M. SACCHI, S. INFUSO and E. MARSELLA

LATE PLIOCENE - EARLY PLEISTOCENE COMPRESSIONAL TECTONICS IN OFFSHORE CAMPANIA (EASTERN TYRRHENIAN SEA)

Abstract. The interpretation of available multichannel seismic profiles, and the subsidence analysis of boreholes, which shows notable short-term departures from the expected long-term trends for basin subsidence, allow to recognize a late-stage phase of compressional tectonics, Late Pliocene-Early Pleistocene in age, in offshore Campania, between the Sorrento Peninsula and Cape Palinuro. In connection with the Tyrrhenian Sea opening, extensional and strike-slip tectonics have developed in this area since Late Miocene, mostly after the major compressional phases that built up the western sectors of the Southern Apenninic fold and thrust belt. Seismic lines show that tectonic deformation occurred along a major system of SW-NE trending listric faults, also controlling the present-day half-graben setting of the Salerno Basin. The Late Pliocene - Early Pleistocene compressional phase (which shows a NNW-SSE direction for the maximum horizontal shortening) reactivated the pre-existing SW-NE fault system and was responsible for tectonic inversion within the Salerno Basin. It also caused the development of shallowing-upward sequences on the top of the forming compressional structures, as well as deformation and flexural uplift to subaerial exposure of basin flanks (Mesozoic carbonate reliefs together with part of the Lower Pleistocene basin infill), and, at the same time, subsidence in the basin center. According to our interpretation, compression may have a fundamental role in controlling or enhancing tectonic uplift and/or subsidence, and tectonic phases recognized at sea can be tentatively correlated with "neotectonic" evidence documented on land. After Early Pleistocene, a new generalized tectonic subsidence started in the Salerno Basin, but, in later times, compression was still going on in some restricted areas within the Salerno Basin and close to the southern border of the Picentini Mountains, towards the inner part of the Sele Plain. Tectonic deformation and erosional truncations within the Upper Pleistocene sequences in the offshore south of Salerno, as well as local tectonic uplift of uppermost Pleistocene deposits several meters above the present-day sea level on land, suggest that compressional events may have still been active up to very recent times. Evidence of Late Neogene-Quaternary compressional tectonics in extensional domains, has already been described for several places in the Mediterranean and in the northern Atlantic region. We infer that this "non-orogenic" contractional phase, which seems to be of regional extent, may be related to major intra-plate stress changes.

INTRODUCTION

The study area is located on the hinge zone between the Campania segment of the Southern Apenninic fold and thrust belt, and the peri-Tyrrhenian basins domain (Fig. 1). This segment of the Apenninic chain has undergone tectonic contraction since the Miocene and is formed by a stack of thrust imbricates whose thickness is of the order of 10 km (Mostardini e Merlini, 1986; Casero et al., 1988; Patacca and Scandone, 1989).

Since the Late Pliocene, strong vertical tectonics has developed and caused a first broad uplift of the western sectors of the Apenninic chain (Brancaccio et al., 1987, 1991; Brancaccio e Cinque, 1988; Russo, 1990). Several phases of uplift have been recognized and related to extensional tectonics during the Pleistocene. Uplifting areas were migrating from west to east at the same time as the peri-Tyrrhenian margin was affected by strong tectonic subsidence (Brancaccio et al., 1991; Patacca et al., 1990).

Manuscript received, January 21, 1993; accepted, September 10, 1993.

Geomare Sud, CNR Istituto di Geologia Marina, Via Vespucci 9, 80142 Napoli, Italy.

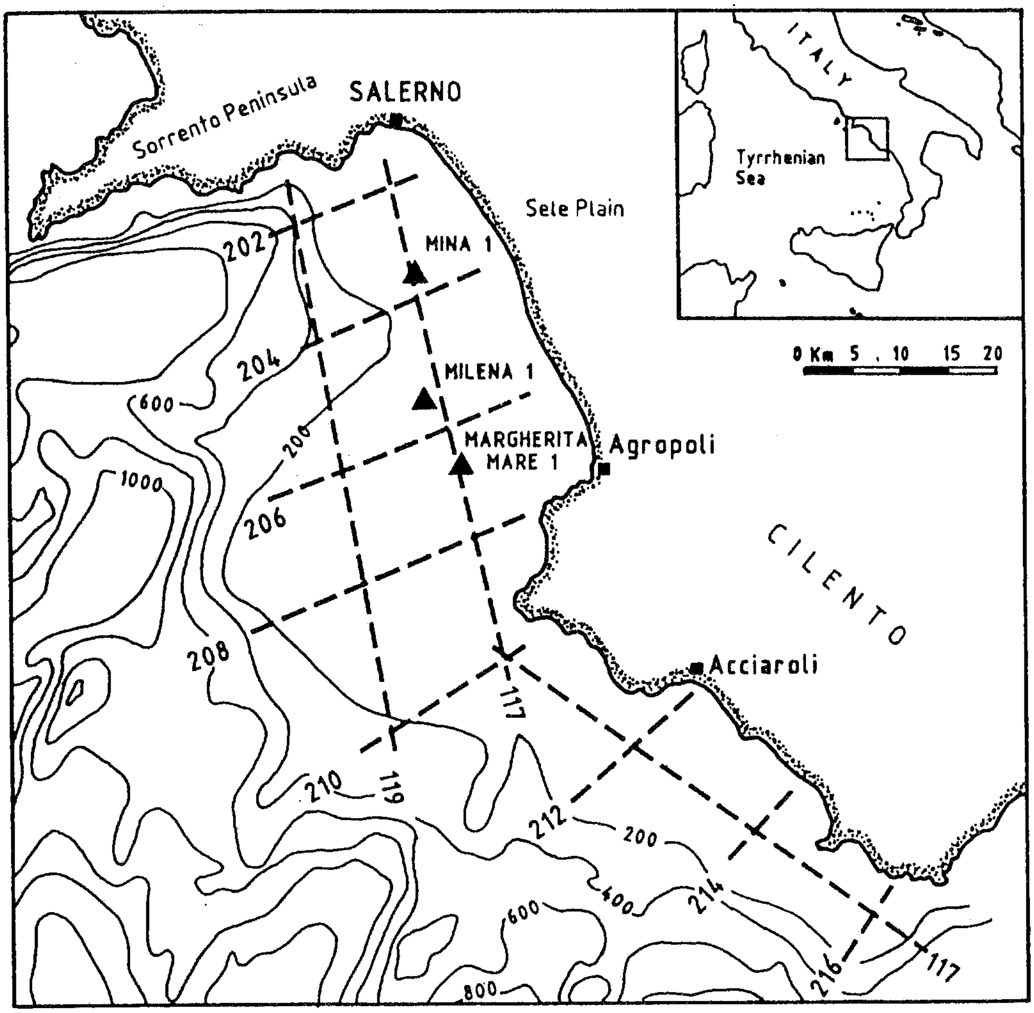

Fig. 1 — Study area with location of seismic lines and wells. Seawater depths (isobathes) are in meters.

All along the eastern Tyrrhenian margin, the Late Miocene - Pleistocene tectonic activity was controlled mainly by listric normal faults and strike-slip faults and, as a consequence, a number of peri-Tyrrhenian basins, located along the continental margin and/or on land, were generated (Selli, 1981; Bartole et al., 1984; Zitellini et al., 1984; Finetti and Del Ben, 1986; Lavecchia, 1988; Mariani e Prato, 1988; Bernini et al., 1990; Bartole et al., 1991).

The Salerno Basin, together with the Sele Plain on land, forms the Sele Basin, which is one of the relatively deep peri-Tyrrhenian basins. It started to form in the Late Miocene (Brancaccio et al., 1987, 1991; Russo, 1990) and is bounded, to the north and south respectively, by the Sorrento Peninsula and the Cilento structural highs, which have been mostly emergent since the Pliocene (Brancaccio et al., 1987, 1991).

The offshore between Sorrento Peninsula and Cape Palinuro is characterized by a relatively shallow and extensive continental platform (up to 25 km), west of the Cilento coast, with a very thin (from tens to a few hundreds of meters) Plio-Pleistocene sedimentary cover. On the other hand, south of Sorrento Peninsula (Salerno Basin), a very reduced continental platform (11 km max) and steep continental slopes are present, with more than 3000 m of Late Miocene-Pleistocene basin infill (Bartole, 1984; Finetti and Del Ben, 1986; Coppa et al., 1988).

STRATIGRAPHY AND STRUCTURES

The data set used for the interpretation presented in this paper (Fig. 1) consists of about 220 km of multichannel reflection profiles and 3 exploratory wells (Mina 1, Milena 1 and Margherita Mare 1) provided by the Italian Ministry of Industry. Seismic data were acquired in 1968 by the Western Geophysical Company for Agip in the Italian Economic Zone (''Zona E'', southeastern Tyrrhenian Sea).

Stratigraphic thicknesses and age boundaries reported on well logs are sometimes controversial and have been revised in the light of updated literature and seismic interpretation.

Basement units

From a study of seismic profiles, calibrated also with boreholes (Fig. 2), two main seismostratigraphic units representing the ''basement'' for the Late Miocene - Pleistocene sequence in offshore Campania may be recognized and tentatively correlated to corresponding thrust units known on land:

1) A Mesozoic carbonate platform unit which is present in the subsurface throughout the study area (Figs. 2, 3, 4 and 5). Cretaceous limestones and dolomitic limestones have been recovered at the Mina 1, Milena 1 and Margherita Mare 1 well sites. Maximum perforated thickness is of the order of 1300 m at the Milena 1 well.

This unit can be correlated with the M. Picentini - Taburno and Alburno - Cervati Units outcropping on land, respectively to the north and south of the Sele Line (D'Argenio et al., 1973, 1986; Bonardi et al., 1988: Geological map of Southern Apennines).

2) A Miocene siliciclastic unit which lies above the Mesozoic carbonate unit, and is only found in the southern sector of the study area (offshore Cilento) to the south of the Sele Line (Figs. 2, 3 and 4). Maximum thickness is of the order of 1600 m at the Margherita Mare 1 well. Below the Miocene siliciclastic unit (and above the Mesozoic carbonate platform unit), a few hundred meters of a Cretaceous basinal sequence have also been recovered (only at the Milena 1 well).

These two units can be correlated with the oceanic Liguride Unit and associated Miocene foredeep deposits (Cilento Unit) outcropping in the Cilento area on land (Bonardi, 1988).

The already deformed and in places eroded basement appears to be block-faulted by a system of SW-NE trending listric faults dipping SE or subordinately NW. Faults show either a prevalent normal component, giving rise to half-graben systems (Salerno Basin), or a reverse component, giving rise to compressional structures like the Agropoli and Acciaroli faults and to the Palinuro structure (Bartole, 1984), which represents the offshore extension of the M. Bulgheria thrust on land (Figs. 3 and 4).

Listric normal faults, close to the northern flank of Salerno Basin (Fig. 2), tend to root along a low-angle normal fault (the Capri Fault) dipping SE with inclination angles of about 35° and reaching depths of about 6 km below the Mina 1 well site (D'Argenio et al., 1987; Oldow et al., 1993).

Listric reverse faults and thrusts may either root along the major thrust of the Liguride and Cilento Units above the Mesozoic Carbonate unit or cut this surface causing a notable shortening within the sedimentary basement. (Figs. 2, 3 and 4).

Tectonic deformation within the Upper Pleistocene sequence in some restricted areas suggests that some of these faults may have still been active in very recent times, even if with moderate displacement.

Basin sequence

The Tertiary sedimentary sequence starts in the Salerno Basin (the Mina 1 well) with the deposition of Late Tortonian - Messinian clays and marls (and subordinately sands and fine grained limestones) whose thickness approaches 600 m. With no apparent discontinuity, Early Pliocene conglomerates and chalky limestones (with subordinate marls and marly limestones)

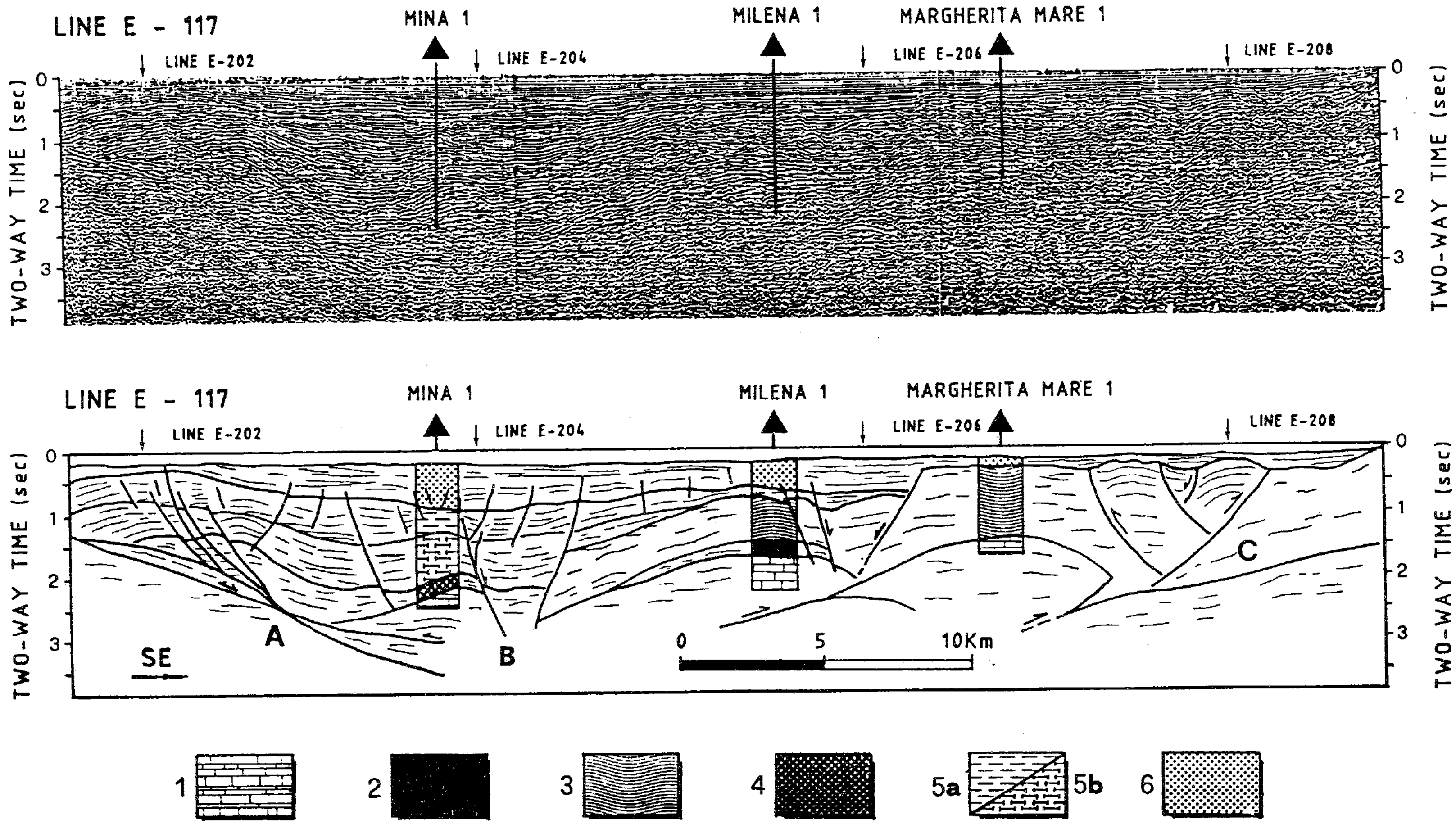

Fig. 2 — Line E - 117 (northern part) and its geologic interpretation. Note the inversion structure within the Salerno Basin; the start of the inversion (Middle-Late Pliocene) is marked by the first onlap on the forming structure; see also intersection with Line E - 202. Key to well stratigraphy: 1) Limestones and dolomitic limestones (Upper Cretaceous); 2) Claystones and shales with intercalated limestones (Cretaceous); 3) Clays and sandstones with intercalated chalky limestones (Miocene); 4) Clays and marls with intercalated sandstones and conglomerates (Upper Miocene); 5a) Conglomerates, chalky limestones and, subordinately, clays and marls (Lower Pliocene); 5b) Marly clays and marls with intercalated sands and conglomerates (Upper Pliocene-Lower Pleistocene); 6) Clays and marly clays with intercalated fine grained sands (Pleistocene). Major tectonic lines: A) Capri Fault; B) Sele Line; C) Agropoli Fault.

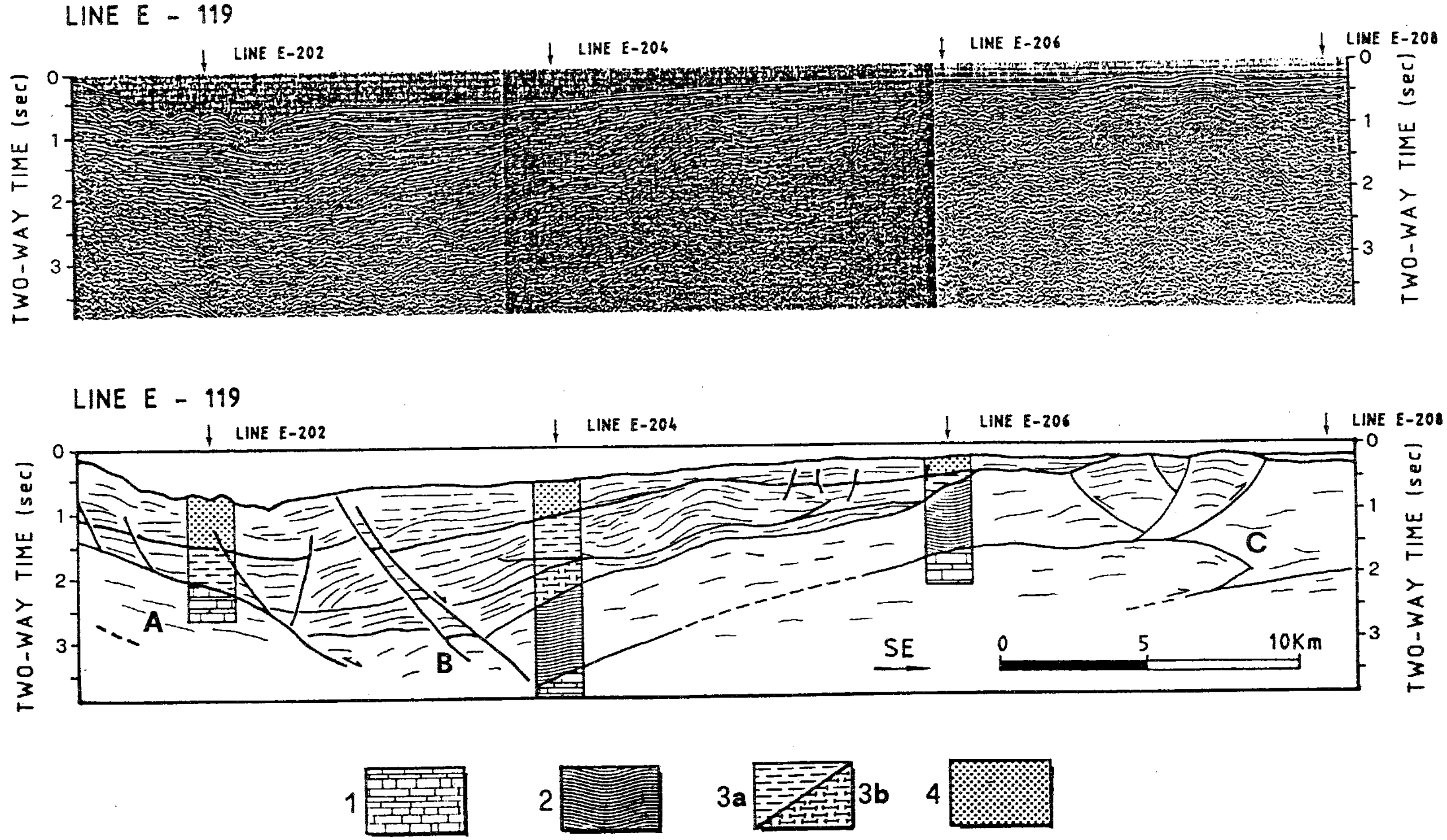

Fig. 3 — Line E - 119 and its geologic interpretation. Note Late Pliocene-Early Pleistocene folding between intersections with lines E - 204 and E - 206. Stratigraphy at the intersection with cross-cutting lines is inferred from seismic interpretation: 1) Limestones and dolomitic limestones (Upper Cretaceous); 2) Clays and sandstones with intercalated chalky limestones (Miocene); 3a) Conglomerates, chalky limestones and, subordinately, clays and marls (Lower Pliocene); 3b) Marly clays and marls with intercalated sands and conglomerates (Upper Pliocene-Lower Pleistocene); 4) Clays and marly clays with intercalated fine-grained sands (Pleistocene). Major tectonic lines: A) Capri Fault; B) Sele Line; C) Agropoli Fault.

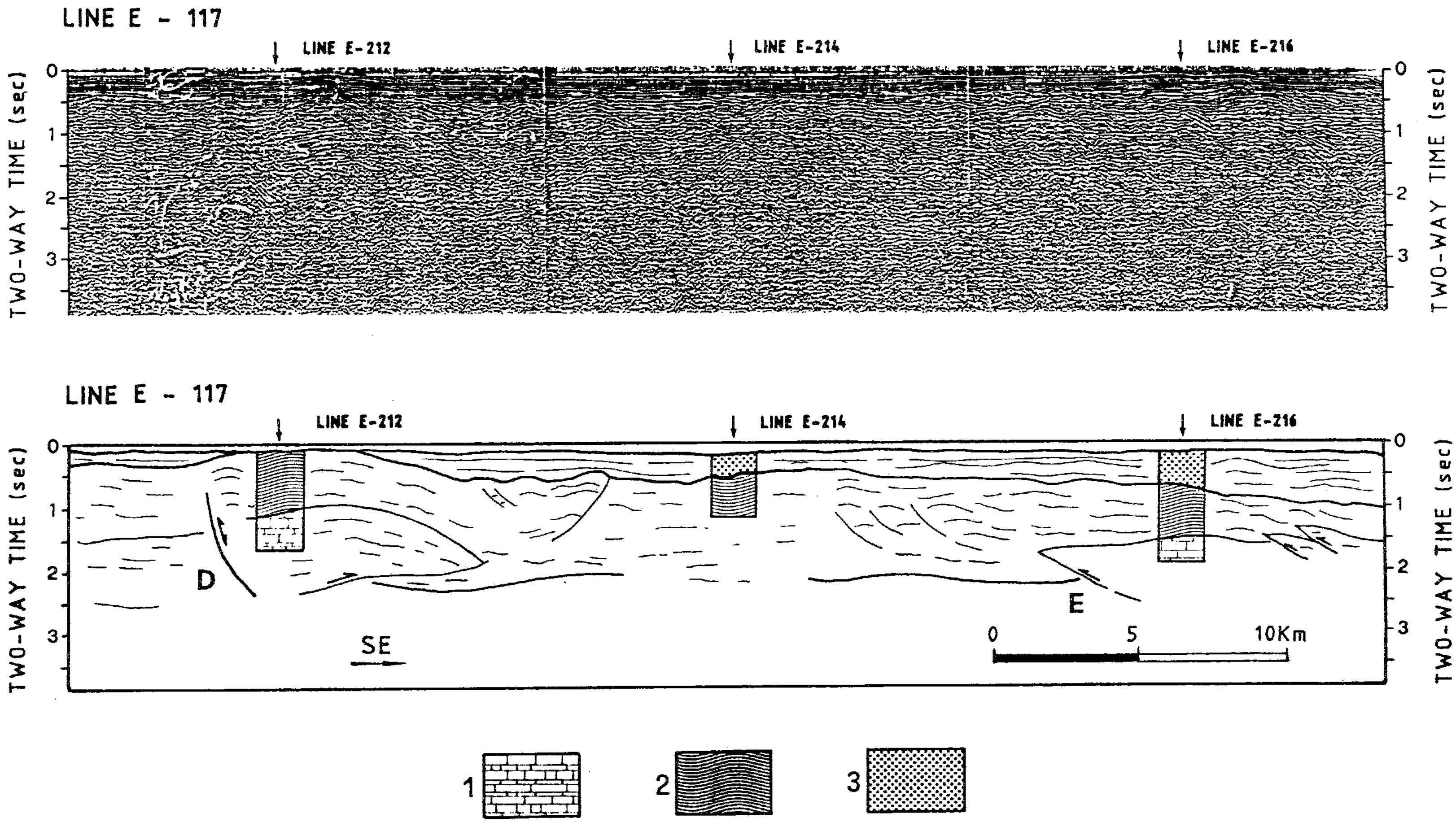

Fig. 4 — Line E - 117 (southern part) and its geologic interpretation. Stratigraphy at the intersection with cross-cutting lines is inferred from seismic interpretation: A) Limestones and dolomitic limestones (Mesozoic); 2) Clays and sandstones with intercalated chalky limestones (Miocene); 3) Clays and marly clays with intercalated fine grained sands (Pleistocene). Major tectonic lines: D) Acciaroli Fault; E) Palinuro Structure.

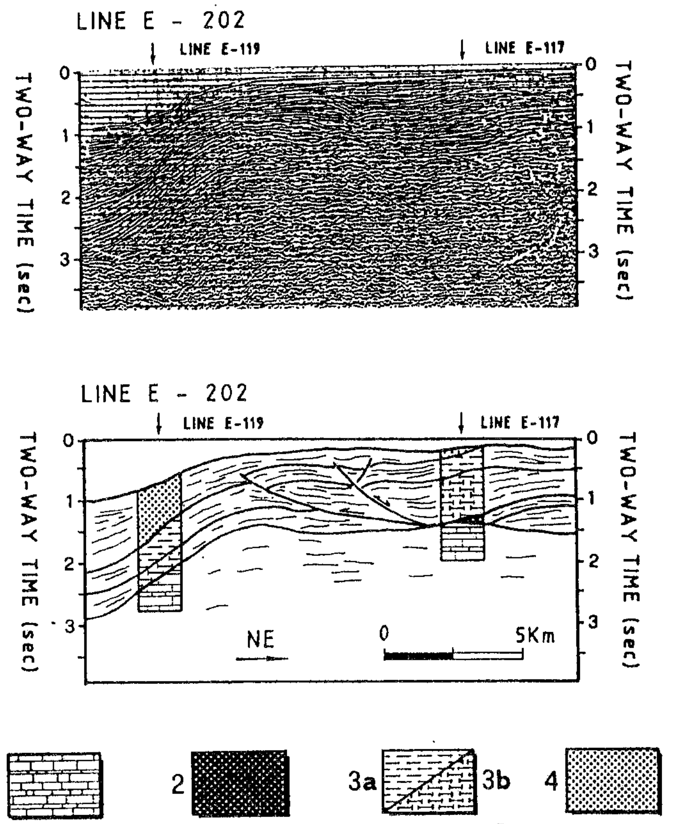

Fig. 5 — Line E - 202 and its geologic interpretation. Note the lateral ramp of the inversion structure visible on line E - 117. Stratigraphy at the intersection with cross-cutting lines is inferred from seismic interpretation: 1) Limestones and dolomitic limestones (Upper Cretaceous); 2) Clays and marls with intercalated sandstones and conglomerates (Upper Miocene); 3a) Conglomerates, chalky limestones and, subordinately, clays and marls (Lower Pliocene); 3b) Marly clays and marls with intercalated sands and conglomerates (Upper Pliocene-Lower Pleistocene); 4) Clays and marly clays with intercalated fine grained sands (Pleistocene).

follow along with Late Pliocene clays and marls (with subordinate sands); total thickness is of the order of 1700 m. The Pleistocene is represented by a relatively thick (about 900 m) sequence of clays and marls (with subordinate sands and organic-rich material) (Fig. 2).

A regional unconformity of probable Messinian age, with non-deposition (lowermost Pliocene is completely missing) and at places subaerial erosion, characterizes the base of the Plio-Quaternary sequence offshore Cilento (the Milena 1 and Margherita Mare 1 wells).

Seismic lines show that the deposits of the Late Miocene - Pliocene basin infill are locally folded and in places disrupted by minor reverse faults, which may in some cases reactivate previous normal fault planes (Figs, 2, 3 and 5).

The start of the tectonic inversion (Middle-Late Pliocene) is marked by the first onlap of layers on the flanks of growing structures (Fig. 2). The formation of new basinal depocenters is then induced by tilting, rotation and deformation of fault blocks.

Shortening within the basement was mainly accomodated along already existent tectonic discontinuities (partly reactivated as reverse faults) and possibly accompanied by local flexure and uplift of basin flanks (Sorrento Peninsula, Cilento offshore). The inferred direction for maximum horizontal stress related to this "non-orogenic" compressional phase is about NNW-SSE.

After the Early Pleistocene, a significant depositional growth of bedding connected with

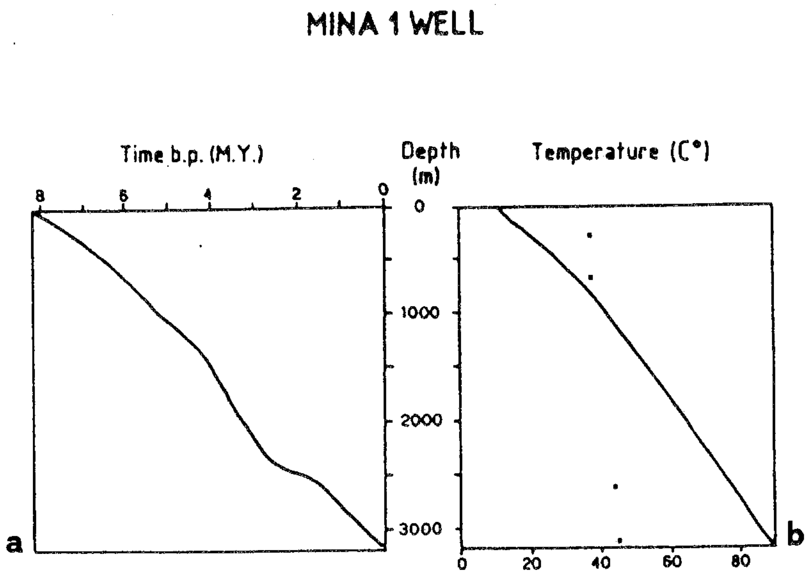

Fig. 6 — Subsidence history and present-day temperature/depth profile of Mina 1 well. Subsurface temperatures (dots) of Figure 6b are reported from Agip data (Agip, 1977). Note short-term deviations from the expected long-term subsidence around Pliocene - Pleistocene boundary (6a), and discrepancy between calculated (continuous line) and measured (dots) temperatures at Mina 1 well (6b). See text for discussion.

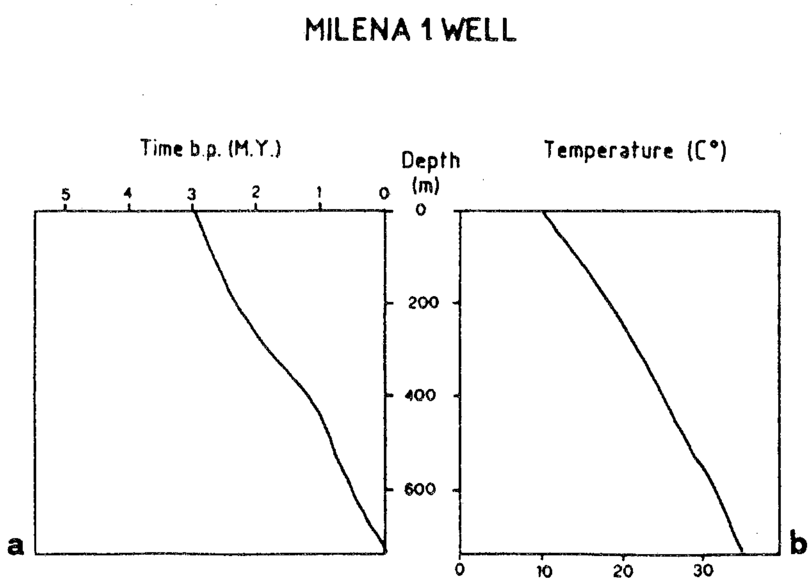

Fig. 7 — Subsidence history and present-day temperature/depth profile of Milena 1 well. Note short-term deviations from the expected long-term subsidence around Pliocene - Pleistocene boundary (7a).

normal listric faults develops within the Salerno Basin, indicating a renewed phase of tectonic subsidence, and some Late Pliocene structural highs become depocenters.

SUBSIDENCE ANALYSIS

A computer program was used to model the time-space evolution of the Mina 1 well (Agip, 1977) and the Milena 1 well. The program is based on a one-dimensional model for basins formed by lithospheric stretching (after Mc Kenzie, 1978). It uses Airy-type isostatic compensation at the bottom of the slab to calculate the subsidence caused by stretching, thermal expansion or contraction of the lithosphere, and by sediment and water loading or unloading.

The subsidence observed in the boreholes has been corrected for compaction and sediment loading, and modelled by using a non-uniform stretching for the lithosphere. Corrections for Plio-Pleistocene long-term sea level changes, and for Late Pleistocene glacio-eustatic sea level changes have also been taken into account.

The subsidence history and present-day temperatures versus depth are plotted in the diagrams of Figs. 6 and 7.

Subsidence analysis at the Mina 1 well site shows, after a period of fast subsidence (up to 50 cm/1000 years) in the Early-Middle Pliocene, a significant decrease in subsidence rates during Late Pliocene - Early Pleistocene (about 20 cm/100 years), followed by relatively fast subsidence (about 30 cm/1000 years) after Early Pleistocene. At the Milena 1 well site, subsidence starts only after Middle Pliocene, with subsidence rates of the order of 24 cm/1000 years on average all through the Plio-Pleistocene.

Subsidence curves of both the Mina 1 and Milena 1 wells show a notable short-term deviation from the expected long-term trend around the Pliocene - Pleistocene boundary. Some Authors (Cloetingh et al., 1990; Cloetingh and Kooi, 1992) have recently pointed out a similar evolution for subsidence patterns occurring widely throughout the North Atlantic-Mediterranean region, suggesting that such anomalies may be related to fluctuating intra-plate stresses due to some global plate rearrangement during the Late Neogene.

Thermal modelling of the Mina 1 well shows that subsurface temperatures tend to be overestimated with respect to the measured values (Fig. 6b), which may also be expected if horizontal stresses are active during basin evolution (Kooi and Cloetingh, 1989).

DISCUSSION

The interpretation of multichannel seismic profiles (Zona E), and the subsidence history reconstructed from borehole data, offer some important elements for understanding the Late Miocene - Pleistocene tectono-stratigraphic evolution of the Campania offshore.

A northern sector (Salerno Basin) and a southern sector (Cilento offshore) may be recognized within this area, showing different morphologic features and tectono-stratigraphic evolutions since Late Miocene.

The southern sector (Cilento offshore) represents a structural high; it was possibly emergent from Middle - Late Miocene, and started subsiding only after Middle Pliocene, with subsidence rates of the order of 24 cm/1000 years (at the Milena 1 well). A strongly developed unconformity of probable Messinian age, indicating non-deposition and at places subaerial exposure, is present at the base of the Plio-Pleistocene sequence (Selli and Fabbri, 1971; Malinverno et al., 1981). The pre-Pliocene "basement" is represented in this area by two major thrust imbricates which are correlatable with the Cilento and Liguride Units (Bonardi, 1988) and with the Alburno Cervati Unit (D'Argenio et al., 1973) outcropping on land.

The northen sector (Salerno Basin), together with the Sele Plain on land, represents a relatively deep basin (the Sele Basin) which evolved from Late Miocene between the Cilento and Sorrento Peninsula structural highs, to the south and to the north, respectively. It is characterized by a Late Miocene - Pleistocene basinal sequence covering a Mesozoic carbonate substratum.

Subsidence analysis at the Mina 1 well site shows, after a period of fast subsidence (up to 50 cm/1000 years) in the Early-Middle Pliocene, a significant decrease in subsidence rates during Late Pliocene - Early Pleistocene (about 20 cm/1000 years), followed by relatively fast subsidence (about 30 cm/1000 years) after Early Pleistocene. Subsidence curves of both the Mina 1 and Milena 1 wells show a notable short-term deviation from the expected long-term trend around the Pliocene - Pleistocene boundary. According to some Authors (Cloetingh et al., 1990; Cloetingh and Kooi, 1992), these anomalies may be related to fluctuating horizontal stresses during basin evolution.

It is generally accepted that from Late Miocene, after the major contractional phases that built up the western sectors of the Southern Apennines, severe extensional processes took place within the prevoius collisional belt. This lead to extensive rifting and rapid tectonic subsidence in the Tyrrhenian (and in the peri-Tyrrhenian) area, with consequent progressive migration of the rift basin-thrust belt-foredeep system towards the Apulian foreland (Finetti and Del Ben, 1986; Kastens et al., 1988; Lavecchia, 1988; Patacca et al., 1988, 1990; Doglioni, 1991).

Nevertheless, most analytical studies on the geology of Campania, both offshore and on land, have failed to propose satisfactory interpretations for contemporaneously acting (at least until Early Pleistocene) compressional and extensional tectonics. Moreover, the Authors do not explain the causes of very large (sometimes up to 3000 m) differential vertical motions (mostly occurring during the Quaternary) along major faults between basins and adjacent structural highs, but rather they interpret them as due to isostatic adjustment of faulted blocks (''Neotectonics'' Auct.). Similarly they do not explain the causes of the abrupt uplift, after a prolonged period of subsidence, of a significant part of the Lower Pleistocene deposits (Conglomerati di Eboli Fm.) within the Sele Plain.

On the other hand, according to our interpretation, compression may have a fundamental role incontrolling or enhancing tectonic uplift and/or subsidence, and compressional phases can be tentatively cortelated with "neotectonic" evidence documented on land. The structural evolution of the study area is related to a major system of SW-NE trending listric faults, which has possibly been active since Late Miocene (Fig. 8). These faults may have a significant left-lateral strike-slip component, as already supposed by Selli (1981). This is suggested mainly by the geological interpretation of seismic lines, showing at places adjacent tectonic blocks with completely different tectonic-stratigraphic evolutions and stratigraphic thicknesses, and by evidence from the regional distribution of Cilento and Liguride Units (which suggests a sinistral movement). This fault system is possibly related to early extensional stages within the Tyrrhenian area.

Thermal analysis of boreholes suggests that the peri-Tyrrhenian continental crust in offshore Campania is relatively cold, if a model of lithospheric stretching is used for basin modelling, or, in other words, that some other processes, involving lower heat loss at depth (e.g., local flexure?, strike-slip tectonics?), may play an important role in basin formation (Cloetingh, 1992).

Unlike in previous interpretations (Bartole, 1984), the Sele Line, which is an important transversal lineament of the Southern Apenninic chain and which separates the northern sector from the southern in the study area, is here regarded as a polyphase transtensional feature with a left-lateral component.

Similarly the Agropoli and Acciaroli faults, and the Palinuro structure, which represents the offshore extension of the M. Bulgheria thrust above the Liguride and Cilento Units (Cilento onshore area), may be interpreted as polyphase transpressional features with a left-lateral component.

All these tectonic lineaments have presumably been active during different stages at least since the Pliocene.

Seismic data suggest, in particular for the Salerno Basin area, that the Capri Fault and possibly the Sele Line were reactivated during the Late Pliocene - Early Pleistocene compressional phase and were active, with different movement components, at least up to Middle Pleistocene.

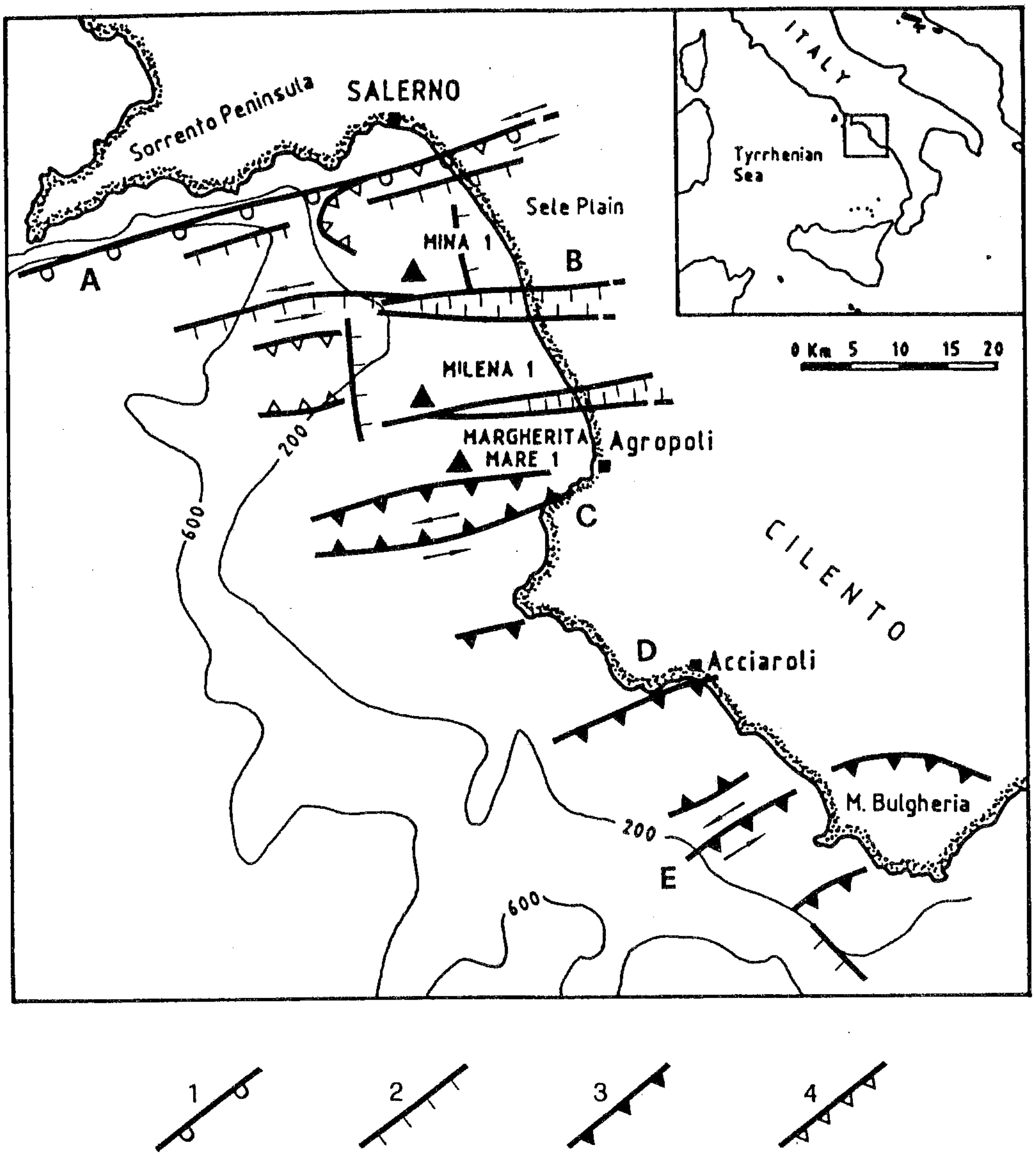

Fig. 8 — Major structures recognized from seismic interpretation in offshore Campania: A) Capri Fault; B) Sele Line; C) Agropoli Fault; D) Acciaroli Fault; E) Palinuro Structure. Key to symbols: 1) Low-angle normal fault. 2) High-angle normal fault. 3) Reverse fault and thrust. 4) Late Pliocene - Early Pleistocene tectonic inversion. Arrows indicate possible trascurrence.

It is more difficult, on the contrary, to get a reliable constraint for the timing of tectonic deformation in Cilento offshore, due to the lack of a complete stratigraphic record for the Plio-Pleistocene sequence. However, because of the consistency of structural patterns and timing of deformation documented on seismic lines, we cannot exclude that also in this area, reverse faults and thrusts (namely the Agropoli and Acciaroli faults and the Palinuro structure-M. Bulgheria thrust), are as young as Late-Pliocene - Early Pleistocene.

The fault system described, possibly accomodated alternating transpression and transtension, causing both uplift and subsidence. The Late Pliocene - Early Pleistocene compressional phase reactivated the pre-existent SW-NE fault system, and was responsible for tectonic inversion in the northern part of the Salerno Basin - Sele plain. According to our interpretation, it also caused the development of shallowing-upward sequences (ending with the Conglomerati di Eboli Fm.) on top of the forming compressional structures, as well as deformation and flexural uplift of basin flanks (Mesozoic carbonate reliefs together with part of the Lower Pleistocene basin infill within the Sele Plain) and, at the same time, subsidence in the basin center.

After Early Pleistocene, a new phase of tectonic subsidence started in the Salerno Basin but, in later times, compression was still going on in some restricted areas within the Salerno Basin and close to the southern border of the Picentini Mountains, towards the inner part of the Sele Plain. Tectonic deformation and erosional truncations within the Upper Pleistocene offshore sequences south of Salerno, as well as tectonic uplift of Eutyrrhenian deposits (130,000 years b.p.) up to about 25 m above the present-day sea level in the Sele Plain (Brancaccio et al., 1991; Russo e Belluomini, 1992), suggest that, locally, compressional events may still have been active up to very recent times.

Evidence of Late Neogene-Quaternary compressional tectonics in extensional domains has already been described in the western Mediterranean (Mauffret et al., 1981), in the Tyrrhenian (Trincardi and Zitellini, 1987; Bernini et al., 1990; Catalano and Milia, 1990; Agate et al., 1993; Gamberi and Argnani, 1993) and in the northern Atlantic region (Cloetingh et al., 1990; Cloetingh and Kooi, 1992). We infer that this "non-orogenic" contractional phase, which seems to be of regional extent, may be related to major intra-plate stress changes, possibly reflecting a plate reorganization of global nature (Cloetingh et al., 1989, 1990; Cloetingh and Kooi, 1992).

Acknowledgments. We owe thanks to Dövényi Péter of the Department of Geophysics at the L. Eötvös University of Budapest who provided the computer program used for subsidence analysis. Thanks are due to S. Cloetingh, M. Talwani, R. Catalano, and to our collegue G. de Alteriis for useful discussions and comments, and also to B. D'Argenio and F. Horváth for a critical review of the manuscript and beneficial suggestions. Special thanks are due to P. Sclafani for helping us in the review of the English text. This reaserch was supported by a C.N.R. grant to the Geomare Sud Institute, Napoli and was partly carried out while the first author held a CNR fellowship at the Eötvös University of Budapest.

REFERENCES

Agate M., Catalano R., Infuso S., Lucido M., Mirabile L. and Sulli A.; 1993: *Structural evolution of the Northern Sicily continental margin during the Plio-Pleistocene.* In: Max M.D. and Colantoni P. (eds), Geological development of the Sicilian - Tunisian Platform. Unesco Report in Marine Science, **58**, 19-24.

Agip; 1977: *Temperature sotterranee. Inventario dei dati raccolti dall'Agip durante la ricerca e la produzione di idrocarburi in Italia.* Agip, Milano.

Bartole R.; 1984: *Tectonic structure of the Latian-Campanian shelf (Tyrrhenian Sea).* Boll. Ocean. Teor. Appl., **3**, 197-230.

Bartole R., Savelli D., Tramontana M. and Wezel F.C.; 1984: *Structural and sedimentary features in the Tyrrhenian margin off Campania, Southern Italy.* Marine Geology, **55**, 163-180.

Bartole R., Torelli L., Mattei G., Peis D. e Brancolini G.; 1991: *Assetto stratigrafico-strutturale del Tirreno Settentrionale: stato dell'arte.* Studi Geologici Camerti, volume speciale (1991/1), 115-140.

Bernini M., Boccaletti M., Moratti G., Papani G., Sani F. e Torelli L.; 1990: *Episodi compressivi Neogenico-Quaternari nell'area estensional tirrenica nord-orientale. Dati in mare e a terra.* Mem. Soc. Geol. It., **45**, 577-589.

Bonardi G.; 1988: *Il Complesso Liguride Auct.: stato delle conoscenze e problemi aperti sulla sua evoluzione appenninica e i suoi rapporti con l'Arco Calabro.* Mem. Soc. Geol. It., **41**, 17-35.

Bonardi G., D'Argenio B. e Perrone V. (eds); 1988: *Carta geologia dell'Appennino meridionale.* Mem. Soc. Geol. It., vol. 41.

Brancaccio L., Cinque A., D'Angelo G., Russo F. Santangelo N. e Sgrosso I.; 1987: *Evoluzione tettonica e geomorfologica della Piana del Sele (Campania, Appenino Meridionale).* Geogr. Fis. e Din. Quat., **10**, 47-55.

Brancaccio L. e Cinque A.; 1988: *L'evoluzione geomorfologica dell'Appennino Campano-Lucano.* Mem. Soc. Geol. It., **41**, 83-86.

Brancaccio L., Cinque A., Romano P., Rosskopf C., Russo F., Santangelo N. and Santo A.; 1991: *Geomorphology and neotectonic evolution of a sector of the Tyrrhenian flank of the Southern Apennines (region of Naples, Italy).* Z. Geomorph., suppl. 82, 47-58.

Casero P., Roure F., Moretti I., Muller C., Sage L. e Vially R.; 1988: *Evoluzione geodinamica neogenica dell'Appennino meridionale.* In: Atti 74° Congr. Soc. Geol. Ital., Sorrento, 13-17 Settembre 1988, Riassunti, **B**, pp. 59-66.

Catalano R. and Milia A.; 1990: *Late Pliocene - Early Pleistocene structural inversion in offshore Western Sicily.* In: Pinet B. and Bois C. (eds) The Potent. of Deep Seism. Profil. for Hydroc. Explor., Editions Technip, Paris, pp. 445-449.

Cinque A. e Romano P.; 1990: *Segnalazione di nuove linee di riva in Penisola Sorrentina (Campania).* Geogr. Fis. e Din. Quat., **13 (1)** 23-36.

Cloetingh S.; 1992; *Lithospheric dynamics and the tectonics of sedimentary basins.* In: Proc. Kon. Ned. Akad. v. Wetensch., **95 (3)**, pp. 349-369.

Cloetingh S., Gradstein F.M., Kooi H., Grant A.C. and Kaminsky M.; 1990: *Plate reorganization: a cause of rapid late Neogene subsidence and sedimentation around the North Atlantic?* Jour. of Geol. Soc., **147**, 495-506.

Cloetingh S. and Kooi H.; 1992: *Tectonics and global change - inferences from Late Cenozoic subsidence and uplift patterns in the Atlantic/Mediterranean region.* Terra Nova, **4**, 340-350.

Cloetingh S., Kooi H. and Groenewoud W.; 1989: *Intraplate stresses and sedimentary basin evolution.* In: Intern. Union of Geod. and Geoph. and Am. Geoph. Union, pp. 1-16.

Coppa M.G., Madonna M., Pescatore T., Putignano M., Russo P., Senatore M.R. e Verrenigia A.; 1988: *Elementi geomorfologici e faunistici del margine continentale tirrenico tra Punta Campanella e Punta degli Infreschi (Golfo di Salerno).* Mem. Soc. Geol. It., **41**, 541-546.

D'Argenio B., Ietto A. and Oldow J.; 1987: *Low angle normal faults in the Picentini Mountains (Southern Italy).* Rend. Soc. Geol. It., **9**, 113-125.

D'Argenio B., Ortolani F. and Pescatore T.; 1986: *Geology of the Southern Apennines. A brief outline.* In: Int. Ass. Eng. Geol., Proc. Intern. Symp. on: Engineering Geology problems in Seismic Areas, Geologia Applicata e Idrogeologia, **6**, 135-161.

D'Argenio B., Pescatore T. e Scandone P.; 1973: *Schema geologico dell'Appennino Meridionale (Campania e Lucania).* Atti Acc. Naz. Lincei, **183**, 49-72.

Doglioni C.; 1991: *A proposal for the kinematic modelling of W- dipping subductions - possible applications to the Tyrrhenian- Apennines system.* Terra Nova, **3**, 423-434.

Fabbri A. and Curzi P.; 1979: *The Messinian of the Tyrrhenian Sea: seismic evidence and dynamic implications.* Giorn. Geol., ser. 2, **43**, 215-248.

Finetti I. and Del Ben A.; 1986: *Geophysical study of the Tyrrhenian opening.* Boll. Geof. Teor. Appl., **28**, 75-155.

Finetti I. and Morelli C.; 1973: *Geophysical exploration of the Mediterranean Sea.* Boll. Geof. Teor. Appl., **15**, 263-344.

Gamberi F. and Argnani A.; 1993: *Seismostratigraphic analysis of the Neogene basins superimposed on the Maghrebian orogen west of the Egadi Islands: preliminary results.* In: Max M.D. and Colantoni P. (eds), Geological development of the Sicilian - Tunisian Platform. Unesco Report in Marine Science, **58**, 61-64.

Incoronato A. and Nardi G.; 1987: *Paleomagnetic evidence for a Peri-Tyrrhenic orocline.* In: Boriani A., Bonafede M., Piccardo G.B. and Vai G.B. (eds), The Lithosphere in Italy. Advances in Earth Science Research. Acc. Naz. Lincei, Roma, pp. 64-76.

Kastens K., Mascle J., Auroux C. and ODP Leg 107 Scientific Party; 1988: *ODP Leg 107 in the Tyrrhenian Sea: insights into passive margin and back-arc basin evolution.* Geol. Soc. Amer. Bull., **100** 1140-1156.

Kooi H. and Cloetingh S.; 1989: *Some consequences of late-stage compression for extensional models of basisn evolution.* Geol. Runds., **78**, 183-195.

Lavecchia G.; 1988: *The Tyrrhenian-Apennines system: structural setting and seismo-tectogenesis.* Tectonophysics, **147**, 263-296.

Malinverno A., Cafiero M., Ryan W.B.F. and Cita M.B.; 1981: *Distribution of Messinian sediments and erosionals urfaces beneath the Tyrrhenian Sea: geodynamic implications.* Oceanol. Acta, **4**, 489-95.

Mariani M. e Prato R.; 1988: *I bacini neogenici costieri del margine tirrenico: approccio sismico-stratigrafico.* Mem. Soc. Geol. It., **41**, 519-531.

Mauffret A., Rehault J.P., Gennesseaux M., Bellaiche G., Labarbarie M. and Lefebvre D.; 1981: *Western Mediterranean basin evolution: from a distensive to a compressive regime.* In: Wezel F.C. (ed), Sedimentary basins of Mediterranean margins, C.N.R. Italian Project of Oceanography, Tecnoprint, Bologna, pp. 67-81.

McKenzie D.P.; 1978: *Some remarks on the development of sedimentary basins.* Earth Planet. Sci. Lett., **40**, 25-32.

Mostardini F. e Merlini S.; 1986: *Appennino centro-meridionale. Sezioni geologiche e proposta di modello strutturale.* Mem. Soc. Geol. Ital., **35**, 177-202.

Oldow J.S., D'Argenio B., Ferranti L., Pappone G., Masella E. and Sacchi M.; 1993: *Large-scale longitudinal extension in the Southern Apennines contractional belt, Italy.* Geology, **21**, 1123-1126.

Patacca E., Sartori R. and Scandone P.; 1990: *Tyrrhenian Basin and Apenninic ares: kinematic relations since Late Tortonian times.* Mem. Soc. Geol. It., **45**, 425-451.

Patacca E. and Scandone P.; 1989: *Post-Tortonian mountain building in the Appennines: the role of the passive sinking of a relict lithospheric slab.* In: Boriani A., Bonafede M., Piccardo G.B. and Vai G.B. (eds), The lithosphere in Italy. Advances in Earth Sciences Research. Ren. Acc. Lincei, **80**, pp. 157-176.

Patacca E., Scandone P., Bellatalla M., Perilli N. e Santini U.; 1988: *L'Appennino meridionale: modello strutturale e palinspastica dei domini esterni.* In: 74° Congr. Soc. Geol. Ital., Sorrento, 13-17 Settembre 1988, Relazioni, pp. 67-69.

Russo F.; 1990: *I sedimenti quaternari della Piana del Sele. Studio geologico e geomorfologico.* Tesi di Dottorato, Università Federico II, Napoli.

Russo F. e Belluomini G.; 1992: *Affioramenti di depositi marini tirreniani sulla Piana in destra del Fiume Sele (Campania).* Boll. Soc. Geol. It., **111**, 25-31.

Selli R.; 1981: *Thoughts on the geology of the Mediterranean region.* In: Wezel F.C. (ed), Sedimentary basins of Mediterranean margins, C.N.R. Italian Project of Oceanography, Tecnoprint, Bologna, pp. 489-501.

Selli R. and Fabbri A.; 1971: *Tyrrhenian: a Pliocene deep sea.* Accad. Naz. Lincei, Rend. Cl. Sci. Fis. Mat. Nat., ser. 8, **50**, 580-592.

Trincardi F. and Zitellini N.; 1987: *The rifting of the Tyrrhenian Basin.* Geo-Mar. Lett., **7**, 1-6.

Van Dijk J. and Okkes M.; 1991: *Neogene tectonostratigraphy and kinematics of Calabrian basins; implications for the geodynamics of the Central Mediterranean.* Tecnophysics, **196**, 23-60.

Zitellini N., Marani M. and Borsetti A.M.; 1984: *Post-orogenic tectonic evolution of Palmarola and Ventotene Basins (Pontine Archipelago).* Mem. Soc. Geol. It., **27**, 121-131.

Zoback M.L. and World Stress Map Team; 1989: *Global pattern of tectonic stress.* Nature, **341**, 291-298.