VALLE BRUCA									CROCE DI TENDA	
	VB1	VB2	VB3	VB4	VB5	VB6	VB12	VB13	VB14	CT15	CT21
Acarinina broedermanni	x										
Acarinina bullbrooki	x	x									x
Acarinina spinuloinflata	x										
Morozovella aragonensis	x										
Morozovella spinulosa		x									x
Truncarotaloides topilensis	x										
Hantkenina dumblei		x									
Hantkenina alabamensis						x		x			
Hantkenina primitiva						x		x			
Globigerinatheka subconglobata	x	x	x	x	x	x	x		x		
Globigerinatheka index						x					
Globigerinatheka seminvoluta			x	x	x						
Muricoglobigerina senni	x		x								x
Subbotina linaperta	x		x								x
Subbotina inaequispira	x	x								x	x
Subbotina frontosa	x	x									x
Turborotalia possagnoensis											x
Turborotalia pomeroli					x	x					
Turborotalia cerroazulensis			x		x	x	x	x			
Turborotalia cocaensis				x	x	x	x	x			
Turborotalia cunialensis							x				
Globigerina eocaena		x	x	x	x	x	x	x	x	x	
Globigerina corpulenta						x	x	x	x		
Globigerina gortanii								x			
Globigerina galavisi			x	x	x		x		x		
Globigerina tripartita								x			
Globigerina venezuelana			x	x	x	x	x	x	x		
Globigerina ampliapertura								x			
Globigerina increbescens					x			x			
Catapsidrax unicavus			x			x					
Catapsidrax gr dissimilis					x	x					

Tab. 2 - Foraminiferal assemblages recognized in the samples studied.

Biostratigraphic data.

The stratigraphic location of 25 samples is shown in fig. 4. We analysed both planktonic foraminifera and coccoliths in detail.

Table 2 summarises the most recent planktonic foraminifera found in the >125 μm residue. These microfaunas were initially interpreted as taphocenoses having the same age as the sediments. In addition, a few older specimens (not shown) were found frequently. We cannot rule out the possibility that in some samples the entire microfauna was reworked, as appeared to be the case for the microfaunas in samples VB 8 to VB 11.

Reworked taxa were very common in the nannoflora assemblages (Tab. 3) and prevailed in all samples. Thirteen samples were barren. Taking into account this widespread reworking, the estimated ages must be interpreted as the oldest possible.

In the Iria-Valle Bruca section, samples VB 1 and VB 2 from the uppermost levels of the Militello Fm. provided a rich but poorly preserved microfauna consisting of *Acarinina*, *Morozovella*, *Hantkenina* and *Globigerinatheka*. If this assemblage was coeval with sedimentation, the age of the Militello Formation in the Iria-Valle Bruca section must be limited to the Middle Eocene. The presence of *M. aragonensis* and only the ancestral form of *Turborotalia cerroazulensis* group-*Subbotina frontosa* indicates the lower part of the Middle Eocene (P10 to P12 zones of Blow, 1969). The nannoplankton assemblages, however, are characterised by the presence of *Sphenolithus predistentus* and *Sphenolithus distentus*, together with *Coronocyclus nitescens* and *Pedinocyclus larvalis* (Tab. 3), indicating an age not older than Early Oligocene (late Rupelian; Zone CP 17/18 Okada & Bukry, 1980 = NP 23 Martini, 1971).

The lower samples collected at the passage between the Militello and Frazzanò Formations (VB 3 and VB 4), contained mainly agglutinated and planktonic foraminifera. The precise identification of planktonic species was difficult due to marked deformation, although most specimens appeared to be large globigerinids. A few, probably reworked, specimens of *Acarinina*, *Morozovella* and Cretaceous species also were observed. Samples VB 5 and VB 6 were rich in planktonic foraminifera and agglutinated Astrorhizidae. The planktonic assemblage included mainly specimens of the *T. cerroazulensis* group (*T. pomeroli*, *T. cerroazulensis*, *T. cocaensis*), large *Globigerina* (*G.* gr. *eocaena*, *G. venezuelana*, *G. galavisi*) and *Catapsidrax* gr. *dissimilis*. Moreover, sample VB 6 also contained *Hantkenina* (*H. alabamensis and H. primitiva*). According to the planktonic foraminiferal assemblages described above, the transition levels between the Militello and Frazzanò Formations in the Iria-Valle Bruca area were deposited during the Late Eocene. However, studies of the coccolith assemblages suggest an Oligocene age for these levels. Sample VB 3, and previous samples, showed the same late Rupelian age. However, the overlying samples were characterised by the appearance of *Triquetrorhabdulus carinatus* (VB 4), indicating an age not older than Late Oligocene (early Chattian; zone CP 19a Okada & Bukry, 1980 = NP 24 Martini, 1971*)*, *Sphenolithus dissimilis* (VB 5), suggesting an age not older than the boundary between the early and late Chattian (top zone CP 19a/CP 19b Okada & Bukry, 1980 = top zone NP 24/NP 25 Martini, 1971), and *Sphenolithus ciperoensis* (VB 6), indicating and age not older than the late Chattian (zone CP 19b Okada & Bukry, 1980 = NP 25 Martini, 1971)(see Tab. 3).

Sample VB 7, from the arenaceous interval of the section, was azoic. Sediments from uppermost interval contained abundant planktonic foraminifera. Each assemblage was consistent in age, while the ages of the samples differed widely. Sample VB 8 (Late Paleocene) and VB 9 to 11 (Maastrichtian) were inconsistent with the stratigraphic succession and indicate intense reworking processes. Samples VB 12 to VB 14 contained Upper Eocene foraminiferal assemblages, which were congruent with those from the lower part of the formation. As to the nannoplankton, sample VB 8 showed an oligotypic association dominated by Coccolithidae, with absolute predominance of small-sized *Coccolithus pelagicus*. Samples VB 9-VB 12 were barren, whereas samples VB 13 and VB 14 contained an important microflora, characterised by the appearance of *Geminilithella rotula* and *Triquetrorhabdulus* aff. *milowi* (Tab. 3), indicating an age not older than early Aquitanian (zone CN1 Okada & Bukry, 1980 = NN1/2 Martini, 1971).

The samples collected in the Croce di Tenda section were unrevealing. A few, characterised by poor assemblages, yielded taxa indicating ages older than those deduced from the Iria-Valle Bruca section. Only samples CT 15 and CT 21 from the Militello Fm. provided rare planktonic foraminifera of a Middle Eocene age. The microfauna was composed mainly of agglutinated foraminifera with planktonic foraminifera of different ages occasionally present (i.e., globotruncanids, acarininids and globigerinids). Only samples CT 15, CT 18 and CT 19 contained nannofloras. The presence of only *Sphenolithus predistentus* indicates an age not older than Middle Eocene.

Considering the foraminifera the uppermost part of the Militello Fm. must be attributed to the Middle Eocene (zones P 10-P 12) and the entire Frazzanò Fm. would have to have been deposited during the Late Eocene (zones P 15-P 16). These age estimates, however, are inconsistent with the nannoplankton species recognised in the same samples. These data indicate that the uppermost part of the Militello Fm. is not older than Early Oligocene (late Rupelian; zones CP 17/18), the transition levels between the Militello and Frazzanò Fms. are not older than Late Oligocene (Chattian; zones CP 19a/CP 19b) and the upper part of the Frazzanò Fm. is not older than early Aquitanian (zone CN 1).

Similar to what usually happens in the southern Apennine and Maghrebian flysch deposits, taxa reworking in the Frazzano' and Militello Formations is a generalised and important peculiarity, and the age indicated by nannofossils is generally younger than the age estimated on the basis of the foraminifera present. We emphasise that in the Frazzanò Fm. the presence of foraminifera younger than Late Eocene has not yet been recognised.

Discussion and conclusion.

The biostratigraphic data demonstrate that the uppermost portion of the Militello Formation, the transition levels between the Militello and Frazzanò Formations and the upper portion of the Frazzanò Fm. have an age not older than Early Oligocene, Late Oligocene and early Aquitanian, respectively. Consequently, the deformation of the Longi-Taormina Domain and the stacking of tectonic units derived from this domain began not earlier than the Early Miocene (Aquitanian).

The renewal of tectonic activity in the southern sector of the Calabria-Peloritani Arc, however, probably began during the Oligocene, both at surface and deeper levels, as recorded by the "sedimentary klippen" of the Militello Formation, by radiometric data concerning the alpine metamorphic overprint of the Aspromonte Unit (28-25 Ma; Bonardi et al., 1991), and by fission-tracks data both of the basement and the Stilo-Capo d'Orlando Fm. (Thomson, 1994).

COCCOLITHS	IRIA-VALLE BRUCA									CROCE DI TENDA		
	VB1	VB2	VB3	VB4	VB5	VB6	VB8	VB13	VB14	CT15	CT18	CT19
Biantholithus sparsus		R	R				R					
Braarudosphaera bigelowi	x	x						x				
Braarudosphaera sp.								R				
Calculites obscurus								R		R		
Ceratolithoides aculeus			R									
Chiasmolithus grandis		R										
Coccolithus eopelagicus	x		R		R	R		R				
Coccolithus miopelagicus		x		x	x		x		x			
Coccolithus miopelagicus >20µ	x		x			x		x				
Coccolithus pelagicus	x	x	x	x	x	x	x	x	x	x	x	
Coronocyclus nitescens	x	x	x	x	x	x		x	x			
Crepidolithus crassus	R											
Cyclicargolithus abisectus	x	x	x	x	x	x		x	x			
Cyclicargolithus floridanus		x		x	x	x		x	x			
Discoaster adamanteus					x	x		x				
Discoaster cf. adamanteus		x										
Discoaster barbadiensis	R	R	R			R.		R	R			
Discoaster deflandrei						x						x
Discoaster delicatus						R	R					
Discoaster gemmeus	R		R	R		R				R		
Discoaster gemmifer		R						R				
Discoaster mohleri			R									
Discoaster multiradiatus	R	R					R					
Discoaster nodifer			R	R		R		R				
Discoaster saipanensis			R	R		R		R		R		
Discoaster tani		R	R						R			
Discoaster spp.		x	x	x	x	x		x			x	x
Ellipsolithus distichus							R					
Ericsonia cava	x	x	x		x	x	x	x	x	x	x	
Ericsonia formosa	R	R	R			R	R	R	R	R		
Ericsonia obruta	x											
Fasciculithus schaubi							R					
Fasciculithus spp.	R	R	R				R	R	R			
Geminilithella rotula								♦				
Helicosphaera euphratis	x				x			x				
Isthmolithus recurvus	x	x										
Lanternithus minutus	R	R	R		R	R		R	R			
Manivitella pemmatoidea	R											
Microrhabdulus decoratus		R										
Micula concava						R						
Micula praemura								R				
Micula prinsi												R
Micula swastica		R										
Pedinocyclus larvalis	x	x						x				
Prinsius bisulcus								R				
Pseudotriquetrorhabdulus inversus	x							R	R			
Pyrocyclus hermosus		x					x	x				
Quadrum gartneri			R					R				
Quadrum trifidum		R										
Reticulofenestra bisecta	x	x	x	x	x	x	x	R	R	x		
Reticulofenestra coenura	x	x	x	x		R		R	R	x		
Reticulofenestra dictyoda	R											
Reticulofenestra gartneri	x	x	x		x	x		x	x			

Reticulofenestra hillae	x	x		x	x			R	R			
Reticulofenestra minuta	x					x			x			
Reticulofenestra oamaroensis			x									
Reticulofenestra perplexa	x	x	x		x	x		x	x	x		x
Reticulofenestra reticulata	R							R	R			
Reticulofenestra scrippsae		x	x			x		R	R			
Reticulofenestra umbilicus	x	R	R			R	R	R	R			x
Sphenolithus anarrhopus	R		R					R	R			
Sphenolithus aff. belemnos			x									
Sphenolithus aff. capricornutus								x				
Sphenolithus ciperoensis						♦						
Sphenolithus conicus	x				x				x			
Sphenolithus cf. conicus								x				
Sphenolithus dissimilis					♦							
Sphenolithus distentus	♦	♦	♦	R	R	R		R	R			
Sphenolithus editus	R							R				
Sphenolithus cf. editus								R				
Sphenolithus moriformis	x	x	x		x	x	x	x	x		x	
Sphenolithus obtusus						R						
Sphenolithus orphanknollensis	R											
Sphenolithus predistentus	♦	♦	♦	R	R	R		R	R	♦	♦	♦
Sphenolithus pseudoradians								R				
Sphenolithus radians	R	R				R		R				
Sphenolithus gr. radians					R							
Sphenolithus aff. tribulosus								x				
Sphenolithus sp.								x				
Stradneria crenulata			R									
Thoracosphaera spp.	x	x	x				x	x				
Tribrachiatus orthostylus					R							
Triquetrorhabdulus cf. carinatus					x			x				
Triquetrorhabdulus carinatus				♦								
Triquetrorhabdulus aff. milowi								♦	♦			
Triquetrorhabdulus sp.		x										x
Watznaueria barnesae	R			R			R	R		R	R	
Watznaueria biporta	R							R				
Watznaueria communis	R										R	
Zygrhablithus bijugatus	x	x	x	x		x		R	R		x	
R = reworked taxa; ♦ = marker												
SAMPLE OLDEST POSSIBLE AGE	VB1-VB2-VB3 late Rupelian					VB4 early Chattian				VB5 early-late Chattian		
SAMPLE OLDEST POSSIBLE AGE	VB6 late Chattian					VB13-VB14 early Aquitanian				CT15-CT18-CT19 Middle Eocene		

Tab. 3 - Coccolithid assemblages recognized in the samples studied and their oldest possible age.

Assigning an Aquitanian age to the Frazzanò Fm. and to the onset of the Longi-Taormina Domain deformation agrees with the age of the metamorphic overprint and, on the scale of the Western Mediterranean, with the stacking of the Rifian and Betic Units equivalent to the Longi-Taormina Unit (Martìn-Algarra, 1987). Such an age assignment contrasts, however, with the Late Oligocene age of the base of the Stilo-Capo d'Orlando Formation, as suggested in recent papers (Lentini et al., 1995; Patterson et al., 1995; Catalano & Di Stefano, 1996; Cavazza et al., 1997).

We believe that the age of the base of the Stilo-Capo d'Orlando Fm. needs to be verified in the entire southern sector of the Calabria-Peloritani Arc. A complete understanding of the deformation age of this sector can be resolved only on a Western Mediterranean scale.

Terrains equivalent to the Stilo-Capo d'Orlando Formation in stratigraphic position and tectono-sedimentary role were found previously in the Internal Domains of the entire Western Mediterranean area, both in Kabylia ("Oligo-Miocène kabyle") and in the Betic-Rifian Arc (Viñuela and Sidi Abdeslam Formations; Martìn-Algarra, 1987; Maate, 1989; Guerrera et al., 1993). We emphasise that the "Oligo-Miocène kabyle" was attributed to the Late Oligocene-Burdigalian interval, whereas the equivalent Betic and Rifian formations were considered Burdigalian in age from their base. Moreover, the latter lie unconformably on all the internal units of the chain, including terrains affected by a high grade metamorphic event, 21±2 Ma old (Zeck et al., 1989). Clasts derived from such metamorphites are known also in the basal strata of these Burdigalian unconformable deposits.

It should be noted that in the Betic-Rifian Arc, below the Viñuela and Sidi Abdeslam Formations, an older sedimentary cycle, named Ciudad Granada-Fnideq cycle, was recognised (Martìn-Algarra, 1987; Maate, 1989; Martìn-Martìn, 1996). This cycle, Late Oligocene-early Aquitanian in age, lies disconformably or slightly unconformably only on the highest units of the chain (Malaguide Units in the Betic Cordillera and Ghomaride Units in the Rif). The Ciudad Granada-Fnideq cycle, consisting of fluvial and marine deposits with very different facies, was supplied exclusively by the underlying Malaguide and Ghomaride terrains and should indicate the onset of tectogenesis in the most internal Betic-Rifian Domains.

Cavazza et al. (1997) recognised alluvial and neritic terrains, named "conglomeratic basal member" and "biocalcarenitic member", in the Eastern Serre, at the base of the Stilo-Capo d'Orlando Formation. These terrains, very different from the typical lithologies of the Stilo-Capo d'Orlando Formation, were recognised only where such a formation lies on the highest tectonic unit of the southern sector of the Calabria-Peloritani Arc (Stilo Unit), like some other terrains outcropping in the same region (sandstones and lignitiferous clays with *Antracotherium* of the Agnana-Antonimina basin, Nicotera, 1963; "red phyllite conglomerate" of the Monte Mutolo-Monte Scifa area, Bonardi et al., 1980; Cavazza, 1989; Palizzi Formation, Bouillin et al., 1985).

These terrains could record the existence, even in the Calabria-Peloritani Arc, of a sedimentary cycle older than the Stilo-Capo d'Orlando Formation, equivalent to the Betic-Rifian Ciudad Granada-Fnideq cycle. In this case, they could show pre-Aquitanian tectonics in the highest (internal) units of the southern sector of the Calabria-Peloritani Arc.

In conclusion, the data presented above indicate that the stacking of the Longi-Taormina Domain Units is not older than the early Aquitanian and suggest the existence of two sedimentary cycles in the Late Oligocene-Early Miocene interval in the southern sector of the Calabria-Peloritani Arc, as in the Betic-Rifian chain, as well as the onset of tectogenetic activity in the most internal domains during the Oligocene.

Acknowledgements.

Thanks are due to F. Proto Decima (Padova) and an anonymous referee who revised the manuscript. This research was supported by the following grants: MURST 40% 1995 (G. Bonardi) and MURST 60% (F. Guerrera and V. Perrone).

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Received May 22, 1997; accepted September 19, 1997