Extensional detachment geometries on the Tyrrhenian margin (the Salerno district)

Emilio CASCIELLO*, Massimo CESARANO*, Alessandro CONFORTI**, Bruno D'ARGENIO**, Ennio MARSELLA**, Gerardo PAPPONE* & Marco SACCHI**

* Dipartimento di Scienze e Tecnologie per l'Ambiente e il Territorio, Università degli Studi del Molise, Isernia, Italia
** Istituto per l'Ambiente Marino Costiero, Consiglio Nazionale delle Ricerche (CNR), Napoli, Italia

ABSTRACT

In the Salerno district large scale extensional tectonics on low angle detachment faults has produced a significant thinning and the dismemberment of the Mesozoic carbonate platform successions that compose the thrust belt in this region. The geometrical characteristics and kinematics of this extensional detachment array have been reconstructed during the National Geologic Mapping Project (CARG) Sheet 467 "Salerno", through detailed structural mapping on land and the integration of offshore seismic lines and stratigraphic analyses.

AIMS

The key objectives that have been pursued during this investigation have been:
1) The identification of cartographic units based on lithostratigraphic criteria that are immediately recognizable in the field (Fig. 1).
2) The chronological definition of cartographic units through biostratigraphic analyses (Figs. 1 and 3).
3) The identification of tectonic units, that is, elements bounded by tectonic discontinuities (faults) which have formed in response to a determinate state of stress and that have been displaced accordingly (e.g.: units relating to the regional overthrust that displaces the Carbonate Platform successions onto the Lagonegro basinal units; units relating to east-verging thrusting; units defined by extensional detachment
faults; etc.).
4) The coherence of the structural/kinematic reconstruction, which has been tested by drawing numerous geological sections oriented both parallel and perpendicular to the observed directions of tectonic transport (Fig. 5).
5) The recognition of the off shore prosecution of structures detected on land
by means of interpretation of seismic lines (Fig. 6).
6) The mapping and analysis of Quaternary deposits of the Salerno basin (Fig. 7) to reveal the youngest deformation in the area.

KEY WORDS

Geological mapping, extensional tectonics, detachment faults, Triassic, tectonic windows, marine geology, seismic interpretation.

RIASSUNTO

Nel distretto di Salerno la tettonica estensionale plio-pleistocenica, agente su piani di detachment a basso angolo, ha prodotto un significativo assottigliamento e lo smembramento delle successioni mesozoiche di piattaforma carbonatica che in questo settore compongono la catena. Nel corso del progetto di cartografia CARG, Foglio 467 Salerno, attraverso l'analisi strutturale a terra e con l'integrazione di dati stratigrafici e linee sismiche a mare, è stato possibile ricostruire le caratteristiche geometriche e cinematiche di questo importante sistema di detachment estensionale.

GEOLOGICAL MAP OF THE SALERNO DISTRICT

Fig. 1 - *The territory shown in this geological map is a portion of the Salerno district exposing extensional klippen and tectonic windows originated from the Late Pliocene-Early Pleistocene extensional tectonics which acted on a regional scale detachment fault system.*

1000 m 500 0 1 km

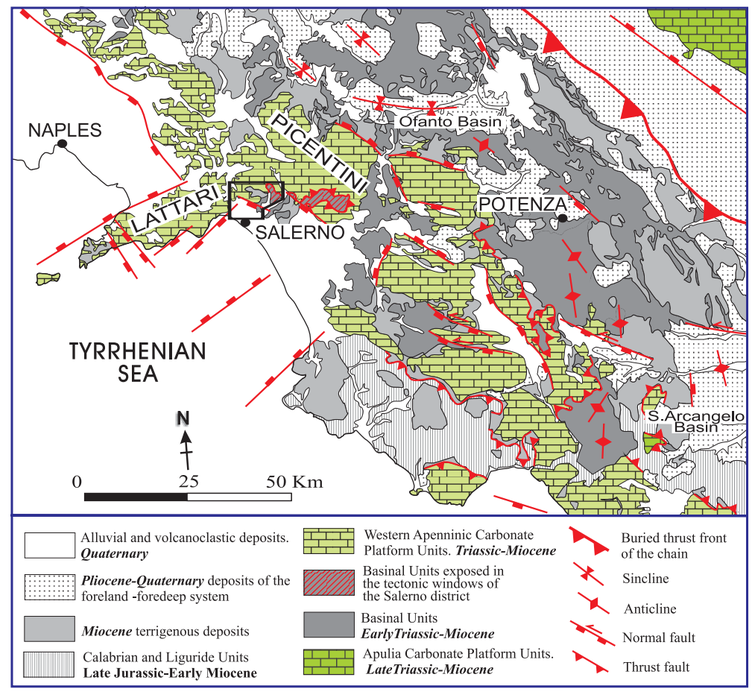


Fig. 2 - *Simplified geological map of the Southern Apennines and location map of the analysed area.*

AI — Pebbly and sandy alluvial deposits of modern and contemporaneous valley floors

A2 — Backshore and coastal dunes sandy deposits. Holocene - Present.

A1 — Anthropic and fill deposits of dune troughs; unselected and poorly sorted reclaim deposits; silt and peaty silts heteropic of dune sands. Marsh and pond clays and silts. Holocene - Present.

DEP — Clayey eluvial deposits originated from the alteration of pyroclastic materials, paleosols, "terre rosse" deposits (lying on slopes inclined 0°-5°). Upper Pleistocene - Holocene.

CPD — Colluvial pyroclastic deposits usually mixed with carbonate rock debris; generally deposited on slopes inclined 15°-30° or located at the base of slopes. Upper Pleistocene - Holocene

PSP — Pyroclastic deposits in primary position, originating from the flegrean and vesuvian activity; often forming successions containing paleosols and buried soils (usually on slopes inclined 0°-15°). Upper Pleistocene.

DT — Scree deposits composed by carbonate rock clasts, subangular in shape, poorly cemented. Upper Pleistocene

TGC — TUFO GRIGIO CAMPANO AUCT. O IGNIMBRITE CAMPANA AUCT. - Ignimbritic materials composed by grey cineritic-scoriaceous tuffs containing lapilli, crystals (mainly micas and sanidine) and showing eutassitic texture; potassic alkalitrachytic composition (average age: 33.000 years). Late Pleistocene

SFP — SINTEMA DEL FIUME PICENTINO - Alluvional gravels and sands often alternating with volcanoclastic colluvial deposits and pyroclastics in primary position. Upper Pleistocene

SFF a b — UNITÀ DEI TRAVERTINI DI FILETTA E FAIANO - Travertines showing facies characteristics relating to: a) Marsh and lacustrine environments. B) Slope and waterfall environments. Middle - Upper Pleistocene

SBP — SINTEMA DI BATTIPAGLIA-PERSANO - Poligenic alluvial gravels, crudely bedded, at times alternating with thin sandy lenses and clayey or silty levels containing rare fresh water mollusca. Middle Pleistocene

SEC — SINTEMA DI EBOLI - Conglomerates and breccias of alluvial and detritic talus, at places containing reddish pedogenic levels and sterile intercalations of sandy and silty leves which reveal a crude bedding. Lower Pleistocene

SALERNO PIGGY-BACK BASIN UNIT

ASM — ARENARIE E SABBIE DI MONTECORVINO - Yellowish sandstones forming beds 2 to 10 cm thick with occasional intercalations of grey mudstones. Thickness 180-200 m. Lower? Pliocene - Messinian

AMS — ARGILLE E ARGILLE SILTOSE DI SALERNO - Crudely bedded mudstones, marly mudstones and sandy mudstones, containing sandstone intercalations 10 to 30 cm in thickness. Approximate thickness 60-90 m. Lower Messinian - Tortonian

SICILIDE BASIN UNIT

AVS — UNITÀ AD AFFINITÀ SICILIDE - Grey, greenish and reddish mudstones and shales, marls, detritic limestones and grey calcarenites showing flute casts and traces of invertebrate organism activity.

M. MAI - M. MONNA UNIT
(scarp to basin carbonate successions)

Upper tectonic unit

CML — CALCARI LASTROIDI AD ECHINODERMI - Dark mudstones, mudstones-wackestones and rarely packstones, containing fragments of pelagic pelecypods ("filaments") forming beds 1 to 40 cm thick. Exposed thickness: 100 m. Dogger

CMM — CALCARI E MARNE - Brownish wackestones and packstones forming beds 5cm to 1,5m thick, containing coated grains, lamellibranch remains, gasteropoda, echinoderm plates and aculei and, rarely, small ammonites, corals and bryozoa. Approximate thickess: 100-130 m. Lias

Lower tectonic unit

COM — CALCARI AD OOIDI - Light grey oolitic limestones with ooliths up to 2mm in diameter, forming beds 0,1-1 m thick and containing fragments of lamellibranchs, echinoderms and crinoid ossicles. Exposed thickness 400 m. Dogger

DCS — CALCARI E DOLOMIE CON SELCE DEI M.TI MAI- Limestones, dolomites and dolomitic limestones (mudstones and wackestones) forming beds 2 to 30 cm thick containing cherty nodules and bands. The whole interval is characterised by slumpings and slump breccias. Thickness ranging from 250 to 550 metres. Lias

CLL — CALCARI E DOLOMIE CALCAREE LISTATE - Well bedded grey limestones and dolomitic limestones in layers 2cm to 50-60cm thick forming regular chromatic alternations. Slumps and "soft sediment" deformations are found in the succession. This interval is heteropic of DBL and ranges in thickness from 200 to 450 m. Rhaetian

M. TOBENNA - M. LATTARI UNIT
(shallow water carbonate platform successions and related siliciclastic cover)

ADT — *ARENARIE DI CASTIGLIONE DEL GENOVESI* - Grey-brownish sandstones forming layers 1-2cm to 1m thick, containing intercalations of grey shales up to 80 cm thick and light coloured mudstones. Exposed thickness 250m. Burdigalian - Serravallian

CIR — *CALCARI A RUDISTE DEL M. STELLA* - Light grey and whitish limestones and dolomitic limestones (mudstone and wackstones) forming layers 5-10 cm to 1,2 m thick, containing rudists and, less frequently, gasteropods. Thickness: 250-300 m. Lower Senonian - Cenomanian p.p.

DCT — *CALCARI E DOLOMIE DEL M. TOBENNA* - Dolomites, calcareous dolomites and limestones forming layers up to 2 m thick, often showing lamination, possibly of stromatolitic origin. Thickness: 250 m. Cenomanian

CRQ — *CALCARI A REQUIENIDI* - Limestones, dolomitic limestones and marly limestones forming layers 2 to 60 cm thick, containing discontinuous levels rich in requienids. Thickness 130 m. Albian

CMO — *CALCARI E MARNE CON ORBITOLINIDI* - Limestones, dolomitic limestones and dolomites ; yellowish and greenish marly limestones and marls are present in the upper portion of the succession where they form layers 5 to 8 cm thick. Thickness 60 m. Aptian - ?Barremian.

Middle Jurassic to Neocomian portions of the shallow water carbonate successions are missing due to tectonic omission operated by extensional detachment faulting.

DBL — *DOLOMIE BIOCLASTICHE E DOLOMIE LAMINATE* - Light grey dolomites well bedded (layers 0,2 to 2m thick) or massive, containing gasteropods, lamellibranchs and algal concretions forming oncoids; sponge biolithites; Megalodontid and serpulid rich dolomites; levels of dolomitic breccias (floatstone and rudstone) with angular clasts. Thickness 700-900. Lower Lias - Rhaetian

DNB — *DOLOMIE NERE BITUMINOSE* - Dark grey to black dolomites and dolomitic limestones, generally laminated, forming layers 1 to 10 cm thick, rarely up to 30 cm. Frequent intercalations are present, composed by shales rich in organic matter and less frequently by yellowish, black or grey marls and clays. This succession includes the "Scisti Ittiolitici Auct." levels. Thickness 80 - 190 m. Rhaetian

DBS — *DOLOMIE A BANDE E DOLOMIE STROMATOLITICHE* - Dolomites, calcareous dolomites and stromatolitic dolomites forming alternating sets of strata characterised by darker and lighter grey colour and by different layer thickness varying from few centimetres to 0,5-1,2 m. Desseccation structures (tepee) are sometimes found on bedding surfaces. Thickness 650- 700 m. Rhaetian - Norian.

CDN — *CALCARI E DOLOMIE NERI* - Black limestones and dolomitic limestones forming layers 5 to 10 cm thick, metric in the upper part of the succession, and containing occasional levels of breccias (rudstone and floatstone). Levels containing Avicula sp. and Myophoria sp. Are found in the succession. Thickness varying from 0 to 120 m. Carnian

MCA — *MARNE AD AVICULA* - Brownish marls and marly limestones, dark mudstones and marly mudstones. Occasional levels of carbonate breccias (rudstones) and levels containing Avicula decipiens and Myophoria vestita are found in the succession. Thickness: 40-130 m. Carnian

DBM — *DOLOMIA DI BASE MASSIVA* - Whitish or grey dolomites, usually massive and intensely cataclastic. Rare intercalations of reddish or green mudstones are present. Thickness ranging from 100 to 400-500 m. Carnian

LAGONEGRO BASIN UNIT

SSL — *SCISTI SILICEI* - Red or greenish cherts, shales and marly shales containing bands and nodules of black chert, cherty calcilutites and calcarenites forming layers occasionally up to 1 m thick. Liassic

CSL — *CALCARI CON SELCE* - Limestones and dolomitic limestones containing nodules and bands of dark chert and intercalations of reddish or greenish shale. Upper Triassic

bedding attitude
- Horizontal
- Inclined (20)
- Vertical
- Overturned

- Stratigraphic contact, supposed stratigraphic contact
- Fault, supposed fault
- Thrust, supposed thust
- Normal fault, supposed normal fault
- Strike slip fault, supposed strike slip fault
- Strike slip fault with unknown direction of displacement

- Inactive alluvial fan
- Recent and active alluvial fan
- Edge of alluvial terrace
- Trace of geological section
- Active quarry
- Abandoned quarry
- Fossiliferous site

INTRODUCTION

The Salerno district is a classic area of interest for the study of the Triassic dolomite successions that compose the lowermost portion of the Apennine carbonate platform (GALDIERI, 1908; DE CASTRO, 1990; ZAMPARELLI *et alii*, 1999). The vast exposures of Triassic successions and their structural setting are the result of a complex deformational history (Fig. 1) which recorded contraction, during the Neogene Southern Apennine orogeny, and large scale extensional processes related to the Late Miocene-Pleistocene formation of the Tyrrhenian basin (D'ARGENIO *et alii*, 1973; PATACCA *et alii*, 1990; OLDOW *et alii*, 1993; FERRANTI *et alii*, 1996; CINQUE *et alii*, 1993). It is the latter extensional features that, through extensive mapping at a 1:10,000 scale and the on land - offshore integration, have been redefined and are discussed in this contribute.

A selected portion of the sheet Salerno (National Geologic Mapping Project - CARG, sheet 467) is shown here in both its terrestrial and offshore components, together with elaborations explicating the characters of the extensional structures that affect this area.

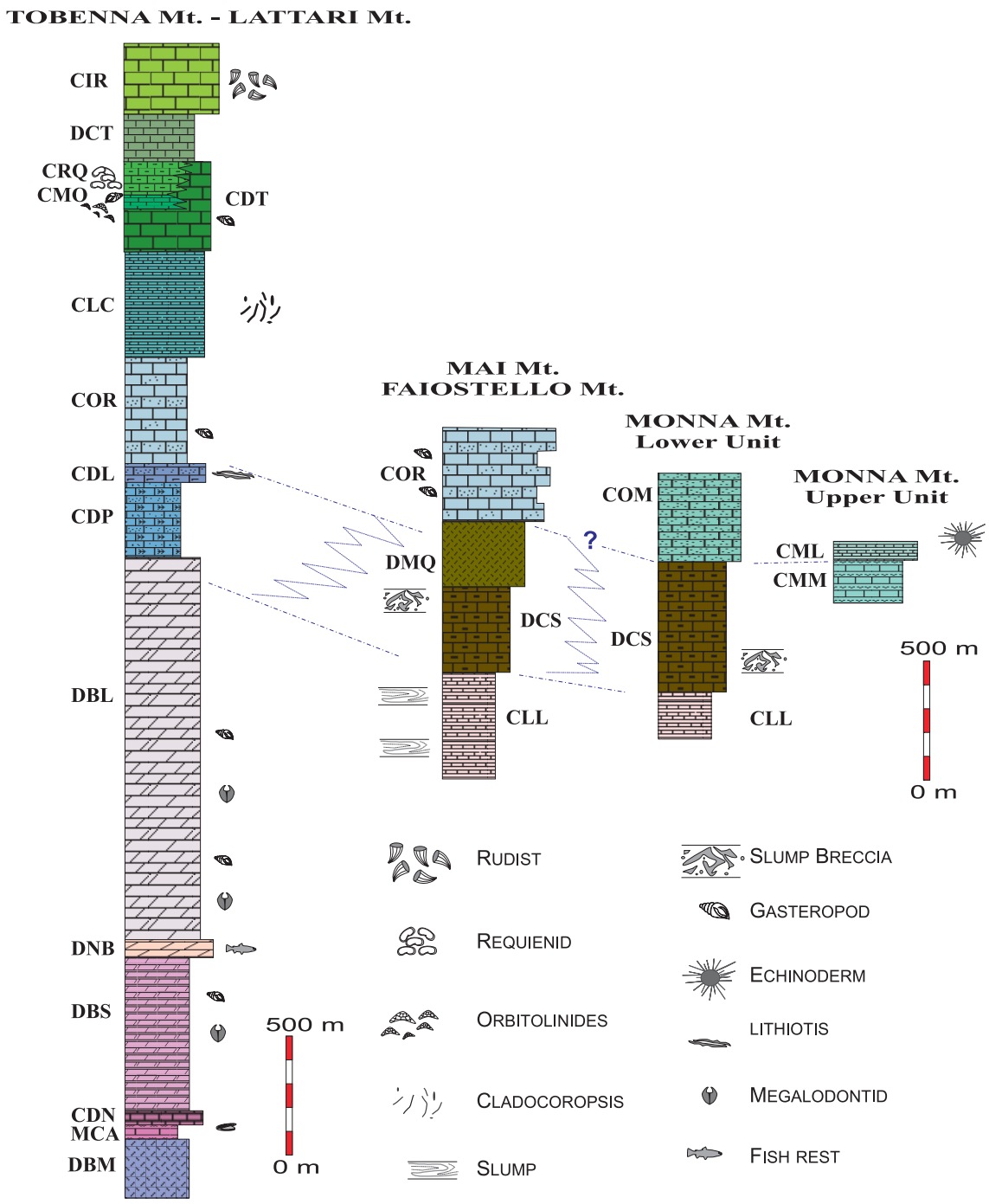
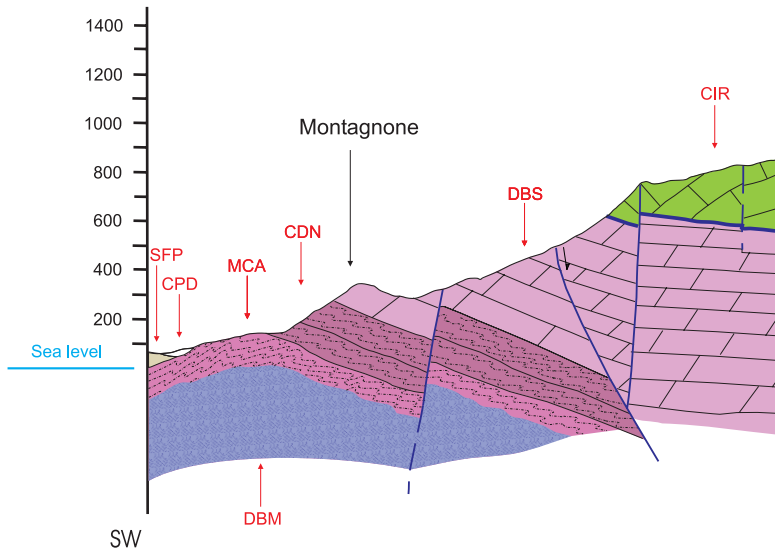


Fig. 3 - *Stratigraphic successions exposed in the studied area and in the whole Salerno district.*



GEOLOGICAL SETTING

The Southern Apennines are a fold and thrust belt generated by progressive northeastward stacking of passive margin sediments, mainly during the Neogene. This led to the formation of a tectonic multilayer composed by alternating “layers” of basinal rocks, originating from the deformation of basinal domains (Sicilide and Lagonegro Units *Auct.*), and carbonate platform successions eradicated from the subducting eastern Adriatic plate.

The investigated area is formed predominantly by Carnian to Late Cretaceous successions of the Apennine Carbonate Platform (MOSTARDINI & MERLINI, 1986; CASERO *et alii*, 1988) which, according to our analysis, attains a total reconstructed thickness of almost 5 km.

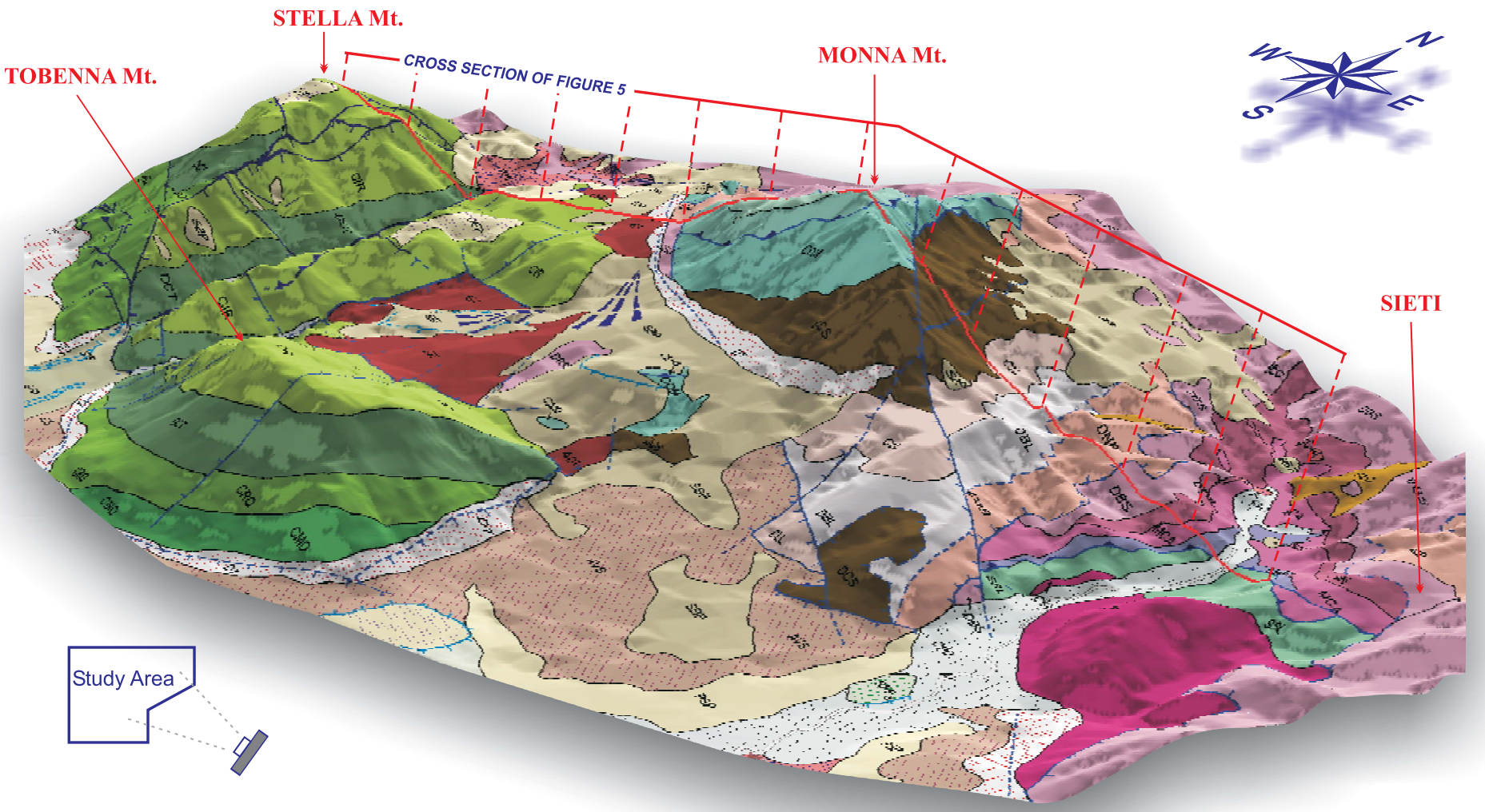


Fig. 4 - *3D geological map of the examined area obtained by draping the raster image of the geological map on the DTM (Digital Terrain Model) of the same area. Note how the highest structural units (Sicilide Unit - AVS) and the upper portion of the carbonate platform successions (Late Cretaceous) are displaced towards the lowermost portion (DBS - Late Triassic) of the same succession. The entire thickness of the Apennine Carbonate Platform succession, almost 5,000 m, is thinned to less than 1,000 m in the Stella Mt. The thinning is even more evident in the Sieti tectonic window where the underlying Lagonegro structural level becomes exposed.*

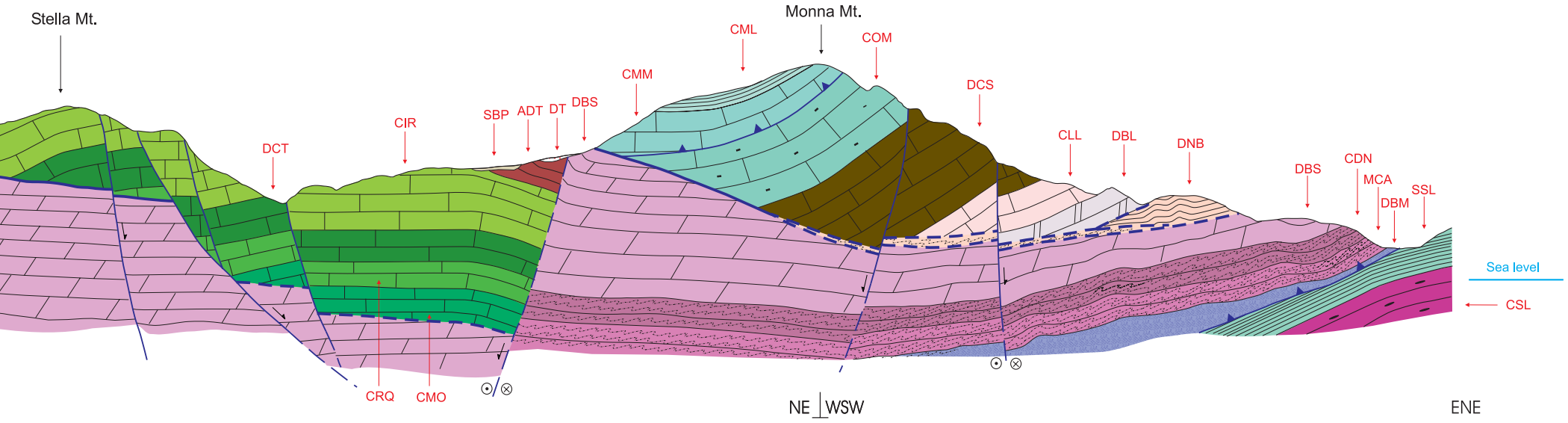


Fig. 5 - *A geological cross section drawn from west to east highlights the structural significance of the analysed extensional detachments. The base of the carbonate platform succession is formed by Carnian -usually cataclastic- dolomites which tectonically overly Liassic basinal deposits of the Lagonegro Basin Units (right corner of section). This is a regional scale overthrust contact which is generally defined by well and seismic data (Mostardini & Merlini, 1986; Casero* et alii, *1988). The exposure of this regional feature in the Sieti tectonic window (Fig. 4), and in other tectonic windows in the Salerno district, Fig. 1, represents an exceptional case generated by the large scale extensional processes investigated here. Extensional detachment faults involve the whole thickness of the carbonate platform succession and dip eastwards further into the Lagonegro structural level, producing a large amount of stratigraphic thinning. This is immediately evident from the large stratigraphic omissions existing along the low angle faults; the Stella and Monna successions are part of the extensional hangingwall and form klippen which, moving from west to east, rest on progressively older and structurally deeper levels of the footwall carbonate succession, and that preserve older contractional structures (Monna Mt.). A younger generation (Middle - Late Pleistocene) of high angle normal faults, trending NW-SE and NE-SW, and transtensional faults oriented WNW-ESE displace the low angle extensional faults.*

The Jurassic evolution of this carbonate platform succession is characterised by the differentiation into a shallow water platform succession and a coeval carbonate scarp succession (Fig. 3).

While the former (Tobenna-Lattari succession) is found with good continuity in the western and northern parts of the investigated area, the Monna-Mai scarp succession is highly fragmented (Figs. 2 and 4) as the result of large displacements in an extensional detachment structural array. This consists of several large faults, often characterised by intense cataclasis, that display an overall dip (generally less than 30°) towards E/SE, extensional displacement towards ESE and large structural and stratigraphic omission (Fig. 5). This array of low angle extensional faults can be understood as being part of a single, large scale, extensional structure.

Offshore seismic data show that an analogous structure extends below the Salerno basin (Fig. 8); this points to a large scale continuity of this major tectonic structure which, plausibly, has played a significant role in the formation of the Salerno basin.

MAPPING

Detailed field mapping was initially aimed at the recognition of objective litostratigraphic criteria; this allowed to distinguish several cartographic units in the Mesozoic carbonate successions.

The chronological definition and lateral correlation between such cartographic units has been assessed through biostratigraphic and sedimentological analyses.

This has led to the identification of a shallow water carbonate platform area, extending northwards and westwards in the Picentini and Lattari Mts. (Fig. 1), and a marginal area represented by carbonate scarp facies which is now found dismembered in the Salerno area.

OFF SHORE GEOLOGY

On-land interpretation of the structural setting has been aided and confirmed by off shore investigations. These were based on core and dredging analysis, sub-bottom profiles and ministerial seismic lines (Fig. 6). Off shore data have allowed to define in detail the stratigraphy of the Late Quaternary deposits (Fig. 7) and to recognise the prosecution of the extensional detachment faults in the Salerno Basin (Fig. 8). The Salerno Basin, together with the Sele Plain on land, represents a relatively deep basin which was individuated

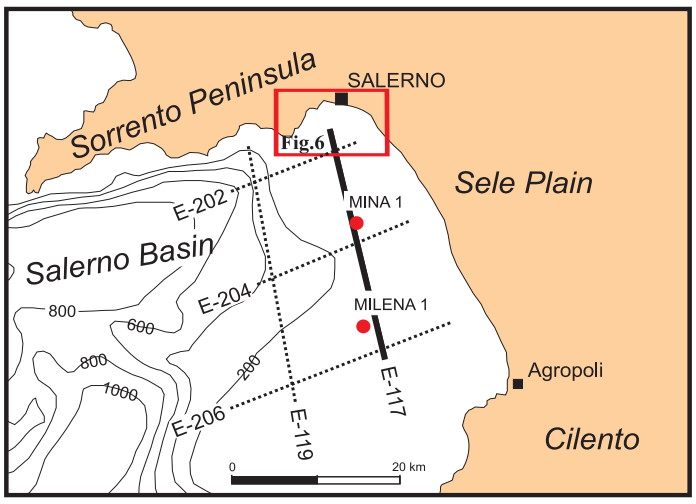


Fig. 6 - *Location map of the analysed seismic profiles and of the exploration wells in the Campania offshore (see Figs. 7 and 8).*

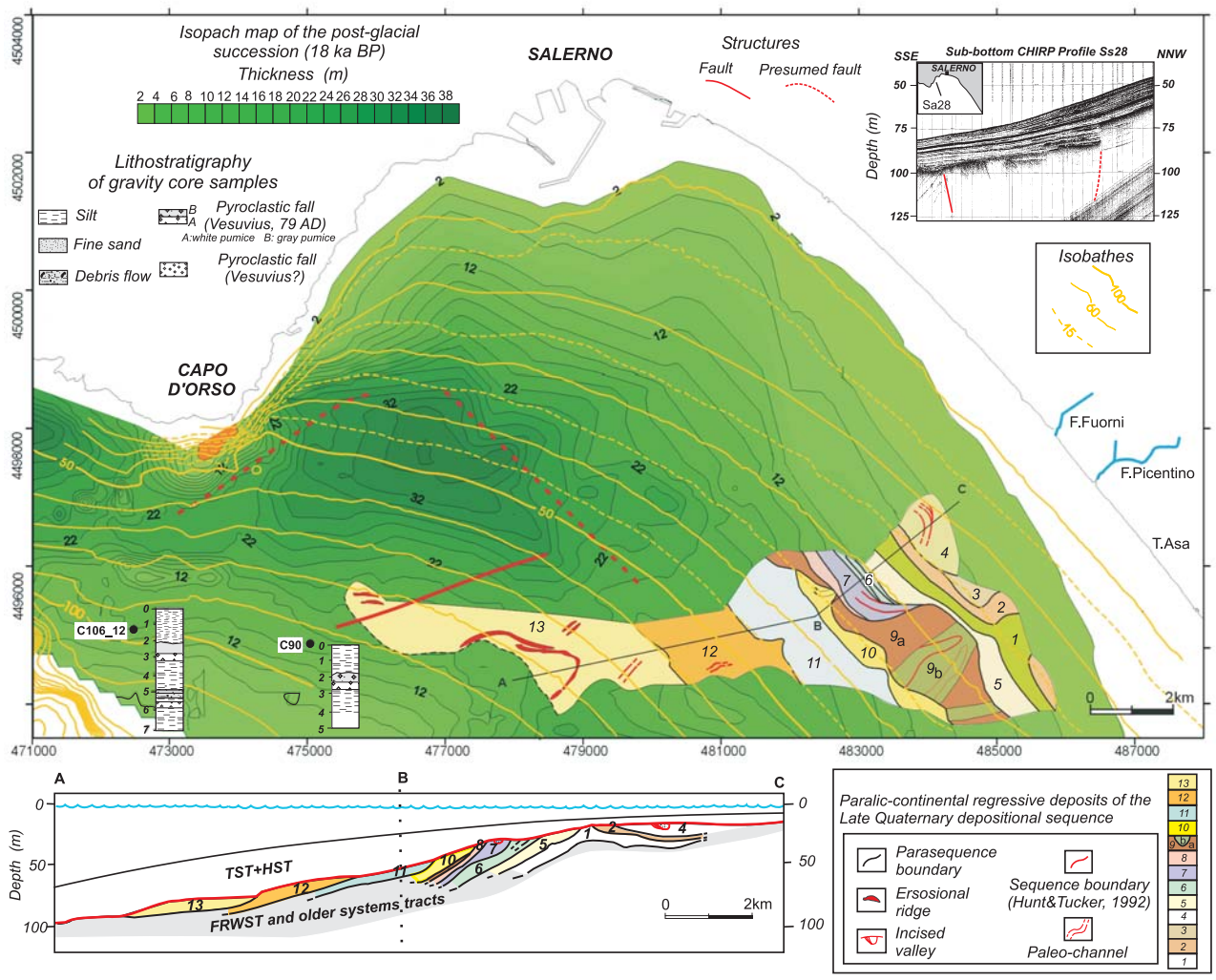


Fig. 7 - *Distribution and characteristics of the Late Quaternary depositional sequence in the Salerno Gulf (boxed area in Fig. 6).*

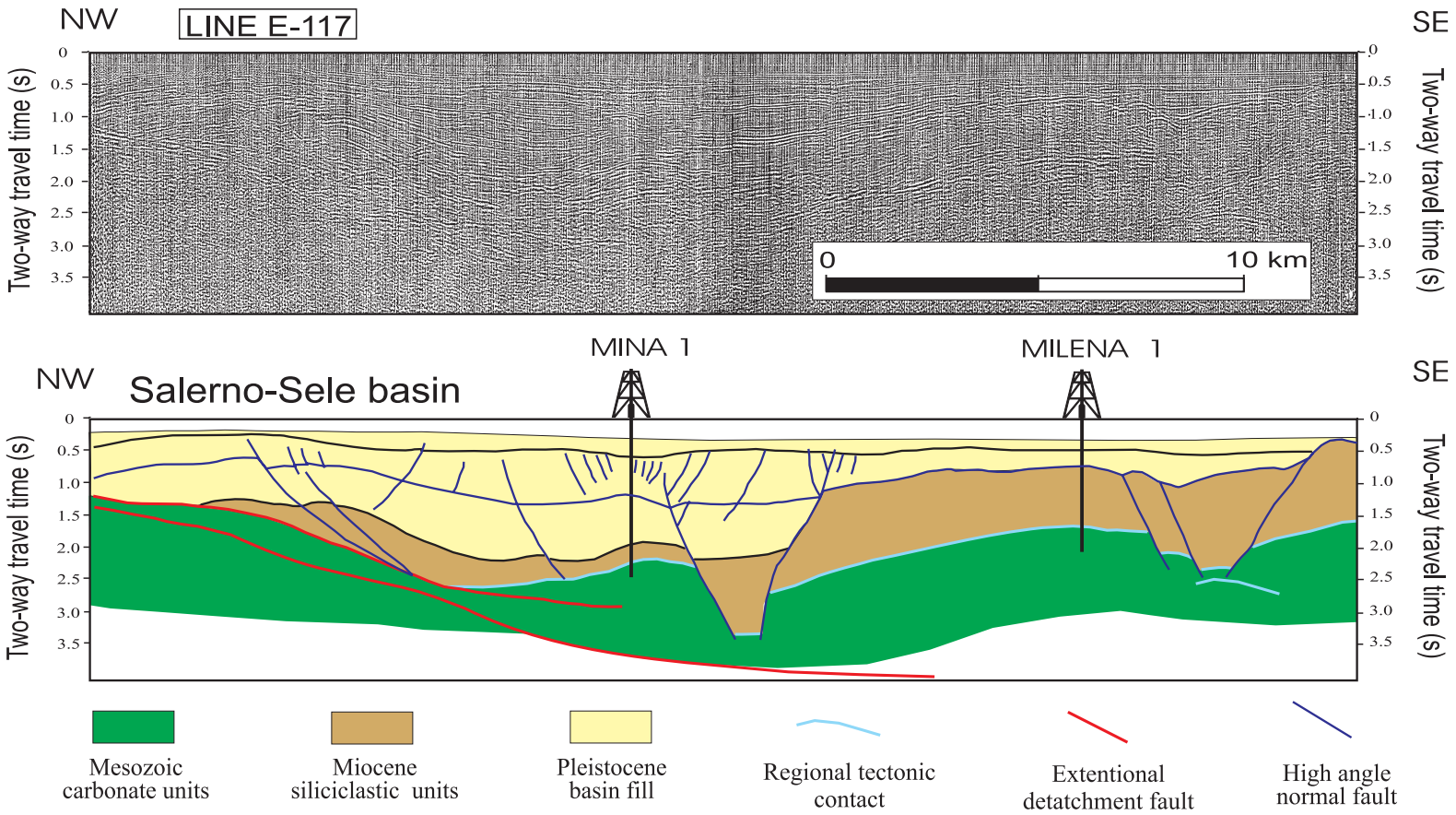


Fig. 8 - *Seismic multi-channel reflection profile of the offshore area of the Salerno Gulf (location in Fig. 6) and interpretation. The tectonic setting is characterised by a series of grabens and half grabens overlying a main detachment fault. A partial and very recent inversion of this extensional structure may be detected.*

since Pleistocene between the Cilento and Sorrento Peninsula structural highs, to the South and to the North, respectively. The pre-Quaternary basement is formed in this area by a Mesozoic carbonate substratum and Miocene siliciclastic wedges and nappes. The Pleistocene succession displays a thickness in the order of 2700 m. The interpretation of seismic profiles suggests that Quaternary structural evolution of the area was associated with the development of a major system of SW-NE trending listric faults. These faults control the half-graben setting of the main tectonic depression. Within the Salerno Basin a number of tectonically deformed areas may be detected. Deformation may involve the Upper Quaternary - Late Pleistocene depositional sequence and reactivates or generates SW-NE oriented faults (SACCHI *et alii*, 1994).

REFERENCES

CASERO P., ROURE F., ENDIGNOUX L., MORETTI I., MULLER C., SAGE L. & VIALLY R. (1988) - *Neogene geodynamic evolution of the Southern Apennines.* Mem. Soc. Geol. It., **41**: 109-120.

CINQUE A., PATACCA E., SCANDONE P. & TOZZI M. (1993) - *Quaternary kinematic evolution of the Southern Apennines. Relationship between surface geological features and deep lithospheric structures.* Annali di Geofisica, **36** (2): 249-260.

D'ARGENIO B., PESCATORE T. & SCANDONE P. (1973) - *Schema geologico dell'Appennino meridionale (Campania-Lucania).* Quad. Acc. Naz. Lincei, **183**: 49-72.

DE CASTRO P. (1990) - *Studies on the Triassic carbonates of the Salerno province (Southern Italy): the Croci d'Acerno sequence.* Boll. Soc. Geol. It., **109**: 187-217.

FERRANTI L., OLDOW J.S. & SACCHI M. (1996) - *Pre-Quaternary Crustal Extension In The Southern Apennines belt, Italy: arcuation and orogen-parallel collapse.* Tectonophysics, **260**: 325-347.

GALDIERI A. (1908) - *Sul Trias dei dintorni di Giffoni. Contributo alla conoscenza del terreno triassico del Salernitano.* Atti Acc. Pontaniana, **38**, Serie II, **13**: 1-124.

HUNT D.W. & TUCKER, M.E. (1992) - *Stranded parasequences and the forced regressive wedge systems tract: deposition during base-level fall.* Sedimentary Geology, **81**: 1-9.

MOSTARDINI F., & MERLINI S. (1986) - *Appennino Centro-Meridionale: sezioni geologiche e proposta di modello strutturale.* Mem. Soc. Geol. It., **35**: 177-202.

OLDOW J.S., D'ARGENIO B., FERRANTI L., PAPPONE G., MARSELLA E. & SACCHI M. (1993) - *Large-scale longitudinal extension in the Southern Apennines contractional belt. Italy.* Geology, **21**: 1123-1126.

PATACCA E., SARTORI R. & SCANDONE P. (1990) - *Tyrrhenian Basin and Apenninic Arc: kinematic relations since late Tortonian times.* Mem. Soc. Geol. It., **45**: 425-451.

SACCHI M., INFUSO S. & MARSELLA E. (1994) - *Late Pliocene-Early Pleistocene compressional tectonics in offshore campania (Eastern Tyrrenian sea).* Boll. Geof. Teor. Appl., **36** (141-144): 469-482.

ZAMPARELLI V., CIRILLI S., IANNACE A., & JABOUL F. (1999) - *Palaeotectonic and Palaeoceanographic controls on microbial-serpulid communities in the Norian-Rhaetian carbonates of Italy: a synthesis.* In: (R. COLACICCHI, G. PARISI & V. ZAMPARELLI (Eds.), Bioevents and Integrate Stratigraphy of the Triassic and the Jurassic in Italy, Palaeopelagos Sp. Publ. **3**: 7-84.