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Geological Map of the Rocca Busambra-Corleone region (western Sicily, Italy): explanatory notes

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ABSTRACT

The geology of the Rocca Busambra-Corleone region, in central-western Sicily, is relevant to the understanding of the central sector of the Maghrebian-Sicilian fold-and-thrust belt.

In the investigated area Mesozoic shallow- and deep-water carbonate deposits pertaining respectively to the Trapanese and the Sicanian successions, and a thick Oligo-Miocene numidian flysch body, crop out. Minor outcrops of Cretaceous-Palaeogene Sicilide complex and syn-orogenic deposits of the Late Serravallian-Early Messinian Castellana Sicula and Terravecchia formations are also present.

A structural analysis reveals complex tectonic relationships between the Trapanese carbonate platform tectonic unit (the Rocca Busambra carbonate ridge) and the overthrusting Sicanian deep-water carbonate (Corleone-Barracù) and numidian flysch tectonic units, outcropping around the carbonate ridge.

In this tectonic frame Rocca Busambra is a 15 km long, E-W-trending large antiform, slightly rotated to the NW-SE on its eastern limb (Pizzo Marabito). The unit forms a southerly verging ramp structure; it is bound, to the south, by E-W and WNW-ESE striking major reverse faults and, to the north, by the E-W striking Busambra fault, that is a back-verging reverse fault characterized by right-handed strike-slip component of movement. The Busambra carbonate platform tectonic unit, that appears to have been thrust up to the surface, is reimbricated above the Sicanian deep-water carbonate and numidian flysch tectonic units; these, in turn, are redeformed. The latter tectonic event overprinted the original tectonic relationships and took place during the Late Pliocene, as evidenced in adjacent regions.

KEY WORDS: *Western Sicily, geological survey and mapping, Mesozoic shallow- and deep-water carbonate successions, tectono-stratigraphic setting, Meso-Cenozoic deformational history.*

INTRODUCTION

The Rocca Busambra-Corleone region (fig. 1a), located in the Belice valley between the southern Palermo Mountains and the north-western Sicanian Mountains, is a very complex area of the Western Sicily fold-and-thrust belt (from now on named FTB).

The first detailed study carried out in the region is due to MASCLE (1979), who compiled a geological map (1:100,000 scale) of the whole Sicanian Mountains region; the related explanatory notes are an important support to the geological knowledge of the area.

CATALANO & D'ARGENIO (1978; 1982a) and CATALANO & MONTANARI (1979) proposed a tectonic framework of western Sicily with a concise description of the stratigraphy. These authors distinguished the main structural-stratigraphic units and their geometric relationships.

Several other studies have been carried out to describe the stratigraphy of the area (WENDT, 1963-1971; MASCLE, 1973, 1979; MARTIRE *et alii,* 2002; BASILONE, 2009) and its structural setting (ROURE *et alii*, 1990; LENTINI *et alii*, 1994; AGATE *et alii*, 1998a; CATALANO *et alii*, 1998, 2010a, b; NIGRO & RENDA, 1999; 2001; MONACO *et alii*, 2000). As a consequence, several and controversial interpretations, concerning both the stratigraphic and the tectonic setting of the Rocca Busambra-Corleone region, grew up.

In spite of the previous and thorough work about the stratigraphy and the tectonics of the study area, no detailed scaled field mapping has yet been compiled.

Regional studies in the frame of the CARG project in Western Sicily (Carta Geologica d'Italia, 1:50,000 scale) have led the present Author to collect new field and analytical data with the aim of compiling a detailed geological map of the Rocca Busambra-Corleone area. The field work carried out at a 1:10,000 scale is assembled and presented on a base-map at a 1:37,500 scale. The main results concerning the geological knowledge of the region, the stratigraphic and structural features are illustrated in the present explanatory notes.

The present work is an attempt to give detailed field map support to some new insight concerning the structural evolution of the region in the frame of the Sicilian FTB. The geology of the area is particularly valuable to the understanding of the tectono-sedimentary evolution of the Mesozoic Sicilian continental margin and the Cenozoic-Quaternary deformational history (including thin-skinned and later envelopment thrusting).

GEOLOGICAL FRAMEWORK OF WESTERN SICILY

Western Sicily is a part of the Maghrebian Sicilian FTB, a segment of the Alpine collisional belt, recently described (CATALANO *et alii,* 2000 and reference therein) as a result of both post-collisional convergence between Africa and Europe and roll-back of the subduction hinge of the Ionian lithosphere (fig. 1b on the frame of the map).

The western Sicilian FTB (fig. 1a) is the result of the piling up of tectonic units derived from the deformation of distinct ancient paleogeographic domains. The latter were developed, during the Meso-Cenozoic, in the Sicilian sector of the southern Tethyan continental margin (BERNOULLI & JENKINS, 1974; CATALANO & D'ARGENIO, 1978; STAMPFLY & BOREL, 2002).

The tectonic edifice is characterized by the occurrence of three main structural levels (fig. 1b), from the bottom, consisting of: *a*) imbricated slices of carbonate

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platform tectonic units (Panormide, Trapanese and Saccense domains); *b*) a wedge of deep-water carbonate thrust sheets (Imerese and Sicanian units); *c*) the Sicilidi nappes and the numidian flysch units, detached from their substrate. These tectonic units are overlain by wedge-top basins, filled by Miocene-Lower Pleistocene clastic deposits, evaporites and carbonates.

The tectonic emplacement took place during the Miocene-Early Pleistocene time interval. It is commonly assumed that a S and ESE verging thrust propagation (CATALANO & D'ARGENIO, 1982a) accompanied by clockwise rotations (CHANNELL *et alii,* 1990; OLDOW *et alii,* 1990) and deep-seated thrust planes with strike-slip component of movements (GHISETTI & VEZZANI, 1984) occurred. The deeper rock successions have been detached from their substrate from these faults, forming axial culminations and ramp structures (OLDOW *et alii,* 1990; CATALANO *et alii,* 1998, 2010a; AVELLONE *et alii*, 2010).

MAPPING METHODOLOGIES

Field mapping was carried out using published base maps (Carta Tecnica Regionale of the Regione Siciliana) at a 1:10,000 scale. Satellite and aerial images were analyzed in order to recognize the main morphostructural features. The geological map is presented at a scale of 1:37,500 in a Transverse Mercator Projection.

Lithostratigraphic criteria and facies analyses were used to distinguish 22 formations. The detailed reconnaissance is also supported by paleontologic analyses. The carbonate deposits were investigated also using petrographical and sedimentological analyses; the resulting lithofacies were biostratigraphically calibrated, mostly based on Jurassic ammonite biozonation (WENDT, 1969), calpionellids biozonation (ALLEMAN *et alii*, 1971), and Cretaceous-Miocene calcareous plankton biostratigraphy (CARON, 1985; IACCARINO, 1985; PERCH-NIELSEN, 1985; FORNACIARI *et alii,* 1996; FORESI *et alii*, 2001; SPROVIERI *et alii*, 1996, 2002).

Field mapping was integrated with structural analyses at a map and mesoscopic scale.

Field results, calibrated by seismic profiles interpretation (CATALANO *et alii,* 1998; 2000), allow us to recognize the spatial continuity of the rock bodies at depth and the structural setting of the study region.

THE GEOLOGICAL MAP

The map includes:

a) a northern sector, characterized by the Rocca Busambra carbonate ridge and its western continuation (Rocca Argenteria, Rocca del Drago), a 15 km long E-W oriented complex morphostructure, made of Mesozoic-Miocene shallow-to-pelagic carbonate succession (Trapanese paleodomain);

b) a south-western sector, around the Corleone town, where the Cretaceous-Miocene carbonate and clastic deposits, pertaining to the Sicanian deep-water succession, outcrop;

c) an eastern and northernmost sector (Godrano-Ficuzza region), where the Oligo-Miocene numidian flysch deposits prevail;

d) minor outcrops of Sicilide deposits, are mapped in the north-westernmost corner;

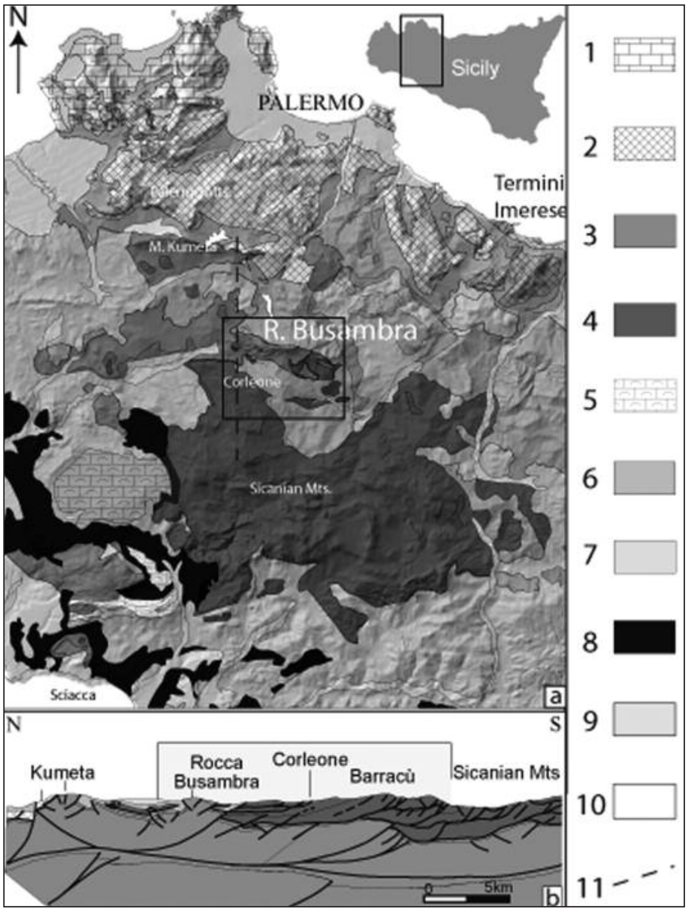

Fig. 1 - a) Structural map of central-western Sicily (modif. from CATALANO *et alii*, 2004); *b*) Regional geoseismic profile (modif. from CATALANO *et alii*, 2000), across the central sector of the western Sicily fold and thrust belt, showing the main tectonic features. LEGEND: 1) Panormide carbonate platform tectonic units; 2) Imerese basin tectonic units; 3) Trapanese-Saccense pelagic platform tectonic units; 4) Sicanian basin tectonic units; 5) M. Genuardo carbonate platform-to-basin tectonic unit; 6) Numidian flysch tectonic units; 7) Miocene syn-tectonic deposits; 8) Miocene-Pliocene deposits; 9) Pleistocene deposits; 10) study area; 11) trace of the regional geoseismic profile of fig. 1b.

e) Miocene foredeep clastic rocks, largely outcropping in the south-western area.

GEOMORPHOLOGIC OUTLINE

The geomorphologic configuration of the study region can be summarized in two different landscape types, related to the outcropping lithologies and to the prevailing morphogenetic processes.

The carbonate highland landscape (Rocca Busambra ridge 1613 m a.s.l.) shows geomorphic forms due to tectonics and morphoselection, such as the several palaeosurfaces, and the wide, structurally controlled, scarps, hundreds of metres high. In the Contrada Giardinello (south of Rocca Busambra ridge on the map), the large block movements and the E-W oriented opening trenches and fractures suggest deep-seated gravitational slope deformation (AGNESI *et alii*, 1978). These phenomena originate mass rock movements of more than 500.000.000 m^3. The landslides have masked the original tectonic relationships between the outcropping tectonic units.

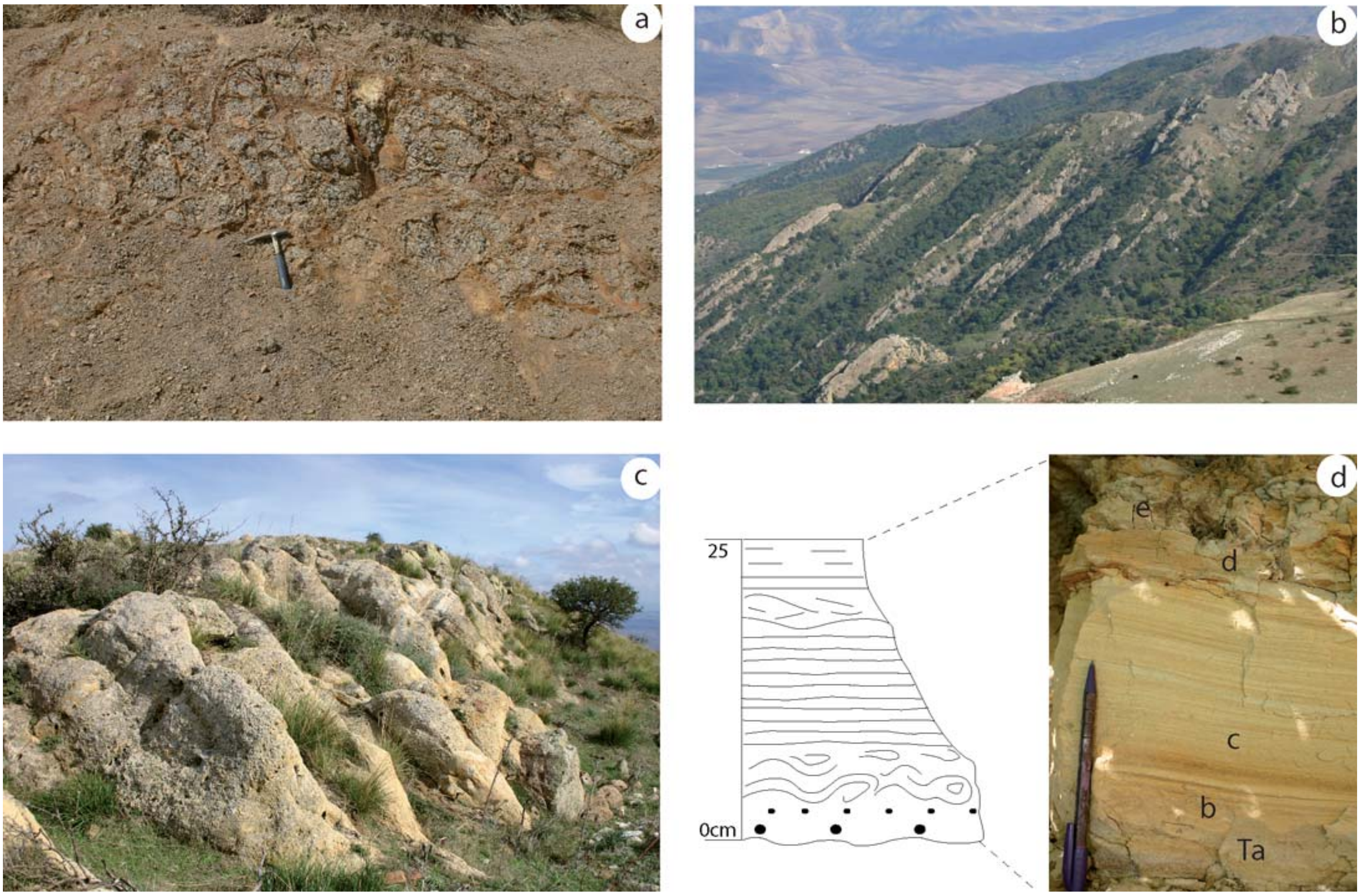

Fig. 2 - The numidian flysch lithofacies: *a*) shales (Portella Colla mb) with iron-manganiferous crusts (Pizzo Candreo); *b*) hectometres turbiditic succession of the Geraci Siculo mb (Bosco della Ficuzza); *c*) massive thick-bedded coarse and well-rounded quartz-conglomerates, alternated with yellow fine-sandstones with parallel and oblique lamination; *d*) detail of a turbiditic bed: Ta) graded conglomerates, b) chaotic coarse sandstones, c) sandstones with normal gradation and parallel lamination, d) laminated mudstones and e) greenish clays.

The marly clayey hilly landscape consists of gentle reliefs with low, inclined slopes, where landslide phenomena and water processes prevail. The mapped landslides, mostly due to a rotational creep, are both active and inactive (no recent movements in the last few decades). The largest landslide bodies are more than 2 km long and 1 km in length, and some tens of metres thick. Spectacular examples are mapped in the region sited to the south of Monte Cardellia, where clayey deposits (Cardellia marls), embedded between two limestone levels («Corleone calcarenites» and Amerillo Fm), are repeatedly mobilized.

Fluvial processes originate several orders of alluvial terraces (mapped along the main rivers) and spectacular erosional canyons in the Corleone town area, where also lateral spreading phenomena occur.

LITHOSTRATIGRAPHY AND FACIES ANALYSIS

The outcropping lithostratigraphic units (fig. 2 on the frame of the map) will be described in descending order, starting from those pertaining to the highest structural units in the study sector. The description is accompanied by some illustrations (figs. 2-9) and summary tables (tabs. 1-4), concerning the main lithostratigraphic, environmental and paleontological features of the formations. The stratigraphic columns presented in figs. 3 and 9 show detailed sequences of the Monte Barracù and Rocca Busambra successions. The following paragraphs describe the individual rock units in some detail.

Sicilide deposits

The Sicilide terrains, a few tens of metres thick, outcrop, as scattered patches, at Case Bifarera, Cozzo Arcuri and Masseria Nicolosi (northern sector of the map), where the rocks tectonically overlie the numidian flysch deposits. They include Late Cretaceous varicoloured silicified clays, shales and marls of the «varicoloured clays» (AVF on the map) and Middle-Late Eocene white pelagic limestones (Polizzi Formation, POZ on the map, tab. 1), with intercalations of graded and laminated packstone-wackestone rich in benthic macroforaminifers, pectinids, *Corallinacean* algae, crinoid and echinoid fragments (tab. 1). The mudstone-wackestone beds show bioturbation (ichnofacies with *Palaeodictyon* isp., *Nereites* isp., *Helminthoida* isp.) and, locally, volcanoclastic layers (Contrada Bifarera).

TABLE 1
Lithostratigraphic characters of the Sicilidi deposits and numidian flysch formation.

	Main lithology		Environ	Fossils content	Age
Varicoloured clays (AVF)	Varicoloured silicized clays, chaotic shales, mudstone and packstone intercalations	20-50m	Bathial plain	Planktonic forams (*Rotalipora appenninica, R. brotzeni and R. reicheli* biozones) and calcareous nannofossils (CC 25-26)	Albian-Cenomanian
Polizzi Fm. (POZ)	White pelagic limestones wirh ichnofacies *(Palaeodictyon* isp., *Nereites* isp., *Helminthoida* isp.), graded and laminated packstone intercalations. Volcanoclastic layers (C.da Bifarera)	20-50m	Depositional slope-to-basin	Planktonic forams (*Hantkenina nuttall, Truncorotaloides rohri, Globigerinatheka semiinvoluta, Turborotalia cerroazulensis s.l.* biozones) and calcareous nannofossils (NP 20 biozone). Nummulitids, alveolinids, discocyclinids, pectinids, corallinacean algae, crinoid and echinoid fragments in the resedimented beds	Middle-Upper Eocene
Numidian flysch Fm. — Geraci Siculo mb. (FYN_5)	Megabeds of well-cemented quartz turbidite sandstones; pebbly conglomerates, some metres-thick, with darkish mudstone intraclasts, are locally interlayered	300-700m	Slope to turbidite fan	Planktonic forams (*Globigerinoides trilobus, Globoquadrina dehiscens dehiscens-Catapsydrax dissimilis* biozones), calcareous nannofossils (MNN 1 and MNN2b) and arenaceous foraminifers *(Ammodiscus* spp., *Cyclammina* spp., *Trochammina* spp.)	Aquitanian-Burdigalian
Numidian flysch Fm. — Portella Colla mb. (FYN_2)	Brown manganesiferous laminated clays, graded and laminated quartz sandstone (FYN2a) intercalations.	100-200m	Slope to toe-slope	Planktonic forams (*Globorotalia opima opima, Globigerina ciperoensis ciperoensis, Globoquadrina dehiscens dehiscens-Catapsydrax dissimilis* biozones) and calcareous nannofossils (NP 24-25, MNN 1b)	Chattian-Lower Aquitanian

NUMIDIAN FLYSCH DEPOSITS

The numidian flysch formation consists of Upper Oligocene-Lower Miocene clays and shales with thick turbiditic quartz-sandstone and conglomerate intercalations (fig. 2). The unit, more than 800 m-thick, widely outcrops both in the northern and eastern sector of the map, where it tectonically overlies the Sicanian rock unit. The terrigenous wedge lacks of its original Mesozoic-Eocene carbonate substrate, found elsewhere. The formation is made up of two members (tab. 1).

The Portella Colla member (FYN_2 on the map) consists of 100-200 m-thick brown manganiferous laminated clays (fig. 1a), locally scaly, with m-thick yellowish siltstones and fine-graded and laminated quartz-sandstone intercalations; it outcrops at Nicolosi, Scalilli, Bifarera, Madonna di Tagliavia areas (north-western sector of the map) and at Pizzo Candreo (few metres). Planktonic foraminifers and nannoplankton content suggest a Chattian-Lower Aquitanian age.

The Geraci Siculo member (FYN_5 on the map) consists of an upward thickening turbiditic sequence (fig. 2b). The recognized lithofacies are: *a*) massive thick-bedded conglomerate (fig. 2c) alternated with yellow-reddish fine-to-coarse planar- and oblique-laminated sandstone. The conglomerate layers, with erosional lower boundary are coarse and well-rounded quartz grains; *b*) siliceous sandstones, commonly with erosional lower boundary, and complete turbiditic facies sequences (fig. 2d); mud-supported texture pebbly conglomerate, ten metres-thick, with darkish mudstone intraclasts, are locally interlayered. The Geraci Siculo member is well-exposed in the Bosco della Ficuzza, Bosco del Cappelliere, Marosa and Cozzo Donna Giacoma areas (eastern and southern sector of the map). It is dated as Lower Miocene (based on planktonic foraminifer and nannofossil biostratigraphy, tab. 1).

INCERTAE SEDIS DEPOSITS

At Contrada Bicchinello (south of Pizzo Nicolosi), a small rock body of Eocene breccias and bioclastic packstone-grainstone with benthic macroforaminifers (nummulitids, alveolinids), crustacean and bivalve fragments (Bicchinello limestone, PUN on the map), crops out. These deposits are believed to be the remnants of tectonic slices pertaining to the Prepanormide tectonic units (CATALANO *et alii*, 2010a and reference therein).

SICANIAN DOMAIN DEPOSITS

The whole Sicanian succession is well exposed at Monte Barracù, immediately to the south of the study region (MASCLE, 1979; AGATE *et alii*, 1998b), as shown by the detailed stratigraphic column (fig. 3). Its depositional characteristics point to a deep-water Triassic-Miocene paleodomain. In the study area only some lithostratigraphic units are mapped (tab. 2):

a) Mufara Formation (MUF on the map). Late Triassic (Carnian) thin-bedded laminated grey mudstone and dark-yellowish marls, with halobids, ammonites, radiolarians,

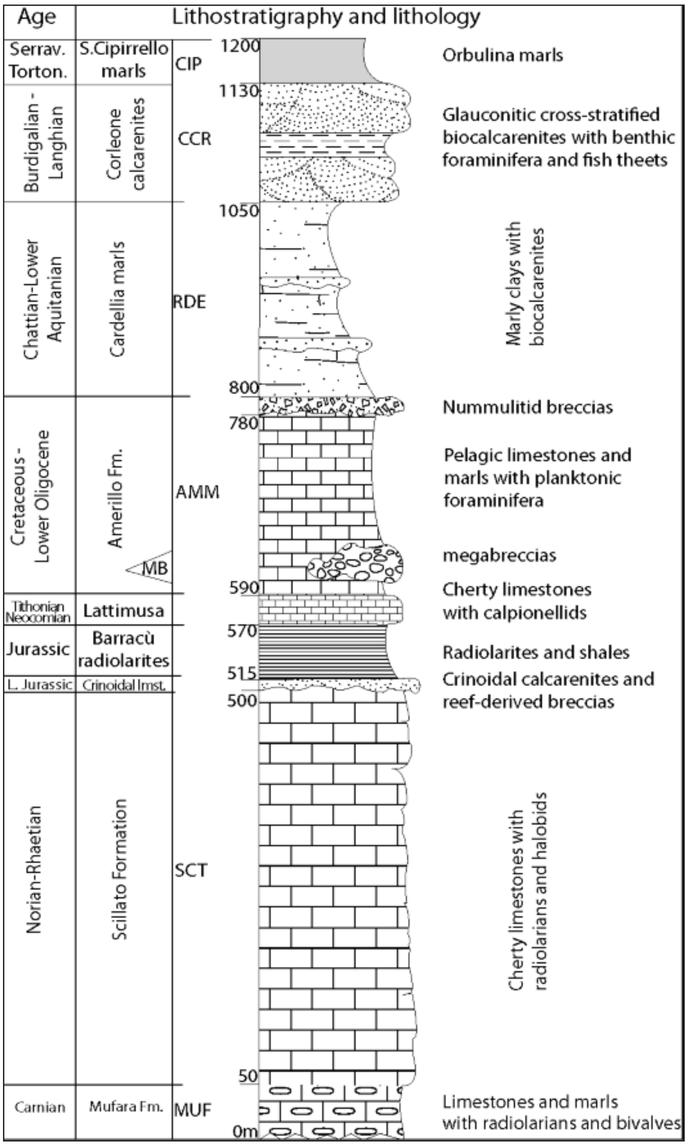

Fig. 3 - Triassic-Miocene deep-water Sicanian stratigraphic succession, measured and sampled along the Monte Barracù natural section.

conodonts, palinomorphs, gastropods and rare arenaceous foraminifers. It outcrops, 10-30 m thick, at Masseria Cicio, Masseria del Casale, Puntale l'Ape, Masseria Nicolosi and Cozzo Tondo. The beds are strongly folded and faulted;

b) Hybla Formation (HYB on the map). Lower Cretaceous grey-blackish thin-bedded cherty limestones with radiolarians, sponge spiculae and planktonic foraminifers (fig. 4a), whitish marls rich in belemnites (*Duvalia lata* BLAINVILLE) and mollusc shells. Coarse-grained packstone with *Aptychus* fragments, are interlayered. The unit is mapped along the Rocca Busambra ridge in the Contrada Giardinello (south of Pizzo Marabito), where in spite of the strong deformation (folds and faults), it is up to 50 metres thick; its lower boundary does not outcrop on the map.

c) Amerillo Fm (AMMa-d on the map, fig. 5). The formation is Upper Cretaceous-to-lower Oligocene reddish-to-whitish thin limestones and marly limestones (figs. 5a, b) with planktonic foraminifers (fig. 4b), limestones with ichnofacies (fig. 5c) and calcareous turbidites with macroforaminifers (fig. 5d and fig. 4c). Carbonate megabreccias (AMMm on the map) occur in beds in the Campanian-Lower Maastrichtian interval of the pelagic suc- cession. They are well-cemented sub-rounded cobbles and boulders deriving from the break up of the upper Triassic-Jurassic peritidal limestones and pelagic deposits.

The Amerillo Fm, 200 m-thick, outcrops at Portella del Vento, Piano della Tramontana, Contrada Giardinello, Casale and Pirrello (south-eastern side of the Rocca Busambra ridge), where the lithofacies described above are identified and mapped. These deposits, previously interpreted as pertaining to the Trapanese domain (GIUNTA & LIGUORI, 1975; MASCLE, 1979), appear well correlated with the typical Sicanian Amerillo Fm outcropping at Monte Barracù (southern edge of the map).

d) Cardellia marls (RDE on the map). Chattian-Lower Aquitanian marls and dark-green marly clays with iron nodules are rich in calcareous plankton; benthic macroforaminifers (nummulitids and *Nephrolepidina* spp.) bearing turbidite packstone (fig. 4d) are interlayered. These beds, 100-200 m-thick, conformably follow the Amerillo Fm. The recently proposed «Cardellia marls» formation outcrops at Contrada Bifarera (northwestern corner of the map, see also MASCLE, 1979), at Contrada Casale and Pirrello (southern side of Rocca Busambra), around the town of Corleone and at Monte Cardellia, where the proposed type section (fig. 6) is based on the biostratigraphic study of BIOLZI (1985).

e) Corleone calcarenites (CCR on the map). Lower Miocene glauconitic grainstone and packstone with benthic macroforaminifers (figs. 4e, f), calcareous and quartz-sandstones and greenish silty marls, unconformably follow. The lower boundary of the unit is a sharp and ero- sional unconformity surface above the Cardellia marls, as seen along the Monte Cardellia section (see fig. 6). The «Corleone calcarenites», 20-80 m-thick, outcrop at Cozzo Zuccarone-Cozzo Rubino anticline and, with maximum thickness, at Monte Cardellia and in the Corleone town, where the Rocca dei Maschi natural section was analyzed and sampled with detail to propose the type section of the formation. The measured succession (fig. 7), 70 metres thick, yellow and green in colour due to the occurrence of abundant glauconite minerals, consists of cyclic alternations of quartz-glauconitic sandstones and bioclastic packstone in dm-thick beds with green marls. Several lithological intervals can be evidenced due to the composition of the beds and their erodible features; the succession is organized at least in two 3rd order transgressive-regressive cycles.

f) San Cipirello marls (CIP on the map). Upper Serravallian-Lower Tortonian grey and sky-blue clays, clayey marls and sandy marls with rich planktonic content, 50-150 m-thick. The marls outcrop at Cozzo Zuccarone, Contrada Pirrello, Sant'Ippolito and Vallone del Poggio (Corleone town area), where conformably overlay, with a sharp surface, the «Corleone calcarenites».

The lower portion of the Sicanian succession (Scillato Fm, oolitic calcarenites and Prizzi breccias, Barracù radiolarites and Lattimusa, fig. 3) does not outcrop in the study region. Seismic profile interpretation and subsurface data suggest these rocks are presently buried in the region (CATALANO *et alii*, 1998; 2004).

TRAPANESE CARBONATE PELAGIC-PLATFORM DEPOSITS

The Rocca Busambra rocks pertain to the Meso-Cenozoic Trapanese paleogeographic domain (CATALANO &

TABLE 2

Lithostratigraphic characters of the Cretaecous-Miocene formations of the Sicanian succession.

Fms	Main lithology		Environ.	Fossil content	Age
San Cipirello marls (CIP)	Grey and sky-blue clays, clayey marls and sandy marls	50-150m	outer shelf	plankton forams (MMi 5-7 biozones), calcareous nannofossils (MNN 6a, MNN 7a and *Minilytha convallis* biozones)	Lower Tortonian-Upper Langhian
Corleone calcarenites (CCR)	Glauconitic grainstone-packstonea, calcareous and quartzitic sandstones and greenish siltitic marls	40-80m	coastal to deltaic influenced by tidal currents	Large benthonic forams (*Operculina complanata, Miogypsina* spp., *Nephrolepidina* spp.), plankton forams (*Globoquadrina dehiscens dehiscens-Catapsydrax dissimilis, Globigerinoides trilobus, Praeorbulina glomerosa* s.l. biozones)	Langhian-Upper Aquitanian
Cardellia marls (RDE)	Marls and dark green marly clays with ironized nodules; intercalations of turbiditic packstone 20-100 cm-thick	100-150m	slope to outer shelf	plankton forams (*Globoquadrina dehiscens dehiscens-Catapsidrax dissimilis, Globorotalia kugleri* biozones), calcareous nannofossils (NP 24-25 biozones); nummulitids and *Nephrolepidina* spp.	Lower Aquitanian-Chattian
Amerillo Formation AMMd	Limestones, calcareous marls: Breccias and bioclastic coarse-grained packstone	up to 200m	deep-water basin interested by gravitational processes (debris and grain flow)	large benthonic foraminifers (nummulitids), algae (*Subterraniphyllum thomasi*)	Lower Oligocene
Amerillo Formation AMMc	grey wackestone and marls with *Cancellophycus*			plankton forams (*Cassigerinella chipolensis-Pseudohastigerina micra* biozones)	Lower Oligocene
Amerillo Formation AMMb	white wackestone with black chert nodules			plankton forams (*Turborotalia cerroazulensis* s.l., *Globigerinatheka semiinvoluta, Truncorotaloides rorhi* biozones)	Upper-Middle Eocene
Amerillo Formation AMMm	calcareous megabreccias			plankton forams (*Globotruncana elevata, Glt. aegyptiaca, Morozovella subbotinae, M. formosa formosa* biozones)	Lower Maastrichtian-Campanian
Amerillo Formation AMMa	reddish mudstone and marls in thin strata				Lower Eocene-Upper Cretaceous
Hybla Fm. (HYB)	Grey-blackish thin bedded cherty limestones, green-whitish marls, packstone with *Aptychus* fragments	up to 50m	deep-water basin	plankton forams (*Globigerinelloides algeriana, Ticinella primula, Biticinella breggiensis* biozones), radiolarians, sponge spiculae, belemnites (*Duvalia lata*) and mollusc shells	Albian-Aptian

D'ARGENIO, 1978), where shallow marine and pelagic carbonate platform deposited progressively. The typical condensed sedimentation and facies variability of the Jurassic-Cretaceous deposits have been already investigated (CHRIST, 1960; TAMAJO, 1960; WENDT, 1963-1971; JENKYNS, 1970a; MARTIRE & BERTOK, 2002; BASILONE, 2007), as well the tectono-sedimentary features of the Jurassic-Cretaceous deposits exposed at the Piano Pilato sector (WENDT, 1971; GIUNTA & LIGUORI, 1975; MASCLE, 1973, 1979; GULLO & VITALE, 1986; MARTIRE & MONTAGNINO, 2002; BERTOK & MARTIRE, 2009).

Tectono-stratigraphic features, such as paleofaults, buttress unconformity relationships, a dense network of neptunian dykes with several infilling generations and several large hiatuses, have been recently discussed as useful constraints to the palinspastic restoration of the Jurassic-to-Miocene tectono-sedimentary evolution of the Rocca Busambra (BASILONE, 2009).

The succession starts with: well-exposed Upper Triassic-Lower Jurassic carbonate shallow marine deposits which form the main bulk of the Rocca Busambra carbonate ridge. They include:

a) Marabito limestones (ITO on the map). Dolomitized upper Triassic sponge-bearing reef limestones (figs. 8a, b and tab. 3), 30 metres thick, outcropping in the easternmost sector of the Rocca Busambra (Pizzo Marabito);

b) Inici Formation (INI on the map). White peritidal limestones, up to 400 m thick, display different shallow-water lithofacies (figs. 8c, d) organized in shallowing upward sequences. The fossil content (tab. 3) dates these beds to the Hettangian-Sinemurian time interval. The top of the white peritidal limestones appears to be dissected by a dense network of neptunian dykes. Impressive examples of these neptunian dykes are seen in the Rocca Argenteria quarry, where WENDT (1971) has restored the chronological evolution of the filling sediments. A regional unconformity marks the top of the Inici Formation which is capped by a blackish Fe-Mn crust. The latter is interpreted as an hardground related to the carbonate platform drowning (JENKYNS, 1970a) and due to probable anoxic events and bioerosion (DI STEFANO & MINDSZENTY, 2000);

c) the Inici Fm limestones are unconformably followed by the Jurassic condensed deposits of the Buccheri Fm. This unit includes two members:

i) *Bositra* limestones (BCH_1 on the map). A few metres thick, reddish-brown to grey wackestone/packstone (figs. 8e, f) and local laminitic stromatolites with rich pelagic fauna (tab. 3) of Bajocian-Early Kimmerid-

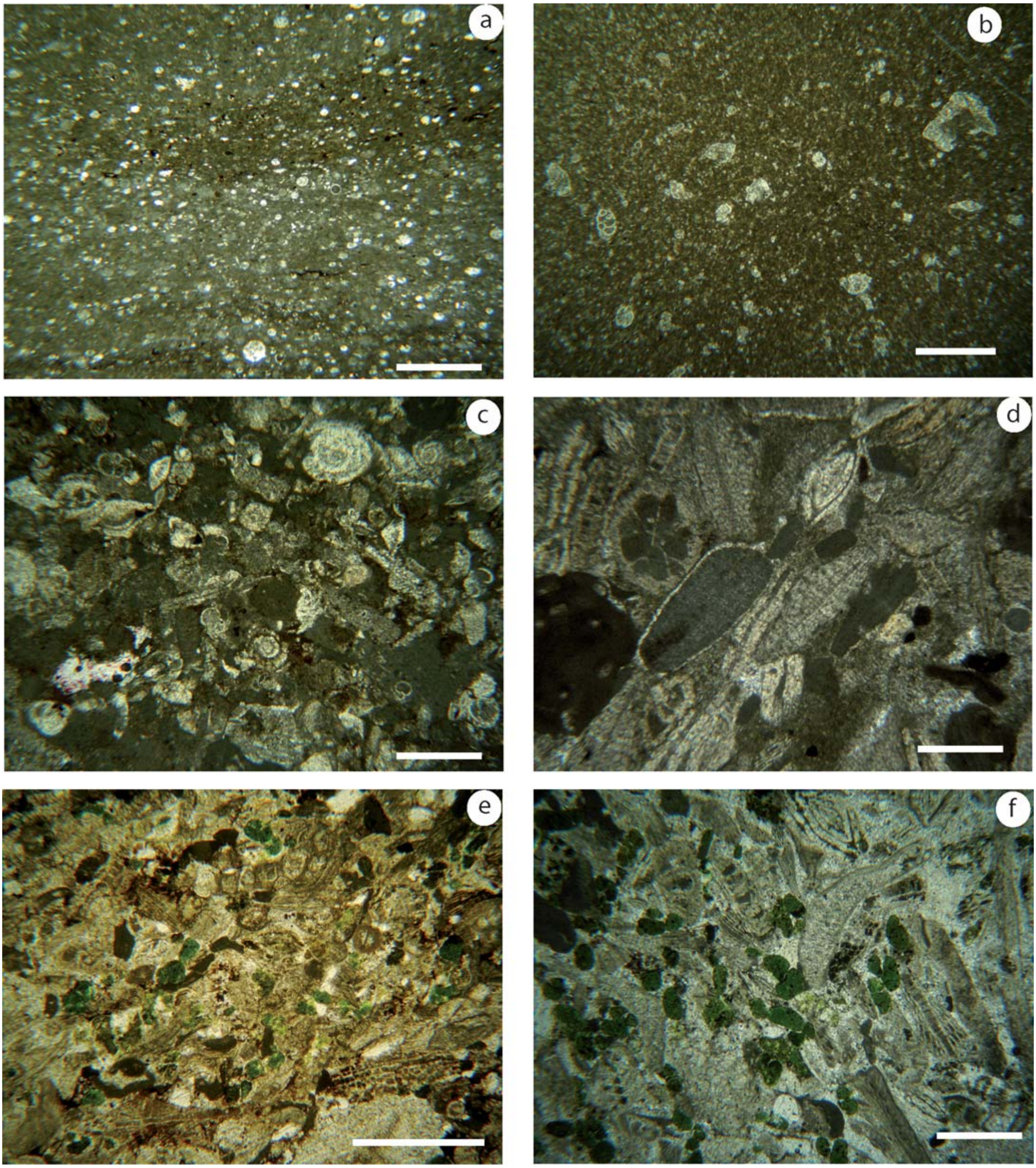

Fig. 4 - Microfacies of the Cretaceous-Miocene deposits of the Sicanian succession: *a*) mudstone with radiolarians, planktonic foraminifers and sponge spiculae (Hybla Formation, Contrada Giardinello, scale bar 1mm); *b*) wackestone with globotruncanids and heteroelicids (scaglia rossa lithofacies, Amerillo Formation, Piano della Tramontana, scale bar 1mm); *c*) packstone with benthic macroforaminifers, calcareous algae, corals and intraclasts (nummulitid breccias lithofacies of the Amerillo Formation, Monte Barracù, scale bar 1mm); *d*) packstone with benthic macroforaminifers, coral fragments and intraclasts (calcareous turbidite intercalations in the Cardellia marls, Contrada Pirrello, southern limb of Rocca Busambra, scale bar 1mm); *e*) and *f*) grainstone with benthic foraminifers, algae fragments, intraclasts and glauconitic grains (Corleone calcarenites, Rocca dei Maschi, scale bar 1mm).

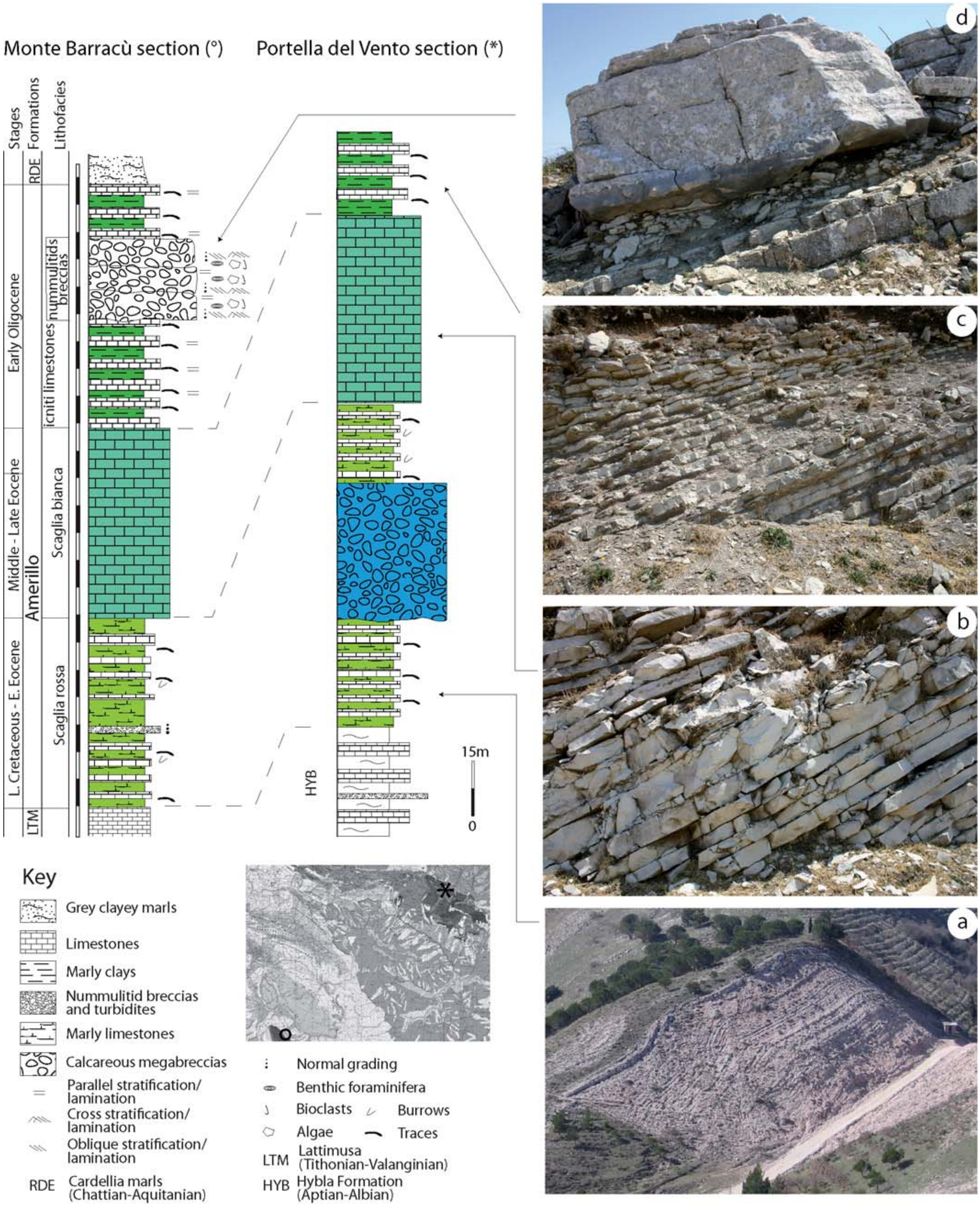

Fig. 5 - Comparison between the Sicanian Amerillo Fm outcropping at Monte Barracù and Piano della Tramontana (eastern Rocca Busambra ridge, see location map). Impressive characters of the main lithofacies are shown: *a*) strongly deformed reddish limestones and marls (red scaglia lithofacies, Portella del Vento, Rocca Busambra); *b*) thin white cherty limestones (white scaglia lithofacies, Monte Barracù); *c*) rhythmic alternations of thin grey limestones with ichnofacies *(Cancellophycus* isp.*)* and greenish marly clays (Monte Barracù); *d*) calcarenites and breccias with nummulitids (Monte Barracù); the m-thick resedimented bodies show erosional lower boundary, parallel and oblique lamination and gradational structures.

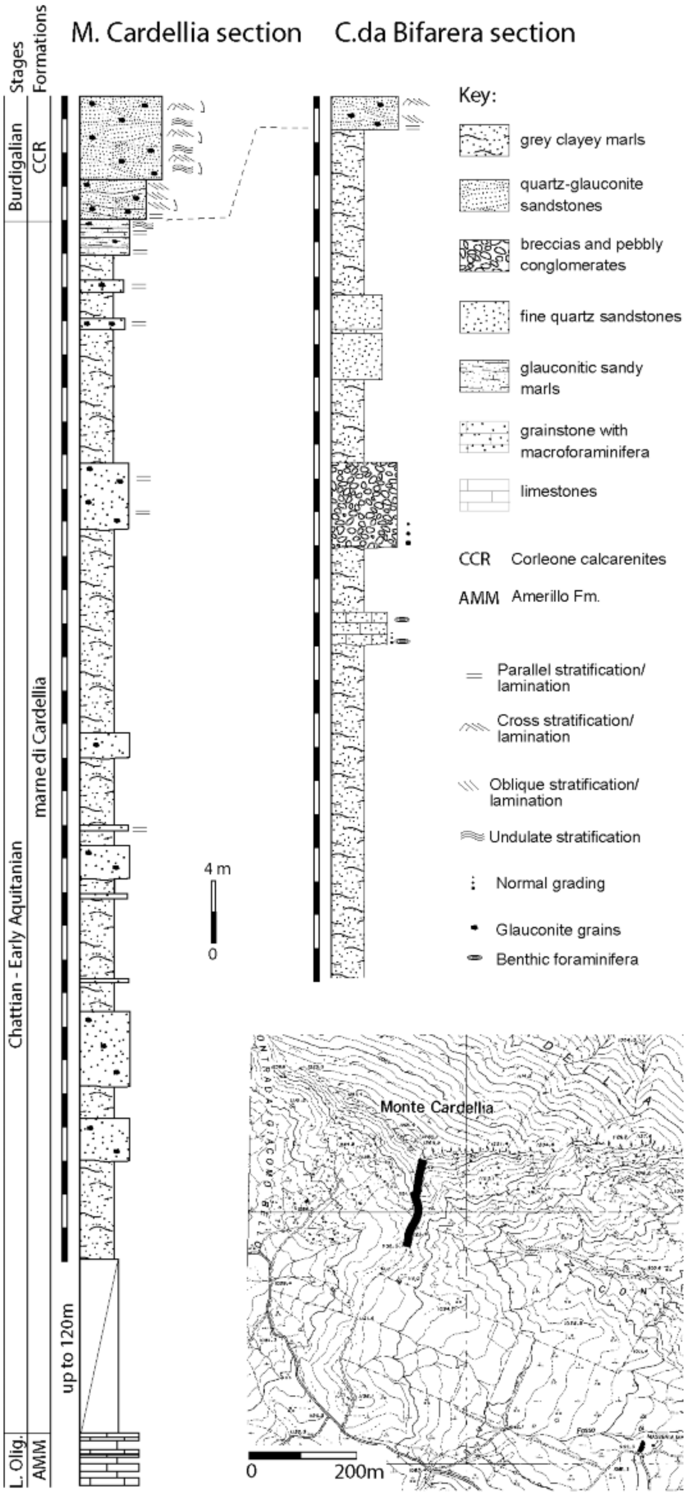

Fig. 6 - Detailed stratigraphic sections of the Cardellia marls, measured and sampled along the Monte Cardellia proposed type section (see location map) and Case Bifarera outcrop (north of Rocca Busambra).

gian age (Wendt, 1969). They outcrop mostly in the Piano Pilato region. This lithofacies is easily recognized by the dark dm-sized nodules that are encrusted by ferromanganese oxides (Wendt, 1963; Jenkyns, 1970b, 1971) and the interlayered cm-sized dark Fe-Mn crusts;

ii) *Saccocoma* limestones (BCH_3 on the map) are thick-bedded, tabular and massive red-to-grey pelagic crinoid-bearing grainstone-packstone, a few metres thick, outcropping along the whole ridge. The rich fossil content (tab. 3) dates these beds to Late Kimmeridgian-Tithonian age;

d) crinoidal limestones (RND on the map) include red-to-grey massive grainstone-packstone, 50-80 cm thick, in places encrusted by Fe-Mn layers; they are, locally, the basal sediments of the Buccheri Fm.

Uppermost Jurassic-Eocene pelagic carbonate deposits of the Lattimusa, Hybla and Amerillo Fms. (tab. 3, respectively LTM, HYB and AMM on the map), follow upwards.

A prominent thick massive, tabular and/or lenticular-shaped Upper Cretaceous carbonate megabreccia is interlayered into the Amerillo Fm.

The Amerillo Fm, in its turn, is unconformably covered by the Lower-to-Middle Miocene «Corleone calcarenites» and topwards the San Cipirrello marls.

Three main sections (fig. 9a), having different tectono-sedimentary patterns, are described to illustrate the variable stratigraphic settings of the Rocca Busambra ridge.

a) *Piano Pilato section*

It is located at the westernmost side of Rocca Busambra (fig. 9b). The succession shows a Jurassic «condensed pelagic» facies association (Buccheri Fm), unconformably followed by both the Upper Cretaceous pelagic limestones (Amerillo Fm) and by the Lower Miocene reworked pelagic deposits («Corleone calcarenites»). This sequence rests unconformably above the sub-horizontal beds of the Inici Fm peritidal limestones.

Synsedimentary tectonics originated several, south-dipping, largely subvertical (60-80° steep) WNW-ESE-oriented paleofaults displacing the Inici Fm deposits (fig. 6 on the frame of the map). The fault planes are sealed by Upper Jurassic, reworked, pelagic deposits (upper member of the Buccheri Fm) that lie with a buttress unconformity against the hanging-wall scarp of the fault plane. The western side of Piano Pilato (Pizzo Nicolosi) shows several WNW-ESE faults that downthrow the Jurassic carbonates, giving rise to a horst and graben setting (Pizzo Nicolosi and Rocca Ramusa graben structures, fig. 3 on the frame of the map); the morphotectonic depressions are filled by a 40 m-thick package of Upper Cretaceous pelagic deposits of the Amerillo Fm. The latter directly onlaps the Jurassic floor of the depressions; in the meantime they crop out, with buttress unconformity, against the subvertical walls (fig. 4 on the frame of the map).

b) *Rocca Busambra-peak section*

Located in the central sector of the ridge (fig. 9b), the Rocca Busambra-peak shows the carbonate megabreccias that either rest unconformably over the Jurassic condensed deposits of the Buccheri Fm or abruptly onlap the peritidal limestones of the Lower Jurassic Inici Fm (fig. 5 on the frame of the map). At places, the former fill up shallow, channelled gullies. The mapped synsedimentary tectonic structures are subvertical ENE-WSW normal faults (with a few to several metres of downthrow) that dissect the Inici Fm peritidal limestones and the Jurassic condensed Buccheri Fm deposits (fig. 5 on the frame of the map).

c) *Pizzo Marabito section*

Located along the easternmost side of the ridge (fig. 9b), the rock succession deeply differs from those previously described. The Upper Triassic reef of the Marabito limestones is unconformably overlain, with buttress unconformity, by both the Buccheri and Lattimusa Fms (fig. 8 on the frame of the map). Synsedimentary tectonic features in the Upper Triassic reef limestones are fissures, neptunian dykes and *in situ* breccias. ENE-WSW trending pre-Upper Jurassic subvertical fault planes are also present (fig. 8 on the frame of the map).

Miocene foredeep (wedge-top basin) deposits

Upper Miocene deltaic conglomerate, sandstone and clay, pertaining to the Castellana Sicula and Terravecchia Fms. (tab. 4), are mapped in the southwestern area.

The Castellana Sicula Fm (SIC on the map), is a clayey sequence with quartz sandstone intercalations, a few metres to 150 m-thick. It unconformably overlies the San Cipirello marls at Vallone del Poggio (west of the town of Corleone), Trentasalme and Bicchinello areas (immediately to the south and south-west of Pizzo Nicolosi), or the numidian flysch at Contrada Pirrello and Casale (south of Rocca Busambra) and the Sicilidi deposits at Contrada Bifarera (northern edge of the map). The poorly and badly-preserved fossil content dates these deposits as Late Serravallian-Early Tortonian.

The Terravecchia Fm (TRV_1 and TRV_2 members), is mapped at Cozzo Riddocco and Vallone del Poggio (southwest of Corleone). The basal member consists of calcareous and siliceous graded conglomerates; these display lenticular and pinch-out geometries and thickness variability from a few metres to up to 20 m. The conglomerate elements, mostly consisting of glauconitic «Corleone calcarenites», suggest that the source areas of the clastic material are those of the substrate that they overlie. Differently, the same deposits outcropping at Contrada Bifarera (north of Rocca Busambra, immediately off the map) consist of siliceous and quartz-arenitic elements, suggesting an overall cannibalization of the quartz-sandstones of the numidian flysch.

The overlying member displays cross-laminated sandstones, up to 30 m-thick, laterally and upwards passing to siltitic and grey clays, pertaining to the pelitic member (outcropping just outside the edge of the map). The fossil content of the clayey lithologies indicates their Late Tortonian-Early Messinian age (Di Stefano & Catalano, 1978). The basal boundary of the Terravecchia Fm is an erosional unconformity above the older rock units; it is well shown at the Vallone del Poggio area, where the formation overlies sandstones and clays of the Castellana Sicula Fm.

Quaternary deposits

Quaternary-to-Recent deposits, developed in the frame of the morphogenetic evolution of the area, are mapped in detail with the aim of supplying basic infor-

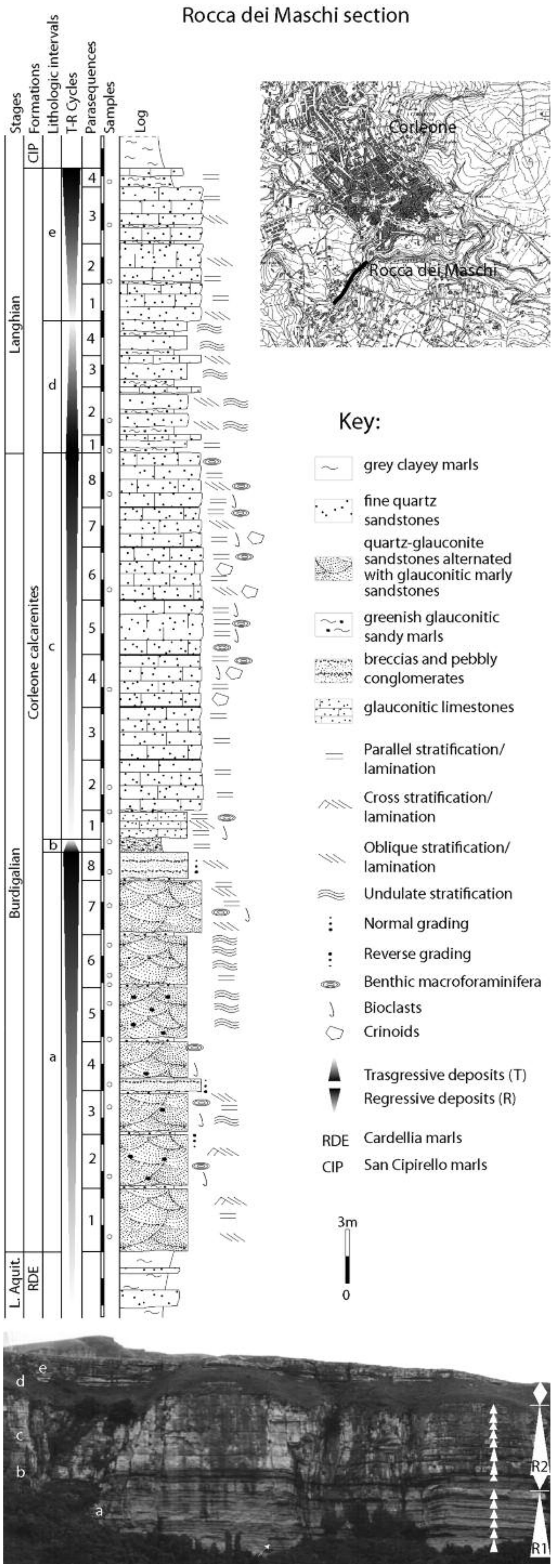

Fig. 7 - Proposed type section of the Corleone calcarenites at Rocca dei Maschi (town of Corleone). The columnar section displays the sedimentological and lithological characters of the several lithological intervals and facies associations distinguished, and the cyclic arrangement of the succession (T-R sequence cycles and parasequences). In the picture below (Rocca dei Maschi natural section) are overprinted the lithological intervals (*a* to *d*), the T-R cycles (R1, R2) and the parasequence cycles (white arrows); The time interval of the uppermost cycle is based on the occurrence of the markers of the *Praeorbulina glomerosa* s.l. biozone.

TABLE 3
Lithostratigraphic characters of the Triassic-Miocene formations of the Trapanese Rocca Busambra succession.

Fms	Main lithology	Lower boundary		Fossil content	Age
San Cipirello marls (CIP)	brown and dark clayey marls, locally with glauconite	conformable with CCR	15-150m	planktonic forams (MMi 5-MMi 9 and MMi 11 biozones) calcareous nannofossils (MNN5b-MNN 7b and *Minylitha convallis* biozones)	Upper Langhian-Lower Tortonian
Corleone calcarenites (CCR)	yellow-green glauconitic globigerinid-bearing packstone-grainstone	buttress unconformity with INI	30m	planktonic forams (*Globigerinoides trilobus, Praeorbulina glomerosa* s.l. biozones)	Burdigalian-Langhian
Amerillo Fm. (AMM)	white and red planktonic foraminifers-bearing wackestone and calcareous megabreccias	paraconformable on HYB, buttress unconformity with BCH and INI	5-50 m	plankton forams (*Rotalipora reicheli, Rotalipora cushmani, Globotruncana ventricosa, Turborotalia cerroazulensi* s.l. biozones), calcareous nannofossils (CC10 biozone)	Cenomanian-Maastrichtian and Upper Eocene
Hybla Fm. (HYB)	marls and cherty limestones; bio-intraclastic (*Aptychus* and mollusc fragments) floatstone	transitional on LTM	>50 m	planktonic forams (*Globigerinelloides algeriana, Biticinella breggiensis*), calcareous nannofossils (CC7-8 biozones)	Aptian-Albian
Lattimusa (LTM)	pink to white thin bedded cherty mudstone, locally intraformational pebbly mudstone and resedimented bioclastic breccias	Transitional on BCH_3; onlap and buttress unconformity with INI and ITO	3-15m	calcareous nannoplankton (*Nannoconus steinmanni*), radiolarians, belemnites, ammonites and calpionellids (*Calpionella, Calpionellopsis and Calpionellites* biozones)	Upper Tithonian-Neocomian
Buccheri Fm. BCH_3	tabular and massive red to grey pelagic crinoids-bearing grainstone/packstone	downlap or buttress unconformity with the BCH_1, INI, ITO	2-10m	*Saccocoma* sp., benthic forams (Protopeneroplis striata), Globochaete sp., Aptychus sp., brachiopods, belemnites and ammonites	Upper Kimmeridgian-Lower Tithonian
Buccheri Fm. BCH_1	reddish, brown to grey bioclastic wackestone/packstone with dark dm-sized Fe-Mn nodules, laminitic stromatolites	onlap with RND and with the blackish Fe-Mn crust capping the Inici Fm.	0.5-3m	ammonites (*S. humpresianum, G. garantiana, P. parkinsoni, R. anceps* biozones), radiolarians, thin-shelled pelagic bivalves (*Bositra buchi*), protoglobigerinids	Bajocian-Lower Kimmeridgian
Crinoidal limestones (RND)	Red to white massive grainstone packstone, encrusted by Fe-Mn oxides	onlap with INI	0-0.8m	Crinoid ossicles and plates (*Pentacrinus* sp.), benthic foraminifera and ammonites	Toarcian
Inici Fm. (INI)	:algae and mollusc-bearing wackestone-packstone, stromatolithic and loferitic packstone, oolitic and bioclastic packstone/grainstone	not outcropping. In adjacent areas is paraconformable on Sciacca Fm.	400m	gastropods, brachiopods, ammonites (*Arietites bucklandi, Echioceras raricostatum*), calcareous algae (*Cayeuxia* sp., *Thaumatoporella parvovesiculifera, Paleodasycladus mediterranu*), benthic foraminifera (*Involutina liassica*)	Hettangian-Sinemurian
Marabito limestones (ITO)	dolomitized sponge-bearing boundstone. It becomes a clast-supported *in situ* breccias	not outcropping. A lateral transition with Sciacca Fm. is inferred	30m	Calcareous sponges (*Follicatena irregularis, Panormida* sp., *Cheilosporites tirolensis*) associated with rare corals and calcareous algae	Norian-Rhaethian

TABLE 4
Lithostratigraphic characters of the Miocene syntectonic deposits.

Fms	Main lithology		Environ	Fossil content	Age
Terravecchia Fm. TRV_2	Yellowish badly cemented quartz sandstones in thick beds, with planar and crossed lamination and bioturbation and thin conglomerate intercalations	up to 30m	Fluvio-deltaic, passing upwards to open marine	Planktonic forams (MMI5- MMI 11 biozones); calcareous nannofossils (MNN 6a, MNN 7a and *Minilytha convallis* (pars), *Reticulofenestra rotaria* biozones). The fossil conten has been found in the upper pelitic member, not outcropping in the map	Upper Tortonian-Lower Messinian
Terravecchia Fm. TRV_1	Large-size (decimetric) grey and withish calcareous and siliceous conglomerates, frequently embriciated and graded; the elements deriving, mostly, from dismantling of the CCR	up to 20m			
Castellana Sicula Fm. (SIC)	Grey, white-yellowish clays and sandy clays with poorly and bad-preserved benthic foraminifera (*Ammonia inflata, Elphidium* spp.) with, locally, thick intercalations of quartzitic-micaceous sandstones	up to 150m	Open platform-to-slope	Planktonic forams (*Neogloboquadrina praeatlantica, Neogloboquadrina acostaensis* biozones)	U.Serravallian-L.Tortonian

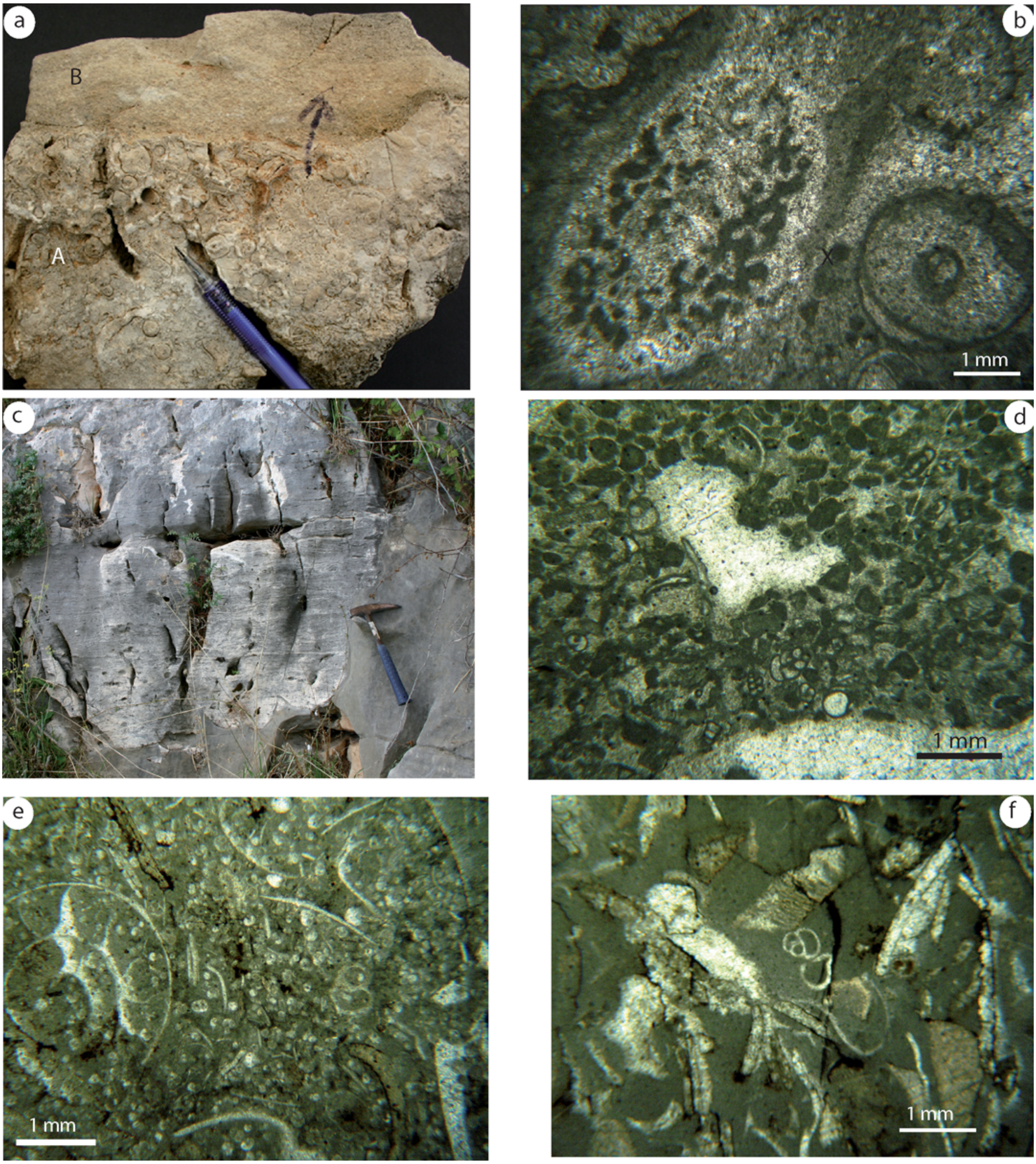

Fig. 8 - Characteristic lithofacies and microfacies of the Upper Triassic-Lower Jurassic carbonate shallow-water deposits (Marabito limestones and Inici Fm) and the Jurassic «Rosso Ammonitico» deposits (Buccheri Fm) outcropping along the Rocca Busambra ridge: *a*) dolomitized Upper Triassic sponge-bearing boundstone (A) followed upwards by oolitic grainstone (B), Pizzo Marabito. The boundary between the two lithofacies is an erosional surface; *b*) the same facies as above, showing cement (X) filling the space in between sponge elements; *c*) stromatolite lithofacies of the Lower Jurassic peritidal limestones (Inici Fm), intersected by subvertical neptunian dyke (hammer); *d*) oolitic and bioclastic grainstone with benthic foraminifers of the Inici Fm; *e*) wackestone with ammonites, radiolarians, *Aptychus* and thin-shelled fragments of the *Bositra* limestones (lower mb of the Buccheri Fm); *f*) packstone with thick-shelled molluscs, echinoid fragments, benthic foraminifers (*Saccocoma* limestones, upper mb of the Buccheri Fm).

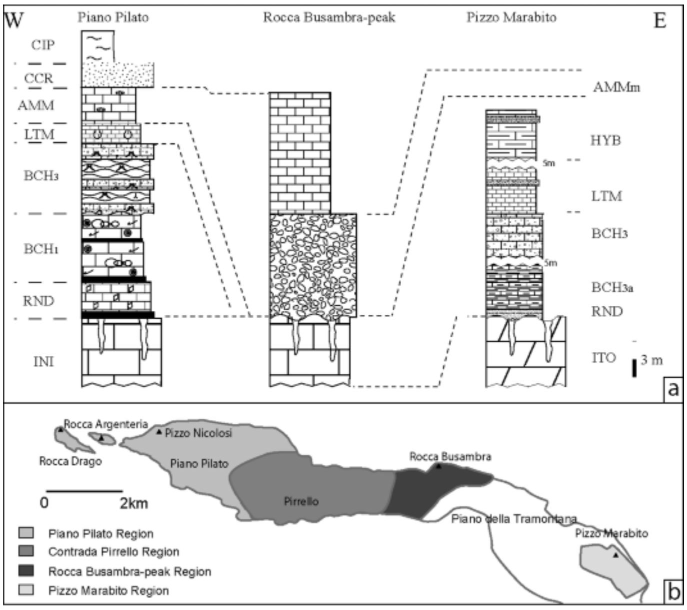

Fig. 9 - a) Stratigraphic sections measured and sampled along the Rocca Busambra ridge. In *b*) detail of the different regions distinguished.

mation for territorial planning purposes. The rocks are grouped in synthems (UBSU, *sensu* SALVADOR, 1994), as recently described by DI MAGGIO *et alii* (2009).

Continental and alluvial deposits, originated from the last postglacial phase, are grouped in the Capo Plaia synthem.

The synthem encompasses: *a*) scree and debris flow outcropping along the foot of the carbonate massifs (AFLa on the map); *b*) eluvial products and colluvial deposits, consisting of heterometric clasts, welded in a clayey matrix (AFLb on the map); these deposits are due to *in situ* alterations of the substrate and to geomorphological side processes; *c*) alluvial deposits, consisting of clays, sands and pebbly grains, outcropping along the rivers or forming terrace deposits (AFLc on the map); *d*) active and quiescent landslides (AFLd on the map), related to rotational and deep-seated gravitational processes, are widely diffused in the study region.

TECTONICS

A structural map (fig. 9 on the frame of the map) and some geological cross-sections (figs. 10, 14 and geological cross-section AA" on the frame of the map) display the tectonic setting of the study area and the geometrical relationships among the mapped rock units. The structural relationships among the tectonic units are recognized also with the help of the published subsurface seismic data. The tectonic edifice includes (from the top): Middle-Upper Miocene syntectonic deposits; Sicilide nappe, that overthrusts the numidian flysch tectonic unit at Cozzo Arcuri (northern edge of the map). The numidian flysch tectonic wedge overthrusts the Sicanian Corleone-Barracù tectonic unit. These units, in turn, tectonically rest above the Trapanese-derived carbonate plat- form Busambra tectonic unit.

When carefully investigated, each one of the main tectonic units displays different structural elements and internal deformations.

1) The syntectonic deposits (Castellana Sicula and Terravecchia Fms), mostly outcropping in the southwestern corner of the map, are deformed by successive folds and, mainly, by NE-SW to NW-SE oriented strike slip and normal faults. The geological sections across the area (fig 10a and geological cross-section AA" on the frame of the map) show how the deposits, mapped north of the Rocca Busambra ridge, unconformably seal the Sicilide and numidian flysch rock bodies; while, the deposits mapped at Vallone del Poggio-Cozzo Riddocco (south of Rocca Busambra) unconformably lie above the Middle Miocene Sicanian deposits.

2) The large, thick numidian flysch tectonic unit (from now on named the NFU unit), overthrusts, along a nearly flat surface, the Miocene San Cipirello marls and «Corleone calcarenites» of the Sicanian Corleone-Barracù tectonic unit, as shown in the Pirrello and Lavanche regions (to the south of Rocca Busambra), at Cozzo Zuccarone, at Tagliavia, Bifarera (original tectonic window) and at Scalilli (north-western corner of the map). At Casale (immediately south of Piano Pilato), Puntale l'Ape and at Cozzo Tondo (northern side of the Rocca Busambra-peak) the unit, tectonically, rests above the Upper Triassic Mufara Fm folded beds (geological cross-section AA" on the frame of the map and fig. 10d). In the Bosco della Ficuzza region, the NFU unit displays large (decametric wavelength) NW-SE-oriented folds, back-verging NEwards (fig. 10b). NE-SW-oriented strike-slip faults, related to a southwest-verging fold-system, dissect the quartz-sandstone numidian flysch intercalations at Cozzo Donna Giacoma and at Bosco della Ficuzza.

3) The Corleone-Barracù tectonic unit (from now on named the CBU unit) is mapped: *a*) at Contrada Bifarera (northwestern corner of the map), along the Cozzo Zuccarone structure and around the town of Corleone, where it is represented by Oligo-Miocene carbonate-clastic rocks; *b*) at Piano della Tramontana-Pizzo di Casa and Monte Barracù, where the unit is made of thick, and strongly deformed, Cretaceous-to-Lower Oligocene pelagic limestones and *c*) along the steep scarps of the Rocca Busambra ridge, where only scattered patches of the Mufara Fm, tectonically overlying the Miocene San Cipirrello marls, are present.

At Contrada Bifarera the Sicanian rocks are thrust, along high-angle reverse faults, over the already emplaced numidian flysch tectonic unit (fig. 10a).

The main setting of the CBU unit, characterized by asymmetric folds, internal low-angle reverse faults and décollement surfaces, is outlined by two culminations:

i) the Cozzo Zuccarone is an E-W and WNW-ESE oriented antiform with narrow and asymmetric south-verging folds (geological cross-section AA" on the frame of the map and fig. 10a); the structure is evidenced by the occurrence of the carbonate «Corleone calcarenites» layer, sandwiched by two marly clay levels (Cardellia marls and San Cipirrello marls). The antiform is also dissected by NW-SE right-handed strike-slip faults, oblique to the major fold hinges. Locally (Cozzo Spolentino), low angle thrust planes imbricate the Oligocene-Miocene clastic-carbonate sequence, showing splay geometries (fig. 10c). This tectonics confirm that the Oligo-Miocene clastic sequence appears wholly detached from the underlying Amerillo Fm substrate (figs. 10a-c).

ii) Piano della Tramontana is a W-E and WNW-ESE oriented antiform with hectometric wavelength (fig. 11).

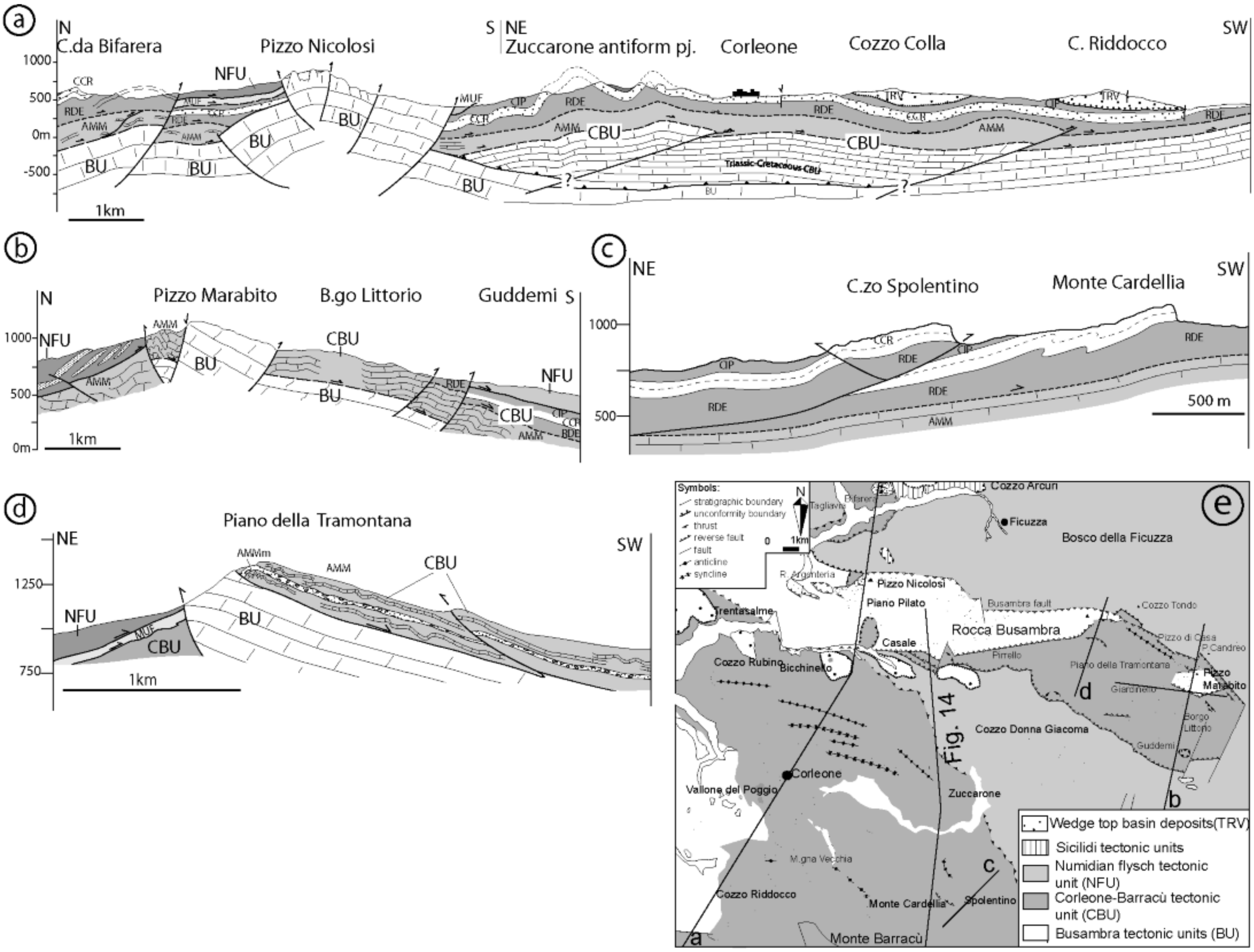

Fig. 10 - Tectonic relationships among the outcropping structural units in the study region. The Trapanese Busambra carbonate platform tectonic unit (BU) is the lowermost structural level of the tectonic edifice. This unit, in its turn, is overthrust, along low-angle tectonic surfaces, by the Sicanian Corleone-Barracù (CBU) and numidian flysch (NFU) tectonic units. The present-day structural setting is due to the deep-seated high-angle reverse faults with lateral component of movement. Traces of the *a*, *b*, *c*, *d* and of fig. 14 geological cross-sections are located in the structural map (*e*).

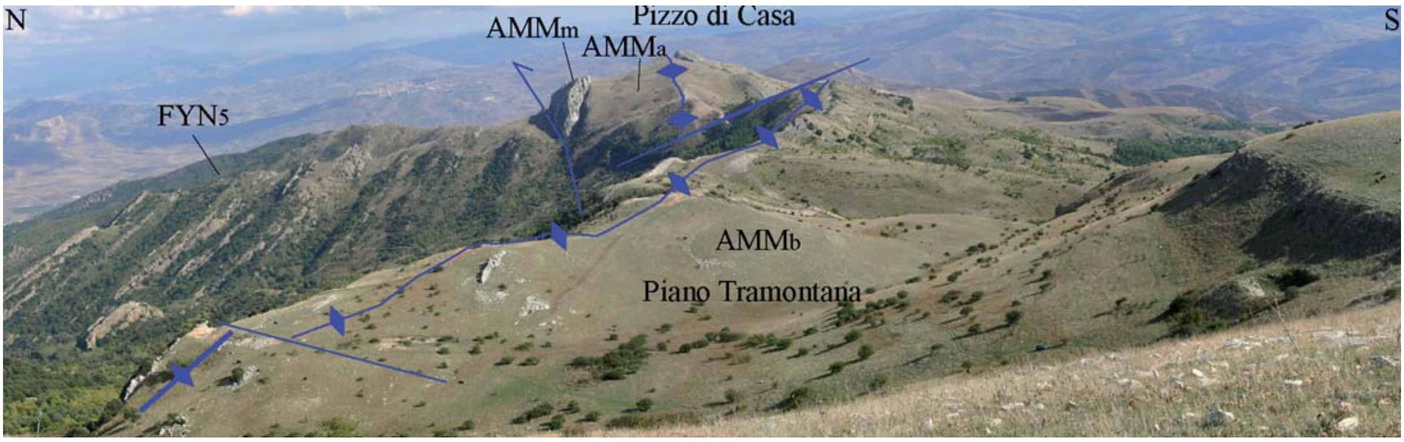

Fig. 11 - Piano della Tramontana antiform, eastern side of Rocca Busambra. It is possible to see the tectonic contact between the Pizzo di Casa Sicanian deposits (AMMm: calcareous megabreccias, AMMa red scaglia and AMMb white Scaglia of the Amerillo Fm) with the numidian flysch (Geraci Siculo mb, FYN_5). At Piano della Tramontana the ENE-WSW oriented anticline is displaced by NS faults.

Fig. 12 - South-verging chevron folds and reverse faults in the pelagic Amerillo Fm at Pizzo di Casa (eastern side of Rocca Busambra ridge).

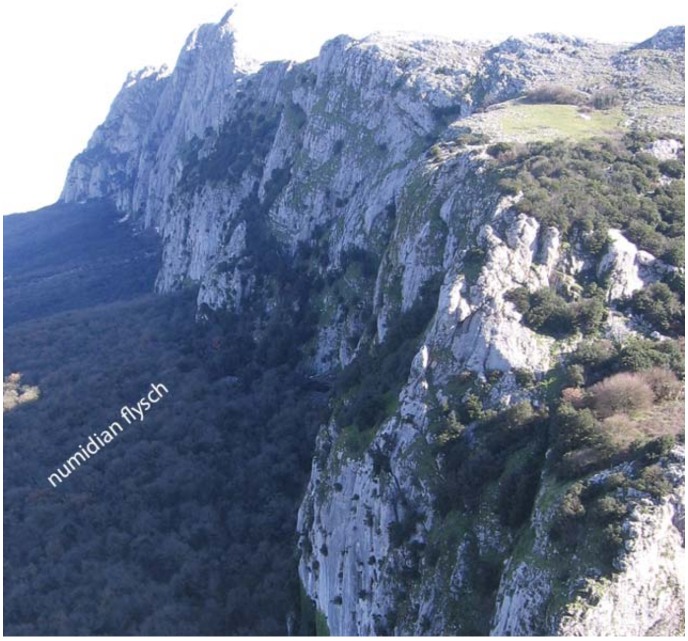

Fig. 13 - Morphostructural scarp of the Busambra high-angle reverse fault, along which the carbonate unit overthrusts the numidian flysch tectonic unit. Northern side of Rocca Busambra.

The core of the major anticline displays a south-verging narrow fold-system of chevron and box-fold type, further displaced by south-verging low-angle reverse faults (fig. 12). Disharmonic surfaces separate the more ductile upper Mesozoic-Paleogene strata from the lower Mesozoic deep-water limestones (mainly Scillato Fm). The antiform is bounded northwards by a transpressional high-angle back-thrust that downthrows the numidian flysch wedge with respect to the pelagic limestones (fig. 11). Westwards (near the Rocca Busambra-peak), the previously-mentioned Piano della Tramontana antiform overthrusts the Busambra tectonic unit, as evidenced by the periclinalic culmination of the folded Sicanian thin-bedded limestones (fig. 10d).

4) The Busambra tectonic unit (from now on named the BU unit) develops along the Pizzo Nicolosi-Pizzo Marabito ridge as an E-W to NW-SE trending large carbonate antiform. The structure is bounded northward and southward by E-W and WNW-ESE high-angle reverse faults, which separate the carbonate platform unit from the adjacent numidian flysch and Sicanian units (figs. 10a, b, d and fig. 6 on the frame of the map). Eastwards the unit disappears beneath the Sicanian Cretaceous-Lower Oligocene pelagic limestones outcropping at Piano della Tramontana. At Pizzo Marabito the carbonate structure plunges to the east disappearing beneath the numidian flysch unit.

The main tectonic lineaments mapped along the Busambra unit are:

– WNW-ESE and NW-SE syndepositional extensional-to-transtensional faults and fractures (Catalano & D'Argenio, 1982b; Basilone *et alii*, 2010) dissecting the Mesozoic carbonates at different stratigraphic levels (figs. 4-8 on the frame of the map);

– large N-S and NNW-SSE oriented structures folding the Mesozoic limestones.

– E-W to NW-SE transpressional, high-angle fault, characterized by several hundreds of metres of downthrow, associated to vertical fault line scarps (Busambra fault, fig. 13). The south-dipping fault planes display kinematic indicators, suggesting dextral movements along the fault planes (Catalano *et alii*, 2010a, b).

– WNW-ESE, W-E and WSW-ENE striking and southward-verging, high-angle thrust faults characterize the southern side of Rocca Busambra (fig. 10a and fig. 6 on the frame of the map);

– NS and NNE-SSW oblique faults with left-lateral component of motion (tear faults?), dipping to the E and

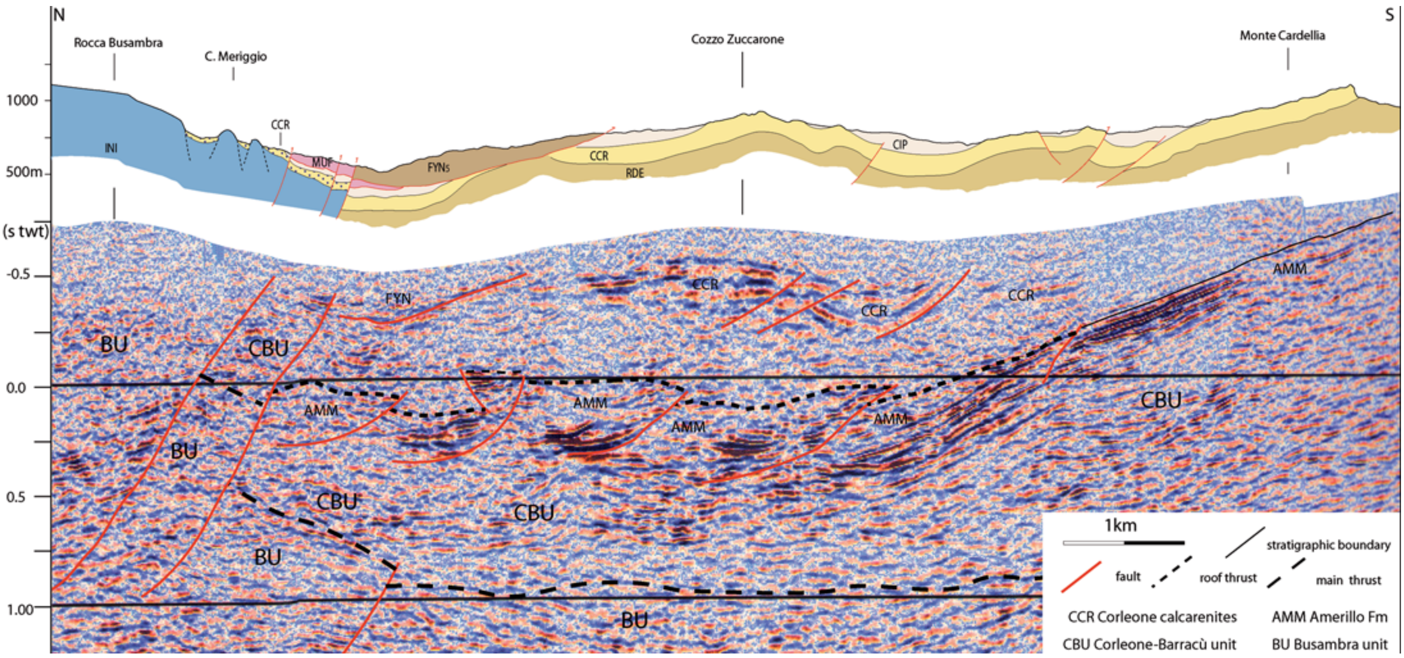

Fig. 14 - a) The seismic profile across the Rocca Busambra-Monte Cardellia area (see trace in fig. 10a) shows the structural relationships between the Trapanese carbonate platform Busambra unit (BU) and the deep-water Sicanian Corleone-Barracù unit (CBU); *b*) The geological section, crossing the same area, shows the surface interpretation of the topmost part of the seismic profile.

ESE, dissect the central and eastern sectors of the ridge. These faults are antithetic to the main dextral transpressional E-W system.

– SW dipping, NW-SE trending normal faults displace the ridge structure, mostly in its westernmost sector.

DISCUSSIONS

The recognized surface structural setting is consistent with the buried structure reconstructed in the study region (fig. 14) according to geological interpretations of the seismic profiles crossing the area.

Comparing these interpretations provides a better understanding of: 1) the structural setting and the backthrust structures of the Rocca Busambra, 2) its paleotectonic evolution, 3) the deformation style of the Sicanian units and 4) the relationships between the Upper Miocene wedge-top basins deposits and the deformed substrate.

1) The Busambra unit, as described in this paper, is the culmination of a larger anticline, bordered by two, main transpressive faults of a south-verging ramp structure (figs. 10a and 14 and geological cross-section AA” on the frame of the map). The E-W high-angle back-verging reverse fault (Busambra fault, figs. 10a and 13), which gradually flattens with depth (see seismic interpretations by Agate *et alii*, 1998a; Catalano *et alii*, 2000 and Albanese *et alii*, 2005), might be considered as a deep-seated structures.

The resulting structural setting is different compared to the previous interpretations: Mascle (1979) described the BU unit as a sedimentary klippen resedimented in the Miocene marls basin. Catalano *et alii* (1978), Roure *et alii* (1990), Lentini *et alii* (1994), Monaco *et alii* (2000) interpreted the carbonate platform Busambra tectonic unit as primarily overthrusting the Sicanian rock units. However, Agate *et alii* (1998a) and Catalano *et alii* (2000), described the Sicanian units as overthrusting the Trapanese Busambra unit, based on seismic profiles interpretation. The local setting of the Trapanese rock units above the Sicanian ones is a late effect of the structural «envelopment» (out of sequence) between the two rock units.

The previously-mentioned transpressional Busambra fault was described as a normal fault (Roure *et alii*, 1990), or a deep strike-slip fault (Monaco *et alii*, 2000), or a deep-seated positive flower structure in the frame of the main strike-slip tectonics (Nigro & Renda, 2001).

2) In the Rocca Busambra ridge the Mesozoic synsedimentary tectonics and the restored depositional setting suggest the occurrence of a stepped fault margin with condensed sequences (Piano Pilato), passing to a horst and graben system (Pizzo Nicolosi) and to slope areas (Pizzo Marabito). The latter are characterized by a scalloped upper slope passing to a base-of-slope environment (Rocca Busambra-peak).

To consider the Piano Pilato stepped margin as the slope margin of the Barracù Sicanian basin (as proposed by Martire & Bertok, 2002 and Bertok & Martire, 2009) appears difficult due to the structural setting discussed above (the Sicanian units regionally overthrust the Trapanese carbonate platform rock units, see also Basilone, 2009).

The Mesozoic faults are reactivated by the deep-seated transpressional structures, as proved by mesostructural analyses carried out along the Rocca Busambra ridge (BASILONE *et alii*, 2010). The latter show how the faults involving the Mesozoic deposits display the same trend of the Late Tertiary reverse faults crossing the mapped area. Similar features are described in adjacent regions (e.g. Kumeta ridge, AVELLONE *et alii*, 2010).

3) The S- and SW-wards vergent Sicanian Corleone-Barracù tectonic unit is, on the whole, thrust over the carbonate Busambra tectonic unit along a partly buried low-angle surface (figs. 10a and 14a). Based on the field observation and on the seismic profile interpretation (fig. 14), a duplex geometry of the tectonic unit is pointed out. The duplex tectonic style of the CBU is in agreement with similar features described in the eastern Sicanian Mountains (VITALE & GIAMBRONE, 1995; VITALE, 1996; CATALANO *et alii*, 1996).

The detachment surfaces, within the deep-water Sicanian succession, disconnect the more ductile upper Mesozoic-Paleogene strata from the lower Mesozoic deep-water limestones. As a consequence, uncoupled levels of the CBU unit overlie the main thrust surface above the BU unit (as it is possible to observe in the geological map, along the southern limb of the Rocca Busambra ridge and in fig. 10d).

The originally flat thrust surface and the local décollements are, at present-day, tilted and deformed according to the late deformation of the carbonate platform substrate.

In detail, both the Oligo-Miocene roof thrust and the Cretaceous-Eocene horses were later redeformed giving rise to the main E-W and WNW-ESE plicative structures such as the splay structures (Cozzo Spolentino, fig. 10c), and the associated fold systems (e.g. Cozzo Zuccarone antiform, fig. 14 and Piano della Tramontana antiform).

4) The Middle-Upper Miocene deposits (Castellana Sicula and Terravecchia Fms) are believed to be deposited in a wedge-top depozone (CATALANO & D'ARGENIO, 1990; BUTLER & GRASSO, 1993). The mapped outcrops overlie different substrata and are characterized by lithological differences (nature of the conglomerates). These features demonstrate that these deposits were formed in separated basins, originally faraway from each other and respect to the present-day location, with different source areas of the clastic materials.

Timing of deformation

The tectonic edifice in the study area is the result of several deformational events, from the Triassic to the Pleistocene. These have deformed the sedimentary successions that settled along the African continental margin paleogeographic zone. The timing of the deformation is constrained by the age of the foredeep basins and the first unconformable deposits.

Preorogenic phase

During the Mesozoic-Early Miocene continental margin phase, synsedimentary tectonics accompany depositions in carbonate platform-basin systems. It is clearly put in evidence by both the syntectonic deposition along the Trapanese carbonate platform Rocca Busambra succession and the sudden thickness variations of the outcropping Sicanian succession.

Postcollisional phase

This phase started with the continental margin deformation, following the latest Oligocene-Early Miocene counter-clockwise rotation of Corsica-Sardinia and its collision with the African margin. During the collision time two main tectonic events occur. The older documented deformation relates to the emplacement of the Sicilidi units above the Lower Miocene numidian flysch. The latter is, at present time, stacked above Lower Tortonian marls, representing the top of the Sicanian Units. There is a large consensus about the decoupling of the numidian flysch from its Imerese (or more internal) Meso-Cenozoic carbonate substrate. Both the Imerese units and the already detached numidian flysch units were emplaced above the Sicanian units after the Early Tortonian (figs. 1 and 2 on the frame of the map and MASCLE, 1979; CATALANO & D'ARGENIO, 1978; ROURE *et alii*, 1990). The deep-sea rock bodies of the Sicanian domain appear thrust over the Lower Tortonian marls pertaining to the carbonate platform Trapanese Busambra succession. The latter appear involved in the deformation after the Sicanian units emplacement, as put in evidence by the already described local thrusting of the carbonate platform Busambra rock unit over the Sicanian Barracù tectonic unit. The Sicanian rock units appear redeformed, after the Miocene early tectonic event, as put in evidence by different orientation trends of the fold systems. This second plicative event caused the deformation of the Messinian-Lower Pliocene deposits, as shown in the surroundings of the study region, and took place in the Late Pliocene. More recent extensional tectonics (Early Quaternary times in western Sicily) are not clearly discernible in the area.

CONCLUSIONS

The geological map (1:37.500 scale) of the Rocca Busambra-Corleone region (central-western Sicily) is presented here, based on facies analysis, physical stratigraphy, biostratigraphy and structural analysis. The map, originally compiled at a 1:10,000 scale, represents a new approach to the geology of the region.

A detailed mapping and the stratigraphy illustrate the several outcropping lithostratigraphic units (more than 22 formations and members), some proposed type sections and the characters of the Piano della Tramontana (eastern side of the Rocca Busambra ridge) deposits as pertaining to the Sicanian succession.

The mesoscopic and large-scale structural analysis depicts a tectonic setting comparable with subsurface geometries (suggested by seismic data). The collected data restore a tectono-sedimentary evolution from Mesozoic extensional rifting-phase to Late Tertiary compressive belt deformation:

– extensional-to-transtensional Mesozoic-Lower Miocene tectonic pulses have punctuated the tectono-sedimentary evolution of the Rocca Busambra area;

– thin-skinned tectonics (shallow-seated structures) have developed with duplex and embricate fan geometry of the Sicanian deep-water carbonate and numidian flysch tectonic units. These units have progressively overthrust the Trapanese carbonate platform Busambra unit during the Late Miocene;

– deep-seated structures originated from a transpressional Pliocene tectonic event have deformed the Busambra unit at a depth. The late tectonics involve the already emplaced units (Sicilidi, numidian flysch and Sicanian units), that, in turn, are passively bent and redeformed.

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