B. MAUZ(*) & P. RENDA(**)

TECTONIC FEATURES AT THE NW-COAST OF SICILY (GULF OF CASTELLAMMARE)
Implications for the plio-pleistocene structural evolution of the southern Tyrrhenian continental margin(***)

INDICE

ABSTRACT

Detailed field studies coupled with geological mapping and litho-and biostratigraphical analyses allow to reconstruct the structural evolution of the north-western sicilian coast (Gulf of Castellammare) since the Upper Miocene. By evolving two models for this area, implications for Plio-Pleistocene tectonic processes on the southern Tyrrhenian continental margin can be inferred.

Five fault systems acting at least since the upper Miocene are recognised: 1) a transcurrent fault system roughly N-S orientated with maximum activity in the Pliocene which, however, is not clearly recognisable in the field; 2) a system of approximately E-W orientated reverse faults, probably correlated with strike-slip movements, with maximum activity in the late Pliocene; 3) a system of NNW-SSE orientated normal faults, active in the early Pleistocene, causing the formation of two sedimentary basins; 4) a system of NNE-SSW orientated normal faults, active from early to late Pleistocene and causing the uplift of blocks; 5) a fault system with NE-SW orientation, active at present-day.

Two models match with the identified tectonic elements implying two different types of structural development: 1) a reversion in deformation style during Plio-Pleistocene boundary from a horizontal and compressional to an extensional regime. The rifting of the Tyrrhenian basin reached the southern continental margin in the upper Pliocene causing the formation of grabens along the NW-Sicilian coast. 2) If strike slip movements continued to the Pleistocene time, extensional tectonics would have caused the formation of pull-apart basins.

Nevertheless, the Gulf of Castellammare basins belong to the series of Neogene, peri-Tyrrhenian sedimentary basins which are genetically linked to the extensional regime of the Tyrrhenian back arc basin.

(*)Forschunsstelle Archaometrie der Heidelberger Akademie der Wissen schaften am Max-Plank-Institute fur Kernphysik, Postfach 103980, D-69029 Heidelberg.

(**)Dipartimento di Geologia e Geodesia, Università di Palermo. Corso Tukory 131, 90134 Palermo.

(***)Lavoro eseguito con fondi M.U.R.S.T. 40% (Responsabile nazionale M.B. Cita) e Fondi C.N.R. n. 9302094 ct. 05 (Responsabile P. Renda).

RIASSUNTO

In questo lavoro viene ricostruita l'evoluzione strutturale plio-pleistocenica dell'area di Castellammare del Golfo (Sicilia nord-occidentale).

Sono stati riconosciuti cinque sistemi di faglie che interessano l'area dopo il Miocene sup.: 1) sistema di faglie trascorrenti destre orientato N-S attiva presumibilmente dalla fine del Miocene e con massima attività nel Pliocene; 2) sistema di faglie inverse orientato circa E-O probabilmente collegato al sistema di trascorrenti destre con attività nel Pliocene sup.; 3) sistema di faglie dirette orientato NNO-SSE attivo nel Pleistocene inf.; 4) sistema di faglie dirette orientato NNE-SSO attiva nel tardo Pleistocene inf.; 5) sistema di faglie trascorrenti orientate circa E-O con probabile attività recente.

Gli elementi strutturali riconosciuti hanno permesso di elaborare due ipotesi sull'evoluzione strutturale dell'area. Nell'area di Castellammare del Golfo al passaggio Plio-Pleistocene si formano due *graben* causati dal cambiamento dello stile tettonico da trascorrente e compressivo ad estensionale, dovuto al "*rifting*" del Tirreno e alla migrazione del suo asse verso SE.

I movimenti orizzontali, dall'inizio del Pleistocene, provocano la formazione di bacini di "*pull-apart*". Ciò in accordo con il modello del Tirreno come "*back arc basin*".

KEY WORDS: Structures, Pliocene-Pleistocene, NW-Sicily coast.

PAROLE CHIAVE: Evoluzione strutturale, Pliocene-Pleistocene, Costa nord-occidentale della Sicilia

INTRODUCTION

At the northern coast of Sicily, several areas are built up by thick successions of Pliocene-Pleistocene marine sediments. In the area of the Gulf of Castellammare, well exposed outcrops give an unique opportunity to study the Plio-Pleistocene structural evolution of the southern margin of the Tyrrhenian Sea.

The Gulf area is situated between the Palermo Mountains at the East, the Trapanese Mountains at the West, the area of Grisí at the South and the continental margin of the Tyrrhenian basin at the North. It is located between the Maghrebian thrust-fold-belt and the small shelf of the southern Tyrrhenian Sea and therefore, occupies a key position in the geological framework of the area. The coastal area of the gulf is built up by shallow water deposits of approximately 90 m thickness exhibiting many features of later tectonic strain.

Studying sedimentology and palaeontology of several areas on Sicily, Ruggieri (1978) and Ruggieri *et alii* (1979) recognise two sedimentary cycles in the Plio-Pleistocene series (Selinuntian cycles). The Ist Selinuntian cycle (*Fm. Marnoso-arenacea*; Ruggieri &

Torre, 1973) characterises a regressive sedimentary sequence from the early Piacenzian to the Emilian substage. The IInd Selinuntian cycle indicates a transgressive sedimentary sequence from the Emilian substage to the upper part of the Sicilian substage. The cyclicity was driven by tectonic phases causing several sedimentary discontinuities as well as stratigraphic gaps. Ruggieri (1978) attributed the arenites of the gulf to the IInd Selinuntian cycle and mentioned that in most of the Plio-Pleistocene series of N-Sicily, the Selinuntian substage is lacking.

Studying the structure of the adjacent Palermo mountains, Abate *et alii* (1978) recognise vertical dislocations in predominant ENE-WSW direction which might be responsible for the "half-graben of Partinico" and the course of the modern shore-line. These dislocations are younger than middle Pliocene.

Seismic data from the Tyrrhenian side of the Sicilian continental margin suggest Pliocene and lower Pleistocene strata stacked in thick discontinuous lowstand systems tracts overlain by condensed transgressive systems tracts and thin highstand systems tracts (Catalano *et alii*, 1993). The series were characterised by several tectonically driven unconformities which indicate eustatic sea-level falls at 2.4, 2.1, 1.4 and 1.2 Ma (Catalano *et alii*, 1993).

The Gulf of Castellammare area was investigated by detailed field studies during geological mapping (scale: 1:10.000) and by litho- and biostratigraphical analyses. It was our main objective to evaluate the migration of the shore line during the Plio-Pleistocene in order to get information about the relationship between tectonic processes and eustatic oscillations. The present paper complements our previous report (Mauz & Renda, 1991) by focusing on the structural features of the study area and their implications for the development of the southern Tyrrhenian shelf. More details about litho and biostratigraphy and climatic aspects observed in the Plio-Pleistocene deposits are given in Mauz (1994).

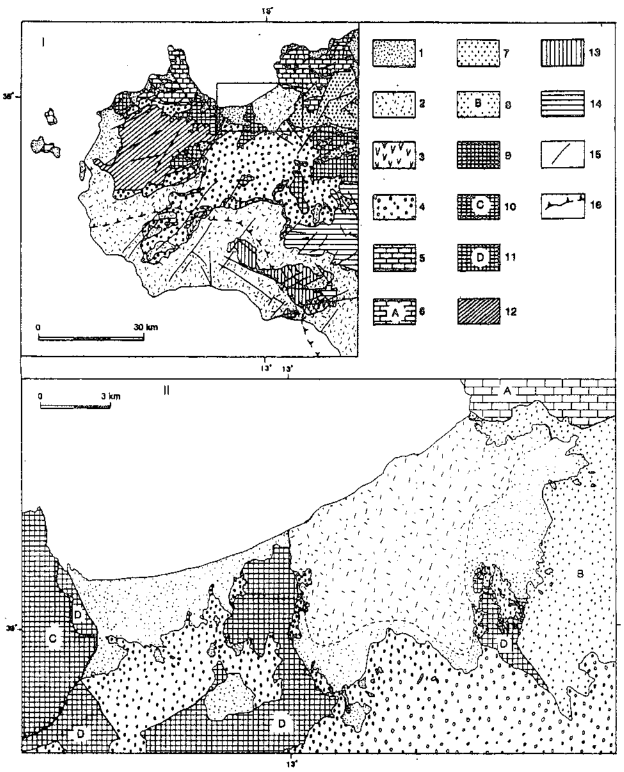

Fig. 1 - Structural scheme of NW-Sicily (I, after Catalano *et alii*, 1985) and of the Gulf of Castellammare area (II). 1 = Pleistocene deposits; 2 = Pliocene - Pleistocene deposits; 3 = evaporites (upper Messinian); 4 = *Terravecchia Formation* (Upper Tortonian - lower Messinian); 5 = Panormide unit (undifferentiated); 6 = Cozzo di Lupo unit (Panormide unit); 7 = Imerese unit (undifferentiated); 8 = Sagana - Belmonte - Mezzagno unit (Imerese unit); 9 = Trapanese unit (undifferentiated); 10 = Monte Inici unit (Trapanese unit); 11 = Monte Bonifato - Calatubo unit (Trapanese unit); 12 = Monte Bosco - Monte Luziano unit (inner Panormide unit); 13 = Saccense unit (undifferentiated); 14 = Sicani unit (undifferentiated); 15 = normal and reverse fault; 16 = thrust front.

GEOLOGICAL SETTING

The Gulf of Castellammare is superimposed on the Maghrebian thrust-fold-belt. The fold-belt, forming the northern part of Sicily mainland, represents the connecting link between the Africa-vergent chains of the Tunisian - Maghrebides and the Southern Apennines. The chain is characterised by imbricate thrust complexes emplaced mainly during early and middle Miocene and by decreasing deformation towards the south. At the NW-coast of Sicily, these complexes are predominantly built up of limestones and dolomitic limestones, marlstones, mudstones and turbidite sediments representing paleogeographic units of upper Trias to middle Miocene age (Catalano & D'Argenio, 1982). The Mesozoic-Tertiary rocks exhibit structural features characterised by approximately E-W orientated fold axes, by S-vergent nappes, by E-W striking thrust fronts, by dextral transcurrent fault systems trending roughly NW-SE and by NE-SW trending normal and reverse faults (Giunta & Liguori, 1973; Catalano *et alii*, 1978; Abate *et alii*, 1978).

Due to its position on the southern coast of the Tyrrhenian basin, the Gulf area links the fold-belt in the south to the abyssal basin in the north (Fig. 1). Offshore seismic data of the transition zone indicate apparent physical continuity of the Panormide nappe affected by tensional listric faults. Towards the north, the Panormide units should pass into sharp-to-basin Panormide rocks partly obscured by thick sedimentary fills of the Erice Basin (Catalano *et alii*, 1985). This basin, like other offshore basins in this area, is bounded by a number of NW-SE dextral strike slip faults and NE-SW trending normal faults dissecting the thrust belt (Baticci *et alii*, 1983). These fault systems has been active since the late Miocene at least until late Pliocene.

By sequence stratigraphic analysis based on seismic data, Catalano *et alii* (1993) recognise on the NW-Sicilian shelf, emergent areas during Pliocene and lower Pleistocene due to uplift of the thrust-belt. During middle-late Pleistocene, progressive drowning of the nearshore and offshore area caused southward migration of the shore-line.

The modern NW-Sicilian shelf seems to extend not more than 7 km. It covers an area in which the crustal thickness decreases towards the north from 25 km to 20 km (Giese & Morelli, 1975) while the Bouguer-isoanomalies increase (Morelli, 1985). Intermediate and shallow seismic activity is measured below W-Sicilian mainland (Locardi, 1985).

STRATIGRAPHIC FRAMEWORK

At the NW-coast of Sicily, stratigraphic units range from the late Trias to the late Pleistocene (Fig. 2). In the study area, the following units were mapped: clays, sandy clays and marls (*Fm. S. Cipirello*; upper Langhian - middle Tortonian); sandy clays, sands and conglomerates (*Fm. Terravecchia*; upper Tortonian - lower Messinian); biolitithes with corals (*Porites sp.*), calcarenites and calcirudites (Messinian); gypsum and clayey gypsum (upper Messinian); clayey marls and white marls with planktonic foraminifera ("*Trubi*"; lower Pliocene); clays and silty clays (upper Pliocene); litharenites, biocalcarenites, biocalcirudites, silty marls, quartzsands and conglomerates with *Hyalinea baltica* (Santernian - Emilian); silty clays with *Globorotalia truncatulinoides excelsa* (Sicilian); red quartzsands with gravel (middle Pleistocene); sandy marls, quartzsands and conglomerates with macrofossils (middle-upper Pleistocene).

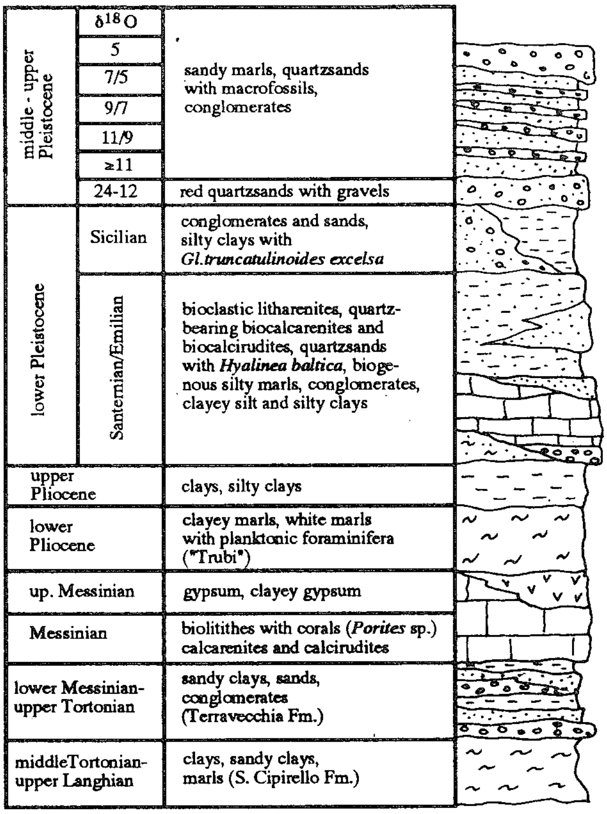

Fig. 2 - Stratigraphy of the study area. (Thicknesses are unscaled).

STRUCTURAL FEATURES

From the late Miocene to the Holocene, five systems of tectonic elements illustrating different types of structures can be distinguished (Fig. 3).

Late Miocene - Pliocene. The late orogenic phase is characterised by molasse sediments, reef-related limestones and evaporites. These deposits exhibit both northward and southward dipping beds and vertical beds. Moreover, along the western and eastern margins of the Gulf, a tectonic contact between the late Miocene deposits and the dolomites and limestones of Triassic and Cretaceous age of the thrust belt is present. Slikensides appear locally in the rocks along the contact zone, indicating horizontal movements in approximately NW-SE direction. However, the nature of the molasse deposits and the high solubility of the evaporites hamper a detailed study of horizontal stress fields as well as of fold structures and vergencies. Field evidence argues the presence of two approximately NW-SE trending dextral strike slip faults, forming the contact surface between lower-middle Miocene pelagic deposits and Triassic respectively Cretaceous dolomites and limestones. Tilted segments along the eastern side of the master strike slip fault suggest transtensional features within the horizontal movements. Two further dextral transcurrent faults in approximately N-S direction seem to affect mainly the lower-middle Miocene and the upper Miocene deposits (Fig. 3).

The Pliocene deposits, characterised by clays and marls ("*Trubi*") passing into clays and silty clays, also exhibit folding. Moreover, the deposits are affected by approximately E-W striking reverse faults active at least until the late Pliocene (biozone MPL 4).

Therefore, both fault systems should have been active at least until the late Pliocene.

Late Pliocene - early Pleistocene. In the Eastern part of the gulf, lower Pleistocene shallow water deposits lie discontinuously on rocks ranging in age from late Oligocene to late Pliocene, illustrating a stratigraphic gap at the Plio-Pleistocene boundary. In the western part, Pleistocene sediments overlie directly upper Miocene molasse deposits (Fig. 1). In the whole gulf area, Pleistocene deposits are affected by two systems of normal faults: the first system trends in NNW-SSE orientation, starting probably during the Plio-Pleistocene boundary. It is characterised by fault planes dipping between 60° and 70° to the west and to the east. The normal faults indicate fault blocks downthrown toward a central axis in an en-echelon pattern. The second system is evidenced by NNE-SSW trending faults. Fault planes of this system dip with high angles (60°-70°) and with low angles (c. 40°) to the south and to the north. Movements along these faults probably started during Emilian - Sicilian boundary, crossing the first system with an angle of c. 60° (Fig. 3).

By the first fault system, two major basins were formed and contemporaneously filled with shallow water sediments (Mauz & Renda, 1991). At outcrop, the thickness of these sediments ranges from 2-85 m. Subsurface data show that the thickness of strata can exceed 95 m. This fact illustrates both the en echelon pattern of blocks towards the north and the irregular distribution of subsidence rate.

Fault dips and fault throws indicate extension of more than 150 m for each basin and a differential uplift of more than 300 m over the whole gulf area.

Middle-late Pleistocene. Deposits of middle-upper Pleistocene age are characterised by reddish siliciclastic alluvial fan sediments passing laterally into foreshore sediments of coastal terraces. Whereas tectonic features are not preserved in the terrigenous deposits, the well cemented littoral sands and conglomerates exhibit NE-SW trending listric normal faults. The offset of the coastal terraces indicates continuous uplift starting in the early Pleistocene and the northward migration of the shore line.

Holocene. Thermal springs are arranged along a

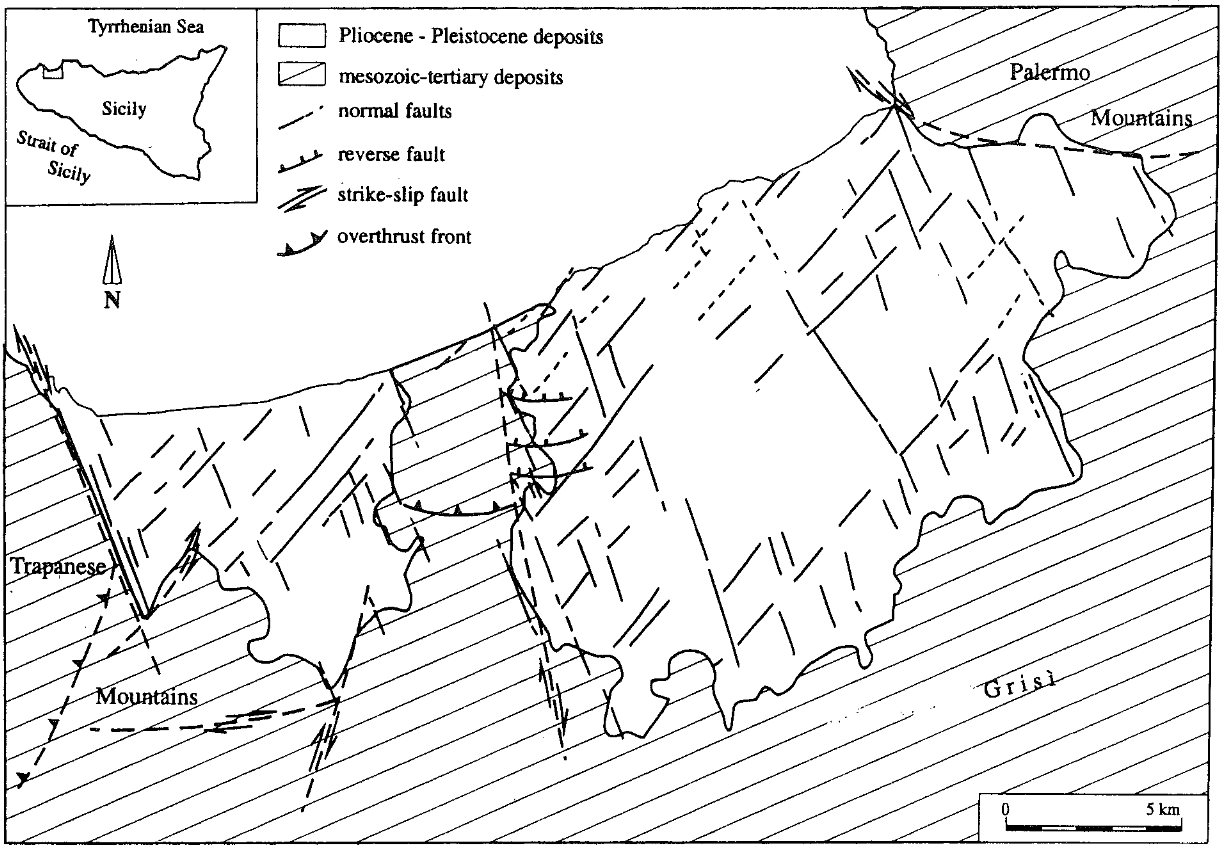

Fig. 3 - Structural elements in the Gulf of Castellammare area.

tectonic contact between Tertiary strata. From field evidence, we suppose a present-day active sinistral transcurrent fault roughly trending NE-SW.

MODELS FOR THE PLIO-PLEISTOCENE STRUCTURAL EVOLUTION

Three types of movement are identified affecting the neogenic-quaternary deposits: strike slip, ramp upfaulting and vertical faulting. We suggest the reverse faults to be a transpressive effect of strike slip faulting. Therefore, both fault systems should have been active at least until the late Pliocene. By attributing these movements to the time interval of maximum activity, a complex kinematics stands out.

From the identified tectonic elements the following structural processes are inferred: during the late Miocene and Pliocene, a hinterlandward propagation of a compressive stress acting with the adjacent thrust fold belt is at work. At the Plio-Pleistocene boundary, crest zones of strata reach the sea level due to two contemporaneously operating processes: folding and glacio-eustatic withdrawal of the sea level. During the early Pleistocene, an extensional stress causes the formation of two basins. At the beginning of the middle Pleistocene, uplift causes the emergence of the area.

However, for several reasons (the mostly unconsolidated nature of the involved deposits, the pronounced climate contrasts during study time, the high settlement density) kinematic analyses often evade field control. Reasonably, two models for the Plio-Pleistocene structural evolution of the gulf are sketched, both fitting the field observations.

Troughs. The first system of normal faults generates two wedge-shaped grabens separated by a horst (Fig. 4). Their internal asymmetry is caused by both the migration of the graben axis from the south-east to the north-west and the driving parameters of near-shore sedimentation. The graben - horst structure characterises extensional movements on the inner shelf of the southern Tyrrhenian Sea during upper Pliocene and lower Pleistocene. This result matches closely to the thinned upper lithosphere as well as to the decreasing crustal thickness in the area (Morelli, 1985).

Thus, a reversion in deformation style took place at Plio-Pleistocene boundary. This inversion might be explained by the rifting processes of the Tyrrhenian basin (Selli, 1985; Morelli, 1985). The rift propagation could have reached the thrust fold belt in the South during the late Pliocene. Consequently, the NW-Sicilian coast got involved in the extensional regime of the Tyrrhenian basin only since the upper Pliocene. This interpretation is in contrast with Argnani (1990) who argues already the late Miocene and Pliocene extensional structures in the Strait of Sicily to the opening processes of the Tyrrhenian basin.

Pull-apart basins. The contact zones between the Mesozoic-Tertiary rocks and lower Pleistocene basin-fills are not only characterised by the master faults (Fig. 3) but also strike slip faults and reverse faults are. The basins are bounded on the western and eastern side by

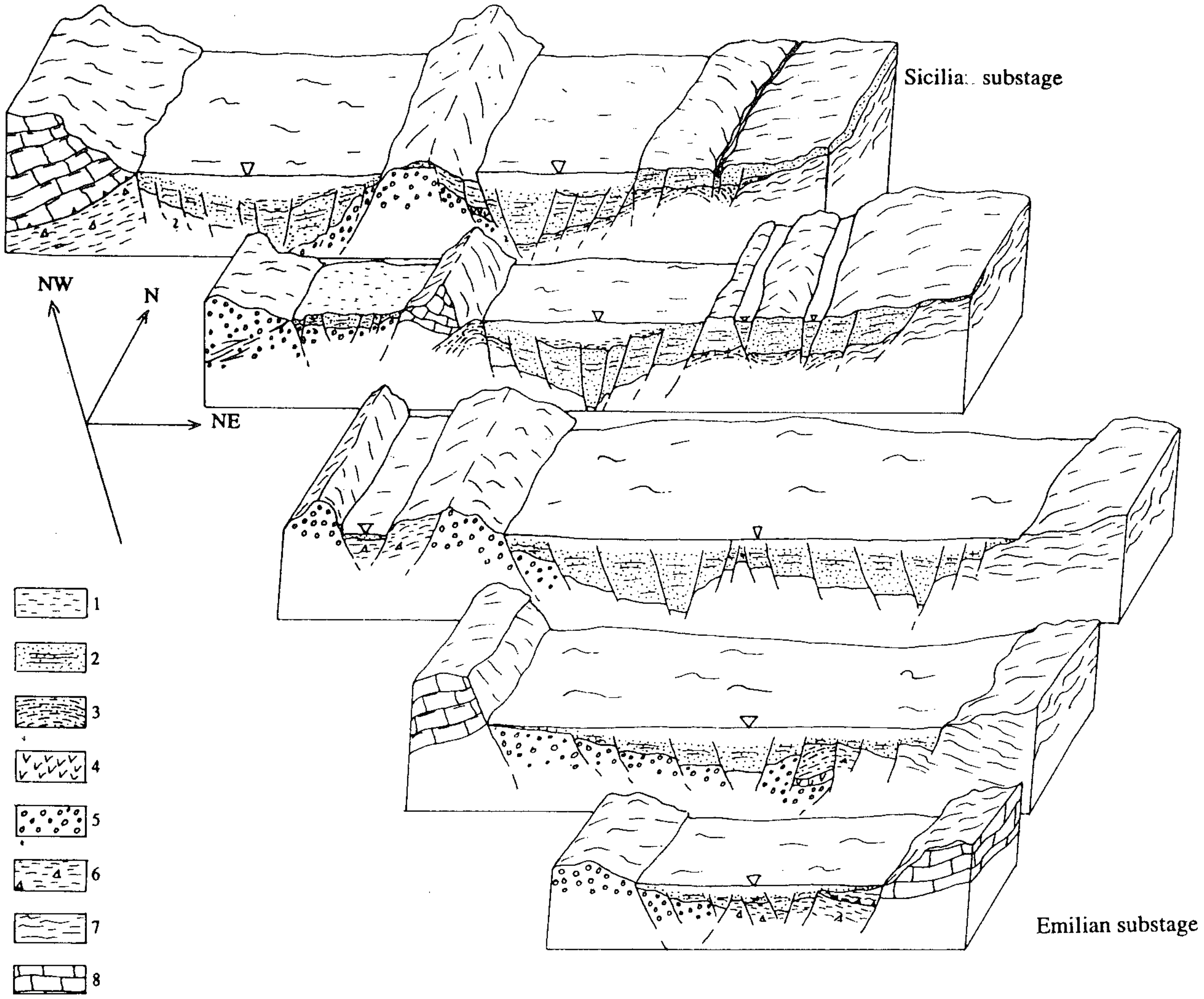

Fig. 4 - Interpretative sections across the geological map of the Gulf of Castellammare illustrating the model for graben development.

1 = Lower Pleistocene (Sicilian) deposits; 2 = Lower Pleistocene (Emilian - Sicilian) deposits; 3 = Pliocene deposits; 4 = Upper Messinian deposits; 5 = Late Miocene deposits (*Terravecchia Formation*); 5 = Lower-Middle Miocene deposits; 6 = Oligocene - Lower Miocene deposits; 7 = Mesozoic deposits.

segments of the strike slip faults coupled with an orthogonal reverse fault system. On the southern and northern side, normal faults trending obliquely to the strike slip fault are also present. Assuming that activity along the strike slip faults did not stop in the late Pliocene, contemporaneous kinematics due to horizontal and compressive stress can be detected.

According to the model of AYDIN & NUR (1982), geometrical and/or mechanical irregularities of the strike slip faults evoke, when motions along single faults within the transcurrent fault system occur. These irregularities cause simultaneity of extensional and compressional zones around the master strike slip fault. The horizontal movements are accompanied by right upfaulting causing reverse faults perpendicularly or parallel trending. At the stepover region, a depression can be formed bounded by strike slip faults with a significant slip.

If activity along the transcurrent fault system continued in the Pleistocene, the sedimentary basins would suggest the formation of pull-apart basins during late Pliocene and early Pleistocene (Fig. 5).

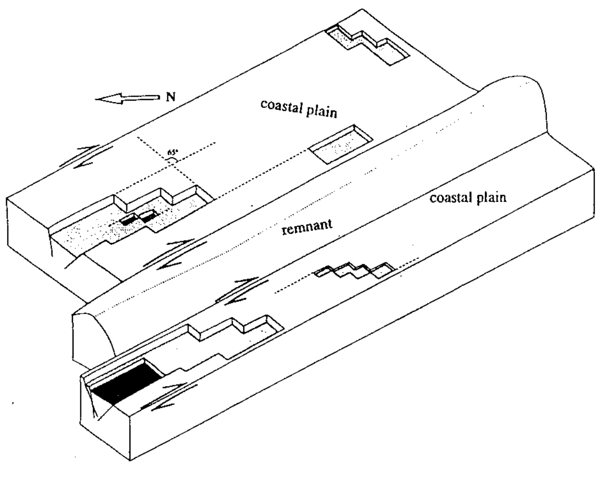

Fig. 5 - Model for pull-apart basin development. Several basins are formed within the coastal plain. A remnant is remaining in the centre of the area.

DISCUSSION

The Gulf of Castellammare belongs to Neogene, peri-Tyrrhenian sedimentary basins, genetically linked to the extensional Tyrrhenian back arc basin trending perpendicular to the thrust front. Some of these basins, however, show evidence of compression, acting contemporaneously to the distensive stress (GAMBERI & ARGNANI, this volume).

A possible reversion of deformation style in the Gulf of Castellammare implies progressive migration of the extensional regime in the Tyrrhenian Sea. The migration should be linked up with lateral shifting of the central axis from an approximately N-S direction to a NW-SE direction (SELLI, 1985; WEZEL, 1985). Within such a *scenario*, the gulf occupies during middle Pleistocene the margin of the basin and, therefore, was affected by uplift. This model fits the results of the seismic data which emphasize the northward migration of subsidence on the NW-Sicilian shelf after the late Pliocene (CATALANO *et alii*, 1993). In this case, the subsidence of the gulf has to be interpreted as a local effect, since it evolves later of the rifting of the Tyrrhenian basin.

Examples from the Sicani Mountains (MONACO *et alii*, this volume) and the Egadi Islands (ABATE *et alii*, this volume) show that horizontal motions occurred at the S-Tyrrhenian margin during late Pliocene and Pleistocene. Thus, assuming that this is the case of the Gulf of Castelammare, the formation of pull-apart basins can be explained. Such basins imply contemporaneous horizontal and compressive stress in the transition zone between the thrust fold belt and the Tyrrhenian basin.

In a plate tectonic context, two models are discussed to explain the simultaneity of extension and compression in the upper crust (ARGNANI, 1990). The first emphasises the roll-back of thinned crust of the African margin overlain by the European lithosphere. The European plate is stretched by trench pull and thinned off until rupture. By assuming a continental collision, the second model describes a lithospheric mantle delamination process that prograded southward. The delamination is caused by instability of the lithospheric root in the collision zone. In both models, the Tyrrhenian Sea is thought to represent a back arc basin implying a convergent plate boundary (BOCCALETTI & GUAZZONE, 1972).

CONCLUSIONS

In the Gulf of Castellammare, five systems of tectonic elements are recognised the late Miocene onwards: (1) a transcurrent fault system with dextral components with a N-S orientation with maximum activity in the Pliocene which is not clearly identifiable in the field; (2) a system of E-W trending reverse faults probably correlated with strike-slip movements; (3) a system of NNW-SSE orientated normal faults affecting the lower Pleistocene deposits; (4) a system of NNE-SSW orientated normal faults affecting the lower, middle and upper Pleistocene deposits; (5) a fault system in NE-SW orientation probably still active.

The fault-fold systems are the product of compressional tectonics coupled with strike slip movements, affecting molasse and nearshore sediments mainly during the Pliocene. Synsedimentary subsidence affected the lower Pleistocene shallow water sediments and uplift occurred during middle and late Pleistocene.

The subsidence was driven by NNW-SSE orientated normal faults which caused the formation of two basins arranged symmetrically at the East and the West side of an intervening fault block. Uplift starting probably during Emilian - Sicilian boundary, is linked with NE-SW trending normal faults.

Because kinematic indicators are seldom preserved and stress factors are difficult to measure, two models for Plio-Pleistocene structural evolution are presented. The first model emphasises fault block tectonics leading to the formation of two grabens separated by a horst. The model implies an inversion in the deformation style of the gulf area and propagation of the extensional tectonics of the Tyrrhenian basin from the NW to the SE. The second model suggests the formation of pull-apart basins assuming the activity of a transcurrent fault system at least until the middle Pleistocene.

REFERENCES

ABATE B., CATALANO R. & RENDA P. (1978) - *Schema geologico dei Monti di Palermo.* Boll. Soc. Geol. It., **97**, 807-819.

ABATE B., FERRUZZA G., INCANDELA A. & RENDA P. (1995) - *Fase tettonica trascorrente nelle Isole Egadi.* In: *Geodinamica e tettonica attiva del sistema Tirreno-Appennino.* Camerino 9-10 Febbraio 1995, Riassunto.

ARGNANI A. (1990) - *The Strait of Sicily Rift Zone: Foreland Deformation related to the Evolution of a Back-Arc Basin.* J. Geodyn., **12**, 311-331.

AYDIN A. & NUR A. (1982) - *Evolution of Pull-apart Basins and their scale independence.* Tectonics, **1**(1), 91-105.

BLOT C. (1971) - *Etudes sismologiques de Vulcano.* Cah. Orstom. Sér. géophys. **11**, 32, Paris.

BOCCALETTI M. & GUAZZONE G. (1972) - *Evoluzione paleogeografica e geodinamica del Mediterraneo: i bacini marginali.* Mem. Soc. Geol. It., **13**, 162-169.

CATALANO R., D'ARGENIO B., MONTANARI L., RENDA P., ABATE B., MONTELEONE S., MACALUSO T., PIPITONE G., DI STEFANO E., LO CICERO G., DI STEFANO P. & AGNESI V. (1978) - *Contributi alla conoscenza della struttura della Sicilia occidentale. Il profilo Palermo Sciacca.* Mem. Soc. Geol. It., **19**, 485-493.

CATALANO R. & D'ARGENIO B. (1982) - *Schema geologico della Sicilia.* In: CATALANO R. & D'ARGENIO B. (eds.) - *Guida alla Geologia della Sicilia occidentale.* 1. Centenario della Soc. Geol. It., Palermo, 9-41.

CATALANO R., D'ARGENIO B., MONTANARI L., MORLOTTI E. & TORELLI L. (1985) - *Marine Geology of the NW-Sicily Offshore (Sardinia Channel) and its Relationships with Mainland Structures.* Boll. Soc. Geol. It., **104**, 207-215.

CATALANO R., DI STEFANO E., LO CICERO G., INFUSO S., VAIL P.R. & VITALE F.P. (1993) - *Basin Analysis and Sequence Stratigraphy of the Plio-Pleistocene of Sicily.* Proc. of the Int. Sci. Meeting Saclantcen Underwater Research Centre, La Spezia, Italy. Unesco-Reports in Marine Science, **58**, 99-104.

GAMBERI F. & ARGNANI A. (1995) - *Evoluzione stratigrafico-strutturale dei bacini neogenici sovraimposti alla catena appenninico-maghrebide nei dintorni delle Isole Egadi.* In: *Geodinamica e tettonica attiva del sistema Tirreno-Appennino.* Camerino 9-10 Febbraio 1995, Riassunto.

GIESE P. & MORELLI C. (1975) - *Main features of crustal structures in Italy.* In: SQUYRES C.H. (ed.) - *Geology of Italy*, **1**, 221-243.

GIUNTA G. & LIGUORI V. (1973) - *Geologia dell'estremità nord-occidentale della Sicilia.* Riv. Min. Sic. **23**, 136-138, 165-226.

LOCARDI E. (1985) - *Neogene and Quaternary Mediterranean Volcanism: The Tyrrhenian Example.* In: STANLEY D.J. & WEZEL F.C. (eds.) - *Geological Evolution of the Mediterranean Basin*, pp. 273-292. New York, Berlin, Heidelberg, Tokyo.

MAUZ B. (1994) - *Die quartäre Landschaftsgeschichte des Küstentieflands am Golf von Castellammare (NW-Sizilien). Untersuchungen zu Tektonik, Sedimentation und Eustasie auf der Basis einer geologischen Spezialkartierung.* Ph.D. dissertation, University of Heidelberg.

MAUZ B. & RENDA P. (1991) - *Evoluzione tettono-sedimentaria del bacino plio-pleistocenico di Castellammare del Golfo (Sicilia Nord-Occidentale).* Mem. Soc. Geol. It., **47**, 167-180.

MONACO C., TORTORICI L. & VINCIGUERRA G. (1995) - *Tettonica trascorrente pleistocenica nel settore meridionale dei Monti Sicani (Sicilia occidentale).* In: *Geodinamica e tettonica attiva del sistema Tirreno-Appennino.* Camerino 9-10 Febbraio 1995, Riassunto.

MORELLI C. (1985) - *Geophysical Contribution to Knowledge of the Mediterranean Crust.* In: STANLEY D.J. & WEZEL F.C. (eds.) - *Geological Evolution of the Mediterranean Basin*, pp. 65-82. New York, Berlin, Heidelberg, Tokyo.

RUGGIERI G. & TORRE G. (1973) - *Geologia delle zone investite dal terremoto del Belice. 1) La tavoletta Gibellina.* Riv. Min. Sic., **139-141**, 27-48.

RUGGIERI G. (1978) - *Una Trasgressione del Pleistocene Inferiore nella Sicilia Occidentale.* Il Nat. Sic. IV,II **(3-4)**, 159-171.

RUGGIERI G., SPROVIERI R. & UNTI M. (1979) - *Evidenze della Trasgressione dell'Emiliano (Pleistocene inferiore) nella Sicilia orientale.* Boll. Soc. Geol. It. **98**, 469-473.

SELLI R. (1985) - *Tectonic Evolution of the Tyrrhenian Sea.* In: STANLEY D.J. & WEZEL F.C. (eds.) - *Geological Evolution of the Mediterranean Basin*, 131-153, New York, Berlin, Heidelberg, Tokyo.

WEZEL F.C. (1985) - *Structural Features and Basin Tectonics of the Tyrrhenian Sea.* In: STANLEY D.J. & WEZEL F.C. (eds.) - *Geological Evolution of the Mediterranean Basin*, pp. 153-194. New York, Berlin, Heidelberg, Tokyo.