BOLLETTINO DI GEOFISICA TEORICA ED APPLICATA VOL. XXXVI, N. 141-144 - MARCH-DECEMBER 1994

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MAIN STRUCTURAL DOMAINS OF THE CENTRAL MEDITERRANEAN REGION AND THEIR NEOGENE TECTONIC EVOLUTION

Abstract. The Central Mediterranean area is composed of several structural domains which extend along an orocline belt from Tunisia to the Southern Apennines, through Sicily and Calabria. These domains originated during orogenic processes induced by the Europe-Africa convergence. In the present-day configuration of the region the following domains can be distinguished: the foreland domain, which is divided into three major sub-domains; the orogenic belt domains, consisting of three distinct tectonically superimposed "chains"; and the hinterland domains, represented by the European fragment of the Sardinian Block and by the Tyrrhenian Sea. Each domain originated in a distinct period corresponding to a stage in the polyphasic deformation of the region. The present-day outlines derived from the late orogenic tectonic events (post-Tortonian) which gave rise to the youngest domains and modified the pre-existing ones. The foreland domain is composed of two continental blocks: the Pelagian Block, which extends from eastern Tunisia (Sahel) to southeastern Sicily (Hyblean Plateau), and is mostly submerged, and the Apulian Block, facing the Southern Apennines. The two blocks are made up of a 20-30 km thick continental crust underlying a very thick Meso-Cenozoic carbonate sequence. They are separated by a thinned crustal area (10-15 km), the Ionian Basin, which faces towards the Calabrian Arc. Two major fault escarpments connect the continental blocks with the basin. These features probably originated during Mesozoic times and have controlled the palaeogeography of the domain. The fault escarpment bounding the Pelagian Block to the east, the Malta Escarpment, was reactivated by prevalently normal movements during the Plio-Pleistocene. The foreland edge facing the orogenic belt contains very narrow and discontinuous foredeep basins (the Bradanic Foredeep and Gela Foredeep) which are interrupted where the foreland-chain boundary is represented by Plio-Pleistocene transcurrent zones (N-S Axis in Tunisia, Nameless Bank in the Sicily Channel). The most external and deepest structural domain of the orogenic belt is the External Thrust System, a gently deformed thrust belt which has developed since the Tortonian. This domain involves sequences similar to those outcropping in the foreland sub-domains which are characterized by the lack of flysch-type terrigenous cover. In Sicily the External Thrust System developed on the margin of the Pelagian Block giving rise to the Sicanian Chain, a thrust belt which extends westwards in the Sicily Channel (Adventure Bank) as far as the Sardinia Straits (Egadi thrust belt) and the Atlas Mts. in Tunisia. The Sicanian Chain outcrops extensively in Western Sicily, where it dips to the north under the more internal Maghrebian Chain. In Eastern Sicily the Sicanian Chain forms a duplex structure buried under the more internal units at a depth of about 7000 m. In the Southern Apennines, the External Thrust System, corresponding to the Apulian Chain, has developed since the Upper Miocene by the deformation of the most internal Apulian carbonate sequences and forms a duplex structure mostly buried under the more internal domains. The southern continuation of this duplex structure has also been detected from subsurface data below the units of the Calabrian Arc. The intermediate domain of the orogenic belt is represented by the Apenninic-Maghrebian Chain, a strongly deformed thrust belt created since the Early Miocene. This domain is composed of allochthonous units involving Meso-Cenozoic sequences deriving from several palaeodomains. The chain is characterized by a huge bulk of Early Miocene to Upper Miocene syn-orogenic flysch-type terrigenous cover which is mostly detached from the original substratum and migrated foreward to the front of the chain. The Appenninic- Maghrebian Chain formed mostly before the Tortonian and progressively overthrust, as a whole, the more external domains during the late orogenic tectonic events. In that period the chain suffered further deformations and was involved in a continuous passive tectonic transport over the foreland areas, due to duplexing processes in the substrata. The most internal and uppermost domain of the orogenic belt is represented by the Kabilo-Calabride Chain, a highly deformed thrust belt, involving basement nappes mostly composed of Hercynian crystalline rocks and their Meso-Cenozoic sedimentary covers. This domain shows Upper Eocene- Early Miocene syn-orogenic flysch-type deposits. The Kabilo-Calabride Chain outcrops on the northern coast of Africa and in the Calabrian Arc.

Manuscript received March 26, 1993; accepted September 10, 1993.

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Its submerged continuations have been detected from seismic data and drilling in the Sardinia Straits and along the northern coast of Sicily. This domain represents a pellicular tectonic element extensively overlying the Apenninic-Maghrebian Chain. The overthrust of the Kabilo-Calabride domain onto the Apenninic-Maghrebian Units dates back to the Burdigalian, and the tectonic contact between them is recognizable, in Sicily, along the so-called "Taormina Line". This structure does not represent a transform structure seated at the southern edge of the Calabrian Arc, as is supposed by many authors; field data suggest that this alignment corresponds to an erosional front of a sub-horizontal thrust surface. This surface has also been detected on seismic lines through the Calabrian Arc, showing the extensive overthrust of Kabilo-Calabride Units upon the Apenninic-Maghrebian ones. Small klippen of Kabilo-Calabride Units rest on the Maghrebian Chain in north-eastern Sicily, ahead of the Taormina Line, while small tectonic windows of Maghrebian terranes have been found along the north-eastern coast of Sicily.

In the hinterland areas, the Sardinian Block represents a fragment of an Hercynian chain, originally belonging to the European Foreland, which suffered a counterclockwise rotation towards the SE during the Oligo-Miocene. During these rotational processes the Sardinian Block acted as an active margin, overriding a westward subducting crust, and extensively overthrusting the Kabilo-Calabride domain. At present, the Sardinian Block is as much dissected as the Kabilo-Calabride domain by the extensional faults bounding the Tyrrhenian Sea. The latter corresponds to a domain created since Upper Serravallian times by a regional extensional regime which affected the pre-existing internal domains of the Africa-verging orogenic belt. The amount of shortening varies along the axis of the orogen. It reaches its maximun in the Calabrian Arc, where the three domains of the orogenic belt are extensively superimposed over each other, and tends to its minimum towards the Central Appennines and Tunisia, where the internal orogenic domains remained back and the External Thrust System outcrops widely. The transition between sectors of the orogenic belt characterized by different shortening rates occurs along strike-slip fault systems which drove the migration of the units towards the area of maximum shortening. These fault systems are widespread within the orogenic domains, but they have different kinematic behaviours in each domain. The strike-slip faults dissecting the Kabilo-Calabride and the Apenninic-Maghrebian Chain cut a pre-existing thrust geometry and, often, are detached from the deep seated shear-zone since they were transported during the late orogenic tectonic movements. The strike-slip faults of the External Thrust System behave as lateral ramps connected to the Recent thrust fronts. The displacement of the orogenic belt along Recent strike-slip faults may be related to movements along transform faults activated during the opening of the Tyrrhenian Sea. The evidence suggests that the domains of the orogenic belt and those of the hinterland during late "collisional" processes were deformed together, thus behaving as a single tectonic unit. Further data, both from seismic and geological investigations, are required to unravel the connections between the late tectonic evolution of the orogen and the recent activity along the main lineaments of the foreland. New data are needed to establish whether late orogenic processes are restricted to the margins of two colliding plates or whether they represent intra-plate deformations superimposed over the Europe and Africa suture.

INTRODUCTION

The Central Mediterranean region is a complicate structural puzzle formed from the orogenic belt which rose up during the Neogene Africa-Europe collision.

During the Neogene, the area was characterized by the coexistence of extensional and compressive processes interacting with each other in the later orogenic phases. These processes gave rise to new structural features and strongly modified those pre-existing, thus creating the complex structure of the area.

Several models of the region have been proposed by various Authors as new geological data were collected. Each model showed some particular aspect, but neglected others. The models often failed tests in the field.

To better delineate the main outlines of the region, more detailed field data on a regional scale and their integration with seismic data on- and off-shore are required.

In the present paper, an overall definition of the principal structural domains of the Central Mediterranean area is proposed. The main purpose of this paper is to point out the links between on-shore sectors of each domain and their off-shore continuation, using new data collected in the last few years during detailed field mapping throghout the orogenic belt from Sicily to the Southern Apennines. The main improvements in this redefinition of the domains are due to the new field data from the Sicanian, Nebrodi and Peloritani Mountains in Sicily and from the Lucanian Apennine in the Southern Apennines.

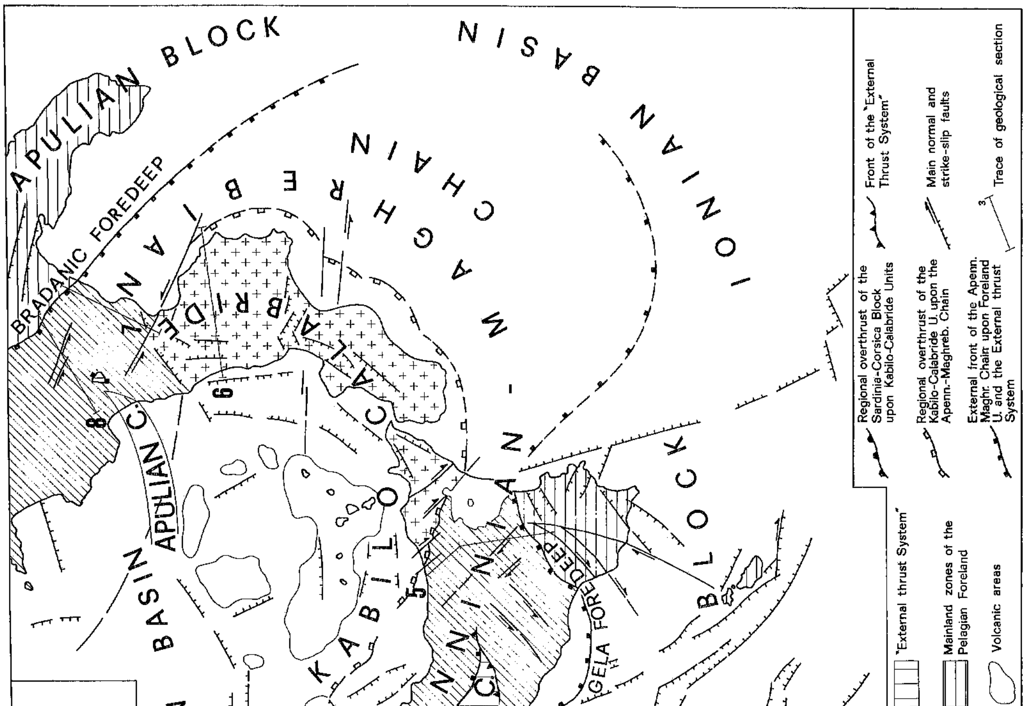


Fig. 1 - The Central Mediterranean domains.

STRUCTURAL DOMAINS

The Central Mediterranean region is composed of several sectors distinguishable by the homogeneity of their structural features and geological evolution. Each sector represents a structural domain whose characteristics derive from its particular geological history and from the role it played during the collisional processes in the area. These domains are currently involved in the Africa-verging orogenic system dominating the area. The different structural domains originated in successive moments of the geological evolution of the belt as the orogenic front migrated towards the external areas of the system.

Each of the studied domains is composed of "sub-domains" which, in turn, consist of a number of "sectors". The sub-domains and their sectors are differentiated by local structural and stratigraphical characteristics.

In the present-day configuration of the Central Mediterranean region the following domains can be distinguished: the foreland domain, which is divided into three major sub-domains; the orogenic belt domains, consisting of three distinct tectonically superimposed "chains" (the External Thrust System, the Thin-skinned Chain and the Crystalline Chain), and the hinterland domains, represented by the European fragment of the Sardinian Block and by the Tyrrhenian Sea.

Foreland

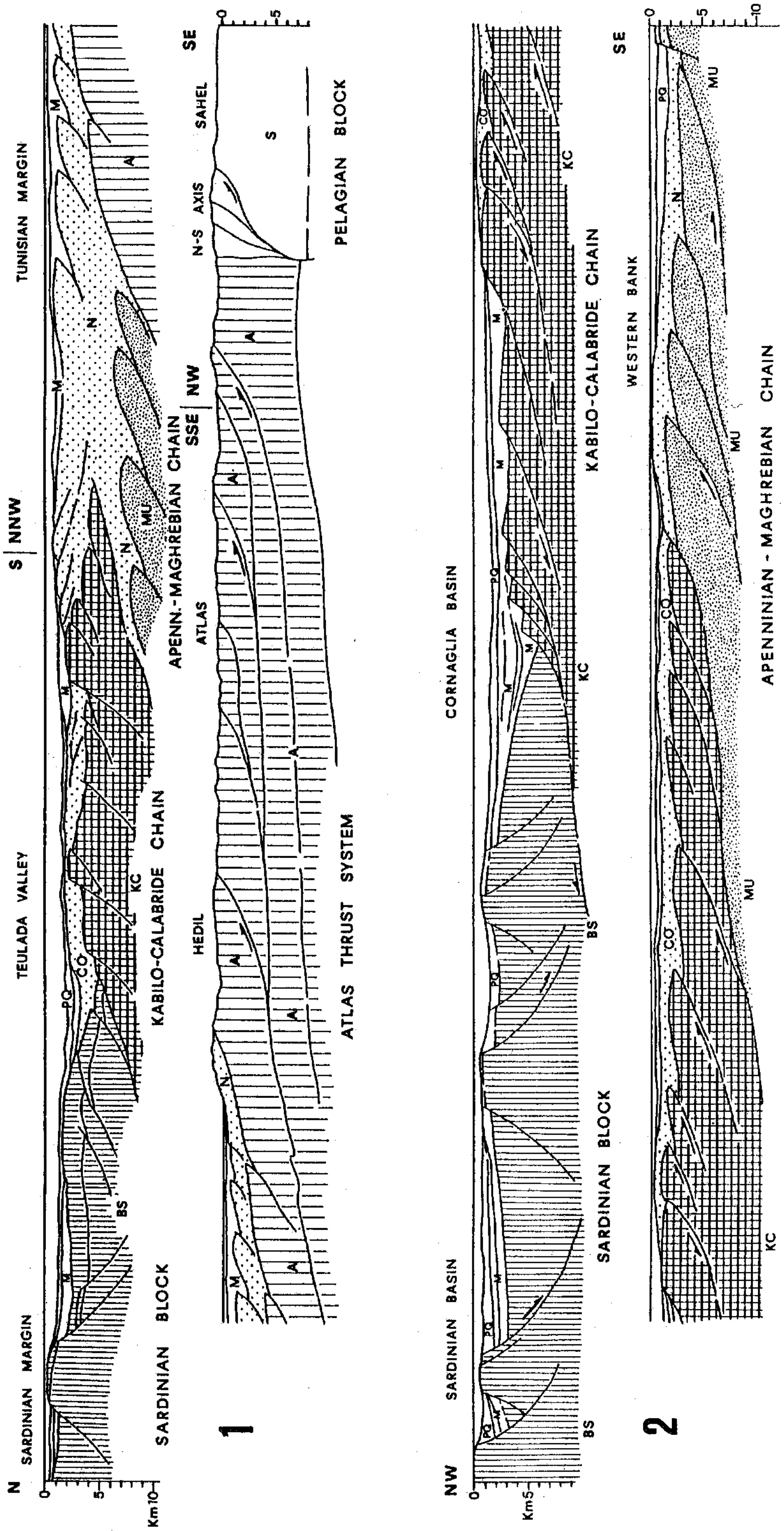
The Foreland is the externalmost structural domain and comprises a wide, roughly undeformed area, belonging mostly to the subducting African continental margin. It extends from Tunisia to the Adriatic Sea. The foreland consists of three major sub-domains, amongst which two main continental "blocks" are recognizable, the "Pelagian Block" to the SW and the "Apulian Block" to the NE. These two blocks are separated by a wide thinned-crust area corresponding to the "Ionian Basin" (see Fig. 1). Each of these sub-domains is in turn composed of several sectors characterized by distinct mechanical behaviours, according to their ability to bend beneath the migrating orogenic belt. These sectors are bound by major, roughly N-S oriented transform fault zones responsible of the segmentation of the foreland areas (see Fig. 1).

Pelagian Block

This is the westernmost sub-domain of the Foreland and extends from Tunisia to Sicily. The Pelagian Block (Burollet et al., 1978) is characterized by a 25-30 km thick continental crust including a very thick Meso-Cenozoic carbonate sequence containing several interleaved volcanic horizons (Patacca et al., 1979). It is an E-W segment of the African continental margin (Dewey et al., 1989) deflecting to the north beneath the migrating units of the orogenic belt.

The sequences of the Pelagian Block are mostly submerged but crop out in the Sahel region

Fig. 2 - Regional profiles from the Sardinia Channel to Tunisia (for location see Fig. 1). Profile 1 crosses all the structural domains of the central Mediterranean region. It passes through the Sardinian Block, the Kabilo-Calabride Chain, then the Apenninic-Maghrebian Chain and the Atlas Mts, and finally the Foreland areas of Sahel in Tunisia (after Ben Avraham et al., 1990, modified). Profile 2 (after Catalano et al., 1989, modified) crosses the hinterland domains and the Apenninic-Maghrebian Chain located between Sardinia and Western Sicily. On these profiles the late orogenic modifications of the pre-existing thrust system are well documented. They were mainly caused by extensional tectonics that produced wide structural depressions filled by Upper Miocene syn-tectonic deposits (e.g. Teulada Valley on profile 1; the Sardinia Basin and the Cornaglia Basin on profile 2). These depressions seem to represent the south-western continuations of the Tyrrhenian Basin. On these two profiles the Oligo-Miocene pre-rift deposits filling perched basins have been detected. These deposits must be correlated to the Capo d'Orlando Flysch outcropping in Sicily and Calabria. In the external areas of the profiles the Apenninic-Maghrebian Chain is well represented. It consists essentially of the detached Numidian Flysch sequences which are incorporated in several back-verging slices. The Apenninic-Maghrebian units rest tectonically upon the External Thrust System (the so-called Atlas Mts. in Tunisia and the Sicanian Chain in Sicily). Profile 1 crosses the foreland areas of Sahel passing through the N-S axis showing the geometry of an asymmetric flower structure.
LEGEND: PQ = Plio-Pleistocene deposits; M = Upper Miocene syn-post-rift deposits; SARDINIAN BLOCK: BS = Hercynian basement; KABILO-CALABRIDE CHAIN: CO = Capo d'Orlando Flysch (Upper Oligocene-Lower Miocene); MU = Meso-Cenozoic units of the Apenninic-Maghrebian Chain; EXTERNAL THRUST SYSTEM: A = Atlas units; FORELAND: S = Sahel successions.


N
S | NNW
SARDINIAN MARGIN
TEULADA VALLEY
TUNISIAN MARGIN
SARDINIAN BLOCK
KABILO-CALABRIDE CHAIN
APENN.-MAGHREBIAN CHAIN
Km
HEDIL
ATLAS
SSE | NW
N-S AXIS
SAHEL
SE
ATLAS THRUST SYSTEM
PELAGIAN BLOCK
1
NW
SARDINIAN BASIN
CORNAGLIA BASIN
WESTERN BANK
SE
SARDINIAN BLOCK
KABILO-CALABRIDE CHAIN
APENNINIAN - MAGHREBIAN CHAIN
2

of Tunisia, in the Sciacca area of Western Sicily and in the Hyblean Plateau in Eastern Sicily (see Figs. 1 and 2).

A major N-S trending fault zone, the Malta Escarpment, bounds the Pelagian Block to the east towards the Ionian Basin. This fault system is composed of prevalently normal faults, dating back to Mesozoic times, which reactivated during the Pliocene and Quaternary (Scandone et al., 1981; Casero et al., 1984; Fabbri et al., 1982). According to Carbone et al. (1982a; 1982b) and Grasso and Lentini (1982) the Malta Escarpment in Recent times has been responsible for the progressive collapse of the eastern margin of the Pelagian Block facing the Ionian Basin, involving also the eastern slope of Etna and playing an important role in the seismotectonic evolution of the area. According to Grasso (1993) the Recent activity of the Malta Escarpment is characterized by a left-lateral component of motion which gives rise to several NW-SE oriented Plio-Pleistocene grabens distributed en-echelon along the eastern border of the Hyblean Plateau.

Further N-S trending transfer zones cut the northern edge of the Pelagian Block into three distinct areas, each characterized by different mechanical behaviour as it approached the thrust front of the orogenic belt (Grasso and Reuther, 1988). Among them the "Gela Basin" (see Fig. 1) actually deflects beneath the frontal area of the Central Sicily Chain, while the "Nameless Bank" and the Hyblean Plateau represent two bouyant kinematic blocks colliding with the orogenic belt front, respectively to the west and the east (Cogan et al., 1989).

Because of the discontinuity of the flexing processes, a discontinous Plio-Pleistocene foredeep basin developed facing the chain in Sicily. This depression, filled by Plio-Pleistocene terrigenous deposits, is very narrow in the Catania area and widens out southwestwards in the direction of the Gela off-shore, from which it extends to the Nameless Bank (see Fig. 3, profile 7) (Argnani et al., 1986). The Catania-Gela Foredeep breaks off in Western Sicily where the present foreland-chain boundary consists of a complicated Plio-Pleistocene transcurrent belt (Argnani et al., 1986).

A similar structural setting characterizes the Tunisia area, where a N-S trending strongly deformed belt has been interpreted as a left-lateral transcurrent zone (N-S axis of Boccaletti et al., 1988; 1989; 1990) separating the folded areas of the Atlas Mts. from the undeformed areas of the Sahel. This N-S transform fault zone represents the western boundary of the Pelagian Block.

The segmentation of the northern edge of the Pelagian Block is indirectly reflected in the geometry of the overthrusting allochthonous units. The presence of N-S trending fault zones, which disappear under the chain, results in an induced lobate shape of the front of the orogenic belt, whose migration was stopped by the collision with the "continental blocks", but continued in front of the deflecting areas of the foreland (e.g. the Gela Basin).

According to many Authors the recent tectonic activity along the major N-S trending transform fault zones of the Pelagian Block is to be related to the tectonic evolution of the whole Sicily

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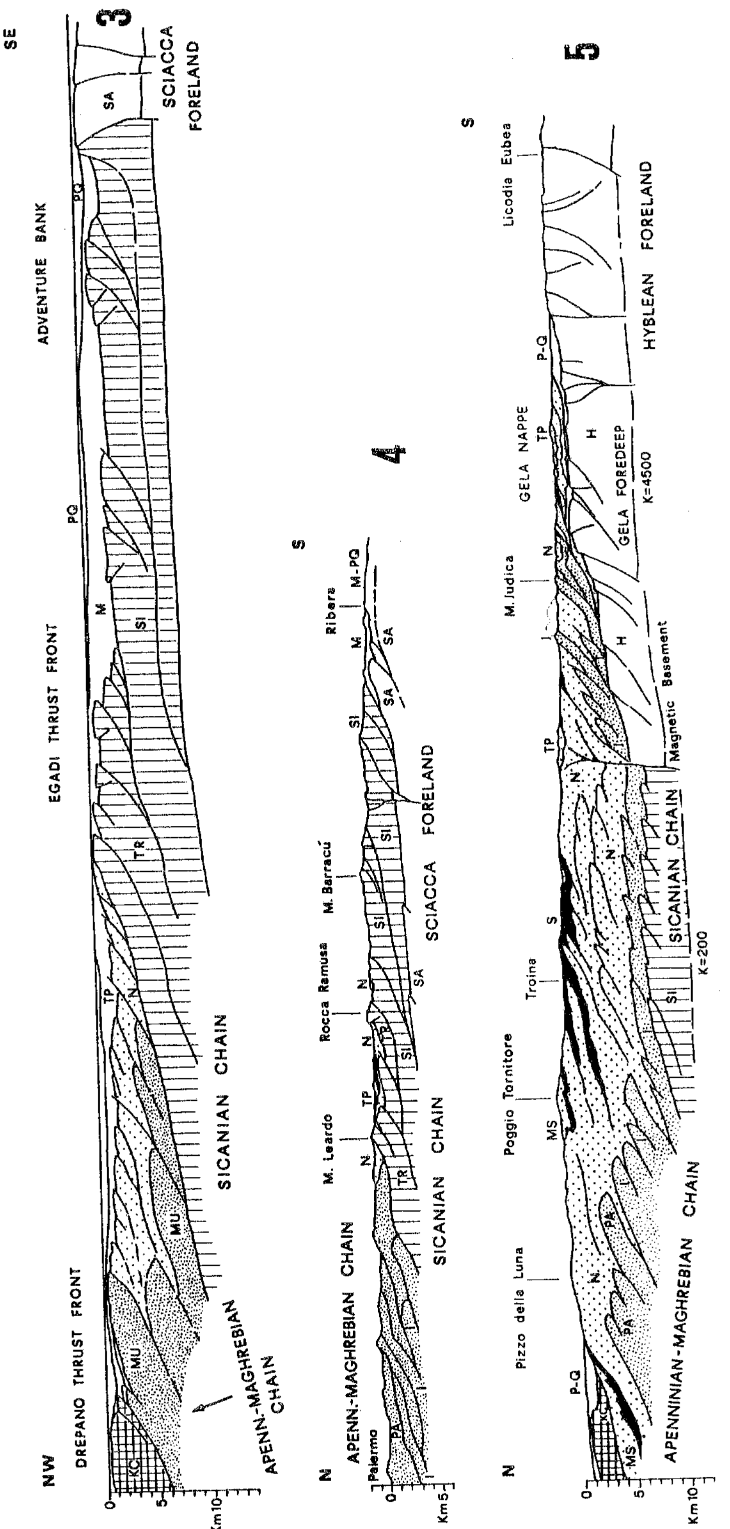
Fig. 3 - Regional profiles across Sicily and Sicily Channel. Profile 3 (after Ben Avraham et al., 1990) is located in the Western Sicily off-shore and represents the foreward continuation of profile 2 of Fig. 2. Profile 3 mostly cross the External Thrust System on which the Apenninic-Maghrebian chain lies in the internal portions. To the northwestern edge of the profile the Kabilo-Calabride units resting on the Apenninic-Maghrebian Chain are represented. The Sicanian Chain is separated from the foreland areas by transcurrent fault zones SE of Adventure Bank. The lack of a Recent foredeep basin is a characteristic of the area. Profiles 4 and 5 cross Western and Eastern Sicily, respectively (after Lentini et al., 1990a). These two profiles evidence the different structural styles of the two areas crossed. In Western Sicily the Sicanian Chain outcrops extensively and reaches an altitude of 1700 m a.s.l. In this area few remnants of the Apenninic-Maghrebian Chain have been preserved from erosion.
In Eastern Sicily the regional duplex structure is still well recognizable (see text). In this area the Sicanian Chain is completely buried beneath almost 5000 m of allochthonous terrains. The differences in depth of the Sicanian Chain in the two sectors must be related to the different capacities of the foreland areas for flexing, which was higher in Eastern Sicily.
LEGEND: PQ=Plio-Pleistocene deposits; KABILO-CALABRIDE CHAIN: KC=Kabilo-Calabride units s.l.; APENNINIC-MAGHREBIAN CHAIN: MU=Apenninic-Maghrebian units s.l.; TP=Tortonian-Pliocene deposits; MS=M. Soro Flysch; S=Sicilide Complex units; SICANIAN CHAIN: TR=Trapanese units; SI=Sicanian units; PELAGIAN BLOCK: M-PQ=Upper Miocene-Pliocene-Pleistocene deposits; M=Miocene deposits; SA=Saccense units.


3
NW
SE
DREPANO THRUST FRONT
EGADI THRUST FRONT
ADVENTURE BANK
SCIACCA FORELAND
SICANIAN CHAIN
APENN.-MAGHREBIAN CHAIN
4
N
S
Palermo
M. Leardo
Rocca Ramusa
M. Barracù
Ribera
APENN.-MAGHREBIAN CHAIN
SICANIAN CHAIN
SCIACCA FORELAND
5
N
S
Pizzo della Luna
Poggio Tornitore
Troina
M. Judica
GELA NAPPE
Licodia Eubea
HYBLEAN FORELAND
GELA FOREDEEP
K=4500
Magnetic Basement
SICANIAN CHAIN
K=200
APENNINIAN-MAGHREBIAN CHAIN

Channel. This area shows three major NW-SE oriented graben structures (Pantelleria, Linosa, Malta throughs) filled by Plio-Pleistocene turbidite deposits (Maldonado and Stanley, 1977; Winnock, 1981). These depressions overlie a thinned crust area (20 km) and are characterized by positive gravimetric anomalies, high heat flow (Della Vedova e Pellis, 1979; Zolotarev and Sochelnikov, 1980; Finetti, 1984) and strong volcanic activity. Such characteristics suggest active rifting processes throughout the area. According to some Authors (Cello et al., 1985; Reuther and Eisbacher, 1985; Grasso et al. 1986; Boccaletti et al., 1990) these "rift" structures can be related to a transtensive regime; this activated E-W and NW-SE oriented fault system which formed a number of adjacent pull-apart basins.

Ionian Basin

This represents a wide undeformed basinal area located between the two continental "blocks" of the Foreland Domain (see Fig. 1).

This sub-domain is partly floored by oceanic-type crust, as suggested by the high Bouguer anomalies (Makris et al., 1986), which dates back to Mesozoic times, and underlies 6000 m of thick sedimentary cover (Hinz, 1974), including Upper Mantle derived intrusions. The crustal thickness of the whole area does not exceed 20 km.

The Meso-Cenozoic sedimentary sequence of the Ionian Basin progressively thickens northwestwards, in proximity to the Calabrian Arc (see Fig. 1), because of the presence of repeated terrigenous horizons consisting of coarse grained levels and olistostromes. In this proximal area, known as the "Cobblestones Zone" of Sartori (1982), the sedimentary sequences are slightly deformed by thrusts.

The Ionian Basin is bounded to the west by the Malta Escarpment. This structure is responsible for the huge deepening of the basinal floor to the east (from a few meters to several kilometers). Samples dredged up from the escarpment show the presence along the fault scarps of Meso-Cenozoic carbonate sequences similar to those cropping out in the Hyblean Plateau (Cita et al., 1980; Scandone et al., 1981). The reconstruction of the tectono-sedimentary evolution suggests a recent activation of the fault system which caused the progressive collapse of the eastern margin of the Hyblean Plateau (Carbone et al., 1982b; Sartori et al., 1991).

To the north the transition between the Ionian Basin and the Apulian Block is represented by a thinned crust belt generated by Mesozoic extensional tectonics (Finetti, 1982). This faulted belt partly reactivated in Recent times forming the present external margin of the Bradanic Foredeep (see following pages) (Pescatore and Senatore, 1986).

Apulian Block

The Apulian Block is the southern edge of the Adria microplate facing the Southern Apennines, and represents the northernmost sub-domain of the Foreland domain in the study area. It is composed of a 35 km thick continental-type crust partly consisting of a very thick Meso-Cenozoic carbonate sequence (Ricchetti, 1980) outcropping widely in the Puglia district. The foreland sequences deflect southwestwards beneath the forewards migrating Southern Apennines units. The collapsed carbonate sequences bordering the foreland area from the Bradanic Foredeep, a narrow NW-SE trending structural depression filled by Plio-Pleistocene terrigenous deposits. This foredeep widens out SE-wards joining the Ionian Basin. The fault scarps forming the front of the foredeep basin derived from reactivation of the pre-existing boundary between the Ionian Basin and the Apulian Block and are not parallel to the front of the Chain.

The seismic data of the area clearly show that the foredeep sequences are slightly deformed by thrusts to form the transition between the foreland domain and the adjacent internal domain.

External thrust system

The External Thrust System is the externalmost orogenic belt domain, formed since the Tortonian, and involving sequences similar to those outcropping in the foreland areas. This domain was created by a thrusting of part of the foreland deflected beneath the overthrusting allochthonous units of the more internal domains.

In Sicily the External Thrust System is represented by the Sicanian Chain which originated from the deformation of the internal margin of the Pelagian Block. In the Southern Apennines the External Thrust System derived from post-Tortonian deformation of the innermost sector of the carbonate Apulian Platform. In both areas the External Thrust System is composed of thick Meso-Cenozoic carbonate sequences that differ from those involved in the more internal domains in lacking Oligo-Miocene flysch-type cover.

From a geometric point of view the External Thrust System is characterized by an imbricated stack of tectonic slices connecting with each other along a deep seated sole-thrust. The whole edifice is only slightly detached from the substratum and partly rests upon the original crystalline basement. There are a few lesser detachments in the upper stratigraphic horizons.

A wide area of Central Tunisia, the Atlas region, characterized by fault propagation folds connected with deep-seated blind thrusts, has been attributed to the External Thrust System.

Sicily External Thrust System: Sicanian Chain

The Sicanian Chain forms the Sicani Mountains in Western Sicily and extends to off-shore areas of the Adventure Bank in the Sicily Channel (Argnani et al., 1986) (see Fig. 2, prof. 2; Fig. 3, prof. 3 and 4). In the Sicanian Chain, several units are involved, each of them characterized by a different Mesozoic sequence and vertical facies distribution (Trapanese Units and Sicanian Units of Catalano and D'Argenio, 1982). It is a south-verging thrust belt consisting of a hinterland-dipping imbricate fan with ramp and flat geometry (Boyer and Elliot, 1982). It developed by deformation of a complex continental margin of basin and range configuration during Mesozoic times, as shown by lateral facies variability within the Jurassic and Cretaceous horizons.

Neogene thrust structures mostly originated along pre-existing rock weakened zones, and ramp-thrusting often follows the older fault zones bounding the Mesozoic horst structures (see Fig. 4).

The Sicanian Chain extends northwestwards, is partly buried under the more internal domains and comprises the units cropping out in the S. Vito lo Capo and Trapani areas. These latter units represent wide culminations of the External Thrust System breaching the whole overlying orogenic belt. To the west a further continuation of the Sicanian Chain is represented by the units forming the Egadi Islands and those flooring the Sicily Channel to the south (Egadi Fold-Thrust Belt of Argnani et al., 1987) (see Fig. 3, prof. 3).

The Sicanian Chain originated in the Tortonian. In its innermost sectors the youngest involved terrains date back to the Upper Serravallian-Early Tortonian. To the South progressively younger horizons are involved in the thrust system. Along the external front, Plio-Pleistocene levels are displaced by thrusts. The Sicanian Chain developed as a duplex structure underlying the allochthonous terrains of the more internal domain. In Western Sicily the upper horizon of this duplex structure has been deeply eroded and a few remains, preserved from erosion, are represented by the Numidian Flysch and Mufara Fm. klippen. A duplex structure is still well preserved in Eastern Sicily, where a completely buried structural horizon is recognizable on seismic lines at a depth of about 7 km (see Fig. 3, prof. 5) (Bianchi et al., 1987). Four main pieces of evidence suggest assigning this horizon to the Sicanian Chain:

1) In Eastern Sicily the buried structural horizon underlies that unit which is considered the externalmost of the Maghrebian domain, represented by the Mt. Iudica Unit. So the buried horizon might be an unknown, more external Maghrebian unit, or the eastern continuation of the Sicanian Chain.

2) The Mt. Iudica Unit, despite its frontal position within the orogen, deformed from the Upper Serravallian-Early Tortonian. This suggests that the units outcropping along the front were tectonically transported to their position overthrusting more external units long after their first deformation.

3) All the Recent deposits involved along the front are allochthonous, and coeval autochthonous deposits must be buried.

4) Finally, analogies with the Southern Apennines support such a structural restoration.

The whole imbricate stack outcropping in the frontal area of the orogen in Eastern Sicily, the so-called Gela Nappe (Ogniben, 1960), tectonically rests on the Plio-Pleistocene Foredeep deposits and consists of an allochtonous edifice more advanced than the Sicanian Chain and directly resting on the margin of the foreland domain (see Fig. 3, prof. 5).

Southern Italy External Thrust System: Apulian Chain

In the Southern Apennines a buried thrust system, involving mostly carbonate sequences, has been detected beneath the outcropping units by seismic and borehole data (Carbone e Lentini, 1990; Lentini et al., 1990b; Casero et al., 1988). This thrust system originated as a duplex structure underlying the units of more internal domains from the deformation of the innermost portion of the Apulian Carbonate Platform. This structural horizon has been called the Apulian Chain by Carbone and Lentini (1990) or the Apulian Thrust System by Lentini et al. (1990b).

The Apulian Chain crops out in the Lucanian Apennines at Mt. Alpi, which consist of a Recent culmination breaching the overlying structural horizons. The Mt. Alpi structure seems to be related to Pleistocene strike-slip tectonics (Catalano et al., 1991; Vinci, 1993). The mostly carbonate sequences outcropping in the Mt. Alpi structure have Messinian terrigenous cover similar to that overlying the buried Apulian carbonate sequences in adjacent areas.

In the areas sourrounding Mt. Alpi, further mostly carbonate sequences outcrop. Nevertheless they are involved in the Apenninic-Maghrebian Chain and are covered by Early Miocene terrigenous horizons. So they cannot be correlated to the Mt. Alpi Unit, neither stratigraphically nor from the structural point of view.

To the east the top of the Apulian carbonate sequences is represented by progressively younger horizons, dating from the Early Pliocene (Rotondella area) to Early Pleistocene (Bradanic Foredeep).

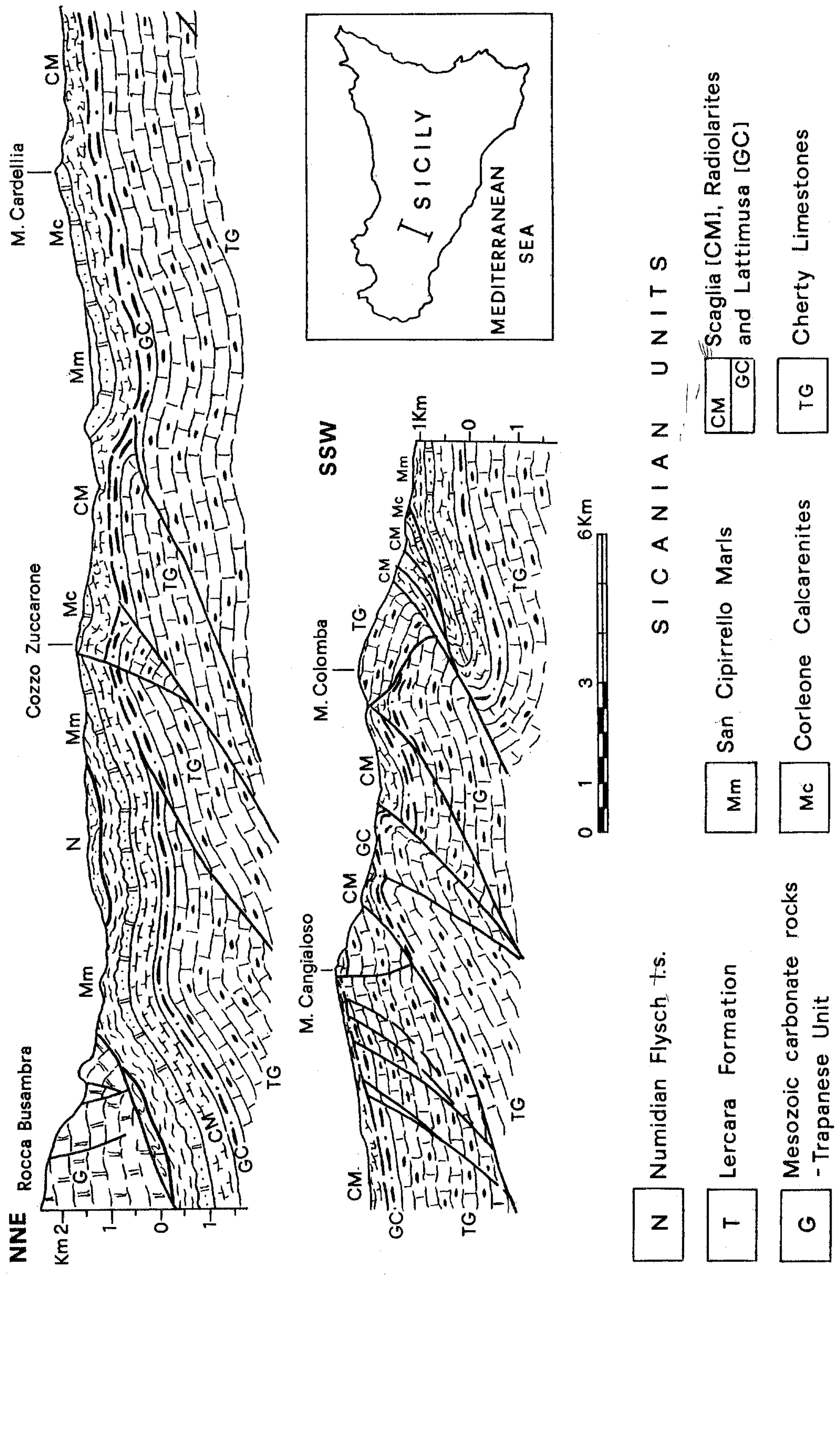
Further field studies are required to analyze the carbonate sequences outcropping in the internal areas of the Southern Apennines. Such sequences might be considered the result of a rising of the Apulian substratum and thus would play a role analogous to that of the Mt. Alpi structure.

From the geometrical point of view the Apulian Chain forms a mostly buried regional duplex structure, partly modified by Recent breaching structures. A similar structural setting has been detected in the Molise district (Cello et al., 1988; 1989). Seismic data (Mostardini e Merlini, 1986) show a northward continuity of the Apulian Chain which, according to many Authors, crops out in the Maiella structure.

Thin-Skinned Chain: Apenninic-Maghrebian Chain

The Central Mediterranean orogen is mostly composed of the Apenninic-Maghrebian Chain domain. This consists of a thin-skinned thrust system, which originated in the Lower Miocene from the deformation of Meso-Cenozoic sequences belonging to several palaeodomains. These sequences were dismembered during the Neogene thrust deformation, and the original thick flysch-type cover generally detached from its substratum. Presently the detached flysch cover forms the externalmost units of the chain, and the Mesozoic-Palaeogenic sequences are involved in the internal part of the thrust system.

Fig. 4 - Geological cross-section cutting the Sicani Mts. in the area of Rocca Busambra and the Sosio Valley. The cross-section gives a detailed segment parallel to profile 4 in Fig. 3 in the tract from Rocca Ramusa to Barracù Mt. It cuts the imbricate stack of Sicanian units, showing the ramp and flat geometry of the thrust system. In the Sicanian Chain both carbonate platform sequences (Trapanese units) and basinal sequences (Sicanian Units) are involved. The latter are composed of several different Mesozoic sequences, indicating deposition within a fault controlled basin. The structural data collected in the area suggest that Neogene thrusting partly reactivated pre-existing Mesozoic fault surfaces.
The Tertiary cover of both the Trapanese and Sicanian units is similar to that overlying the foreland Saccense Units. This shows the general homogeneity of these palaeodomains before the beginning of thrust deformation. Only few lesser detachments of the Tertiary cover are recognizable in the Sicanian Chain.
In the Sicanian Chain a few klippen of Maghrebian units (mainly Numidian Flysch) have been detected. The same role is played by the Mufara Fm. sequences overlying the Sicanian sequences, such as those sequences involved along the Rocca Busambra overthrust.


NNE
SSW
Rocca Busambra
M. Cardellia
Cozzo Zuccarone
M. Cangialoso
M. Colomba
SICILY
MEDITERRANEAN SEA
Km 2
1Km
6Km
SICANIAN UNITS
N Numidian Flysch l.s.
T Lercara Formation
G Mesozoic carbonate rocks - Trapanese Unit
Mm San Cipirrello Marls
Mc Corleone Calcarenites
CM GC Scaglia [CM], Radiolarites and Lattimusa [GC]
TG Cherty Limestones

The Thin-skinned Chain is composed of several stratigraphical-structural units extensively superposed. Each unit is, in turn, made up of several imbricate tectonic slices arranged in a duplex-type geometry (see Fig. 5). It corresponds to the so-called Apenninic-Maghrebian Chain of the Authors and extends from Northern Africa to the Southern Apennines. It extensively overlies the External Thrust System, resting upon horizons younger than the Tortonian. Locally the Apenninic-Maghrebian Chain, where it has stepped over the intermediate domain, directly overlies the Plio-Pleistocene foredeep areas.

The extent of the Apenninic-Maghrebian Chain tectonic transport over the external domains varies along the axis of the orogen. It reaches its maximum values in the Calabrian Arc and progressively reduces to the north, towards the Southern and Central Apennines, and to the south, towards Eastern and Western Sicily. In this latter area the front of the Apenninic-Maghrebian Chain corresponds to an erosional northward retreated front, while in Eastern Sicily and the Southern Apennines the front of the chain (the Gela Nappe of Ogniben, 1960 and Metaponto Nappe of Ogniben, 1969) is buried beneath the Pleistocene deposits of the foredeep.

The geometry of the Apenninic-Maghrebian Chain was mostly imposed during the Tortonian and before emplacement onto the external domains. Late orogenic tectonic transport over the External Thrust System and final duplexing processes modified the pre-existing geometry. Further shortening within the Apenninic-Maghrebian Chain and the ultimate emplacement of the frontal nappes must be related to these late events.

Commonly in the Apenninic-Maghrebian Chain the Oligo-Miocene terrigenous cover is completely detached from its Mesozoic-Palaeogenic substratum (Carbone et al., 1991; Lentini et al., 1991). The decoupling surfaces between cover and substratum have been active from the Early Miocene to the latest orogenic phases. So progressive foreward advance of terrigenous cover units occurred. The extent of the terrigenous cover decollement correlates with the degree of shortening in the area, and reaches its maximum in the Calabrian Arc.

Crystalline Chain: Kabilo-Calabride Chain

The Crystalline Chain is composed of several tectonic units with Hercynian crystalline rock basement and remnants of the original Meso-Cenozoic sedimentary cover. It extends from the Kabilia Chain, in Algeria, to the Calabrian Arc, thus forming most of the southern margin floor of the Tyrrhenian Sea and the Peloritani Mt. in NE Sicily (see Fig. 1).

In the Peloritani Mts. the Kabilo-Calabride Chain is composed of five main tectonically superposed nappes, each characterized by crystalline basement of different metamorphic grade. Higher metamorphic grade rocks form the uppermost nappe, which lacks the Meso-Cenozoic sedimentary cover. The underlying nappes have crystalline basements characterized by a progressive decrease in metamorphic grade from uppermost to lowermost. Upon these units, relicts of Meso-Cenozoic, mostly carbonate sequences rest (Ogniben, 1960; Lentini e Vezzani, 1975). These sequences are derived originally from a continental margin.

Several types of Cenozoic terrigenous cover rest unconformably upon the Peloritani Units. Among these, the Capo d'Orlando Flysch (or Stilo-Capo d'Orlando Fm. of Bonardi et al., 1980) plays an important role. This conglomeratic-arenaceous-argillaceous formation has arkosic composition and is characterized by the onlap of its horizons to the substratum rock units. The Capo d'Orlando Flysch represents the filling of originally satellite basins resting on the Peloritani Units, fed by the innermost crystalline source areas. This terrigenous cover seals most of the contact between the Peloritani units and is, in turn, involved in the later thrust structure that deformed the Peloritani orogenic belt. This belt (Calabride Complex of Ogniben, 1960) tectonically

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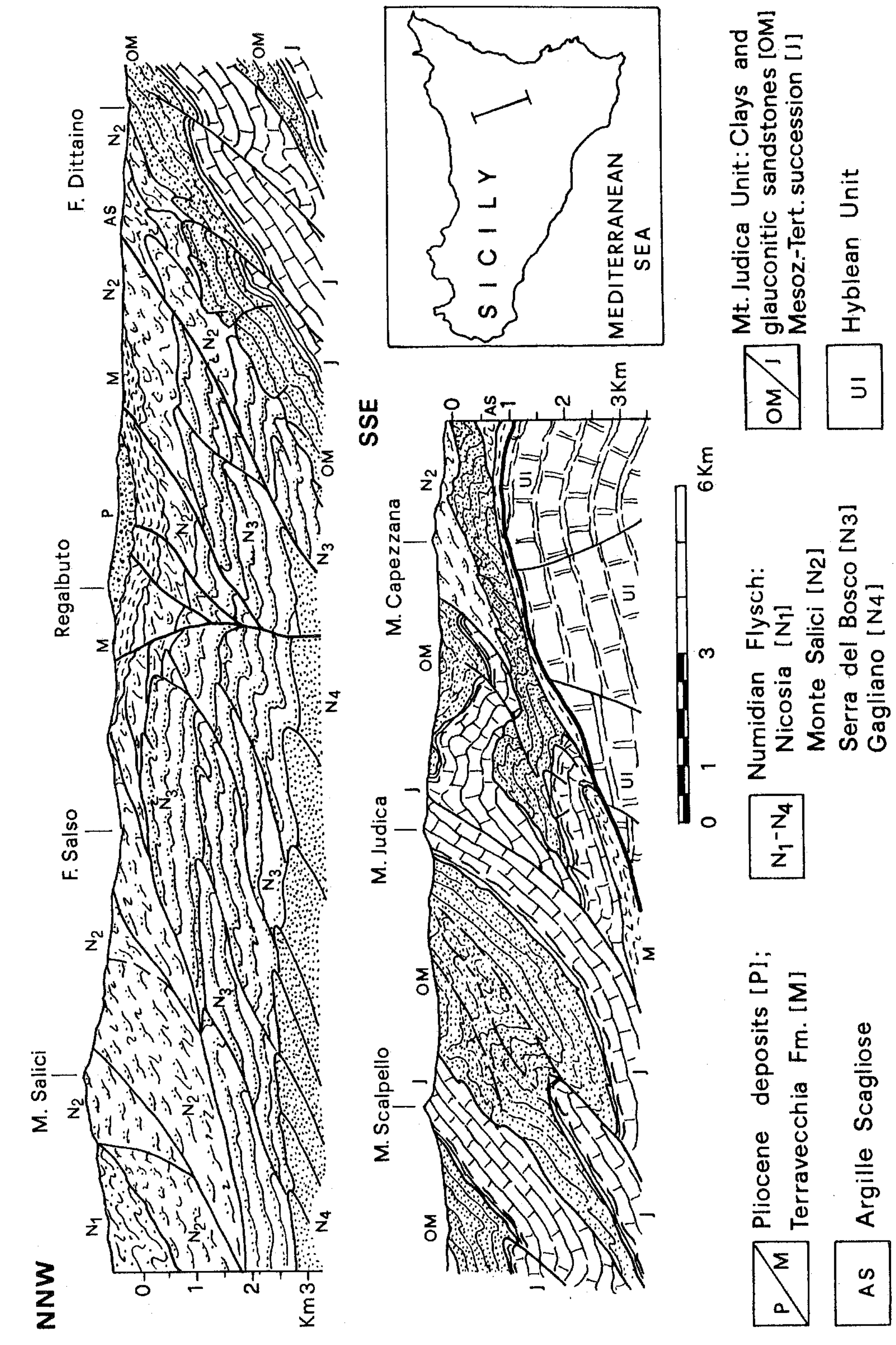
Fig. 5 - Geological cross-section through the Apenninic-Maghrebian Chain in Sicily (after Carbone et al., 1990, modified).
This is a more detailed segment of profile 5 in Fig. 3. The cross-section mainly shows the geometry of the detached Numidian Flysch sequences. They are arranged in several tectonically superimposed duplex structures, each corresponding to a distinct structural-stratigraphical unit. In the southern portion of the cross-section the Mt. Iudica Unit resting on the collapsed foreland sequences is represented. Along the sole-thrust in the frontal areas Tortonian and Messinian horizons resting on the Early Pliocene horizons of the foreland are involved.


NNW
SSE
M. Salici
F. Salso
Regalbuto
F. Dittaino
M. Scalpello
M. Judica
M. Capezzana
Km
6 Km
SICILY
MEDITERRANEAN SEA
Pliocene deposits [P];
Terravecchia Fm. [M]
Argille Scagliose
Numidian Flysch:
Nicosia [N1]
Monte Salici [N2]
Serra del Bosco [N3]
Gagliano [N4]
Mt. Judica Unit: Clays and glauconitic sandstones [OM]
Mesoz.-Tert. succession [J]
Hyblean Unit

overlies, as a whole, the innermost units of the Apenninic-Maghrebian Chain. The tectonic contact between the two domain is well exposed in NE Sicily from the S. Fratello area on the Tyrrhenian coast, to the Taormina area on the Ionian coast. The alignment is commonly known as the "Taormina Line", an ambiguous term by which several Authors indicate an important regional transform zone. Actually the so-called Taormina Line is the emergence of a thrust surface and represents an erosional front of the Calabride overthrust originally extending further southeastwards than at present. The Calabride Units has a sub-horizontal attitude, as suggested by the presence of several tectonic windows, located on the Tyrrhenian slope of NE Sicily, in which the Maghrebian substratum outcrops. All this evidence contrasts with the interpretation of the Taormina Line as a wrench fault zone or as a surficial expression of a flower structure (see text of Fig. 6).

The Calabride overthrust rests on tectonic slices of an accretionary wedge composed of Cretaceous chaotic horizons (Mt. Soro Unit) (Lentini, 1982). The lack of Cenozoic terrigenous levels in the footwall of the thrust is probably due to the complete detachment of such horizons. These latter are represented by originary fore-arc basin lower Oligocene deposits which form an imbricated fan along the leading edge of the Kabilo-Calabride Chain.

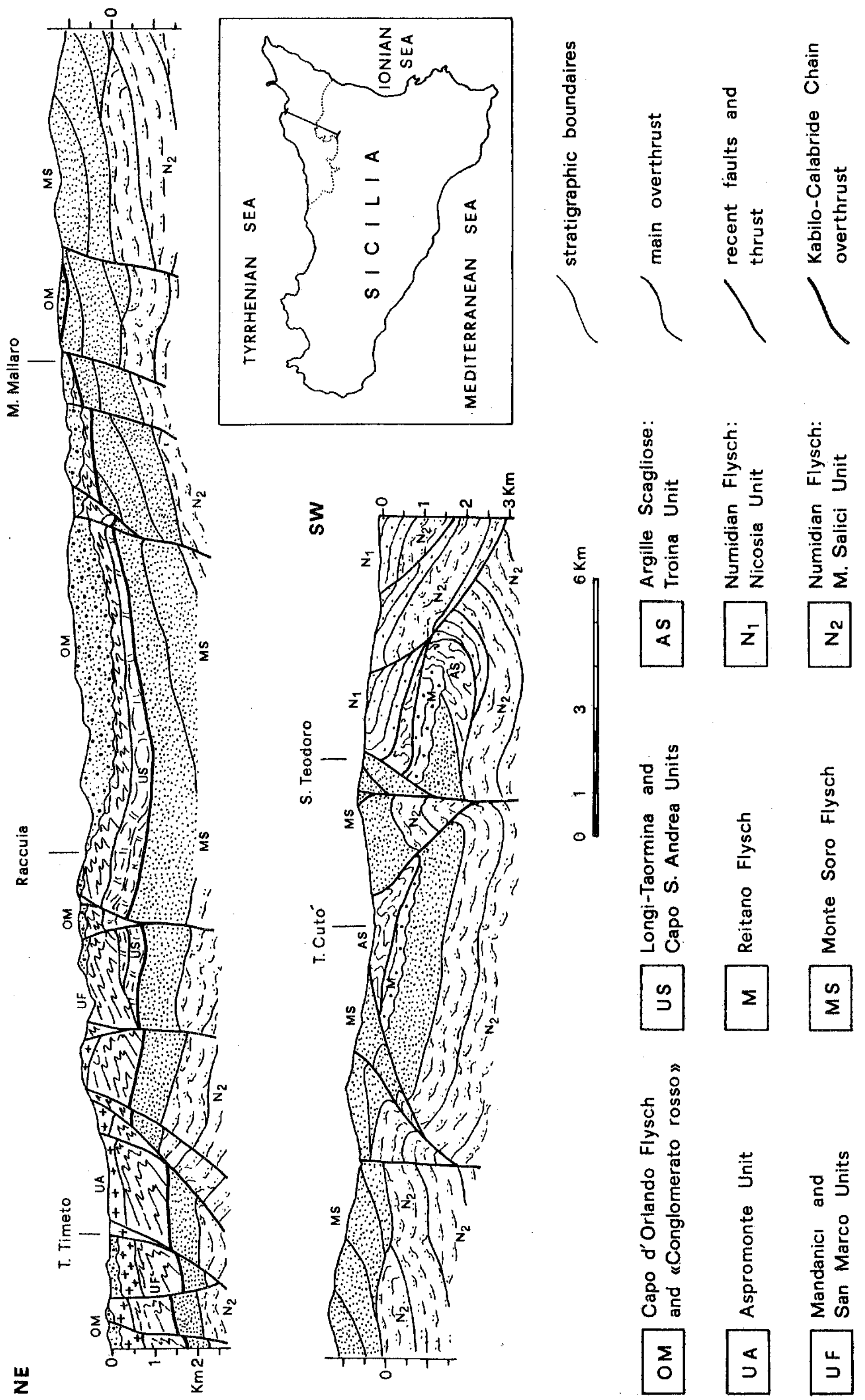
The progressive Calabride overthrust on the fore-arc system ceased before the wide retrovergent transport of Maghrebian units (Antisicilide Units of Lentini and Vezzani, 1975) on the Burdigalian horizons of the Capo d'Orlando Flysch. The tectonic contact of the Antisicilide Nappe is sealed by the Upper Burdigalian-Langhian levels of the Floresta Calcarenites. The Floresta Calcarenite Fm. post-dates the overthrust which must be assigned to the Burdigalian.

The Calabride thrust front has been deeply modified by a NW-SE dextral strike-slip fault system and its conjugate structures. This fault system cuts both the Kabilo-Calabride domain and the Apenninic-Maghrebian Chain. So it developed long after the Calabride emplacement and is connected to later tectonic events common to several structural domains. Transcurrent faults dissect the domains and are not restricted to the boundaries between them. The juxtaposition of a strike-slip system upon an older thrust system, combined with the deep erosional processes of the Calabride overthrust, gives rise to the well known Taormina Line which thus assumes a merely geographical significance.

Analogously the whole Calabrian Arc should be interpreted as a geographical rather than structural connection between the Southern Apennines and Sicily. It is actually represented by a continuity in the deeper structural horizons of the Arc both of the Apenninic-Maghrebian Chain and of the External Thrust System, as detected on seismic lines (Fig. 7, prof. 6) (Cello et al., 1990). The Kabilo-Calabride Chain in the Calabrian Arc thus represents only a pellicular tectonic element. Such evidence strongly contrasts with the assumption that the Calabrian Arc is bounded to the north and to the south by two major transform lines, the "Sangineto Line" and the "Taormina Line", which were activated during the Kabilo-Calabride emplacement. The Sangineto Line in Calabria should also be interpreted as a surficial alignment of merely geographic importance, like the Taormina Line in Sicily.

On the northern edge of the Calabrian Arc (Calabro-Lucanian Boundary) several ophiolitic units outcrop (Liguride Complex of Ogniben, 1969). They represent the remnants of an oceanic palaeodomain originally located between the Maghrebian and Kabilo-Calabride palaedomains.

Fig. 6 - Geological cross-section through northeastern Sicily.
The cross-section shows the geometric relationship between the Kabilo-Calabride and Apenninic-Maghrebian units. In northwestern Sicily the Kabilo-Calabride units form a pellicular structural horizon extensively overlying the Maghrebian units. The thrust surface underlying the Kabilo-Calabride units has a sub-horizontal attitude. This thrust surface crops out near Malloro Mt. along the so-called "Taormina Line". In the area, evidence for a main wrench zone is completely lacking. The cross-section clarly shows that the present Kabilo-Calabride front has been sculptured by erosional processes. Several "tulip structures" and "palm-tree structures" displacing the pre-existing thrust system geometry are well exposed along this cross-section. They represent the surficial expressions of the NW-SE dextral strike-slip faults dissecting the area. In the northeastern portion of the cross-section the listric faults responsible for the Tyrrhenian margin collapse are well represented. The southwestern termination of the cross-section cuts the bach-verging thrust sheets forming an E-W belt northwest of Etna, from Troina to Randazzo-Mojo Alcantara.


NE
SW
T. Timeto
Raccuia
M. Mallaro
T. Cutò
S. Teodoro
Km
TYRRHENIAN SEA
IONIAN SEA
S I C I L I A
MEDITERRANEAN SEA
6 Km
OM
Capo d'Orlando Flysch and «Conglomerato rosso»
US
Longi-Taormina and Capo S. Andrea Units
AS
Argille Scagliose: Troina Unit
UA
Aspromonte Unit
M
Reitano Flysch
N1
Numidian Flysch: Nicosia Unit
UF
Mandanici and San Marco Units
MS
Monte Soro Flysch
N2
Numidian Flysch: M. Salici Unit
stratigraphic boundaires
main overthrust
recent faults and thrust
Kabilo-Calabride Chain overthrust

The post-Tortonian structures (e.g., strike-slip fault systems) have been responsible both for modifications of the edges of the Calabrian Arc and for the segmentation of this tract of orogen. Two almost distinct sectors are actually recognizable within the Arc. They are separated by a main ENE-WSW oriented shear zone located in the "Stretta di Catanzaro" area (Boccaletti et al., 1984). North of this line the crystalline units were involved from the late Cretaceous in a Europe-verging orogenic belt before being displaced into the Africa-verging thrust belt from Oligocene times (Amodio Morelli et al., 1976; Bonardi et al., 1982; Tortorici, 1982). The southern sector of the Calabrian Arc, including the Peloritani Mt., directly overthrusts the Apenninic-Maghrebian Chain units with an Africa-verging polarity.

Sardinian Block

This represents a fragment of the European Foreland composed of a segment of the Hercynian Southern European Chain and originally adjacent to the present northwestern coast of the Mediterranean Sea (Carmignani et al., 1992). The present position of the Sardinian Block is the result of an Oligo-Miocene counterclockwise rotation, as shown by the contemporaneous opening of the Balearic Basin behind the Sardinian Block (de Jong et al., 1973; Rehault et al., 1984) and the development of the Western Sardinian Rift (Cherchi e Montandert, 1982).

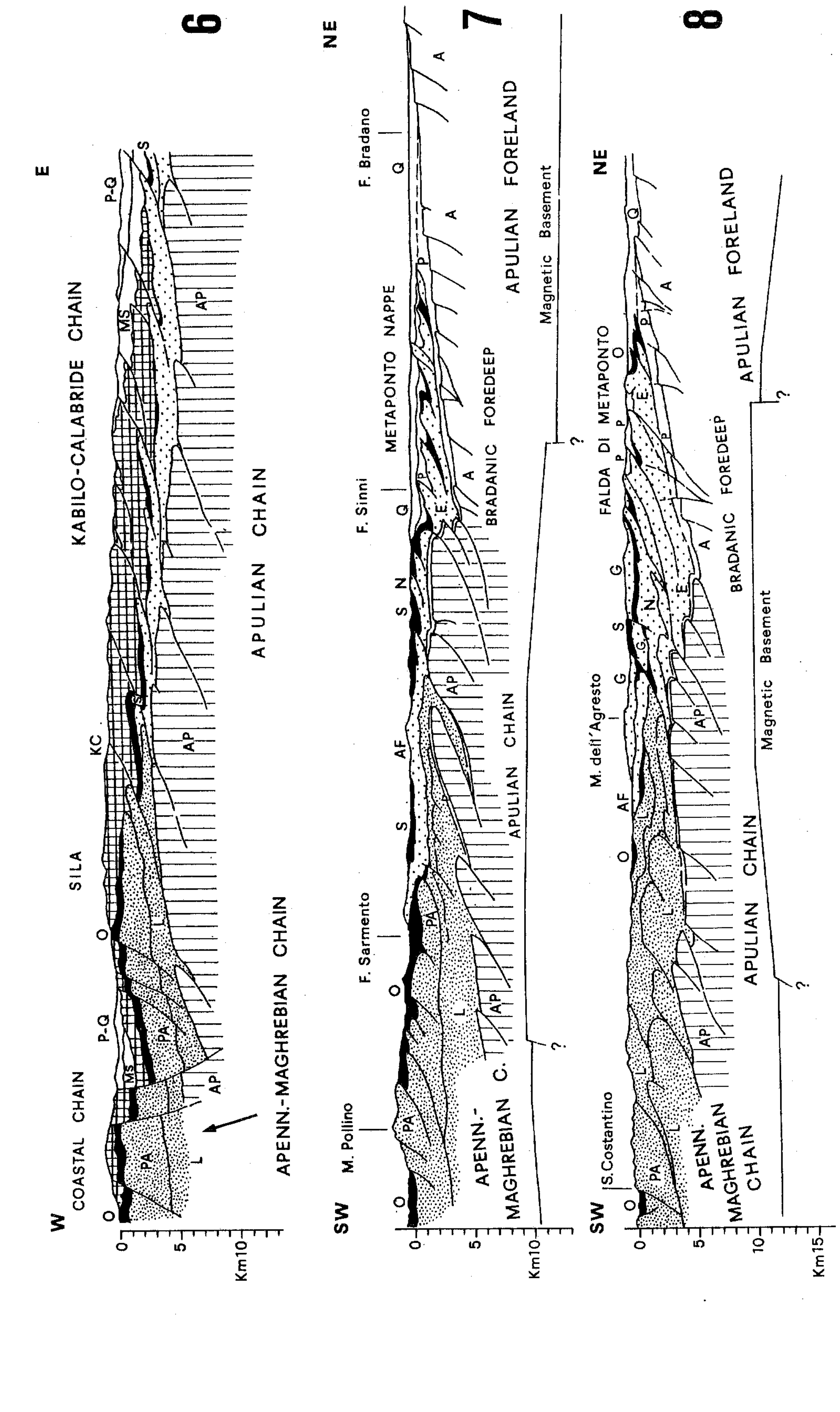
Seismic profiles along the Sardinia Channel clearly show that listric normal faults separate the Kabilo-Calabride Units from the Sardinian Block ones. This fault system was probably activated along pre-existing thrust surfaces located between the Sardinian Block units and the Kabilo-Calabride domain (see Fig. 2). The Sardinian units were involved in the Africa-verging orogenic belt, because of their Oligo-Miocene rotation, which resulted in subduction processes along the eastern Sardinian margin which are well documented by alcalicalcic-type volcanic activity. Some Authors restricted the compressional events of the Sardinian Block to the end of the rotational processes that dates back to the Burdigalian. During the Oligo-Miocene the Sardinian Block certainly acted as source area for terrigenous sequences which deposited in the Apenninic-Maghrebian palaedomains (e.g. Tusa Tuffites Fm.).

The innermost position of the Sardinian units within Africa-verging orogenic belt however suggest that Alpine deformation of the Sardinian Block started almost in the early Oligocene just before the beginning of the deformation of the Kabilo-Calabride units.

Tyrrhenian Basin

The Tyrrhenian Basin originated in the Serravallian (Lentini et al., 1993) by extensional processes involving part of the previously cited structural domains. This basin developed in the innermost portion of the orogenic belt contemporaneously with the foreward migration of the external thrust front. The Tyrrhenian Basin is composed of two main sectors. The northern sector is floored by tectonic units belonging both to the Alpine and to the Northern Apennine Chains. This portion of the basin does not exceed 2000 m in depth. The southern sector of the Tyrrhenian Basin shows a complex floor morphology dominated by two oceanic areas (the Vavilov Basin and the Marsili Basin) deriving from a stretching of the original continental crust (Rehault et al., 1986). The crustal thickness of the southern sector of the Tyrrhenian Sea varies from 20 to 30 km, and decreases to 7 km in the center of the oceanic area (Finetti and Morelli, 1973; Steinmetz et al., 1983). In these latter areas, high heat flow values are encountered (Della Vedova et al., 1984). Malinverno and Ryan (1986) calculated the total amount of extension due to the rift processes along an E-W section of the Southern Tyrrhenian Basin to be nearly

Fig. 7 - Regional profiles through Calabria and the Southern Apennines (after Ben Avraham et al., 1990, modified). In these sections the regional duplex structure is recognizable. It is composed of the Apulian Chain buried beneath the more internal domains. Duplexing processes caused the foreward migration of the upper structural horizons. This tectonic transport occurred along decoupling surfaces separating the different structural domains. The motion along the thrust surfaces transferred along ramps, and thus breaching the whole orogenic belt and inducing further shortening within the orogenic domains. In the three profiles the total bulk of the detached Oligo-Miocene cover is well represented (see text). Profiles 7 and 8 clearly show the flower structures characterizing the frontal area of the orogen. They represent the surficial expression of the NW-SE trending strike-slip faults dissecting the front of the chain and the Bradanic Foredeep.


6
W
E
COASTAL CHAIN
SILA
KABILO-CALABRIDE CHAIN
APENN.-MAGHREBIAN CHAIN
APULIAN CHAIN
Km10
7
SW
NE
M. Pollino
F. Sarmento
F. Sinni
F. Bradano
METAPONTO NAPPE
BRADANIC FOREDEEP
APULIAN FORELAND
Magnetic Basement
APENN.-MAGHREBIAN C.
APULIAN CHAIN
Km10
8
SW
NE
S.Costantino
M. dell'Agresto
FALDA DI METAPONTO
BRADANIC FOREDEEP
APULIAN FORELAND
Magnetic Basement
APENN. MAGHREBIAN CHAIN
APULIAN CHAIN
Km15

350 km.

The morphology of the Tyrrhenian Basin is dominated by a bathyal plane from which several volcanic edifices rise up.

The basin is surrounded by fault-controlled sedimentary basins such as the Sardinian Basin, the Cornaglia Terrace and the Sardinian Channel along the Sardinian margin and the Paola, Gioia and Cefalù Basins along the Southern Apenninic and Sicilian margins (Rehault et al., 1987). More detailed information about the outlines of the Tyrrhenian Basin is available in several papers by various Authors (Selli, 1974; Selli and Fabbri, 1971; Boccaletti and Guazzone, 1972; 1974; Boccaletti et al., 1985; Colantoni et al., 1981; Scandone, 1979; Patacca et al., 1990). The present paper focuses on the off-shore prosecutions of the structural domains within the collapse areas of the Tyrrhenian Basin.

Upon the submerged sectors of the different domains, thick Tertiary sedimentary sequences have been recognized. Within them pre-rift and syn-post-rift tracts are distinguishable. The seismic analysis recently carried out examined essentially the syn-post-rift deposits, post-Tortonian in age, neglecting the significance of the older sediments. Such pre-rift terrigenous horizons outcrop widely in the peri-Tyrrhenian basins.

Oligo-Miocene sediments have been detected under the Late Miocene cover along the Eastern and Southern margin of Sardinia (Fabbri and Nanni, 1980). In the Cornaglia Terrace, pre-rift sediments have been recognized by Rehault et al. (1987). Profile 2 on Fig. 2, modified after Catalano et al. (1989), shows, in the central part of the Sardinia Channel, Oligo-Miocene terrigenous cover filling perched basins originating during the Oligocene. Such deposits might be correlated with the Capo d'Orlando Flysch outcropping in the Calabro-Peloritani Mts., and pre-date the opening processes. In other peri-Tyrrhenian basins, e.g., the Paola Basin (Argnani and Tricardi, 1988) and the Gioia Basin (Sartori, 1982; 1989), which are prevalently filled with Late Miocene-Pliocene deposits, very thin Oligo-Miocene sequences have been detected.

A comparison between sequences of the peri-Tyrrhenian basin with those outcropping on land ought be the key to a better understanding of the off-shore seismic data. For instance in northern Sicily, terrigenous sequences record a huge change in the tectono-sedimentary history during the Serravallian. The Oligo-Miocene horizons, comprising Langhian-Serravallian levels, deposited in perched basins fed from northern source areas. During the Upper Serravallian, a rapid change in the tectonic setting induced the deposition of northward prograding clastic fans. This huge change must be related to the earlier opening processes of the Tyrrhenian Basin (Lentini et al., 1993).

So the Upper Miocene deposits of peri-Tyrrhenian basins play a different role with respect to those of the more external areas of the orogen (Terravecchia Fm. of Schmidt di Friedberg, 1962). These latter deposited within satellite basins. The Mio-Pliocene peri-Tyrrhenian horizons deposited on faulted blocks bounded by listric normal faults. Narrow elongated basement exposures parallel to faults correspond to the external apex of the tilted faulted block. The whole structure controlling the Mio-Pliocene peri-Tyrrhenian deposits fits well into the general transtensive regime which has affected the region since the Upper Serravallian.

A strong shortening occurred in the Central Mediterranean area before the opening of the Tyrrhenian Basin. In the pre-rift period the Sardinian Block units were already overlying the Kabilo-Calabride units which, in turn, were resting widely on the Apenninic-Maghrebian domain. Before the Upper Serravallian, most of the Apenninic-Maghrebian Chain was already deformed. So only the Apenninic-Maghrebian Chain overthrust the external domains, and the late orogenic duplexing processes occurred during the Tyrrhenian Basin's opening in the hinterland of the orogenic system.

POST-TORTONIAN GEODYNAMIC EVOLUTION

The present day structural setting of the Central Mediterranean domains derives from post-Tortonian deformational events, which are characterized by active shortening in the frontal areas and contemporaneous extensional processes in the hinterland of the orogenic system. This later

Neogene deformation has resulted in the rising up of new structural domains, such as the Tyrrhenian Basin and the External Thrust System, and in the partial modification of the pre-existing ones. Later tectonic phases have been responsible for the development of a regional duplex structure which is currently recognizable from the Central Apennines to Sicily (Carbone e Lentini, 1990; Cello et al., 1990; Lentini et al., 1990b) (see Fig. 3 and 7). This duplex structure is composed of a lower horizon, seated between roof- and floor- thrusts, corresponding to the External Thrust System, and an upper horizon, which consists of the more internal orogenic domains, resting on the roof-thrust. During duplexing the roof-thrust acted as an active decoupling surface along which foreward migration of the upper horizon of the structure towards the foreland areas occurred. So an induced pellicular tectonic structure developed as a response to deep seated deformational processes (Lentini et al., 1990b; Catalano, 1993).

During its foreward migration the pellicular element of the duplex structure deformed in such a way as to follow the foreland indents. These processes were the main cause of the lobate-shape of the orogenic front and the activation of transfer fault zones dissecting the areas of the orogen. The irregular distribution of the thick continental-type crust sectors within the foreland areas was responsible for diachronic and discontinous collisional phenomena along the orogenic front. The latter gave rise to complex transcurrent zones (e.g., N-S Axis in Tunisia, see Fig. 2, prof. 1, and the Nameless Bank in the Sicily Channel, see Fig. 3, prof. 3) separating the deformed areas from the "bouyant" foreland sector which did not flex beneath the migrating chain. The areas of orogen sourrounding the transfer zones also suffered the late-orogenic transcurrent tectonics, as in the case of the Sicanian Chain which is strongly dissected by ENE-WSW strike-slip faults.

In those sectors where foreland flexing has only recently ceased, relicts of Plio-Pleistocene foredeep basins are still well recognizable, as in the case of the Bradanic Foredeep. Where flexing of foreland areas is still active the Foreland-Foredeep system migration is currently continuing, as in the case of the frontal areas facing the Ionian Basin.

In general terms the post-Tortonian thrust migration and duplexing processes ceased where the "bouyant" sector of the foreland collided with the orogenic belt, activating transcurrent fault zones.

So different stages of the same evolutionary history are "frozen" in the different sectors of the orogen. The mature stage is recognizable where collisional processes have fully developed since the Upper Miocene. An intermediate stage is characteristic of the areas in which only recent collisional processes have been active. The initial stage of development has been detected where thrusting processes are still active.

In the mature segments of the orogen, thrusting ceased earlier than in the other sectors. This resulted in a lesser amount of shortening, in a lesser amount of foreward migration of the internal domain units and in a general uplift of the External Thrust System domain. So the mature segments of the orogen are characterized by wide exposures of the External Thrust System (e.g. the Atlas Mts. and Sicanian Chain; see text on Fig. 3). In the other sectors of the orogen, thrusting has been active longer, causing a greater amount of shortening and foreward migration of the pellicular units. In such sectors the External Thrust System is mostly or completely buried (see Figs. 3 and 7).

The different amounts of shortening of adjacent sectors are accomodated by strike-slip faults systems, NW-SE dextral transcurrent faults having been recognized in all the domains of the orogen in Sicily. Such faults have been active since the Tortonian. They caused the SE foreward migration of the units. The same structures play different roles in the different domains. In the Sicanian Chain they activated during the thrusting and acted as lateral ramps of the main thrust structures. The same fault system in the innermost domains dissects the pre-existing thrust geometry (Lentini et al., 1990b). The fault zones within the internal domains were completely detached from their deep seated wrench zone as they were passively foreward transported.

In the Calabrian Arc, north of "Stretta di Catanzaro", E-W oriented sinistral transcurrent faults have been recognized. In the Southern Apennines, NW-SE oriented, left-lateral, strike-slip fault systems dissect the whole orogenic belt (Lentini 1991; Carbone et al., 1991). Such structures might represent either the inward continuation of the Pleistocene transcurrent system affecting the frontal areas of the orogen, or the product of the post-Tortonian wrench tectonics connected with the SE migration of the Calabrian Arc, like in the NW-SE system of Sicily.

A clear segmentation also affects the Tyrrhenian Basin. This is composed of several sectors each characterized by different amounts of post-Tortonian extension. The maximum extension occurred behind those segments of the orogen characterized by maximum shortening. The two phenomena seem to be strictly connected, as pointed out by several Authors (Malinverno and Ryan, 1986; Patacca and Scandone, 1989; Ben Avhram et al., 1990; Patacca et al., 1990). The available data are not sufficiently detailed to define the actual geometrical connection between on-shore structures within the orogen and off-shore transform fault zones of the Tyrrhenian Basin.

In the regional reconstruction proposed by Ben Avraham et al. (1990) the fault zones dissecting the Calabrian Arc represent the conjugate Riedel shears of a major E-W transform fault zone located to the north of Sicily. To support this latter idea, further analysis ought be carried out to better define the geometry and kinematics of such an off-shore structure. New field data collected in the Patti Gulf area, along the northern coast of Sicily, show that the coast-line is tectonically controlled by NW-SE dextral strike-slip faults and NE-SW normal faults with a slight sinistral component. We can hypothesize that a similar setting would characterize the northern off-shore areas of the Tyrrhenian Basin, north of Sicily.

The actual causes for the coexistence of extensional and compressive tectonics in the Central Mediterranean area are still debated. Some Authors (Malinverno and Ryan, 1986; Patacca and Scandone, 1989; Patacca et al., 1990) assign the Tyrrhenian Basin opening and contemporaneous Africa-verging shortening in the external areas to a passive sinking of a lithospheric slab, NW- plunging beneath the Calabrian Arc. According to these Authors the total motion between the African and European plates has been accomodated along the front of the orogen. Further analyses must be carried out to better understand the link between the neotectonic structures of the orogen and those of the foreland.

In the Southern Apennines the possible continuation of the transcurrent shear zone from the Bradanic Foredeep to the foreland areas needs to be verified, and it needs to be understood whether the NW-SE dextral strike-slip fault system in Sicily connects with the normal faulting of the Malta Escarpment.

CONCLUSIONS

In the Central Mediterranean, several structural domains progressively developed in the different stages of the region's polyphasic evolution. These domains linked up to give rise to a complex structural puzzle. A more complete reconstruction of these domains both on-land and off-shore is derived from a better integration of new field data with those of literature. A principal distinction has been proposed to discriminate between hinterland domains, suffering late orogenic extension, and the external domains of the orogen. The latter are involved in a regional duplex structure recognizable throughout the studied orogenic belt.

All the detected domains are dissected by late orogenic fault systems which developed during the later collisional events which affected the area.

A better integration of geological and geophysical data is required to fully understand the geometry of the buried structural horizons and to analyze the wide off-shore areas.

The main aims of future analysis are to focus on the relationship between the evolutions of the orogenic belt and foreland areas to understand whether they act as two independent sectors separated by the orogenic front or whether they represent two welded elements acting as a whole.

Aknowledgements. This research was supported by the Italian M.U.R.S.T., grants n. 20120253/91 in the framework of the project: "Rapporti tra Arco Calabro-Peloritano e Appennino" and by C.N.R., grant n. 91.00013.05 and n. 92.00856.05 in the frame of the project: "Rapporti catena-avanfossa in Sicilia e Appennino meridionale".

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