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THIN SKINNED DEFORMATION AND STRUCTURAL EVOLUTION IN THE NE SEGMENT OF THE GELA NAPPE, SE SICILY

CONTENTS

ABSTRACT

The Gela Nappe represents the southern termination not only of thrusting on Sicily but also of compressional deformation in this segment of the Maghrebian orogen. The nappe, a fold-thrust complex carried on a basal detachment, involves units including a thick sequence of clays of Tortonian age, upon which rest, variably folded and faulted, Messinian evaporites. The major period of folding and thrusting occurred after the deposition of the Early Pliocene Trubi Fm. These units are found in the footwall to the basal thrust at the AGIP Ramacca 1 borehole.

The foredeep fill is governed by pre-existing fault-controlled basin floor topography. These faults appear to have conditioned the structural evolution of the Gela Nappe initially as it thickened internally and then detached from its substratum to be emplaced onto the foreland.

Deformation of the Gela Nappe occurred mainly by thin-skinned thrusting with an overall foreland (SE) vergence. Less penetrative back thrusts and overturned folds are widespread and serve to accommodate the shortening created by deeper, low angle, decollement planes.

Important stratigraphic sequence boundaries, linking the thrust belt to the foreland, can be used to define the nature of the stratigraphic template prior to the deformation and emplacement of the Gela Nappe.

RIASSUNTO

La Falda di Gela, nel suo segmento nord-orientale presenta come termini piú profondi le argille ed arenarie glauconitiche dell'Unità di M.Judica di età Oligocene superiore-Serravalliano su cui poggiano tettonicamente l'oligo-miocenico Flysch Numidico e isolati lembi alloctoni di Unità Sicilidi.

La successione supramiocenica è data prevalentemente da argille grigio-azzurre su cui poggia la serie evaporitica messiniana suddivisibile in tre distinte unità separate da due discordanze, prodotto della tettonica sinsedimentaria inframessiniana. I sedimenti pliocenici sono costituiti dai Trubi del Pliocene inferiore su cui poggiano in discordanza, solo nella parte frontale della falda, argille del Pliocene superiore-Pleistocene inferiore che costituiscono ottimi markers stratigrafici per datare i movimenti tardivi del fronte della falda. Nelle deformazioni superficiali sono sempre chiaramente coinvolti i Trubi. A parte la tettonica sinsedimentaria supramiocenica, l'attuale assetto strutturale della falda è stato quindi raggiunto dopo il Pliocene inferiore. Le strutture predominanti sono date da pieghe e faglie inverse a luoghi retrovergenti, che spesso restano confinate nell'ambito della serie evaporitica e dei Trubi, perdendo la loro evidenza in profondità dove sono presenti superfici di scollamento suborizzontali o a basso angolo.

La Falda di Gela, nel tratto esaminato, presenta spessori complessivi sempre inferiori ai 1000 metri e poggia sui Trubi che costituiscono il top della successione iblea.

La successione supramiocenica coinvolta nella Falda di Gela, sembra essersi deposta in un bacino di avanfossa controllato da faglie normali sul bordo dell'avampaese e ubicato parecchi chilometri (> 12) a nord dell'attuale margine del Plateau Ibleo. Durante il Messiniano, si registrano le fasi precoci di deformazione sinsedimentaria. Dopo il Pliocene inferiore, durante la strutturazione degli elementi piú esterni del thrust belt maghrebide (Unità di Monte Iudica), le originarie successioni di avanfossa, che attualmente costituiscono il segmento della Falda di Gela preso in considerazione, avrebbero subito il forte raccorciamento attualmente osservato e avrebbero utilizzato preesistenti faglie normali presenti lungo il margine dell'Avampaese Ibleo come preferenziali rampe frontali per i thrusts principali. In questa fase anche la parte del Plateau Ibleo incuneata al di sotto di questo segmento di catena, già inarcata per fenomeni di *bulge* periferico o per sollevamento isostatico durante il Miocene superiore, sarebbe entrata in compressione con lo sviluppo di faglie inverse in parte sovrapposte su preesistenti faglie normali che delimitavano l'Avanfossa mio-pliocenica.

KEY WORDS: SE Sicily, Foredeep, Gela Nappe, Thin-skin deformation.

PAROLE CHIAVE: Sicilia sud-orientale, Falda di Gela, Avanfossa, Deformazioni duttili pellicolari.

INTRODUCTION AND STRUCTURAL SETTING

At the northern margin of the Hyblean Plateau, SE Sicily, the narrow Gela-Catania Foredeep (centred on the River Margi alluvial plain) separates the outcropping edge of the foreland from the Gela Nappe. This nappe consists of a tectonic wedge (CRISTOFOLINI *et al.*, 1979; LENTINI, 1982; CARBONE *et al.*, 1982) which has moved SSE with an overall vergence towards the foreland. In SE Sicily it represents the latest compressional episode at the front of the Maghrebian thrust belt. The front of the Gela Nappe (Fig. 1) can be traced for several kilometres offshore from its type area in S Sicily (CATALANO, 1988; ANTONELLI *et al.*, 1988; ARGNANI *et al.*, 1989). Both on and offshore, the nappe exhibits a well-pronounced tapered frontal wedge with an overall geometry similar to that generated in ana-

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logue model experiments (DAVIS *et al.*, 1983) as suggested by ARGNANI, 1989. Strong similarities also are found between the geometrical shape of this thrust wedge and classical accretionary complexes (see WESTBROOK *et al.*, 1988). However, such comparisons (ROURE *et al.*, 1990) are perhaps premature before examining the nature of thin-skinned deformation within the thrust complex.

Regionally the deformational history of this external zone of the central south Sicilian segment of the Maghrebian thrust belt dates from the Late Miocene. Available subsurface data (LENTINI *et al.*, 1987; BIANCHI *et al.*, 1989) indicates that the Oligo-Miocene clays and glauconitic sandstones (more external tectonic units of the area) are thrusted above Tortonian clays. However, the prominent unconformities within the Messinian Evaporitic sequence indicate progressive synsedimentary deformation of rocks which now constitute the nappe front since Messinian time. This latter fact is supported both by intraformational unconformities and the thickness changes within the Upper Evaporitic Complex deposits. These sediments are interpreted as filling perched structural depressions formed during the migration of the thrust system towards the foreland (GRASSO & LA MANNA, 1988). Subsurface data show that the nappe moved on a sole thrust composed of the topmost levels (Messinian and Early Pliocene) of the Hyblean Plateau foreland succession.

STRATIGRAPHIC OUTLINES OF THE ALLOCHTHONOUS TERRANES OF THE GELA NAPPE

Detailed field mapping of the frontal zone of the allochthonous terranes permits the recognition of two separate belts (GRASSO & LA MANNA, 1988). Along the SE flowing River Gornalunga (Fig. 1) are extensive outcrops of Late Oligocene-Middle Miocene clays and glauconitic sandstones upon which rest tectonically emplaced variegated clays and marly limestones (Sicilide Units) and brown clays and quartzarenites (Numidian Flysch).

Collectively, both Sicilide and Numidian Flysch units represent remnants of larger tectonic slices which have suffered earlier deformation. The emplacement of the Sicilide terranes above the Numidian Flysch occurred during the Burdigalian-Langhian. Later, during Serravallian times, both units were overthrust southwards onto the top of the glauconitic sandstones levels. The glauconitic sandstones, in turn, were deposited above the more external Monte Judica palaeogeographic domain (LENTINI, 1974).

South of the Gornalunga River, around the town of Ramacca (Fig. 1), the stratigraphical sequence starts with Tortonian clays and sands including brown clay olistostromes at their top. The overlying Messinian Evaporitic sequence can be divided (GRASSO & LA MANNA, 1988) into three main units. A Lower Evaporite Complex (Tripoli, Calcare di Base and swallow tail gypsum) is separated from the overlying Upper Evaporite Complex (grey diatomitic marls and laminated gypsum levels) by a well marked angular unconformity. A third member consisting of thinly bedded lime mudstones, stromatolitic in places, suggests deposition under lagoonal conditions. This topmost Messinian member is separated from the underlying strata by a further unconformity. Younger sediments consist of Early Pliocene chalks (Trubi Formation) which rest unconformably on older strata with clear onlap onto lower parts of evaporite complexes. Deep marine Plio-Pleistocene clays are restricted to the frontal zone of the Nappe and are partly involved in the tectonic deformation. A regional geological sketch illustrating the tectonic framework of SE Sicily (Hyblean Plateau, Gela Nappe and Mt. Judica units), is given in Fig. 1.

THIN-SKINNED DEFORMATION

Ductile deformation of the Gela Nappe occurred mainly by thin-skinned thrusting with an overall foreland vergence. Less penetrative back thrusts and overturned folds are widespread and serve to accommodate the shortening created by deeper decollement planes.

Major deformations, along the frontal fault break of the Gela Nappe (hereinafter referred as Gela Frontal Thrust, GFT) and its hangingwall took place during the main phases of orogenic transport which occurred after Trubi deposition, from Early Pliocene to the earliest Pleistocene. The resulting structures, are well exposed and easy to reconstruct along areas characterized by extensive outcrops of Messinian evaporites and Early Pliocene chalks. For this purpose the competent "Calcare di Base" in particular, is a useful structural marker. In order to show the mode and the main structural style of thin-skin deformation along the Gela Frontal Thrust, two areas have been mapped in detail along its NE segment (areas A and B on Fig. 1). The associated cross sections show the dominant style of the observed thin-skin deformations.

Cozzo Monaci-Castello di Serravalle Ridge. This ridge develops on both banks of the River Ferro, along its mouth, in the very frontal part of the nappe looking towards the foredeep where the River Margi is flowing (Fig.2). The structure observed at Poggio Carbonari is characterized by multiple foreland-verging thrust sheets (cross section B-B') typical of imbricated thrust systems (sensu DAHLSTROM, 1970; BOYER & ELLIOTT, 1982; BUTLER, 1982, 1987). About 1 Km eastwards, at Cozzo Monaci the main foreland verging thrust front is associated with minor antithetic back thrusts (cross section A-A'). Antiformal folds are found at the Castello di Serravalle outcrops together with thrust faults which we consider to join downwards onto the main floor thrust at shallow depths.

The latest movements on the frontal part of the nappe are, for this locality, recorded by Early Pleistocene clays.

West of the town of Ramacca, in the ridge extending from La Montagna to Poggio Bosco (Fig. 3 which covers the box B on Fig. 1) the structure is characterized by narrow folds with axial trend NW-SE, often with overturned limbs and/or affected in the hinge zone by local hinterland-verging backthrusts. All these structures post-date the deposition of Early Pliocene Trubi Fm which is involved in them.

ROURE *et al.*, 1990 interpreted the Gela Nappe and other parts of the thrust as being an accretionary prism suggesting direct comparisons with oceanic subduction complexes. We do not adopt this approach because it may obscure important geodynamic links between the thrust stack and its foreland, as recorded by foredeep

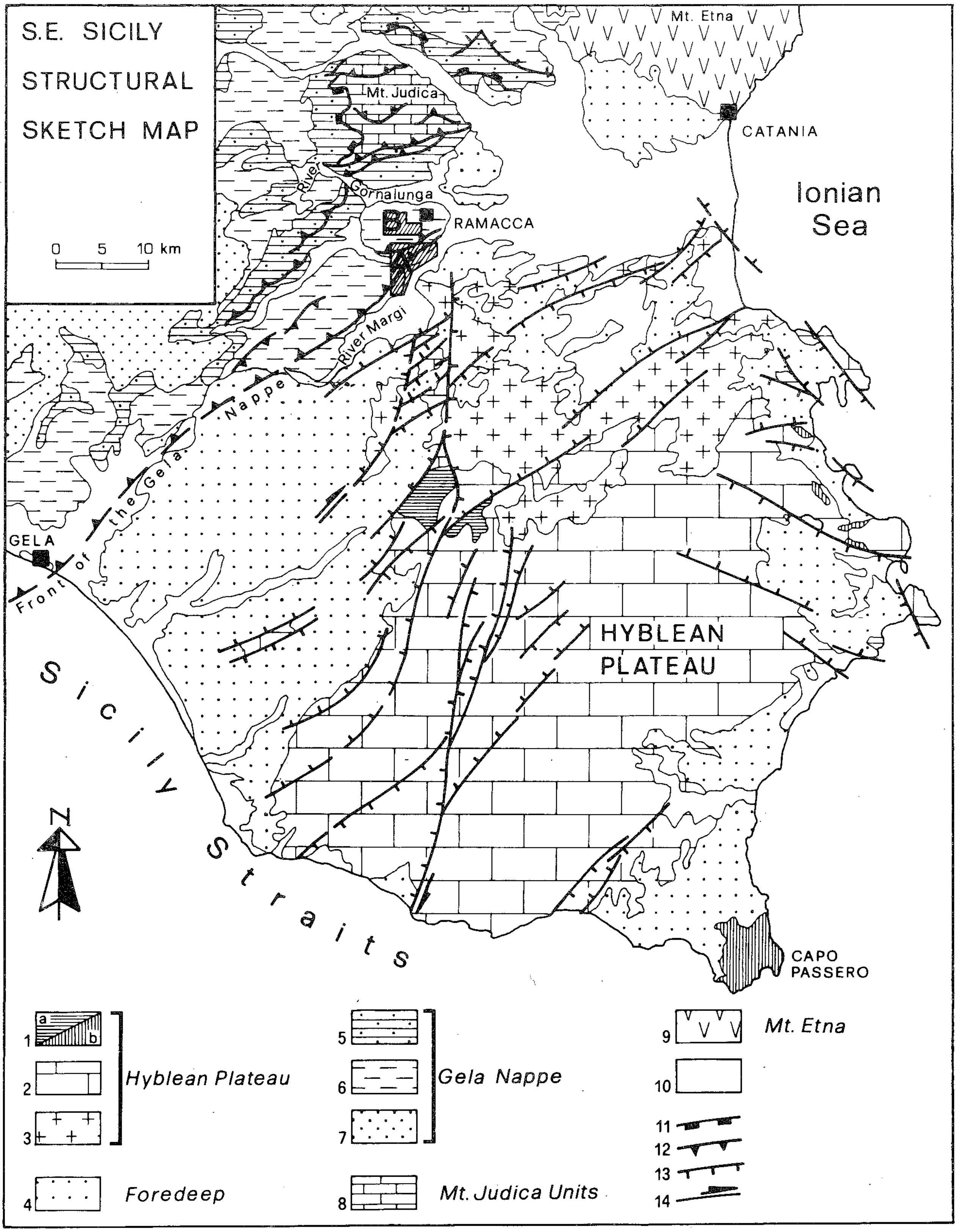

Fig. 1 - Map of the southeastern Sicily showing location of the Hyblean Plateau, Gela Nappe and other main structural units. Deailed maps of Figs. 3 and 4 cover the area within boxes A and B on the NE segment of the Gela Nappe.
Symbols: 1) Late Cretaceous mafic volcanics and reef limestones (a), deep marine cherty limestones and marls (b). 2) Oligo-Miocene platformal to open marine carbonates and marls. 3) Plio-Pleistocene mafic volcanics. 4) Plio-Pleistocene calcarenites and clays deposited along the margins of the Hyblean Plateau and the foredeep. 5) Late Cretaceous to Early Tertiary allochthonous terranes (Variegated Clays, Numidian Flysch) further involved in the later Gela Nappe deformation together with 6) Late Miocene-Early Pliocene evaporites and chalks. 7) Pleistocene sands and clays slightly deformed. 8) Late Triassic - Middle Miocene succession of the Mt Judica Unit. 9) Mount Etna volcanics. 10) Recent alluvium and beaches. 11) Tectonic contact. 12) Main thrust fault. 13) Normal fault. 14) Wrench fault.

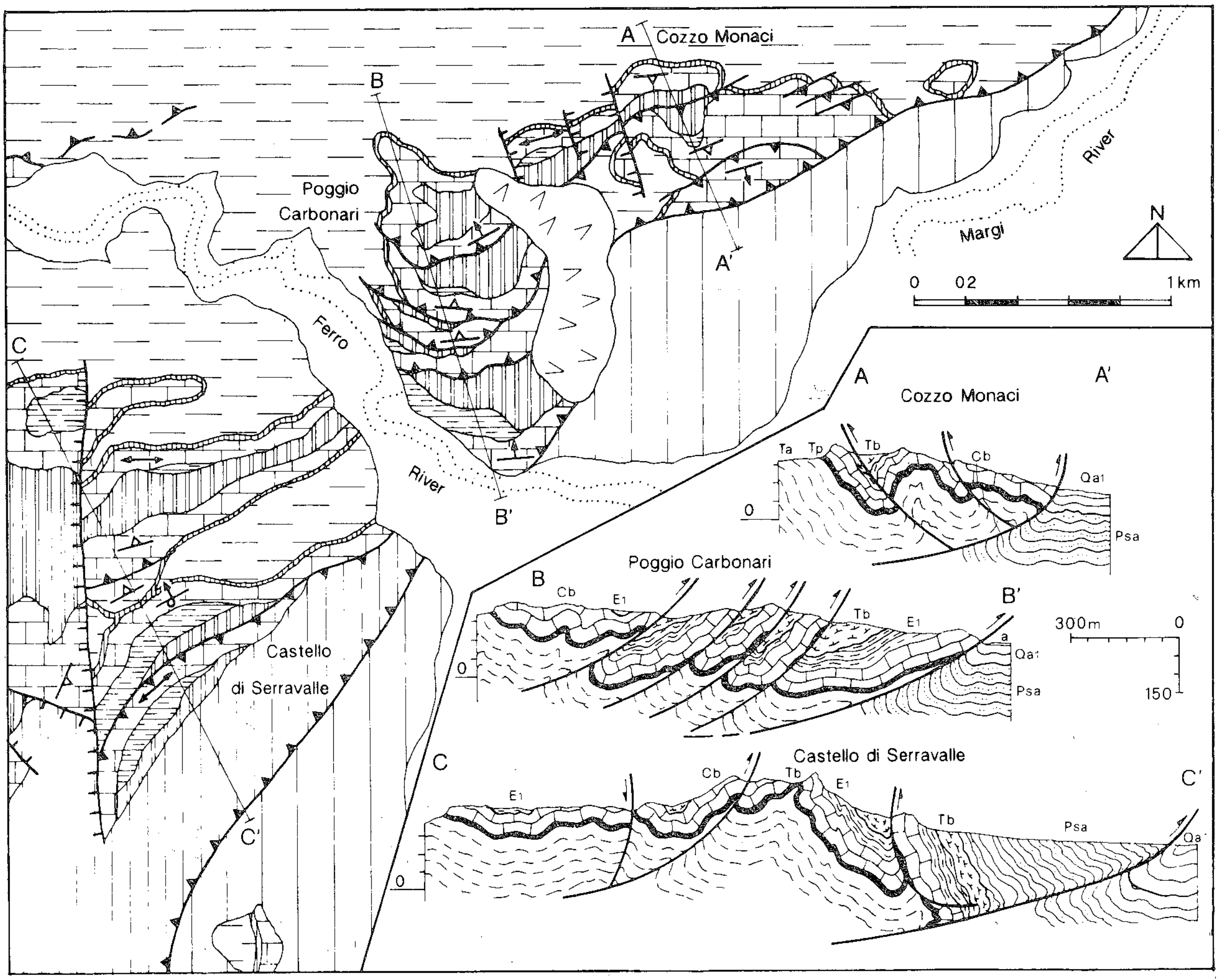

Fig. 2 - Structural map (box A on Fig. 1) and cross sections to illustrate the mode of deformation along the frontal part of the Gela Nappe (GFT).(Captions as on Fig. 3; cross sections = twice mapp scale). Cozzo Monaci displays a foreland-verging thrust front and associated minor back-thrust. Poggio Carbonari imbricates depict a true foreland-verging thrust system. At Castello di Serravalle, Late Pliocene marls (Psa) are also involved in the deformation as well as the earliest Pleistocene clays (Qa1) which underlie the thrust wedge. The deformational style changes over short distance perhaps due to the occurrence of tear faults (beneath the River Ferro and the landslide?). Normal faults occur orthogonal to the thrusts.

deposits. We now explore these links through stratigraphic correlations to examine the evolution of the foredeep basins.

MIO-PLIOCENE STRATIGRAPHIC SEQUENCE BOUNDARIES

Major stratigraphic sequence boundaries, linking the thrust belt to the foreland have been tentatively correlated in order to define the former stratigraphic template before the main tectonic transport of the Gela Nappe. Fig. 4 shows an attempt of such a correlation linking Late Miocene successions measured in outcrops on the Gela Nappe with the Ramacca 1 borehole. To link these sequences to those cropping out in the foreland two sections have been measured in the NW margin of the Hyblean Plateau. The main stratigraphic characters of the Miocene-Early Pliocene sequence on the NW Iblean Plateau, are described below.

The oldest strata exposed in the NW margin of the Hyblean Plateau consist of c. 80 m of carbonates (Ragusa Fm) of Early-Middle Miocene age.

Grey marls of the Tellaro Formation conformably succeed the Ragusa Formation carbonates. Regionally, thicknesses exceeding 300 m are typical on the Hyblean Plateau, however, thicknesses of 150 down less than 50 m are common around the NW margins (GRASSO & PEDLEY, 1990). Variable thicknesses of mafic volcanics occur at the top of the formation, as submarine flows or volcaniclastics. The planktonic microfauna indicates a Middle to Late Miocene age (Serravallian to Late Tortonian) for these marls.

The Monte Carrubba Formation conformably succeeds the Tellaro Formation. It consists of 2-8 m. of yellow mudstones and local grainstones of Late Tortonian to Early Messinian age. This unit represents the final Miocene deposit covering the northwestern Hyblean Plateau. However, in marginal areas towards the NW, younger Messinian evaporites are preserved in narrow NE-SW oriented grabens, with local accumulation exceeding 80 m in thickness (Fig. 4).

Fluvial conglomerates, breccias and lacustrine sand deposits (2-5 m.) unconformably cap both the evaporitic beds and the Monte Carrubba Formation. A diagnostic fresh-water fauna indicates that they are Late Messinian in age. (DI GERONIMO *et el.*, 1991).

Deposition of the Miocene succession in the NW

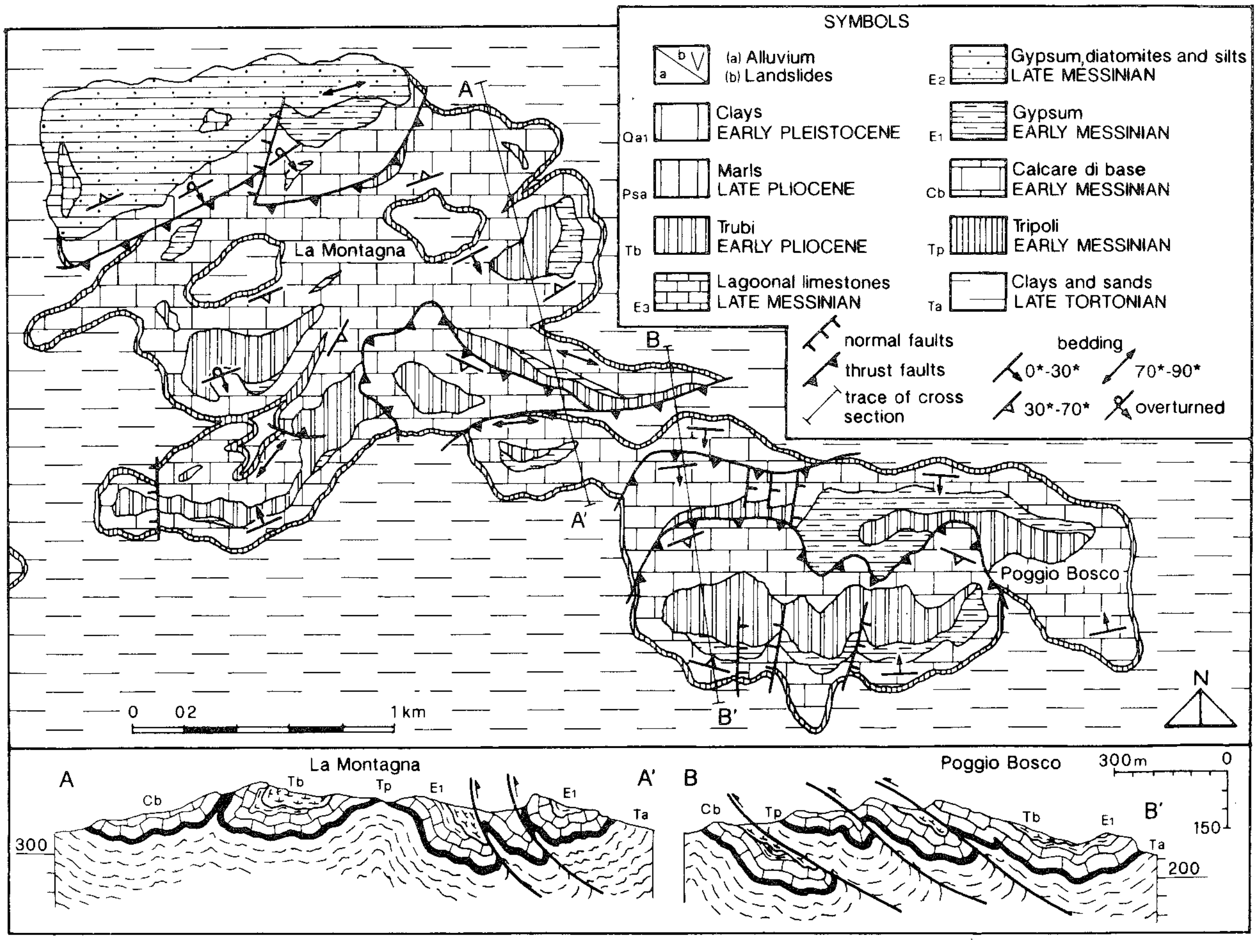

Fig. 3 - Further examples of thin-skinned deformation along the front of the Gela Nappe. Between La Montagna and Pog-gio Bosco (box B on Fig. 1) develops an imbricate system of thin-skinned back thrusts. The Early Pliocene chalks pre-date the deformations. Scale of cross sections = 1.5 map scale.

margins of the Hyblean Plateau was tectonically controlled. The earliest manifestation is the formation of NE-SW oriented horst at the top of the Ragusa Formation (GRASSO & PEDLEY, 1990), and consequent deposition of an attenuated thickness of Tellaro Formation marls (less than 50 m). After the Late Tortonian volcanic episode, evaporite deposition followed. The evaporite strata attain exceptional thicknesses in the graben zones flanked by the earlier horst areas. The continental sediments are developed on top of a karst surface both above evaporites in the vicinity of the depocentres and above the shallow water Messinian carbonates.

Post-Miocene deposits consist of up to 60 m of "deep" marine chalks (Trubi Formation) which overlie the Messinian strata of NW marginal Hyblean Plateau with marked unconformity.

Recently the Gela Nappe was penetrated by the AGIP Ramacca 1 drill hole which crossed the basal detachment and passed down into Early Pliocene chalks and then older carbonates. This proved the "allochthonous" nature of the Gela Nappe and suggests that the Hyblean foreland continues to the N, beneath the frontal thrust structures.

Consider the regional northward thinning of Middle-Late Miocene marine sediments from the foreland to the modern foredeep areas (well logs Mineo 1, Mineo 2 and Ramacca 1 on Fig. 4). This suggests that the modern foredeep area was significantly up-arched during Late Miocene and Early Pliocene. This can be interpreted in two ways:

1) the peripheral bulge to the flexurally driven foreland basin

2) the isostatically uplifted footwall to extensional faults.

This uplift occurred prior to the regional subsidence which took place from Middle Pliocene onwards and coincides with the major foreland-directed emplacement of the Gela Nappe.

AN ATTEMPT OF RESTORATION

Fig. 5 (upper diagram) gives a simplified picture of the modern tectonic setting of the front of the Maghrebian thrust belt in SE Sicily. It includes the Gela Nappe s.s. and the Mt Judica thrust sheets which represent the tectonic unit lying immediately north of the Gela Nappe (see Fig. 1 for the location of main units).

The lower template (not to the scale) is constructed to show the relationships between the Late Miocene to Pleistocene foredeep sediments and the underlying platform, based on surface geology, the AGIP Ramacca 1 borehole and regional studies (BIANCHI *et al.*, 1987).

Southward termination (onlap) of sedimentary sequences are considered to be controlled by normal faults (downthrowing to the north). These predicted faults may have controlled the size of frontal thrust

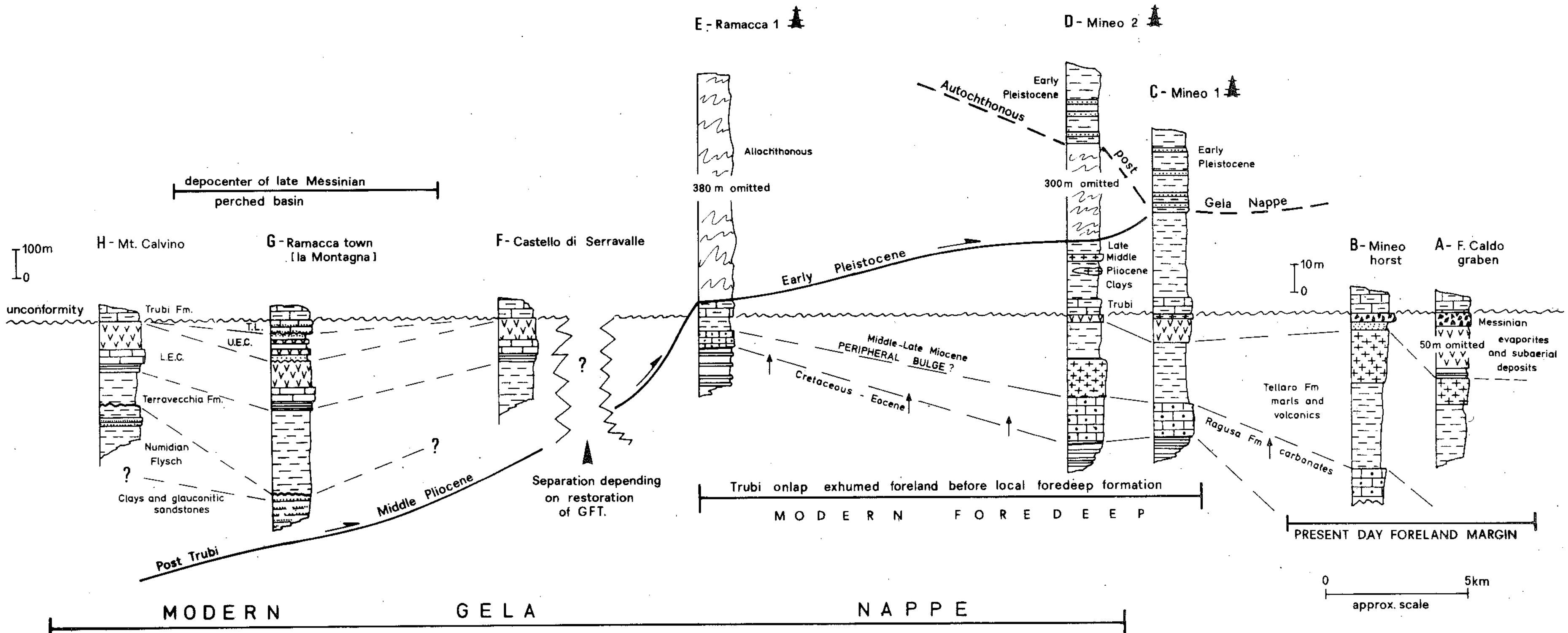

Fig. 4 - Representative stratigraphic columns illustrating the correlations between the Hyblean foreland (A, B), the modern foredeep (C), the Gela thrust front (D), the buried foreland in Ramacca 1 drill hole (E) in the footwall to the GFT and the Gela Nappe (F, G, H). The horizontal scale is uncertain. Note the variation in vertical scale between the drill holes and the Gela Nappe (C, D, E, F, G) and outcrop-based sections on the Hyblean foreland (A, B). Important regional unconformities can be defined through angular discordances, onlap and missing stratigraphic units. See text for discussion.

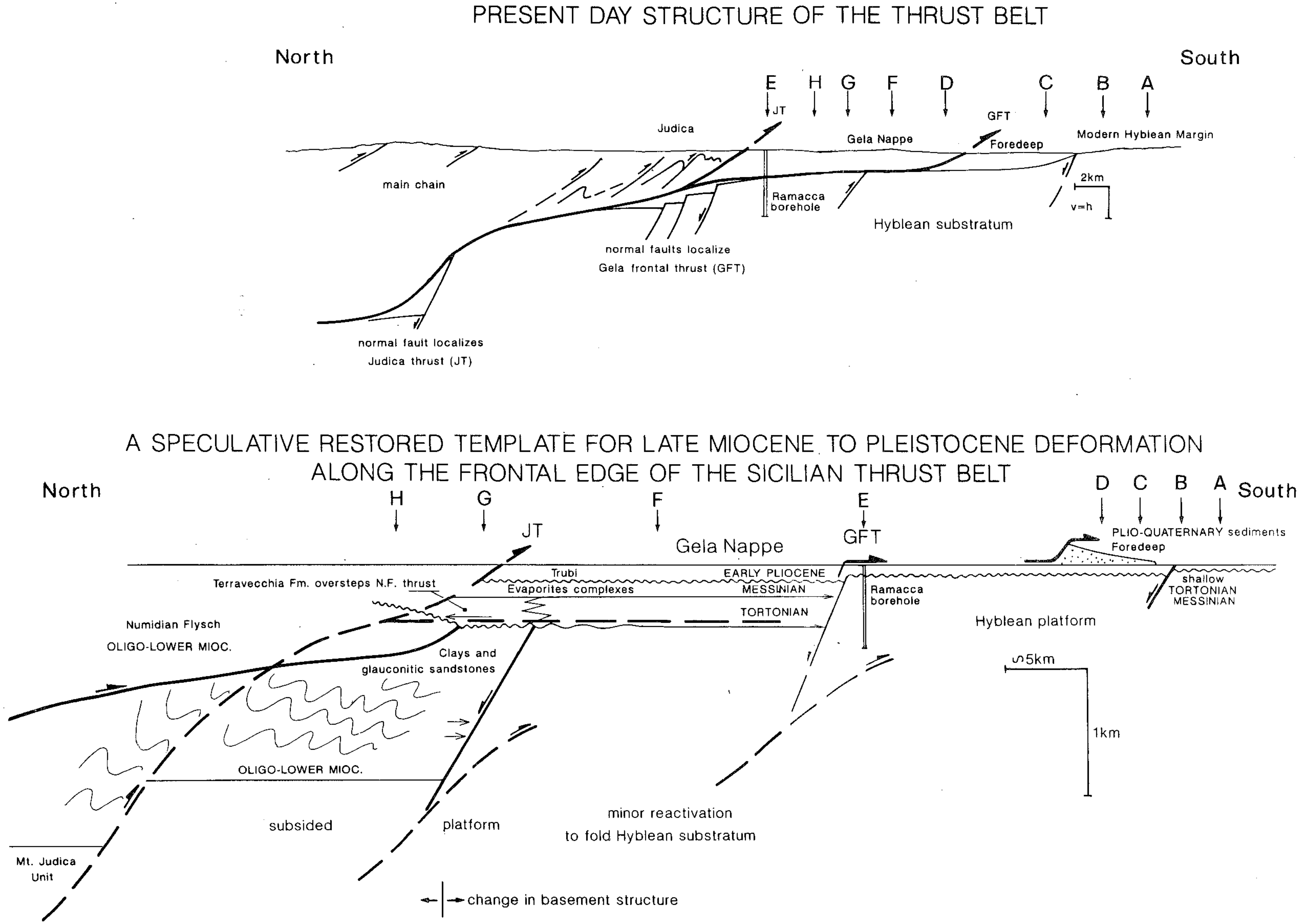

Fig. 5 - Schematic regional cross-section through the frontal part of the Maghrebian thrust belt in SE Sicily and its speculative restoration to show the relationship between different generations of Neogene foredeep basins, the foreland and thrust structures. Both the original and the present day positions of the representative stratigraphic sections of Fig. 4 are indicated. See text for discussion.

ramp, (e.g. the Gela Frontal Thrust (GFT) and the Mount Judica thrust JT.

The shortening within the Gela Nappe can be explained as due to buttressing against the normal fault (which controlled the Terravecchia basin) before emplacement onto the Hyblean Plateau. Perhaps deformation of the Oligo-Miocene terrigenous sequences (clays and glauconitic sandstones) to the north may have a similar cause, shortened against another normal fault. The edge of the old Oligo-Miocene basin is shown to coincide with normal faults controlling the Hyblean margin as detected by different basement types (BIANCHI *et al.*, 1987). Mount Judica thrust (JT) restores north of this basin margin fault. The role of these deep seated normal faults in controlling the thin-skinned deformation must be considered in geodynamic analyses of the thrust belt. In this respect we find some attempts at applying simple orogenic wedge theory (DAVIS *et al.*, 1983, PLATT, 1986) to the Sicilian thrust belts (e.g. ROURE *et al.*, 1990) rather unhelpful.

The dominant structural style does not imply major tectonic inversions from depth, but rather that thrust ramps may be located preferentially by the pre-existing normal faults. Probably the GFT, has not reactivated the predicted normal fault but might have been located by it. However some reactivations may be possible to arch the Hyblean substratum in the southern part of the section. It is unclear whether the JT reactivated or is nearly located by a normal fault.The horizontal scale of our restoration remains unclear and is dependent upon a structural reconstruction of the Gela Nappe and other thrust structures which account not only for thrust displacements but also shortening accommodated by faulting and more distributed strain. The importance of these deformation mechanisms has yet to be resolved.

DISCUSSION AND CONCLUSIONS

Our preliminary reconstruction of frontal structures of the SE Sicilian thrust belt allows us to define a palaeoforedeep basin which was a distinct depocentre from Tortonian through the Messinian and into Lower Pliocene times. The earliest episodes of deformation within this basin occurred during the Messinian. Active extension just in advance of thrust is indicated in the footwall to the GFT. In the Ramacca 1 drill-hole Trubi overlies thin Miocene carbonates belonging to the Hyblean succession. On the Hyblean Plateau Trubi overlies either Miocene or younger carbonates. It is likely that the Trubi onlapped across a gentle unconformity linking the foredeep sequence with the present Hyblean margin. Yet today these outcrops are separated by normal fault scarps separating the Hyblean Plateau from the River Margi valley, modern analogues for the predicted faults which controlled the palaeoforedeep basin.

This study has identified two distinct late Miocene-Early Pliocene foredeep sequences along the frontal part of the Maghrebian Chain in SE Sicily. The Terravecchia basin, formed ahead of the Monte Judica thrust complex in Tortonian-Messinian times, became stacked into the Gela Nappe. This phase of deformation, developed after the Early Pliocene, is associated with the generation of the modern foredeep of the River Margi valley.

The two basins represent an external-ward stepping of the foredeep onto the Hyblean platform during the development of the thrust belt. However, it was not a simple progressive onlapping such as characterises classic foreland basins (e.g. BEAUMONT, 1980). We believe that the Late Miocene-Early Pliocene basin occurs because its outer edge was determined by normal faults, along the leading edges of the consumpting foreland. Certainly equivalent faults define the outer extent of the modern foredeep along the northern margin of the Hyblean Plateau. The general implication is that sedimentary sequences within foredeep basins need not merely be controlled by the well known actions of sediment supply and sea level variations within a tectonic model expressed solely in terms of subsidence governed by the flexural support of tectonic loads in the orogenic hinterland. Sediment geometries, particularly the subtle onlapping of basin fill against the pre-orogenic shelf deposits, are particularly susceptible to modification by other fault activity.

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REFERENCES

ANTONELLI M., FRANCIOSI R., PEZZI G., QUERCI A., RONCO G.P., VEZZANI F. (1988) - *Palaeogeographic evolution and structural setting of the northern side of the Sicily Channel.* Proc. 74th. Congr. Soc. Geol. It., 79-86, Napoli.

ARGNANI A. (1989) - *The Gela Nappe: evidence of accretionary melange in the Maghrebian Foredeep of Sicily.* Mem. Soc. Geol. It., **38**, 419-428.

ARGNANI A., CORNINI S., TORELLI L. & ZITELLINI N. (1989) - *Diachronous foredeep-system in the Neogene-Quaternary of the Strait of Sicily.* Mem. Soc. Geol. It., **38**, 407-417.

BEAUMONT C. (1980) - *Foreland basins.* Geophysical Journal of the Royal Astronomical Society, **65**, 291-329.

BIANCHI F., CARBONE S., GRASSO M., INVERNIZZI G., LENTINI F., LONGARETTI G., MERLINI S. & MOSTARDINI F. (1989) - *Sicilia orientale: profilo geologico Nebrodi-Iblei.* Mem. Soc. Geol. It., **38**, 429-458.

BOYER S.E. & ELLIOTT D. (1982) - *Thrust systems.* Bulletin of the American Association of Petroleum Geologist, **66**, 1196-1230.

BUTLER R.W.H. (1982)- *The terminology of structures in thrust belt..* Journal of Structural Geology, **4**, 239-245.

BUTLER R.W.H. (1987) - *Thrust sequences.* Journal of the Geological Society, **114**, 1-15.

CARBONE S., COSENTINO M., GRASSO M., LENTINI F., LOMBARDO G. & PATANÈ G. (1982) - *Elementi per una prima valutazione dei caratteri sismotettonici dell'Avampaese Ibleo.* Mem. Soc. Geol. It., **24**, 507-520.

CATALANO R. (1988) - *Stratigraphy and structures of Sicily mainland and Sardinia Channel-Sicily Straits. A comparison.* 74th Congresso Soc. Geol. It., Sorrento 13-17 Settembre 1988, Relazioni, 145-154, Ed. DE FREDE.

CRISTOFOLINI R., LENTINI F., PATANÈ G. & RASÀ R. (1979) - *Integrazione dei dati geologici, geofisici e petrologici per la stesura di un pro-*

filo crostale in corrispondenza dell'Etna. Boll. Soc. Geol. It., **98**, 239-247.

DAHLSTROM C.D.A. (1970) - *Structural geology in the eastern margin of the Canadian Rocky Mountains.* Bulletin of Canadian Petroleum Geology, **18**, 332-406.

DAVIS D., SUPPE J., DAHLEN F.A. (1983) - *Mechanics of fold and thrust belts and accretionary wedges.* Journal of Geophysical Research, **88**, 1153-1172.

DI GERONIMO I, ESU D. & GRASSO M. (1991) - *Gli strati a "Congerie" del Messiniano superiore del margine nord-occidentale ibleo. Caratteristiche faunistiche e possibili implicazioni paleogeografiche e paleoclimatiche.* Atti Acc. Peloritana dei Pericolanti, **67**, (1989), suppl. n. 1, 129-150, (Vol. spec. in memoria di G. Seguenza), Messina.

GRASSO M. & LA MANNA F. (1988) - *Lineamenti stratigrafici e strutturali del fronte della Falda di Gela affiorante a NW del Plateau Ibleo (Sicilia Sud-Orientale).* Geol. Romana (in stampa).

GRASSO M. & PEDLEY H.M. (1990) - *Neogene and Quaternary sedimentation patterns in the northwestern Hyblean Plateau (S.E. Sicily): the effect of a collisional process on a foreland margin.* Riv. It. Paleont. Strat., **96**, 219-240.

LENTINI F. (1974) - *Caratteri stratigrafici e strutturali della zona di Mt. Judica (Sicilia Orientale).* Riv. Min. Sic., **145-147**. 1-22.

LENTINI F. (1982) - *The geology of the Mt. Etna basement.* Mem. Soc. Geol. It., **23**, 7-25.

LENTINI F., GRASSO M., CARBONE S. (1987) - *Introduzione alla geologia della Sicilia e guida all'escursione.* Convegno della Soc. Geol. It. "Sistemi Avanfossa-Avampaese lungo la Catena Appeninico - Maghrebide", Naxos-Pergusa, 22-25 aprile, 66 pp.

PLATT J.P., (1986) - *Dynamics of orogenic wedges and uplift of high-pressure metamorphic rocks.* Geol. Soc. Am. Bull., **97**, 1037-1053.

ROURE F., HOWELL D.G., MULLER C., MORETTI I. (1990) - *Late Cenozoic subduction complex of Sicily.* Journ. of Structural Geology, **12**(2), 259-266.

WESTBROOK G.K., LADD J.W., BUHL P., BANGS N. & TILEY G.J. (1988) - *Cross section of an accretionary wedge: Barbados Ridge complex.* Geology, **16**, 631-635.