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32nd INTERNATIONAL GEOLOGICAL CONGRESS

Field Trip Guide Book - P45

THE CRUST IN WESTERN AND CENTRAL EASTERN SICILY

Leader: R. Catalano

Associate Leaders:
A. Sulli, G. Avellone, L. Basilone

Florence - Italy
August 20-28, 2004

Post-Congress **P45**

The scientific content of this guide is under the total responsibility of the Authors

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R. Catalano, A. Sulli, B. Abate, M. Agate,
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Did they know about Tyrrhenian opening?

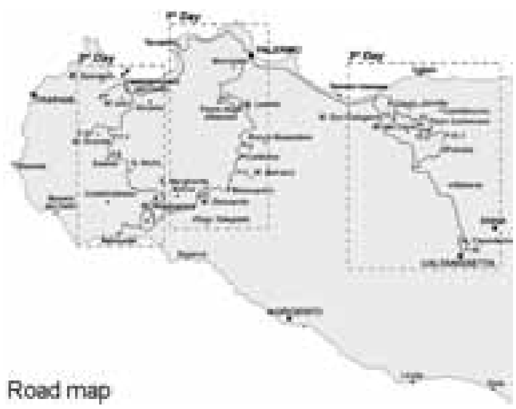
Leader: R. Catalano
Associate Leaders: A. Sulli, G. Avellone, L. Basilone

Introduction

The field trip here proposed has the aim of illustrating the structural setting of the Sicilian chain with its deformed foreland. Correlation between outcropping and buried structures will be performed using the results of the available deep seismic lines (kindly supplied by AGIP). Renewed field data and borehole stratigraphy combined with a geophysical approach (seismics, paleomagnetism, gravimetry, and magnetics) have been added to the work done since the seventies, by the present leader and his co-workers. The field trip will provide new insights into the deep structures, their geometric relationships and the kinematic evolution of the chain-foreland system growing as an accretionary wedge mainly made up of basinal mesocenozoic carbonate thrust sheets overriding a 10-km-thick platform carbonate thrust wedge. This thrust pile, common to both western and eastern Sicily, is well illustrated in the western Sicily outcrops and will mostly be reconstructed in central eastern Sicily. On the whole, the results obtained will certainly lead to a new deal in relation to environmental conservation, geothermal and fresh water evaluation, as well as petroleum perspectives in Sicily.

Conscious as we are that many geological problems must still be solved, we have planned the Field Trip with the aim of provoking debate that aptly relate to the observed features. To that end, the reader is referred to the most recent data collected by some of us and briefly illustrated in the Regional geological setting.

The three-days Field Trip will develop along three main transects crossing western and central eastern Sicily, back and forth from the chain to the foreland, in areas where both intense geological studies and deep seismic information have mainly contributed to what we know about them.



Road map

As well as their geology, the crossed regions offer beautiful landscapes and the well-known archeological remains of the last 3000years of civilization in Sicily.

On the 28th of August, participants will be welcomed with an evening ice-breaker and a brief illustration of the field trip, at the Conchiglia Hotel in Mondello, a well-known resort near Palermo.

The first day will be devoted to the fold and thrust belt outcropping in western Sicily, which stretches from the Tyrrhenian coast to southernmost Sicily.

Early in the morning, having left Palermo, we will crosscutfrom the highest tectonic units to the deformed foreland, an area that shows well-exposed rock stratigraphy and tectonic structures. Keeping in mind the main regional geology, we will show the setting of the Monte Kumeta, Rocca Busambra, Monte Barracù and Monte Genuardo structures in time to reach the Selinunte Temples.

After visiting the Greek center, partially destroyed by Carthagininians and earthquakes, participants will be free to swim and sunbathe along the seashore. Then, after a sensuous dinner, we will stay overnight at a Belice mouth hotel.

The second day will deal with westernmostSicily's structure, this time going from the deformed foreland area to the chain in the north. On our way to the fixed destination, we will see the following features in sequence: deformed foreland characters and the emergence of Plio-Pleistocene thrust-top basins; buried and surface flat and ramp structures, culminating at Montagna Grande; and tightly-packed carbonate thrust units, cropping at the Capo S. Vito Peninsula. We will reach the Tyrrhenian Sea at the Castellammare Gulf just in time to have a beautiful sightseeing tour of the Zingaro Reserve, sailing by boat along the coast. Swimming will be possible before a free sea food dinner. Late in the evening we will be back to our hotel in Palermo.

On the third and last day, a long trip will bring us to the well-known Caltanissetta basin, to visit a 2,5 ma. old thrust-top basin characterized at Capodarso by coastal deposits. Having left this area, and going north, we will approach the Madonie Mts. Regional Park. In this splendid scenery, 2000-meters above sea level, we will visit shallow and deep sea carbonates,

and debate about the tectonic boundaries among the large carbonate units, in order to offer alternative interpretations of this puzzling geological structure.
Field references are adjoined to the “references cited” paragraph.

Regional geological setting[1]

*R. Catalano***

This brief paper endeavours to introduce the fundamentals of the structure and stratigraphy of Sicily, as acquired from the most recent studies and research.

Sicily is part of the western central Mediterranean and is developing along the African-European plate boundary. It is a segment linking the African Maghrebides with the Southern Apennines across the Calabrian accretionary wedge (Figure 1). The chain and its submerged western and northern extensionsare partly located between the Sardinia block and the Pelagian-Ionian sector, and partly beneath the central southern Tyrrhenian sea (Figure 1).

In this sector of the Mediterranean area, the main compressional movements, after the Paleogene Alpine orogeny, began with the latest Oligocene-Early Miocene counterclockwise rotation of Corsica-Sardinia–believed to represent a volcanic arc-and its collision with the African continental margin. Thrusting occurred in connection with the westward subduction of the Adriatic and Ionian lithosphere beneath the Corsica-Sardinia block. Today, westward subduction is indicated by a North-dipping Benioff zone, as deep as 400 km, west of Calabria and the Apennines, and the related calc-alkaline volcanism in the Eolian Islands. Subduction and thrusting are contemporaneous with back arc-type extensions in the Tyrrhenian Sea.

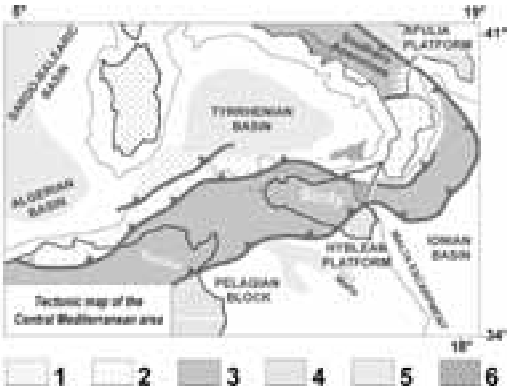


Figure 1 - Tectonic map of the central Mediterranean area 1) Corsica-Sardinia; 2) Calabrian Arc and Kabylias; 3) Maghrebian-Sicilian-Southern Apennine nappes and deformed foreland; 4) foreland and mildly folded foreland; 5) areas with superimposed extension; 6) Plio-Quaternary volcanoes.

Figure 2 - Index map

The structure of the mainland of Sicily (excluding the Peloritani corner, Figure 2) is here illustrated by a number of deep geologic profiles crossing both Western and Eastern Sicily from North to South (Pl. 1,2). The geological sections integrate the recent interpretations of several reflection seismic profiles (AGIP) with the available stratigraphic, paleomagnetic and structural surface data, as well as those of the, mostly reinterpreted, hydrocarbon exploration well logs.

The above described tectonic units derived primarily from the deformation of basinal and platform carbonate successions. The resulting lithotectonic assemblages are presented in order of their geometric position in N-S sections across the present day chain (Figure 4). Their stratigraphy and facies domains are resumed in a common scheme (Figure 4), including Western and Eastern Sicily. The distribution of the main lithotectonic assemblages and their tectonic relationships are illustrated in a general structural map of western and central Sicily (back cover Figure).

Previous studies in Sicily

Catalano & D’Argenio (1978, 1982), Catalano et alii (1989 and references therein), Roure et alii (1990), Giunta (1993), Lentini et alii (1995), Catalano et

(Footnotes)
*[1] This paper owes much to the scientific support of A. Sulli (seismic reflection interpretations), G. Avellone, L. Basilone (field geology), M. Agate (stratigraphy). **Department of Geology and Geodesy, Università di Palermo.*

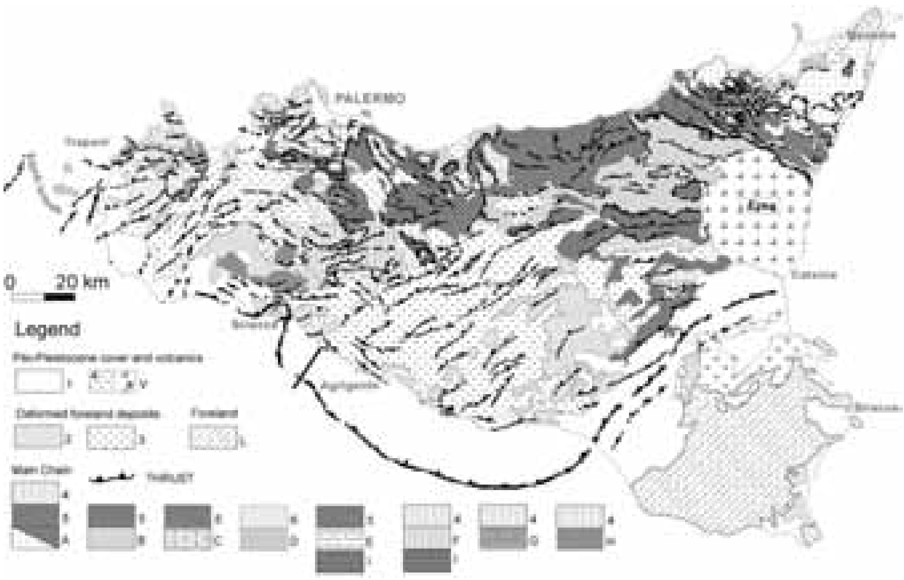


Figure 3 - Structural map of Sicily (mod. from Catalano et al., 1996). 1.Pleistocene; Deformed foreland basins (2.L.. Pleistocene-U. Pliocene; 3.L. Pliocene-U. Tortonian; 4.M.. to L.. Miocene); Flysch units (5. L. Miocene-U. Oligocene); Shelf margin (6. L. Miocene-U. Oligocene); A. Calabrian tectonic units (Oligocene-Paleozoic); B. Sicilide units (Oligocene-U. Mesozoic); C. Panormide units (Oligocene-Trias); D. Pre-Panormide units (Oligocene-Trias); E. Imerese units (Oligocene-U. Mesozoic); F. Sicanian units (Oligocene-U. Mesozoic); G.. Trapanese units (Oligocene-Trias); H. Saccense units (Oligocene-Trias); I. L. Permian-Middle Triassic allochthons; L. Hyblean units (L. Pleistocene-Trias); V. Volcanics: (a) Pliocene, (b) Pleistocene.

alii (1996), Monaco et alii (1996), and Nigro & Renda (1999), have already described Western and Central Sicily as a thin-skinned imbricate wedge of mesocenozoic carbonate and siliciclastic rocks. Catalano and D'Argenio (1978, 1982), suggested palinspastic restorations of the tectono-stratigraphic assemblages now exposed in the chain, and characterized by carbonate platforms and intervening basins lying on a sector of the Mesozoic African margin.
Nappe transport in Central and Western Sicily began in the Early Miocene and is documented by syntectonic deposits (Broquet, 1970; Catalano & D'Argenio, 1978, 1982; Mascle, 1979; Catalano et alii, 1989). Contractional deformation was accompanied by the development of coeval piggyback basins within the chain (Catalano et alii, 1989). A structural investigation (Oldow et alii, 1990) associated with paleomagnetic studies (Channell et alii, 1990) confirmed that large-scale clockwise rotations of the thrust sheets occurred during the Late Miocene-Pliocene and were accompanied by a progressive shifting in tectonic transport direction from east to south. Recent papers (Catalano et alii, 2000a; Catalano et alii, 2002) have described Western Sicily on the base of several seismic lines.
Field studies in Eastern Sicily have described a tectonic wedge formed by the stacking of several thrust nappes over the Iblean foreland (Ogniben, 1960, Catalano & D'Argenio, 1982, Ghisetti & Vezzani, 1984, Bianchi et alii, 1989, Grasso et alii, 1991, Lentini et alii, 1995, Lickorish et alii, 1999). The structure of the easternmost Sicilian chain, first illustrated by Lentini (1983), has further been confirmed by a deep north-to-south cross section (Bianchi et alii, 1989), running from the Nebrodi Mountains, northern Sicily (Figure 3), to the Hyblean foreland. Roure et alii (1990), using the same data as Bianchi et alii (1989), constructed a different structured geological section, crossing eastern Sicily. Recently, Bello et alii (2000), using several seismic sections, described the most complete structural setting of Eastern Sicily.

Stratigraphy and facies domains

Regional facies analysis indicates that the Paleozoic-Mesozoic to Paleogene rock assemblages fill, today found in Sicily, represents the sedimentary cover of distinct paleogeographic domains which belonged to the "Tethyan" ocean and the African continental margin prior to the onset of the deformation. In

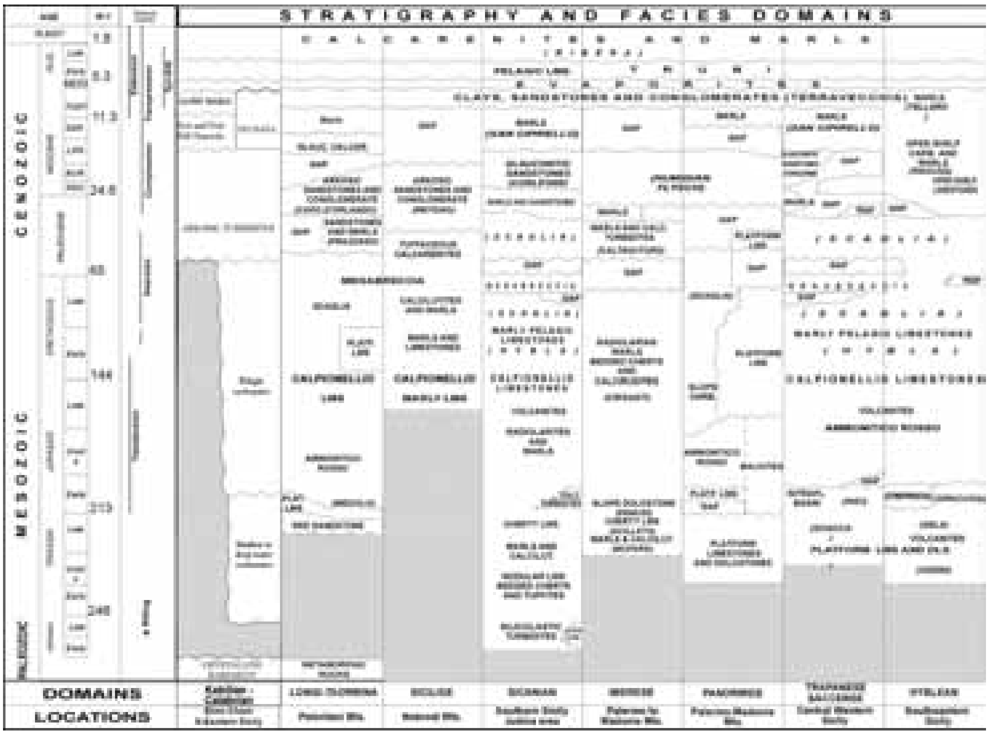


Figure 4 - Stratigraphy and facies domains of Sicily (Time scale according to Harland et alii, 1990).

contrast, the Miocene-Pleistocene rocks were deposited during the deformation of the mentioned domains. The stratigraphic characteristics of the different rock bodies exposed within the chain, are here briefly summarized to illustrate the synopsis in Figure 4.

1 - The "Tethyan" rock units

These consist of rock bodies derived from the deformation of the so-called Sicilide domain (Ogniben, 1960). The sedimentary successions, characterized by Upper Jurassic-Oligocene basinal carbonates and sandy mudstones (Monte Soro Unit and Variegated Clays Auct.), also include Upper Oligocene-Lower Miocene, terrigenous turbiditic successions (internal Flyschs) detached from their substrate. The original substrate (oceanic crust ?) is not known.

2 - The African rock units

The sedimentary successions (now forming the main tectonic units) are Mesozoic-Lower Miocene, deep-water carbonates and cherts (locally named Sicilide, Imerese, and Sicanian) and Meso-Cenozoic shelf carbonates (Pre-Panormide, Panormide, Trapanese, Saccense and Iblean-Pelagian).

2.1 - Meso-Cenozoic basinal carbonate successions

The Imerese succession consists of Triassic (Carnian) to Oligocene, thin-bedded deep-water limestones and bedded cherts, with Jurassic-Eocene carbonate platform-generated debris flows. The carbonate succession is locally unconformably covered by uppermost Oligocene-Lower Miocene, siliciclastic deposits (marly shales, turbiditic sandstones, and quartzarenites). The Lower Miocene rock-interval, locally known as Numidian Flysch, often appears detached from the older substrate.

The main bulk of the Sicanian rock assemblage consists of deep-water Carnian to Lower Miocene carbonates, followed by Middle Miocene clastic carbonates and marls. Lower Permian to Middle Triassic deep water clastic and carbonatic deposits, with shallow water carbonate olistoliths, are believed to be the old substratum of the Sicanian succession. Both Imerese and Sicanian basinal successions have in common the same basal lithofacies consisting of Middle Upper Triassic marls and cherty limestones

(Mufara and Scillato Fms.). The Sicanian succession clearly lacks the Jurassic-Eocene redeposited shallow water carbonates, and the Upper Oligocene-Lower Miocene Numidian-type strata that are lithologies typical of the Imerese sequence.

2.2 - Meso-Cenozoic carbonate platform successions

-The Pre-Panormide succession, cropping in Westernmost Sicily, is made up of a) Triassic-Lower Liassic carbonate platform dolostones and limestones, grading upwards into Jurassic slope-to-basin or pelagic carbonate platform deposits; b) Lower Cretaceous to Eocene cherty, turbiditic limestone, unconformably followed by Oligocene-Lower Miocene marly limestone, Nummulitid-bearing glauconitic biocalcarenites, and Numidian(?) quarzarenites. Lower-Middle Miocene shallow water glauconitic limestones and marls follow upwards.

- The Panormide type successions crop out in the Capo San Vito Peninsula as well as in the Palermo and Madonie Mountains (back cover Figure). The Upper Triassic-Middle Liassic carbonate platform, mostly consisting of reef deposits, is onlapped by Jurassic pelagic platform rocks (Rosso Ammonitico) that are followed by Upper Jurassic-Lowermost Oligocene reefoidal and slope limestones. Lower Miocene open shelf limestones (locally known as "Mischio") unconformably cover, at this site, the eroded Meso-Cenozoic carbonate body.

- The Trapanese type succession crops out in western Sicily and is penetrated by several wells. Upper Triassic-Middle Liassic carbonate platform dolomites and limestones are followed by Jurassic-Lower Oligocene pelagic platform deposits (Rosso Ammonitico with intensive neptunian dykes, Mn-crust condensed facies, Calpionellid and Scaglia limestone). Upper Oligocene-Lower Miocene resedimented biocalcarenites, open shelf to coastal, and glauconitic sandstones (Corleone Fm.) unconformably cover the Meso-Cenozoic substratum.

- The carbonate platform rock bodies which crop out to the southwest in the Magaggiaro-Sciacca area and are buried in southwestern Sicily (boreholes in the Castelvetrano-Mazara area), have been described in the past as pertaining to the Saccense domain (Catalano & D'Argenio, 1978). The Saccense type succession is similar to the Trapanese one, apart from the Oligocene-Lower Miocene shallow water deposits. At Monte Genuardo (Figs. 3, 4), a unique succession outcrops, where the Upper Triassic peritidal deposits are followed by the Liassic to Lower Miocene slope to basin carbonates (Catalano & D'Argenio, 1982).

2.3 - Upper Serravallian-Pleistocene deposits

Both in western and eastern Sicily, Serravallian to Tortonian terrigenous deposits, mostly clayey and marly, crop out throughout Sicily, either overlying paraconformably the Lower Miocene cover of the Trapanese-Saccense and Sicanian succession, or unconformably overlapping the already deformed Panormide-Imerese rock units and the Numidian Flysch-Sicilide nappes. This sandy marls unit is capped unconformably by reddish to yellow polygenic conglomerates, clayey sandstone and marls (Terravecchia Fm., Upper Tortonian-Lower Messinian). Large bodies of Lower Messinian coral reefoidal limestone lie over an eroded sandy substratum of the Terravecchia Fm. Messinian evaporites lap over an erosional surface, cutting the underlying strata. The Messinian evaporitic succession is predominantly eroded in the northern areas, becoming widespread to the south and the east, in the outcrops of southern Sicily.

The evaporitic strata are overlain disconformably by the well- known Trubi Fm., that is characterized by marl-limestone couplets.

A thick sedimentary wedge of mostly carbonate-clastic rocks overlies the Trubi limestone both in western and eastern Sicily. From the base upwards, these rocks are composed of fine turbiditic sandstone and biocalcarenites, and hemipelagic shales with interbedded calcarenite mudstones. uppermost Pliocene-Upper Pleistocene sandy shales, and shallow water carbonates, cover the westernmost and eastern areas.

3. The collisional complex of Sicily

Three elements characterize the "collisional" complex of Sicily and adjacent offshore areas (Figure 1).

3.1 - The Foreland

The foreland region is exposed in southeastern Sicily (Iblean Plateau) and continues offshore southwards in the Sicily Channel and eastwards in the Ionian Sea (Figs. 1, 3). The autochthonous sedimentary wedge (about 7 km thick) overlies an "African" continental crust and consists of thick Triassic-Liassic platform and slope-to-basin carbonates, overlain by Jurassic-Eocene pelagic carbonates and Tertiary open shelf clastic deposits (Figure 4 and Patacca et alii, 1979; Lentini, 1983; Bianchi et alii, 1989; Antonelli et alii, 1991). Seismic and well data indicate lateral facies transition from the Iblean domain towards the Saccense-Trapanese domains located in western Sicily (Antonelli et alii, 1991). Towards the Ionian sector, the described foreland preserves the features of a NNW-SSE ancient passive continental margin-oceanic abyssal plain system (Catalano et alii, 2000b; Catalano et alii, 2001).

3.2 - The Foredeep

The WNW-ESE trending foredeep (Figs. 1, 3) is a narrow, weakly deformed depression (Gela Basin), partially buried by the frontal termination (the Gela Nappe) of the Sicilian chain. It extends from the Iblean Platform onland to the southern Sicilian offshore (Figure 3). The basin developed from the Late Pliocene onwards, as suggested by biostratigraphic analyses, and is probably related to the inflection of the carbonate substrate due to the frontal nappe loading. The basin fill consists of Plio-Pleistocene pelagic marly limestones, and sandy clays unconformably overlying the Messinian evaporites.

3.3 - The Chain

A complex chain of thrust imbricates outcrops in Sicily, and is locally more than 15 km thick, consisting (from internal to external) of a "European" element (Peloritani Units) a "Tethyan" element (Sicilide Units) and an African element (Maghrebian Apenninic Units),.

We will look at the structural grain, taking into account the characteristics of the three main geographic sectors of Sicily along which the chain develops.

3.3.1 - Westernmost Sicily

Geoseismic cross sections, calibrated by both borehole stratigraphy and related field geology, were used to interpret the main structure at depth in westernmost Sicily. The structural edifice shows, from the bottom:
- a 7-8 km thick wedge of Meso-Cenozoic carbonate platform imbricates (Panormide, Trapanese-Saccense Units); - a 1 to 3 km thick stack of Upper Mesozoic-Middle Miocene, thin basin carbonates and clastics (Pre-Panormide Nappes) overriding the Trapanese Units; - and Upper Tortonian-Middle Pleistocene strata that fill syntectonic basins.

The carbonate platform tectonic wedge consists of northward dipping ramp-like imbricates arranged in large antiforms (Pl. 1a). The wedge extends to southwestern Sicily and culminates in the Montagna Grande outcrop (back cover Figure). There, the two superimposed carbonate bodies are more than 8 km thick (Pl. 1a, b). NW-verging back-thrust faults splay out from the main structure (Montagna Grande near Calatafimi). The whole body lies northwards beneath the basinal Pre-Panormide nappes and dips below the Panormide- derived thrust wedge of the S. Vito Peninsula (back cover Figure).

The Pre-Panormide nappes consist of a stack of thin, flat lying bodies that were originally emplaced above the Serravallian-Lower Tortonian marls of the Trapanese units. Locally, the original thrust bodies are passively refolded and transported by later deformation over the uppermost Miocene-Pliocene strata, resulting in the origination of NE-SW trending and minor NW-striking, fold and fault structures (back cover Figure).

3.3.2 - Central Western Sicily

The overall tectonic edifice is formed, from the bottom, of the following structural levels, bounded by large-scale subplanar discontinuities (Pl. 1c, d, e).

- The lowermost level is an 8 to 9 km thick thrust wedge of over 3 km thick imbricates, consisting of a stack formed by carbonate platform rocks belonging to the Panormide, Trapanese and Saccense domains. The southward-verging carbonate platform imbricate fan system (Pl. 1c, d, e, Pl. 2f, g, h) develops from the Tyrrhenian coast to the latitude of the Sciacca area. Faults form at shallow depth and sole out in a slightly north-dipping detachment surface, in a progressive migration towards the submerged Pelagian carbonate foreland, close to the southern Sicilian coast (back cover Figure, Figure 3, Pl. 2h).
- The intermediate structural level consists of a stack of about 2-3 km thick thrust ramps overriding, along a gentle N-dipping detachment level, the carbonate platform imbricates. From north to south they consist of the Imerese and Sicanian basinal carbonate thrust sheets (Pl. 2f, h). These are overthrust by the thin Numidian nappe, and, in places, by remnants of the Sicilide nappe. The NE-dipping Imerese basinal thrust sheets, with associated south-verging asymmetric folds, crop out in the eastern Palermo Mts. region, where they overthrust the Panormide Units (Catalano & Di Maggio, 1996) as well as the Trapanese carbonate platform imbricates. Later back-thrusting in the underlying Trapanese carbonate platform units, inverting the original stacking order, brought the latter to override the Imerese units (Pl. 2f, h). The Sicanian imbricate stack is found southwards of the Rocca Busambra-Maranfusa alignment, extending up to the southern slope of the Sicani Mts in the Ribera region (back cover Figure). The Sicanian stack is buried in central and eastern Sicily beneath the Neogene-Pleistocene Gela accretionary wedge (Pl. 2h, l, n), and

continues eastwards, where it outcrops in the Judica-Scalpello area located in southeastern Sicily. The basinal carbonate units show duplex accretion, and later (Pliocene) internal imbrication. The carbonate platform units, in turn, appear to locally overthrust the previously emplaced Sicanian thrust sheets along high-angle fault planes at the Rocca Busambra ridge and in the Sicani Mountains subsurface (Pl. 2f, h, l). The same geometric setting shows the Genuardo tectonic unit that overthrusts (Pl. 1c, d, e) the carbonate platform units in the southwestern study sector (back cover Figure); this unit extends westward and northwards beneath the Upper Neogene clastics of the Belice Basin.

- The uppermost level is represented by i) Miocene molasse deposits, Messinian evaporites and Lower Pliocene Trubi limestones that appear folded, faulted and detached from their substrate; ii) Middle Pliocene-Lower Pleistocene clastic carbonate deposits, filling large syntectonic depressions; iii) the Gela nappe (frontal part of the chain) overlying both the Sicanian and the Saccense tectonic units in the southern part of the study area (Pl. 2h).

3.3 - Eastern Sicily

A grid of seismic profiles, linking the Iblean plateau to the Nebrodi Mts. (Figs. 1, 2, Pl. 2o), and constrained by field and borehole data, have recently supplied new information on the deep structure of the accretionary wedge amassing in Eastern Sicily (Bello et alii, 2000). Three main structural levels can be distinguished in the chain, which lies, according to magnetometric and gravimetric data, above a not involved northward-dipping crystalline basement that is located at a depth spanning from about 15 km beneath the Tyrrhenian margin to 7 km beneath the Iblean foreland (Pl. 2i, m).

a) The lowest level of the chain results from the Meso-Cenozoic, mostly carbonate platform, S-verging 3-4 km thick ramps (Panormide-Trapanese to Iblean p.p. rock bodies), that overthrust the carbonate foreland located in the Iblean region.

b) The intermediate level consists of a stack of thin flat-lying Meso-Cenozoic basinal carbonate thrust sheets (Imerese to the north and Sicanian to the south, Pl. 2l) resting on the deformed carbonate platform (Pl. 2m). The carbonate basinal units, buried below a wedge of Sicilide and Numidian units, 4 km thick (Pl. 2m), rise to the surface only in the M. Judica-Scalpello ridge, where the Sicanian embricates thrust over the Iblean-Pelagian foreland (Figure 3).

c) The upper structural level is a thrust wedge made of the Sicilide-Numidian units and the Gela Nappe, overlain by the Plio-Pleistocene syntectonic basins.

The Sicilide units are believed to have been emplaced during Early Miocene, on top of the more external rock units. The Sicilide complex reaches its greatest thickness in northeastern Sicily (Figure 3, Pl. 2m), where it has been preserved in a wide depression of the chain (Bianchi et alii, 1989). In the northeastern corner of Sicily, the Sicilide nappes underlie the Peloritani Crystalline Units (Figure 3).

The Gela Nappe (Grasso et alii, 1991) overthrusts its Upper Pliocene foreland marine sediments (Figure 3, Pl. 2h, l, m, n). Its submerged thrust front thins in the southern Sicilian offshore (Pl. 2l).The allochthonous wedge is composed of Cretaceous-Eocene Sicilide, Miocene Numidian Flysch and Lower Miocene to Lower Pleistocene folded and faulted clastics, evaporites and marly carbonates.

The accretion of the Gela Nappe began in the Middle Pliocene and was active up to the Middle Pleistocene, as proved by the deposits as old as 0.8 Ma involved in the deformation (Pl. 2l).

4. Compared tectonic evolution

The tectonic history of the Sicily fold and thrust belt is one of an essentially continuous forward migration with a combination of duplexing and clockwise nappe rotations. Following the Early Miocene “collision” (subduction?) of the Sardinia Block with the African margin, the evolution of the thrust belt-foredeep system started in the Late Oligocene with the internal imbrication of the already formed crystalline Calabrian (Peloritani) units and their emplacement above the Sicilide domain. Reflecting the transport direction, the foreland basins, filled by Upper Oligocene-Lower Miocene Flyschs, migrated progressively eastward. Deformation first reached the oceanic(?) and/or thinned continental crust basinal domain with the detachment of the Sicilide terrains and the Lower Miocene Flyschs that were emplaced southeastwards, over more external domains, forming the structurally highest units in the chain. Their transport is bracketed between Langhian and Early Tortonian, as demonstrated by the occurrence of the Middle Miocene sandy clays that seal the already deformed Numidian/Sicilide nappe complex (Figure 5).

This early phase of thrusting involved, during the Lower-Middle Miocene, the basinal carbonate-derived rock bodies (Imerese-Sicanian) with duplex geometries and major tectonic transport (Figure 5). The preferred detachment levels were Permian clastic and carbonate, Middle Triassic marls with dolomites, and Lower Tertiary pelagic carbonates and turbiditic

siliciclastics.
Deep-seated thrusting detached and deformed the buried underlying carbonate platform rock body (Figure 5), determining axial culmination and antiformal stacks. The wedging at the depth of the carbonate platform substrate, implied re-imbrication and shortening into the overlying basinal carbonate nappe pile, as well as in the highest structural

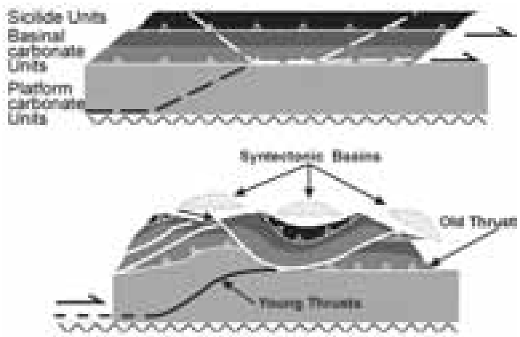


Figure 5 - Kinematic model for the study area (adapted from Roure et alii, 1998).

levels, thus accommodating their progressive stacking (Figure 5). Most of the thrusting involving the carbonate platform body occurred during Late Miocene-Early Pleistocene. This deformation timing is supported by the age of the syntectonic deposits filling the thrust-top basins on the growing chain, and by the tectonic involvement of the overlapping Pliocene-Lower Pleistocene clastics during the late imbrication.
Field-recognized, high-angle fault planes, with mesoscopic, strike-slip structures (Ghisetti & Vezzani, 1984; Monaco et alii, 1996; Abate et alii, 1998) appear on deep seismic profiles to sole out along detachment planes, but never appear to cross the crystalline basement. The faults indicate that the thrust was accompanied by lateral movements related to right oblique transpression accompanying latest Miocene-Early Pleistocene clockwise rotations. Northwards in the belt ("hinterland zones"), the already imbricated substrate was eroded and block-faulted after the Messinian along listric and normal growth faults (Agate et alii, 1993). The extensional event opened half-grabens that were progressively filled by clastic wedges. Later, structural inversion of the half-graben deposits took place between 2.5 and 1.4 Ma. Between 1.4 to 0.8 Ma, extensional structures dissected the basins, which again experienced compressive transpressive deformation between 0.8 and 0.5 Ma. The last 0.5 Ma has involved strong vertical tectonics. The two main extensional events are linked to the opening of the Tyrrhenian Sea.

5. Mesozoic paleogeography

The palinspastic restoration of the present-day structural edifice defines a Sicilian Mesozoic crustal paleogeography characterized by a wide carbonate platform (represented by the Panormide Trapanese-Saccense and Iblean domains) developing onto the African continental crust, flanked to the (present-day) north by a large basinal area (where Sicilide, Imerese and Sicanian deepwater domains developed, Fig 6b, 7). Rifting events locally involved the large shallow water domain, probably starting from Late Triassic time. Major extensional features appear to dissect the top of the Triassic-Liassic carbonate platform,

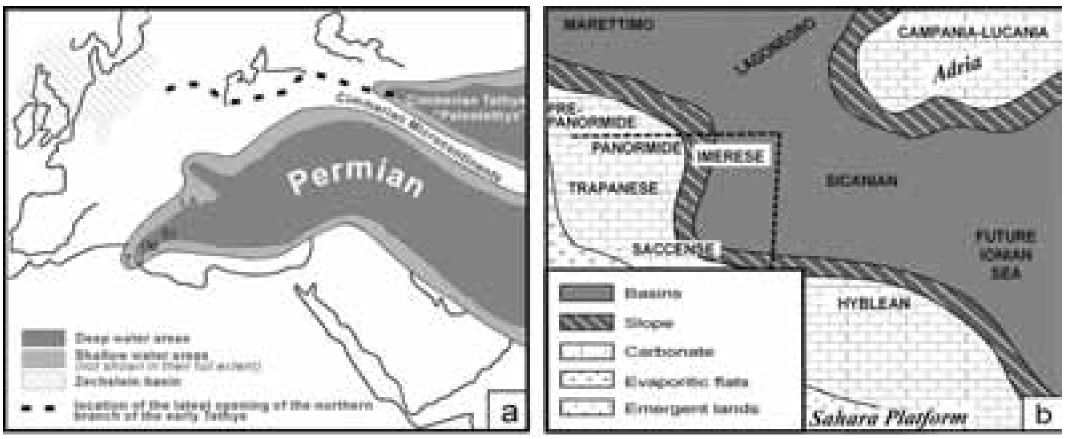


Figure 6 - Paleogeographic reconstructions during the Permian and Triassic: a) Middle Permian; b) Late Triassic. Dashed lines are the traces of the sections in Figure 7.

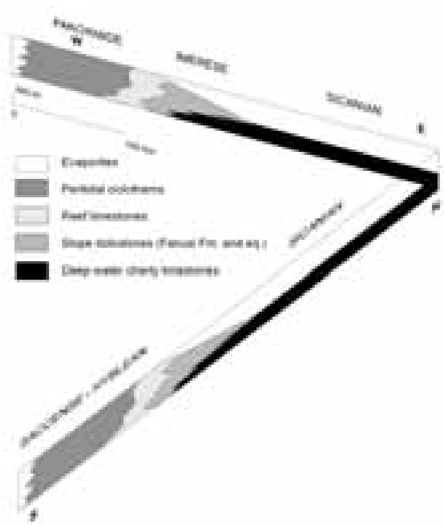


Figure 7 - Palinspastic sections across the platform-basin system of Sicily in the Late Triassic time (for location see Figure 6).

with the formation of margins and troughs (pelagic carbonate platform).
Permian to Lower Triassic deep-water siliciclastic and carbonatic deposits indicate the occurrence of a deep-water basin in Sicily (Catalano et alii, 1991, and references therein) that was connected eastward to the Permian main Tethyan domains. The connection must have passed across the present Ionian Sea, separating Apulia from Gondwanian Africa at that time, and later in the Early Triassic (Figure 6a). During the Jurassic, the Sicilian area was affected by profound modifications of the paleogeography and lateral facies shifts (Di Stefano, 2002; Santantonio Ed., 2002) in response to N-directed extension tectonics linked to the sinistral transcurrent motions between Africa and Europe (Dewey et alii, 1989). Jenkins (1970) described the foundering of sectors of the carbonate platforms due to accelerated subsidence, uplift and erosion, which were all developing contemporaneously.
Folding and faulting of the pre-Middle Eocene multilayer, together with occurrence of large carbonate megabreccias bodies, and deep truncations and regional gaps at the Cretaceous-Eocene boundary (Catalano and D'Argenio, 1982), correlate to some offshore structures imaged by reflection seismics (Antonelli et alii, 1991), and suggest that the Lower Mesozoic half-graben and basinal structures have often been inverted as positive structures. These events could be seen in the framework of the dextral relative motion of Africa with respect to Europe, during the Cretaceous-Paleocene time (Dercourt et alii, 1986).
New and recent data from the adjacent Pelagian-Ionian region (Catalano et alii, 2000b; Catalano et alii, 2001) are particularly important for understanding the Early Mesozoic history of this area. The present day SE-NW trending location of the Ionian basin and the Sicilian and Southern Apennines mesozoic paleogeography, suggest that the oceanic crust could continue to the west-northwest (Figure 8) as already depicted by Catalano et alii (2001). Such a region could have been the place of the more internal deposits (Sicilide) firstly thrust over the African continental margin (Figure 8).

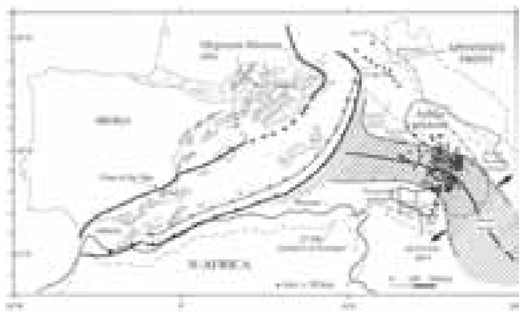


Figure 8 - Late Oligocene-Early Miocene palaeogeography of the central Mediterranean.

6. Conclusions

The structure of Sicily essentially consists of a carbonate accretionary wedge, mainly made up of basinal Meso-Cenozoic carbonate basinal units, overriding a 8 km-thick platform carbonate thrust wedge which is, in turn, detached from an undeformed crystalline basement. Both imbrication geometry and internal deformation of the original units, suggest a tectonic evolution due to a combination of underplating and rotation of the thrust units towards the Pelagian foreland. The timing of the deformation is bracketed between Early Miocene and Early-Middle Pleistocene. The progressive detachment of the more internal Meso-Cenozoic carbonate basinal units and their transport above the external units occurred during the Early-Late Miocene. The uncoupling of the carbonate platform from its basement and its duplexing, as well as the re-imbrication and shortening of the overlying basinal thrust sheets, took place during the latest Miocene-Early Middle Pleistocene. These events are believed to be linked to transpressional tectonics accompanied

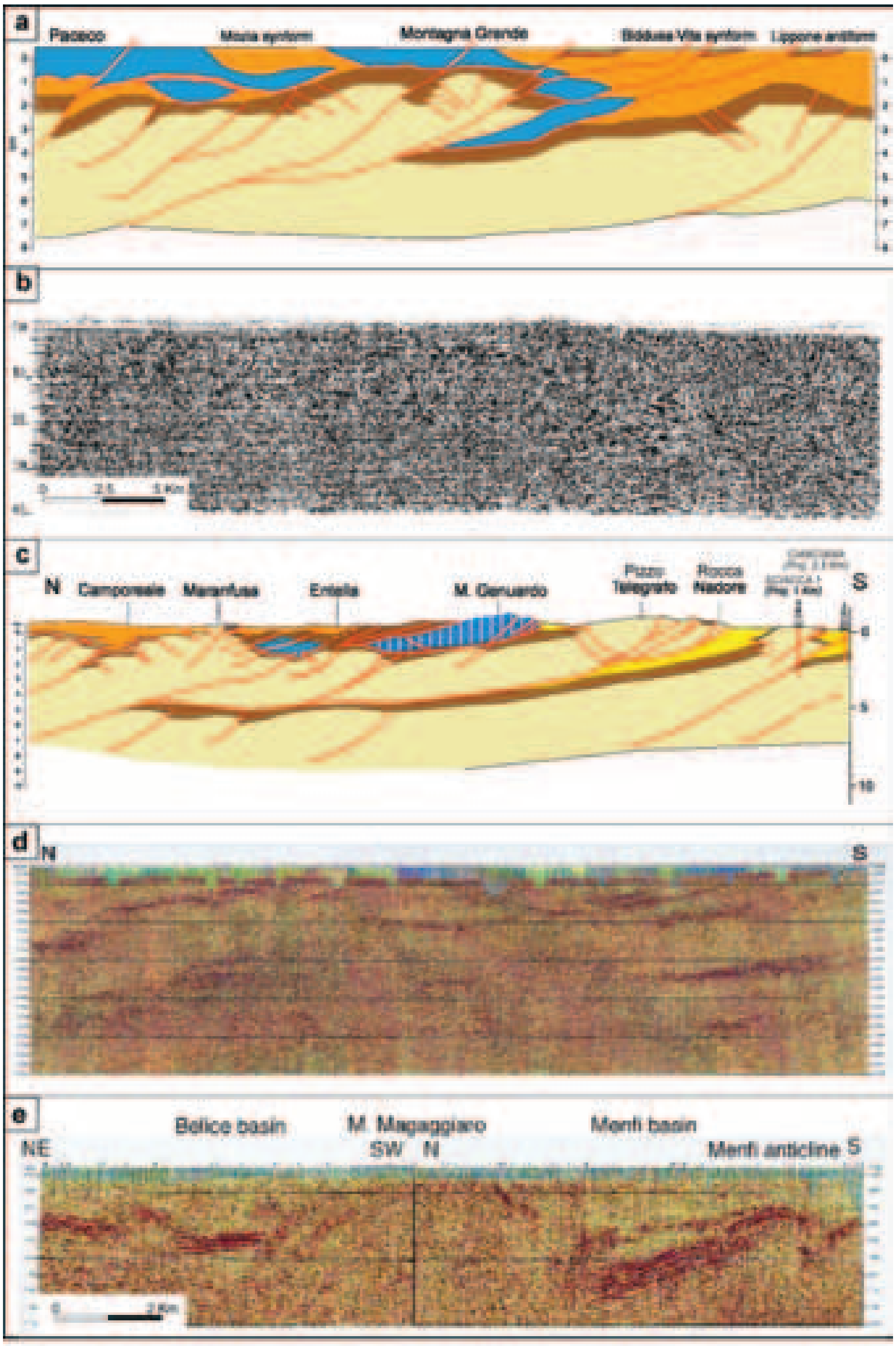


Plate 1 - ab) balanced cross section (based on the uninterpreted seismic profile {b}) across westernmost Sicily (modified from Catalano et alii, 2002); it shows a late reimbrication of the basinal Pre-Panormide Units; cd) geoseismic cross section (based on the uninterpreted seismic profile {d}) imaging the structural grain along the Kumeta-Sciacca belt e) seismic section crossing the south-western Magaggiaro ridge that bounds the Pliocene-Pleistocene Belice and Menfi basins (c to e after Catalano et al., 2000, an interpreted version is illustrated in Figure 29); for symbols see Pl. 2.

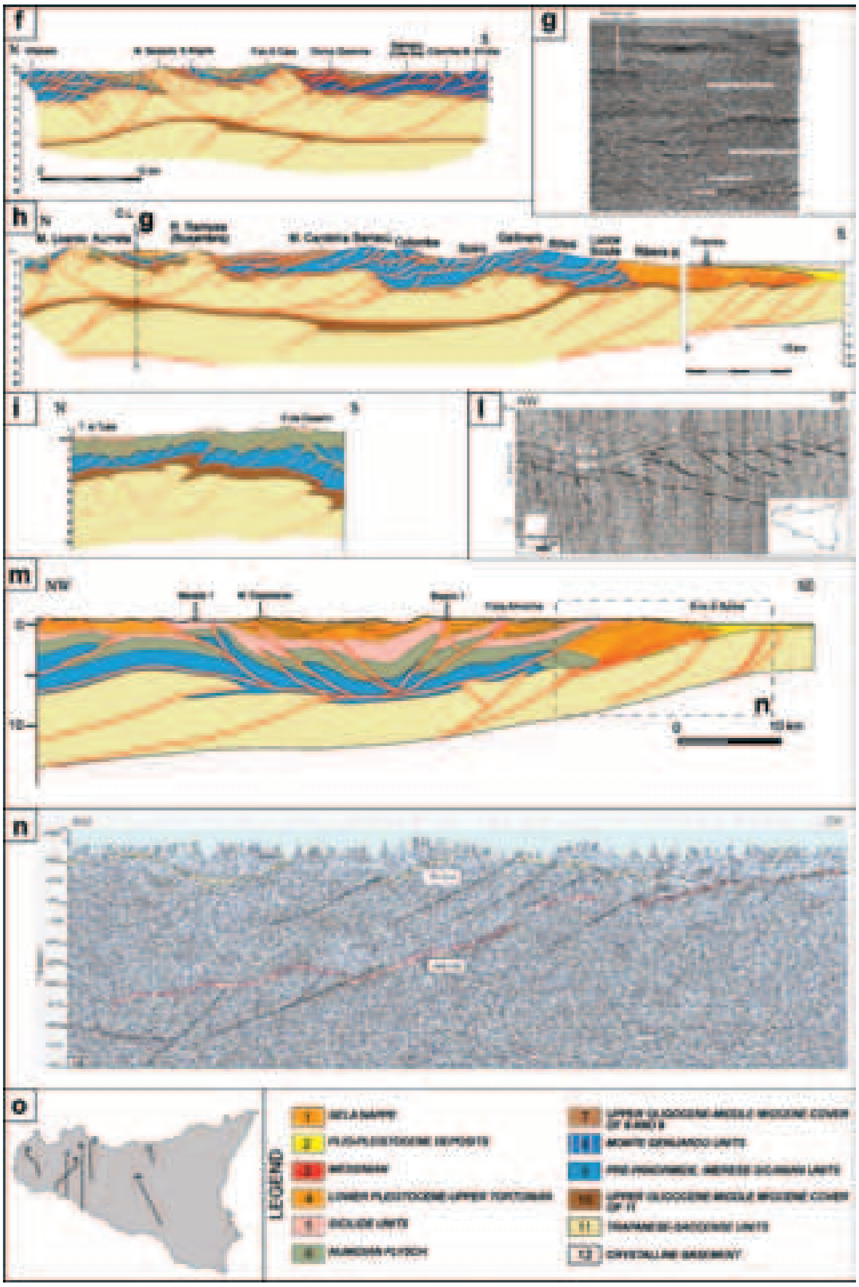


Plate 2 - f) Geoseismic cross section showing as the Imerese (to the north) and Sicanian (to the south) basinal thrust sheet overthrust the carbonate platform tectonic wedge. The Northern sector is controlled by field outcrops; g) Geoseismic cross section from the Kumeta ridge to the southern Sicily offshore, showing further imbrication of a thick stack of Sicanian units after the uncoupling_ at depth and the local pushing up of the carbonate platform. The Miocene-Pliocene rock body involved in the Gela accretionary wedge is shown in its submarine extent imaged by (l); i) Geoseismic cross section located in the northern Sicily sector, displaying Numidian Flysch and Imerese basinal thrust sheets overlying the deformed carbonate platform substrate; m) Geoseismic cross section in central eastern Sicily (modified from Bello et al., 2000); its southern part is based on the interpreted seismic profile (n); it shows the structural setting of the rock bodies located beneath the Caltanissetta basin; o) traces map of the cross sections.

by clockwise thrust rotations.

The palinspatic restoration of the tectonic wedge, suggests that the Imerese and Sicanian original domains were located in a more internal paleogeographic setting, with respect to the carbonate platform, during Triassic-Jurassic time. This restoration is in agreement with the model of a rifted Triassic carbonate platform, attached to the African craton, and irregularly bordered by a widespread basinal domain.

DAY 1

29 August 2004

The chain along the Palermo-Sciacca Bridge (Central Western Sicily)

G. Avellone, L. Basilone, R. Catalano, A. Sulli and M. Barchi.

Main purpose

To describe the central-western Sicily main structural grain, characterized by the thrusting of basinal thinner tectonic units (Imerese and Sicanian rocks) over the carbonate platform rock units (Trapanese and Saccense).

Field itinerary

Palermo, Piana degli Albanesi-Monte Kumeta (Stop 1), Rocca Busambra (Stop 2), Corleone village, Monte Barracù (stop 3), M. Genuardo (stop 4), and Selinunte.

The first day is devoted to visiting a region extending from the Tyrrhenian Sea to the Sicily Channel. Along this N-S belt, well-known as the Western Sicily Bridge, there are excellent exposures, which are useful to observe the stratigraphy and surface structures of the main rock bodies incorporated in the chain.

Leaving the town, we will crosscut the Palermo Mountains (Figure 9), which comprise of large bodies of basinal (Imerese Units) and platform deposits (Panormide Units), in order to observe in the Piana degli Albanesi valley the thrust of the Imerese units over the Trapanese carbonate platform Kumeta ridge (Stop 1). Leaving the top of Monte Leardo, we will cross the Numidian Flysch nappe and the syntectonic molasse of Terravecchia Fm., to reach the Rocca Busambra-Rocche di Rao ridge formed by carbonate

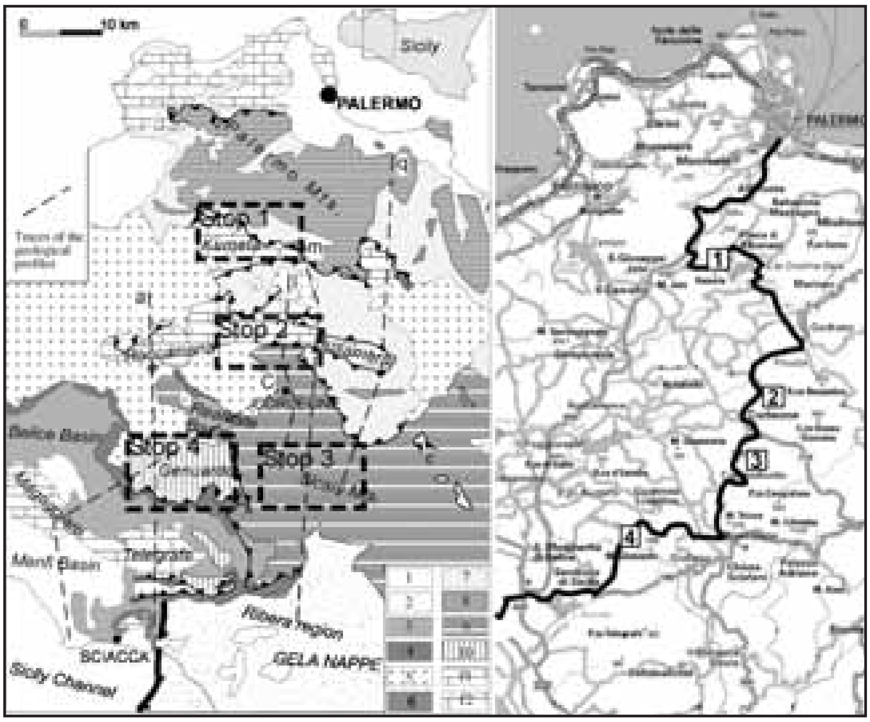


Figure 9 - a) Large scale structural map of the study area (modified from Catalano et alii, 2000). Legend: 1. Pleistocene deposits; 2. Gela thrust wedge; 3. Middle Pliocene-Lower Pleistocene; 4. Lower Pliocene; 5. Upper Miocene terrigenous strata; 6. Sicilide Nappe; 7. Numidian Nappe; 8. Imerese units; 9. Sicanian units; 10. Genuardo units; 11. Trapanese-Saccense units; 12. Panormide units.Boxes point out the investigated areas. b) Road map and stops.

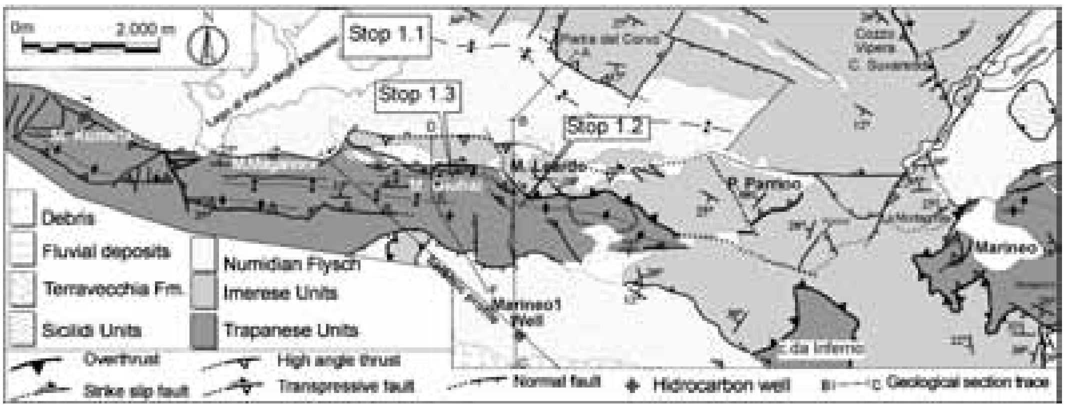


Figure 10 - Structural map of southern Palermo Mts.- Kumeta ridge showing the main tectonic features of the visited area. (Avellone & Barchi, 2003 mod.).

platform rocks, also pertaining to the Trapanese Units. A panoramic view of the structural relationships between the Trapanese and Sicanian Units and their continuation at depth will be displayed in Stop 2.

After having crosscut the Miocene glauconitic calcarenites of Sicanian sequences, we will climb up Monte Barracù (Stop 3), to visit the whole Sicanian succession, in an interesting close up down section. The mesocenozoic succession of the M. Genuardo sequence is the aim of Stop 4.

Geological setting

Surface geology is illustrated in the large-scale structural map (Figure 9) that depicts the occurrence of the mesocenozoic Panormide and Imerese thrust systems overriding the Trapanese-Saccense carbonate platform thrust wedge. This thrust wedge crops out in the Kumeta-Busambra-Maranfusa ridges, as well as in the Magaggiaro-Telegrafo and Sciacca area. The carbonate tectonic wedge is overlain by the Sicanian and Genuardo Units (Sicani Mts. region). The Upper Oligocene-Lower Miocene Numidian Nappe is uncoupled from its supposed Imerese substrate; it tectonically overlies most of the carbonate thrust pile. The whole edifice is covered by Tortonian-Lower Pleistocene foredeep and thrust top basins.

Stop 1:

Monte Leardo-M. Rossella region. Overthrusting of the Imerese Units.

G. Avellone, M. Barchi and A. Sulli.

Main purpose:

To observe the overthusting of the Imerese Units on the Trapanese Units along the east-west trending Kumeta ridge.

Geological setting

This portion of the Sicilian belt consists of a stack of imbricated thrust sheets, made up of Mesozoic-Cenozoic sedimentary cover, originally pertaining to the "Imerese" and "Trapanese" Domains. Overthrusting of the Imerese Units on the Trapanese Units (here called Imerese Thrust), crops out in the Mt. Leardo-Marineo area (Figure 10).

The Imerese Thrust is well-exposed, although its attitude has been strongly modified by later tectonic evolution.

The Imerese Units are made by Carnian to Eocene

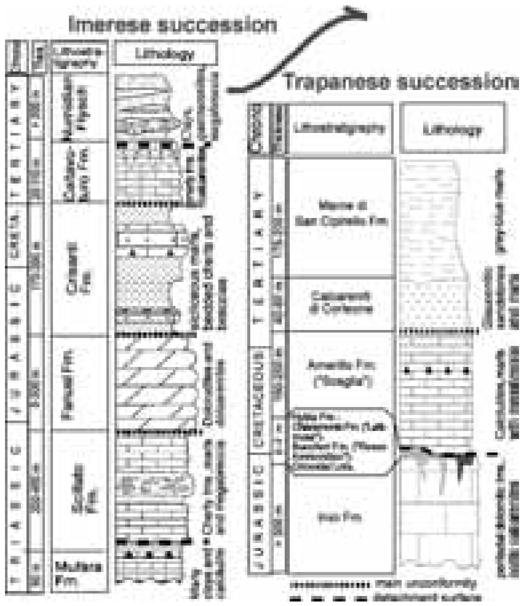


Figure 11 - Lithostratigraphy of the Imerese and Trapanese successions in the Palermo Mountains

slope to basin deposits, and Upper Oligocene-Lower Miocene siliciclastic cover, locally decolled from its substrate (Numidian Flysch, Figure 11).

The Trapanese succession is characterized by carbonate platform dolomitic limestones (Middle Liassic), Jurassic-Eocene pelagic carbonate platform deposits, followed unconformably by Langhian to Lower Tortonian glauconitic calcarenites and marls (Figure 11).

The deformation history of the region consists of two major tectonic events: 1) Emplacement of the Imerese Units over Trapanese Units (Imerese Thrust, post Lower Tortonian).

The Imerese units were originally emplaced along a low-angle regional thrust, in a thin-skinned mode. Thrusting was accompanied by large clockwise rotations (Oldow et al., 1990). 2) Deep-seated compressional and/or transpressional deformation of the Trapanese Units, that has passively faulted and folded the pre-existing low-angle Imerese Thrust (post Miocene).

Stop 1.1:

Piana degli Albanesi valley. Imerese Thrust panoramic view.

Standing on the Numidian Flysch deposits which unconformably overlie the Imerese Meso-Cenozoic basinal carbonates, we get a panoramic view of the Imerese Thrust, looking towards Mt. Leardo (Figure 12a). The geological section shows how the Imerese

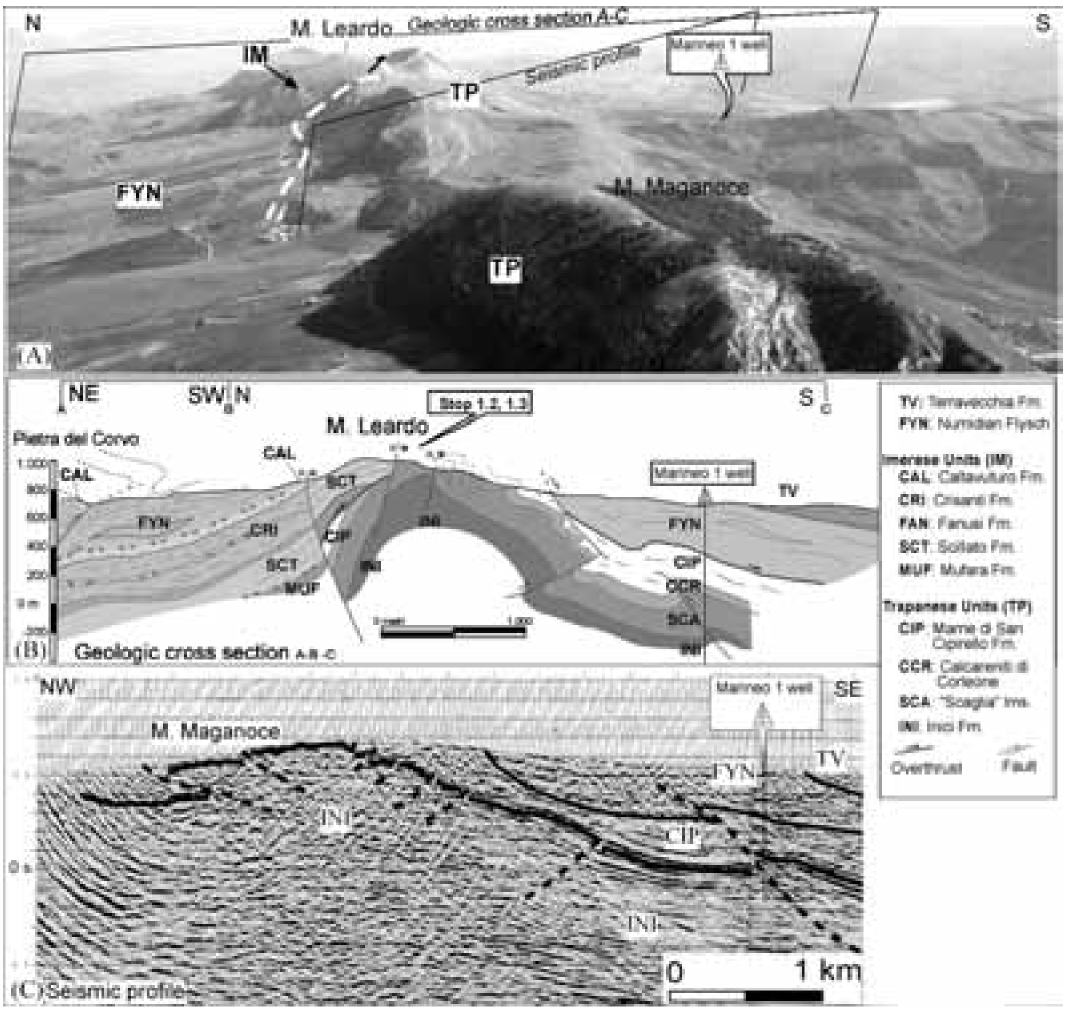


Figure 12 - Monte Leardo area:
panoramic view (a), geological cross section (b) and seismic profile (c), see traces in Figure 10.

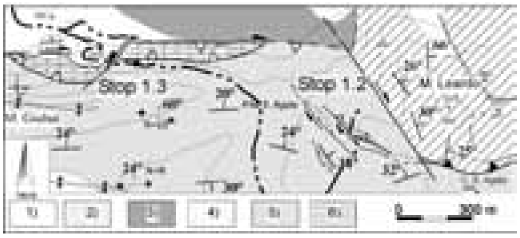


Figure 13 - Geological map of the M. Giuhai - M. Leardo area. 1) debris; Imerese Units: 2) cherty limestone and bedded cherts (Upper Carnian-Neocomian); 3) marls and calcilutites (Carnian); Trapanese Units: 4) glauconitic sandstones (Langhian); 5) undifferentiated marls, siliceous and marly limestones (Cretaceous-Eocene); 6) carbonate platform deposits (Lower Liassic).

Thrust is folded and faulted by later tectonic events (Figure 12b).

Stop 1.2:

Mt. Leardo area. The Imerese Thrust and its later deformation.

The map in Figure 13 shows the Imerese thrust front, presently trending WNW-ESE; the Imerese rock body (mostly consisting of Triassic Scillato Fm.) overlies the Trapanese sequence (here represented by the Cretaceous “Scaglia” limestones).

The thrust plane is folded upward, following the deformation of the underlying Trapanese Units. The thrust plane is also displaced by a right-lateral fault zone, dipping NE-ward 50° to 70°. Within the Trapanese Units, a similar, right-handed tranpressional fault (Figure 13) produces the stacking of the Liassic platform rocks (LP) over the Cretaceous “Scaglia” limestones (CS).

Stop 1.3:

Mt. Giuhai area. Folds in the Trapanese Units.

This stop is devoted to the observation of the internal deformation of the Trapanese “Scaglia” marly limestones (Figure 14). Two subsequent systems of tectonically-generated folds (H1 and H2 hinges, trending about W-E and N60 respectively) have been recognised, overlying pre-existing, ductile folds developed in still soft sediments (slumps).

Stop 2:

Structural setting of the Rocca Busambra-Rocche di Rao ridge.

L. Basilone, A. Sulli and S. Merlini

Main purpose:

To illustrate some stratigraphic characteristics of the outcropping rocks, and to show the continuation at depth of the structural relationships between the Trapanese and the Sicanian Units.

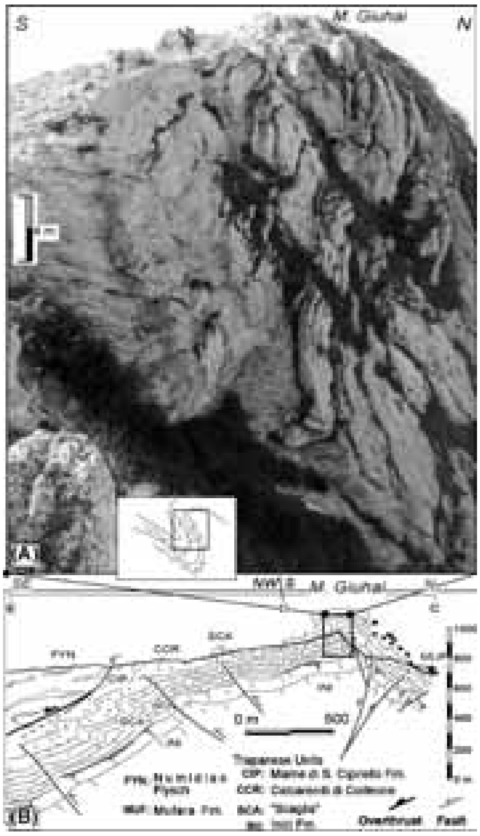


Figure 14 - Minor folds in the Trapanese Units. The asymmetry of the folds is coherent with their structural position, within the major south verging anticline (a), as illustrated in the geological cross section (b, trace in figs. 2, 6). Modified from Avellone & Barchi, 2003.

Geological setting

The visited region (Figure 15) is characterized by the occurrence of three main structural levels, consisting, from the bottom of a) carbonate platform embricates (Trapanese Units); b) a wedge of basinal carbonate thrust sheets (Sicanian Units); c) the Numidian Flysch nappe; and d) synorogenic Upper Miocene molasse (Terravecchia Fm.). This structural pile has been reconstructed with the help of seismic profiles constrained by field geology (mesoscopic data and stratigraphy). In the region, Rocca Busambra (a carbonate platform ridge trending east-west, about 15 km long) appears pushed up to the surface, breaching

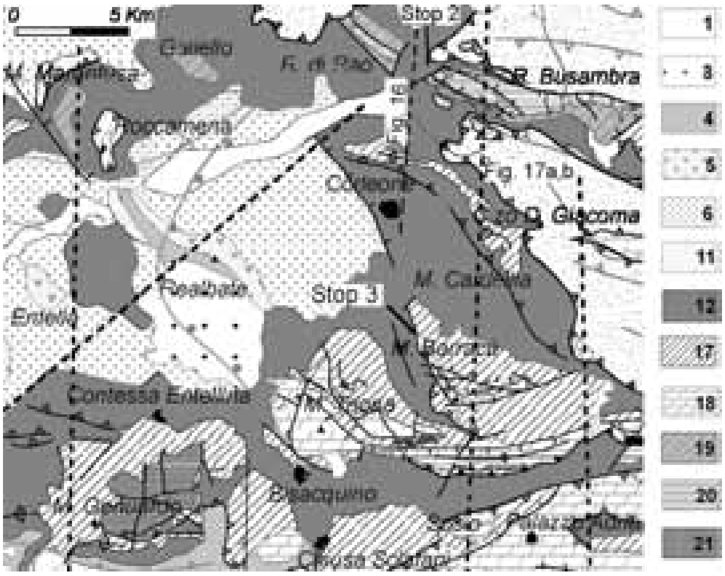


Figure 15 - Geological map of the crossed area with cross-section traces. Legend:1) Olocene, 3)Pliocene, 4)Trubi, 5)Evaporites, 6)Terravecchia Fm., 11) Numidian Flysch, 12) Marls and glauconitic (L. Miocene-U. Oligocene),17) Pelagic carbonates and radiolarites (Paleogene-Jurassic),18) Cherty Lms. (U. Trias), 19) Pelagic platform deposits (Paleogene-Jurassic),20) Platform carbonates and dolomites (L. Lias-U. Trias).

the tectonically-overlying basinal Sicanian Units (Mt. Barracù and the Units' subsurface continuation). The geological sections of Figure 16 and 17 show the above mentioned structural setting of the visited region.

Stop 2.1:

Standing on the Rocca Argenteria hill. A geoseismic section across the Rocche di Rao ridge.

The deep structural setting of the Rocche di Rao ridge is illustrated by a geoseismic section (Fig.16, see trace in Fig.15) that images the subsurface continuation of the structure. The relationships with the buried Sicanian thrust sheets can be seen (Fig. 16).

Stop 2.2:

Cozzo Guardiola: Structural relationships between the Trapanese and the Sicanian Units. Panoramic view.

Driving southwards to Corleone, we will stop at Cozzo Guardiola to have a look at the outcropping relationships between the carbonate platform (R. Busambra Unit) and the basinal Sicanian thrust sheets that are well preserved in the adjacent Monte Barracù. A field section from R. Busambra to Mt. Barracù, reveals the surface characteristics of the structural relationships, that are schematically redrawn in the geoseismic section of Figure 17 which images a duplexing (see lefthand side) of the basinal Units.

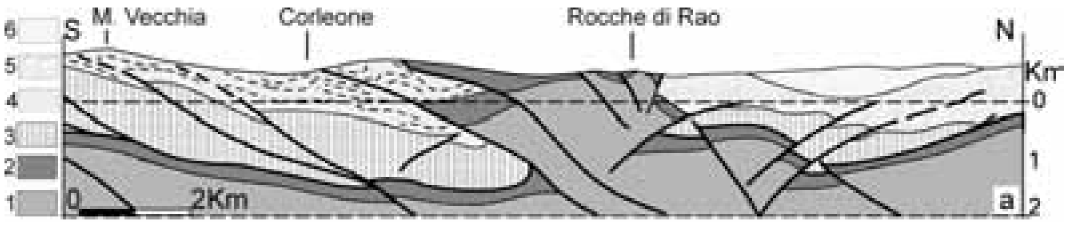


Figure 16 - Rocca Argenteria. Geoseismic profile (a) displaying the subsurface structural relationships between the Trapanese platform (1) terrigenous cover (2) outcropping in the Rocche di Rao ridge (shown in b) and the basinal Sicanian and Imerese Units (3,4). Numidian Flysch nappe (5) and molassic U. Miocene deposits (6).

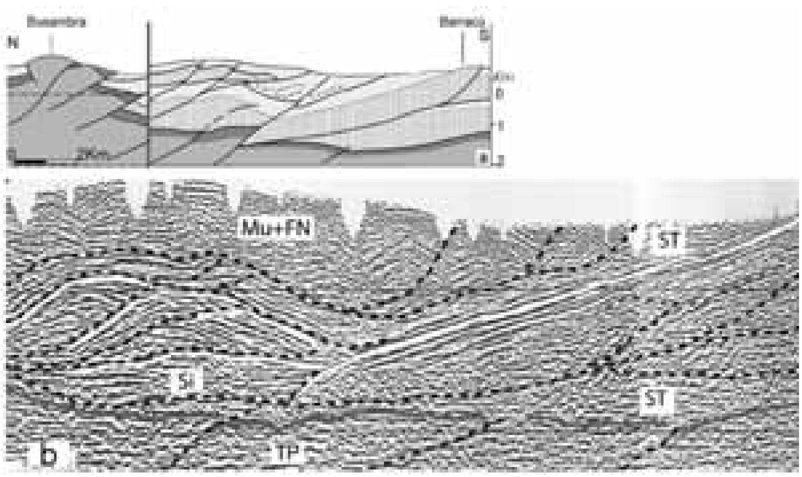


Figure 17 - (a) Geoseismic cross-section showing the subsurface structure at Rocca Busambra and Monte Barracù; same legend as in Figure16. (b) Interpreted seismics image duplex deformation of the Sicanian Units (Si). Mu+FN: Numidian Flysch and Mufara Fm. ST: Oligo-Miocene cover. TP: Trapanese Units.

Discussion

The overthrusting of the Rocca Busambra above the Sicanian rocks is not an early tectonic feature. The regional tectonic evolution suggests that the carbonate platform substrate, earlier overrided by the basinal carbonate units, was later detached and deformed by deep-seated thrusts (see also Pl. 2 f, h). The wedging at depth of the carbonate platform, implies further reimbrication and major shortening of the basinal carbonate units, in order to accommodate their original extent, in several stacked thrust sheets as imaged by the seismic lines here shown.

Stop 3:

The Sicanian basinal succession at the Monte Barracù

L. Basilone and M. Agate

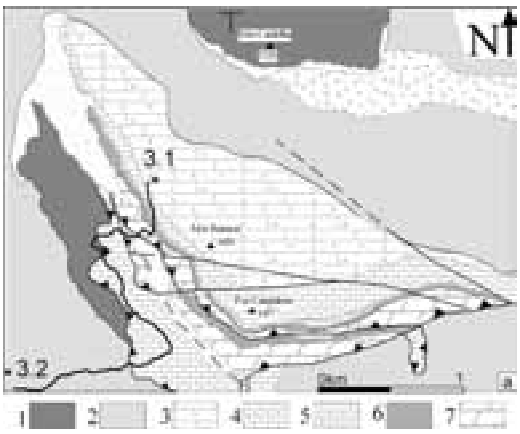


Figure 18 - Simplified geological map of the M. Barracù-M. Cardellia area. Legend: 1-7) see columnar section in Figure 19.

Main purpose:

To illustrate a sedimentary successiontype of the Sicanian Domain and its tectonic setting.

Introduction

The Sicanian Units are made by Triassic-Paleogenic pelagic carbonate deposits. The internal imbrication of the Sicanian thrust wedge, displaying here duplex geometry (Figure 17), is well exposed along the western side of Monte Barracù (Figure 18).

Stop 3.1:

Top of the Monte Barracù. Stratigraphy of the Sicanian succession.

After having reached the top of Monte Barracù, we will go down for a detailed facies analysis of the whole Miocene-Triassic rock succession (Figure 19, and for more stratigraphic details see introductive paper).

Stop 3.2:

Balatelle hill. Frontal panoramic view of the Mt. Barracù.

Coming back to Campofiorito village, we will reach the place where a well-exposed, SW trending, natural section will display the structural setting and the internal deformation of the Mt. Barracù tectonic unit, the highest unit in the thrust sheet forming the Sicanian thrust system. The structure, on the whole, mimics the characteristics of a duplex geometry.

The two tectonic units, forming the main structure of Monte Barracù, are separated by a low angle fault plane. The Monte Barracù Unit, in turn, thrusts southwards over a wedge of Sicanian splays forming the Monte Colomba Unit (see Pl. 2f, h). Both the Sicanian thrust bodies rest on the deformed

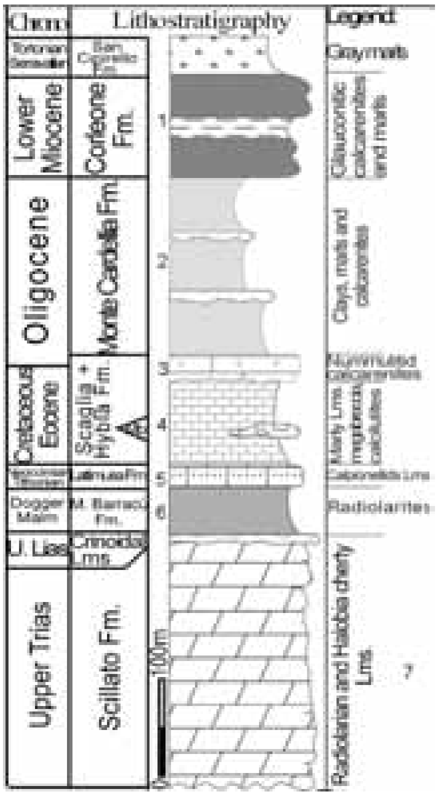


Figure 19 - Stratigraphic section of the Barracù Sicanian Unit.

Figure 20 - Southwestern side of Monte Barracù. High angle reverse fault E-W direction. Legend: Tr) Upper Triassic cherty limestone, Gr) Jurassic radiolarites, Sc) Cretaceous-Palaeogene "Scaglia" limestone.

carbonate platform substrate (Figs. 16, 17). High angle reverse faults (Figure 20) and associated normal faults can be observed along the track.

Stop 4:

Monte Genuardo.

A. Sulli, G. Avellone and L. Basilone.

Main purpose:

This stop focuses on the unusual characteristics of the Meso-Cenozoic Monte Genuardo succession, and on the structural relationships with the adjacent carbonate platform and basinal rock units.

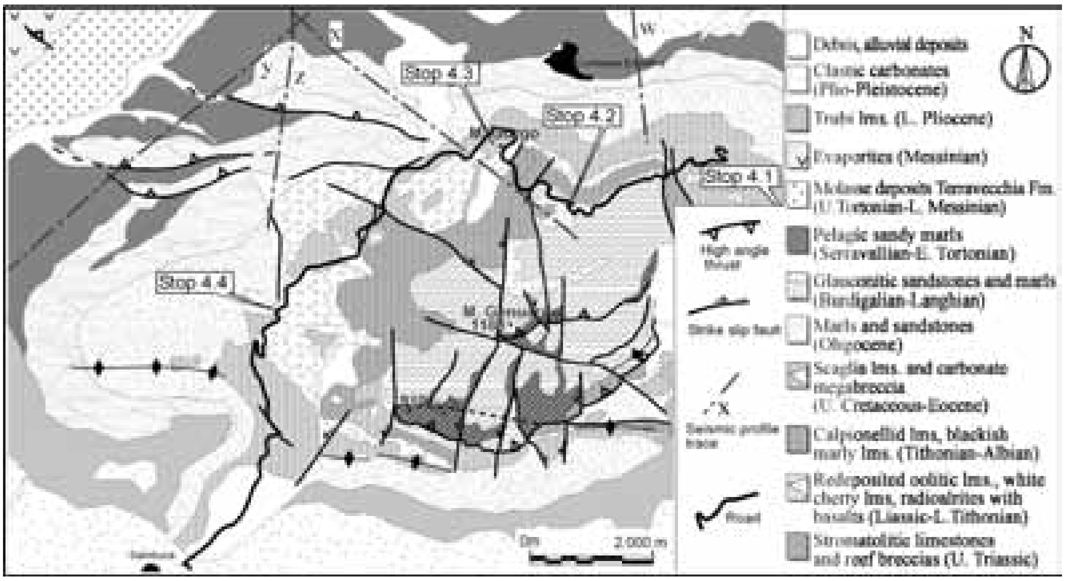


Figure 21 - Reinterpreted geologic map (source:Di Stefano & Vitale, 1993). Trace of the geoseismic setions are indicated.

Geological setting

The Monte Genuardo succession (Figure 21), consists of Upper Triassic stromatolitic dolomites and reefoidal breccia limestones, and Jurassic to Eocene slope-to-basinal deposits, encompassing Jurassic thick basalt levels and Cretaceous Megabreccias, followed upwards by Oligocene sandy marls and Lower-Middle Miocene glauconitic sandstones and marls. These strata are unconformably covered by Upper Tortonian-Messinian terrigenous and evaporitic deposits, and Plio-Pleistocene Globigerina marls, clays and calcarenites (Mascle, 1979; Di Stefano & Vitale, 1993). The Triassic-Liassic rock interval is comparable to the isochronous Trapanese-Saccense shelf deposits, while the Liassic-Lower Miocene lithofacies compares well with the age-equivalent pelagic carbonates of the Sicanian succession (Mascle, 1979; Catalano & D'Argenio, 1978). The Monte Genuardo unit forms a south-verging, strongly deformed ramp anticline that thrusts southwards over the Trapanese-Saccense Monte Magaggiaro-Pizzo Telegrafo units, with a locally overturned forelimb (Figure 21, back cover Figure, Pl. 1c, d). Following the Tortonian original emplacement, minor thrusts with a strike-slip component have dissected the whole lithologic succession. The geoseismic sections shown here crossing the Monte Genuardo unit (Figure 22), generally confirm the surface geology and highlight the occurrence of a slope sedimentation in the Genuardo main rock body.

Stop 4.1:

Giuliana western slope
Main Purpose:

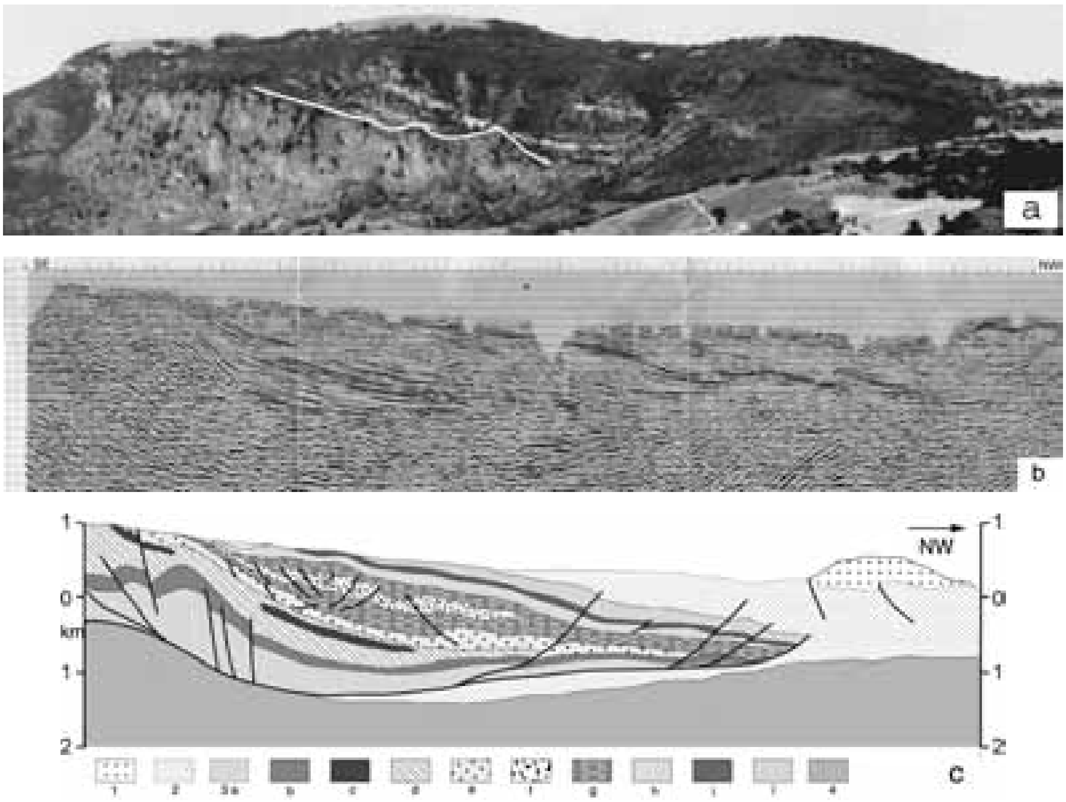


Figure 22 - (a) Panoramic view of the eastern side of Monte Genuardo. (b) NW-SE seismic section (X in Figure 21) crossing the northwestern sector (see map). (c) Interpretation of (b), showing the stratigraphic setting of Monte Genuardo unit and its relationships with the underlying Trapanese-Saccense units. 1. Evaporites, Trubi and calcarenites; 2. terrigenous deposits; 3. Monte Genuardo unit (a. carbonate platform; b. oolitic calcarenites; c. Basaltic intercalation within d. jurassic cherty limestones; e. calcilutites and marls; f. megabreccia intercalations within g. Scaglia calcilutites; h. sandy marls; i. glauconitic sandstones; l. marly clays; 4. Trapanese-Saccense units and its cover. For a detailed chronology see Figure 21.

To show in a seismic scale panoramic view the eastern side of the Monte Genuardo stratigraphic features to compare the field outcrop with buried stratigraphy as illustrated in Figure 22.

Seismics image a lower part, 0.2 to 0.5 s/twt thick, correlational to the platform carbonates, downthrown by N-dipping extensional faults. The succession lying above carbonate platform rocks shows large variations in thickness and shape, confirming the characteristics of slope-to-basin deposits revealed by field analysis.

The rock body, interpreted as having been deposited during the Upper Jurassic-Eocene interval, appears locally detached from the substrate. On the whole, the Monte Genuardo unit appears to thrust southwards, overlying the Monte Magaggiaro-Pizzo Telegrafo ridge. The body thins out northwards, beneath Messinian-Pleistocene rocks, and directly overlies the Trapanese-Saccense substrate.

Stop 4.2:
S. Maria del Bosco area.
Main Purpose:
To visit a Jurassic pelagic succession with basaltic intercalations.

We will cross the northern tip of Mt. Genuardo in order to observe along the road a succession of radiolarian-bearing calcilutites and marls, Toarcian-Oxfordian in age (known as Calcari di S.Maria del Bosco Fm.), with intercalations of basaltic rocks consisting of pillow lavas (Figure 23).

Figure 23 - Pillow lavas near S. Maria del Bosco.

These basalts are commonly associated with dykes and intercalations or lateral changes, into tephra to hyaloclastic sequences. The western Sicilian Jurassic magmatism is typical of continental “within-plate” areas subjected to extension and lithospheric thinning. This was related to a rift phase that affected the marginal parts of the African continent in the Mesozoic.

Stop 4.3:
Monte Gurgo.
Main Purpose:
To describe the deep structural setting of Mt. Genuardo, as shown by the available geoseismic sections. Some deep seismic sections crossing the Mt. Gurgo area, will depict the relationships between the Jurassic-Eocene carbonate succession and the clastic-terrigenous Oligocene-Miocene cover in the western sector of Monte Genuardo. The structural setting inferred from outcropping and deep seismic data is quite different from that previously described in literature.

Stop 4.4:
The carbonate Megabreccias at Adranone (a residual wall of a Vith century fortress town)
Main purpose:
To show the characteristics of the carbonatic Megabreccias bodies intercalated in the Maastrichtian pelagic mudstone and wackestone (“Scaglia”-type limestones).

The Mt. Genuardo stratigraphic succession encompasses the largest and thickest tabular body of Cretaceous Megabreccias outcropping in Sicily. The Megabreccias appear as massive- to roughly-bedded bodies of carbonatic rock fragments (mostly of carbonate platform) of various size, more or less packed, according to the distribution of the basinal micritic mud and sands forming the matrix (Figure 24).

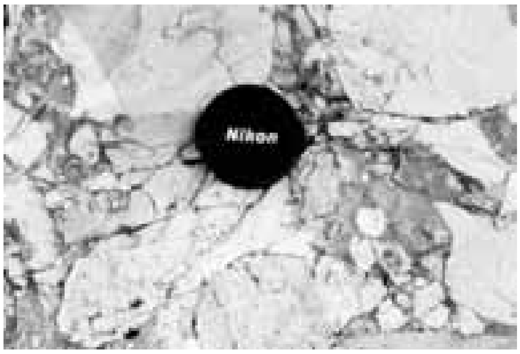


Figure 24 - A detail of the texture of the megabreccia body.

The individual megabreccia bodies display a more or less tongue or wedge -shaped geometry. When seen in longitudinal section, these bodies show a maximum thickness towards the source area. When seen in cross section they appear as channel fillings.

These bodies, formed in a basinal setting, are widespread all over western Sicily, and have been found also in the Hyblean area and in the Peloritani Mts. The Megabreccias event was probably related to both a sea level fall and a tectonic episode. The latter could be framed in the Inversion Tectonics known to be widespread in Europe during the Late Cretaceous.

Conclusive remarks

The Genuardo Unit, on the whole, is structurally (geometrically) sandwiched between the Trapanese-Saccense carbonate platform and the Sicanian basinal carbonate units. The original emplacement of the Genuardo deformed rock body took place during the Tortonian (as with the Sicanian Units). Later deformation during the Pliocene caused the present day tectonic setting.

The palinspastic restoration of the Genuardo structural setting, suggests that its sedimentary domain was located at the margin of the Trapanese-Saccense, and that it was the SW-ward termination of the Sicanian basin.

DAY 2

The structure of westernmost Sicily.

M. Agate, B. Abate, R. Catalano, A. Sulli, L. Basilone and S. Merlini.

Main Purpose

To observe the westernmost Sicily thust pile and its Neogenic syntectonic basins.

Field itinerary

Following an ideal South-North crosssection, the Second Day will be devoted to the progressively deformed northwards crustal transect located in westernmost Sicily. We will follow a south-to-north route (Figure 21). Leaving the Belice mouth we will reach the Mt. Magaggiaro area, to look at the characteristics of the southern tip of the westernmost Sicily, where syntectonic Miocene-Early Pleistocene basins occur, using borehole constrained geoseismic sections, correlating subsurface and land geology (Stop 5). Moving northwards, we will cross two Miocene-Pliocene clastic successions settled in the Western Belice and Vita basins (Figure 25). We will

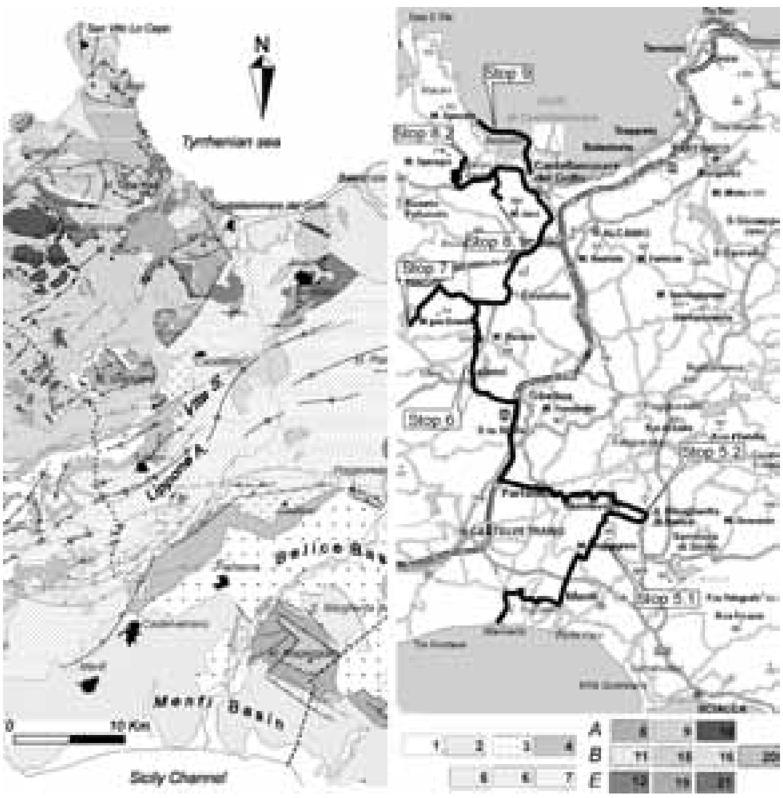


Figure 25 - Geological (left) and road map right with the 2°day itinerary. 1) Recent; 2) Clastic carbonates, Pleistocene-Pliocene; 3) Marls and calcarenites, Pliocene; 4) Trubi, e. Pliocene; 5) Evaporites, Messinian; 6) Reef carbonates and Terravecchia Fm.; l. Messinian-U. Tortonian. A) Pre-Panormide Units: 8) Shelf Lms., l. Miocene; 9) Shales and sandstones, l. Miocene - Oligocene; 10) Marly calcilutites, Eocene - Cretaceous. B) Panormide Units: 11) Glauconitic calcarenites, e. Miocene; 15) Shelf to slope Lms., Cretaceous - Oligocene; 16) Pelagic Lms., Jurassic - e. Cretaceous; 20) Platform Lms., Triassic - Lias. E) Trapanese Units: 12) Sandy marls, l. Miocene; 19) Pelagic platform deposits, Oligocene - Jurassic; 21) Platform carbonates and dolomites, Lias - Trias.

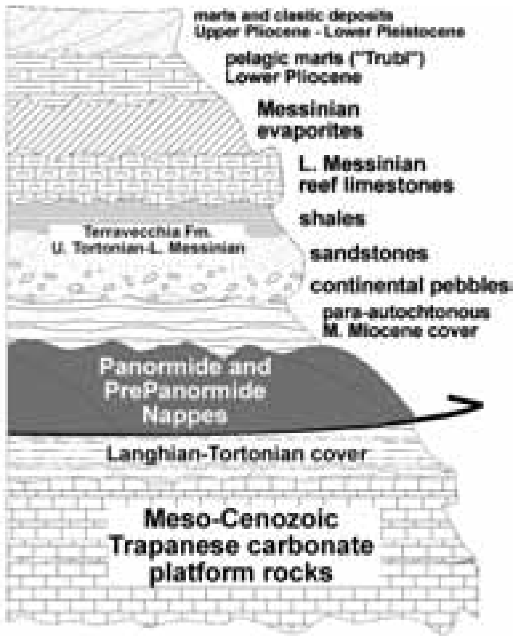


Figure 26a - Columnar section of the deposits crossed in westernmost Sicily.

observe Messinian coral reef in detail, and evaporites (Stop 6, Monte Rose), and along the road, the Upper Miocene Molasse. Cross-cutting the WSW-ENE alternating antiform-synform main structure, we will reach the outcropping mesocenozoic carbonate ramps of Montagna Grande. The stratigraphic features of the Trapanese succession in westernmost Sicily and the structural pattern of the buried carbonate wedge will be shown (Stop 7). Shortening and complexity of the south vergent chain increase northwards along the Tyrrhenian coast. Stop 8 will depict, both in a panoramic view and in detail, the Panormide thrust over the Trapanese carbonate platform. Stop 9 will complete the illustration of the above mentioned structural setting, while sailing by boat along the eastern coast of the S. Vito Peninsula where "Lo Zingaro", the famous natural park, is to be seen.

Geological Setting

The tectonic units incorporated in the westernmost Sicilian Chain display mostly carbonate platform Triassic-Liassic rocks, followed upwards by pelagic Jurassic-Lower Oligocene limestones capped by Oligo-Miocene clastic-carbonatic deposits. A hundred -meters thick pile of clastic, organogenous and evaporitic synorogenic deposits overlay all the before mentioned tectonic units. These rocks are latest Miocene-Pliocene in age and appear less deformed with respect to the substrate (Figure 26a).

When westernmost Sicily is crossed along a S to N transect, it shows a) a southern sector (e.g. Mt. Magaggiaro area, Figure 27), with the characteristics of a deformed foreland and b) a northern sector, formed by a pile of tectonic units reaching a thickness of about ten km (Pl. 1ab).

The thrust edifice displays (Catalano et alii, 2002, and references therein) from northwest to southeast some Trapanese-Saccense carbonate platform structural ramps which trend ENE, separated by two ENE-trending deep depressions filled by deformed Upper Miocene - Lower Pleistocene rocks (Pl. 1ab). The southernmost ramp corresponds to the large Lippone

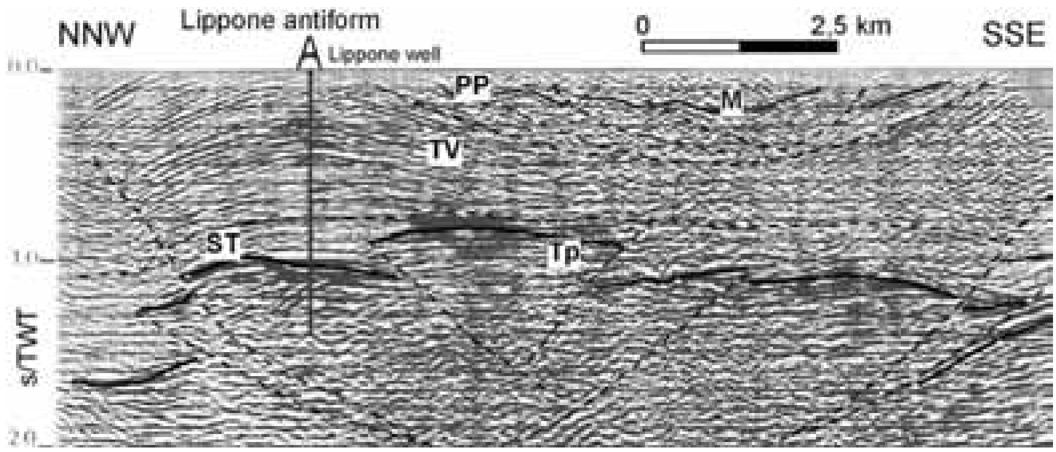


Figure 26b - The seismic section illustrates the tectonics of the Lippone Antiform; legend: PP: Pliocene deposits, M: Messinian, TV: Terravecchia Fm clastics, ST: Langhian-lower Tortonian marls, Tp: top of the Trapanese Carbonate Platform Unit.

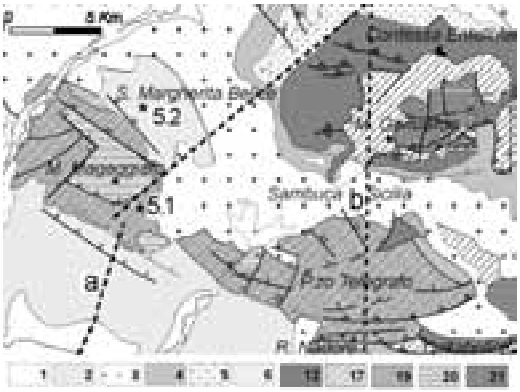


Figure 27 - Structural map of Monte Magaggiaro-Pizzo Telegrafo and traces of geoseismic sections. Same legend as in Figure 25.

Antiform, where a gas reservoir occurs (Figure 26b). The foreland-verging thrust planes are accompanied both in the geometrically highest and lowest structural units, by back-thrusting structures. The lower boundary of the carbonate platform tectonic wedge reaches a depth of approximately 8-9 km down to the basement. In the northernmost sector (the S. Vito Peninsula), the carbonate Panormide units are seen to thrust over the Trapanese units (Abate et alii, 1993). The latter, south- and westward, are buried under the pre-Panormide nappes that, east- and southeastward, thin out. The pre-Panormide tectonic bodies appear, in turn, deformed by more recent tectonics (Plio-Pleistocene), that caused inversion of the earlier tectonic structures.

Stop 5:

Monte Magaggiaro-Pizzo Telegrafo Units and their relationships with the Plio-Pleistocene thrust top basins.

A. Sulli, R. Catalano, G. Avellone

Main purpose:

To infer the present-day structural relationships between the Monte Genuardo structural Unit and the Pizzo Telegrafo-Mt. Magaggiaro ridge.

As mentioned before, a large ridge of carbonate platform rocks (Monte Magaggiaro and Pizzo Telegrafo) outcrops in the visited area (Figure 27).

Surface geology points out that the above mentioned units underthrust the Genuardo ramp anticline and its lateral, buried eastwards, continuation (Figs. 21, 28, Pl 1c, e). These bodies are southward-verging embricates, dissected by northeastward directed back thrusts, unconformably overlain by tectonically-involved Upper Miocene-Pleistocene deposits (Figure 25).

The Monte Magaggiaro succession consists of: uppermost Triassic - Lower Liassic platform carbonates (Sciacca and Inici Fm., known for more than 2500 m in some exploration wells); Middle Jurassic-Eocene pelagic platform deposits; uppermost Oligocene - lowermost Miocene shelf limestones, with algae, benthic foraminifera and molluscs overlain by Serravallian-Tortonian grey marls (Di Stefano and Vitale, 1993).

The Monte Magaggiaro ridge separates two large Neogene-Early Pleistocene depressions: the Belice and Menfi Basins, filled respectively by about 700 m and 1500 m thick Messinian evaporites, Lower Pliocene sandy shales and chalks, and Middle Pliocene-Lower Pleistocene mixed siliciclastic-carbonate shelf deposits (Vitale, 1995).

The Belice basin develops to the north of the NW-SE trending Magaggiaro major ramp anticline. The Menfi basin, mainly filled by Pleistocene deposits and developed on a carbonate platform south-vergent ramp (Figure 28), extends along the southern coast of Sicily.

Stop 5.1:

M. Magaggiaro quarry.

Main purpose:

To illustrate the Meso-Cenozoic Trapanese-Saccense succession and its relationships with the Plio-

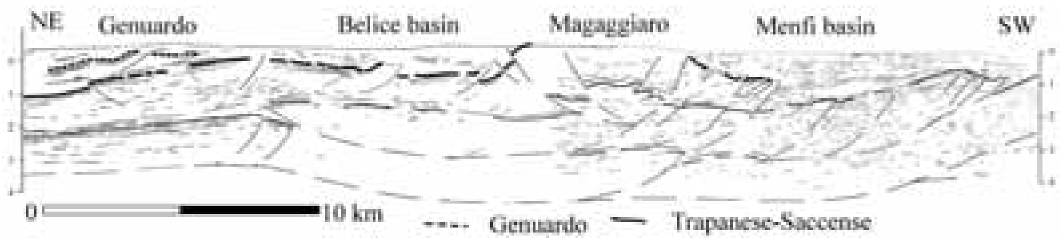


Figure 28 - Geoseismic interpretation of the section (a) in Figure 27, showing the structural setting of the Monte Magaggiaro antiformal stack thrusting over the Belice and Menfi basins.

Pleistocene syntectonic basins.

Monte Magaggiaro appears as a nearly horizontal plateau, whose Liassic carbonate platform can only be seen in some quarries.

The quarry wall shows some stratigraphic characteristics of the already mentioned carbonate platform succession. The Monte Magaggiaro structure is an antiformal stack, which has separated the Belice and the Menfi Basins since the Late Messinian. The structure is bounded north- and southwards by high angle reverse faults that appear to have been active until Late Pliocene-Early Pleistocene, as it has locally overthrust deposits of this age. At depth, growth structures show evidence of the tectonic involvement of the Pliocene-Lower Pleistocene clastics during the late imbrication (Pl. 1e).

Stop 5.2:

Santa Margherita Belice.

Main purpose:

To infer the structural relationships between the M. Genuardo and the Pizzo Telegrafo Units.

From Santa Margherita Belice village we will enjoy a panoramic view of the structural relationships

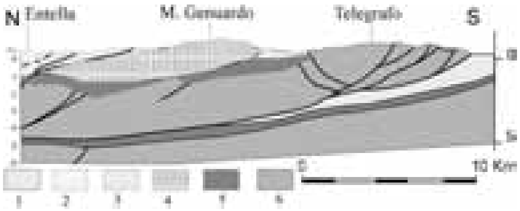


Figure 29 - Geoseismic section (b in Figure 27), showing the relationships between Monte Genuardo and Pizzo Telegrafo units. 1. Plio-Pleistocene deposits; 2. U. Miocene terrigenous and evaporitic deposits; 3. M. Miocene terrigenous cover of 4. Monte Genuardo carbonate succession; 5. M.-U. Miocene cover of 6. Trapanese-Saccense units.

between the Monte Genuardo ramp anticline and the underlying Pizzo Telegrafo carbonate platform ramp. The available geoseismic sections (Figure 29 Pl 1, c, d) allow for the inference of the subsurface continuation of the Pizzo Telegrafo carbonate body and the geometry of its emplacement .

Stop 6:

Crossing the Neogene syntectonic cover.

The Monte Rose (Salemi) Messinian reef.

M. Agate, L. Basilone and R. Catalano.

Main Purpose:

To infer, by stratigraphic relationships and

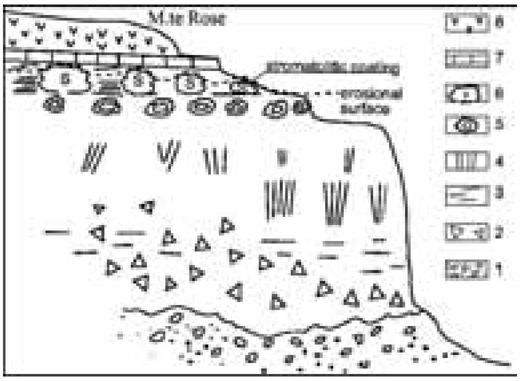


Figure 30 - Columnar section at M.te Rose (Salemi). Symbols explained in the text (after Catalano, 1979).

sedimentological features, the paleoenvironmental characters of the Porites bearing reefly limestones.

At Monte Rose near Salemi, Porites reef limestones and their slope counterpart unconformably overlie the sandy levels and pebbles of the Upper Tortonian - Lower Messinian Molasse (Terravecchia Fm, (1) in Figure 30). The visited succession shows from the bottom (Figure 33): (2) Porites breccias alternating with carbonatic silt and sands (20-30 m); (3) dish-like Porites; (4) long Porites sticks more than 1m high (20 m;); (5) red-algae calcarenite and rhodoliths (algal balls; 50-80 cm; (6) Siderastraea-Porites mound (head colonies); (7) mollusk-bearing wackestone; (8) gypsum.

Environmental restoration suggests that these coral build-ups are referable to a back-reef lagoon where little patch reefs developed.

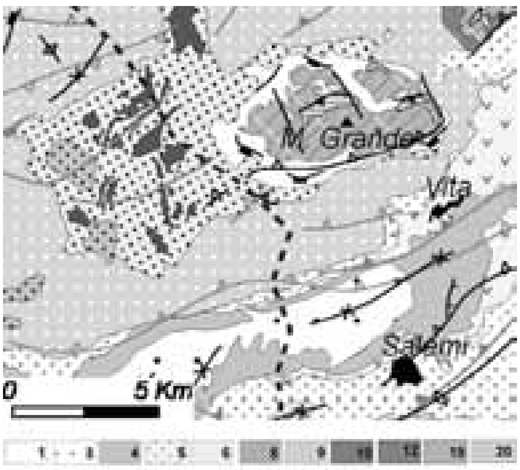


Figure 31 - A) Structural map of Montagna Grande area. The trace of seismic sections of Figure 33 is also shown.

Stop 7:
The deep structural setting of the Montagna Grande ramp anticline
R. Catalano, A. Sulli and S. Merlini

When seen in outcrop, Montagna Grande is a structural high of carbonatic Meso-Cenozoic rocks (Figure 31). The lower portion of the succession is made up of more than 500 meters of peritidal platform lms. (Inici Fm, Lias), onlapped by condensed nodular pelagic lms. (Rosso Ammonitico, Bathonian-Tithonian –Santantonio ed., 2002). This contact is marked by a regional unconformity, capped by a thick crust of Fe-Mn oxides. The Montagna Grande appears surrounded WNW by Cretaceous - Lower Miocene rocks pertaining to the Pre-Panormide Nappe and southeastward by the Tortonian - Pliocene succession forming the northern flank of the Vita Synform.

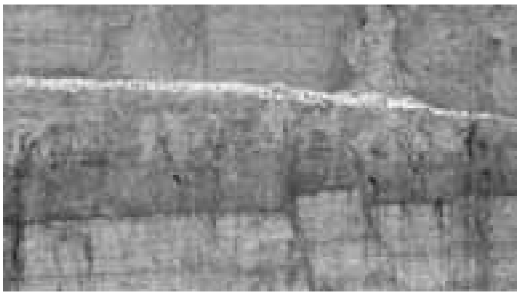


Figure 32 - General view of Poggio Roccione quarry front. White neritic limestones of Inici Fm. underlie Rosso Ammonitico (R.A.) pelagic deposits. Syndepositional faults offset the basal portion of R.A.

We will be looking at the lower part of the Trapanese succession, focusing on the Dogger-Lias boundary (Figure 32). Special attention will be paid to the previously-described features, which correspond well to the deep structure imaged by some geoseismic sections crossing the area adjacent to the Montagna Grande antiform (Figs. 31, 32).

Stop 7.1:
Montagna Grande western slope: thrust envelopment of Trapanese units over the already deformed pre-Panormide nappes.

A deep seismic section, NNW-SSE trending, crosses the area a few hundred meters westwards from Mt. Grande (Figure 33). This profile shows internal imbrication and the development of the structure along a fault plane which superimposes two Trapanese carbonatic bodies. This imbrication post-dates the emplacement of the geometrically overlying Pre-Panormide nappes, (as can be seen in Plate 1, a, b), that display the later thrusting of the Trapanese Units over the Pre-Panormide nappes.

Stop 8:
The Northern sector of the Chain (S. Vito Peninsula): the Panormide Thrust.
B. Abate, M. Agate, C. Di Maggio and R. Catalano
Main Purpose:

To observe field evidence which supports the thrusting of the Panormide carbonate platform units over the Trapanese ones.

In the S. Vito Peninsula and Inici Mount, two stacked carbonatic massifs, characterized by different sedimentary successions, crop out (Figure 34 and Abate et alii, 1993). The geometrically upper unit is made up of Mesozoic-Paleogene calcareous rocks pertaining to the Panormide Domain (Figure 35). The lower unit (M. Inici) consists of Mesozoic-Paleogene calcareous rocks pertaining to the Trapanese paleodomain. Cretaceous-Miocene successions of pelagites, bioclastic and terrigenous rocks, derived

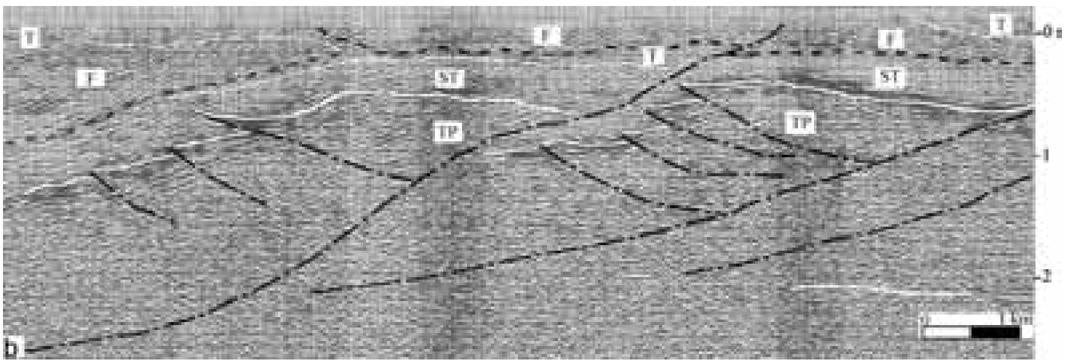


Figure 33 - Seismic profile showing the structure of the buried southwestwards sector of M. Grande antiform.

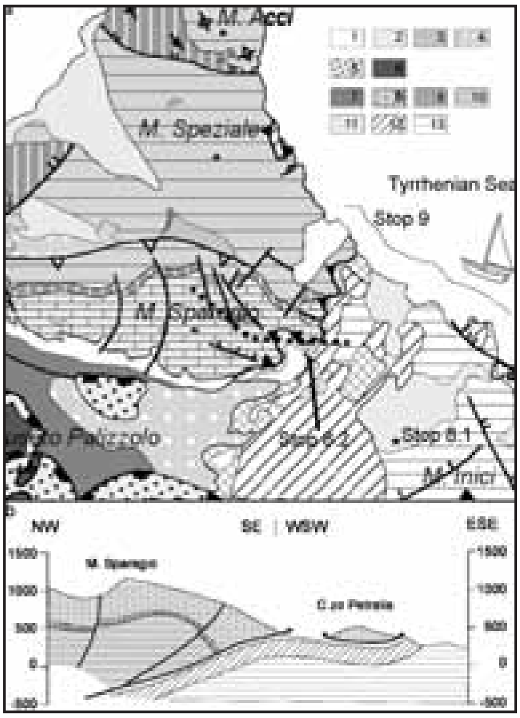


Figure 34 - Structural map of the southeastern corner of S. Vito peninsula (top) and Geological cross-section showing the Panormide Units overthrusting the Trapanese Units. Legend as Figure25

from Pre-Panormide Domain, overthrust both Panormide and Trapanese terrains.

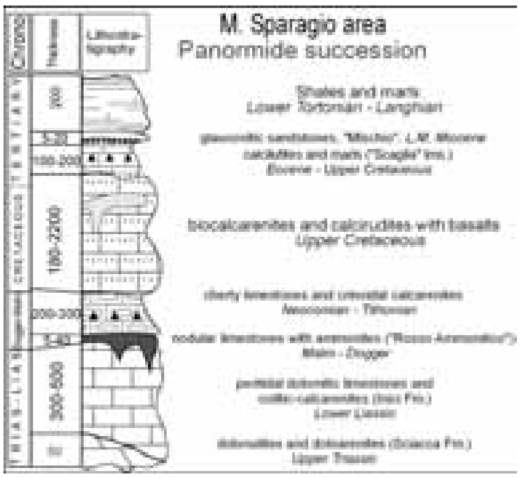


Figure 35 - Stratigraphic column of the Panormide carbonate platform succession.

Figure 36 - Southeastern slope of M. Sparagio (Visicari). Intensely fractured Panormide Cretaceous limestones (left) above Serravallian shaly cover of the Trapanese Units.

Stop 8.1:

Northern slope of M. Inici

From this region we can observe the tectonic overriding of the Panormide Units above the Trapanese ones. This tectonic contact shows a westward dipping flat thrust plane. In the hanging wall, the Panormide rocks are involved in a South-West verging ramp anticline (Figure 34).

Stop 8.2:

Visicari

Along the south-eastern slope of Mt. Sparagio (Castello di Baida, Visicari) the Panormide rocks overthrust the Serravallian-Early Tortonian cover of the Trapanese Units (Figure 36).

Stop 9:

Sailing across the SW sector of the Gulf of Castellammare

Main purpose:

To show field relations along the steep side of the S. Vito Peninsula from the sea.

Leaving the Castellammare del Golfo harbour, we will sail along the western termination of the Gulf.

The eastern steep side of the S. Vito Peninsula behaves as a natural cross section (Figure 37), showing the relationship between the Panormide and the underlying Trapanese rock bodies.

While sailing through the adjacent Gulf of Castellammare, shallow and deep submarine structures will be illustrated by means of seismic lines and multibeam images.

Conclusive Remarks

Integrated field data and geoseismic sections crossing westernmost Sicily show a southern sector representing the deformed foreland, and a northern region, with major shortening, formed by a thick thrust pile.
In the thrust pile, the higher tectonic element is a complex nappe structure which originated from the Early Tortonian deformation of the pre-Panormide and Panormide domains. These units rest above a carbonate platform imbricate fan, with ramp and flat geometry, resulting from the Late Miocene - Early Pleistocene deep-seated deformation of the Trapanese and Saccense carbonate platform substrate.
Underthrusting of the Trapanese-Saccense units also induced late stage refolding and further shortening in the previously emplaced pre-Panormide nappe, and fault propagation folds in the Neogene cover.

DAY 3

Madonie Mts. and Caltanissetta basin
R. Catalano, M. Mancuso, A. Contino, C. Di Maggio, M. Agate, A. Sulli, G. Avellone and L. Basilone.

Main purpose

To illustrate and compare the central eastern Sicilian sector of the chain-foredeep system which crops out from the Caltanissetta basin to the Madonie Mts.

Field itinerary

Palermo, Enna, Capodarso, Tre Monzelli, Petralia, Piano Battaglia (Madonie Mts.), Collesano, Palermo.

Having left Palermo, we will cross northern central Sicily along the motorway, to reach the Caltanissetta basin area (Figure 38) where evaporites and clastics prevail in outcrop. Crosscutting the northern side of a backthrusting structure composed by Miocene-Pliocene rocks, we will visit the slightly deformed Late Pliocene clastic carbonatic filling of the Capodarso basin. After visiting this well-preserved coastal system, we will crosscut the large antiform located to the south of the Madonie Mts. Along the road, from the car, we will be able to see its core, which is made of the Numidian Flysch and Sicilide variegated clay thrust-nappes that are unconformably covered by Neogene deposits. This large Neogene antiform hides a complex carbonate thrust wedge located at depth.

Having reached Petralia village, we will start to climb up the Madonie Mts. from their southern slope to visit progressively the uppermost Oligocene-Lower Miocene Numidian Flysch, encompassing large bodies of calcareous Megabreccias (Monte San Salvatore) directly observable at Portella di Mandarini (Stop 11.1); the Panormide Triassic platform and Jurassic reef limestones (Stops 11.2, 11.3); and the Imerese basin Triassic-Jurassic thick succession of the Nipitalva valley (Stop 11.4).
This stratigraphic background will introduce the ambitious purpose of the third day: to scan the structural setting of this important sector of the Sicilian-Maghrebian chain at Portella Colla (Stop 12). Two contrasting hypotheses on the structural evolution of the present day Madonie Mts. tectonic

Figure 37 - Western side of the S. Vito Peninsula.

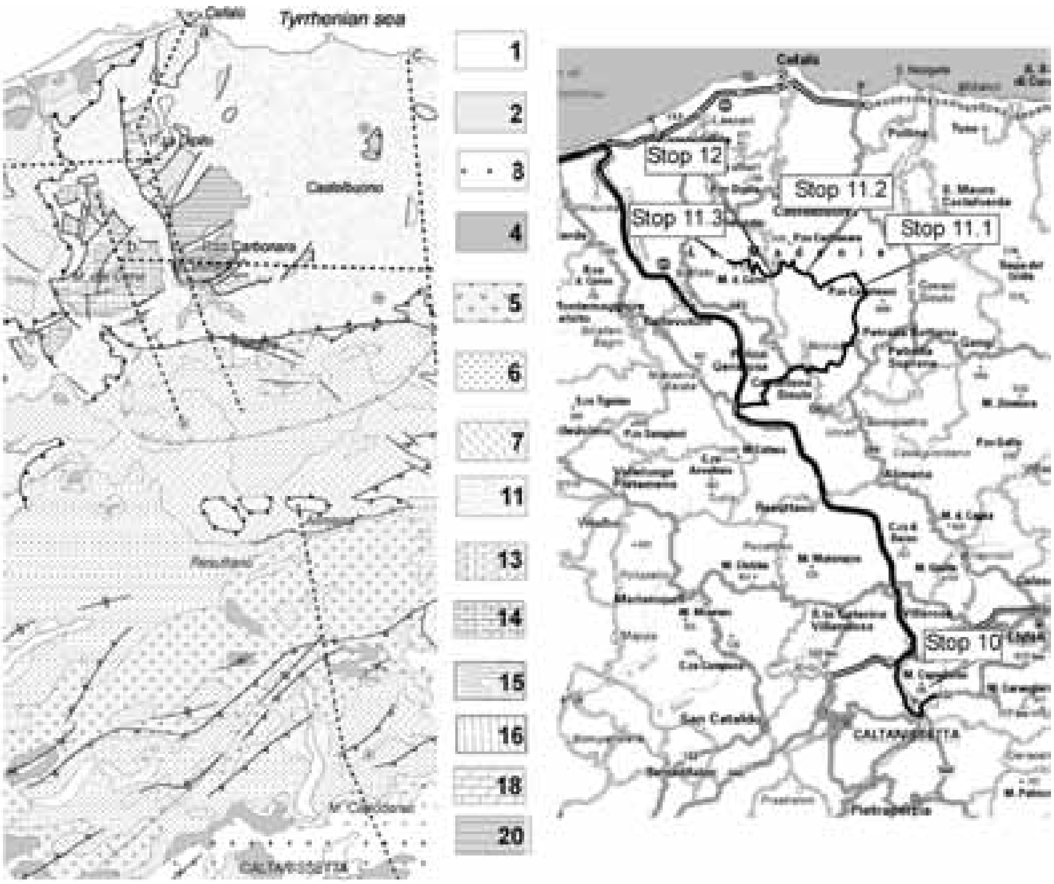


Fig 38 - (a) Regional geologic map. Dashed lines indicate the main geological and geoseismic sections crossing the visited area; (b) road map.

edifice will be presented and discussed, with the help of some geoseismic sections crossing the adjacent region and its marine offshore.

With still in mind the splendid and unforgettable scenery of one of the most glorious regions in the world, you will reach, (already missing Sicily we hope!), Palermo to go back home.

Geological setting

The surface carbonate structures, previously described along the Palermo-Sciacca Bridge in Western Sicily do not outcrop in Eastern Sicily (except in the Madonie Mts.), being buried below thousand of meters of internal Numidian Flysch - Sicilide Units and Neogene-Early Pleistocene basin deposits (back cover Figure).A case history of these basins is illustrated in the Mt. Capodarso area.

While the main surface geological setting is known from previously-collected data, there is poorly-related knowledge of the subsurface structure down to the basement. Recently-done geophysics and borehole-constrained geoseismic sections directly illustrate the main tectonic grain of the Eastern Sicily. It displays from the top: a), internal Units (Sicilide and decoupled Numidian Flysch thrusts) that overlie b), the Mesozoic basinal carbonates (Imerese and Sicanian) units, which in turn thrust above c), deformed carbonate platform rock bodies (Panormide, Trapanese and deformed Hyblean units) that together override d), the Hyblean foreland (Figure 38, back cover Figure). Foredeep satellite basins progressively filled by Upper Tortonian - Lower Pleistocene terrigenous, evaporitic and clastic deposits overlay the thrust pile as it is shown by geoseismic section crossing the area (Pl. 2 m, n).

Stop 10:

The thrust-top basins of the Central Sicily. The Capodarso Mount section.

M. Mancuso, R. Catalano, M. Agate

Main purpose:

To focus on the Pliocene sedimentary facies and its depositional architecture of a thrust-top basin, on the Central Eastern Sicily thrust belt.

Introduction

Plio-Pleistocene syntectonic basins, outcropping in Central Sicily, provide several examples of coarse-grained, bioclastic coastal lithosomes, sandwiched in offshore deposits, which record changes of relative sea level and evolution of tectonic structures (Butler and Grasso, 1993; Catalano et al, 1993; Vitale, 1998; Catalano et al, 1998 and references therein).

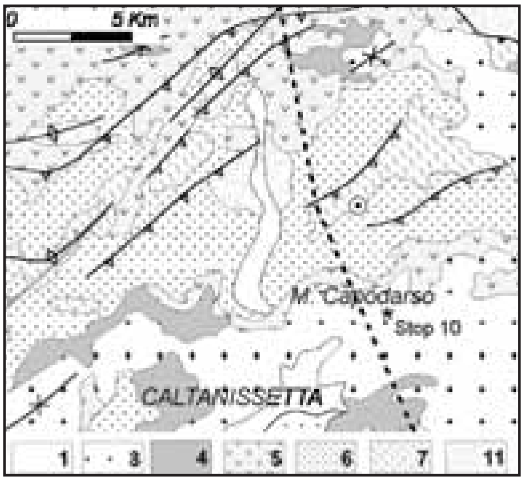


Figure 39 - Geological map of the Capodarso Basin area. Same legend as in Figure 38.

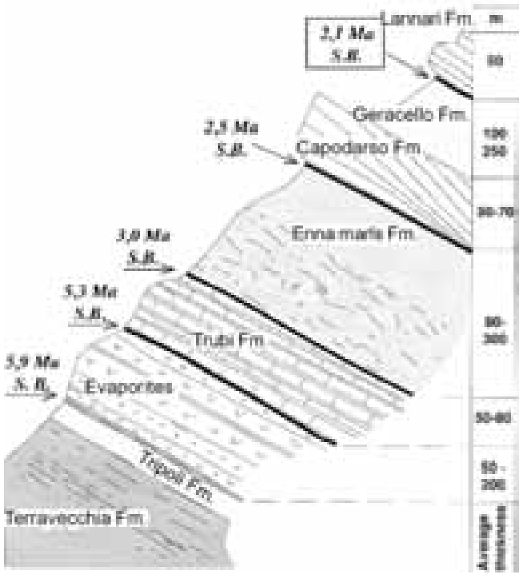


Figure 40 - Lithostratigraphic succession of the Capodarso section (after Catalano et alii, 1993).

The visited area lies in the so-called "Caltanissetta basin", an Upper Neogene depression filled by Plio-Pleistocene deposits (Figure 39). The structural analysis of the region has pointed out that Messinian-Early Pliocene deposits are affected by thrusts and associated folds, with a nearly exact East-West trend, while the overlying Upper Pliocene deposits are involved in a NE-SW trending fold and fault system (Vitale, 1998). Deposits younger than 2 Ma appear less deformed or unfolded. Recently, new seismic data suggest that the formation of these basins was due to the development of deep-sited thrusts with related foreland and hinterland verging structures (Catalano et alii, 1998; Bello et al., 2000).

Figure 41 - Panoramic view of the west-northwestern flank of the Capodarso Mount.

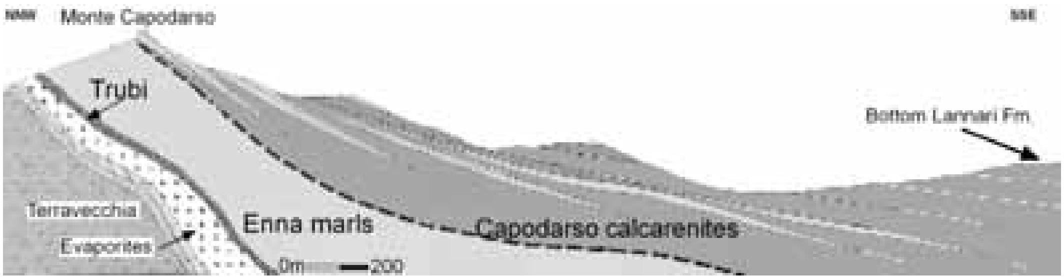


Figure 42 - NNW-SSE geological section of the Capodarso Mount (modified from Vitale, 1998).

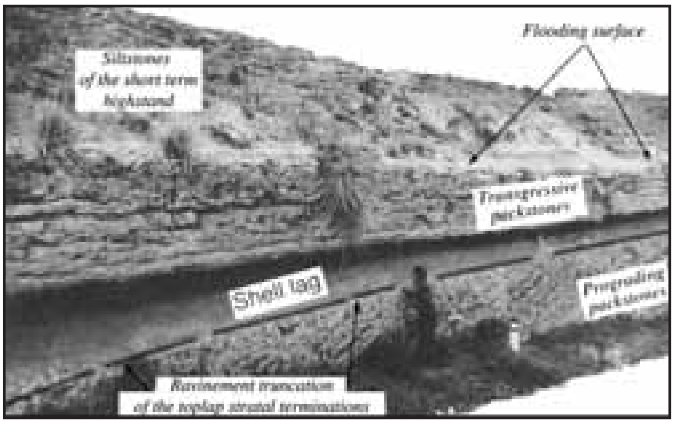


Figure 43 - Mulino del Barone. The Capodarso parasequences.

Stop 10.1:
The Middle Pliocene Capodarso sedimentary wedge.
Main purpose:
To illustrate a well-preserved coarse grained coastal wedge and fold-growth related stratal patterns, deposited between 2.5 Ma and 2.1 Ma.
In the Capodarso Mount, the observed coastal wedge (Figs. 40, 41) unconformably overlies a clastic-evaporitic substrate, consisting of terrigenous deposits of the Terravecchia Fm (Early Messinian); diatomites and shales (Tripoli Fm, Messinian); evaporites with intercalated marls (Gessoso- Solfifera Fm, Messinian); pelagic marly limestones (Trubi Fm, Lower Pliocene); and silty claystones and siltstones ("Marne di Enna" Fm, Middle Pliocene).
The "Marne di Enna" Fm is truncated by the coastal cross-bedded packstone to grainstone bodies, the "Calcareniti di Capodarso" (interpreted as a depositional sequence). The lowermost sandy interval of the Capodarso Fm is characterized by a prominent progradational pattern. The Capodarso deposits laterally and upward pass into the shelfal mudstone interval (Geracello Fm), which is in turn followed by offshore siltstones and sandy mudstones of the Lànnari Fm (Figure 40).
The Capodarso Sequence fills a 10 km wide NE-SW trending syncline (Figure 42), and represents a "lowstand prograding complex", stacked in parasequences, which developed after the 2.5 Ma relative sea–level fall.
The starting point of the individual sandy portion of each parasequence clearly migrated along the syncline flank, generating a slightly divergent fan, with a decrease of the parasequences dips (Figs. 41). The hinge of the major anticline could have been eroded since the time of deposition of the "Capodarso lowstand prograding complex" (LPC, Vitale 1998).
Some features highlight the tectonic control on the deposition of the Middle Pliocene successions, as, for example, the marked stratigraphic expansions are expressed by divergent stratal patterns.

Stop 10.2:
Mulino del Barone
Main purpose:
To observe sigmoid-oblique bedding patterns and internal surfaces in the "Calcareniti di Capodarso".
The second stop will take place at the Mulino del Barone, along the slope of Monte Salsello, where a set of parasequences of the Capodarso LPC will be observed (Figure 43). These large-scale cross-stratified lithosomes, about 20m thick, show a sigmoidal configuration. The surface of the foresets is erosive because of a rapid rise of the relative sea level. Shoreface retreat creates a ravinement surface, covered by a residual shell lag (Figure 43).
Trangressive subhorizontal beds onlap onto the top of the shell lag, forming a thin backstepping packstone thickening-upward wedge. Highstand siltstones,

deposited above the flooding surface, represent the last term of the units and record the gradual deepening of the depositional environment.

Stop 11:

Stratigraphy of the Madonie Mountains.

B. Abate, R. Catalano, A. Contino, L. Basilone and M. Agate.

Main purpose:

To decribe some peculiar stratigraphic characters of the carbonate rock bodies, to serve as an introduction to the debated structural setting of the Madonie thrust pile.

Introduction

Some interesting stratigraphic sites will be visited with the aim of illustrating well-exposed Panormide and Imerese sedimentary successions (Figure 44).

The Imerese Succession consists of Upper Triassic to Oligocene limestones, marly limestones and siliceous rocks deposited in a deep sea environment; the Panormide Succession is made of Upper Triassic to Lower Oligocene mostly shallow water carbonates (Figure 44). Both the Panormide and Imerese successions were covered unconformably by the Upper Oligocene-Lower Miocene syntectonic Numidian Flysch.

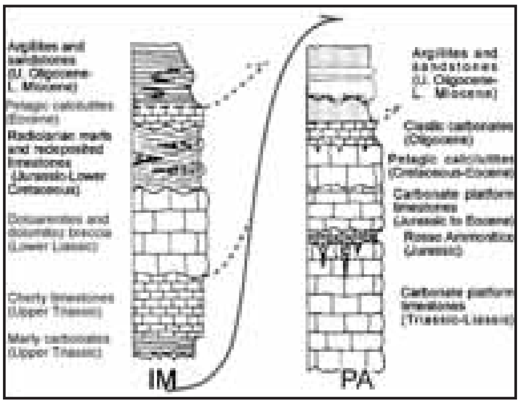


Figure 44 - Stratigraphic successions of the Imerese (IM) and Panormide (PA) units.

Stop 11.1:

Portella di Mandarini.

Main purpose:

To illustrate the carbonate Megabreccias intercalation in the terrigenous Numidian Flysch.

Introduction

The Upper Oligocene-Lower Miocene terrigenous Numidian Flysch comprises of several intercalations of megaconglomerates and megabreccias. The Numidian Flysch and interbedded megabreccias unconformably overlie a substrate formed by Upper Triassic limestones and marls, thick Liassic dolomitized carbonates, Jurassic radiolarites, and

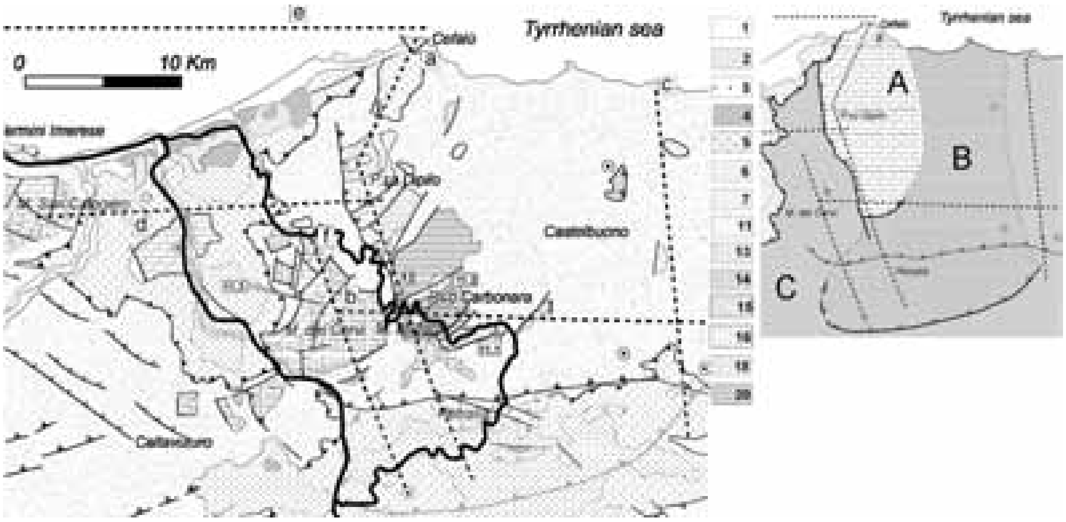


Figure 45 - Geologic map of the Madonie Mts. and adjacent areas. For legend see Figure 25. To the right, simplified sketch of the main tectonic setting. A, B and C represent respectively the Panormide Unit, the Imerese Quacella and Monte dei Cervi Unit.

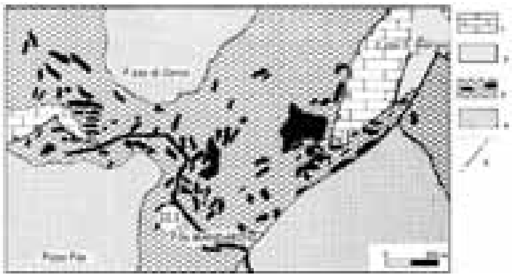


Figure 46 - Simplified geological map at Portella di Mandarini. Mesozoic dolomites (1), Cretaceous-Eocene marly lms. (2), silty clays and arenites with carbonate megabreccias (3), followed byLl. Miocene quartzarenites and silty clays (Numidian Flysch) (4) pertaining to the Quacella tectonic unit.

Figure 47 - Portella di Mandarini. Calcareous Megabreccias.

Cretaceous- Eocene reddish calcilutites. These rocks are generally believed to be deposited along the slope of the Imerese basin. At the present day, they form the Quacella tectonic Unit (Figs. 45, 46).

At Portella di Mandarini we will visit one of the best outcrops of the Flysch with Megabreccias (Figs. 46, 47) The carbonatic megabreccia bodies have a typical amygdaloid or flat lensoid shape, and appear roughly to conform with the bedding. Their thickness can reach, at places, more than 100 m. The elements, cm to dm in size, are mostly cobble to boulder, which often appear rounded. The combined effects of both the synsedimentary tectonics and eustatic fall, could have induced repeated discharge of carbonate debris, which accumulated over the slope base zone during the deposition of the shales.

Stop 11.2:

Panormide carbonate Platform at Piano Battaglia.

Main purpose:

To visit Norian Spongid reef limestones and Upper Jurassic coralgal limestone.

The field succession develops along the road (Figs. 45, 48), With the Spongid limestones at the bottom, and followed upwards by the Upper Jurassic coralgal limestones (Figs. 49, 50).

Stop 11.3:

The Imerese Triassic succession at Monte dei Cervi. Nipitalva valley.

Main purpose:

To show the basin to slope, Carnian to Lower Liassic carbonates of the Imerese domain.

Down in the Nipitalva Valley, a succession of Upper Carnian-Early Norian thin-bedded cherty calcilutites and marls can be followed (Figure 51). The cherty and fine laminated calcilutites contain radiolarians and rare pelagic pelecypods (Halobia sp). Topwards, the couplets sequence is interrupted by a thick channellized grainflow episode, characterized by a fining upward graded intercalation. Going further uphill, the clastic intercalations become more frequent; the pelagic cherty calcilutites are gradually replaced by: a) well-stratified laminated and graded doloarenites and dolomitized breccias (grains mostly come from the underlying cherty calcilutites); b) massive dolomitized breccias and laminated dolomites; and c) well-bedded calcareous breccias with large carbonate platform facies fragments (Figure 51b).

Stop 12:

Portella Colla. The debated structural setting.

R. Catalano, C. Di Maggio, A. Contino, A. Sulli, G. Avellone, L. Basilone and B. Abate.

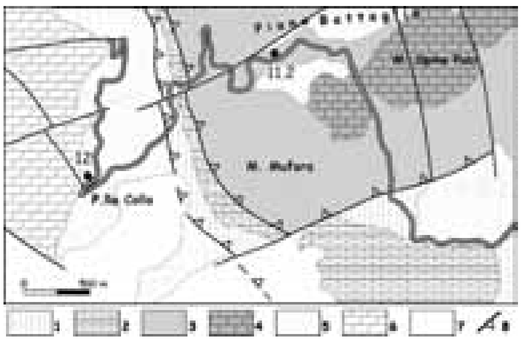


Figure 48 - Simplified geological map of the Portella Colla area. Marls and limestones (1), Mesozoic dolomites (2) (Quacella Unit). Triassic-Liassic (3) and Jurassic-Cretaceous platform carbonates (4) pertaining to the Panormide tectonic Unit. Numidian Flysch (5) and Imerese basinal carbonates (6) (Monte dei Cervi Unit). Debris (7). Mod. from Abate et alii (1982).

Figure 49 - Piano Battaglia. Norian sponge boundstone.

Main purpose:
To show the local tectonic features and propose alternative interpretations.

Introduction
A large carbonate thrust wedge, consisting of meso-cenozoic carbonate platform (Panormide), and basinal (Imerese) rock units, outcrops in the northerly located Madonie Mts. area. The more accepted tectonic interpretation describes the overriding of the Panormide carbonate platform above the basinal Imerese units, that is believed to have taken place during the Early Miocene (Ogniben 1960, Grasso et alii 1978, Abate et alii 1982, Bianchi et alii 1989, Renda et alii 1999). An alternative interpretation of the local structural setting and the relationships between Imerese and Panormide embricates is here presented.

Looking at the geological setting (Figure 45a, b), we recognize from the top: a) two first order Imerese tectonic units with their Numidian terrigenous, often detached cover, outcropping in the Monte dei Cervi sector (Mt. dei Cervi Unit, C) and SE-ward to the Panormide body (Quacella Unit, B); and b), the Panormide Unit mostly cropping out from north to south in two main culminations (Pizzo Dipilo and Pizzo Carbonara, A).

The Panormide Unit appears to thrust over on the Imerese-Quacella Unit. The thrusting, along a N-ward dipping SSE verging fault plane (Figure 45a), involves the Lower Pliocene Trubi or the Sicilide deposits that overlie the Imerese rocks.

The carbonate platform Unit plunges eastward (Figure 45) in subsurface below the Imerese Units, as seen in seismic lines and boreholes located a little farther to the east (Figure 52a).

The carbonate body is bounded to the west by the NNE-SSW Dipilo-Carbonara tectonic line (already called “Mufara-Gratteri”, Renda et alii, 1999), that abruptly juxtaposes the Monte dei Cervi Imerese-Numidian rocks with the Panormide ones (Figure 45), thus showing that the Monte dei Cervi Unit does not underthrust beneath the Panormide carbonates.

The Dipilo-Carbonara line shows at the surface the characteristics of a NE dipping, high angle reverse fault, as already pointed out by Agnesi et alii (2000); after the Early Pliocene this line caused the pushing up to the surface of the carbonate platform Unit that breached the already emplaced Imerese and Numidian Flysch units (thrust envelopment), inverting in this area the original structural order.

Some geological sections, crossing the adjacent offshore and land area (Figure 52b), and based on subsurface data from seismic profiles and boreholes, reconstruct the following regional setting: a substrate of carbonate platform ramps upon which

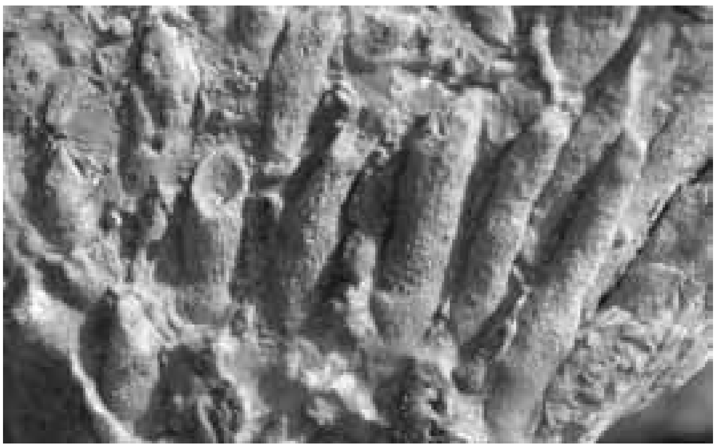


Figure 50 - Piano Battaglia.
Upper Jurassic Coralgal limestones.

Volume n° 5 - from P37 to P54

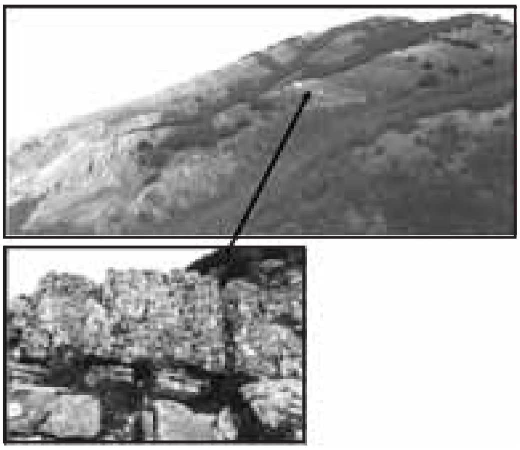


Figure 51 - Nipitalva Valley. Panoramic view of the Triassic-Lower Liassic Imerese Basin sequence.

basinal thrust sheets (Imerese Units) occur. The present day structural setting of the Madonie Mts. can be explained according to the kinematic model illustrated in Figure 5.

Conclusion

Unlike the previous studies which indicated the Panormide as primarily overthrusting the Imerese rock bodies in the thrust pile, our data point out that the present day structural setting of the Panormide, in the studied area, is a tectonic feature formed after the emplacement of the Imerese Units above the Panormide ones.

The backstripping of the Meso-Cenozoic carbonate units piled up in the area, implies a more internal (present-day northern) location of the Imerese Domain, instead of the largely-accepted internal location of the Panormide Domain. Our paleogeographic reconstruction envisages, from the Triassic, a unique carbonate platform, bordered to the (present day) north by a basinal domain that is consistent with the paleogeographic model depicted in Figs. 6, 7.

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Benedetto Abate, Mauro Agate, Giuseppe Avellone, Luca Basilone, Antonio Contino, Maria Mancuso, Fabrizio Pepe, Attilio Sulli, Giuseppe Grimaldi, Saverio Merlini (AGIP), Massimiliano Barchi (Perugia) are acknowledged for the strong support on the scientific as well as the technical side.

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September 2003.
The leader of the Field Trip
Raimondo Catalano

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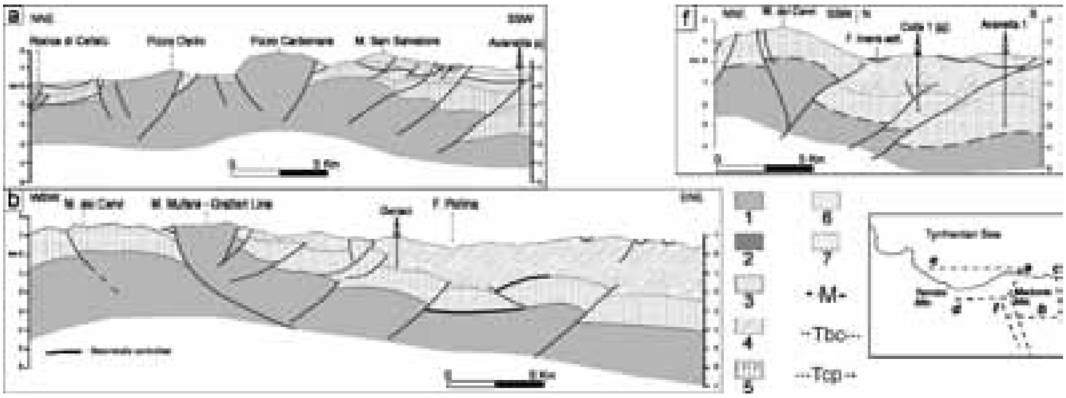

Figure 52a - Tectonic setting of the Madonie Mts. Cross sections a) and b) point out the structural relationships of the Panormide unit (Pizzo Dipilo and Pizzo Carbonara) with the adjacent rock units. Cross section f) shows a wedge of Imerese thrust sheets and their detached Numidian Flysch; depth of carbonate platform is inferred (see Figure 45).

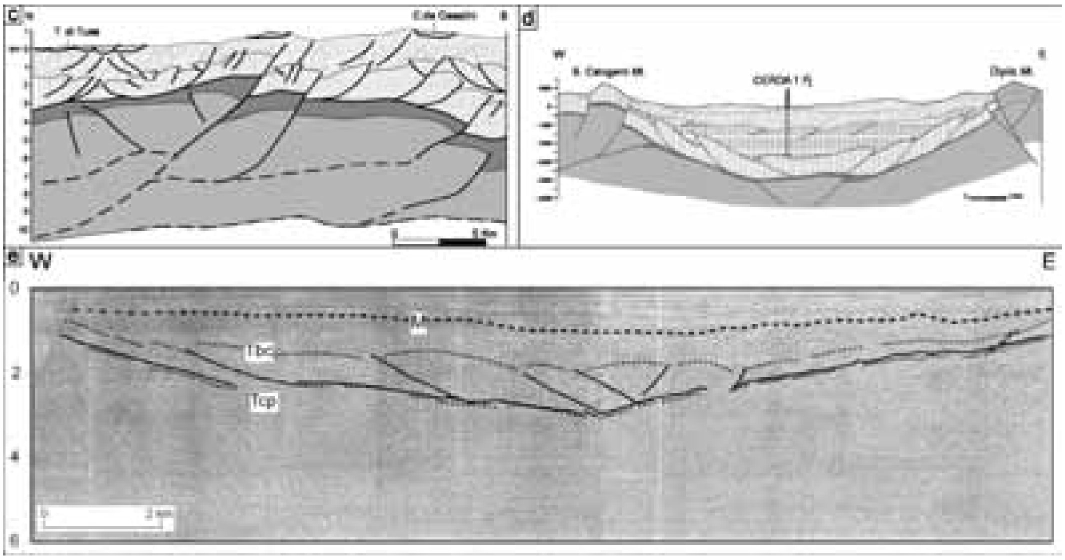

Figure 52b - Structural setting of the onshore and offshore areas adjacent to the Madonie Mts. Cross section c) is based on a seismic profile crossing the area; it shows from N to S a thick wedge of carbonate platform units that underlies the Imerese and Numidian Flysch units, crossed by boreholes. Cross section d) is a W-E structural reconstruction between Monte S. Calogero and the northern P. Dipilo culmination, based on field and borehole data; depth of carbonate platform units is inferred. The high-angle reverse line bounding westward the P. Dipilo unit is the extension of the similar structure revealed in section b (Dipilo-Carbonara line). Section e) is a simplified interpretation of the AGIP seismic section crossing the close offshore between Termini Imerese and Cefalù (see map of Figure 45). It shows a rising of the interpreted carbonate platform reflectors on both sides. In the eastern side the rising could be correlated to the Panormide rocks outcropping along the coast of Cefalù. The interpreted Imerese rock body is to be compared, on both sides, with field outcrops. The structural grain is comparable with the onshore setting of section d). Legend: 1. Meso-Cenozoic Carbonate platform units; 2. Tertiary cover of 1; 3. Meso-Cenozoic Basinal units; 4. Oligocene-Miocene terrigenous cover (Numidian Flysch); 5. Detached L. Mesozoic basinal sequences; 6. U. Mesozoic - L. Tertiary Sicilide units; 7. U. Miocene-Pleistocene deposits; M: top Messinian; Tbc: top basinal carbonate; Tcp: top carbonate platform.

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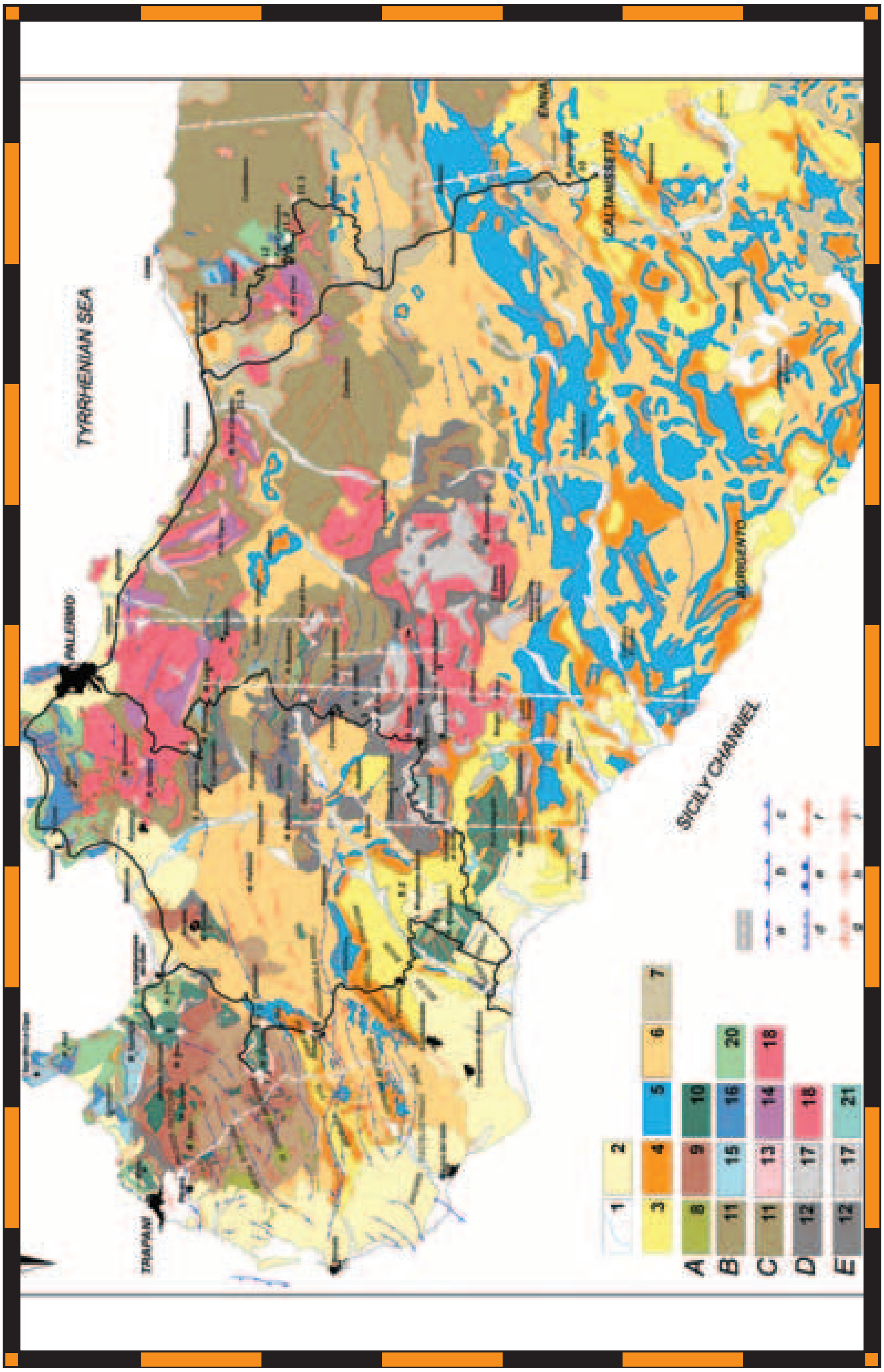
Back Cover:

Structural and stratigraphic geologic map (from Catalano & Grimaldi this book) showing road map with sites quoted in the text and traces of the geoseismic and geologic cross sections illustrated in Plates 1, 2..

Key: 1) Recent; 2) Clastic carbonates, Pleistocene-Late Pliocene; 3) Marls and calcarenites, Pliocene; 4) Marly Calcilutites (Trubi), Lower Pliocene; 5) Evaporites, Messinian; 6) Reef carbonates, Lower Messinian; Terravecchia Fm., Lower Messinian – Upper Tortonian. 7) Sicilide Units (Langhian-Lower Tortonian); A: Pre-Panormide Units: 8) Biocalcarenites and arenaceous strata (Mischio), Lower Miocene; 9) Calcarenites, shales and glauconitic quarzarenites, Oligocene; 10) Marls and pelagic calcilutites with biocalcarenites, Lower Cretaceous–Lower Oligocene. B) Panormide Units: 11) Marly arenaceous member, Langhian-Lower Tortonian, glauconitic Calcarenites, Lower Miocene; 15) Shelf to slope Calcarenites and calcilutites, Lower Cretaceous -Oligocene; 16) Calcilutites and Calcarenites, Jurassic-Lower Cretaceous; 20) Platform carbonates and dolomites, Trias-Lias. C) Imerese Units: 11) Numidian Flysch; 13) Pelagic carbonates, Upper Cretaceous-Oligocene; 14) Radiolarites with resedimented carbonates, Jurassic-Lower Cretaceous; 18) Cherty limestones, Upper Carnian-Lower Liassic; 22) Limestones and marls, Carnian; D) Sicanian Units: 12) Marly arenaceous member, Langhian-Lower Tortonian; glauconitic calcarenites, Lower Miocene; 17) Pelagic carbonates, radiolarites and resedimented carbonates, Dogger-Oligocene; 18) Cherty limestones and calcareous breccias, Upper Carnian-Lower Liassic; 22) Limestones and marls, Carnian; E) Monte Genuardo Unit : 12) Marly arenaceous member, Langhian-Lower Tortonian; 17) Pelagic platform deposits Jurassic-Oligocene; 21) Carbonate platform to slope margin deposits Triassic-Liassic; F) Trapanese-Saccense Units: 12) Marly arenaceous member, Langhian-Lower Tortonian; glauconitic calcarenites, Lower Miocene; 19) Pelagic platform deposits, Jurassic-Oligocene; 20) Platform carbonates and dolomites, Trias-Lias. a, b, c) buried thrust fronts; d) Pre-Panormide Nappe Fronts; e) leading edge of the Sicanian units; f, g) thrust fronts in outcrop; h, i) Fold axes; l) extensional faults; m) reverse faults; n) strike-slip faults.

FIELD TRIP MAP



Edited by APAT