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Permian-Cenozoic deep-water carbonate rocks of the Southern Tethyan Domain. The case of Central Sicily

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Abstract

We present an integrated stratigraphy of the outcropping and buried Permian-Cenozoic deep-water carbonate successions, forming some of the tectonic units mostly buried beneath the Late Neogene sedimentary cover in the fold and thrust belt of Central Sicily.

Three main successions, pertaining to the well known Lercara, Imerese and Sicanian domains, have been reconstructed on the basis of a detailed facies analysis, seismostratigraphic interpretation, biostratigraphy (mostly based on palynological data) and comparison between outcropping and subsurface deep-water sediments.

The main results reveal a continuous sedimentation of the deep-water Southern Tethyan Sicilian succession since the Permian to Cenozoic. In detail: a) the Permian-Middle Triassic terrigenous and carbonate deep-water successions, outcropping or buried in the Cerda, Lercara-Roccapalumba and Sosio Valley regions, are well comparable to each other and represent the common substrate of the Mesozoic-Paleogene Imerese and Sicanian carbonate successions; b) the Mesozoic-Paleogene deep-water carbonates, when compared among them, reveal the occurrence of different sedimentary successions (Imerese and Sicanian); c) the Oligo-Miocene foreland basin terrigenous sediments (Numidian flysch) clearly differ from the coeval foreland pelagic to open-shelf carbonates.

The paleogeographic reconstruction envisages: a) during the Permian-Triassic, a wide subsident continental rifting area, bordered by a shallow-water domain periodically supplying the basin with calciturbiditic to gravity flows sedimentation (rift stage of the Southern Tethyan margin); b) during the Jurassic-Paleogene, two different deep-water basins developed in a context of a post-rift stage. The different sedimentation reflects the location of the Imerese and Sicanian basins, respectively, along adjacent rimmed shelf and stepped carbonate platform margins.

Key words: Permian-Cenozoic stratigraphy, deep-water carbonates, surface and well-log data, seismic calibration, Central Sicily

1. Introduction

A synthesis of the surface and subsurface geological history of Sicily has documented, in the last decades, that a Permian/Mesozoic to Cenozoic mostly carbonate platform and deep-water rocks are now exposed as allochtonous units within the Sicily Fold and Thrust Belt (Figs. 1, 2; see also CATALANO & D'ARGENIO, 1978; BIANCHI *et alii*, 1989; OLDOW *et alii*, 1990; ROURE *et alii*, 1990; CASERO & ROURE, 1994; LENTINI *et alii*, 1994; CATALANO *et alii*, 1996; 2000; NIGRO & RENDA, 1999; 2002; BELLO *et alii*, 2000; GRANATH & CASERO, 2004; FINETTI *et alii*, 2005). The Permian-Mesozoic carbonate tectonic rock units derive from the Miocene to lower Pleistocene contractional deformation of the sedimentary successions developed on the Southern margin of the Tethyan realm.

In the past, Sicily has been analysed by several stratigraphic studies (facies analysis and physical stratigraphy, accompanied by biostratigraphy) of its carbonate rocks, fair to well exposed in the Permian to Cenozoic successions. The results brought to separate shallow and deep-water sediments deposited in the so-called carbonate platform (shelf) and deep-water domains (the carbonate platform-basin systems, CATALANO *et alii*, 1976; 1996; SCANDONE *et alii*, 1977; DI STEFANO, 2002 among others).

Some detailed biostratigraphic and sedimentological studies were dedicated to the Permian to Mesozoic deep-water deposits outcropping in Sicily (BROQUET, 1968; SCANDONE *et alii*, 1972; MASCLE, 1979; CATALANO & D'ARGENIO (eds.), 1982; DI STEFANO *et alii*, 1996). Based on their depositional characters some of these deposits were assigned to the so-called Permian-Middle Triassic Lercara basin, and to the Mesozoic-Paleogene Imerese and Sicanian basins. Among them, the debated Permian-Middle Triassic outcropping rocks (MONTANARI, 1968; MASCLE, 1979), including the famous "Sosio limestones" (GEMMELLARO, 1887-1899), have been the object of several important studies over the past century mostly aimed at defining their paleontological content (see quotations in MASCLE, 1979 and FLÜGEL *et alii*, 1991). These rocks were locally named Lercara Complex to describe and to map the strongly deformed Permian-Middle Triassic outcropping deposits (CATALANO *et alii*, 2010a, b, 2011).

Recently, detailed facies analyses (CATALANO *et alii*, 1988; 1991, FLÜGEL *et alii*, 1991; KOZUR, 1993; DI STEFANO & GULLO, 1997) allowed new paleogeographic reconstructions on the Permian-Mesozoic evolution and the suggested spreading of the Neotethys in the Ionian Sea (CATALANO *et alii*, 2001; VAI, 2001; STAMPFLI & BOREL, 2002, 2004; ROBERTSON, 2006; HANDY *et alii*, 2010).

Referring to the Southern margin of the Tethys realm it appears useful to mention, for the aims of this study, its long debated distinction in two different domains: the Alpine Tethys occurring in the western side and the Neotethys in the eastern side. The latter is believed either to have been formed synchronously (from Oman towards the Ionian Sea) during the Permian (STAMPFLI *et alii*, 2001) or to have extended progressively during the Late Permian-Early Mesozoic time interval in the eastern Mediterranean towards the Ionian Sea, as a late secondary branch (ROBERTSON, 2006; FRIZON DE LAMOTTE *et alii*, 2011).

In either scenario Sicily could belong to the passive margin of the Permian ocean (STAMPFLI & BOREL, 2002) or to a Permian continental rift (CATALANO *et alii*, 1991), extending in a strip connecting Sicily to the Jeffara (Tunisia) zone. The Sicilian domains were connected eastward to the Neotethys branch since the early Mesozoic. During this period a wide carbonate platform (including Panormide, Trapanese-Saccense and Iblean) was flanked to the (present-day) ENE by a deep-water (including Imerese and Sicanian) basin. During the Jurassic, to the east of Sicily, the Ionian Ocean spreaded out in the wake of the northward drifting Adriatic Plate (CATALANO *et alii*, 2001, 2014 and references thereinafter).

Unlike the previous investigations, which yielded several data for wide areas of Sicily, the region here proposed for the study, located in Central Sicily (Fig. 2), resulted as being poorly known in both stratigraphy and structural setting of the deep-water carbonate thrust units, locally hided by a complex stack of the Numidian flysch and Sicilidi thrust nappes, associated with the

Late Neogene deformed wedge-top basins (GUGLIOTTA *et alii*, 2014; GASPARO MORTICELLI *et alii*, 2015).

New field studies (see also the results of the recent geological mapping of the CARG project, CATALANO *et alii*, 2010a, b, 2011) integrated with seismostratigraphic analysis of the available seismic lines and the analysis of many informative core samples from several drilled boreholes that have reached the buried rock bodies in the study area, were essential to compare subsurface and outcropping Permian to Mesozoic deep-water rocks.

Main aim of the present paper is to provide a detailed description of the sedimentologic, lithostratigraphic and biostratigraphic characteristics of the lithologies both encountered by the boreholes and sampled along the field sections, integrating the previous regional stratigraphic knowledge. These results were helpful i) to restore a complete Permian-Cenozoic stratigraphic scheme, with details for the Permian-Triassic deposits and ii) to improve our knowledge about paleoenvironmental condition and paleogeographic evolution of the Permian-Mesozoic deposits in Central Sicily.

2. Regional geological setting

Sicily, located in the central Mediterranean, links the African Maghrebides with the Apennines across the Calabrian accretionary wedge (Fig. 1) and is considered a segment of the Alpine collisional belt, described as a result of both post-collisional convergence between Africa and Europe and roll-back of the subduction hinge of the Ionian lithosphere (CATALANO *et alii*, 2013b and references thereinafter).

Sicily is a thick orogenic wedge formed by the following structural defined elements (inset in Fig. 2):

a) a foreland area, cropping out in south-eastern Sicily (Iblean Plateau) and also submerged in the Pelagian Sea;

b) a narrow NW-dipping recent foredeep, weakly deformed and partly buried on land and in the offshore Gela Basin;

c) a Fold and Thrust Belt (FTB) consisting of a complex stack of S- and SE-verging thrust imbricate systems, locally more than 20 km-thick, formed from the top by an "European" element (Calabrian thrust units), a "Tethyan" element (Sicilidi thrust units) and an African element (Sicilian thrust units) (CATALANO & D'ARGENIO, 1982; ROURE *et alii*, 1990; LENTINI *et alii*, 1994; CATALANO *et alii*, 1996, 2013b ; BELLO *et alii*, 2000; FINETTI *et alii*, 2005).

The Sicilian units are a stack, both of Mesozoic-Paleogene deep-water carbonates and carbonate platform thrust wedge, which is detached from its crystalline basement (CATALANO *et alii*, 2013b and references thereinafter). In the Sicilian FTB two main tectonic events are envisaged: shallow- and deep-seated thrusts (ROURE *et alii*, 1990; OLDOW *et alii*, 1990; AVELLONE *et alii*, 2010) occurred, respectively, during the Miocene and Late Pliocene-Early Pleistocene time intervals (CATALANO *et alii*, 1996, 2000; BELLO *et alii*, 2000).

The simplified structural map of Fig. 2 shows the surface distribution of the main tectono/stratigraphic units (stratigraphic successions) in Sicily. The stratigraphic and sedimentary characteristics of the different rock bodies exposed within the Sicilian orogen are briefly summarized in the synopsis of Fig. 3.

3. Study area

The study area, a sector of the previously described Sicilian FTB (Fig. 2), is comprised of the carbonate stack complex of the Termini Imerese and Madonie Mts and, to the south, the eastern side of the Sicani Mts (Sicanian thrust wedge) and the western "Caltanissetta basin".

The outcropping rocks, as represented in the large-scale field map of Fig. 4a, and their structural setting (see Figs. 4b, c) are schematically illustrated hereafter:

a) a northernmost sector (see Fig. 4d) that shows the occurrence of NW-SE-trending ramp anticlines (CATALANO *et alii*, 2011), involving deep-water Meso-Cenozoic rocks (Imerese units) and their Numidian flysch cover;

b) a central-western sector (Lercara-Roccapalumba region, Fig. 4d) displaying a wedge stack of Permian to Middle Triassic siliceous turbidites, deep-water limestones and reef-derived resedimented carbonates, locally tectonically mixed with the Mufara Fm marly limestones (Carnian in age);

c) a central sector in the Valledolmo-Alia region (Fig. 4d) which shows the Sicilidi and Numidian flysch nappes that extend south-eastwards in subsurface in the "Caltanissetta basin". This allochtonous thick wedge overthrusts, locally, both the Permian-Triassic and the Mesozoic carbonate (Imerese and Sicanian) units (Figs. 4a, b);

d) a south-westernmost sector (including the eastern side of the Sicanian thrust system in the Sicani Mts, Figs. 4d), that displays (Fig. 4a): i) a thrust stack of Sicanian (Cammarata) units overthrust by ii) a minor tectonic unit (La Montagnola). This unit has been also recognized in subsurface (AVELLONE *et alii*, 2013), where it appears to overthrust the buried easterly extension of the previously mentioned Sicanian (Cammarata) thrust stack (Fig. 4c). The Jurassic-Miocene deep-water to slope deposits outcropping at La Montagnola are here believed as pertaining to the Imerese succession (see also BASILONE *et alii*, 2013b);

e) a south-easternmost sector (Fig. 4d) that displays Miocene-Pliocene clastic, evaporitic and carbonate deposits, filling wedge-top basins coeval to the Late Neogene thrust stacking.

4. Materials and methods

This study was mostly carried out by the analysis of several boreholes (Avanella 1, 3051m TD; Bivona 3, 2650m TD; Castellana 1, 1076m TD; Casteltermini 1, 5710m TD; Colla 1, 2238m TD; Creta 1, 3203m TD; Lercara 1 (Agip), 1483.2m TD; Lercara Friddi 1, 610.8m TD; Platani 2, 3378.5m TD; Roccapalumba 1, 2707m TD; Valledolmo 1, 3197.3m TD), located within the region. The data achieved from the core samples were compared and integrated with those yielded by the samples collected from some field sections scattered in the study area at Monte dei Cervi, Sclafani Bagni, La Montagnola (Imerese type sections) and at Cammarata and Barracù Mts. (type sections of the Sicanian domain, see Figs. 2, 4a).

Borehole stratigraphy has been carried out in cooperation with Eni e&p. Lithologic logs, ditch cutting and cores, available thin sections (more than 1000 samples), synthetic records (sonic and gamma ray, synthetic seismogram) and time-depth conversion of lithological data from boreholes, following some of the methodologies applied by PATACCA (2007) in Southern Apennines, were used for the lithostratigraphic analysis of the investigated successions.

The dating and correlations of some lithostratigraphic units were mostly based on the palynomorphs biozonation (see also FRIXA & TRINCIANTI, 2006; TRINCIANTI *et alii*, in press), which appears as the most useful stratigraphic tool (particularly for the Paleozoic-Lower Mesozoic deposits) to constrain their age. The palynomorph biochronology appears in good agreement with previous datations obtained using radiolarian, conodont and mollusc biostratigraphy (see DE WEVER *et alii*, 1979; DE CAPOA BONARDI, 1984; CATALANO *et alii*, 1988; 1990; KOZUR, 1993; GULLO & KOZUR, 1992; DI STEFANO & GULLO, 1997). Some of the several lithological units recognized were referred to the known Sicilian lithostratigraphic nomenclature, as recently emended and classified (BASILONE, 2012).

The stratigraphic results both of the study field sections and of the lithological logs of some of the several boreholes drilled in the region (Figs. 4a) and their correlation are reported in Fig. 6.

Boreholes and geological data were compared with seismic attributes and reflector pattern of a high-covering industry 2D seismic profiles grid (courtesy of Eni e&p) extending for the study area (Fig. 4e), to depict the structure of the tectonic edifice and generate wide correlations among the interpreted units. Stratigraphic information from boreholes and outcrops, constrained by geophysical data, allow us to identify some groups of lithostratigraphic units and their lateral extension in the region.

Seismostratigraphic analysis was carried out by using check shot data from exploration boreholes to tie the seismic information to well data (Fig. 5). Where the well data was lacking along the seismic lines, we calibrated the shallow seismic data from surface geology and the deeper from seismic facies known in the surrounding areas, where further stratigraphic constraints are present (Fig. 4a). Particular characteristics, such as reflector pattern and seismic attributes (amplitude and frequency of the signal, lateral continuity of the reflectors), were used to define seismic facies. These facies were calibrated by the over-mentioned boreholes and were instrumental in defining a correspondence with the main geological units

5. Data collection and results

Based on the main lithologic and sedimentologic characteristics of the analysed drilled logs and field sections (Figs. 6-8) the several lithologies have been grouped in some lithostratigraphic units, that are described more in detail (Tabb. 1-4) taking in account the results of the facies analysis, biostratigraphy and biochronology. As some of them have shown different characters respect to the lithostratigraphic units mentioned as previously recognized in Sicily, we have informally defined new formations. These are illustrated in the composite frame of Fig. 7. In the next paragraphs the different units here discussed, for sake of clarity, have been framed in some main chronostratigraphic intervals: a) the Permian-Middle Triassic, that include most of the studied rock units, b) the Upper Triassic, c) the Jurassic-Paleogene and d) the Oligo-Miocene intervals.

The biostratigraphy and biochronology (summarized in Tabb. 1-4) and microfacies illustrations (Pls. I-VII) will help the reader through the discussion.

a) *Permian-Middle Triassic interval*

Comparing the materials recovered from the boreholes (Fig. 4a) and from the field sections of the Lercara-Roccapalumba and Sosio Valley regions (Fig. 2), the following formations have been distinguished (see Fig. 7):

Lercara sandstone (labelled LER). Claystones, quartz-micaceous turbiditic sandstones and light-brown calciturbiditic packstone and grainstone (Tab. 1, Figs. 7, 8) with shallow-water derived fragments (fusulinids, *Tubiphytes* sp., dasycladacean algae), recovered at the bottom of the Casteltermini 1 borehole (Fig. 6), are dated Mid-Artinskian to Early Roadian (Early-Middle Permian) on the base of rare microflora (Tab. 1). The equivalent outcropping arenaceous beds display several *Nereites* ichnofacies suggesting a very deep-water depositional environment (more than 2000m of water depth, accordingly to KOZUR *et alii*, 1996).

Roccapalumba clay and siltstone (RCS). Grey-greenish and reddish siltitic clays, marls and pelites (Tab. 1, Fig. 7) rich in conodonts, radiolarians and palynomorphs are alternated with laminated quartz-subfeldspar siltstones and fine sandstones (Figs. A, B in Pl. I). These rocks have been drilled for a few hundred metres in the Casteltermini 1 (Fig. 6) and Lercara Friddi 1 boreholes and for more than 1000m in the Lercara (Agip) 1 and Roccapalumba 1 boreholes. The microflora assemblage (Pl. II and Tab. 1) suggests a Middle-Late Permian age. Grey-green fissural basalts (never known before) are also encountered in the Roccapalumba 1 borehole, as intercalated in these rocks (Fig. C in Pl. I). The above quoted arenaceous intercalations, more frequent and thicker in the upper part of the successions drilled by the Lercara Friddi 1 borehole, also display glauconite, phosphates and pyrite in traces (Fig. D in Pl. I). In the drilled sections, these lithofacies (Tab. 1) are interlayered both to thick reef-derived calcareous breccias rich in fusulinids, spongid and coral fragments (more than 150m in thickness as observed in the Casteltermini 1 borehole) and to thin calcareous skeletal packstone-to-grainstone with rare oolites, calcareous algae (dasycladacean), echinoids, ostracods and mollusc fragments (Figs. E, F in Pl. I). Comparable calcareous breccias have been sampled in the Lercara-Roccapalumba and Sosio Valley field sections, where they occur as isolated blocks (*Sosio limestone*). Sedimentological data suggest for these deposits a slope to deep-water environment characterized by the occurrence of a large turbiditic fan system and slope apron carbonate breccias (see also FLUGEL *et alii*, 1991).

Manganaro clayey limestone (MNG). Siltitic clays, thin-bedded radiolarians and pelagic bivalves bearing-clayey mudstone-wackestone (Figs. A, B in Pl. III) and laminated fine quartz-sandstones (Fig. C in Pl. III) are interlayered with calcareous matrix-supported breccias (Fig. D in Pl. III). These rocks (Tab. 1, Fig. 7) have been encountered in the Roccapalumba 1 borehole, where thin beds of resedimented intra-bioclastic to oolitic grainstone-packstone (Figs. E, F in Pl. III) and recrystallized fossiliferous reddish mudstone also occur. The unit was dated as Lower Triassic on the basis of palynomorph assemblages (Tab. 1).

Daonella limestone (DAO). Laminated mudstone-wackestone (Tab. 1, Fig. 7) with radiolarians, rare sponge spicules and pelagic bivalves (Figs. A-D in Pl. IV), calcareous breccias and fine intra-bioclastic calciturbiditic packstone with ooids, mollusc fragments and calcareous algae (Figs. E, F in Pl. IV), have been drilled for some hundreds of metres in the Platani 2, Casteltermini 1 and Valledolmo 1 boreholes (Fig. 6). Based on their palynological content (see Pl. V, Tab. 1) the described rocks unit is assigned to the Late Anisian/Ladinian-Early Carnian time interval. The pelagic *Daonella limestone* pass upwards into the Carnian pelecypods bearing marly limestones (widely known as Mufara Fm), as revealed by the Platani 2, Casteltermini 1 and Valledolmo 1 boreholes lithostratigraphy (Figs. 6, 7).

b) *Upper Triassic interval*

Mufara Formation (MUF). Radiolarians and pelagic pelecypods (Figs. A in Pl. VI) bearing claystone/calcareous mudstone couplets (Tab. 2, Fig. 7) and thin oolitic grainstone and skeletal packstone (Fig. B in Pl. VI) intercalations, sampled at Cammarata Mt. section (Fig. 8a) and drilled by the Platani 2 for about 400m (Fig. 6), are dated as Julian-Tuvalian on the basis of their palynomorphs content (Tab. 2). In the Valledolmo 1 borehole and along the Monte dei Cervi (Madonie) section, the same pelagic lithologies are repeatedly alternated to thick reef-derived carbonate breccias. Basaltic lava fragments found in the boreholes could be compared with the volcanic rocks, frequently occurring in the outcropping Mufara Fm. These features have been also interpreted as fractures filling ultrabasic dykes (VIANELLI, 1970); their controversial interpretation and debated age have been recently discussed by CIRRINCIONE *et alii* (2014).

Scillato Formation (SCT). This is a monotonous more than 500m-thick pelagic cherty limestone succession (Tab. 2, Figs. 6, 7, 8a, b, c), consisting of radiolarians and pelagic bivalves-bearing mudstone-wackestone (Fig. C in Pl. VI). The Formation is dated as Upper Carnian-Rhaetian (see Tab. 2). Thick-bedded resedimented calcareous breccia and calcarenite intercalations, found in the uppermost portion of the Monte dei Cervi field section (Fig. 8c) are compared with the Upper Triassic shallow-water derived breccias (Fig. D in Pl. VI) of the Creta 1 borehole (Fig. 6). Conversely, the coeval breccias sampled along the Cammarata Mt. (Fig. 8a) and Barracù Mt. field sections and recovered from the Platani 2 borehole (Fig. 6), are mostly made of calcilutite fragments (removed from the same cherty limestones, Figs. E, F in Pl. VI, see also DI STEFANO *et alii*, 1996). Besides, cherty limestones, interlayered with thick Norian-Rhaetian varicoloured marls and black shales (*Bivona* facies, Tab. 2), have been drilled by the Bivona 3 borehole, pointing out the extreme facies variability of these lithologies.

c) *Jurassic-Paleogene interval*

The Jurassic-Paleogene chronostratigraphic interval displays two coeval successions, each one characterized by different lithostratigraphic units. The first, reconstructed from the sections drilled and outcropping in the northernmost studied area (Madonie-Termini Imerese region, Fig. 4d), consists, from the bottom, of:

Fanusi Formation (FUN). The dolomitized rocks (Tab. 3a), recovered in the Colla 1 borehole (Fig. 6), are lithologically comparable to the white vacuolar and poorly sorted dolomitized breccias (up to 300m-thick) sampled along the Monte dei Cervi and Sclafani Bagni field sections (Figs. 8b, c). An "Infraliassic" age is commonly indicated on the basis of its stratigraphic position, as the unit is included between the Upper Triassic cherty limestones (SCT) and the Lower Jurassic (middle Liassic) crinoidal limestones. A base of slope apron sedimentation is suggested (BASILONE, 2009)

Altofonte breccias (ALT). Graded channelized breccias rich in reef-deriving fragments and laminated bio-intraclastic packstone (Figs. A-D in Pl. VII), Late Sinemurian-Pliensbachian in age (see BARTOLINI *et alii*, 2002), are interlayered with reddish to yellowish crinoidal calcarenites and marls (*Crinoidal limestones*, MCD). These lithofacies (Tab. 3a), underlain by dark clayey marls, have been found both in the Creta 1 borehole (Fig. 6) and in the Monte dei Cervi and Sclafani Bagni field sections, where the unit unconformably overlies the Fanusi Fm (Figs. 8b, c). Conversely, the coeval dolomitized calcareous breccias found in the Avanella 1 (Fig. 6) and Valledolmo 1 boreholes, where the elements are mainly deep-water cherty limestone pebbles, unconformably overlies the Upper Triassic Scillato Fm. Sedimentological data for these deposits suggest debris flow processes acting along a slope-to-base of slope depositional environment.

Crisanti Formation (CRI). Dark and reddish radiolarites, bedded cherts and siliceous mudstones alternated with very thick wedge of resedimented shallow-water calcareous breccias, conglomerates and turbiditic litho-bioclastic grainstone-packstone (Tab. 3a), were recovered by several boreholes and sampled along the La Montagnola, Monte dei Cervi and Sclafani Bagni field sections (Figs. 6, 8b). The formation, widely believed to be Middle Jurassic-Upper Cretaceous in age, consists of four members (see Tab. 3a), bounded among them by onlapping and erosional unconformity surfaces (Fig. 8b). Sedimentological data suggest a very deep-water depositional environment for the chert lithologies (more than 2000m of water depth and below the CCD, MCBRIDE & FOLK, 1979).

Caltavuturo Formation (CAL). The darkish red clays, green marly clays and red brick wackestone (Paleocene-Eocene in age), with thin-bedded oolitic grainstone and bioclastic packstone (Tab. 3a), encountered in the Avanella 1 borehole are correlatable with the greyish marls and marly limestones observed at La Montagnola field section (Fig. 6). In outcrop, the Middle-Upper Eocene thick intercalations of graded and laminated nummulitid-bearing grainstone-rudstone (*Nummulitid breccias,* Tab. 3a) are followed upwards by the Lower Oligocene darkish and greenish marls with *Lepidocyclina*-bearing packstone (Tab. 3a). The latter are correlatable with the coeval blackish clays alternated with corallinaceous algae-bearing packstone, found in the boreholes.

The Jurassic-Paleogene succession, reconstructed from the sections drilled and outcropping in the south easternmost studied area (Cammarata region, Fig. 4d), consists, from the bottom, of:

Oolitic calcarenite (OOL). The few metres-thick resedimented oolitic grainstone (Figs E, F in Pl. VII), drilled by the Platani 2 borehole (Fig. 6) and sampled along the Cammarata Mt field section, were dated Upper Hettangian-Sinemurian (Tab. 3b). These rocks, overlying unconformably the Upper Triassic cherty limestones of the SCT (Fig. 8a), are followed by well-cemented matrix-supported belemnitic calcareous breccias and green clays (BMG and CGM in Tab. 3b) with benthic foraminifers and ostracods (Sinemurian-Pliensbachian age).

Barracù Formation (BCU). A condensed-like succession of ammonitic and belemnitic limestone, Bajocian-Callovian in age, followed by a few metres of darkish radiolarites of Kimmeridgian-Early Tithonian age (Tab. 3b) has been drilled by the Platani 2 borehole (Fig. 6) and sampled along the Cammarata Mt. field section (Fig. 8a). This rock unit is largely correlatable with the coeval darkish radiolarites and clays (Bajocian-Kimmeridgian, CHIARI *et alii*, 2008), followed by few metres or resedimented Late Kimmeridgian-Early Tithonian bioclastic packstone-grainstone (Tab. 3b), of the Barracù Formation (BASILONE, 2012).

The Upper Jurassic Calpionellid limestones (*Lattimusa*, LTM, Tab. 3b) and Lower Cretaceous marly limestones with belemnites and planktonic foraminifers (*Hybla Formation*, HYB, Tab. 3b) have been drilled by the Bivona 3 borehole. They, discontinuous and thin in the study field sections, conformably follow the above-mentioned Jurassic deposits.

Amerillo Formation (AMM). The several different lithofacies of these pelagic fine-grained limestones (Tab. 3b) found in the Platani 2 (Fig. 6) and Bivona 3 boreholes are comparable with those sampled in the field sections (Fig. 8a). The drilled basalt thin intercalations (Bivona 3 borehole) clearly are correlatable to those found in outcrop (MONTANARI, 1989). In the field sections, the sampled Upper Cretaceous-Eocene pelagic limestone pass upwards to Lower Oligocene green marls, ichnites-bearing wackestone and *Nummulitid* graded breccias (Tab. 3b).

d) <u>*Upper Oligocene-Lower Miocene interval*</u>

Numidian flysch (FYN) and *Tavernola Formation* (TAV). Terrigenous pelites and turbiditic quartz- and glauconitic-sandstones (Tab. 4a), have been crossed by several study boreholes (Fig. 6) and sampled along the field sections in the Madonie Mts and Alia-Valledolmo region (Fig. 4a). These rocks, Upper Oligocene-Lower Miocene in age (Tab. 4a), unconformably rest on the pelagic limestones of the Caltavuturo Fm.

Differently, in the Platani 2 (Fig. 6) and Bivona 3 boreholes and along the field section (Fig. 8a), coeval rocks include clastic-carbonates and hemipelagic marls (Tab. 4b) of the Chattian-Lower Aquitanian *Cardellia marls* (RDE), Lower Miocene *Corleone calcarenites* (CCR) and upper Serravallian-lower Tortonian *San Cipirrello marls* (CIP).

6. Seismostratigraphic analysis

Seimic reflection lines interpretation was able to distinguish features and geometry (e.g. internal discontinuities, key horizons allowing for the characterization of seismic units) of the different seismic bodies and to correlate them with different geological units. Three main seismic units (Figs. 9a, b) are here described in detail:

The *seismic unit 1* is characterized by discontinuous, low amplitude and frequency, alternating with high amplitude reflectors, with a minimum thickness in the range of about 0.3-0.4 s (twt) up to 2.0 s (twt) (A in Fig. 9b). As directly constrained by the Cerda 1, Roccapalumba 1 and Valledolmo 1 stratigraphic logs, the seismic unit is originated by clays, sandstones and cherty limestones of Permian-Triassic age. The unit laterally extends discontinuously in the study area, reaching different thickness values: about 3000m in the northernmost Cerda region, more than 1000m in the Lercara-Roccapalumba region and a few hundred meters in the southernmost Valledolmo area. Some of the major thickness values are referred to tectonic deformation (duplex stack).

The *seismic unit 2* consists of a 0.8-0.9 s (twt) (~1500 m) thick package (Figs. 9a). Seismic data, constrained by boreholes (e.g. Castellana 1 well, B in Fig. 9b) information, image from the top: a) subparallel medium to high amplitude reflectors alternated with low amplitude to transparent interval (correlatable to the shales and sandstones of the Numidian flysch, FYN); b) strong and continuous high amplitude reflectors (correlatable to the calcilutite and marls of the Caltavuturo and Crisanti Fms, CAL and CRI); c) subparallel, homogeneous low frequency and medium to high amplitude reflectors (correlatable to the Jurassic Radiolarites mb of Crisanti Fm, CRI_1); d) subparallel medium amplitude and frequency, medium to low lateral continuity reflector package (correlatable to the cherty limestones of the Scillato Fm, SCT), e) medium to high amplitude and medium-to-low frequency reflectors, with medium-to-low lateral continuity (correlatable to the marl-calcilutite of the Mufara Fm, MUF). On the whole, the correlated rocks pertain to the Imerese type succession. Due to its variable thickness, (reaching its maximum value in the central-northern sector of the study area, Madonie Mts outcrops and Valledolmo regions, see Fig. 4a), its internal geometries and occurrence of discontinuities, this unit mimics deformed and stacked thrust sheets.

The *seismic unit 3* is characterized by a 0.5–1.0 s (twt) (~ 950–2000 m) thick package (C in Fig. 9b). Seismic data, constrained by borehole logs (e.g. Platani 2 well, Fig. 6), image carbonate units belonging to the Sicanian succession. In details, from the top it consists of: a) a high amplitude and frequency, almost continuous reflectors (correlatable to the San Cipirrello marls and Corleone calcarenites, CCR); b) a subtransparent package (correlatable to the Cardellia marls, RDE); c) a high amplitude, medium frequency and almost continuous reflector package (correlatable to the pelagic limestones of the Amerillo, Hybla and Lattimusa Fms, AMM); d) a package of high amplitude, medium to low frequency reflectors (correlatable to siliceous limestones of the Barracù Fm, BCU); e) subparallel medium to high amplitude and medium frequency reflector package, locally with good lateral continuity (correlatable to the cherty limestones and marls of the Scillato Fm, SCT), f) medium to high amplitude and medium to low frequency reflectors, with poor lateral continuity (correlatable to the marl-calcilutite of the Mufara Fm, MUF), g) medium to high amplitude, discontinuous reflectors (correlatable to the pelagic *Daonella limestone*, DAO). This unit, extending in the central-southern sector of the study area (from the Valledolmo region to the Sicani Mts and eastwards in sub-surface, Fig. 4a), is imaged as deformed and arranged in stacked thrust sheets, reaching a maximum thickness values ranging from about 2.5 to 3.5 km moving towards the southern sectors, at depths of about 3.8 to 7 km (Fig. 4b).

7. Discussion

Integration among borehole and field data provided new information (lithology, biostratigraphy, biochronology) on the occurrence of some lithostratigraphic units never described before and their role into better define the complex stratigraphic frame and the paleoenvironmental meaning of Central Sicily Permian to Cenozoic deposits (Fig. 10). The seismostratigraphic interpretation contributed to recognize their geometric relationship and to appraise their subsurface extension (Fig. 11). Accordingly, three main carbonate type successions have been recognized:

a) a more than 1000-thick succession resulting from the integration of boreholes stratigraphy with the segments of the field sections located in the Cerda, Lercara-Roccapalumba and Sosio Valley regions (Fig. 2 and Fig. 11a). The succession includes the Permian-Middle Triassic terrigenous and carbonate strata (Fig. 10).

b) a 1500m-thick sequence, resulting from boreholes stratigraphy and Sclafani Bagni, Monte dei Cervi, La Montagnola field sections (Figs. 6, 8b, c) comparison. Its main facies characters represent the type rock section of the Imerese domain (*Auct*.). These rocks (Fig. 10), at present-day, are involved in a tectonic units stack that laterally outcrop from the Palermo to the Madonie Mts (Fig. 11b) and, in the study region, extend in subsurface as provided by the available boreholes (Fig. 6) and seismic lines (seismic unit 2). These units disappear southeastwards, near the Marianopoli region (Figs. 4b, 11b);

c) the third type of succession can reach thickness of about 2000 m. It results from the integration of boreholes stratigraphy with the Cammarata and Barracù Mts field sections (Figs. 6, 8a). The facies analysis assigns the rock sequence (Fig. 10) to a deep-water paleodomain known in Sicily as Sicanian basin. The Sicanian rock units, widely outcropping in the Sicani Mts, plunge in the subsurface of the study region southward and eastward of Cammarata Mt (Figs. 4b, 11c). These buried rock bodies extend southwards beneath the Butera basin (Fig. 11c) and further eastwards, in the tectonic window of the Judica and Scalpello thrust wedge (Fig. 2).

7.1. Buried and outcropping Permian-Triassic deposits: a comparison

Previous studies on the Permian-Triassic deposits have recognized and described some lithostratigraphic units outcropping in both the study region and Western Sicily (CATALANO *et alii*, 1991; DI STEFANO & GULLO, 1997 and references thereinafter). In outcrop, due to the strong Tertiary contractional deformation, the true stratigraphic relationships among the Permian-Middle Triassic deposits are generally hided. So, the complexity of the surface geology has produced uncertainty about these rock units, their age and their stratigraphic setting (see CARCIONE *et alii*, 2004 and references thereinafter). The acceptable stratigraphic continuity of the drilled Permian-Triassic rocks, their comparison with the deposits outcropping in the study adjacent areas (Fig. 7) and the recognition of new lithostratigraphic units filling the gaps of the previous stratigraphic schemes, allow us to put a new stratigraphic order (Fig. 10). In this view, the described new lithostratigraphic rock units are here compared with the already published units.

a) the Lower-Middle Permian *Lercara sandstone* could be compared with the well-known "Kungurian flysch" (CATALANO *et alii*, 1991) outcropping in the Lercara-Roccapalumba region and to the "San Calogero Flysch" (DI STEFANO & GULLO, 1997) outcropping in the Sosio Valley; b) the Middle-Upper Permian *Roccapalumba clay and siltstone*, could be age-correlated with the "Olistrotrome unit", "Wordian clay" and "Red clay unit" of the Sosio Valley, dated on the ground of conodonts and very deep-water radiolarians content (see CATALANO *et alii*, 1991; KOZUR, 1993; DI STEFANO & GULLO, 1997); c) the thick, reef-derived calcareous breccia (*Sosio limestone*, Fig. 7) are believed to correspond to the same age "Sosio megablocks" (CATALANO *et alii*, 1991) outcropping both in the Lercara-Roccapalumba region and in the Sosio Valley (for their description see also FLÜGEL *et alii*, 1991; DI STEFANO & GULLO, 1997; ROBERTSON, 2006); d) the Lower Triassic *Manganaro clayey limestone* (Fig. 7) have been encountered only in the boreholes. No outcropping coeval rock bodies with equivalent deep-water sedimentary origin is known from previously published researches. We suggest that they may be age-correlated with the resedimented limestones recognized in small and isolated outcrops in the Sosio Valley and presumed by KOZUR (1993) as equivalent of the "red Hallstatt limestones"; e) the Ladinian-Lower Carnian *Daonella limestone* appears comparable and largely coeval with the few metres-thick "cherty limestones and pinkish nodular limestones" (Fig. 7) found in the Sosio Valley (CATALANO *et alii*, 1990; KOZUR, 1991). The *Daonella limestone* may be correlated also with the pelagic "Lumachella limestone and resedimented breccias" recently described by DI STEFANO *et alii* (2012) in the Madonie Mts and believed of Ladinian age. Based on field and lithostratigraphic observations, the *Daonella limestone* could include the "Ladinian marls and pelecypods limestones" found in the Madonie Mts, Caltanissetta and Sosio Valley areas and erroneously referred to the Mufara Fm by CARRILLAT & MARTINI (2009); f) the middle-upper Carnian pelecypods-bearing marly limestones of the Mufara Fm and the g) Upper Carnian-Rhaetian cherty limestones of the Scillato Fm, display similar lithological characteristics in all the outcrop and subsurface sections (Figs. 6, 9). The Norian-Rhaetian blackish and greenish shale intercalations (*Bivona* facies, Tab. 2), recovered only in the Bivona 3 borehole, appear lithologically correlatable and coeval with the lithofacies of the Scillato Fm described in the neighbouring field section of Pizzo Mondello (DI STEFANO *et alii*, 1998), candidate GSSP section for the Carnian/Norian boundary (NICORA *et alii*, 2007; BALINI *et alii*, 2008).

The new lithostratigraphic units, contributing to reduce the stratigraphic gaps, improve the sedimentary continuity of the deep-water succession for the whole Permian-Triassic time interval (Fig. 10). The occurrence of the Upper Triassic Mufara and Scillato Fms, stratigraphically overlying the Permian-Middle Triassic deposits, suggests that the latter were the common substrate for both the Imerese and Sicanian basinal domains (Fig. 10).

7.2. Jurassic-Miocene successions: main differences

New data originated by the present interpretation confirm that the Jurassic-Miocene rock successions (i.e. Imerese and Sicanian, Fig. 10) evidence a different sedimentary evolution since the Early Jurassic, as suggested by the following observations:

a) the thick resedimented shallow-water carbonate debris units (see Tab. 3a) occur only along the Imerese section and are absent in the whole Jurassic-Paleogene Sicanian succession (Fig. 10). In the latter a pelagic sedimentation (including intrabasinal slumped material) prevails;

b) the presence in the Imerese section of very thick Middle-Upper Jurassic deep-water bedded cherts and radiolarites (Crisanti Fm, see Tab. 3a) contrasts with the coeval pelagic thinner radiolarian-bearing jaspers and ammonite-bearing cherty limestones (Barracù Fm, Tab. 3b), occurring in the Sicanian succession;

c) the occurrence in the Imerese section of Lower Cretaceous bedded cherts and marls (spongolithic mb, CRI_3, Tab. 3a), contrasts with coeval pelagic limestones and blackish marls (Hybla Fm, Tab. 3b) sampled along the Sicanian section;

d) the Upper Cretaceous-Lower Oligocene pelagic limestones (AMM, Tab. 3b), including Maastrichtian and Eocene carbonate megabreccia episodes (CATALANO & D'ARGENIO, 1978; DI STEFANO *et alii*, 1996), recognized in the Sicanian succession, lithologically differ from the coeval Rudistid breccias mb (CRI_4, Tab. 3a) and the hemipelagic marly limestones (CAL, Tab. 3a) sampled along the Imerese section (Fig. 10);

On the whole, the Imerese section is dominated by gravity-flow slope deposits while the Sicanian one mostly reflects a more distal and open sea pelagic sedimentation (Fig. 10). This documents the original different location assumed by the two paleogeographic domains with respect to the shallow-water carbonate source area.

7.3. Depositional setting and sedimentary evolution

The Permian-Cenozoic paleotectonic and sedimentary evolution is here described throughout three main time interval stages (Fig. 12), representing the main steps of the evolution of a continental margin of the Southern Tethys realm:

Permian-Triassic stage

Depositional features of the study Permian-Middle Triassic stratigraphic units reflect the evolution of a subsident rifting area, already believed as an intracontinental basin ("Lercara basin" of CATALANO & D'ARGENIO, 1978), or an open and deep pelagic realm which was the westward continuation of the oceanic Tethys ("Permian Sicanian domain" of CATALANO *et alii*, 1991) or a passive margin of the westward prolongation of the Neotethys (STAMPFLI & BOREL, 2002). This slope to very deep-water basin (Fig. 12a) was bordered by i) carbonate reefs (e.g. Permian Tunisian deposits, TOOMEY, 1991; RIGO, 1998), which periodically supplied the deeper-water areas with calciturbiditic to gravity flow sediments (see also FLÜGEL *et alii*, 1991; ROBERTSON, 2006) and ii) an emerged continental region (ROBERTSON, 2006 and references thereinafter) which could have been the source area of the previous quoted terrigenous clastic deposits. Similar depositional pattern, described from others European (DUVAL *et alii*, 1998, JACQUIN & DE GRACIANSKY, 1998), Alpine Tethys (STAMPFLI *et alii*, 2002; BERRA & CARMINATI, 2010) and African regions (BOUAZIZ *et alii*, 1999; 2002; GABTNI *et alii*, 2009; CARMINATI *et alii*, 2013; PASSERI *et alii*, 2014), has been related to the evolution of the Southern margin of the Tethyan realm.

Up to the end of the Triassic this basin, filled by a pelagic sedimentation in continuity with the before illustrated Lower and Middle Triassic rocks (Fig. 10), was bordered by a wide carbonate platform domain (CATALANO *et alii*, 1996), whose progradational margins fragmented by extensional tectonics (see also DI STEFANO *et alii*, 1990; 2010) fed with detrital materials the monotonous pelagic sedimentation (Fig. 12a). The several synsedimentary fault and gravity slide features affecting the Upper Triassic cherty limestone (BASILONE, 2009a; BASILONE *et alii*, 2014) document the occurrence of active tectonics that may be related to the latest Triassic rifting episode of this continental margin (Fig. 12a).

Further on, in Sicily the lacking of ophiolites, as those reported from Eastern Mediterranean and Oman regions (BLENDINGER *et alii*, 1990; ROBERTSON, 2002 and references thereinafter), and the nature of the basalts included in the Permian-Triassic rocks succession (believed due to a tholeiitic-fractionated magmatism, CENSI *et alii*, 2000; CIRRINCIONE *et alii*, 2014), are in favour of a rifting basin developed on a stretched continental crust. The hypothesis that lithospheric thinning processes (with associated magmatic underplating of the lower-crust and/or ductile deformation) which could have affected the Southern margin of the Tethyan realm in the same time interval, is also inferred for the central-southern Sicily sector, by a distinctive signature of seismic reflectivity in the lower crust and upper mantle (VALENTI *et alii*, 2015).

Finally, based on the new data here presented, we are in favour to the hypothesis that Sicily pertained to a region whose Permian-Early Jurassic history was punctuated by several rifting phases which predate the spreading of the Neotethys in the Ionian sector (BERNOULLI *et alii*, 1990; CATALANO *et alii*, 2001; STAMPFLI & BOREL, 2002, 2004; ROBERTSON, 2006 HANDY *et alii*, 2010; FRIZON DE LAMOTTE *et alii*, 2011).

Jurassic-Paleogene stage

The impressive shallow-water resedimented carbonate debris events, acting during the Early and Middle Liassic time (Fanusi Fm breccias, Altofonte breccias and Belemnitic breccias, Fig. 10), point out an active subaerial erosion of the carbonate platform source area as consequence of the earliest Jurassic extensional tectonics (Figs. 12b, c). This Jurassic rifting stage of the continental margin (MANATSCHAL & BERNOULLI, 1998; STAMPFLI & BOREL, 2002; SCHETTINO & TURCO, 2010 among others), in Sicily has produced the dislocation of the original wide carbonate platform area (the so-called "platform disintegration", JENKYNS, 1970). In this view, we suggest from our results that this rifting event could caused the structuration of the previous Permian-Triassic basin in two different separated domains (Imerese and Sicanian), whose Mesozoic sedimentary evolution was strictly related to the tectono-stratigraphic setting of the relative adjacent carbonate platform margins (Figs. 12b, c). The occurrence of a rimmed carbonate platform may have fed a large amount of materials resedimented into the nearby basin (Fig. 12b) in the frame of a "bypass-to-depositional slope margin" (*sensu* MCILREATH & JAMES, 1978). In this view, the Mesozoic-Eocene Panormide carbonate platform (*Auct.*) is believed the source area for the resedimented materials in the Imerese basin (according to ABATE *et alii*, 1982; BASILONE, 2009a). Conversely, a carbonate shelf with stepped margins (*sensu* SANTANTONIO, 1993; 1994), evolving to a drowning platform (*sensu* SCHLAGER, 1981), could have influenced the pelagic sedimentation in the nearby Sicanian basin deep-water environment, developing a "ramp-slope" margin (Fig. 12c, BASILONE *et alii*, 2010; 2014). This hypothesis suggests that during the Mesozoic the Sicanian basin could have been proximal to the already drowned carbonate platforms (i.e. Iblean, Saccense and Trapanese pelagic platforms).

On the whole the depositional features of the Middle Jurassic-Paleogene deep-water successions reflect the evolution of subsident post-rift basins (Fig. 12b, c), as well documented in other perimediterranean regions (e.g. BERNOULLI & JENKYNS, 1974; WINTERER & BOSELLINI, 1981; BERTOTTI *et alii*, 1993 and many others).

Oligo-Miocene stage

The afore-mentioned different location of the two deep-water domains is, also, supported by the occurrence of strongly different Oligo-Miocene deposits (Fig. 10). The Upper Oligocene-Lower Miocene Numidian flysch density flow deposits developed in a foreland basin (the so-called “Maghrebian Flysch Basin”, FRIZON DE LAMOTTE *et alii*, 2000), which resided in the western Alpine Tethys realm between a growing accretionary prism (Calabrian Arc) to the north and the passive African margin to the south (see HANDY *et alii*, 2010; THOMAS *et alii*, 2010 and references thereinafter). Conversely, the Sicanian Oligo-Miocene open-shelf/slope succession (Fig. 10) developed in a still undeformed foreland of the Sicilian margin.

Conclusions

This paper want to contribute to the regional stratigraphy of rock units, located between the Madonie and eastern Sicani Mts (central sector of the Sicilian FTB). Integrating boreholes stratigraphy, seismostratigraphy and field geology of the main Permian-Paleogene deep-water, mostly carbonate rocks, provides the most complete and up-to-date stratigraphic, sedimentologic and chronostratigraphic dataset, utilized to fill the gaps due to the incompleteness of the outcropping successions.

Main results show that:

a) the recognized lithofacies associations or informal lithostratigraphic units (as the Upper Permian *Roccapalumba clay and siltstone*, Lower Triassic *Manganaro clayey limestone*, Ladinian-Lower Carnian *Daonella limestone* and others) and biostratigraphy of the rock units have established an almost continue Permian-Triassic succession, reducing the gaps of the previous descriptions;

b) the acceptable stratigraphic continuity of the drilled Permian-Late Triassic terrigenous and carbonate slope to basin successions validates the occurrence of a common substrate for the Mesozoic-Paleogene deep-water carbonates (Imerese and Sicanian);

c) the Imerese section differs from the Sicanian one in the Jurassic-Paleogene rock intervals as suggested by the described facies differences. The Imerese succession displays the characters of a gravity-flow slope dominated deposits. Conversely, the Sicanian section displays dominant pelagic carbonate facies with few reworked deposits. The resedimented shallow-water materials, enclosed in the Jurassic-Paleogene carbonates, suggest a different location of the Imerese and Sicanian domains with respect to the original setting shallow-water source areas;

d) the different paleogeographical location of the two basinal areas is confirmed during the Oligo-Miocene evolution, when sandstone and mudstone of the Numidian flysch fill the Imerese basin while the coeval pelagic marls and open-shelf carbonates were deposited in the Sicanian basin.

The paleogeographic reconstruction envisages: a) during the Permian-Triassic, a wide subsident continental rifting area, bordered by a shallow-water domain periodically supplying the basin with calciturbiditic to gravity flows sedimentation (rift stage of the southern margin of the Tethys realm); b) during the Jurassic-Paleogene, two different deep-water basins developed in a context of a post-rift stage. The different sedimentation reflects the location of the Imerese and Sicanian basins, respectively, along adjacent rimmed shelf and stepped carbonate platform margins.

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Figure Captions

Fig. 1 – Schematic structural map of the central Mediterranean (modified after CATALANO *et alii*, 2013b).

Fig. 2 - Structural map of Sicily (modified after CATALANO *et alii*, 2013b); black dotted line the study area. Inset map shows the main elements characterizing the collisional complex of Sicily: 1) undeformed Pelagian-Iblean foreland; 2) present-day foredeep; 3) orogenic wedge: Calabrian-Peloritani units (a); main FTB (b-c) southwards buried by (d) the Gela Thrust System (GTS). BUPP: boundary of the undeformed Pelagian Platform.

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Fig. 5 – Example of well to seismic tie (right side). The average Vp velocities of the main seismic intervals are displayed in detail (left side). Nf: Numidian flysch and Tavernola Fm; Im: Imerese succession; Si: Sicanian succession; PT: Permian-Middle Triassic succession

Fig. 6 - Comparison and correlation of the outcropping deep-water sections and the synthetic log stratigraphy of some boreholes drilled in the studied area. Inset figures display boreholes and field sections location (b) and the tectonic relationships among the drilled units (c).

Fig. 7 – Scheme of comparison among the lithofacies and lithostratigraphic units of the Permian-Upper Triassic deep-water deposits recognized along the drilled successions and outcropping in the Lercara-Roccapalumba region and Sosio Valley. Time scale according to GRADSTEIN *et alii* (2004). The outcropping data derive from the integration of previous studies (CATALANO *et alii*, 1988-1992; FLÜGEL *et alii*, 1991; DI STEFANO & GULLO, 1997; ROBERTSON, 2006). Dotted lines with arrows indicate tectonic relationships. On the right the new proposed terminology for the Permian-Middle Triassic formations is shown.

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of the Scillato Fm; MUF: top of the marl-calcilutites of the Mufara Fm; DAO: top of the pelagic Daonella limestones.

Fig. 10 – Timetable of tectono-sedimentary events recognized along the Permian-Cenozoic successions, based on outcrop and well data. Time scale according to GRADSTEIN *et alii* (2004).

Fig. 11 - Surface and subsurface distribution in Central Sicily of the study Permian-Triassic (a), Imerese (b) and Sicanian (c) successions.

Fig. 12 – Paleogeographic sketches illustrating the sedimentary evolution of the platform-to-basin systems throughout the main time interval evolution stages: a) Permian-Triassic rift stage during which a subsident rifting basin was bordered by a carbonate platform rimmed by reefs; Jurassic-Paleogene postrift stage during which a rimmed shelf-by pass slope (Imerese) margin (b) and a ramp-slope (Sicanian) margin (c) were developed.

Tab. 1 – Permian-Middle Triassic lithostratigraphic, sedimentologic and biostratigraphic characteristics of the drilled studied units.

Tab. 2 – Upper Triassic lithostratigraphic, sedimentologic and biostratigraphic characteristics of the drilled studied (Avanella 1, Creta 1, Platani 2, Casteltermini 1, Bivona 3 boreholes) and outcropping (Monte dei Cervi, Sclafani Bagni, Cammarata Mt., Barracù Mt. sections) studied units.

Tab. 3a – Jurassic-Paleogene lithostratigraphic, sedimentologic and biostratigraphic characteristics of the drilled (Avanella 1, Colla 1, Creta 1, Valledolmo 1 boreholes) and outcropping (Monte dei Cervi, Sclafani Bagni, La Montagnola sections) studied units.

Tab. 3b – Jurassic-Paleogene lithostratigraphic, sedimentologic and biostratigraphic characteristics of the drilled (Platani 2, Casteltermini 1, Bivona 3 boreholes) and outcropping (Cammarata Mt., Barracù Mt. sections) studied units.

Tab. 4a – Oligo-Miocene lithostratigraphic, sedimentologic and biostratigraphic characteristics of the drilled (Avanella 1, Colla 1, Creta 1, Valledolmo 1 boreholes) and outcropping (Monte dei Cervi, Sclafani Bagni, La Montagnola sections) studied units.

Tab. 4b – Oligo-Miocene lithostratigraphic, sedimentologic and biostratigraphic characteristics of the drilled (Platani 2, Casteltermini 1, Bivona 3 boreholes) and outcropping (Cammarata Mt., Barracù Mt. sections) studied units.

Tab. 5 – Seismic characters of the seismic units distinguished in the study area and correlation with the lithologic units.

Pl. I - Characteristic microfacies of the Late Permian Roccapalumba clay and siltstone (RCS). Fig. A: red brown planar laminated clay siltstone with cm-thick layers of greenish to light-grey crossed laminated (ripples) siltstone-fine sandstone and siltitic mudstone intercalations (core 2, 708-711 m, Roccapalumba 1 well, macroscopic sample, photograph field about 10 cm); Fig. B: thin layer of coarse siltstone with quartz, feldspar, mica, glauconitic and phosphate fragments interlayered in to red siltitic clays (core 1, 484.6-485.9 m, Lercara 1 (Agip) well, crossed polarized light (XPL), scale bar 0,4 mm); Fig. C: grey to dark greenish altered basaltic rock with calcitic veins (cutting 68-72m, Roccapalumba 1 well, PPL, scale bar 1 mm); Fig. D: siltstone/fine sandstone with quartz, feldspar, glauconitic and phosphate fragments (cutting 231-234 m, Roccapalumba 1 well, plane polarized light (PPL), scale bar 0,4 mm); Fig. E: calcareous breccias with reef-derived fragments (cutting 64-67m Lercara Friddi 1 well, scale bar 1 mm); Fig. F: reworked bioclastic packstone showing benthic foraminifers, algae encrusting organism (core 5, 915-916m, Lercara 1 (Agip) well, scale bar 1 mm).

Pl. II - Late Permian microflora from Roccapalumba 1 well (400x).

Pl. III - Characteristic microfacies of the Lower Triassic Manganaro clayey limestone (MNG). Fig. A: wackestone-packstone with pelagic pelecypods (core 14, 2336-2339,7 m, Roccapalumba 1 well, scale bar 1 mm); Fig. B: red clays with pelagic pelecypods (cutting: 2402-2405 m, Roccapalumba 1 well, scale bar 0,4 mm); Fig. C: laminated quartzitic sandstone (core 6: 1635, 5-1637, 5 m, Roccapalumba 1 well, PPL, scale bar 2 mm); Fig. D: red mudstone with siliceous sandstone and white shallow-water carbonate clasts (core 16, 2427, 6-2431, 2 m, Roccapalumba 1 well, macroscopic sample, scale bar 1 cm); Fig. E: calcareous breccia (rudstone) with shallow-water derived clasts (core 8: 1724-1727 m, Roccapalumba 1 well, macroscopic sample, scale bar 0,5 cm); Fig. F: grainstone/packstone with surficial oolites, pelecypods fragments and coated grains (core 8: 1724-1727 m, Roccapalumba 1 well, scale bar 1 mm).

Pl. IV - Characteristic microfacies of the *Daonella* limestone (DAO). Fig. A: wackestone with radiolarians and pelagic pelecypods (core 26, 2979,1-2981.5m, Platani 2 well, scale bar 1mm); Fig. B: wackestone with pelagic pelecypods (core 26, 2979.1-2981.5m, Platani 2 well, scale bar 1mm); Fig. C: mudstone with intercalation of siltstone-wackestone with radiolarians (core 25, 2882-2884m, Platani 2 well, scale bar 2 mm); Fig. D: grey laminated mudstone with radiolarians, dark grey and greenish clay and recrystallized mm-layers rich in radiolarians (core 27, 3052-3056m, Platani 2 well, scale bar 2mm); Fig. E: packstone-grainstone (calcareous turbidites) with ammonites, radiolarians, pelagic pelecypods and peloids (core 26, 2979.1-2981.5m, Platani 2 well, scale bar 2 mm); Fig. F: fine packstone/grainstone with ooids, intraclasts and bioclasts (core 26, 2979.1-2981.5m, Platani 2 well, scale bar 1mm).

Pl. V - Ladinian-Early Carnian microflora and Permian-Carboniferous reworking from Platani 2 well (400x).

Pl. VI - Characteristic microfacies of the Upper Triassic Mufara (MUF, Figs. A, B) and Scillato (SCT, Figs. C-F) Fms. Fig. A: mudstone-wackestone with radiolarians, ammonites and pelagic pelecypods (core 24: 2724.9-2727.3 m, Platani 2 well, PPL, scale bar 2 mm), with intercalations of Fig. B: intra-bioclastic and oolitic fine packstone (core 26: 3052-3056 m, Platani 2 well, PPL, scale bar 1 mm); Fig. C: brown wackestone-packstone with radiolarians and pelagic pelecypods (cutting 1740-1743 m, Platani 2 well, PPL, scale bar 0,4 mm); Fig. D: bioclastic and intraclastic (shallow-water derived fragments) grainstone and coral boundstone fragments (core 5, 3067.5-3076 m, Creta 1 well, PPL, scale bar 2 mm); Fig. E: dolomitized calcareous breccias with elements of pelagic mudstone with radiolarians (cores 18-19, 2189-2182 m and 2192-2194 m, Platani 2 well, macroscopic samples, photograph field about 15 cm); Fig. F: grey calcareous breccias with blackish clayey-marls pelagic clasts (core 19, 2192.6-2194.1 m, Platani 2 well, PPL, scale bar 0,4 mm).

Pl. VII - Characteristic microfacies of the Lower Jurassic Altofonte calcareous breccias (ALT, Figs. A-D) and oolitic limestones (OOL, Figs. E-F). Fig. A: packstone with algae, crinoids, benthic foraminifera and intraclasts (core 3: 2833-2841 m, Creta 1 well, PPL, scale bar 2 mm); Fig. B: packstone/grainstone with algae, peloids and large oncoids (core 3: 2833-2841 m, Creta 1 well, PPL, scale bar 2 mm); Fig. C: grainstone with codiacean algae, crinoids, benthic foraminifera and intraclasts (core 3: 2833-2841 m, Creta 1 well, PPL, scale bar 2 mm); Fig. D: packstone/grainstone with dasycladacean and codiacean algae, mollusc fragments, peloids and intraclasts (core 3: 2833-2841 m, Creta 1 well, PPL, scale bar 2 mm); Fig. E: oolitic and bioclastic wackestone-packstone (cutting 1666-1664 m, Platani 2 well, PPL, scale bar 1 mm); Fig. F: oolitic grainstone (cutting 1691-1694 m, Platani 2 well, PPL, scale bar 0.5 mm).

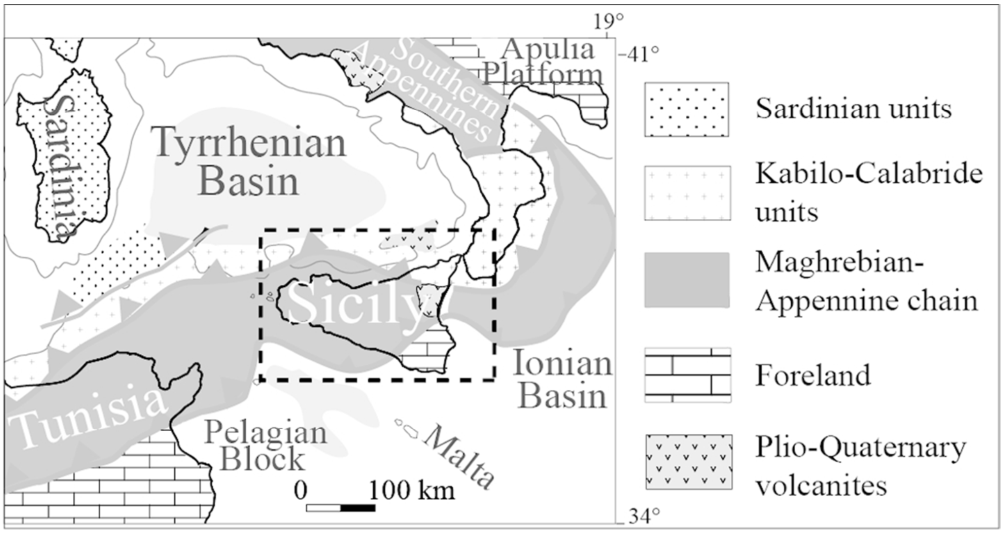
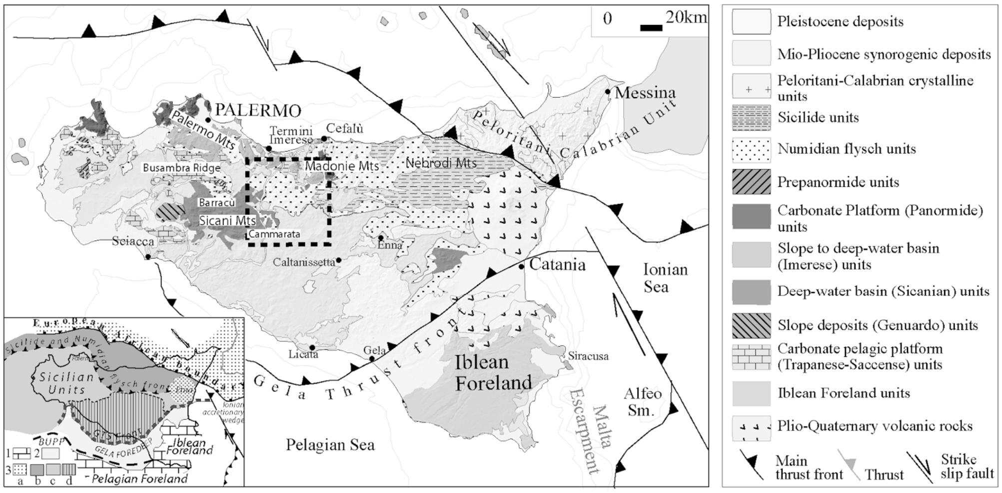


Fig. 1 – Schematic structural map of the central Mediterranean (modified after CATALANO et alii, 2013b).
90x47mm (300 x 300 DPI)



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180x88mm (300 x 300 DPI)

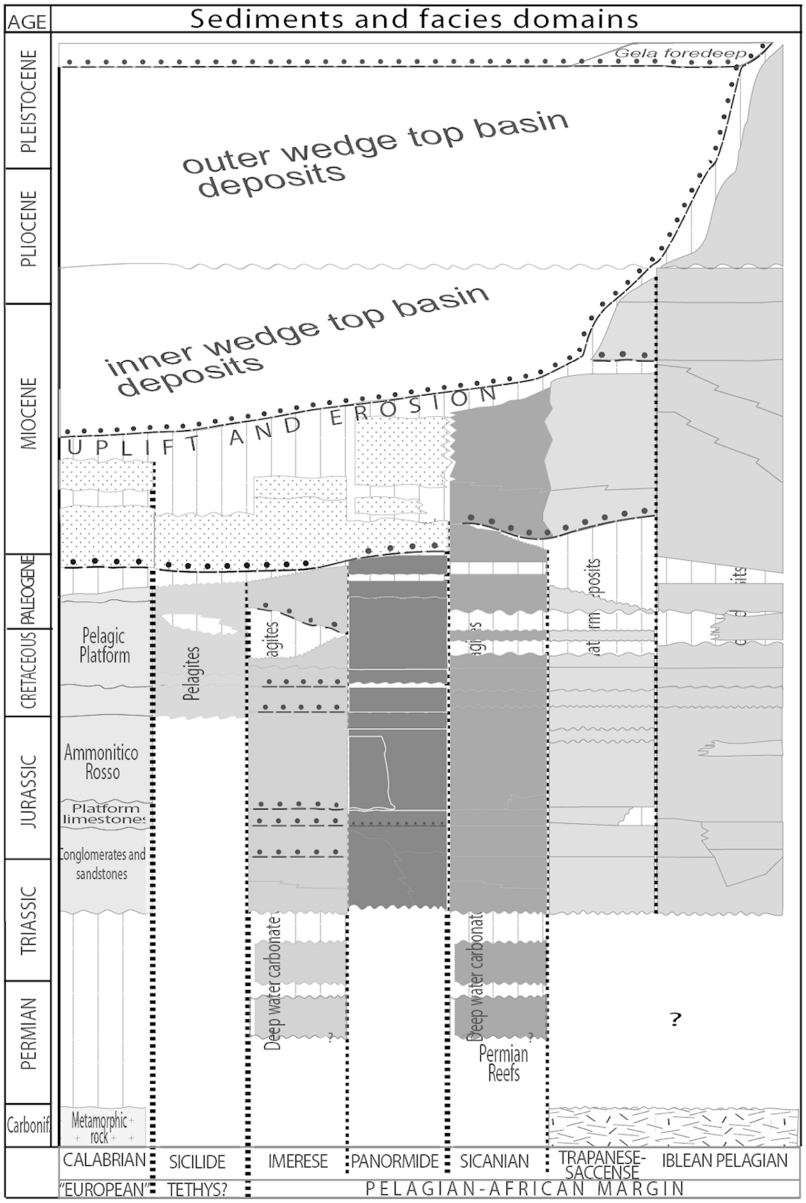
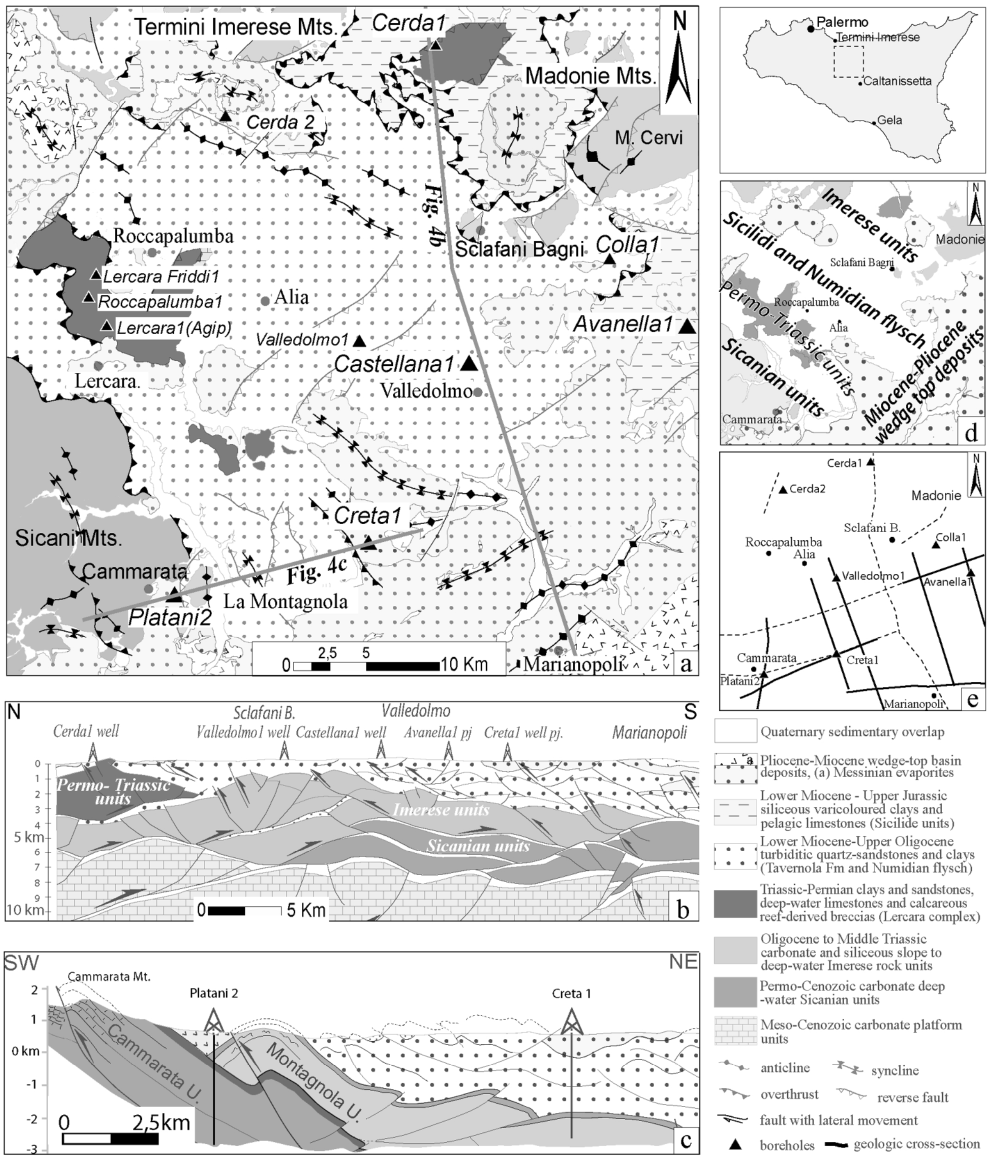


Fig. 3 – Lithostratigraphy and facies domains of the outcropping and buried deposits in Sicily (modified after CATALANO et alii, 2013b).
90x132mm (300 x 300 DPI)



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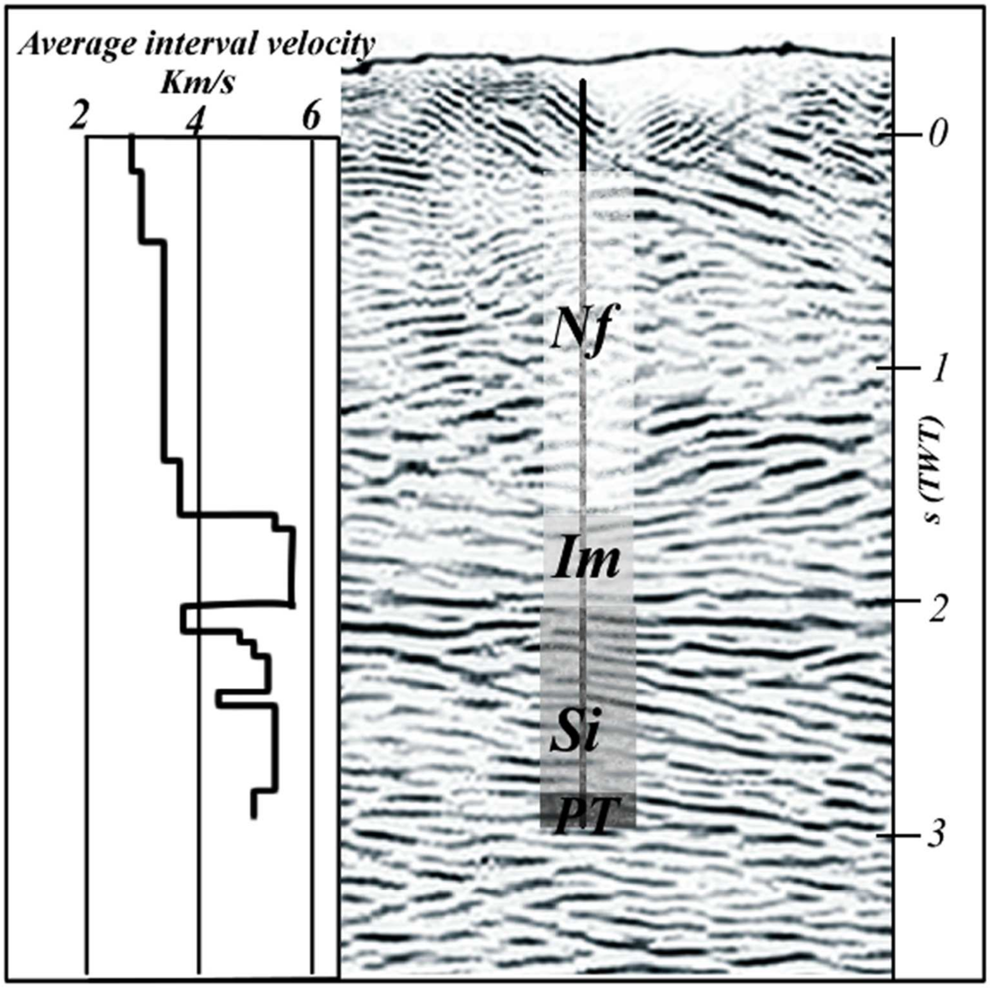
182x214mm (300 x 300 DPI)



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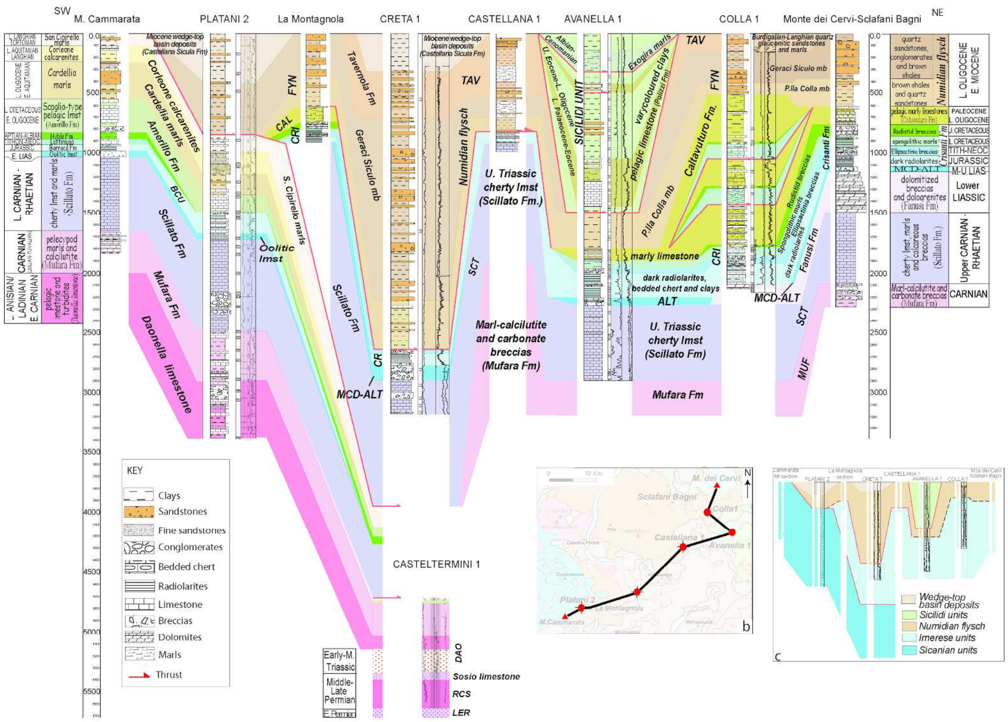
74x74mm (300 x 300 DPI)



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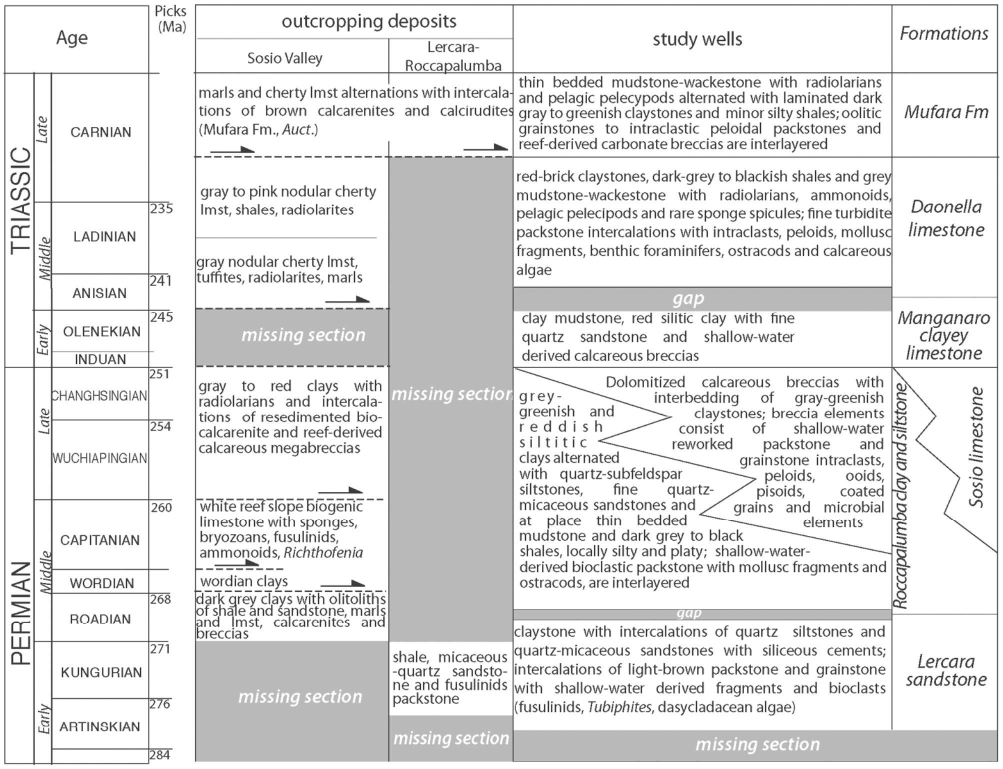
244x178mm (300 x 300 DPI)



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181x149mm (300 x 300 DPI)

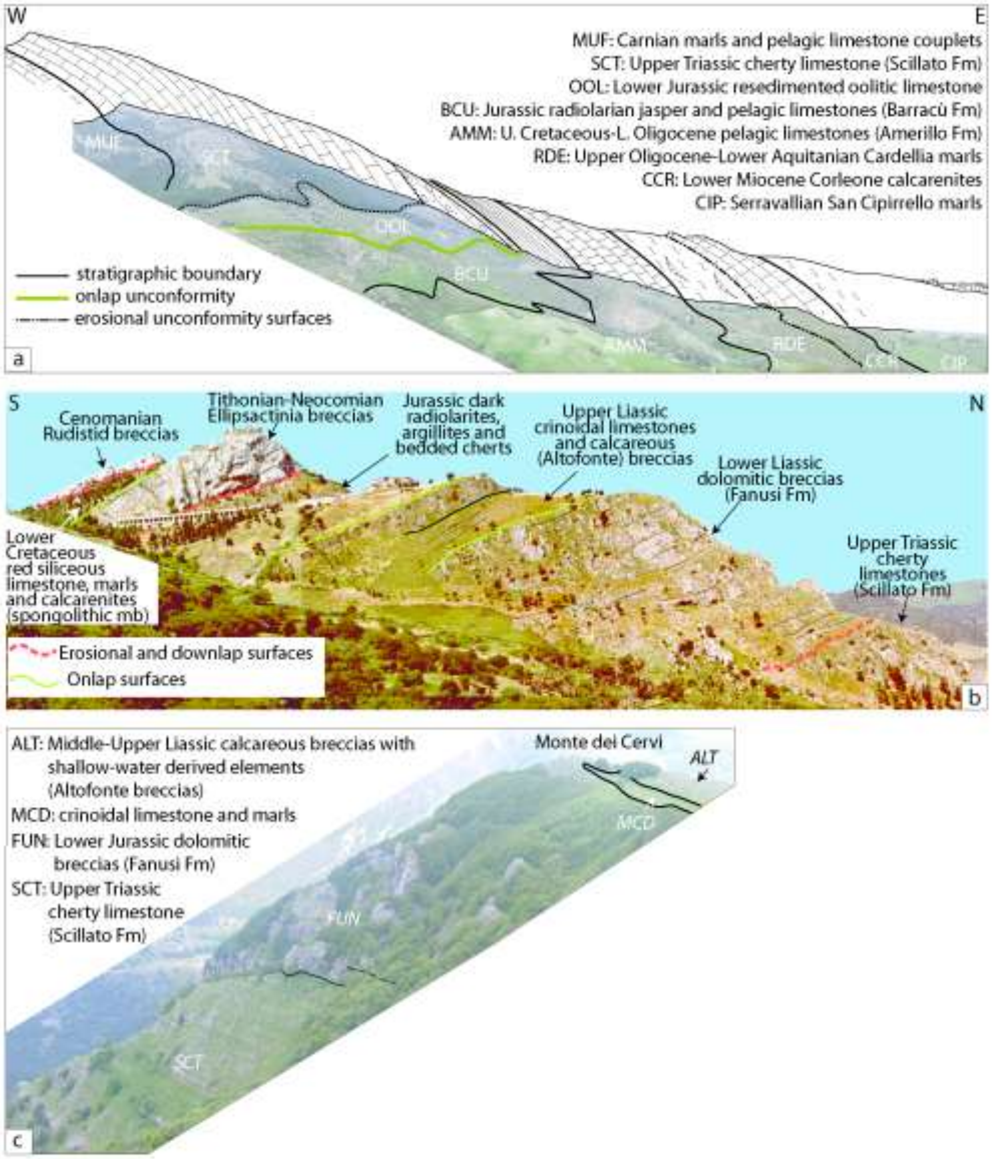
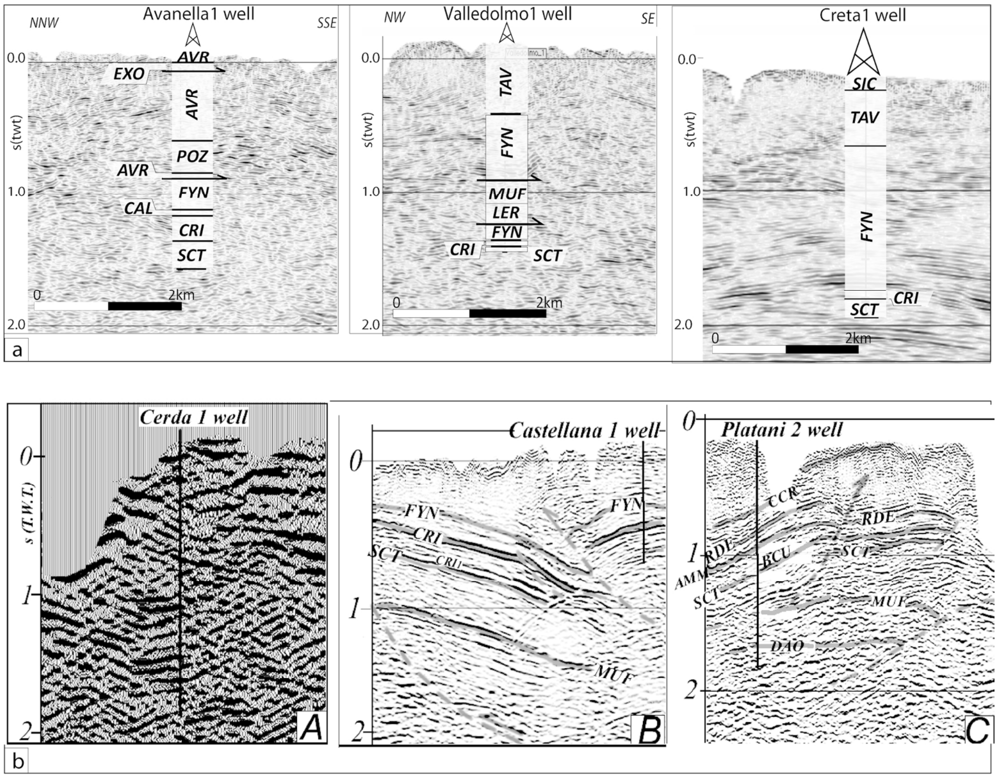


Fig. 8 - Outcropping study sections: a) Cammarata Mt natural section; b) Rocca di Sclafani Bagni natural section; c) Monte dei Cervi natural section.
182x214mm (300 x 300 DPI)



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180x139mm (300 x 300 DPI)

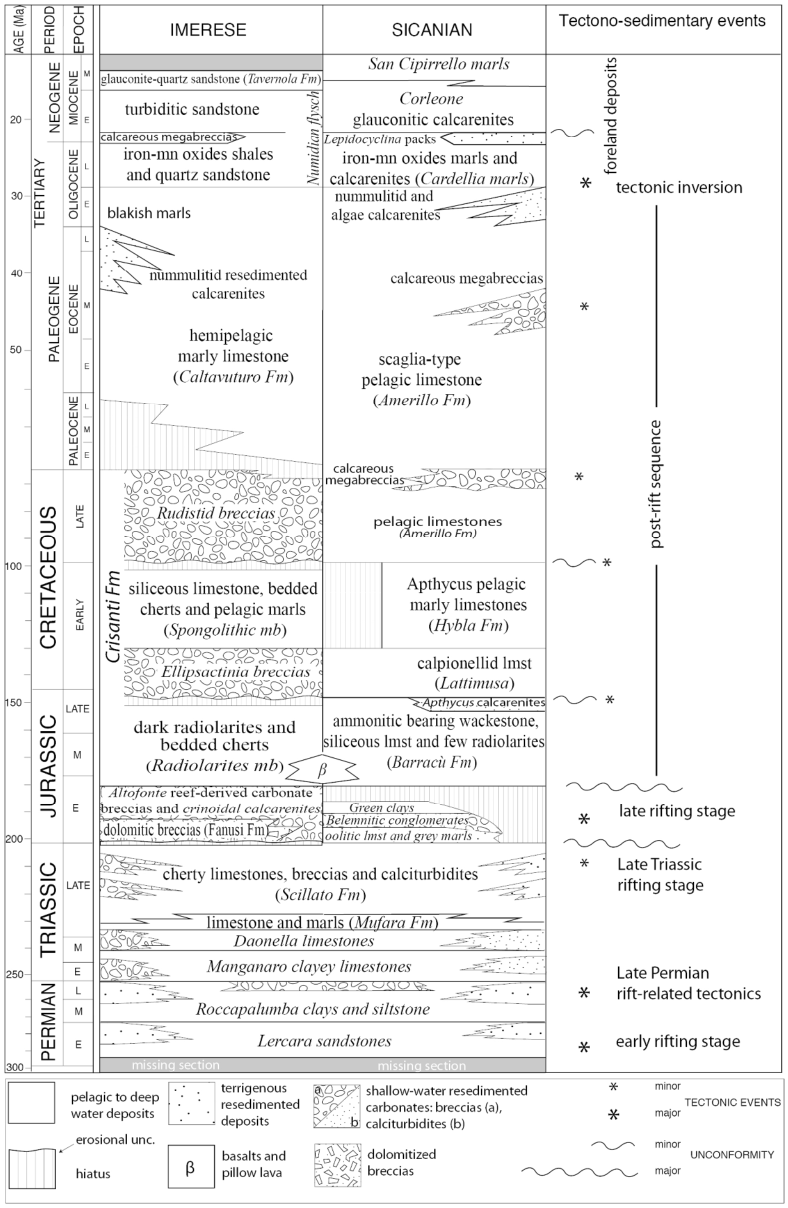


Fig. 10 – Timetable of tectono-sedimentary events recognized along the Permian-Cenozoic successions, based on outcrop and well data. Time scale according to GRADSTEIN et alii (2004).
160x246mm (300 x 300 DPI)

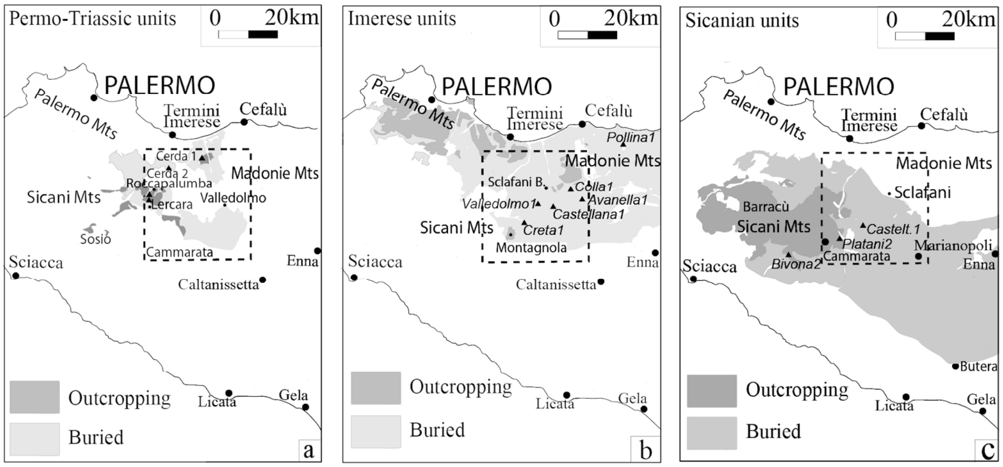
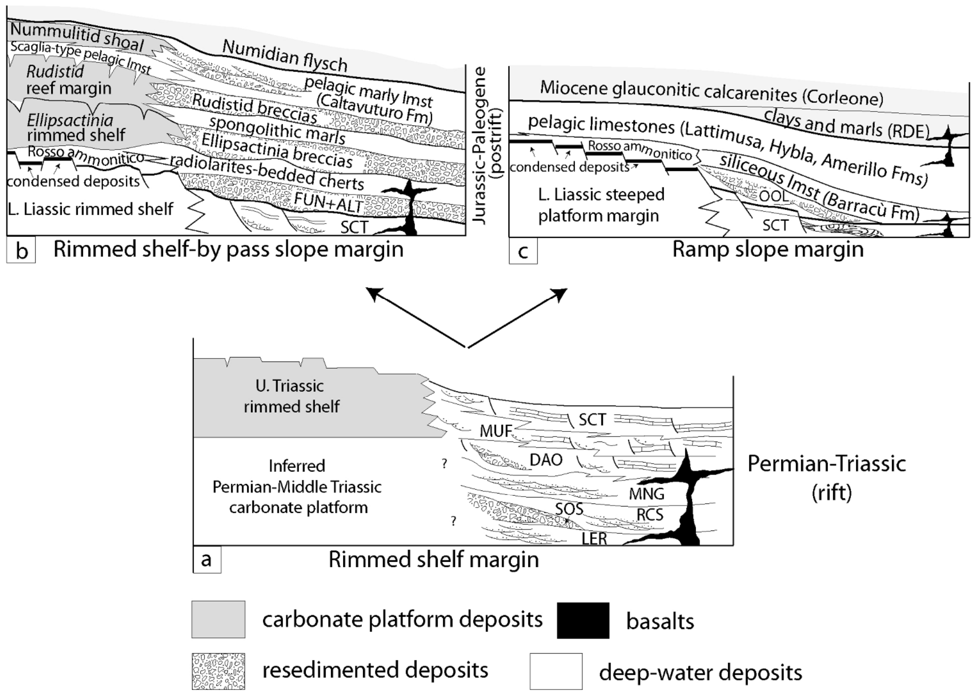


Fig. 11 – Surface and subsurface distribution in Central Sicily of the study deep-water successions: a) Permian-Triassic units, b) Imerese units, c) Sicanian units.
180x83mm (300 x 300 DPI)



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195x133mm (300 x 300 DPI)

Formations	Labels	section: field	section: well	thick(m)	Lithology	depositional environment	fossil content: field section	fossil content: drilled section (palynomorphs)	Age	Main references
Daonella limestones	DAO		x	>400	Radiolarians, rare sponge spicules and pelagic bivalve-bearing mudstone-wackestone, locally laminated (Figs. A-D in Pl. IV) alternated with green marls, grey to blackish shales and red-brick claystones. Intercalations of calcareous breccias and fine intra-bioclastic calciturbiditic packstone with *Aeolisaccus* sp., ooids, peloids (Figs. E, F in Pl. IV) small mollusc fragments, ammonoids and calcareous algae	deep-water	*Daonella tyrolensis, Diplopora annullatissima*	*O. pseudoalatus, Rimaesporites potoniei, C. secatus, M. crenulatus, Palaeospongiosporis europaeus, S. speciosus, Lueckisporites junior, Lunatisporites acutus, D. verrucosus*	Ladinian-Early Carnian	Frixa & Trincianti, 2006; Di Stefano *et alii*, 2012; Trincianti *et alii*, in press
Manganaro clayey limestones	MNG		x	>200	Radiolarians and pelagic bivalves bearing darkish-red silitic clays alternated to thin bedded clayey mudstone-wackestone, locally dolomitized (Figs. A, B in Pl. III). Thin intercalations of laminated fine quartzitic sandstones (Fig. C in Pl. III) with carbonate cements frequently occur together with thick calcareous breccias (floatstone) made up of siliceous and calcareous shallow-water subangular elements, welded by red-to-green marly matrix (Fig. D in Pl. III)	deep-water-base of slope	*Posidonia wengensis*. conodonts (*Gladigondolella, Pseudofurnisius)*	*Endosporites papillatus, Aratrisporites* sp., *Densoisporites* sp., *Lundbladispora* sp.	Early Triassic	Kozur, 1993; Frixa & Trincianti, 2006
Roccapalumba clay and siltstone	RCS		x	>1000	grey-greenish and reddish siltitic clays, marls and pelites, locally passing to fine grey mudstone, rich in conodonts, radiolarians and palynomorphs alternated with laminated quartz-subfeldspar siltstones (Fig. A in Pl. I) and fine sandstones, rich in quartz, micas and feldspars (Fig. B in Pl. I); at place, thin bedded mudstone and dark grey to black shales. Frequent intercalations of both thin calcareous skeletal packstone-to-grainstone with rare oolites, calcareous algae (dasycladacean), echinoids, ostracods and mollusc fragments (Figs. E, F in Pl. I), and thick calcareous breccias (*Sosio limestones*) with carbonate platform-derived elements (packstone-grainstone and boundstone) rich in fusulinids, spongid and coral fragments, intraclasts, coated grains, peloids, ooids and microbial elements.	slope to deep-water, carbonate apron and turbidites	conodonts (*Mesogondolella phosphoriensis, Sweetognathus subsymmetricus*), radiolarians (*Albaillellacea*)	*Protohaploxypinus, Striatopodocarpites* and *Vittatina* genus, *Nuskoisporites* sp., *Corisaccites alutas, Playfordiaspora* cf. *crenulata; Hamiapollenites* sp., *Lueckisporites virkkiae*, *Potonieisporites* sp. and *Hamiapollenites, Gardenasporites, Strotersporites, Gigantosporites* genus). In the resedimented beds: fusulinids, calcareous algae (dasycladacean), echinoids, mollusc fragments, richtofenids	Middle-Late Permian	Catalano *et alii*, 1991; Flügel *et alii*, 1991; Di Stefano & Gullo, 1997; Frixa & Trincianti, 2006; Trincianti *et alii*, in press
Lercara sandstone	LER		x	>500	claystone with intercalations of quartz-siltstones and quartz-micaceous turbiditic sandstones with prevailing siliceous cements and deep-water *Nereites* ichnofacies; intercalations of light-brown calciturbiditic packstone and grainstone with shallow-water derived fragments and bioclasts (fusulinids, *Tubiphytes* sp., dasycladacean algae, *Earlandia* sp.)	slope to deep-water, turbiditic complex	conodonts (*Mesogondolella intermedia, M. idahoensis, Neotreptognathodus pequopensis, Sweetognathus behnkeni*), radiolarians (*Pseudoalbaillella scalprata scalprata, P.*	*Hamiapollenites* cf. *H. karroenss, Crucisaccites* sp., *Rhizomaspora*; *Verrucosisporites* sp., *Indotriradites niger*, *Nuskoisporites* sp., *Striatopodocarpidites* sp., *Potonieisporites* sp., *Plicatipollenites* spp., *Vittatina* sp., *Barakarites rotatus*	Mid Artinskian-Early Roadian	Catalano *et alii*, 1991; Kozur *et alii*, 1996; Trincianti *et alii*, in press

Formations	Labels	section field	section well	thick(m)	Lithology	depositional environment	fossil content: field section	fossil content: drilled section (palynomorphs)	age	Main references
Bivona facies	BIV		x	>500	radiolarians, pelagic pelecypods, sponge spiculae and ammonite bearing clayey mudstone-wackestone with intercalation of thick green marls levels; downwards prevalent darkish clays and grey-to-reddish marls alternated with micritic pelagic cherty limestones. Thin arenaceous beds are interlayered. Resedimented packstone, with benthic forams, bioclasts, oolite, cherty limestone pebbles and clast-supported thick breccias-to-conglomerates, welded by calcite cements, whose clasts consist of coral boundstone fragments	deep-water to restricted circulation		palynomorphs (*Rhaetogonyaulax rhaetica, Granuloperculatipollis rudis*, *Corollina mejerana, C. siciliana, C. kedangensis*, *Samaropollenites speciosus, Minutosaccus crenulatus, Patinasporites* sp., *Ovalipollis* sp.). In the resedimented beds: mollusc and gasteropod fragments, upper Triassic benthic forams *(Galeanella* sp. *Variostoma cochlea*, *Ammobaculites pulcher*, *Lingulina* gr *tenera* and Permian *(Hemigordius* sp.)	Norian-Rhaetian	Frixa & Trincianti, 2006
Scillato Fm	SCT	x	x	400-500	radiolarian and pelagic pelecypods bearing thin bedded cherty mudstone-wackestone (Fig. C in Pl. VI), locally alternated with varicoloured marls and resedimented bioclastic packstone-grainstone and reef-derived breccias also with pebbly mudstone (Fig. D, E, F in Pl. VI)	deep-water-to-slope	pelagic pelecipods *(Halobia styriaca, H. norica)*, ammonites, conodonts	*Corollina meyeriana, Ovalipollis pseudoalatus, Paracirculina quadruplicis, Camerosporites secatus, Perinopollenites elatoides, Multiplicisphaeridium dendroidium*	Upper Carnian-Rhaetian	De Wever et al., 1979; De Capoa Bonardi, 1984; Frixa & Trincianti, 2006
Mufara Fm	MUF	x	x	200-300	Light grey to beige, locally dolomitized, cherty mudst-wacks with radiolarians, ammonites and pelagic pelecypods (Fig. A in Pl. VI) alternated with laminated dark grey to greenish claystones and minor silty shales; reef-derived carbonate breccias with *Thaumatoporella* sp., *Tubiphytes obscurus* Maslov, calcareous sponges, oncooids, thin oolitic grainstone, peloidal and skeletal packstone (Fig. B in Pl. VI). Quartz-micaceous to lithic fine sandstones and siltstones, basalts	deep-water	conodonts (*Gladigondolella thethydis* and *Paragondolella polignathiformis noha* biozones), ammonites, *Daonella* spp., *Halobia* spp.	*Partitisporites quadruplices, P. verrucosus, P. novimundanus, Patinasporites densus, Vallasporites ignacii, Camerosporites secatus, O. pseudoalatus, Staurosaccites quadrifidus, Minutosaccus crenulatus, Enzonalasporites vigens, Samaropollenites speciosus, Duplicisporites granulatus)*	Julian-Tuvalian	Catalano et al., 1992; Di Stefano et al., 1998; 2010; Carillat & Martini, 2009; Frixa & Trincianti, 2006

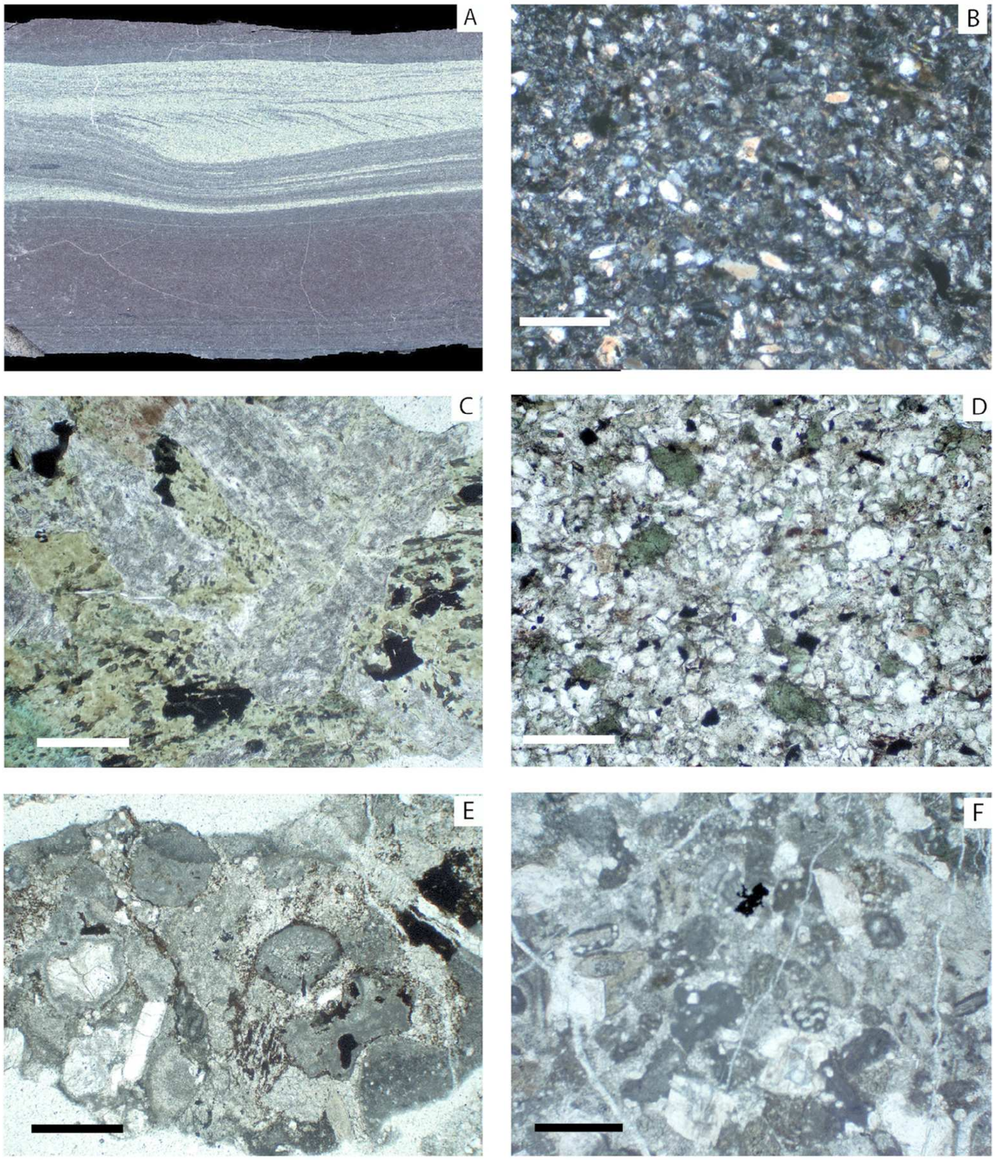
	Formations	Labels	section: field	section: well	thick.(m)	Lithology	depositional environment	fossils and biostratigraphy: field section	fossils and biostratigraphy: drilled section	Age	Main references
	Caltavuturo Formation	CAL	x	x	200-250	alternation of varycoloured marls, marly limestones, mudstone-wackestone; resedimented packs-grains and breccias rich in large benthic forams and corallinaceous algae; calcimetric values from 50%, up to 15% at the top	slope to deep-water /pelagic-to-hemipelagic	planktonic forams (*Globotruncana spp., Globorotalia spp., Globigerina spp., Morozovella velascoensis, M conicotruncata, Planorotalites pusilla, Globigerinatheka spp., Turborotalia cerroazulensis), Nummulites partschi*		Latest Cretaceous-Early Oligocene	Schmidt di Friedberg, 1964-65; Montanari, 1966; Catalano *et alii*, 2011
Crisanti Fm	Rudistid breccias	CRI_4	x	x	80-100	reef-derived (rudistid bioherma) calcareous breccias alternated to graded and laminated grainstone with abundant rudistid fragments and benthic forams	base of slope/turbiditic fan	*Orbitolina* cf. *conica, O. texana, Orbitoides media, Siderolites* cf. *calcitrapoides,* Bryozoan, *Bacinella irregularis* Radoicic, *Rotalipora appenninica* Renz, *Globotruncana* spp.		Late Cretaceous (Cenomanian)	Montanari, 1966; Basilone, 2009a
Crisanti Fm	spongholithic mb	CRI_3	x	x	0-50	siliceous mudstone/wackestone with radiolarians and sponge spiculae, spongolithic marls, clays, siliceous argillites and jaspers, mostly reddish in colour	deep-water	*Ticinella primula, Dorothia gradata, Lenticulina subalata, Marginulina planiscula, Saracenaria* aff. *forticosta*	palynomorphs *(Inaperturopollenites* sp., *Araucariacites* sp.); nannofossils (*L. carniolensis, C. margerelii, C. cuvillieri, A. infracretacea, A. wisei), Calpionellopsis oblonga*	Hauterivian-Albian	Montanari, 1966; Frixa & Trincianti, 2006; Basilone, 2009a;
Crisanti Fm	Ellipsactinia breccias	CRI_2	x	x	25-50	reef-derived massive calcareous breccias and conglomerates, graded and laminated packstone and laminated oolitic grainstone	base of slope/debris flow	*Ellipsactinia* sp., corals, algae (*Clypeina jurassica*), benthic forams (*Kurnubia palastiniensis, Labyrinthina mirabilis, Pianella pygmaea, Everticyclammina hedbergi, Protopeneroplis striata*), *Lithocodium aggregatum, Bacinella irregularis, Tubiphytes morronensis*		Late Tithonian-Neocomian	Scandone *et alii*, 1972; Basilone, 2009a
Crisanti Fm	radiolarites mb	CRI_1	x	x	50-80	thin bedded darkish laminated radiolarites, bedded cherts, claystones, siliceous marls and, locally,volcanic rocks (tuffites and pillow lavas)	deep-water	sponge spiculae, radiolarians, ostracods, *Aeolisaccus* sp., *Trocholina* sp., *Thaumatoporella* sp., *Bositra* sp.		Toarcian-Early Tithonian	McBride & Folk, 1979; Basilone, 2009a
	Crinoidal lmst and Altofonte breccias	MCD-ALT	x	x	5-15 and 25-50	crinoidal and oolitic grainstone-packstone and clast-supported reef-derived calcareous breccias, whose elements are boulder to pebbles of Upper Triassic shallow-water carbonates with calcareous sponges, corals, thick-shell molluscs (megalodontids), calcareous algae, benthic forams and oncoids fragments (Figs. A-D in Pl. VII).	slope-base of slope	*Lenticulina varians, Nodosaria fontinensis, Dentalina mucronata*; NJT4a-5a biozones	palynomorphs (*Corollina meyeriana, Concavisporites* spp., *Trachisporites* sp., *Veryhachium* spp., *Granuloperculatipollis rudis*),	Late Hettangian - Sinemurian	Montanari, 1966; Bartolini *et alii*, 2002; Basilone, 2009a; Catalano *et alii*, 2010a
	Fanusi Formation	FUN	x	x	250-300	white massive vacuolar dolomites with few thin clayey intercalation, graded dolomitized breccias and laminated doloarenites, grey fine-grained dolomitized breccias	slope apron	no recognizable fossil content		Earliest Jurassic	Schmidt di Friedberg, 1964-65; Scandone *et alii*, 1972; Basilone, 2009a

Formations	Labels	section field	section well	thick (m)	Lithology	depositional environment	fossils content: field section	fossils content: drilled section	Age	Main references
Amerillo Fm	AMM	X	X	200-300	alternations of red and light red limestone and marly limestone (Scaglia rossa lithofacies, Upper Cretaceous-Lower Eocene); planktonic forams bearing white wackestone with darkish cherts (Scaglia bianca, Middle-Late Eocene); *Cancellophycus*-bearing grey wackestone and green clays (*Icniti limestones*, Lower Oligocene); graded calcareous breccias and laminated grainstone-packstone (*Nummulitid calcarenites* Lower Oligocene)	deep-water to slope	*Rotalipora* spp., *Globotruncana* spp., *Morozovella* spp., *Turborotalia cerroazulensis* s.l., *Cassigerinella chipolensis/Pseudohastigerina micra; Subterraniphyllum tomasi* Elliot, nummulitids and lepidocyclinids in the resedimented beds		Late Cretaceous-Early Oligocene	Patacca *et alii*, 1979; Mascle, 1979; Catalano *et alii*., 2010a; Basilone, 2011; 2012)
Hybla Fm	HYB		X	0-30	grey-blackish thin-bedded cherty limestones with radiolarians, sponge spiculae and planktonic foraminifers, alternated with whitish marls rich in belemnites; intercalations of packstone with *Aptychus* and mollusc fragments	deep-water	*Duvalia lata* (Blainville); *Hedbergella similis, Globigerinelloides ferreolensis, Gl. algeriana, Ticinella primula, T. breggiensis,* palynomorphs *(Afropollis jardinus)*		Aptian-Albian	Patacca *et alii*, 1979; Rio & Sprovieri, 1986; Bellanca *et alii*, 2002
Lattimusa	LTM	X		10-20	white and varicoloured calpionellid pelagic limestones (chalk) with few alternations of calcareous marls	deep-water	*Crassicolaria, Calpionella, Calpionellopsis, Calpionellites* biozones		Tithonian-Neocomian	Catalano & Liguori, 1971
Barracù Fm	BCU	X	X	10-50	red to greyish belemnite and ammonite-bearing pelagic mudstone-wackestone, alternated with red clays and siliceous marls. Few metres of radiolarites and bedded cherts (Cammarata section). Darkish radiolarites and siliceous clays, bedded cherts, vulcanites, resedimented grainstone-packstone with benthic forams, calcareous algae	deep-water, fissural magmatism, grain flow	*Bositra buchi* Roemer, radiolarians (UAZ 3-6 and 9-11), sponge spiculae, *Watznaueria barnesae, Belemnites semisulcatus, Lamellaptychus beyrichi*. In the resedimented beds: *Saccocoma sp., Protopeneroplis striata*		Bajocian-Early Tithonian	Broquet *et alii*, 1967; Mascle, 1979; Chiari *et alii*, 2008; Basilone, 2011
Green clays	GCM	X		0-15	vaycoloured clays with benthic foraminifers and shallow-water ostracods *(Bairdia* spp.)	hemipelagic	*Lenticulina* spp., *Lingulina* spp., *Marginulina* spp., *Frondicularia* spp.,		Pliensbachian	
Belemnite breccias	BMG	X		0-10	thick poorly-cemented massive calcareous breccias and conglomerates. The elements, mostly consisting of pelagic cherty limestone pebbles and, in minor percentage, by shallow water-derived fragments (oolitic grainstone, sponge and coral boundstone), are welded by yellow-greenish clayey marls matrix rich in belemnites	channalized debris flow	belemnites, ostracods, *Dentalina* cf. *varians*		Sinemurian-Pliensbachian	Broquet *et alii*, 1967; Broquet, 1968; Basilone *et alii*, 2014
Oolitic lmst and grey marls	OOL	X	X	0-10	Graded and laminated intra-bioclastic and oolitic packstone-grainstone (Figs. E, F in Pl. VII) with benthic foraminifers, crinoidal and brachiopod fragments alternated with thin-layered green to reddish clays	ramp-slope/ grain flow deposits	*Involutina liassica* Jones		Upper Hettangian - Sinemurian	(Broquet *et alii*, 1967; Mascle, 1979)

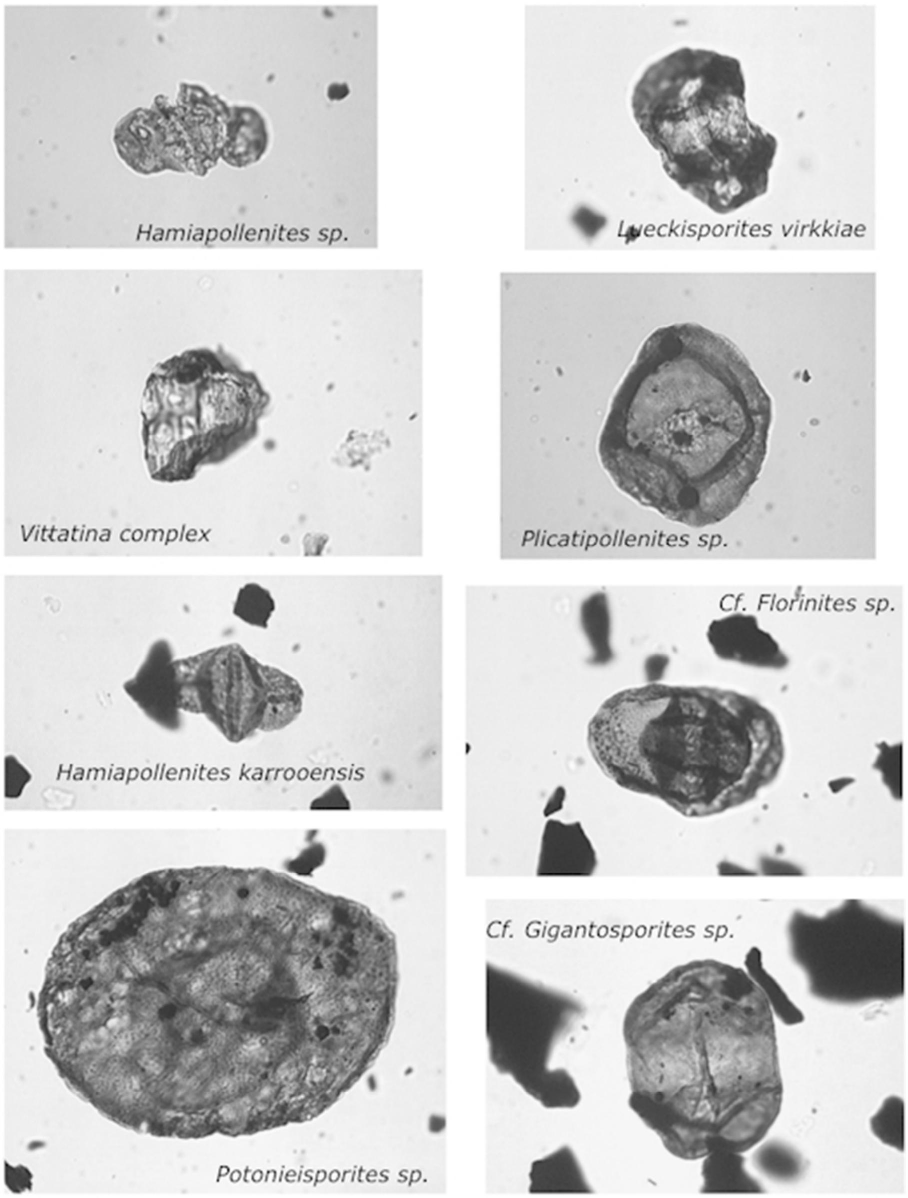
Formations	Labels	section: field	section: well	thick.(m)	Lithology	depositional environment	fossil content: field section	fossil content: drilled section	age	Main references
Tavernola Formation	TAV	x	x	>200	withish marls and sandy pelites alternated to quartz-glauconitic sandstones	base of slope-turbitites	*Cataspydrax dissimilis, Globigerinoides trilobus, Praeorbulina glomerosa*		Burdigalian-Langhian	Marchetti, 1960; Catalano *et alii*, 2010a, b; 2011
Numidian flysch	FYN	x	x	>400	brown pelites and clays alternated to turbiditic quartz-sandstones, marlstones and resedimented *Lepydociclina*-bearing packstone-grainstone	base of slope-turbitites	calcareous nannofossils (NP24-25 biozones), planktonic forams (*Gl. ciperoensis, Glt. kugleri* biozones), dynoflagellates (DM1, DM2, DO3 biozone)		Late Oligocene-Early Miocene	Wezel, 1966

Formations	Labels	section field	section well	thick.(m)	Lithology	depositional environment	fossil content: field section	fossil content: drilled section	age	Main references
S. Cipirello marls	CIP	x	x	150	hemipelagic marls with plankton forams	upper slope-to-basin	*Orbulina suturalis* (MMI 5-11 biozones)		Serravallian-lower Tortonian	Ruggieri & Sprovieri, 1970
Corleone calcarenites	CCR	x	x	50-100	large benthic foraminifera-bearing glauconitic grainstones and thin green marls	coastal-to-deltaic	*Myogipsina* spp. *Gbd. Trilobus,*	palynomorphs *(Polysphaeridium* sp., DM1, DM2 biozones), forams (*Catapsydrax dissimilis Paragloborotalia kugleri* biozones)	Burdigalian-Langhian-	Ruggieri, 1966; Lo Cicero & Pratini, 1981; Basilone, 2009b; 2011
Cardellia marls	RDE	x	x	200-250	plaktonic foraminifera-bearing marlstones and resedimented *Lepydociclina*-bearing packstone-grainstone	outer shelf-to-slope	calcareous nannofossils (NP24-25 biozones), planktonic forams *(Gl. ciperoensis, Glt. kugleri* biozones)	palynomorphs *(Chiropteridium* spp., DO3b biozone) bemthic forams *(Lepidocyclina* sp., *Amphistegina* sp.), planktonic forams (*Globigerina angulisuturalis, Globigerina ciperoensis, Paragloborotalia opima* biozones)	Chattian-Early Aquitanian	Biolzi, 1985; Catalano *et alii*., 2010a; Basilone, 2011

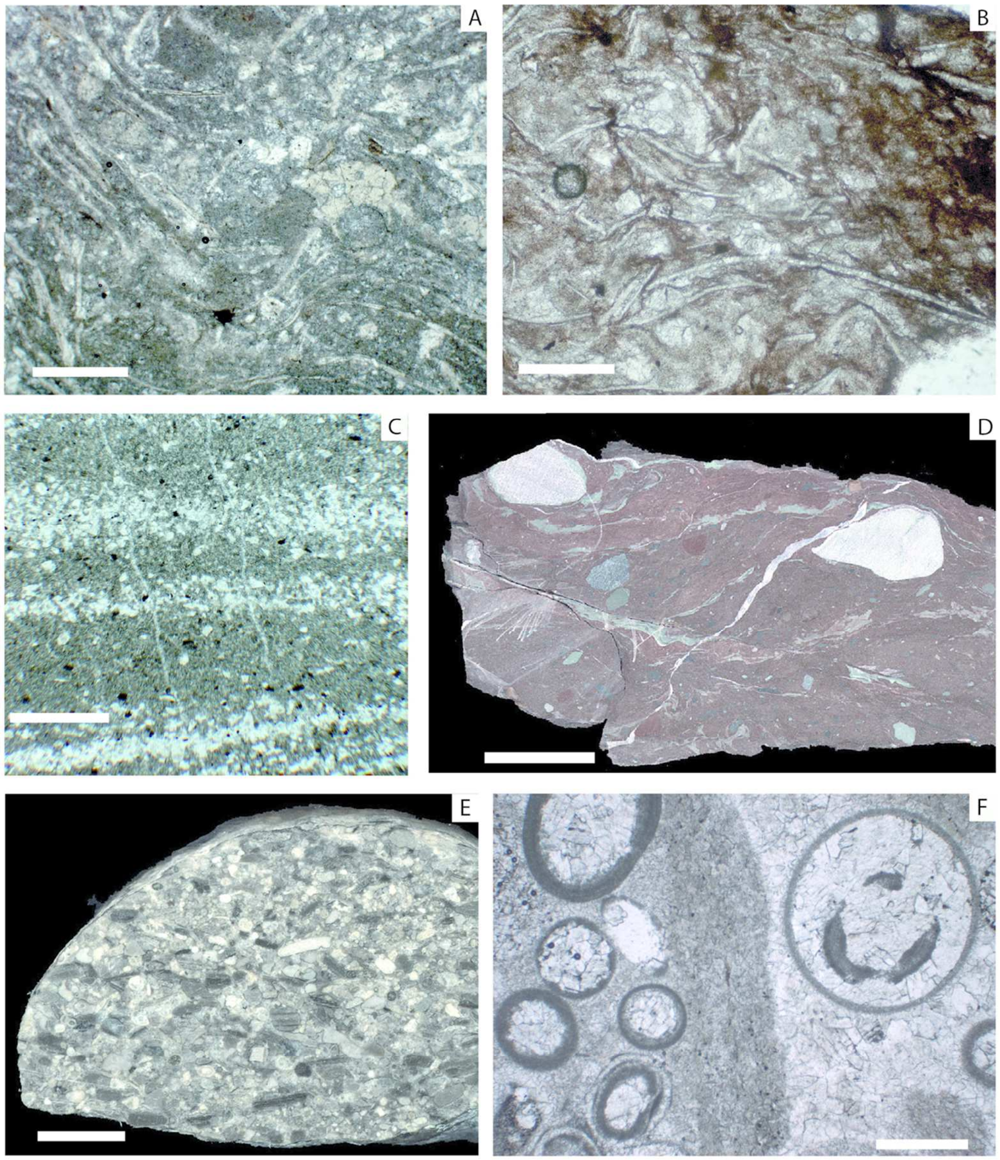
Seismostratigraphic unit	seismic characters	correlated lithologic units	areal extension (km^2)
Unit 1 (A in Fig. 13)	discontinuous, low amplitude and frequency, alternating with high amplitude reflectors, with a minimum thickness in the range of about 0.3-0.4 s (twt) up to 2.0 s (twt)	Permian-Triassic units (part of the Lercara Complex and Mufara Fm)	900
Unit 2 (B in Fig. 13)	i) high to medium amplitude, medium-to-high frequency group of reflectors, 0.8-0.9 s (twt) 1500 m-thick, bounded at the top by ii) subparallel medium to high amplitude reflectors alternated with low amplitude to transparent interval and at the bottom by iii) medium to high amplitude and medium-to-low frequency reflectors, with medium-to-low lateral continuity	i) Mesozoic carbonate Imerese section; ii) shales and sandstones of the Numidian flysch (FYN in Fig. 13B); iii) marl-calcilutite of the Mufara Fm (MUF in Fig. 13C)	4.050
Unit 3 (C in Fig. 13)	i) a sub-parallel, continuous and medium-high amplitude reflector package, 0.5–1.0 s (twt) about 950–2000 m-thick bounded at the top by ii) a high amplitude and frequency, almost continuous reflectors and at the bottom by iii) medium to high amplitude, discontinuous reflectors upwards replaced by medium to high amplitude and medium to low frequency reflectors, with poor lateral continuity	i) Mesozoic carbonate Sicanian section; ii) San Cipirrello marls and Corleone calcarenites (CCR in Fig. 13C); iii) marl-calcilutite of the Mufara Fm (MUF in Fig. 13C) and *pelagic Daonella limestone* (DAO in Fig. 13C)	4.500



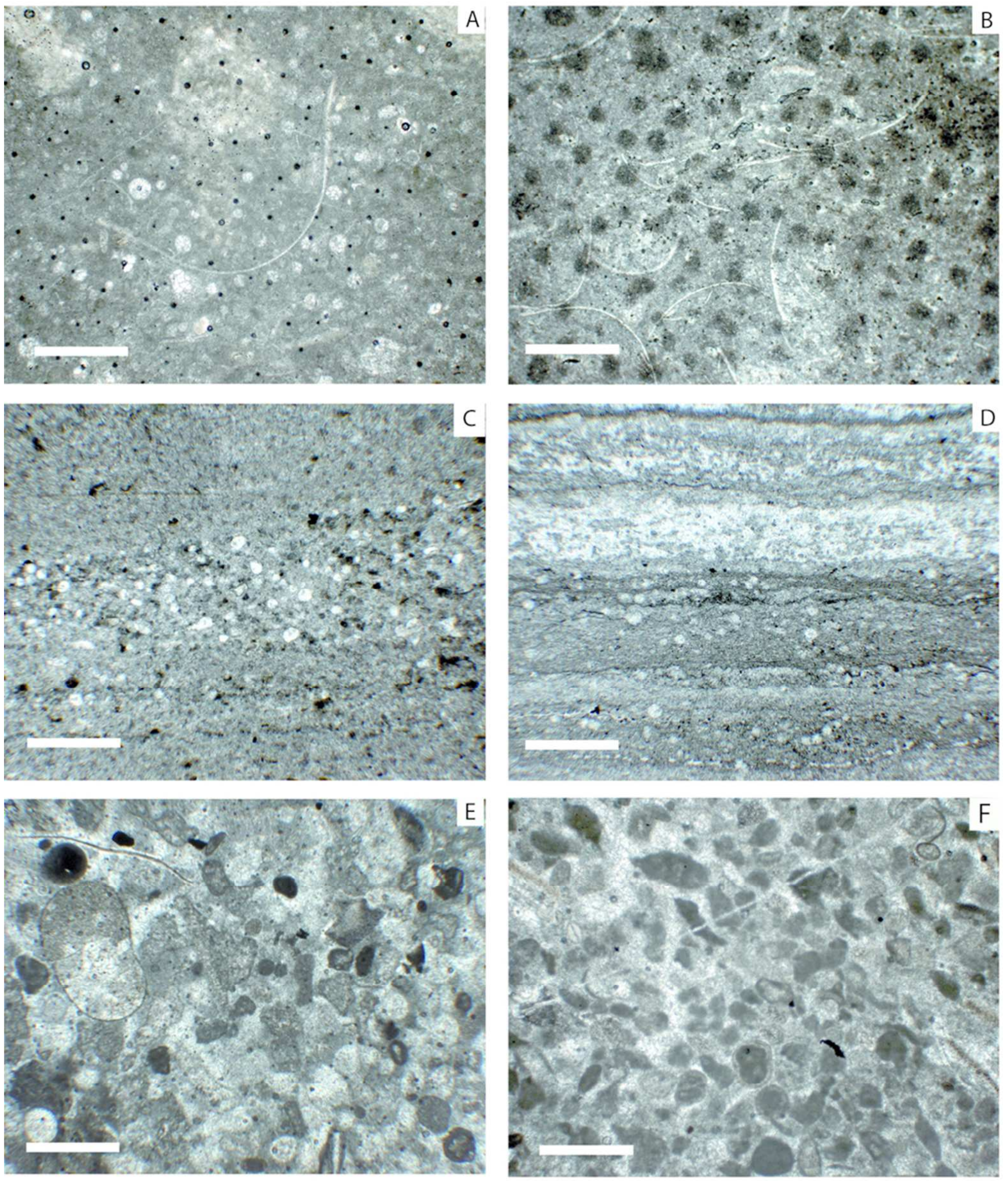
Pl. I - Characteristic microfacies of the Late Permian Roccapalumba clay and siltstone (RCS). Fig. A: red brown planar laminated clay siltstone with cm-thick layers of greenish to light-grey crossed laminated (ripples) siltstone-fine sandstone and siltitic mudstone intercalations (core 2, 708-711 m, Roccapalumba 1 well, macroscopic sample, photograph field about 10 cm); Fig. B: thin layer of coarse siltstone with quartz, feldspar, mica, glauconitic and phosphate fragments interlayered in to red siltitic clays (core 1, 484.6-485.9 m, Lercara 1 (Agip) well, crossed polarized light (XPL), scale bar 0,4 mm); Fig. C: grey to dark greenish altered basaltic rock with calcitic veins (cutting 68-72m, Roccapalumba 1 well, PPL, scale bar 1 mm); Fig. D: siltstone/fine sandstone with quartz, feldspar, glauconitic and phosphate fragments (cutting 231-234 m, Roccapalumba 1 well, plane polarized light (PPL), scale bar 0,4 mm); Fig. E: calcareous breccias with reef-derived fragments (cutting 64-67m Lercara Friddi 1 well, scale bar 1 mm); Fig. F: reworked bioclastic packstone showing benthic foraminifers, algae encrusting organism (core 5, 915-916m, Lercara 1 (Agip) well, scale bar 1 mm).
178x210mm (200 x 200 DPI)



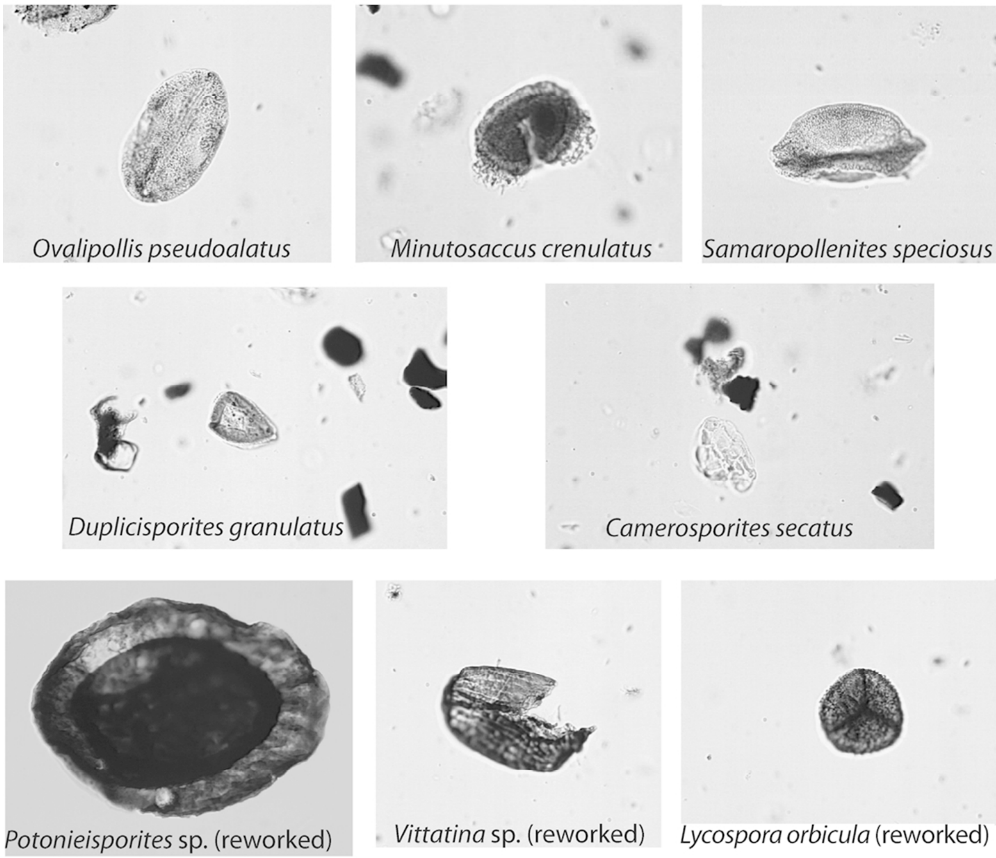
Pl. II - Late Permian microflora from Roccapalumba 1 well (400x).
184x244mm (72 x 72 DPI)



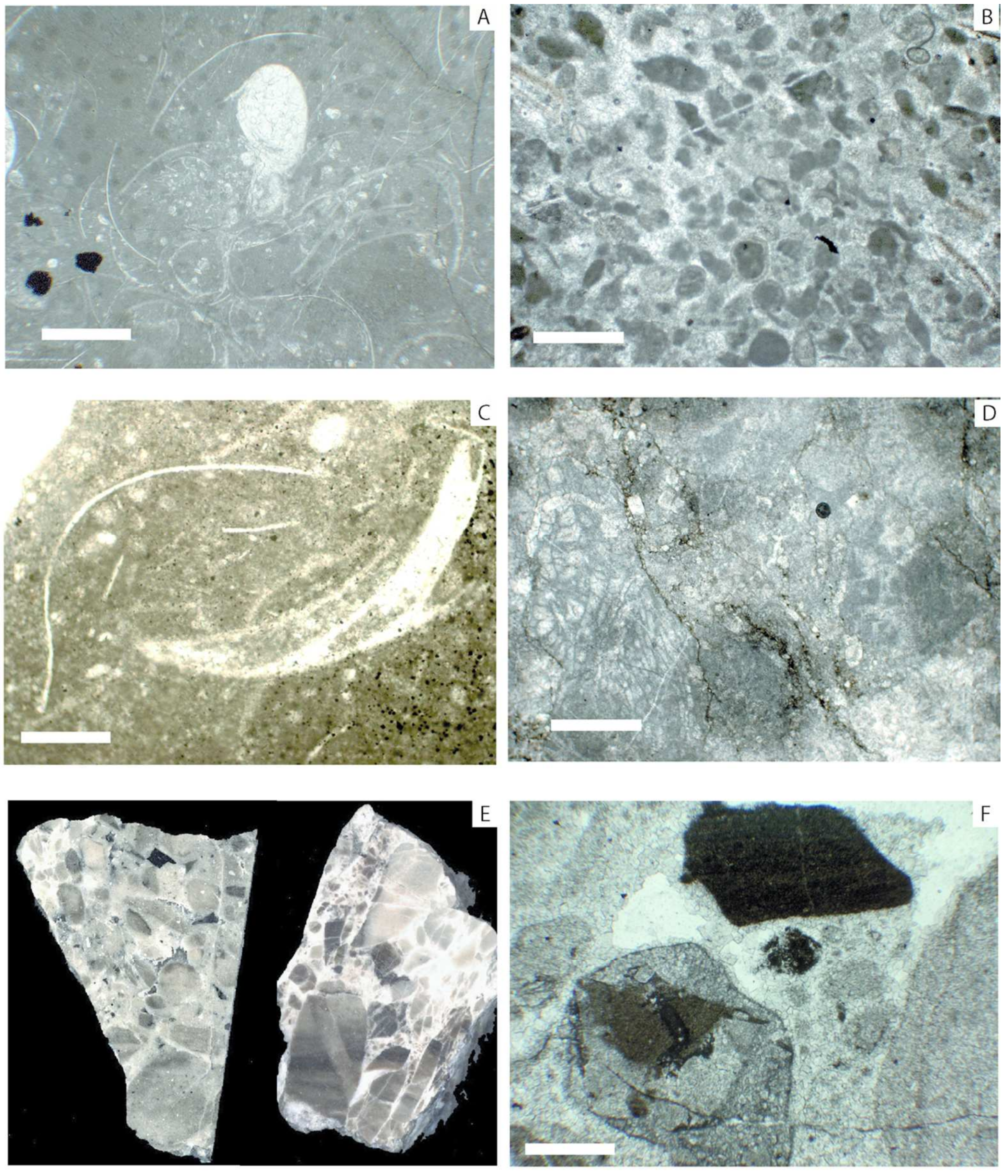
Pl. III - Characteristic microfacies of the Lower Triassic Manganaro clayey limestone (MNG). Fig. A: wackestone-packstone with pelagic pelecypods (core 14, 2336-2339, 7 m., Roccapalumba 1 well, scale bar 1 mm); Fig. B: red clays with pelagic pelecypods (cutting: 2402-2405 m., Roccapalumba 1 well, scale bar 0,4 mm); Fig. C: laminated quartzitic sandstone (core 6: 1635, 5-1637, 5 m., Roccapalumba 1 well, PPL, scale bar 2 mm); Fig. D: red mudstone with siliceous sandstone and white shallow-water carbonate clasts (core 16, 2427, 6-2431, 2 m., Roccapalumba 1 well, macroscopic sample, scale bar 1 cm); Fig. E: calcareous breccia (rudstone) with shallow-water derived clasts (core 8: 1724-1727 m., Roccapalumba 1 well, macroscopic sample, scale bar 0,5 cm); Fig. F: grainstone/packstone with surficial oolites, pelecypods fragments and coated grains (core 8: 1724-1727 m., Roccapalumba 1 well, scale bar 1 mm).
177x206mm (200 x 200 DPI)



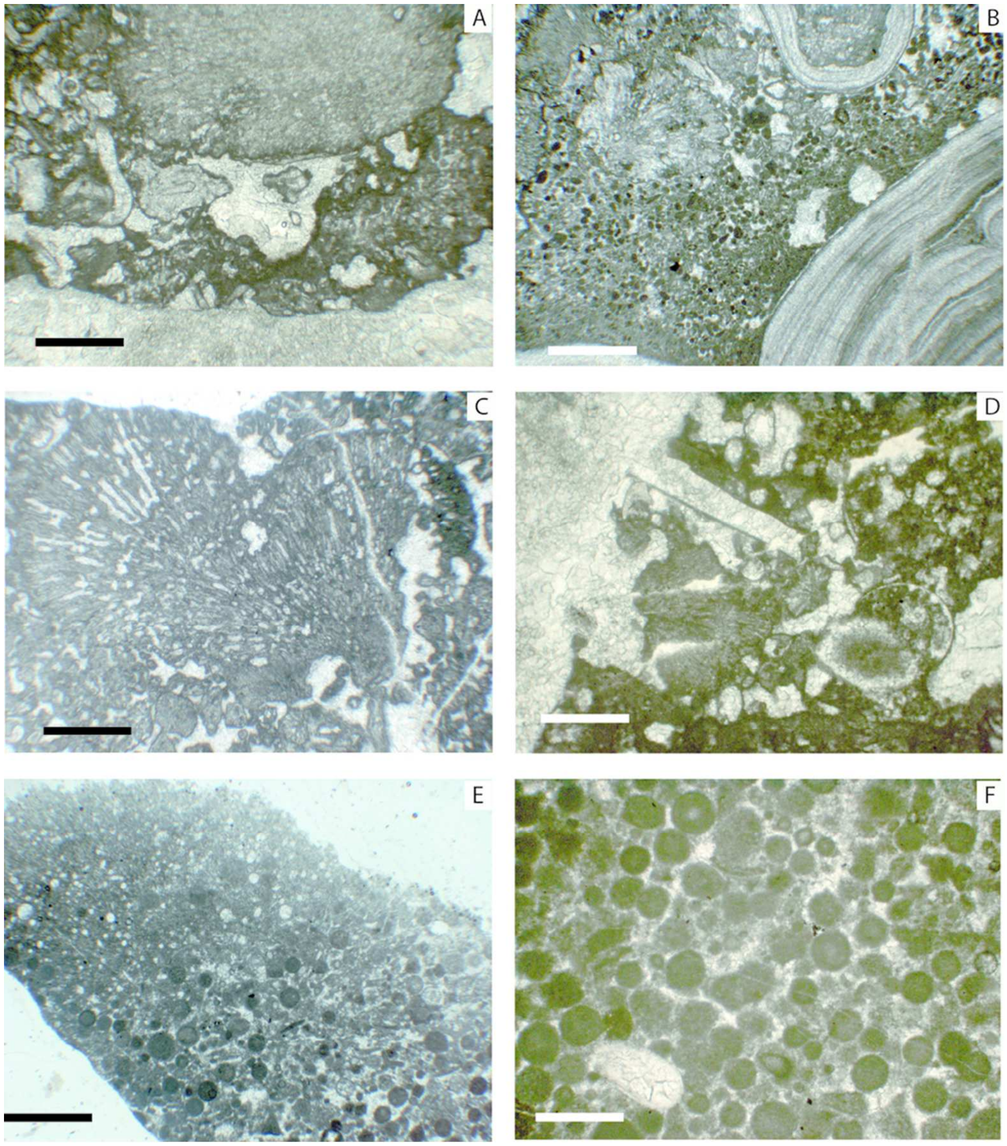
Pl. IV - Characteristic microfacies of the Ladinian Daonella limestone (DAO). Fig. A: wackestone with radiolarians and pelagic pelecypods (core 26, 2979,1-2981.5m, Platani 2 well, scale bar 1mm); Fig. B: wackestone with pelagic pelecypods (core 26, 2979.1-2981.5m, Platani 2 well, scale bar 1mm); Fig. C: mudstone with intercalation of siltstone-wackestone with radiolarians (core 25, 2882-2884m, Platani 2 well, scale bar 2 mm); Fig. D: grey laminated mudstone with radiolarians, dark grey and greenish clay and recrystallized mm-layers rich in radiolarians (core 27, 3052-3056m, Platani 2 well, scale bar 2mm); Fig. E: packstone-grainstone (calcareous turbidites) with ammonites, radiolarians, pelagic pelecypods and peloids (core 26, 2979.1-2981.5m, Platani 2 well, scale bar 2 mm); Fig. F: fine packstone/grainstone with ooids, intraclasts and bioclasts (core 26, 2979.1-2981.5m, Platani 2 well, scale bar 1mm).
176x209mm (150 x 150 DPI)



Pl. V - Late Ladinian-Early Carnian microflora and Permian-Carboniferous reworking from Platani 2 well (400x).
186x161mm (150 x 150 DPI)



Pl. VI - Characteristic microfacies of the Upper Triassic Mufara (MUF, Figs. A, B) and Scillato (SCT, Figs. C-F) Fms. Fig. A: mudstone-wackestone with radiolarians, ammonites and pelagic pelecypods (core 24: 2724.9-2727.3 m, Platani 2 well, PPL, scale bar 2 mm), with intercalations of Fig. B: intra-bioclastic and oolitic fine packstone (core 26: 3052-3056 m, Platani 2 well, PPL, scale bar 1 mm); Fig. C: brown wackestone-packstone with radiolarians and pelagic pelecypods (cutting 1740-1743 m, Platani 2 well, PPL, scale bar 0,4 mm); Fig. D: bioclastic and intraclastic (shallow-water derived fragments) grainstone and coral boundstone fragments (core 5, 3067.5-3076 m, Creta 1 well, PPL, scale bar 2 mm); Fig. E: dolomitized calcareous breccias with elements of pelagic mudstone with radiolarians (cores 18-19, 2189-2182 m and 2192-2194 m, Platani 2 well, macroscopic samples, photograph field about 15 cm); Fig. F: grey calcareous breccias with blackish clayey-marls pelagic clasts (core 19, 2192.6-2194.1 m, Platani 2 well, PPL, scale bar 0,4 mm).
179x209mm (200 x 200 DPI)



Pl. VII - Characteristic microfacies of the Lower Jurassic Altofonte calcareous breccias (ALT, Figs. A-D) and oolitic limestones (OOL, Figs. E-F). Fig. A: packstone with algae, crinoids, benthic foraminifera and intraclasts (core 3: 2833-2841 m, Creta 1 well, PPL, scale bar 2 mm); Fig. B: packstone/grainstone with algae, peloids and large oncoids (core 3: 2833-2841 m, Creta 1 well, PPL, scale bar 2 mm); Fig. C: grainstone with codiacean algae, crinoids, benthic foraminifera and intraclasts (core 3: 2833-2841 m, Creta 1 well, PPL, scale bar 2 mm); Fig. D: packstone/grainstone with dasycladacean and codiacean algae, mollusc fragments, peloids and intraclasts (core 3: 2833-2841 m, Creta 1 well, PPL, scale bar 2 mm); Fig. E: oolitic and bioclastic wackestone-packstone (cutting 1666-1664 m, Platani 2 well, PPL, scale bar 1 mm); Fig. F: oolitic grainstone (cutting 1691-1694 m, Platani 2 well, PPL, scale bar 0.5 mm).
172x195mm (150 x 150 DPI)