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DEEP GRAVITATIONAL PROCESSES IN THE MARATEA VALLEY (SOUTHERN ITALY): EVIDENCE FROM HIGH RESOLUTION REFLECTION SEISMIC PROFILING OF THE SURROUNDING OFFSHORE

ABSTRACT: AIELLO G., MARSELLA E. & PELOSI N., *Deep gravitational processes in the Maratea Valley (Southern Italy): evidence from high resolution reflection seismic profiling of the surrounding offshore*. (IT ISSN 0391-9838, 2010).

The Maratea Valley (Basilicata) is characterized by deep gravitational movements involving the Meso-Cenozoic calcareous-dolomitic formations (tectonic units «Alburno-Cervati» and «Bulgheria-Verbicaro») interpreted as sackung-type phenomena. The complex morpho-structural setting of the area has been influenced by the Pleistocene extensional tectonics, probably still active. Tectonic dislocations, characterized by a strike-slip component on a regional scale, have caused the superimposition of the Bulgheria-Verbicaro Unit on the Crete Nere Formation and the tectonic contact of the last formation on the Alburno-Cervati unit, cropping out on the right flank of the valley. This paper reports on evidence of the seaward prolongation of the Maratea Valley, based on the geological interpretation of high resolution seismic reflection profiles, recently acquired in the surrounding offshore area. The morpho-bathymetry of the area shows steep and articulated sea bottoms, resulting from the seaward prolongation of the rocky coastal cliffs, up to a water depth of –30 m, where the continental shelf starts. The sea bottom then becomes more regular, up to the shelf break, located at about 2 km of distance from the shoreline, at water depths ranging from –100 m and –120 m. The shelf break is articulated and incised by deep channels linked to the head of a submarine canyon (the Maratea canyon). The canyon is affected by a regressive erosion that is probably still active and controlling the submarine gravity instabilities identified in the slope sequences recognised in the seismic reflection profiles.

KEY WORDS: Maratea Valley, Deep gravitational deformations, Geological structures, Morphobathymetry, Basilicata, Eastern Tyrrhenian margin.

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RIASSUNTO: AIELLO G., MARSELLA E. & PELOSI N., *Processi di deformazioni gravitative profonde nella Valle di Maratea (Italia meridionale): evidenze dai profili sismici a riflessione ad alta risoluzione*. (IT ISSN 0391-9838, 2010).

I processi gravitativi profondi sono stati l'oggetto di studi geologici condotti su numerosi affioramenti d'Italia, con particolare riferimento alla loro distribuzione sul territorio ed agli aspetti geomorfologici (Dramis & Sorriso Valvo, 1983; Dramis & *alii*, 1983), in particolare negli esempi regionali delle Alpi centrali (Forcella, 1984a; 1984b; 1987a; 1987b; Forcella & *alii*, 1982), della Sicilia occidentale (Agnesi & *alii*, 1978; 1984; 1987), dell'Appennino centrale (Ambrosetti & *alii*, 1982; Bosi & *alii*, 1983; Canuti, 1982; Calamita & *alii*, 1982) e dell'Appennino meridionale (Carmignani & *alii*, 1981; Ciaranfi & *alii*, 1983; Crescenti & *alii*, 1984; D'Elia & *alii*, 1987; Genevois & *alii*, 1987; Guerricchio & Melidoro, 1979a; 1979b; 1981). Due Seminari sui Processi Gravitativi Profondi sono stati svolti dal Gruppo Informale del Consiglio Nazionale delle Ricerche nel 1984 e nel 1987 (Sorriso Valvo, 1984; Sorriso Valvo & Crescenti, 1987).

La Valle di Maratea (Basilicata) è caratterizzata da movimenti gravitativi profondi che coinvolgono le formazioni calcareo-dolomitiche mesozoiche (unità tettoniche «Alburno-Cervati» e «Bulgheria Verbicaro»), interpretate come fenomeni di tipo *sackung* (Guerricchio & Melidoro, 1979b; Colantoni & *alii*, 1997).

Il complesso assetto morfo-strutturale dell'area è stato influenzato dalla tettonica estensionale pleistocenica, probabilmente ancora attiva. Le dislocazioni tettoniche, caratterizzate da una componente trascorrente a scala regionale, hanno provocato la sovrapposizione dell'unità Bulgheria-Verbicaro sulla Formazione delle Crete Nere ed il contatto tettonico dell'ultima formazione con l'unità Alburno-Cervati, affiorante sul fianco destro della valle. Dislocazioni tettoniche lungo faglie dirette, rotazioni di blocchi ed ampliamento strutturale della Valle di Maratea sono state prodotte come effetto di una velocità differenziale durante la tettonica trascorrente. Il Flysch delle Crete Nere («Unità Liguridi»), che ha assunto un comportamento plastico a causa degli alti contenuti d'acqua, ha dato luogo ad un processo di flusso, relativamente profondo (30-50 m) all'interno della valle. Questo ha costituito un livello di scivolamento basale per le coperture sedimentarie detritiche e per le unità carbonatiche affioranti lungo il fianco sinistro della valle e nei rilievi circostanti, dove si sviluppano i movimenti gravitativi profondi.

La Valle di Maratea mostra fenomeni gravitativi complessi, che sono direttamente collegati con l'attività sismica e tettonica nell'area (Rizzo, 1997). L'apertura della valle stessa può essere vista come il risultato dell'attività di una faglia trascorrente, che ha dato luogo a sforzi transtensivi nella parte centrale della valle ed alla formazione di una struttura di tipo *pull-apart*. Nel margine settentrionale della valle, dove l'attività tettonica ha provocato il sovrascorrimento del blocco carbonatico meridionale su quello nord-orientale, sono visibili strutture transpressive e di tipo *horse* (Rizzo, 1997). Nella valle sono presenti importanti frane causate dall'attività sismotettonica: un flusso lento e continuo evolve nella parte superiore della valle in fenomeni di tipo *spreading*, *sackung* e *sagging*, che si muovono lungo il limite sud-orientale della valle su un substrato di argille plastiche.

L'assetto geologico della Valle di Maratea a terra è connesso con l'evoluzione tardo-pleistocenica ed olocenica della piattaforma continentale e della scarpata circostanti e con significative variazioni glacio-eustatiche del livello marino durante il Quaternario superiore. I profili sismici a riflessione multicanale acquisiti durante la crociera GMS00-05 (Ottobre-Novembre 2000) a bordo della N/O Urania del CNR, usando una sorgente sismica di tipo Watergun ed un sistema di acquisizione Stratavisor (Marsella & *alii*, 2001) hanno fornito nuove evidenze sull'assetto morfo-strutturale dell'offshore di Maratea. Tale offshore mostra sequenze sismiche, di età compresa tra il Pleistocene superiore e l'Olocene, coinvolte da faglie dirette ad andamento NE-SW e caratterizzate da intervalli caotici, ubicati a livelli stratigrafici diversi ed interpretati come *slumpings*. L'attività di faglie dirette ha anche controllato la formazione del *canyon* di Maratea, ubicato in corrispondenza di un ciglio della piattaforma tettonicamente controllato, che borda una stretta piattaforma continentale. La presenza della testata del *canyon* di Maratea è rilevante, dato che il *canyon* incide le masse instabili della Valle di Maratea ed induce scivolamenti sottomarini attraverso fenomeni di erosione regressiva. Rapide variazioni di spessore delle sequenze sismiche sono inoltre state osservate sui profili sismici.

I profili sismici monocanale di alta risoluzione, che sono stati acquisiti sulle stesse linee di navigazione della sismica multicanale hanno rivelato la presenza di un'unità sismica, affiorante a fondo mare, spessa circa 10 metri e caratterizzata da orizzonti sismici regolarmente stratificati. Questa è probabilmente composta da sedimenti marini di granulometria sottile e potrebbe corrispondere con i depositi di *highstand* dell'ultimo ciclo glacioeustatico. L'elevata penetrazione dell'energia acustica suggerisce che questa unità è formata da sedimenti sotto-consolidati o normalmente consolidati. Questo è confermato dalla presenza di scivolamenti granulo-a-granulo di tipo *creeping* al fondo mare e nei primi metri della sequenza. Al di sotto di questa unità, una seconda sequenza sismica, con uno spessore medio di 20 m, mostra una minore penetrazione dell'energia acustica ed è probabilmente caratterizzata da litologie più grossolane. L'attività di processi erosivi recenti è suggerita da una densa rete di canali tributari, che incide la scarpata superiore, raggiungendo profondità d'acqua superiori ai –600 m.

Le evidenze sismo-stratigrafiche basate sull'interpretazione geologica dei profili *Watergun* e *Subbottom Chirp* suggeriscono una forte tettonica sinsedimentaria, che ha controllato l'architettura stratigrafica delle sequenze sismiche, che appaiono inoltre intensamente deformate da faglie dirette. Le fasi tettoniche estensionali hanno contribuito all'innesco di processi di instabilità gravitativa sottomarina, come il *creeping* e lo *slumping*, evidenti nelle sequenze sismiche dell'area.

TERMINI CHIAVE: Valle di Maratea, Deformazioni gravitative profonde, Strutture geologiche, Morfobatimetria, Basilicata, Margine tirrenico orientale.

INTRODUCTION

The aim of this paper is to report on new geophysical data collected through multichannel and single-channel reflection seismics (Watergun and Subbottom Chirp) by the Institute of Marine Coastal Environment of the National Research Council of Naples, Italy on the continental shelf and slope off the Maratea Valley (Basilicata, southern Italy). The relationships between the geologic and structural settings on land and the seismic stratigraphy of late Pleistocene-Holocene sedimentary sequences in the surrounding offshore were investigated.

The geologic and structural framework of the Maratea Valley shows important connections with the late Pleistocene and Holocene geologic evolution on the continental shelf and slope, mainly in terms of late Quaternary sea level glacio-eustatic fluctuations (Shackleton & Opdyke, 1973; Martinson & *alii*, 1987). Near the coastline, the morpho-bathymetry of the area, located offshore the Basilicata region (southern Italy), is characterized by steep and articulated sea bottoms, resulting from the seaward prolongation of rocky coastal cliffs (Colantoni & *alii*, 1997). A preliminary interpretation of the geologic evolution of the landslides involving the valley and the surrounding continental shelf has been proposed by the authors based on bathymetric and seismic surveys carried out on the sea bottoms surrounding the Maratea Valley. It is worth noting that there is a submarine canyon (the Maratea canyon) through which an intense regressive erosion induces retrogressive failures at the foot of unstable masses of the coastal belt, triggering both rotational slumps and translational slides. Along the high and articulated coastal cliffs, the Mesozoic carbonates and the overlying clastic sequences show hints of marine terraces and/or evidence of palaeo-shorelines occurring at several altitudes and correlated with the late Pleistocene to Holocene glacio-eustatic fluctuations (Colantoni & *alii*, 1997). In particular, in the southern portion of the harbour, a marine terrace located at +8 m, partly covered by slope breccias, crops out; to the north-west of the Fiumicello beach (Ogliastro-Cersuta) a terrace incised in calcarenitic deposits with *Cladocora coespitosa*, was observed located between +4 m and +5 m. These stratigraphic levels, already recognised in Mesozoic carbonate deposits located outside the Maratea Valley, are ascribed to the last interglacial (Tyrrhenian or isotopic stage 5e of about 125-115 ky) or to other periods of highstand, preceeding the climatic optimum of about 20 ky B.P. The shoreline which constitutes the terminal part of the Maratea Valley does not reveal the marine terrace located at –8 m, but only some outcrops of calcarenites with *Cladocora coespitosa*, that form isolated blocks above the sea level (Colantoni & *alii*, 1997). Consequently, the deposits cropping out in the Maratea Valley have been dislocated after the development of the marine terraces; consequently, it can be hypothized that the neotectonic movements involving the Maratea Valley are very recent.

Deep gravitational processes have been intensively studied in Italy, particularly in reference to their geomorphological aspects and their distribution on the Italian territory (Dramis & Sorriso Valvo, 1983; Dramis & *alii*, 1983), including the regional examples of the central Alps (Forcella, 1984a; 1984b; 1987a; 1987b; Forcella & *alii*, 1982), western Sicily (Agnesi & *alii*, 1978; 1984; 1987), of the central Apennines (Ambrosetti & *alii*, 1982; Bosi & *alii*, 1983; Canuti, 1982; Calamita & *alii*, 1982) and of the southern Apennines (Carmignani & *alii*, 1981; Ciaranfi & *alii*, 1983; Crescenti & *alii*, 1984; D'Elia & *alii*, 1987; Genevois & *alii*, 1987; Guerricchio & Melidoro, 1979a; 1979b; 1981). Two Seminars on Deep Gravitational Processes were organised by the associated Informal Group of the National Research Council of Italy in 1984 and 1987 (Sorriso Valvo, 1984; Sorriso Valvo & Crescenti, 1987).

The deep gravitational deformations (already known in literature as *sackung*, *gravitational spreading*, *gleistung*) can be interpreted in terms of superficial landslides and gravitational tectonics. These movements have been singled out by several authors in different parts of the world, but only recently this phenomenon has captured the attention of Italian scientists. The occurrence of these landslides on the Italian territory was revealed in a systematic way by the F.P. «Conservation of the soil», Subproject «Slide Phenomena». Among the main characteristics of these movements are: (a) the great volume of the involved masses, (b) the very ancient age of the deformations (palaeo-landslides), (c) the slow evolution during geologic time (of a deep-seated creep type), (d) the persistence of gravity instability conditions through time, (e) the occurrence of break landforms typical of materials warping in a rigid way due to fast accelerations of the deformations and, (f) movement reactivations during seismic and meteoric events (Sorriso Valvo & Crescenti, 1987). The occurrence of these movements affects slope stability, the hydrogeologic setting and the behaviour of these areas after seismic events (D'Elia & *alii*, 1987). In particular, the *sackung* of the Maratea mountains (Basilicata) was singled out for the first time by Guerricchio & Melidoro (1979b). Several deep gravitational deformations were recognised at northern and southern margins of the structure of m.te S. Michele-M.te Zepparra (hydrological basin of the Bussento River).

The deep gravitational deformations are controlled by the lithological, structural, neotectonic and morphologic setting of the area, showing also a high seismic risk. In this geologic framework a fundamental role is covered by the structural factors, i.e. the relationships between rock bodies having a different mechanical behaviour and the occurrence of faults and fractures. The role of the neotectonic uplift as a control factor in the genesis of deep gravitational movements is of problematic interpretation (Rizzo, 1997; 2001). The detachment levels which determine the formation of deep gravitational deformations often coincide with faults or fractures (Varnes, 1978; D'Elia & *alii*, 1987), as it happens in particular, for the Mesozoic-Cenozoic carbonate successions, which are affected by these gravitational processes both in the Maratea Valley and in the hydrographic basin of the Bussento River.

Some of the characteristics of «continuous» type deep gravitational processes are the scarce sensibility to the variations of the exogen factors (e.g. seismic shocks and the pluviometric maxima with historical return), the activity connected with the occurrence of tectonic stresses, the deformations (both continuous and prolonged) over wide time intervals, the plastic deformation of slide bodies, the high depth of slide bodies and the old age of phenomena of geological order (Rizzo, 1997; 2001). Significant deep gravitational movements of «periodic» type factors that must be considered include: the high periodic mobilitation caused by seismic shocks of pluviometric maxima, the slidings on complex, multiple, break planes, the average depth of the slide bodies and historical age.

Important deep gravitational processes were recognized in the Laga Mountains (central Apennines; Dramis & *alii*, 1987), where arenaceous and arenaceous-pelitic turbidites («Flysch della Laga» Auct.), Messinian in age, crop out, unconformably overlying a marly pre-turbiditic complex, formed by the «Marne con Cerrogna» and the «Marne a Pteropodi» Formations, ranging in age between the Helvetian and the Messinian. The corresponding morphologies are characterized by slopes and trenches parallel to the mountain, located at different altitudes, sometimes set up in correspondence to counter-Apennines i.e. NE-SW trending normal faults. In this case the relationship is obvious between deep gravitational process and structural framework, more so than with the increase of energy of the relief after the important uplift phenomena, involving the study area starting from the early Pleistocene (Ambrosetti & *alii*, 1982).

Landslide movements of great dimensions, ascribed to deep gravitational deformations have been recognised in the Pliocene-Pleistocene basin of Lucania (Genevois & *alii*, 1987), where they are controlled both by the occurrence of old mass movements and by the geomorphological and climatic framework. Moreover, of particular importance is the role of the fault escarpments. In one such case, the difference in height produced by tectonics has progressively modified the relief and, consequently, the slope values (Dramis, 1984). Specifically, in correspondence to the great fault escarpments running along the Tyrrhenian coasts of Basilicata and Calabria, now submerged under the sea level, deep gravitational deformations of great dimensions have been produced (Guerricchio & Melidoro, 1979; 1981; Dramis, 1984).

The triggering and the reactivation of deep gravitational deformations have been frequently observed following high intensity earthquakes also on mountains scarcely developed in height, (Dramis & Sorriso Valvo, 1983; Crescenti & *alii*, 1984), as it happened in Campania after the earthquake of November 23 1980.

New high resolution seismic profiles were acquired during the oceanographic cruise GMS00-05 (October-November 2000) onboard of the R/V Urania (CNR), using a Watergun 15 c.i. seismic source, an acquisition system for multichannel seismics Stratavisor (Geometrics Inc.) and a Subbottom Chirp sediment profiler as described in this paper. The profiles provide interesting evidence of the offshore prolongation of the Maratea Valley. A total of more than 1600 kilometres of high resolution seismic profiles were recorded during the oceanographic cruise GMS00_05 (Marsella & *alii*, 2001) in three selected areas offshore Campania (Gulf of Naples, offshore Campania between the Salerno and the Policastro Gulfs and offshore Calabria between Diamante and Capo Cozzo). In particolar, 387 kilometres of seismic profiles were recorded offshore Campania between the Salerno and the Policastro Gulfs. The navigation map of seismic reflection profiles analysed in this paper is reported in fig. 1. The studied sections are located in the Policastro Gulf; two profiles run perpendicular to the Tyrrhenian coastline (seismic profiles S120 e S130 b), the other runs parallel to the coastline (seismic profile S130).

From a methodological and interpretative point of view it is worth noting that, while the multichannel seismics acquired with the Watergun seismic source allows to study the tectono-stratigraphic framework of continental shelf and slope successions, the geological interpretation of Subbottom Chirp profiles (recorded on the same lines of multichannel seismics) allows a detailed study of the seismic stratigraphy in the first subbottom (up to several tens of meters under the sea bottom).

Seismic acquisition equipment provided by the CNR-IAMC of Naples, Italy allowed for the acquisition of multichannel seismic data, from 24 to 48 channels, for high resolution seismic stratigraphy of the continental shelf and slope successions. Multichannel seismic data were acquired by using a Watergun 15 c.i. seismic source; the registration was performed by using a 200 m long seismic streamer (active section = 150 m; passive section = 50 m). Seismic shots were fired at a constant interval distance of 6.25 meters (corresponding to 8 sec). The registration interval was of 6.25 meters; the minimum offset was of 130 m and coverage was 1200%. The sample interval was set at 1 msec. Data was recorded by the hydrophones and the seismic acquisition system Stratavisor Inc. (Geometrics Inc.), thus providing a 24-channel recording with a group interval of 6.25 meters.

Multichannel seismic data was processed through Seismic Unix software and involved: extraction of the first channel from the shot gathers and subsequent application of filtering Automatic Gain Control; spectral analysis of seismic traces by using the Fourier Transform; application of time variant gain in order to reduce seismic noise on the sections. Acoustic data collected by Subbottom Chirp profiler were also processed by Seismic Unix software. Scale changes due to water depth in the SEG-Y format subbottom data were eliminated, with the modified data then plotted graphically. This allowed the cartographic representation of profiles, with a uniform vertical scale. Seismic sections were integrated with a time-variant gain, uniform with increasing depth, which allowed to increase the resolution of the seismic signal on the sections. This improved their quality and facilitated the geological interpretation.

GEOLOGICAL SETTING

The Cilento Promontory represents a morpho-structural high, located between the coastal depressions of the Sele Plain/Salerno Gulf and of the Policastro Gulf, the mountains of which can reach up to 1700 m in height. These mountains are constituted of thick successions of siliciclastic turbiditic sequences («Flysch del Cilento» *Auct.*), dipping landwards towards the main carbonate morphostructures of the southern Apennines («Alburno-Cervati» Unit *Auct.*). Besides the carbonate structures of Palinuro Cape and of the Bulgheria Mt and a few other isolated outcrops, the mountains of the Cilento Promontory are the only ones formed by siliciclastic rocks, which deposited in deep basins during a time interval ranging from the late Mesozoic and the late Miocene. The oldest of these formations belongs to the North Calabrian Units (Bonardi & *alii*, 1985; 1988), which represent the highest stratigraphic-structural unit in this sector of the southern Apennines. In the Cilento area, it is represented by a formation ranging in age between the Malm and the Oligocene and it is composed of dark clays, marls and marly limestones, reaching a thickness of about 1300 meters. The North Calabrian unit is overlain by sinorogenic units, lower Miocene in age, showing a smaller degree of deformation than the overlying tectonic units. Proceeding upwards, the Cilento Flysch includes the Pollica, S. Mauro and Monte Sacro Formations, for an overall thickness of 1500 meters (Bonardi & *alii*, 1988).

The carbonate sequences exposed at Palinuro Cape and in the massif of Bulgheria Mountain exhibit palaeo-sedimentary domains of slope-basin and show different facies with respect to the neritic platform limestones cropping out in correspondence to the Alburno-Cervati mountains (Bonardi & *alii*, 1988).

During the Miocene the tectonic unit of the Bulgheria mountain was overlain by the thrusts of the North Calabrian unit and of the overlying Cilento Flysch. Nonetheless, the terrains of the Bulgheria mountain are actually exposed in outcrop due to a later tectonic uplift of the Bulgheria-Palinuro Cape area (late Miocene-early Pliocene) and to the consequent erosion of the siliciclastic turbiditic units (Antonioli & *alii*, 1994). The uplift of Bulgheria Mt triggered the folding towards the north of the carbonate sequences and their overthrusting on the Calabrian Units through a south-dipping reverse fault, well exposed along the southern rim of the Cilento Promontory (Bonardi & *alii*, 1988).

The terrigenous deposits of the Cilento Flysch, recently revised from a stratigraphic and structural point of view, are composed of several units affected by complex tectonic relationships. In particular, the Torrente La Bruca Formation is constituted of clays and sandstones, limestones and marly limestones, ranging in age from the lower Cretaceous to the middle Eocene and having an overall thickness between 1000 and 1300 meters. The Pollica Formation is composed of stratified sandstones, alternating with mudstones and silty clays (thickness about 800 m) and the S. Mauro Formation, both dated as Burdigalian-Serravallian. These units unconformably overlie the Liguride Units (Frido Unit, Crete Nere Formation and Saraceno Formation) with a contact marked by a basal conglomerate, containing elements of both crystalline rocks and platform carbonates (Bonardi & *alii*, 1985; 1988).

Several morphologic depressions, filled by alluvial deposits, have been identified in the extreme western sector of the Cilento Promontory; their origin is related to NNE-SSW trending (Alento Plain) and NW-SE trending (Castellabate and S. Marco Plains) structural lineaments. These depressions, upper Pleistocene in age (Brancaccio & *alii*, 1995) include trasgressive-regressive sedimentary cycles, related to the glacio-eustatic fluctuations of the isotopic stages 9, 7 and 5 (Shackleton & Opdyke, 1973; Martinson & *alii*, 1987), downthrown by several tens of meters with respect to their original height, between the end of the middle Pleistocene and the beginning of the late Pleistocene.

The Cilento Promontory was affected by a vertical uplift of more than 400 meters during the early Pleistocene-

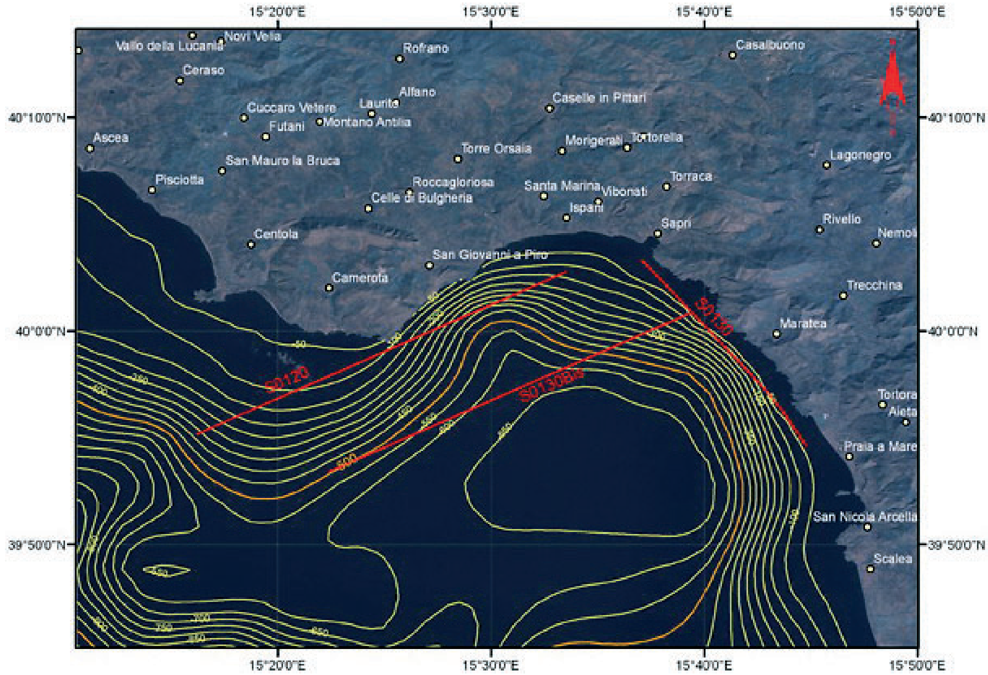


FIG. 1 - Navigation map of multi-channel and single-channel reflection profiles (Watergun and Sub-bottom Chirp) recorded offshore of the Maratea Valley.

Middle Pleistocene. Absolute estimates of the tectonic uplift were obtained from the vertical distribution of the Pleistocene marine terraces. In the northern Cilento the oldest marine terraces (middle Pleistocene) are located at maximum altitudes of 60 m above the sea level (Cinque & *alii*, 1994). On the Bulgheria Mt (southern Cilento) the upper Pliocene-lower Pleistocene marine terraces are uplifted at altitudes of 450 m above the sea level, while the terraces dated to the Emilian are located at maximum altitudes of 350 meters above sea level (Baggioni & *alii*, 1981; Lippmann-Provansal, 1987; Borrelli & *alii*, 1988). Morphological elements of the coastal areas relative to palaeo-highstands of the sea level during the late Pleistocene (isotopic stages 5e and 5c) evidence a tectonic stability of this tract of shoreline from the Tyrrhenian to present-day times (Romano, 1992).

Phenomena of morpho-selection related to the different lithologies of the Cilento Formations often occur in this area. The lithological factor has strongly controlled the siliciclastic production, supplying a great thickness of conglomerates («Conglomerati di Centola»), including different generations of continental deposits, Pleistocene in age.

The Maratea Valley (Basilicata) is characterized by deep gravitational movements, involving the calcareous-dolomitic formations (tectonic units «Alburno-Cervati» and «Bulgheria-Verbicaro»), interpreted as *sackung*-type phenomena. The complex morpho-structural setting of the study area has been influenced by Pleistocene extensional tectonics, that is probably still active. The tectonic dislocations, characterized by a strike-slip component on a regional scale (Schiattarella, 1998), have controlled the tectonic superimposition of the Bulgheria-Verbicaro Unit on the Crete Nere Formation. This formation outcrops in tectonic contact with the Alburno-Cervati unit («Campania-Lucania carbonate platform» *Auct.*; D'Argenio & *alii*, 1973; Ippolito & *alii*, 1975), cropping out on the right side of the Valley.

The Alburno-Cervati unit is mainly composed of calcilutites and calcarenites, Cretaceous in age, and of grey calcilutites and calcarenites with *Alveolinae* and *Spirolinae*, with intercalations of green and red marls of the Trentinara Formation (Selli, 1962). The succession passes upwards to Miocene flysch deposits (Selli, 1962), constituted of glauconitic calcarenites, marls and sandstones (pre-orogenic flysch), by polychrome calcirudites (Piaggine breccias) and sandstones in strata and banks, marls and silty marls (sinorogenic flysch; Sgrosso, 1981).

Normal faulting, block rotations and structural widening of the valley are produced as an effect of differential velocity during strike-slip tectonics. The «Crete Nere» flysch (Liguride Units) takes on a plastic behaviour due to high water contents. It is affected by a flow-type, relatively deep process (30-50 m) within the valley and near the sea. It constitutes a lubricant base for detrital covers and carbonatic units outcropping along its left flank and nearest reliefs, where deep gravitational movements develop.

A geological sketch map of the Maratea Valley is reported in fig. 2, showing the main stratigraphic-structural and morphological lineaments of the study area, related to the activity of palaeo-landslides and recent landslides. In particular, the outcrop of the carbonate rocks in the Maratea Valley is localised on the southern rim of the valley. In the Monte Crivo area both fossil and recent slide scarps occur; moreover, reactivation processes due to deep gravitational processes are documented. Large slabs of

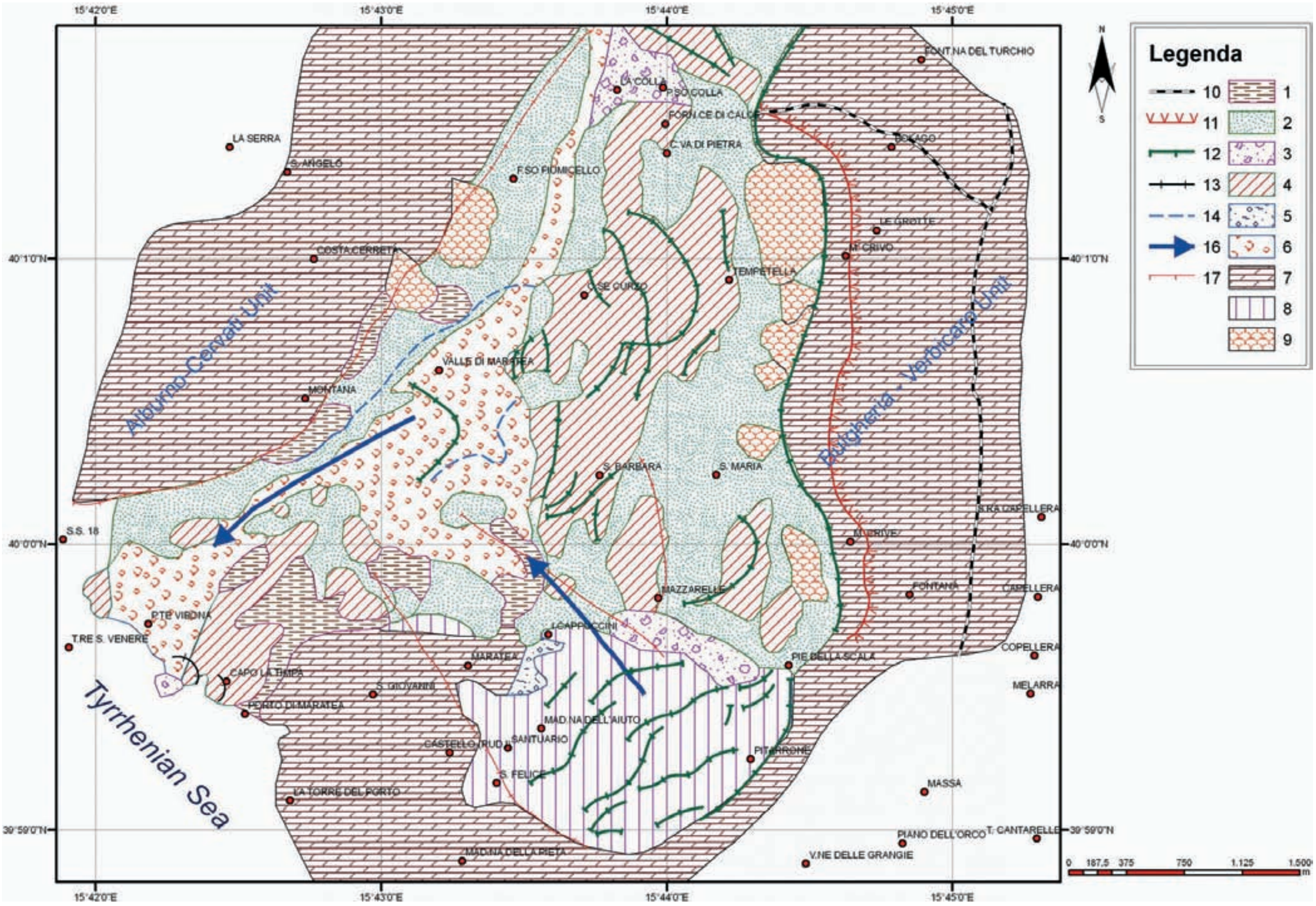


FIG. 2 - Geological sketch map of the Maratea valley (modified after Rizzo, 1997). Key: 1) Red clays (Holocene); 2) Breccias and detritus (Holocene); 3) Calcareous slided blocks; 4) Large units of slided breccia and limestones; 5) Friction calcareous breccias and conglomerates; 6) Crete Nere Formation, Early Cretaceous; 7) Calcareous dolomitic rocks (Mesozoic); 8) Carbonate rocks broken by sackung; 9) Slope breccias; 10) Line of the oldest scarp slide of the Crivo Mt.; 11) Recent scarp slide of the Crivo Mt.; 12) Scarp reactivation due to gravitational (landslide-type) movements; 13) Secondary landslide scarps and trenches; 14) Limit of the landslide body; 15) Main direction of slide movements; 16) Main faults.

breccias and limestones related to the slide bodies occur in the central part and along the south-western and south-eastern flanks of the valley, surrounded by breccias and detritus, Holocene in age. A main direction of the slide movements towards the Tyrrhenian coastline has been surveyed (Rizzo, 1997).

The Tyrrhenian continental margin between the Salerno Gulf and Calabria is characterized by several physiographic units (Coppa & *alii*, 1988; Ferraro & *alii*, 1997). Proceeding from north towards south, the continental shelf of the Salerno Gulf is situated in correspondence of a peri-tyrrhenian basin (Sele Basin) and is characterized by a slope of 0.3°-0.8° and by a gradual shelf break, located at a depth varying between –120 m e –210 m. The Salerno continental shelf presents a thick Holocene sedimentation; at the base of this sedimentation, the wurmian erosional truncation occurs, cutting older deposits, frequently characterized by Pleistocene prograding wedges.

The Cilento continental shelf, located in correspondence to the structural high of the Cilento Promontory, shows a slope varying between 0.3° e 0.8°; its shelf break, located at –220 m of depth, is abrupt. This continental shelf is characterized by a scarce or absent Holocene sedimentation and by the wide diffusion of relic deposits and morphologies; it reaches its maximum widening in correspondence of the Acciaroli town.

Proceeding towards the south, the continental shelf gradually narrows, reaching a width of several kilometres off Palinuro Cape. The shelf break, located at a depth of –220 m, is gradual, while it becomes abrupt off Punta degli Infreschi (Gulf of Policastro), where it is located at –120 m of water depth.

The surrounding continental shelf is characterized by some main valleys and drainage axes, starting from the shelf break and from the main morpho-structural highs. There are several slide bodies between –300 m and –1000 m water depth.

The continental shelf between the Palinuro Cape and the Scalea Cape (including the main physiographic unit of the Policastro Gulf) shows very reduced sedimentary deposits and is crossed by the heads of several channels, triggering extended erosional processes. Its extension is variable, with maximum values reaching 7.5 kilometres at Punta degli Iscoletti and off Sapri and minimum values of less than one kilometer between Punta degli Iscoletti and the Bussento River mouth. The continental shelf shows its maximum extension in correspondence to the Policastro Gulf, where it reaches a width of about 7 kilometres.

Like the Salerno basin, the Policastro basin also shows a thickness of sediments of less than one thousand meters, with a subsidence velocity estimated in the order of 0.2-0.6 m/1 ky (Bartole, 1983; Bartole & *alii*, 1984). Offlap sedimentary successions occur in the study area, determining a seaward progradation of more than 10 kilometres. The prograding sedimentary wedges, deposited during the lowstand phases of the sea level of the middle-Late Pleistocene were eroded during the phases of subaerial exposure of the continental shelf and the successive episodes of eustatic sea level rise (Ferraro & *alii*, 1997). This has determined the formation of wide erosional surfaces at several stratigraphic highs, truncating the prograding units.

The area is characterized by the occurrence of a wide erosional surface, extending from the sea bottom up to –160 m of water depth; this suggests that this surface correlates with the last glaciale episode (18 ky B.P.), i.e. the wurmian regression. Bioclastic sands, characterized by prograding reflectors, occur along two belts localised between –120 m and –160 m of water depth and parallel to the Tyrrhenian shoreline; these deposits are interpreted as parts of submerged beachs related to the isotopic stage 2, based on the identification of the *Arctica islandica*, cold host of the Pleistocene, actually extinct in the Mediterranean (Trincardi & Field, 1991; Ferraro & *alii*, 1997).

Vertical normal faults involve the sectors of the outer shelf and upper slope, propagating in some cases up to the present-day sea bottom; this suggests a recent tectonic activity, often triggering instability processes along the slope.

The trending of the continental shelf between Palinuro Cape and Scalea Cape and of related isobaths follows the physiography of the present-day coastline. The shelf break is abrupt and reaches water depths inferior to –95 m in correspondence to the narrowest sectors of the shelf, while in the more extended sectors it reaches –150 m of water depth. In proximity of the shelf break a morpho-structural terrace occurs with a slope of about 10 meters and a step of about 100 m (Pennetta, 1996a; 1996b). The main source of sediments of the inner shelf is represented by the Bussento River and its tributaries, draining a wide hydrographic basin located between Torre Orsaia and Casaletto Spartano; they are responsible for the formation of a mouth coastal system having low sandy coasts from Torre Orsaia to Villammare.

Under the wurmian erosional surface, seaward prograding deposits occur. They are silty-sandy and relic, genetically related to lowstand phases of sea level. Above this unconformity, coastal and marine depositional systems have been recognised and seem to be linked to the progressive retreating of the coastline induced by the eustatic rise successive to the glaciation, determining a vertical aggradation of the continental shelf of about 10-15 m.

The continental shelf is reached by several channel heads, dissecting the slope and inducing the generalised recession of the platform break; this evolves into an abrupt slope; over the shelf break, mass gravity movements, as slumpings, originate.

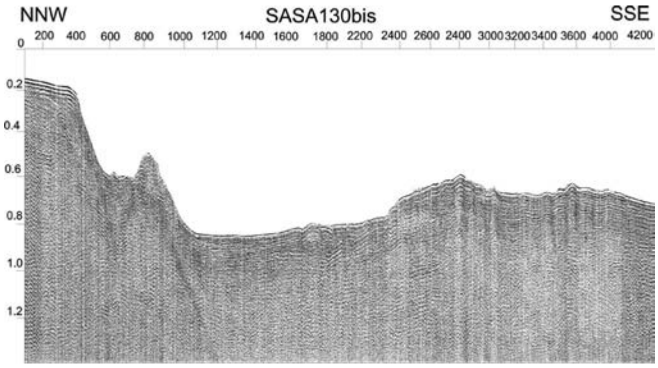
The shelf/slope system, occurring in this sector of the eastern Tyrrhenian margin, is quite immature from a morphological point of view, as shown by the occurrence of thin sedimentary deposits. Large volumes of sediments occur in the Sapri basin; the sediment collecting role played by this basin is facilitated by the effect of barrier operated by the submarine highs bounding the basin itself (Fabbri & *alii*, 1981). The Sapri Basin is bounded to the north and to the west by the abrupt and incised continental slope surrounding, and to the south, by the narrow continental shelf, with high gradients located between Punta degli Iscoletti and Capo Scalea while to the west it is bounded by some morpho-structural highs (slope ridges) with a N-S direction, that are subparallel to the coastline and act as a threshold for sediment dispersal.

SEISMIC STRATIGRAPHY

The geological framework of the Maratea valley on land is connected with the late Pleistocene-Holocene evolution of the surrounding continental platform and slope and with the significant glacio-eustatic fluctuations during the late Quaternary. Near the shoreline the bathymetric setting of the area is characterised by steep and articulated sea bottoms, resulting from the seaward elongment of the rocky coastal cliffs, up to the –30 m isobath (Colantoni & *alii*, 1997), where the continental shelf starts. From the –30 m water depth the sea bottom is more regular up to the shelf break, located at about 2 kilometres from the coastline, at an average water depth of 100-120 meters. In correspondence to the Maratea valley the shelf break retreats up to 900-1000 m from the shoreline, reaching a water depth of –70/80 meters. Here it is articulated and incised by deep channels linked to a submarine canyon's head (the Maratea canyon), involved by active regressive erosion.

High resolution seismic profiles have provided new evidence on the offshore prolongation of the Maratea Valley. As a general rule, the deep gravitational movements already described in the Maratea Valley have influenced the geological setting of the surrounding continental shelf and slope. The continental slope is characterized by deformed sequences, involved by NE-SW normal faults and by slumpings. Normal faulting has also controlled the development of the Maratea canyon itself. The occurrence of the Maratea canyon is significant because the canyon undermines the instable masses of the Maratea valley and induces the development of submarine slides through regressive erosion.

The multichannel seismic profile S130bis crosses the Policastro Gulf with a NW-SE trending (fig. 3; for the localization of the profile see the fig. 1). The seismo-stratigraphic analysis has evidenced a narrow continental shelf, whose stratigraphic architecture is characterized by the occurrence of a prograding sedimentary succession, probably



3 a

3 b

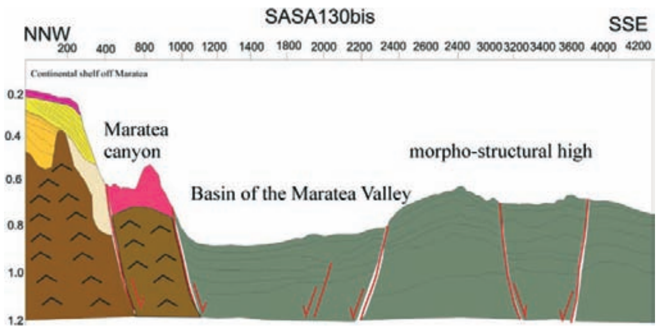


FIG. 3 - (a) Multichannel seismic profile S130bis recorded offshore Maratea; (b) Interpreted seismic profile offshore Maratea. Note the occurrence of several seismo-stratigraphic units overlying an acoustic basement (see the text for further details). Late Pleistocene progradational deposits occur on the continental shelf off Maratea. Tectonically-controlled shelf break occurs at water depth of about –30 m. Slope sequences appear to be deformed by NE-SW trending normal faulting.

Pleistocenic in age (fig. 3). The prograding sedimentary wedge is characterized by preserved clinoforms and by eroded topsets and is truncated at the sea bottom by an erosional unconformity.

The slope gradients appear quite high (ranging from 30° and 45°), according to a hypothesis of a structural control from a normal fault in correspondence to the shelf break.

At the foot of the slope the development of the Maratea canyon is evident.

The time to depth conversion carried out on the seismic profile has shown water depths of about 450 m for the canyon's thalweg. It is evident that the canyon occurrence is also clearly recognizable from the trending of the isobaths, showing a curved shape in plan view in correspondence of the canyon.

The slope sequences, upper Pleistocene to Holocene in age, deposited in an intra-slope sedimentary basin (shot points from 1000 to 2600 in fig. 3), are located at water depths ranging from –600 m and –675 m. After the basin, the sequences are tectonically uplifted in correspondence to a morpho-structural high (shot points from 2600 to 3300 of the seismic profile), bounded by two normal faults, localised in water depths ranging between –562 m and –487 m. This high is interpreted as a slope ridge *sensu* Trincardi & Zitellini (1987); it represents a complex morpho-structural high, controlled by normal faults. The occurrence of these kinds of highs on the continental slope off the Calabria region has already been documented (Pennetta & *alii*, 1996a; 1996b).

The intense synsedimentary tectonics, which characterize the slope successions and the erosional processes, still active in correspondence to the Maratea canyon, have controlled the development of submarine gravity instabilities. The latter are suggested both by rapid thickness variations in the seismic sequences and by the occurrence of several chaotic intervals intercalated at several stratigraphic highs in the recent deposits.

The Subbottom Chirp profile S130bis, running on the same navigation line of the Watergun profile, shows a detailed image of the first few meters below the sea bottom.

In particular, in the first part of the profile (fig. 4) a steep slope reveals the occurrence of the Maratea canyon,

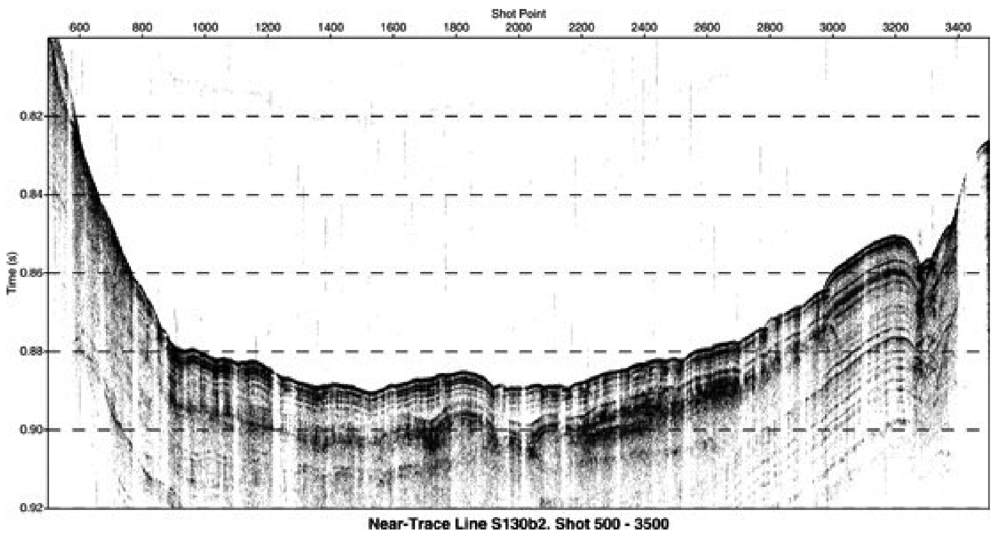


FIG. 4 - Subbottom Chirp profile S130 bis (part 1), showing a detailed, highly resolutive image of the first meters under the sea bottom along the same navigation line of the Watergun profile. Note that the sequences cropping out at the sea bottom are affected by creeping.

reaching in this area water depths of more than –600 m. At the foot of the canyon, the sea bottom, running at water depths of more than 650 m appears quite articulated, as the seismic units identified in the first subbottom. A first seismic unit, about 10 meters thick, shows more or less regularly stratified seismic horizons. This is probably composed of fine-grained marine sediments and corresponds to highstand deposits deposited during the last important transgressive phase (Flandrian transgression). The high penetration of acoustic energy in these strata suggests that the unit is composed of under-consolidated or normally consolidated sediments. Gravitational movements and internal detachments are often present in these kinds of deposits, as confirmed also by the creeping involving recent sediments.

Under this unit a second seismic sequence, with an average thickness of about 20 m, shows less penetration of acoustic energy and is probably composed of coarser lithologies.

The second part of the section S130bis (fig. 5) is characterized by the occurrence of channel-levee complexes and by the occurrence of many channels, showing the recent activity of erosional processes. A sandy levee, located at water depths of –625 m, is localised in correspondence of several lobes of minor extension.

In the last part of the seismic profile S130bis (fig. 6) Holocene sedimentary sequences are spotted with slumpings, resulting from gravity instabilities, which characterize the entire study area.

The seismic profile Subbottom Chirp S130b (fig. 7), perpendicular to the Tyrrhenian shoreline, runs along the continental shelf surrounding northern Calabria. Seismostratigraphic analysis allowed to distinguish, on the continental shelf, an acoustic basement characterized by low-angle prograding clinoforms. The progradations recognised in the acoustic basement show depositional geometries with preserved clinoforms and eroded topsets. This indicates the occurrence of a wide prograding succession, which, during the Pleistocene, widened the continental shelf of the Northern Calabria. The shelf break, of gradual type, is located at water depths of about -150 m. An erosional unconformity is located at the top of the prograding deposits. Coarse-grained wedge-shaped seismic units deposit in the deep channels of the unconformity, forming infillings characterized by bidirectional onlaps. Proceeding upwards we can observe a succession of marine deposits

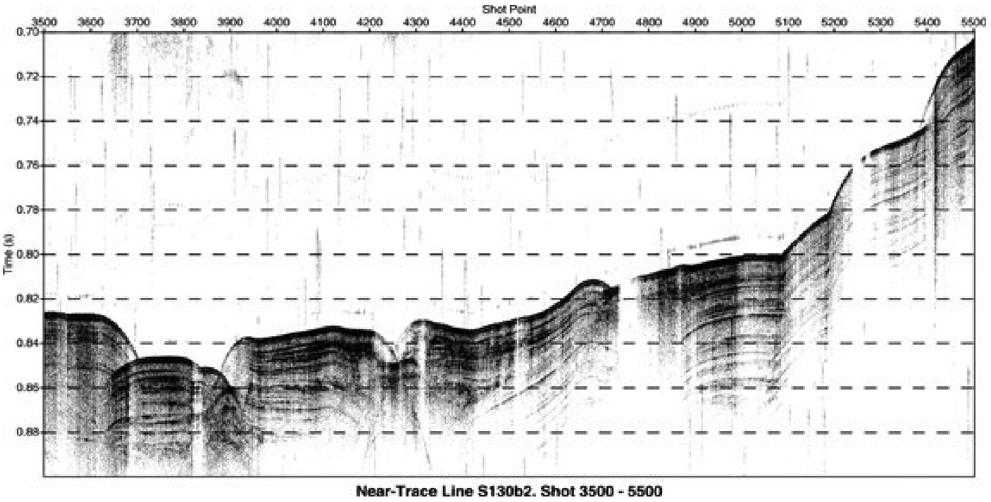


FIG. 5 - Subbottom Chirp seismic profile S130bis (part 2). Main morphological and depositional units distinguished in this area are the channel-levee complexes, often present in the areas surrounding the submarine canyons.

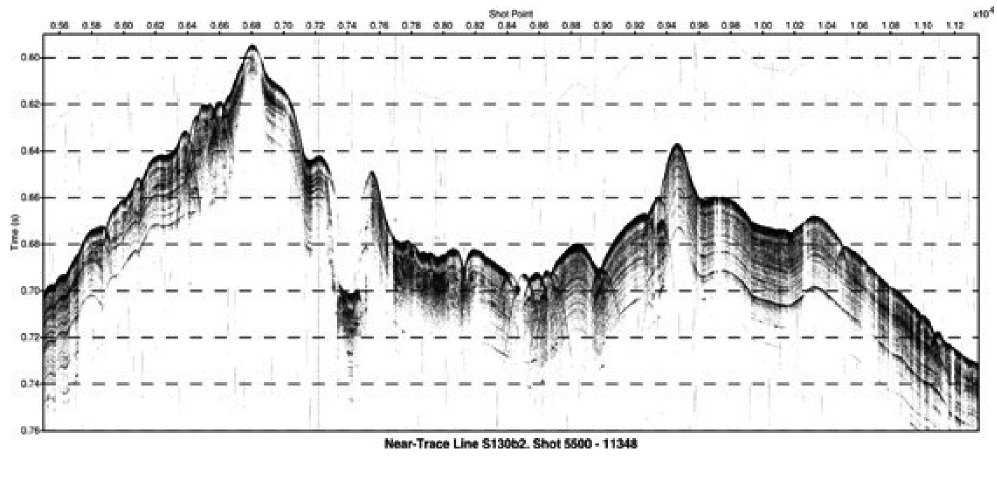


FIG. 6 - Subbottom Chirp profile S130bis (part 3). Holocene sedimentary sequences appear to be clearly affected by slumpings, as a result of submarine instability processes in the area surrounding the Maratea Valley.

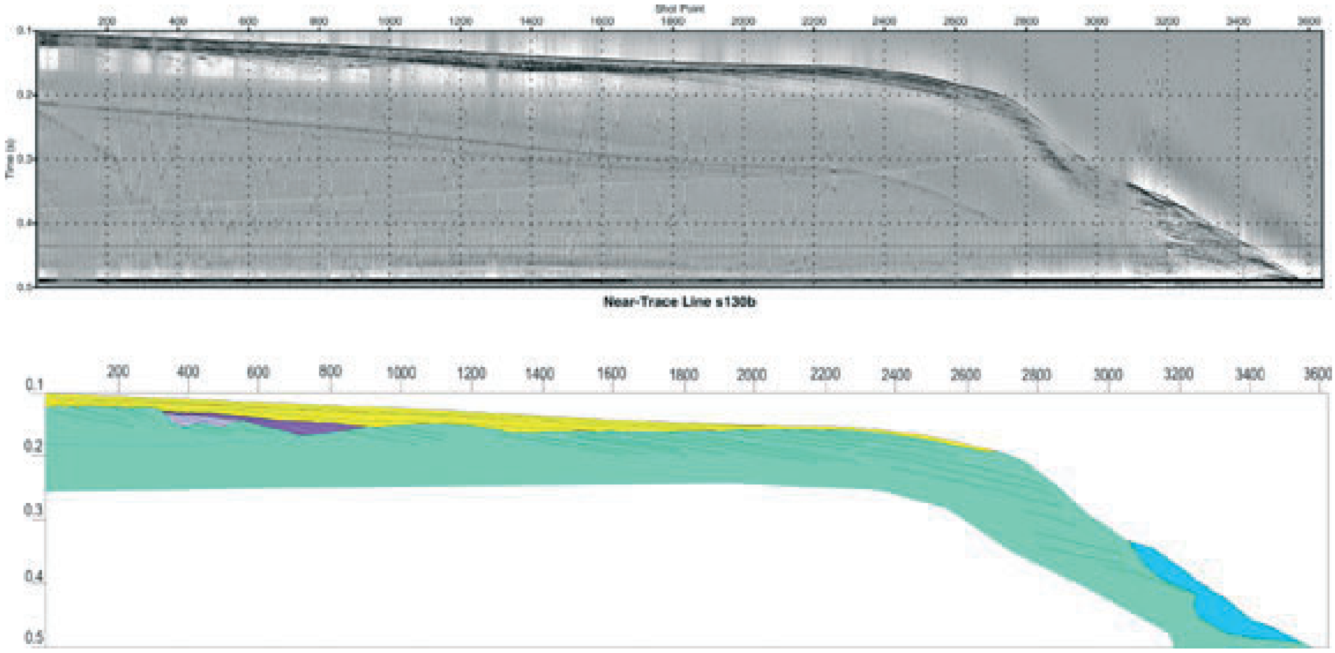


FIG. 7 - Subbottom Chirp profile S130b. Note the occurrence, on the continental shelf, of a wide prograding succession, characterized by clinoforms prograding seawards, with eroded topsets and non-preserved offsets. Note the occurrence of a lenticular unit, filling the incisions and the valley depressions which form in correspondence to the wide erosional surface bounding the acoustic basement at the top. Holocene highstand wedge tends to decrease in thickness towards the shelf break.

characterized by parallel seismic reflectors of high amplitude and continuity. The thickness of this succession is about 60 meters near shore. The deposits progressively decrease proceeding seawards, eventually thinning towards the shelf break. This succession is composed of coastal and marine depositional systems that formed during the progressive retreating of the shoreline induced by the late Quaternary eustatic rise, allowing for an overall vertical aggradation of the continental shelf.

The seismic profile Subbottom Chirp S120 (fig. 8) runs perpendicular to the shoreline in the sector surrounding the Maratea offshore. The geological interpretation of the

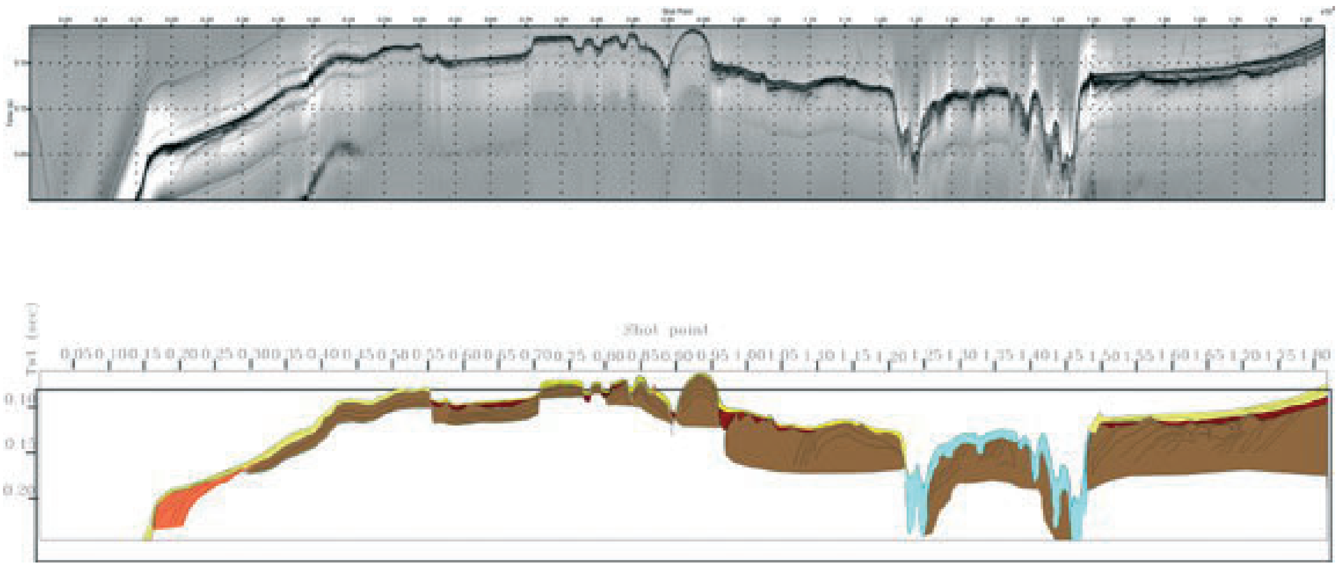


FIG. 8 - Subbottom Chirp profile S120. Note the occurrence of an acoustic basement characterized by a wide prograding succession, which deposits on the whole continental shelf surrounding the Maratea offshore. The Maratea canyon deeply erodes the continental shelf succession and is characterized by a double culmination. Note the occurrence of a prograding wedge at the margin of the continental shelf.

profile has allowed to identify the occurrence of several seismo-stratigraphic units, which characterize the stratigraphic architecture of the continental shelf and slope. This section has clearly crossed the Maratea canyon system, characterized by two main axes, separated by a morphological threshold and by some secondary drainage axes, genetically related to the canyon system. The first sector of the continental shelf (shot points 1.80-1.50) is distinguished for the occurrence of an acoustic basement (represented in brown in the section). It corresponds to the Pleistocene prograding succession, already identified on the section of fig. 7 and interpreted as the relic of a prograding wedge genetically linked to upper Pleistocene lowstand stages. Seismo-stratigraphic evidence suggests that this succession also extends under the system of the Maratea canyon and up the successive sector of the continental shelf. The Maratea canyon deeply incides the continental shelf, allowing the formation of two morphological breaks in slope, bounding the canyon system (fig. 8). In correspondence to the shelf break, localised around –150 m of water depth, a shelf margin prograding wedge develops (represented in orange on the section), characterized by a sigmoidal progradation, which appears draped by the Holocene highstand deposits of the late Quaternary sequence (reported in yellow on the seismic profile). Coarse-grained deposits are frequent and are probably composed of sands and gravels, infilling erosional channels localised in correspondence to the wurmian erosional surface (18 ky B.P.).

The Subbottom Chirp profile S130 runs parallel to the Tyrrhenian shoreline from the Policastro Gulf towards northern Calabria (fig. 9). The geological interpretation of the section has revealed an acoustic basement on the continental shelf, characterized by prograding deposits (see also figs. 7 and 8). The prograding succession is truncated by an erosional surface, probably subaerial, which in some points crops out at the sea bottom.

In the first part of the seismic profile (shots 0-5200) the Holocene highstand deposits (reported in yellow on the section) occur as a thin drape, which tends to close southwards. In correspondence to the break in slope which marks the passage to the Maratea canyon, a recent prograding wedge with sigmoidal progradations has been observed. The Maratea canyon system is articulated in four main axes, localised at water depths ranging from –150 m and –230 m, towards the inner sector of the continental shelf. The Pleistocene prograding succession was observed at more elevated water depths towards the second break in slope bounding the canyon. The recent marine deposits show high thickness, probably due to high sedimentary supply in correspondence to the Bussento River mouth; moreover, the onlap of the first reflectors of the Holocene sequence appears above the Pleistocene acoustic basement.

DISCUSSION AND CONCLUSIONS

The complex and multiple instability phenomena occurring in the Maratea Valley, ascribed to typologies of *sagging*, *sudden spreading failure*, *block-slide*, *lateral spreads* and *translational slidings* and other plastic deformations and to plastic-gravitational type deformations such as *spreading*, *creep* e *squeezing* are strictly dependent on the recent and present-day seismo-tectonic activity in the area.

The measurements of soil movements, relative to the last ten years and integrated by recent geological observations have allowed to distinguish in the Maratea Valley several areas having different kinematics (Rizzo, 2001). In particular, a wide zone of the valley is affected by slow and

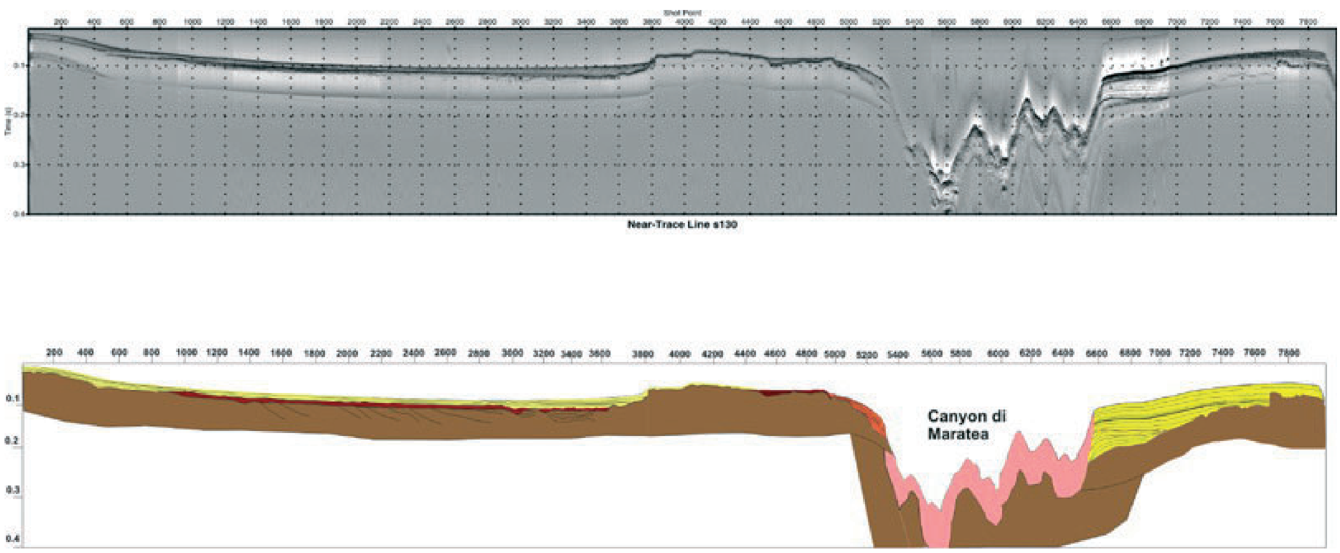


FIG. 9 - Subbottom Chirp seismic profile S130. Note the occurrence (on the left in the profile) of a wide depression at the top of the acoustic basement, representing the seaward prolongation of the Maratea Valley (see the text for further details). In this depression a seismic unit, characterized by wedge-shaped external geometry and coarse-grained lithology deposits. The system of the Maratea canyon is characterized by three axial culminations and by delineated breaks in slope at its margins.

continuous movements (2-3 cm/year), apparently not influenced by the pluviometric and hydrogeological conditions. These gravitational and rather shallow movements, (≤ 50 m) underwent an acceleration during the last twenty years, presumably also in relationship to tensional states triggered by tectonics, previous to and following the seismic event of the 21-03-1982 in the Policastro Gulf.

Deep movements, both tectonic and gravitational in origin, have been hypothised along the strike-slip fault bounding the right flank of the valley (0.5 cm/year).

Based on this geological framework, the Maratea Valley represents the initial stage of the opening of a pull-apart structure, generated by the Pollino strike-slip fault, with little contribution of transpressive and transtensive phenomena (Rizzo, 1997; 2001). In the northern edge of the valley, where the fault bending has thrust the calcareous southern block against the northeastern one, there are transpressive and horse-type structures (Rizzo, 1997; fig. 2).

Within the valley important landslides mainly induced by seismotectonic activity can be observed; a slow and continuous flow evolves in the upper part of the valley in spreadings, sackung and sagging-type phenomena, moving along the south-western limit of the valley on a substratum of plastic clay (fig. 2).

The geomorphology testifies the existence of quick movements and acceleration phases: trenches containing rock falls testify a sudden movement, which resulted from a strong shock, related to upper Pleistocene tectonic activity. Roto-translational slidings, involving detrital covers and shallow clayey colluvial products overlying clays are observed in the central part of the valley and are due to intense seismic and rain events in historical times. Creep and other plastic deformations of shallow clayey covers (squeezing) are located in the previously described area.

The geologic framewok of the Maratea Valley on land is connected with the Late Pleistocene-Holocene evolution of the surrounding continental platform and slope and with the significant glacio-eustatic relative sea level fluctuations during the late Quaternary. Near the shoreline the bathymetric setting of the area is characterized by ripid and articulated sea bottoms, resulting from the seaward prolongation of the rocky coastal cliff, up to the –30 m isobath, where the continental shelf starts (Colantoni & *alii*, 1997).

Rock lithologies (both carbonatic and siliciclastic deposits), cropping out in correspondence to the shoreline, continue along the submerged sector of the coastal cliff, up to a water depth of –30 m. Here they interrupt, in correspondence to an abrupt break in slope, separating the steep coastal sea bottoms from the more regular ones of the continental shelf. Apart from maintaining high gradients which onland characterize the coastal belt, these rocky sea bottoms follow the trending of the coastal belt, characterized by promontories and small bays, thus demonstrating the continuity of the subaerial morphology.

Proceeding seawards, the sea bottoms, covered mainly by sands, are more regular up to the shelf break, located at about 2 km from the coastline, at an average water depth of 100-120 m. In correspondence to the Maratea Valley the shelf break retreats up to 900-1000 m from the shoreline, reaching a water depth of –70/80 m. Here it is articulated and incised by deep channels linked to a submarine canyon's head (Maratea canyon), affected by an active regressive erosion. In fact, this zone is known as «the Fossate», because of the abrupt variations in depth linked to narrow and steep incisions which, joining seawards, form an active drainage system collecting and transporting a large part of the present-day sedimentary supply towards the basin.

High resolution seismic reflection profiles have allowed to define the subsurface stratigraphy in the outer shelf and upper slope off the Maratea Valley. The seismo-stratigraphic analysis, based on some Watergun and Subbottom Chirp seismic reflection profiles, has shown the stratigraphic architecture of the area, characterized by an acoustic basement and several main seismo-stratigraphic units, representing the sedimentary cover. In particular, the available data (figs. 3-9) show a recent sedimentary cover, ranging in age from the Late Pleistocene to the Holocene developing over the acoustic basement, with an irregular trending because of tectonic dislocation and incisions due to subaerial erosion. The sedimentary cover is composed of three main seismic units, with different depositional geometries and seismic facies, separated by regional and/or local unconformities.

The acoustic basement is truncated by a wide erosional surface, which, considering its stratigraphic position and in view of previous studies carried out in the area, (Ferraro & *alii*, 1997; Pennetta & *alii*, 1996a; 1996b) is correlated to the wurmian erosional truncation, referred to the isotopic stage 5e (18 ky; Shackleton & Opdyke, 1973; Martinson & *alii*, 1987). This evidence suggests that the overlying seismic units, which form the sedimentary cover, represent the transgressive and highstand system tracts of the Late Quaternary Depositional Sequence, widely recognised in several sectors of the Italian continental margin (Catalano & *alii*, 1996; Fabbri & *alii*, 2002). This is confirmed by the depositional geometries identified in the seismo-stratigraphic units of the sedimentary cover.

The acoustic basement has been recognised in the continental shelf and is represented by two distinct acoustic facies. The first facies, characterized by low penetration of the acoustic energy, occurs in the near-shore sector of the inner continental shelf (Colantoni & *alii*, 1997). This is not documented in the seismic sections shown in this paper, which have been acquired starting from water depths of –20/30 m. This facies constitutes the seawards prolongation, along the submerged coastal cliff, of Meso-Cenozoic carbonatic and siliciclastic deposits which form the coastal outcrops in the study area. The second facies of the acoustic basement, which was deposited seawards with respect to the rocky outcrops cropping out in the coastal belt, is characterized by a good penetration of the acoustic basement and by progradational geometries, inclined seawards (figs. 7-9). It represents a relic prograding wedge, probably deposited during the lowstand phases of the last glacio-eustatic cycle, Pleistocene to Holocene in age. This interpretation is confirmed by the stratigraphic position of the unconformity bounding the wedge at the top. This unconformity is related to the lowstand phase which, around 18-20 ky B.P. produced a maximum regression, bringing the sea level to a depth that is 110-130 m less than that of the present. This regression was followed by a rapid transgression. Subsequently, during the Holocene climatic optimum (6 ky B.P.) the sea level reached values similar to those of the present. The fast rise of sea level was not linear and various evidences, registered also on several continental margins of the Mediterranean, testify that the transgressive phase was interrupted by several stands. One of them, of about 9-11 ky B.P. (Younger Dryas) was characterized by short regressive episodes or highstands of sea level at water depths that were –40/–60 m deeper than the present day. The trending of the erosional unconformity and of the top of the acoustic basement show a valley type deepening, with a U-type section, that continues seawards to the present-day bottom of the Maratea Valley. This evidences the subaerial palaeotopography which characterizes the glacial maximum (figs. 7-10).

The geological interpretation of the Watergun seismic profile S130bis (fig. 3) has shown that the acoustic basement is downthrown by local tectonic deformations, controlled by NE-SW trending extensional tectonics, related to the one evident onshore, which often involves the overlying detritic cover (fig. 2). This tectonic framework becomes particularly relevant along the margins of the depression representing the seaward prolongation of the Maratea Valley, so enhancing the structural control, which, for the northern margin of the valley, seems to be still active (Rizzo, 1997). Here some normal faults occur, downthrowing both the substratum and the overlying sedimentary cover. N-S trending and NE-SW trending tectonic discontinuities presumably control the definition of the Maratea canyon. The sedimentary cover shows its maximum thickness, ranging from 30 m to 50 m in correspondence to the seaward prolongation of the Maratea Valley, while at both the margins it shows thickness less than 20 m. Towards the coast the sedimentary cover terminates in correspondence to the 20-30 m isobaths, at the contact point with the seawards prolongation of the rocky coastal cliff. Here this cover has a maximum thickness not superior to 10 m and shows typical onlap geometries.

The deepest seismic unit of the sedimentary cover is characterized by irregular, inclined and discontinuous, seismic reflectors; it is probably composed of coarse-grained siliciclastic sediments and fills the main incisions and depressions located at the top of the acoustic basement (figs. 7-10). This unit shows wedge-shaped sedimentary units and bidirectional onlaps. Its maximum thickness reaches the 10 msec reflector (at about 8 m).

The overlying seismic unit is characterized by more regular seismic reflectors, characterized by high frequency and continuity. It is composed by upper Pleistocene marine sediments, reaching about 30 m in correspondence to the seaward prolongation of the Maratea Valley, filling the marine depression of the acoustic substratum. On the contrary, at the margins of the depression, the seismic unit is characterized by small thickness, that is constant proceeding from land to the sea.

The erosional truncation bounding the seismic units of the sedimentary cover at the top, also bounds the base of the present-day and recent marine deposits, which show an overall thickness of about 6-7 m.

In brief, the acoustic characteristics of the crossed grounds, studied through the seismic reflections and the possible correlations with the stratigraphic and structural framework of the emerged sector of the Maratea Valley,

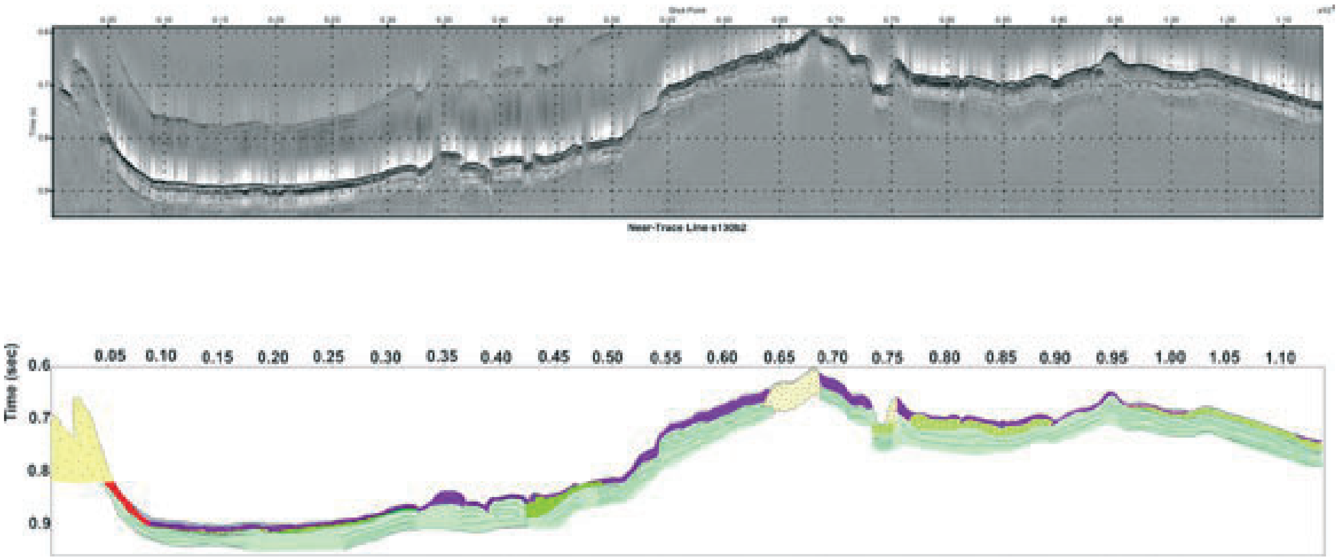


FIG. 10 - Subbottom Chirp profile S130b2, crossing the slope succession of the Policastro Gulf. Note the occurrence of several chaotic intervals, intercalated in the stratigraphic succession, testifying the activity of gravity instability processes controlled both by the intense synsedimentary tectonics and by the occurrence of the Maratea canyon in the adjacent continental shelf.

have allowed to correlate the seismic units with several depositional bodies, schematized as follows.

The first unit of the acoustic basement, not shown by the seismic profiles, but documented nearshore based on references (Colantoni & *alii*, 1997) corresponds with the Mesozoic-Cenozoic carbonates and with the Crete Nere Fm, widely cropping out in the corresponding emerged sector. The relic prograding deposits occurring on the outer shelf may be related with the glacio-eustatic sea level fluctuations of the middle-late Pleistocene.

The oldest unit of the sedimentary cover is deposited over a very irregular unconformity, corresponding to an emersion phase lasting for a relatively long time interval. This unit shows the characteristics of coarse-grained facies of marine deposits, with probable continental episodes.

The youngest units of the sedimentary cover present characteristics of a relatively fine-grained marine deposits. The stratigraphic relationships with the underlying seismic units suggest that they represent the highstand deposits of the late Quaternary depositional sequence.

It is worth noting the role of the Maratea canyon as sediment collector in the continental shelf and in determining submarine gravity instability processes in the study area. These phenomena suggest the occurrence of extended creeping involving present-day and recent marine deposits (fig. 4) and explicates with a slow movement along the slope under the action of gravity. The phenomena of gravity instability in the submarine environment are shown by the occurrence of slumpings. They appear as bodies with wedge-shaped external geometry and chaotic acoustic facies, interstratified at various stratigraphic levels in the sediments of the upper slope (fig. 6). These sedimentary bodies have been produced by the upwards sliding of sediments after their deposition and, specifically, by the alongslope flux of soft marine sediments, underconsolidated at the head and along the walls of the Maratea canyon.

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