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PLIOCENE-QUATERNARY EXTENSIONAL TECTONICS AND MORPHOGENESIS AT THE EASTERN MARGIN OF THE SOUTHERN TYRRHENIAN BASIN (MT. BULGHERIA, CAMPANIA, ITALY)

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RIASSUNTO - *Tettonica estensionale plio-quaternaria e morfogenesi costiera al margine orientale del bacino tirrenico meridionale (M. Bulgheria, Campania, Italia)* - Il Quaternario *Italian Journal of Quaternary Sciences*, **10**(2), 1997, 571-578 - Il M.te Bulgheria costituisce un'area particolarmente favorevole alla ricostruzione degli eventi tettonici e morfogenetici legati all'evoluzione plio-quaternaria del margine tirrenico dell'Appennino campano in quanto, lungo il fianco tirrenico della Campania, è l'unica in cui siano conservate forme erosionali e successioni marine e continentali di età plio-pleistocenica. Tale area è stata oggetto di un'analisi geomorfologica e morfostrutturale e di uno studio stratigrafico di dettaglio sulle successioni plio-pleistoceniche che hanno consentito di pervenire alla ricostruzione, cronologicamente vincolata, degli eventi di modellamento e di disgiunzione verticale occorsi. Sulle successioni plio-pleistoceniche è stato condotto un rilevamento di dati strutturali alla mesoscala che ha permesso, attraverso l'utilizzo del metodo di inversione, la ricostruzione dei *paleostress* responsabili dei diversi eventi deformativi occorsi nell'area nel Plio-Quaternario. In particolare, si è evidenziato che un evento di fagliazione occorso nel Pliocene superiore in risposta ad un campo di *stress* estensionale con σ_3 orientato circa E-W ha guidato l'individuazione, all'interno del massiccio carbonatico, di una depressione endoreica che ha accolto la deposizione di una successione lacustre (successione di Camerota). Mesostrutture riconducibili a tale campo di stress interessano alluvioni di conoide di probabile età medio-pliocenica. All'inizio del Santerniano, un ribassamento generalizzato ha portato al margine del bacino estensionale tirrenico il M.te Bulgheria dove si registra un'ingressione testimoniata dall'appoggio di una successione marina su quella lacustre di Camerota. Successivi movimenti verticali a carattere generalizzato e differenziale interessano l'area la quale, nell'Emiliano, registra un'ulteriore ingressione. I terrazzi e le successioni emiliani sono, quindi, disarticolati da faglie normali ed oblique: l'analisi strutturale indica che tali faglie, come quelle che interessano la successione di Camerota, sono state generate da un campo di *stress* estensionale orientato NW-SE, parallelo a quello che, dal Pliocene medio-superiore ha guidato l'apertura del bacino tirrenico meridionale. Questo evento deformativo può essere, pertanto, ritenuto l'espressione dell'estensione tirrenica nell'area posta al margine della depressione peritirrenica del Golfo di Policastro. Esso si è manifestato nel corso del Pleistocene inferiore in quanto le dislocazioni sono suturate da linee di riva del Pleistocene medio che, disposte a gradinata tra 150 e 10 m s.l.m., hanno una distribuzione continua lungo la costa. Tali paleolinee di riva testimoniano altresì che, nel Pleistocene medio, l'area è stata interessata da un sollevamento generalizzato cessato nel Tirreniano, il quale è testimoniato, nell'area, da depositi e forme di erosione poste tra 7 e 2 m s.l.m..

Key-words: Geomorphology, stratigraphy, structural analysis, extensional tectonics, Pliocene, Quaternary, Tyrrhenian opening, Italy
Parole chiave: Geomorfologia, stratigrafia, analisi strutturale, tettonica estensionale, Pliocene, Quaternario, apertura del Tirreno, Italia

1. INTRODUCTION

Mt. Bulgheria (1225 m a.s.l.) is located on the Tyrrhenian margin of the southern Apennines chain in Campania (south Italy) and forms the southwestern edge of the Cilento promontory, which separates the Gulf of Salerno-Piana del Sele from the Gulf of Policastro. These perityrrhenian depressions underwent severe subsidence during Quaternary times. Along the Tyrrhenian side of Campania, Mt. Bulgheria is the only area where several marine formations of Quaternary age crop out. Moreover, numerous marine terraces and continental formations as well as erosional landforms of Plio-Quaternary age are preserved.

Mt. Bulgheria, which is underlain by resistant carbonate rocks, is a topographic high raising to the north and northwest above lower areas where siliciclastic rocks of the Liguride Unit (Bonardi *et al.*, 1988) and of the Cilento Group (Amore *et al.*, 1988) crop out (Fig. 1). Limestones and cherty limestones cropping out at Mt. Bulgheria are Upper Triassic to Lower Miocene in age. In the lower part of the succession littoral facies are present, which pass upwards to slope- and then to basin-facies. The carbonate rocks are unconformably overlain by Lower Miocene flysch deposits (Scandone *et al.*, 1963). According to Tozzi *et al.* (1996), the present structural setting is the result of three compressive events: the first, occurred at the beginning of the Miocene, produced the thrusting of the allochtonous Liguride Unit over the limestones. The following events, occurred during the Mio-cene, were responsible for the formation of an asymmetrical anticline and for the out-of-sequence thrusting of the carbonate succession over the Liguride Unit. Two extensional events with σ_3 orientations NE-SW and NW-SE were also recognized by Tozzi *et al.* (1996).

This paper reports the results of geomorphological and morphostructural analyses and of a stratigraphical study of Pliocene-Quaternary deposits in the Mt. Bulgheria area. For major details, see Ascione (1997). The results obtained were integrated with the analysis of fault-slip data from Pliocene-Quaternary deposits.

2. PLIOCENE-QUATERNARY GEOMORPHOLOGICAL HISTORY

Geomorphological and morphostructural analyses and the stratigraphical study of the Mt. Bulgheria area allowed the reconstruction of the erosional, depositional and tectonic events responsible for the present geo-

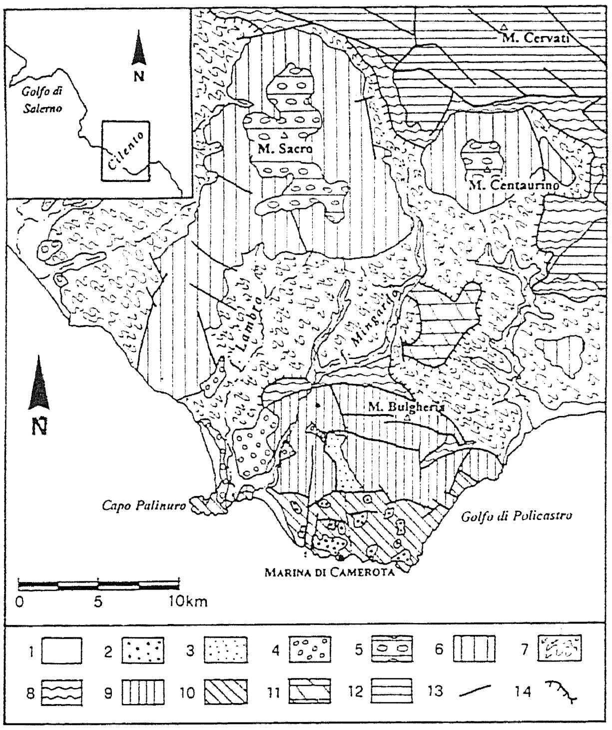


Fig. 1 - Geological sketch map of the Mt. Bulgheria area. 1: Fluvial and beach deposits (Upper Pleistocene-Holocene). 2: Terraced marine successions (Lower and Middle Pleistocene). 3: Lacustrine deposits (Camerota formation) (Upper Pliocene). 4: Alluvial deposits (Middle(?)-Upper Pliocene). 5: Monte Sacro formation (Middle-Upper Miocene). 6: Cilento Group (Middle-Upper Miocene). 7: Liguride Unit (Jurassic-Oligocene). 8: Flysch deposits transgressive onto Mt. Bulgheria and Alburno-Cervati carbonate successions (Miocene). 9: Monte Bulgheria carbonates (Triassic-Lower Jurassic). 10: Monte Bulgheria Unit (Lower Jurassic-Oligocene). 11: Meso-cenozoic limestones of the Rocca Gloriosa succession (Mesozoic-Tertiary). 12: Meso-Cenozoic limestones of the Alburno-Cervati succession. 13: Major faults. 14: Overthrusts.

Schema geologico dell'area del M.te Bulgheria. 1: Depositi marini e fluviali (Pleistocene sup.-Olocene). 2: Depositi marini terrazzati (Pleistocene inf. e medio). 3: Depositi lacustri (Pliocene sup.). 4: Depositi alluvionali (Pliocene medio(?)-sup.). 5: Formazione di Monte Sacro (Miocene medio-sup.). 6: Gruppo del Cilento (Miocene medio-sup.). 7: Unità Liguridi (Giurassico-Oligocene). 8: Depositi flyschoidi trasgressivi sulle successioni carbonatiche del M.te Bulgheria e Alburno-Cervati. 9: Calcari del M.te Bulgheria (Trias-Lias). 10: Calcari del M.te Bulgheria (Lias-Oligocene). 11: Calcari meso-cenozoici della successione di Rocca Gloriosa. 12: Calcari mesozoici (successione Alburno-Cervati). 12: Principali faglie. 13: Sovrascorrimenti.

morphological setting. Furthermore, it was possible to define the Pliocene-Quaternary landscape evolution.

The main geomorphic feature of Mt. Bulgheria is its asymmetric shape, which is given by a steep northern scarp and a smoother southern slope, the profile of which is interrupted by remnants of erosional karst and fluvial surfaces, marine terraces and wave-cut platforms which are found between 800 and 7 m a.s.l. (Plate 1). At the top of the massif, relic benches hanging at elevations from 1000 to 900 m are present. The highest and oldest among these surfaces (which are located between 1000 and 500 m) are remnants of karst and fluvial erosional landforms unconformably cutting the limestones. These relic surfaces testify that the degradation of topographic surface was discontinuous as they record the occurrence of periods in which the local base levels were stable allowing valley widening to prevail onto valley deepening and karst planation processes to take place. Moreover, the selective degradation led to exhumation of the resistant carbonate succession, which was formerly overlain by highly erodible terrigenous formations, which, at present, surround Mt. Bulgheria. Within the massif, the terrigeneous formations crop out only in a structural depression near S.Giovanni a Piro (cfr. Fig. 1).

As to the remnants of karst and fluvial erosional surfaces, those from 700 to 500 m of elevation cut across E-W striking normal faults, which downthrow the carbonate succession southwards (cf. Plate 1). This demonstrates that their formation occurred after a normal block-faulting event had affected Mt. Bulgheria.

A subsequent normal faulting event caused the formation, in the central part of the massif, of a structural depression (hereafter named "Camerota basin"), where lacustrine clays and marls ("Camerota formation") were deposited. The normal faults responsible for this event (which are represented by the fault scarps bordering the Camerota basin) strike NNE-SSW and NW-SE. At the southern and northern ends of the basin, E-W trending fault scarps indicate that E-W trending old faults partly reactivated during the formation of the basin. This is confirmed by the fact that, to the E and W of the basin, the offsets associated with the E-W trending faults bordering the basin disappear and undisturbed karst and fluvial surfaces at elevations from 700 to 500 m a.s.l. cut across the faults themselves (cf. Plate 1).

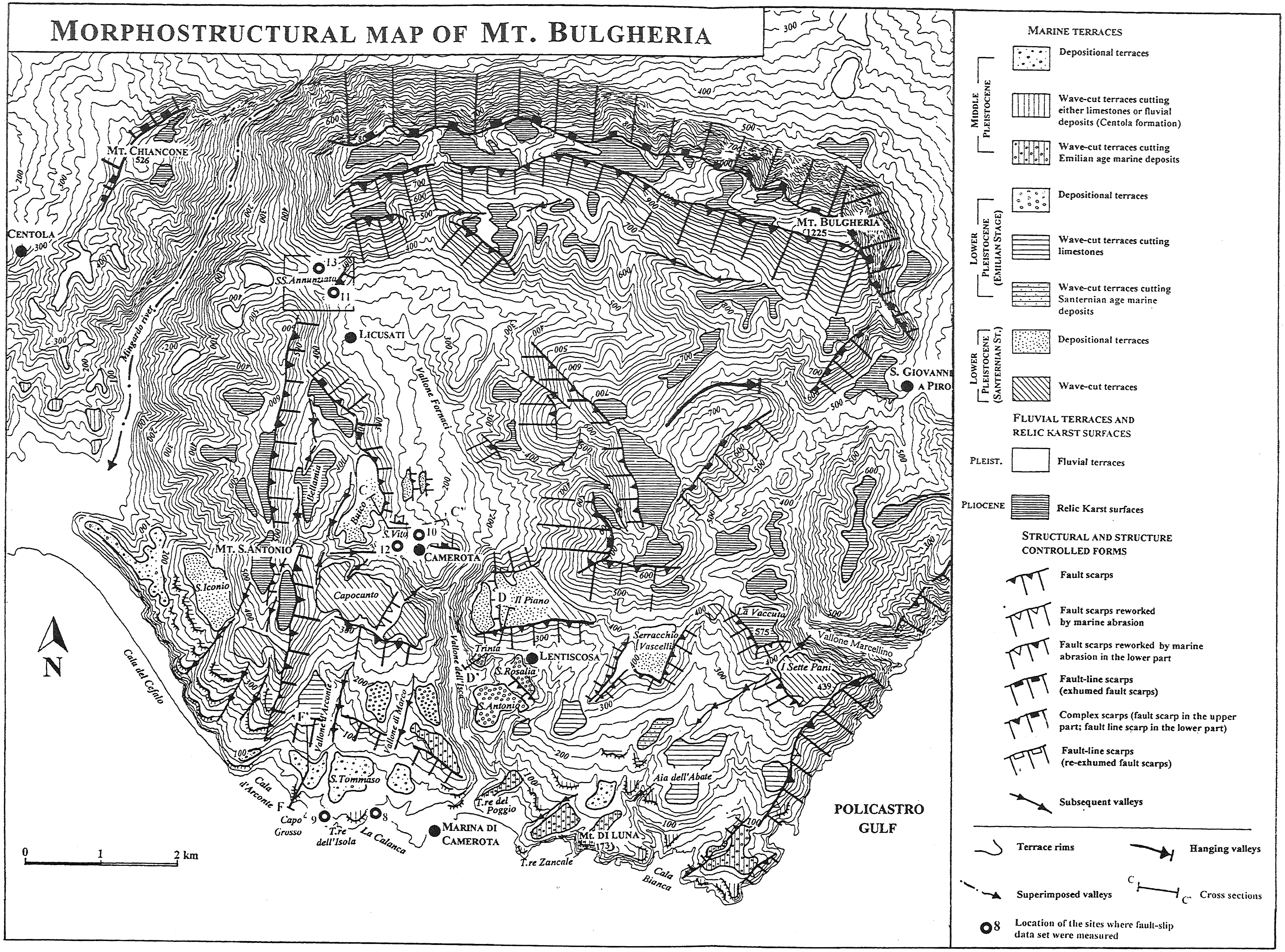
Pollen analyses of clays and marls from the "Camerota formation" give an age younger than 2.6 Ma. Marine clays, sands and pebbles ("S.Vito formation") unconformably rest on top of the lacustrine "Camerota formation" (Fig. 2). The occurrence of small *small Gephyrocapsa* among nannofossils and of *Bulimina elegans marginata* among foraminifers in the marine sands and clays indicates an initial Lower Pleistocene age (Santernian stage) for the "S.Vito formation". An Upper Pliocene age can therefore be estimated for the "Camerota formation".

At the northwestern edge of the basin, the "Camerota formation" stratigraphically overlies a bordering fault scarp which cuts alluvial fan deposits ("Annunziata fan") dipping 10° towards WSW (Fig. 3). The "Annunziata fan", which is older than the lacustrine "Camerota formation" , is thus probably Middle Pliocene in age. Since the stratigraphic succession making up the Annunziata fanglomerates is composed of limestone and cherty gravels of Mt. Bulgheria, it can be assumed that most of the carbonate succession had already been exhumed at the time of the deposition.

The Santernian ingression led also to the formation of wave-cut platforms ("Il Piano", "Capocanto" and "Serracchio Vascelli" terraces; cf. Plate 1); marine conglomerates are rare on these platforms. Nowadays, the platforms are at the elevation of 400 m a.s.l. south of the Camerota basin and on the hills bordering it southwards.

After the Santernian ingression an episode of normal faulting involved the southern portion of Mt. Bulgheria. NE-SW, WNW-ESE and E-W trending fault scarps raised

PLATE1 / TAVOLA 1. - Morphostructural map of Mt. Bulgheria. The square indicates the location of Fig.3.
Carta morfostrutturale del Monte Bulgheria. Il riquadro indica l'area cartografata in Fig.3.



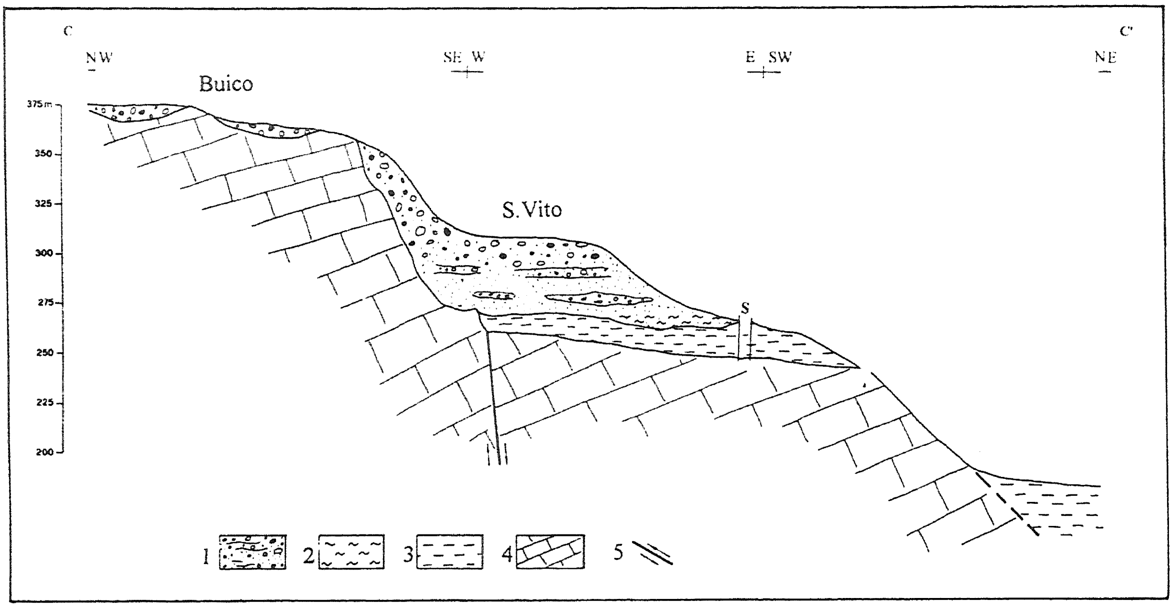


Fig. 2 - 1: Marine silty sands interbedded with pebbles passing upwards to beach pebbles (S.Vito formation) (Lower Pleistocene: Santernian stage). 2. Marine clays (S.Vito formation) (Lower Pleistocene: Santernian stage). 3: Lacustrine silts and marls (Camerota formation) (Upper Pliocene). 4: Limestones (Jurassic). 5: Faults. (Vertical scale is triplicated. See Plate 1 for location).

1: Sabbie limose marine passanti verso l'alto a puddinghe di spiaggia (Successione di S.Vito) (Pleistocene inf.: Santerniano). 2: Argille marine (Successione di S.Vito) (Pleistocene inf.: Santerniano). 3: Limi e marne lacustri (Successione di Camerota) (Pliocene sup.). 4: Calcari (Giurassico). 5: Faglie. (La scala delle altezze è triplicata; per l'ubicazione cfr. Plate 1).

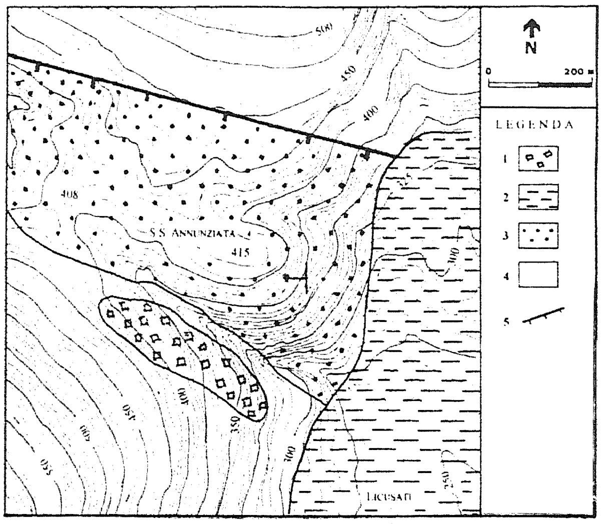


Fig. 3 - (see Plate 1 for location). 1: Slope breccias (Pleistocene). 2: Lacustrine silts and marls (Camerota formation) (Upper Pliocene). 3: Annunziata fanglomerates (Middle[?] Pliocene). 4: Limestones (Triassic-Jurassic). 5: Faults.

(ubicazione in Tav. 1). 1: Brecce di versante (Pleistocene). 2: Limi e marne lacustri (successione di Camerota) (Pliocene sup.). 3: Conglomerati di conoide (conoide dell'Annunziata) (Pliocene medio[?]). 4: Calcari (Trias-Lias). 5: Faglie.

"Il Piano", "Capocanto" and "Serracchio Vascelli" terraces and the whole area to the north of them. Cliff recession in subaerial environment affected the fault scarps: this is testified by slope breccias with a pyroclastic matrix at the toe of the "Il Piano" terrace southern fault scarp. The occurrence of a new tectonic subsidence after the uplift and block-faulting is testified by a wave-cut platform unconformably cutting the slope breccias south of Il Piano (Fig. 4). Laying over this platform, coarse-textured marine conglomerates are found, which represent the base of a transgressive fining-upward succession made up of fine conglomerates, cross-bedded sandstones, silts and shales. At the top of this succession (Lentiscosa formation) regressive conglomerates are present (cfr. Fig. 4). This transgression, which also led to the deposition of Cala Bianca and Torre dell'Isola formations and to the formation of wave-cut platforms, was dated to the Emilian on the basis of the occurrence of *Hyalinea baltica* (Sgrosso & Ciampo, 1966; Ciampo, 1976; Lippmann Provansal, 1987; Borrelli *et al.*, 1988) in the fine-textured sediments.

A further block-faulting episode displaced the Emilian age terraces and wave-cut platforms with offsets reaching hundreds of meters. As a consequence, depositional marine terraces associated with the "Lentiscosa formation" were relatively uplifted (at present, they are at the elevation of 280 m) whereas "Cala Bianca" and "Torre dell'Isola" formations were relatively downthrown. At present, their bases are located below sea level. Faults and fault scarps displacing the Emilian terraces strike mostly NE-SW, and secondarily NW-SE and E-W.

A major change in the tectonic behaviour of Mt. Bulgheria area occurred in Middle Pleistocene times: block-faulting ceased or slowed down whereas *in toto* vertical movements affected the area. Marine terraces and wave-cut platforms of Middle Pleistocene age in fact develop continuously and undisturbed along the coastal belt of Mt. Bulgheria (cf. Plate 1). The occurrence of Middle Pleistocene wave-cut and wave-built terraces, which cut and rest on the Emilian age marine deposits respectively, as well as beach conglomerates and sand-

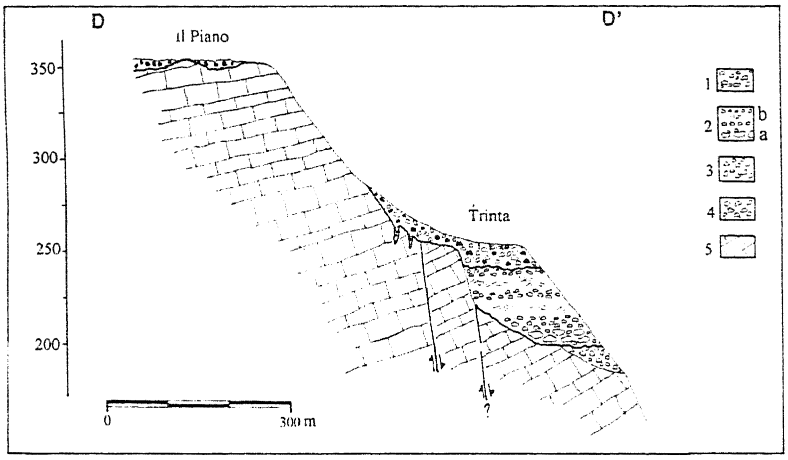


Fig. 4 - (see Plate 1 for location). 1: Regressive marine pebbles (Lentiscosa formation) (Lower Pleistocene: Emilian stage). 2a: Coarse marine conglomerates transgressive onto 3; 2b: pebbles, cross-bedded arenites and calcarenites (Lentiscosa formation) (Lower Pleistocene: Emilian stage). 3: Slope breccias with a pyroclastic matrix (Lower Pleistocene: Santernian stage). 4: Marine pebbles and sands (S.Vito formation) (Lower Pleistocene: Santernian stage). 5: Limestones (Jurassic).

(ubicazione in Tav. 1). 1: Puddinghe regressive (successione di Lentiscosa) (Pleistocene inf.: Emiliano). 2a: Puddinghe marine grossolane trasgressive su 3; 2b: puddinghe e areniti e calcareniti a stratificazione incrociata (successione di Lentiscosa) (Pleistocene inf.: Emiliano). 3: Brecce di versante a matrice piroclastica (Pleistocene inf.: Santerniano). 4: Puddinghe e sabbie marine (successione di S.Vito) (Pleistocene inf.: Santerniano). 5: Calcari (Lias).

cont.

stones patched along valley sides and fault scarps raising the Emilian terraces (Fig. 5), testify that subsidence took place at the end of Early Pleistocene and/or the beginning of Middle Pleistocene leading to the submergence of an area previously emerged. A final uplift then affected the whole area: this is testified by the flight of Middle Pleistocene terraces that are found from 150 to 10 m a.s.l. (cf. Plate 1). Tyrrhenian age notches and terraces with *Strombus* at 7 and 2 m a.s.l. testify that vertical movements ceased since the beginning of Late Pleistocene.

3. ANALYSIS OF FAULT-SLIP DATASETS

The fault-slip orientation in Pliocene-Quaternary formations was measured in various sites (cf. Plate 1) on

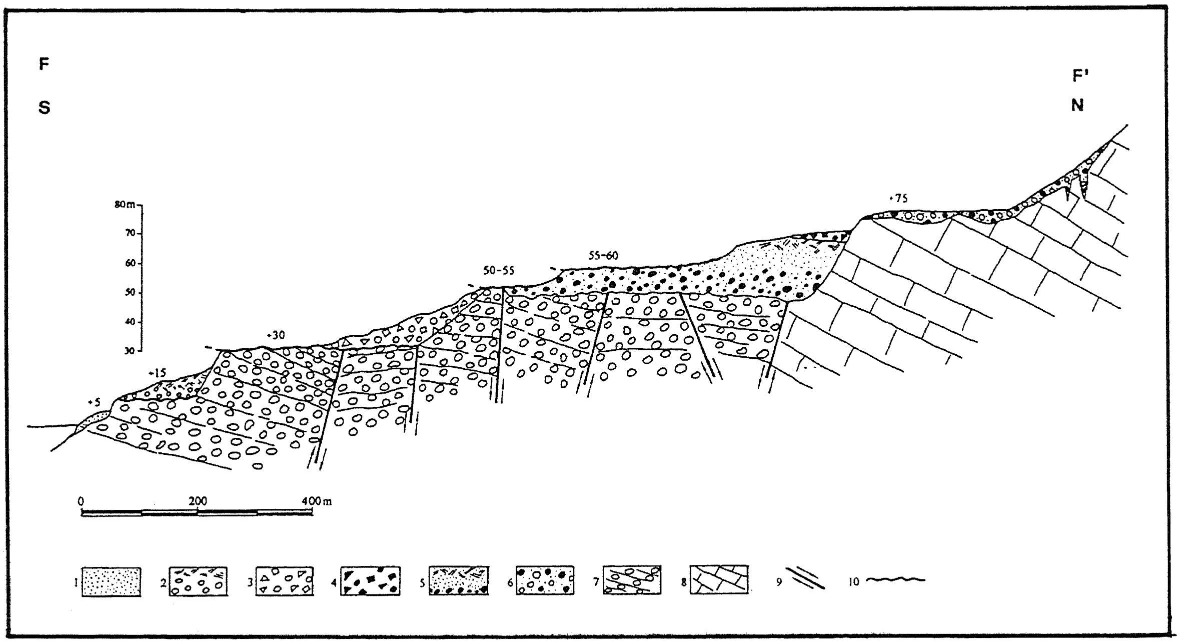


Fig. 5 - Schematic cross-section (see Plate 1 for location). 1: Sands and beach pebbles containing shell fragments (Upper Pleistocene: Tyrrhenian stage). 2a: pebbles, calcarenites and marine sands; 2b: eolian sands (late Middle Pleistocene). 3: Colluvial sands and gravels resting on top of +30 m marine terrace. 4: Colluvial sands and gravels containing Early Palaeolithic (Acheulian) artifacts, resting on top of +50 m marine terrace (late Middle Pleistocene). 5: Marine sandy pebbles and sands passing upwards to eolian sands (termoluminescence age >140,000 yrs.) (Middle Pleistocene). 6: Marine pebbles and sands patched onto fault scarps (Middle Pleistocene). 7: Marine pebbles and calcarenites interbedded with fan delta conglomerates (Torre dell'Isola formation, Lower Pleistocene: Emilian stage). 8: Lime-stones (Lower Jurassic). 9: Faults. 10: Wave-cut platforms. +5, +15 etc.: elevation of marine terraces and notches.

Sezione schematica (ubicazione in Plate 1). 1: Puddinghe e areniti a macrofossili (Pleistocene sup.: Tirreniano). 2: Puddinghe e sabbie marine; sabbie eoliche (Pleistocene medio alto). 3: Colluvioni poggianti sul terrazzo di +30m (Pleistocene medio alto). 4: Colluvioni contenenti manufatti del Paleolitico inferiore (Acheulano) poggianti sul terrazzo di +50 m (Pleistocene medio alto). 5: Puddinghe e sabbie marine passanti a sabbie eoliche (età ottenuta con la termoluninescenza >140.000 anni) (Pleistocene medio). 6: Puddinghe ed areniti cementate a placche su versanti di faglia e fianchi vallivi (Pleistocene medio). 7: Puddinghe e calcareniti con livelli di conglomerati di fan delta (successione di Torre dell'Isola, Pleistocene inf.: Emiliano). 8: Calcari (Lias inf.). 9: Faglie. 10: Piattaforme di abrasione. +5, +15 etc.: quote dei terrazzi e dei solchi di battigia.

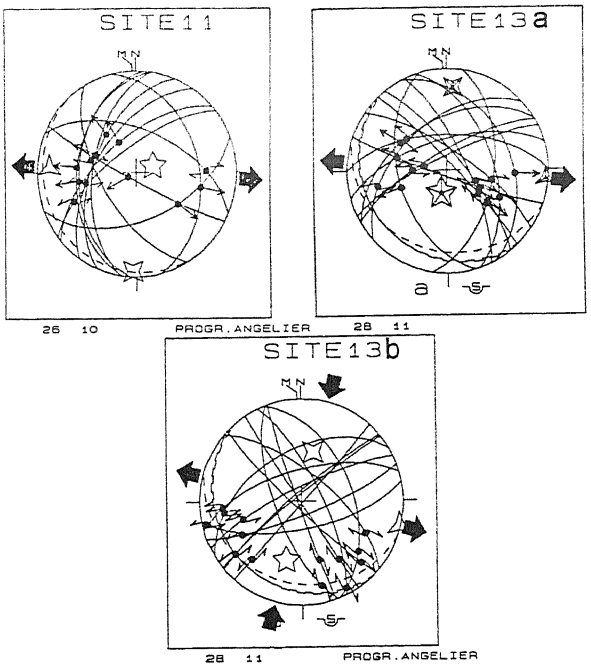


Fig. 6 - Schmidt diagrams (lower hemisphere) of fault-slip data-sets measured in alluvial fan deposits (Annunziata fan) (Middle(?) Pliocene). See Plate 1 for location of Sites 11 and 13.

Diagrammi di Schmidt (emisfero inferiore) delle mesostrutture con indicatori cinematici misurati nei conglomerati della conoide dell'Annunziata (Pliocene medio ?). Vedi Tavola 1 per l'ubicazione dei Siti 11 e 13.

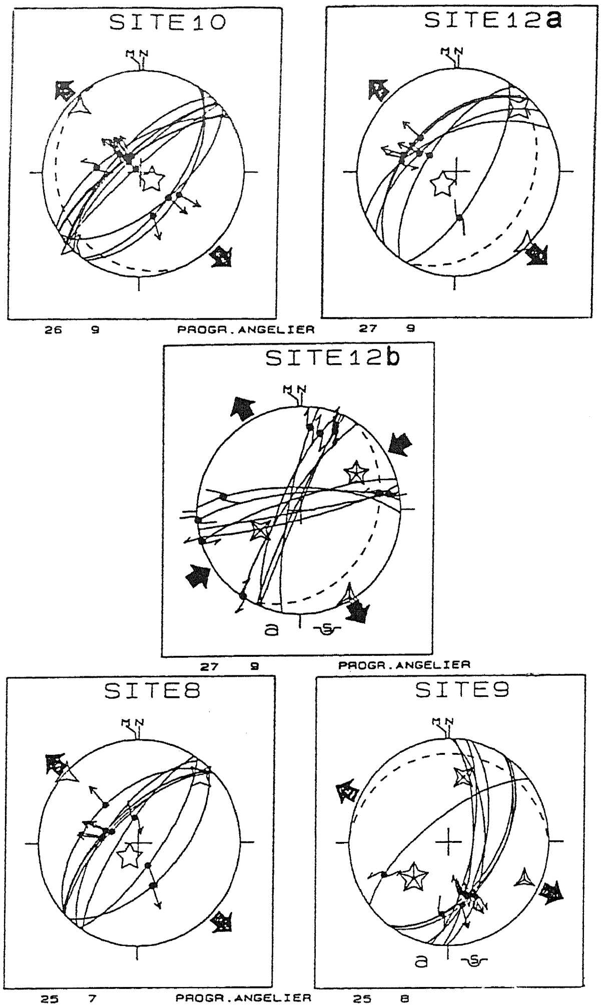


Fig. 7 - Schimdt diagrams (lower hemisphere) of fault-slip data-sets measured in shales and marls of the lacustrine Camerota formation (Upper Pliocene) (Sites 10 and 12) and in conglomerates and calcarenites of the marine Torre dell'Isola formation (Lower Pleistocene: Emilian age) (Sites 8 and 9). See Plate 1 for location of the Sites.

Diagrammi di Schmidt (emisfero inferiore) delle mesostrutture con indicatori cinematici misurati nei limi e marne della Successione lacustre di Camerota (Pliocene sup.) (Siti 10 e 12) e nei depositi marini della successione di Torre dell'Isola (Pleistocene inf. : Emiliano). Vedi Tavola 1 per l'ubicazione dei siti.

striated fault planes and, sometimes, also on striated pebbles with clear sense of movement. The sense of slip was indicated by steps of calcite, tectonic tool marks, stylolitic peaks, tensile fractures and Riedel shears features. The stress inversion technique (Angelier, 1989) was used to relate the observed structures to the causative paleostresses.

Measuraments of fault-slip sets in the Middle(?) Pliocene Annunziata fanglomerates were obtained from striated pebbles. Measurements were collected in two sites located at the nothwestern edge of the Camerota basin (sites 11 and 13, with 12 and 30 slip surfaces respectively), where the Annunziata fan is tectonically juxtaposed to the limestones of Mt. Bulgheria through an E-W trending fault (cfr. Fig. 3). Analysis of data allows for the identification of an E-W trending extension direction in both sites. A strike-slip stress tensor was also determined but the orientation of σ_3 is common in the two stress regimes (σ_1 vertical, see plots 11 and 13a in Fig. 6; σ_2 vertical, see plot 13b in Fig. 6). This feature usually indicates that the extensional and strike-slip regimes are correlated with one another through the permutation of stress axes σ_1 and σ_2 that can occur during a single deformational event (Hippolyte *et al.*, 1992). Such as for other sites in the Southern Apennines (Hippolyte *et al.*, 1995) we consider that these two associated stress regimes are about simultaneous. It means that during the dominant E-W extension a N-S trending confining pressure existed.

In two measurement sites (sites 10 and 12, with 12 and 16 measuraments respectively) data were collected from striated fault planes cutting shales and marls of the Upper Pliocene lacustrine Camerota formation. The two sites were located in the southern part of the Camerota basin, where the lacustrine succession is well exposed (see Plate 1 for location). Analyses of data from sites 10 and 12 indicate a NW-SE trending direction of extension (Fig. 7). As for the analysis of the Annunziata fan fault slip data set, the σ_3 orientation is common to both an extensional (plot 10 and 12a; Fig. 7) and a strike-slip regime (plot 12b; Fig. 7).

In two other sites we measured fault planes in calcareous conglomerates and calcarenites showing fan delta and beach facies of the Emilian Torre dell'Isola formation. The two sites are located close to the southern coastline of Mt. Bulgheria, where the Torre dell'Isola formation is tectonically downthrown and crops out in numerous little grabens alternating with horst structures of Jurassic limestones (Fig. 8). The faults bordering the grabens trend NE-SW. Of the two sites, one (site 8, with

Fig. 8 - Faulting chronology. 1: Faults active during Pleistocene. 2: Faults reactivated during Pleistocene. 3: Faults active during Late Pliocene. 4: Faults reactivated during Late Pliocene.

Cronologia della fagliazione. 1: Faglie attive durante il Pleistocene. 2:Faglie riattivate durante il Pleistocene. 3: Faglie attive durante il Pliocene superiore. 4: Faglie riattivate nel Pliocene superiore.

9 measurements) was located in La Calanca bay, and the other (site 9, with 8 measuraments) in the Torre dell'Isola promontory (see Plate 1 for location). Despite the variety of fault orientations, slip directions are homogeneous and the inversion is a good quality, revealing a NW-SE trending extensional stress field. This direction of extension responsible for deformations in the Torre dell'Isola Pleistocene rocks is coincident with the direction obtained from analyses of data collected in the lacustrine Camerota formation (sites 10 and 12). Therefore this Pleistocene fracturing event affected not only the present coastal belt, but also more inland and elevated areas.

4. DISCUSSION

The integrated study carried out in Mt. Bulgheria allowed us to recostruct in detail the geomorphological and tectonic Plio-Quaternary evolution of the area.

Among the extensional tectonic events recognized, the one responsible for the deformation of the Middle(?) Pliocene Annunziata fan was driven by an E-W striking stress field. The orientation of this stress field is about normal to the strike of fault scarps which cut both the Mesozoic limestones and the Annunziata fan and border the Camerota basin to the E and W. The Camerota basin can therefore be considered as an isolated N-S elongated graben superimposed on Miocene compressional structures. Along the northern margin of the Camerota basin, the deformation of the Annunziata fanglomerates is connected with the normal block-faulting that opened this basin in Late Pliocene times.

This tectonic event driven by an E-W striking extension postdates a block-faulting event which had caused the southward downthrow of Mt. Bulgheria carbonatic succession by means of E-W striking normal faults. Cross-cut relationships between E-W striking faults and relic karst and fluvial landforms higher than 400 m (hereafter named pre-lacustrine surfaces) (see no. 2) indicate, in fact, that their formation occurred after the faulting event along E-W striking faults and prior to the Late Pliocene tectonic event, which was driven by the E-W trending extensional stress field. The latter caused a partial reactivation of some of the pre-existing E-W striking faults (Fig. 8).

After the Tyrrhenian coastline reached Mt. Bulgheria at the beginning of Pleistocene time as a consequence of a subsidence episode affecting the whole area, several block-faulting episodes as well as a succession of uplift and subsidence episodes occurred. Analyses of fault-slip data from the Upper Pliocene Camerota lacustrine formation and from the Torre dell'Isola marine formation of Emilian age show that block-faulting driven by a NW-SE trending extensional stress field occurred during Pleistocene time. Total offsets produced by block-faulting episodes occurred after the Emilian ingression had affected the southern sector of Mt. Bulgheria, can be estimated in hundreds of meters. These displacements uplifted the depositional Lentiscosa terraces up to the elevation of 280 m whereas Cala Bianca and Torre dell'Isola formations were downthrown, their bases being at present below sea level. This NW-SE extensional block-faulting event created NE-SW trending fault scarps such as those which uplifted the Santernian and the Emilian age marine terraces, and those bordering the promontories shaping the present coastline. The structural sea-cliff raising Mt. Bulgheria above the Policastro Gulf perityrrhenian depression is another example. The block-faulting also caused the reactivation of WNW-ESE and E-W trending faults (cf. Fig. 8).

This NW-SE extensional event can chronologically be well constrained: it occurred after the Emilian stage and before the Middle Pleistocene. The cessation of block-faulting is demonstrated by the Middle Pleistocene marine terraces which develop with continuity along the coastal belt of Mt. Bulgheria from 150 to 10 m of elevation. At the same time, the flight of the marine terraces represents the effect of a final uplift which affected the whole area during Middle Pleistocene, the cessation of which in Late Pleistocene being demonstrated by the occurrence of marine terraces and notches of the Tyrrhenian stage at elevations between 7 and 2 m a.s.l., comparable to the elevation reached by the sea during the oxygen isotope stage 5 highstand in stable areas of the Mediterranean region (Ulzega & Ozer, 1982).

5. CONCLUSION

We have shown that the Tyrrhenian coastline has reached Mt. Bulgheria since the beginning of Pleistocene time. At that time Mt. Bulgheria entered the Tyrrhenian extensional basin domain. The Early Pleistocene NW-SE extensional stress field, which governed extensional tectonics, can be correlated with the contemporaneous NW-SE extension responsible for the opening of the Salerno graben to the NW of our study area (Hippolyte, 1992; Hippolyte *et al.*, 1994; 1995). Moreover, the paleostress orientation as determined in the syntectonic Lower Pleistocene sediments of both areas, is very close to the proposed open-ing direction of the Marsili basin in the southeastern Tyrrhenian sea (Moussat, 1983; Moussat *et al.*, 1986; Sartori, 1990). It can be concluded that the NW-SE extensional tectonics represents the inland prolongation of the Tyrrhenian extension. The extensional tectonics affecting Mt. Bulgheria during Early Pleistocene is consid-ered as the onshore expression, to the north of the Poli-castro Gulf, of the extensional tectonics that led to the opening of the southern Tyrrhenian basin. Our study thus shows that the late Tyrrhenian NW-SE extension was a diffused process that affected a much broader area than the deep grabens of the Tyrrhenian margin (Salerno, Policastro).

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