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Assetto stratigrafico e strutturale dei bacini marini di semi-graben in Italia meridionale: evidenze sulla Valle di Salerno (margine continentale della Campania, Italia) in base a dati di sismica a riflessione multicanale e morfo-batimetria Multibeam

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In copertina Modello Digitale del Terreno della Valle di Salerno (particolare)

Stratigraphic and structural styles of half-graben offshore basins in Southern Italy: multichannel seismic and Multibeam morpho-bathymetric evidences on the Salerno Valley (Southern Campania continental margin, Italy)

New results on the seismic stratigraphy and morpho-bathymetry of the Pleistocene sedimentary basin of the Salerno Valley focused on the regional seismic stratigraphy of the Southern Campania passive continental margin (Southern Tyrrhenian sea, Italy) are presented here. Original data include Multibeam bathymetry as well as multichannel and single-channel seismic profiles, recently collected onboard the R/V Urania of the National Research Council of Italy (oceanographic cruise SISTERII).

The Salerno Valley represents a half-graben sedimentary basin, whose identification has been controlled, during the Early Pleistocene, by the master fault Capri-Sorrento Peninsula, showing vertical throws of 1500 metres, which downthrows the Meso-Cenozoic carbonatic acoustic basement under the sedimentary basin. The geologic interpretation of multichannel seismic profiles has enabled the identification of a main unconformity, located at depths ranging from 3000 to 3500 metres under the sea bottom and correlated to the top of the Meso-Cenozoic carbonatic sequence, extensively cropping out onshore in the Sorrento Peninsula structural high. This unconformity bounds upwards the carbonatic acoustic basement, strongly deformed by normal faulting, and represents the base of the Pleistocene basin filling, the Salerno Valley. The basin filling, with an overall thickness exceeding 1000 metres, is characterised by parallel and continuous seismic reflectors alternating with chaotic intervals, having acoustically-transparent seismic facies.

The strong synsedimentary tectonics lasting up to Late Pleistocene times in correspondence to NNW-SSE trending listric normal faults triggered gravity mass instability processes, evident as chaotic acoustic intervals intercalated at various stratigraphic levels in the stratigraphic record shown by the multichannel seismic profiles.

Vengono presentati alcuni nuovi risultati sulla stratigrafia sismica e la morfo-batimetria del bacino sedimentario pleistocenico della Valle di Salerno, che si inquadrano nella stratigrafia sismica regionale del margine continentale passivo della Campania meridionale (Mar Tirreno meridionale, Italia). I dati originali includono un rilievo batimetrico multifascio Multibeam *della Valle di Salerno e profili sismici multicanale e monocanale, recentemente acquisiti a bordo della nave oceanografica Urania del Consiglio Nazionale delle Ricerche (crociera oceanografica SISTERII).*

La Valle di Salerno rappresenta un bacino sedimentario di semi-graben*, la cui formazione è stata controllata, durante il Pleistocene inferiore, dalla faglia diretta regionale Capri-Penisola Sorrentina, che mostra rigetti verticali di circa 1500 metri e ribassa il basamento acustico carbonatico Meso-Cenozoico al di sotto del bacino sedimentario. L'interpretazione geologica dei profili sismici multicanale ha permesso l'identificazione di una* unconformity *principale, localizzata a profondità comprese tra 3000 e 3500 metri al di sotto del fondo mare e correlabile con la sommità della sequenza carbonatica Meso-Cenozoica, estesamente affiorante a terra nell'alto strutturale della Penisola Sorrentina. Tale* unconformity *delimita verso l'alto il basamento acustico carbonatico, fortemente deformato da faglie dirette e rappresenta la base del riempimento sedimentario della Valle di Salerno, di età pleistocenica. Il riempimento del bacino, che ha uno spessore complessivo che supera i 1000 metri, è caratterizzato da riflettori sismici paralleli e continui che si alternano con intervalli caotici, che hanno una facies sismica acusticamente trasparente.*

L'intensa tettonica sinsedimentaria, che è durata fino al Pleistocene superiore e si è esplicata in corrispondenza di faglie dirette listriche ad andamento NNW-SSE, ha innescato instabilità gravitative di massa, evidenziate da intervalli caotici intercalati a vari livelli stratigrafici nella successione sedimentaria mostrata dai profili sismici multicanale.

Introduction

New multi-channel and single-channel seismic profiles and morpho-bathymetric data, consisting of high-resolution Multibeam bathymetry of the Pleistocene sedimentary basin of the Salerno Valley, located on the Southern Campania passive continental margin (Tyrrhenian sea, Italy) have been analysed in order to investigate the tectono-sedimentary evolution of this part of the Southern Tyrrhenian margin during the Pleistocene. The area provides a good example for a better understanding of the evolution of extensional (half-graben) sedimentary basins offshore Southern Italy.

In a similar way to other back-arc basins, the Tyrrhenian sea is an area of ongoing extension inside large-scale convergence zones between the continental plates of Europe and Africa. Tyrrhenian extension started about 10 Myr ago, leading to the Pliocene formation of oceanic crust [Patacca et al., 1990]. Three passive continental margins, Sardinia, Northern Sicily and Southern Italy, border the Southern Tyrrhenian bathyal plain. The area is seismically active and experiences strong horizontal and vertical movements.

The Southern Tyrrhenian continental margin of Campania owes its complex stratigraphic architecture to the interaction between volcanic and sedimentary processes occurred during the Late Quaternary. Starting from 1996, multichannel reflection seismic profiles collected by the CNR-IAMC Institute of Naples, Italy, coupled with high resolution reflection seismics, Multibeam bathymetry and magnetic profiles, have contributed to the knowledge of the tectono-stratigraphic setting of the margin, both on a regional and on a local scale [Aiello et al., 1997a; 1997b; 2001; 2004a; 2005; D'Argenio et al., 2004; Marsella et al., 2002; Secomandi et al., 2003; Siniscalchi et al., 2002].

The Salerno Valley is a Pleistocene half-graben basin originated by the master fault Capri-Sorrento Peninsula, showing vertical throws up to 1500 m and is filled by marine clastic and epicontinental sediments (Fig. 1). Strong seismic reflectors inclined towards SSE with apparent angles of 10°-15° appear on seismic profiles, indicating the occurrence of detachment levels in the carbonatic multilayer [Aiello et al., 1997a; 1997b]. The extension in the Salerno basin is due to groups of listric normal faults converging on low-angle detachment levels. Another preferential detachment level is located on top of the Miocene flysch terrains [Sacchi et al., 1994].

Bathymetric and high-resolution reflection seismic data previously collected in the Salerno Valley [Aiello et al., 1997a; 1997b] indicate that the depositional processes and overfilling of the basin prevail on the continental shelf to the east, while the western sector of the half-graben is the site of erosional and sedimentary processes still active in a canyon (the Salerno canyon), with depths ranging from 600 m to 1000 m. The occurrence of wedging geometries in the sedimentary successions, of tectonic unconformities, of hummocky reflectors and seismic facies intercalated at several stratigraphic levels in the basin filling are hints of strong synsedimentary tectonics and of a strong uplift of the adjacent onshore areas of the southern Apennines during the Pleistocene.

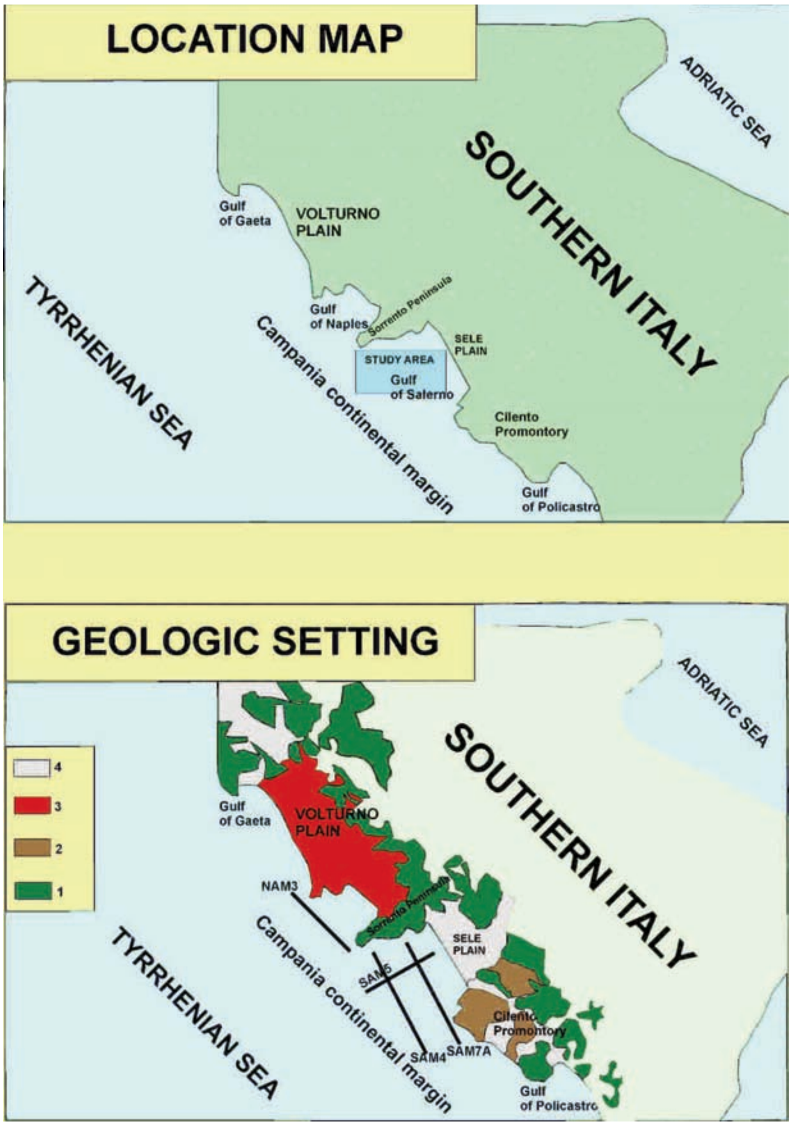

Figure 1 Sketch map showing the location of the study area and the geological setting (in the lower part of the figure) of the Campania Region. The regional seismic stratigraphy of the Campania continental margin has been investigated based on the geological interpretation of the seismic profiles NAM3 (Gulf of Naples), and SAM5, SAM7a and SAM4 (Gulf of Salerno). 1: Meso-Cenozoic carbonates. 2: Siliciclastic flysch deposits. 3: Quaternary volcanic deposits. 4: Quaternary alluvial, coastal and marine deposits.

Figura 1 Mappa schematica mostrante l'ubicazione dell'area in studio (nella parte superiore della figura) e l'inquadramento geologico semplificato (nella parte inferiore della figura) della Campania. La stratigrafia sismica regionale del margine continentale della Campania è stata studiata in base all'interpretazione geologica dei profili sismici NAM3 (Golfo di Napoli), e SAM5, SAM7a e SAM4 (Golfo di Salerno). 1: Carbonati meso-cenozoici. 2: Depositi silicoclastici di flysch. 3: Depositi vulcanici di età quaternaria. 4: Depositi alluvionali, costieri e marini di età quaternaria.

In the Salerno offshore, anticlines with ENE-WSW axes suggest roll-over mechanisms, resulting from the envelopment of listric normal faults or from a tectonic inversion of the half-graben, according to a N-S trending compression or to a transpression along the master fault Capri-Sorrento Peninsula [Aiello et al., 1997a; 1997b; Sacchi et al., 1994]. The extensional processes seem to be very recent in the Salerno basin, being responsible for the present-day topography of the sea bottom and for the foreland uplift along rift shoulders (Sorrento Peninsula).

1. Data and methods

1.1 Data acquisition and processing

New seismo-stratigraphic and morpho-bathymetric data on the Southern Campania continental margin, between the Sorrento Peninsula-Capri island elongment, to the north, and the Salerno offshore, to the south, have been collected by the IAMC-CNR of Naples (Italy), during the oceanographic cruise SISTER II (December 2004) onboard the R/V Urania of the National Research Council of Italy (Scientific Director: dott. Ennio Marsella). The geophysical data were acquired between – 100 m and – 1000 m of water depth.
The Multibeam acquisition was carried out using the RESON Seabat 8160 deep-towed Multibeam, whose calibration was capable of surveying sea bottoms at water depths ranging from 5 m to 4000 m (Fig. 2).
The acquisition of Multibeam lines has been achieved by using a coverage of 50% and following navigation lines parallel to the isobaths. The investigated area is comprised between the Sorrento Peninsula-Capri island structural high and the Policastro Gulf to the south, covering water depths ranging from – 100 m and – 1000 m. The line spacing, varying as a function of the sea bottom water depths, is comprised between 500 m ca. for water depths of -100 m and 1 km ca. for water depths of -800 m. The visualisation of the bathymetric data during the acquisition was made possible by a colorimetric scale, in which the colours correspond to different bathymetric belts (Fig. 3).
During the Multibeam acquisition the calibration of bathymetric data was allowed by CTD profiles (every 7-8 hours), giving information on conductivity, temperature and salinity along the water column (Fig. 4).
Simultaneously with the acquisition of Multibeam bathymetry, high resolution Subbottom Chirp seismo-acoustic profiles have been recorded with the aim of calibrating the morphological setting of the sea bottoms evidenced by the Multibeam bathymetry.
The post-processing of the Multibeam data has enabled the construction of detailed bathymetric data, following the standards of the National Hydrographic Bureau (IHO, 1998). The data elaboration has been carried out by using a module of the PDS2000 software, which enables data filtering.
Multichannel reflection seismic profiles have been recorded using two G/I Airguns seismic source by SSI Sodera in dotation to the IAMC-CNR of Naples, Italy.
The acquisition system is represented by the Geometrics Stratavisor 24 bit seismograph with a 48-channel. The sample interval was set to 0.5 msec, the windows time at 5 s, the receive interval at 6.25 m and the shot interval at 25 m.
Seismic data processing has been carried out following several steps. In a preliminary phase, the editing and the assignment of the field geometry of the seismic dataset have been carried out. Advanced data processing was aimed at reduction of random noise in the data, included removal of unwanted coherent events and reduction of spatial aliasing by means of trace interpolation on common shot gather. The combination of pre-stack DMO and post-stack data migration allowed a better localization of the reflectors on the seismic section. Cycles of velocity analysis and residual

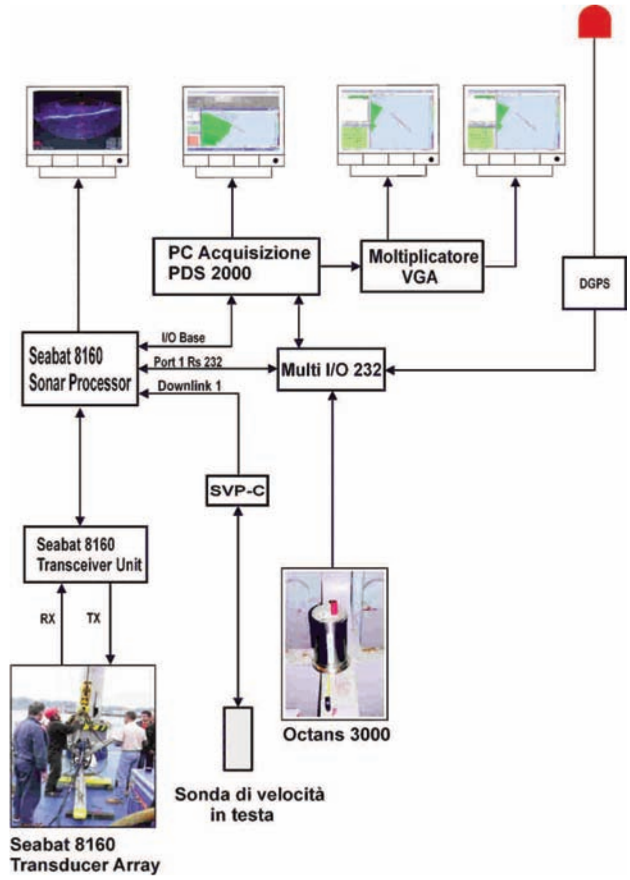

Figure 2 Block diagram showing the functioning of the deep towed RESON 8160 Multibeam system, in dotation to the R/V Urania (National Research Council of Italy), used for the acquisition of bathymetric data in the oceanographic cruise SISTERII.
Figura 2 Schema a blocchi del funzionamento del sistema *Multibeam* per alto fondale RESON 8160, in dotazione alla N/O Urania (Consiglio Nazionale delle Ricerche), usato per l'acquisizione di dati batimetrici Multibeam durante la crociera oceanografica SISTERII.

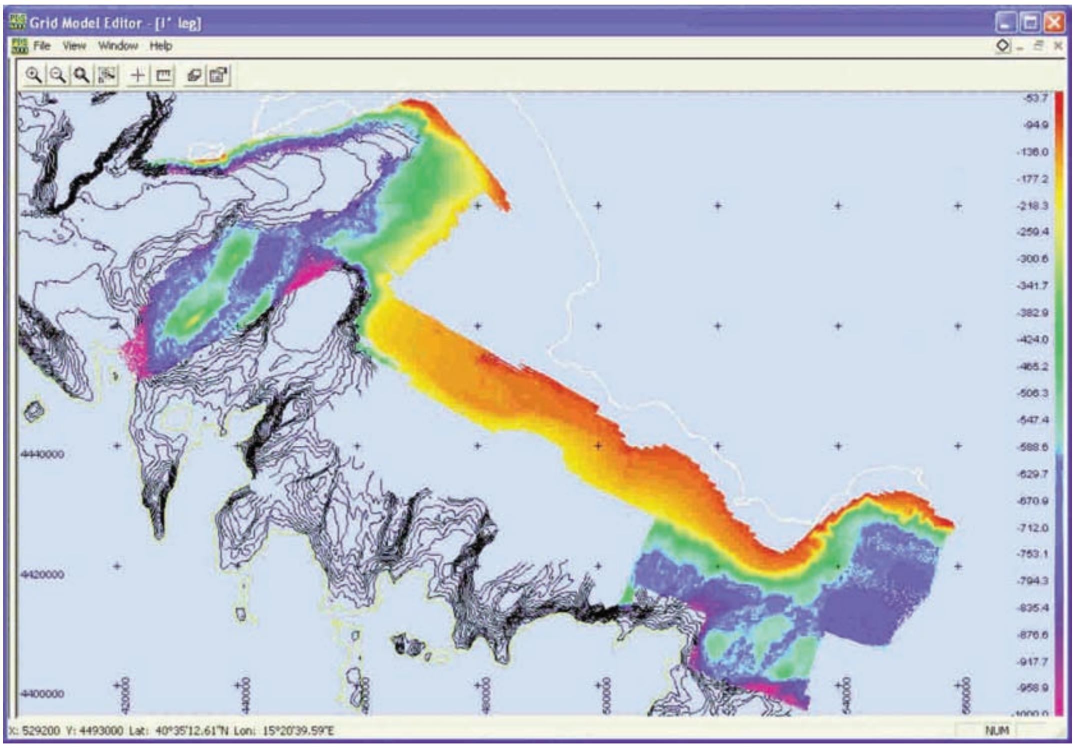

Figure 3 Total coverage map of the Multibeam acquisition during the oceanographic cruise SISTERII.
The visualization of the bathymetric data has been realised through a colorimetric scale and using the software PDS2000 (RESON; navigation and Multibeam acquisition).
Figura 3 Mappa della copertura totale dell'acquisizione *Multibeam* realizzata durante la crociera oceanografica SISTERII. La visualizzazione dei dati batimetrici viene realizzata attraverso una scala colorimetrica ed usando il software PDS2000 (RESON; navigazione ed acquisizione *Multibeam*).

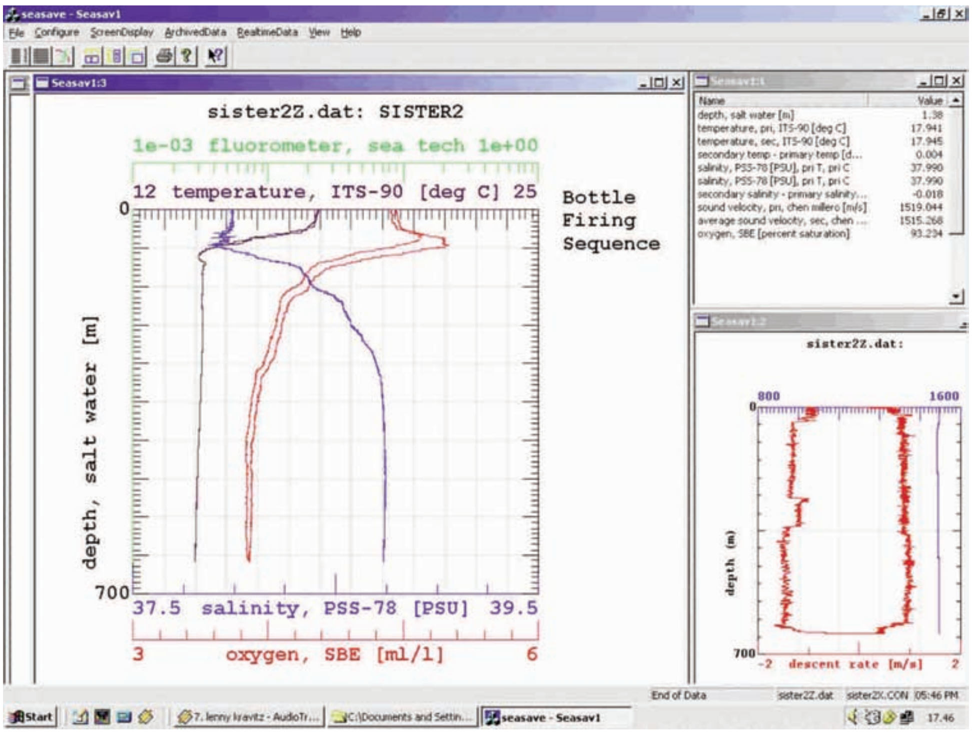

Figure 4 Diagram showing the data of a CTD probe realised onboard in order to calibrate the bathymetric data during the Multibeam acquisition (oceanographic cruise SISTERII).
Figura 4 Diagramma mostrante i dati di una sonda CTD realizzata a bordo durante l'acquisizione batimetrica Multibeam (crociera oceanografica SISTERII) con lo scopo di effettuare una calibrazione dei dati batimetrici.

static corrections improved the quality of the velocity function and therefore, the NMO correction. Pre-stack spiking deconvolution widened the frequency spectra of the signal and boosted data resolution. FK filtering on NMO corrected data, CDP gathers and pre and post-stack predictive deconvolution weakened multiple reflections.

2. Regional seismic stratigraphy of the Campania continental margin

The regional seismic stratigraphy of the Campania continental margin has been summarised by several studies carried out at the IAMC-CNR, based on the interpretation of the seismic data acquired in the area (more than 10.000 km of high-resolution single-channel sparker and air-gun lines). The examination of the Neogene depositional sequences and unconformities has proven to be constructive, providing some constraints on the models, mainly in terms of directions and timing of extensional processes on the Campania continental margin.
The seismo-stratigraphic setting of the area is shown by the seismic profile NAM3 (fig. 5; after Aiello et al., 2001 and D'Argenio et al., 2004). Several seismic sequences separated by unconformities have been distinguished. The acoustic basement is represented by Meso-Cenozoic platform carbonates (unit 1 in fig. 5) cropping out onshore in the Sorrento Peninsula and organised as monoclinalic structure dipping north-westwards.
The basin filling consists mainly of two prograding wedges (units 2 and 4 in Fig. 5), each characterized by distinctive acoustic patterns and seismic facies. They appear to be the most relevant units in the tectono-sedimentary evolution of the area. The oldest one (unit 2) is interpreted as a wide relic prograding wedge, north-westwards dipping, formed by siliciclastic deposits, probably Pleistocene in age and occurring offshore the Sorrento Peninsula. Both the Meso-Cenozoic carbonates and unit 2 have been probably involved in a tectonic tilting during Pleistocene extensional phases, slightly increasing the steepness of seismic reflectors. On the continental shelf, the seismic reflectors are truncated by a main subaerial unconformity (unconformity B in Fig. 5), whose areal extension varies from 2-3 kilometres to several hundred meters. The unconformity B probably indicates a main, relative sea level fall and a strong basinwards shifting of coastal and marine facies, accompanied by sedimentary bypass and strong erosion on the shelf and slope.

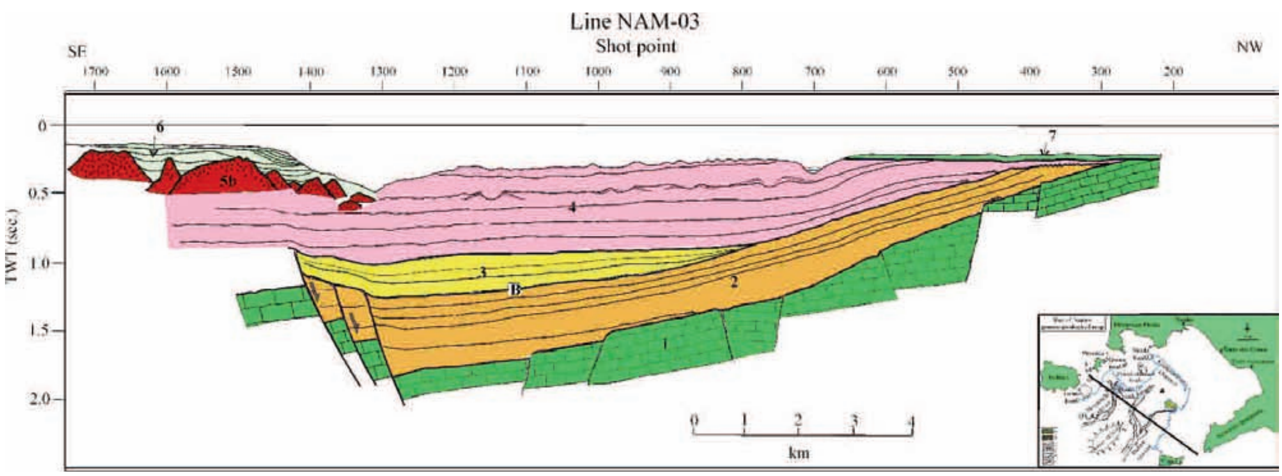

Figure 5 Line drawing of the multichannel profile NAM3 (slightly modified after Aiello et al., 2001 and D'Argenio et al.., 2004) showing the stratigraphic architecture of the Campania continental margin in the Gulf of Naples. The profile runs along a NW-SE transect from offshore, towards the Sorrento Peninsula. The acoustic basement, represented by Meso-Cenozoic carbonates, is strongly downthrown by normal faulting towards the centre of the bay. The basin filling is composed of several seismic sequences; two of them (units 2 and 4) are represented by wide relic prograding wedges and appear to be the most relevant in the tectono-sedimentary evolution of the area. Key. 1: Acoustic basement (Meso-Cenozoic platform carbonates). 2: Early Pleistocene relic prograding wedge. 3: Wedge-shaped, transgressive unit, mainly developed in slope and basin settings, probably composed of siliciclastic deposits. 4: Middle-Late Pleistocene prograding wedge. 5b: Buried volcanic complexes related to Ischia and Procida eruptions, ranging in age from 55 to 18 ky. 6: Late Quaternary marine and coastal deposits: prograding wedges deposited on the continental shelf; drapes filling intra-platform basins.
Figura 5 Interpretazione geologica del profilo sismico multicanale NAM3 (leggermente modificato da Aiello et al., 2001 e D'Argenio et al., 2004) che mostra l'architettura stratigrafica del margine continentale della Campania nel Golfo di Napoli. Il profilo decorre lungo un transetto NW-SE, dall'offshore delle isole di Ischia e di Procida verso la Penisola Sorrentina. Il basamento acustico, rappresentato dai carbonati meso-cenozoici è ribassato da faglie dirette verso il centro del golfo. Il riempimento del bacino è composto da alcune principali sequenze sismiche; due di queste (unità 2 e 4) sono rappresentate da ampi cunei progradanti relitti e sono le più rilevanti per l'evoluzione tettonico-sedimentaria dell'area. Legenda. 1: Basamento acustico (Carbonati di piattaforma meso-cenozoici). 2: Cuneo progradante relitto (Pleistocene inferiore). 3: Unità trasgressiva cuneiforme, sviluppata in scarpata ed in bacino, probabilmente composta di depositi silicoclastici. 4: Cuneo progradante relitto (Pleistocene medio-superiore). 5b: Complessi vulcanici sepolti collegati all'attività eruttiva delle isole di Ischia e Procida, di età compresa tra 55 e 18 ky. 6: Depositi marini e costieri della sequenza tardo-quaternaria: cunei progradanti deposti sulla piattaforma continentale; riempimenti di bacini intra-piattaforma.

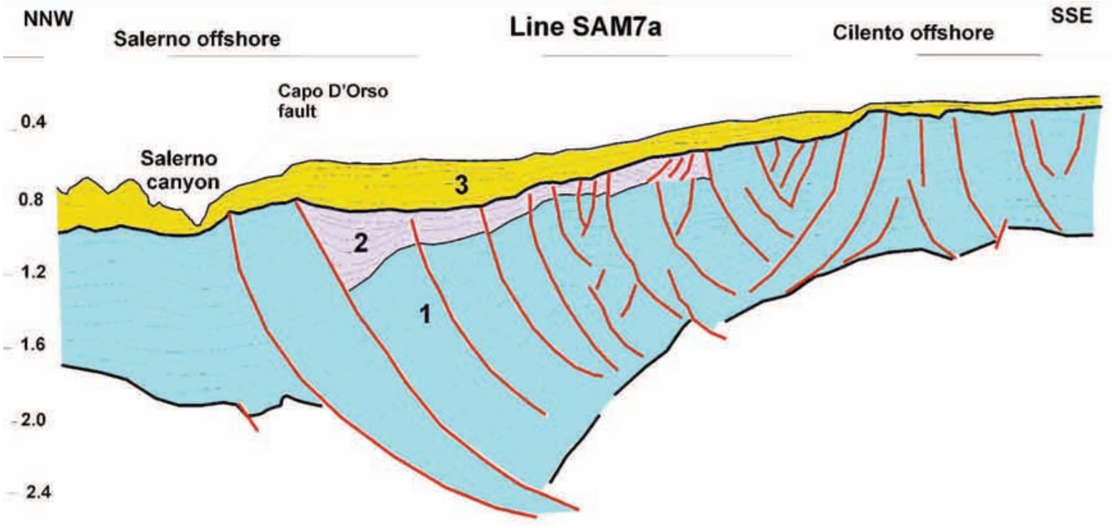

Figure 6 Line drawing of the multichannel line SAM7 showing the stratigraphic architecture of the Campania continental margin in the Gulf of Salerno. The profile runs from NNW to SSE between the Salerno offshore and the Cilento offshore and shows coupled conjugate listric normal faults, related to a master fault (Capo D'Orso fault), NE-SW oriented, strongly downthrowing the Pleistocene basin filling. Key. 1: Early Pleistocene marine deposits, strongly deformed by normal faulting and representing the first seismic unit of the basin filling. 2: Syntectonic sequence, deposited in the central part of the basin, probably during the tectonic activity of the Capo D'Orso fault (Middle Pleistocene?). 3: Late Pleistocene marine deposits, relatively undeformed and representing the early stages of the basin filling.
Figura 6 Interpretazione geologica del profilo sismico multicanale SAM7, che mostra l'architettura stratigrafica del margine continentale della Campania nel Golfo di Salerno. Il profilo decorre da NNW a SSE tra l'offshore di Salerno e l'offshore del Cilento e mostra coppie di faglie listriche dirette coniugate, collegate ad una faglia maestra (faglia di Capo D'Orso), orientata NE-SW, che ribassa fortemente il riempimento pleistocenico del bacino sedimentario. Legenda. 1: Depositi marini del Pleistocene inferiore, intensamente deformati da faglie dirette, che rappresentano la prima unità sismica del riempimento sedimentario. 2: Sequenza sintettonica, deposta nel settore centrale del bacino, probabilmente durante l'attività tettonica della faglia di Capo D'Orso (Pleistocene medio?). 3: Depositi marini del Pleistocene superiore, relativamente indeformati, che rappresentano gli stadi finali del riempimento del bacino sedimentario.

Above the unconformity B, the clinoforms of unit 3 (Fig. 5) progressively onlap the slope and basin areas up to the continental shelf. Unit 3 represents a wedge-shaped, transgressive unit, mainly developed in slope and basin settings and probably composed of siliciclastic deposits.

Above unit 3, a wide prograding wedge (unit 4 in Fig. 5) develops. It shows well-preserved offlap breaks and thickens from the shelf towards the slope. The wedge grades laterally, or alternatively is overlain by the volcanic unit 5 and is deeply incised by the Dohrn canyon axes. Above unit 4 and/or in facies hetheropy with the latter, a wedge-shaped seismic unit, acoustically transparent and volcanic in origin has been clearly identified offshore the Sorrento Peninsula, where it unconformably overlies the Meso-Cenozoic carbonates and/or the seismic unit 2. Prograding wedges deposited on the continental shelf and/or on the flanks of volcanic edifices and sediment drapes infilling local basinal depressions are interpreted as Late Quaternary marine and coastal deposits. Holocene highstand drape, covering the whole margin, is represented by wedge-shaped or drape-shaped units represented by highly continuous parallel and subparallel reflectors.

The Salerno Valley is a Pleistocene half-graben, whose identification and tectonic setting have been controlled by the normal fault (with a probable strike-slip component) Capri-Sorrento Peninsula, showing an average throw of about 1500 metres [Bartole et al. 1983; Bartole 1984; Aiello et al. 1997a; 1997b; Aiello et al. 2007]. This fault has also controlled the origin of the Salerno canyon.

The regional tectono-stratigraphic setting of the Campania continental margin in the Salerno Valley is shown by the geological interpretation of several multichannel lines, recorded in the investigated area (Figs. 6-8).

The seismic profile SAM7a (Fig. 6), running from the Salerno offshore to the Cilento offshore, has shown coupled conjugate listric normal faults inclined towards SSE and NNW. These faults, showing strong downthrows of the clastic multilayer, converge at several stratigraphic levels. In particular, some faults appear to be related to a master fault, NE-SW oriented (Capo D'Orso fault).

This line has explored the shallowest sector of the Salerno Valley, which, unlike the distal areas where the depositional processes prevail during the Late Quaternary, appears to be struck by recent erosional processes, enabling the formation of the Salerno canyon. A main unconformity seems to fossilise the seismic sequences involved by extensional tectonics in correspondence to normal faults; it also marks the beginning of the deposition of relatively undeformed seismic sequences, forming a thick prograding wedge thickening from the platform margin towards the slope and towards the

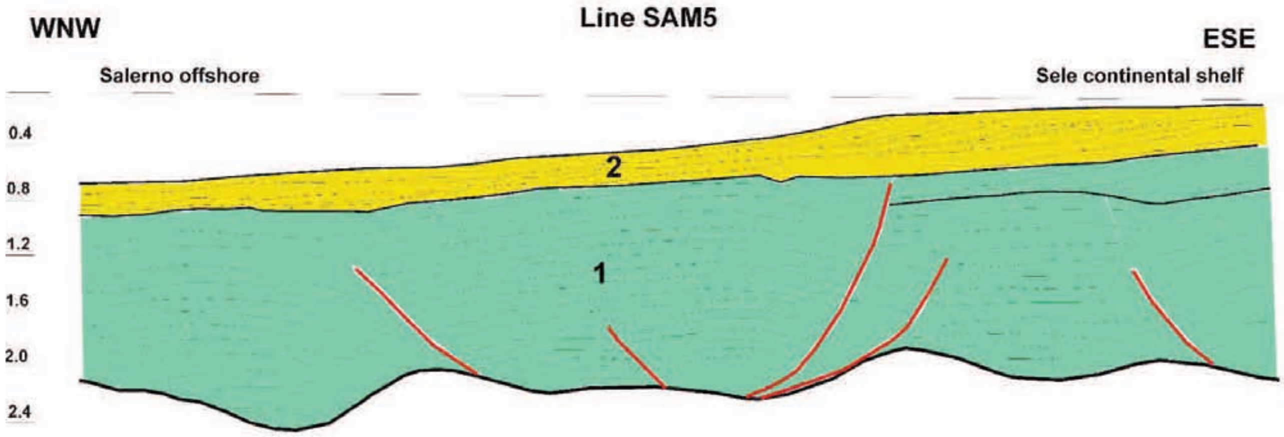

Figure 7 Line drawing of the multichannel profile SAM5, perpendicular to the Tyrrhenian shoreline in the Gulf of Salerno. The profile runs from WNW to ESE and has explored the central sector of the Salerno Valley, where wide antiformal structures involve the Pleistocene seismic sequences. Key. 1: Early-Middle Pleistocene marine deposits, representing the bulk of the basin filling, deformed in correspondence to wide antiformal structures. 2: Late Pleistocene marine and coastal deposits, relatively undeformed, showing progradational geometries on the continental shelf and genetically related to the Sele river; basinwards, parallel and continuous reflectors unconformably overlying the lower sequence.

Figura 7 Interpretazione geologica del profilo sismico multicanale SAM5, perpendicolare alla linea di costa tirrenica nel Golfo di Salerno. Il profilo decorre da WNW a ESE e ha esplorato il settore centrale della Valle di Salerno, in cui ampie strutture antiformi coinvolgono le sequenze sismiche di età pleistocenica. Legenda. 1: Depositi marini del Pleistocene inferiore-medio, che rappresentano la parte principale del bacino sedimentario, deformati in corrispondenza di ampie strutture antiformi. 2: Depositi marini e costieri del Pleistocene superiore, relativamente indeformati, che mostrano geometrie progradazionali sulla piattaforma continentale e sono geneticamente collegate al fiume Sele; verso bacino, riflettori paralleli e continui che ricoprono in discordanza la sequenza sismica inferiore.

Salerno canyon. The prograding wedge has been supplied by the river Sele during the Late Quaternary (Fig. 6).

The seismic profile SAM5 (Fig. 7), showing a WNW-ESE trending (perpendicular to the Tyrrhenian shoreline) runs perpendicularly to the line SAM7 and has explored the central sector of the Salerno Basin, where depositional processes, of basin filling, prevail. The tectonic setting, highlighted on the basis of geological interpretation of seismic profiles,

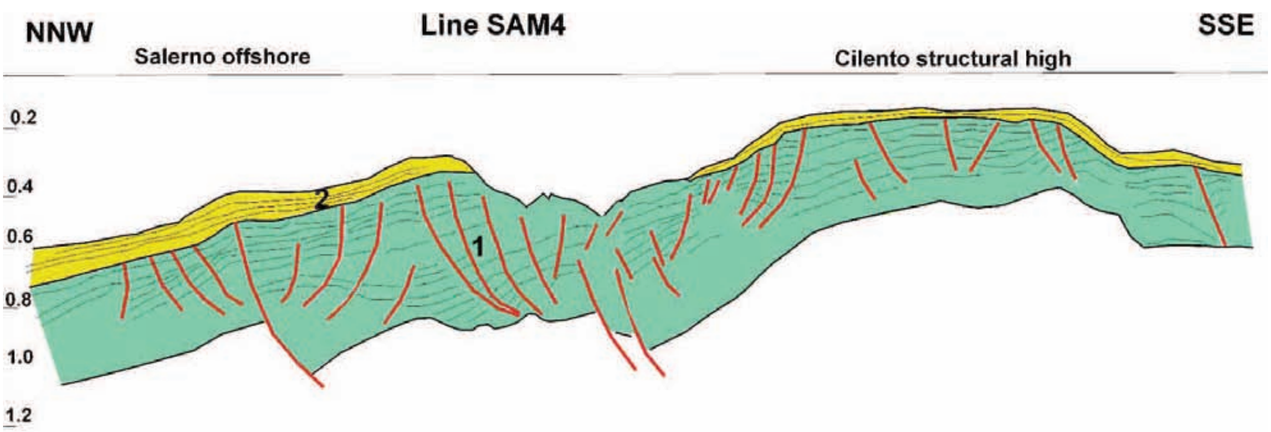

Figure 8 Line drawing of the multichannel profile SAM4, crossing the Salerno-Cilento area from the Salerno offshore towards the structural high of the Cilento continental shelf, already showing the stratigraphic architecture of the Campania continental margin. Key. 1: Early-Middle Pleistocene marine deposits, representing the bulk of the basin filling, strongly deformed by normal faulting and cropping out at the sea bottom in correspondence to main erosional areas. 2: Late Pleistocene marine and coastal deposits, relatively undeformed, characterised by progradational to parallel geometries in correspondence to the Cilento structural high and by parallel and subparallel geometries in the Salerno offshore.

Figura 8 Interpretazione geologica del profilo sismico multicanale SAM4, che attraversa l'area Salerno-Cilento dall'offshore di Salerno verso l'alto strutturale della piattaforma continentale del Cilento, che mostra l'architettura stratigrafica del margine continentale della Campania. Legenda. 1: Depositi marini del Pleistocene inferiore-medio, che rappresentano la parte principale del riempimento del bacino sedimentario, intensamente deformati da faglie dirette ed affioranti al fondo mare in corrispondenza delle principali aree erosionali. 2: Depositi marini e costieri del Pleistocene superiore, relativamente indeformati, caratterizzati da geometrie da progradazionali a parallele in corrispondenza dell'alto strutturale del Cilento e da geometrie parallele e subparallele nell'offshore di Salerno.

is consistent with an extensional tectonic style, complicated by the occurrence of wide antiformal structures with ENE-WSW axes, involving the Pleistocene seismic sequences. The seismic interpretation suggests that these structures are probably linked to roll-over mechanisms, resulting from the envelopment of listric normal faults, shown by the N-S trending seismic profiles. A main tectonic unconformity marks the occurrence of a prograding wedge, relatively undeformed, which has been supplied by the mouth of the river Sele (Figs. 6 and 7).

The stratigraphic architecture of the Sele prograding wedge is well developed on the continental shelf, where a stacking pattern of seismic sequences probably corresponding to a 4th order glacio-eustatic cyclicity has been identified. The offlap breaks of the prograding clinoforms appear well preserved and indicate an aggradational component in the lowest parasequences of the wedge and a more pronounced progradational component in the upper parasequences. A progressive seaward shifting of the parasequences on the continental shelf, up to the present-day shelf break, located at about – 135 m of water depth, indicates a normal coastal progradation, controlled by high sedimentary supply of the mouth of the river Sele. The base of the Sele prograding wedge is bounded by a regional unconformity, marked by the downlap of seismic horizons (Fig. 7).

Further evidence emerges from the interpretation of the seismic profile SAM4 (Fig. 8) running from the Salerno offshore to the structural high of the Salerno continental shelf and giving evidence for the tectonic setting of the clastic multilayer, characterised by several normal faults.

3. Results

3.1 Morpho-bathymetry based on the interpretation of Multibeam data

The morpho-bathymetry of sedimentary basins based on Multibeam surveys represents a research line of increasing interest, mainly for its implications in the coastal and deep sea environmental monitoring in terms of the definition of geologic and environmental hazards.

The Multibeam bathymetric data collected during the SISTERII oceanographic cruise have evidenced the high gradients of the continental slope and the occurrence of erosio-

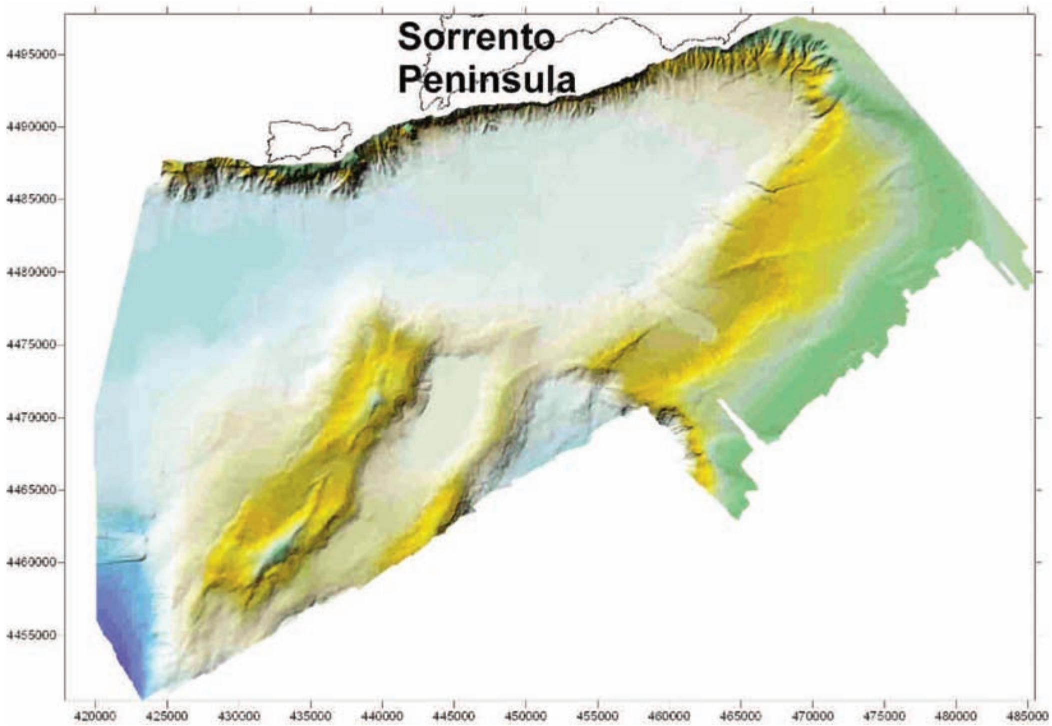

Figure 9 Shaded relief map of the Multibeam bathymetry of the Salerno Valley, covering the southern continental slope bounding the structural high of the Sorrento Peninsula-Capri island and the northern sector of the Gulf of Salerno. Note the occurrence of a dense network of erosional channels deeply eroding the continental slope south of Sorrento Peninsula. The south-western rim of the Salerno Valley is bounded by two complex, NE-SW trending, morpho-structural highs; on their western flank a wide intra-slope basin occurs, located on the – 700 m of water depth.

Figura 9 Mappa a rilievo ombreggiato della batimetria *Multibeam* della Valle di Salerno, che copre la scarpata continentale meridionale 7che delimita l'alto strutturale della Penisola Sorrentina – Isola di Capri ed il settore settentrionale del Golfo di Salerno. Si noti la presenza di una fitta rete di canali erosivi, che incide fortemente la scarpata meridionale a sud della Penisola Sorrentina. Il margine sud-occidentale della Valle di Salerno è delimitato da due alti morfo-strutturali complessi, con andamento NE-SW; sul loro fianco occidentale si osserva un ampio bacino di *intra-slope*, localizzato a profondità d'acqua di – 700 m.

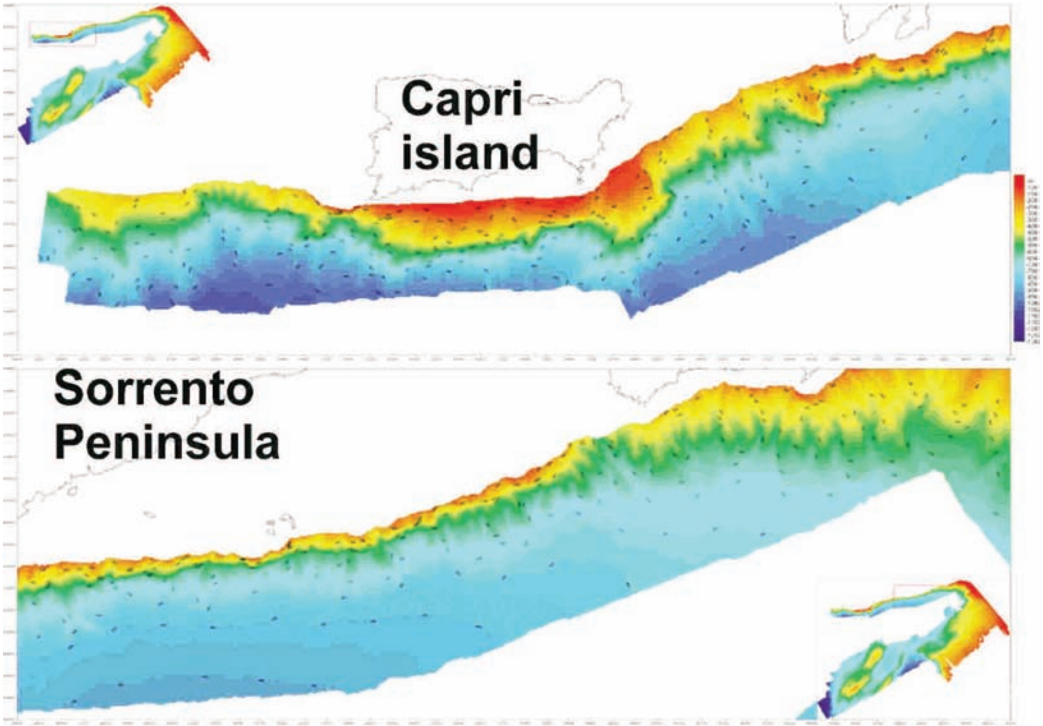

Figure 10 Contour map of the Multibeam bathymetry on the steep, tectonically-controlled continental slope, located between the Capri island and the Sorrento Peninsula. It is irregularly articulated and is characterised by promontories and embayments, reflecting the main structural trends occurring onshore in the Capri island.
Figura 10 Mappa *contour* della batimetria *Multibeam* sulla scarpata continentale acclive, tettonicamente controllata, ubicata tra l'isola di Capri e la Penisola Sorrentina. Questa è irregolarmente articolata ed è caratterizzata da promontori e rientranze, che riflettono i principali andamenti strutturali che si rinvengono a terra nell'isola di Capri.

nal processes, partly still active, mainly at the toe of the slope, where a dense network of channels occurs. The analysis of seismic profiles had already evidenced the tectonic activity of the fault escarpment as a triggering factor for gravity instabilities active during Late Pleistocene and Holocene; this is evidenced also by slumping deposits, characterised by a chaotic seismic facies, intercalated at several stratigraphic levels in the basin filling. On the contrary, in the distal zones of the valley, where deposition prevails, the shallower sector appears in a regime of intense erosion (Salerno canyon) and shows recent tectonic deformations, as antiforms and normal faults, which can be interpreted in the regional framework as hints of intense extensional tectonics, lasting up to recent times [Aiello et al. 1997a; 1997b].
The Multibeam bathymetric data have enabled the construction of a 3D DTM reconstruction, covering an area of 1600 square kilometres, comprising the area between the southern coast of the Capri island to the north-west and the mouth of the river Sele to the south-east (Fig. 9).
The continental shelf of the Salerno Gulf shows a strong asymmetry proceeding from north to south, reflecting the different structural domains of this sector of the Apenninic chain. The variability of extension, of the depth of the shelf break and of the average slopes are controlled by the structural and geological setting of the margin areas [Bartole et al. 1984], more than by the glacio-eustatic variations during the Pleistocene.
The continental slope surrounding the Salerno Gulf is characterised by structural depocentres with a NW-SE Apenninic trending, originated by the extensional phases related to the Tyrrhenian basin, alternating with morpho-structural highs, adjacent to intra-slope basins. In particular, the geological interpretation of the DTM has evidenced the occurrence of two complex NE-SW trending morpho-structural highs (Fig. 9).
As evidenced by the DTM interpretation, the continental slope is a main morphologic and tectonic structure, NE-SW oriented; it starts to the west from the border of the Dohrn canyon, skirts the Capri island in a E-W direction and finally it is parallel to the Sorrento Peninsula, for an overall length of 12 kilometres (Fig. 10). The contour map of the Multibeam bathymetry on the continental slope between the Sorrento Peninsula and the Capri island is represented in Fig. 10.
The slope is irregularly articulated and is characterised by promontories and embayments, reflecting the main structural trends occurring on land in the Capri island. Offshore the Capri island the slope is located at water depths ranging between – 120 m and – 1000 m and its gradients range from

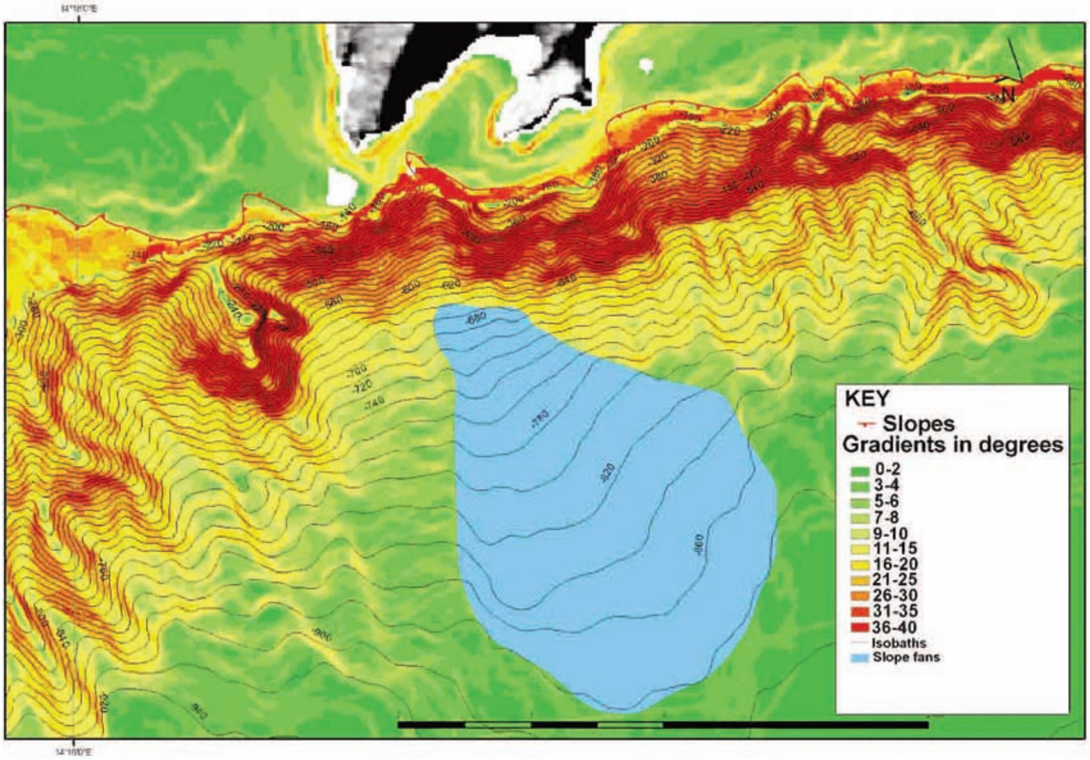

Figure 11 Detail of the slope map constructed on Multibeam bathymetry showing a wide slope fan occurring off the Sorrento Peninsula. It has been reconstructed on the basis of the convex trending of the isobaths at water depths ranging between – 680 m and – 880 m.
Figura 11 Dettaglio della mappa delle pendenze costruita in base alla batimetria *Multibeam* che mostra un'ampia conoide di scarpata localizzata al largo della Penisola Sorrentina: Questa è stata ricostruita in base all'andamento convesso delle isobate a profondità d'acqua comprese tra – 680 m e – 880 m.

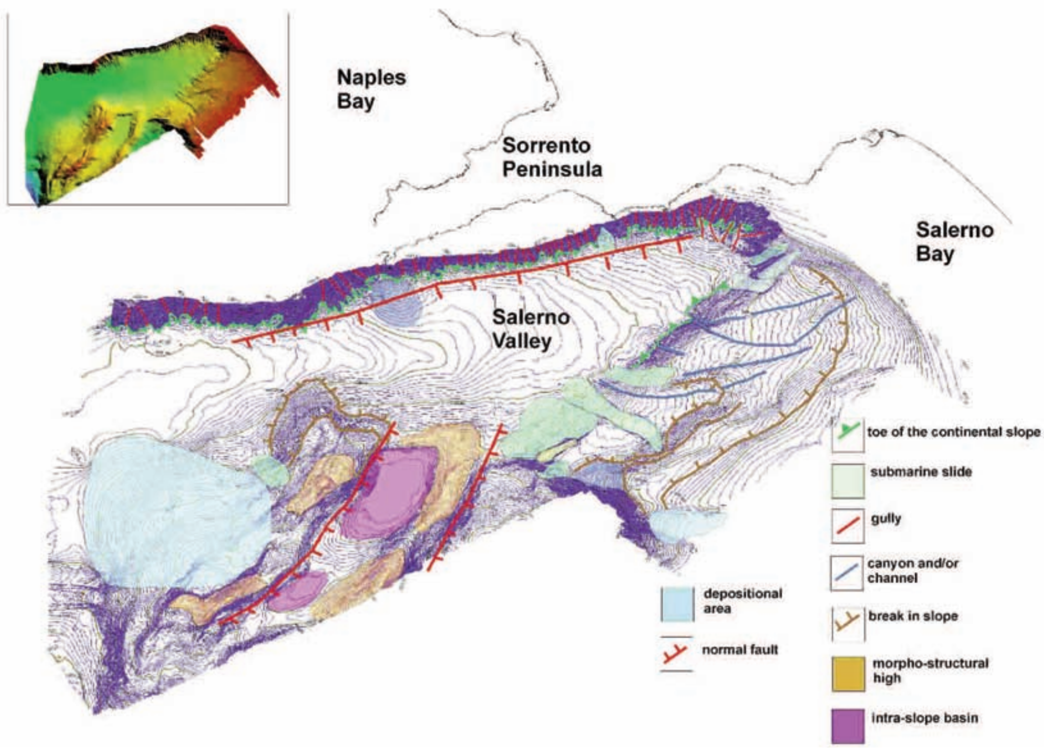

Figure 12 Morphological sketch map of the Salerno Valley superimposed on contour map of the isobaths. The main morphological lineaments have been recognised through the geological interpretation, i.e. the toe of the continental slope, the submarine slides, the erosional gullies, the canyons and/or channels, the breaks in slope, the morpho-structural highs, the intra-slope basins, the depositional areas and the normal faults. In the inset the shaded relief of the area is reported.
Figura 12 Mappa morfologica schematica della Valle di Salerno, sovrimposta alla mappa a *contour* delle isobate. I principali lineamenti morfologici sono stati riconosciuti dall'interpretazione geologica, cioè il piede della scarpata continentale, le frane sottomarine, i canali erosionali, i canyons e/ o i canali, le rotture di pendenza, gli alti morfo-strutturali, i bacini di *intra-slope*, le aree deposizionali e le faglie dirette. Nell'inserto è riportata la mappa a rilievo ombreggiato dell'area in studio.

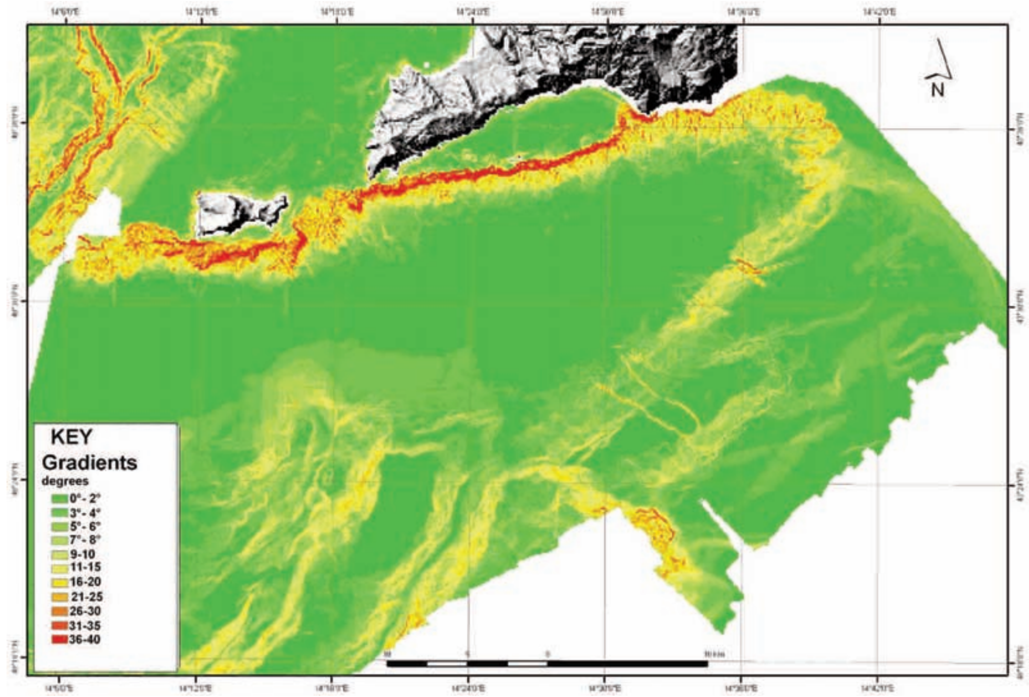

Figure 13 Slope map of the eastern sector of the investigated area, constructed on the basis of Multibeam bathymetry. Note the gradients ranging between 36° and 40° of the continental slope south of the Sorrento Peninsula. Two main breaks in slope have been identified: a first one of about 5° running parallel to the coast in a NW-SE direction; a second one, NE-SW trending, having different gradients ranging between 5° and 15° and developed on sea bottoms varying from – 460 m and – 560 m of water depth.

Figura 13 Mappa delle pendenze del settore orientale dell'area in studio costruita in base alla batimetria *Multibeam*. Si notino i gradienti compresi tra 36° e 40° della scarpata continentale a sud della Penisola Sorrentina. Sono state identificate due rotture di pendenza principali: una prima di circa 5° che decorre parallelamente alla costa con andamento NW-SE; una seconda rottura, con andamento NE-SW, che presenta gradienti diversi, compresi tra 5° e 15° e sviluppata su fondali di profondità comprese tra – 460 m e – 560 m.

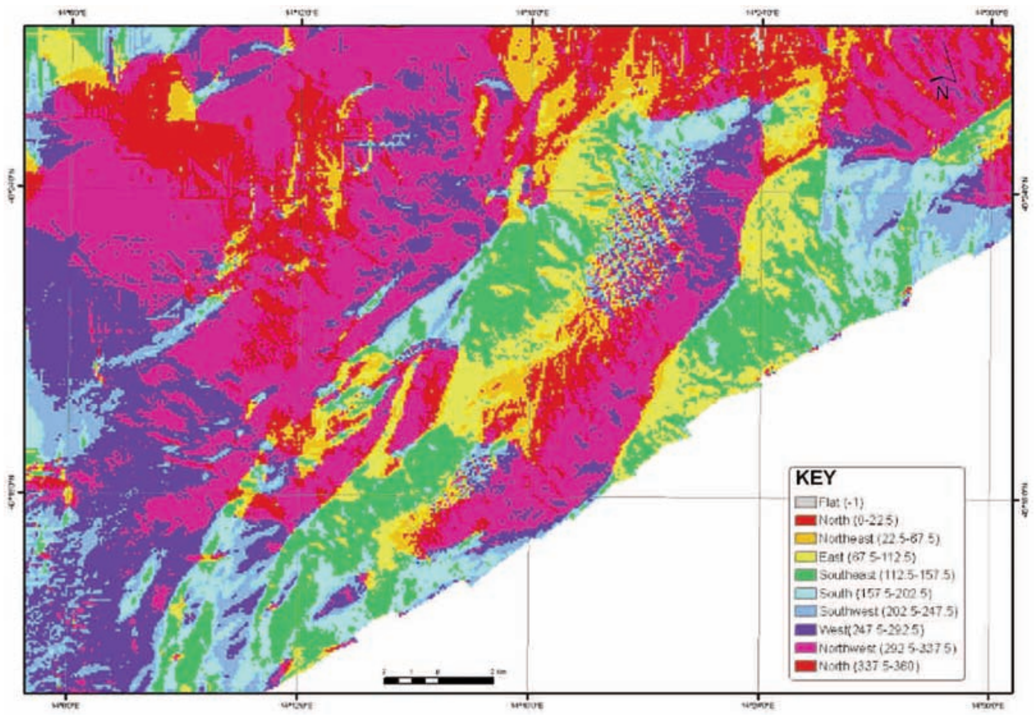

Figure 14 Dip-slip map of the study area. Note the occurrence of several classes of dip-slip of the morpho-structures cropping out at the sea bottom, from flat (-1) to North (0-22.5), to Northeast (22.5-87.5) to East (67.5-112.5), to Southeast (112.5-157.5), to South (157.5-202.5), to Southwest (202.5-247.5), to West (247.5-292.5), to Northwest (292.5-337.5) and to North (337.5-360).

Figura 14 Mappa delle immersioni dell'area in studio. Si noti la presenza di alcune classi di immersione delle morfo-strutture affioranti al fondo mare, da pianeggiante (-1) a immersione verso Nord (0-22.5), a immersione verso Nord-est (22.5-87.5), a immersione verso Est (67.5-112.5), a immersione verso Sud-est (112.5-157.5), a immersione verso Sud (157.5-202.5), a immersione verso Sud-ovest (202.5-247.5), a immersione verso Ovest (247.5-292.5), a immersione verso Nord-ovest (292.5-337.5) e verso Nord (337.5-360).

17.8° to 23°. At the south-western promontory of the island (Punta Ventroso), the gullies occurring on the continental slope create a sub-circular sedimentary structure with a diameter of about 1500 m. In correspondence to the western rim of the Sorrento Peninsula (Punta Campanella) the continental shelf is very narrow (about 400 m); the slope starts at – 120 m of water depth and stops in correspondence to a large slope fan, with a diameter of about 2.6 km and extending up to – 880 m of water depth (Fig. 11).

A sketch morphological map based on the Multibeam interpretation is reported in Fig. 12. The slope is characterised, throughout its extension, by a dense network of gullies, partly reflecting the hydrographic pattern of the corresponding emerged sector, separated by saddles, with variable dimensions. Important submarine slides have been distinguished on the continental slope to the south of the Salerno Valley. Main breaks in slope are located in correspondence to the – 240 m, - 350 m and - 480 m isobaths. Two complex morpho-structural highs (slope ridges), NNW-SSE trending, are located on the south-western continental slope and are separated by an intra-slope basin, with several depocentres. Minor depositional zones occupy several areas of the continental slope.

In its eastern sector (corresponding to the eastern sector of the Sorrento Peninsula) the continental shelf widens, reaching an extension of more than 16 kilometres in the Salerno Gulf. The trending of the slope rotates in a NW-SE direction, proceeding for more than 8 kilometres and maintaining the same morphological characteristics, with high gradients; its structure continues to be very articulated, showing several saddles and gullies. At about 9 kilometres from the shoreline of the Sorrento Peninsula in a SE direction, the slope completely changes its morphological characteristics (Figs. 9-10).

A slope map of the study area is reported in Fig. 13. Two main breaks in slope result from the slope map; the first one of about 5°, running parallel to the shoreline in a NW-SE direction and occurring on sea bottoms varying from – 100 m to – 120 m; the second one of 5°-15°, developed in a NE-SW direction and developed on sea bottoms varying from – 460 m and – 560 m. This latter break in slope seems to be the continuation of the slope rim; but the occurrence of a large channel and three different slide scars make the geomorphological data difficult to interpret.

The south-western area of the continental slope is characterised by the occurrence of two highs parallel and oriented to 45° N. This structure seems to be part of a monoclinalic structure cropping out at the sea bottom dipping towards SE (Fig. 15) or of a horst and graben structure. The first high, located eastwards, is characterized by two main peaks along

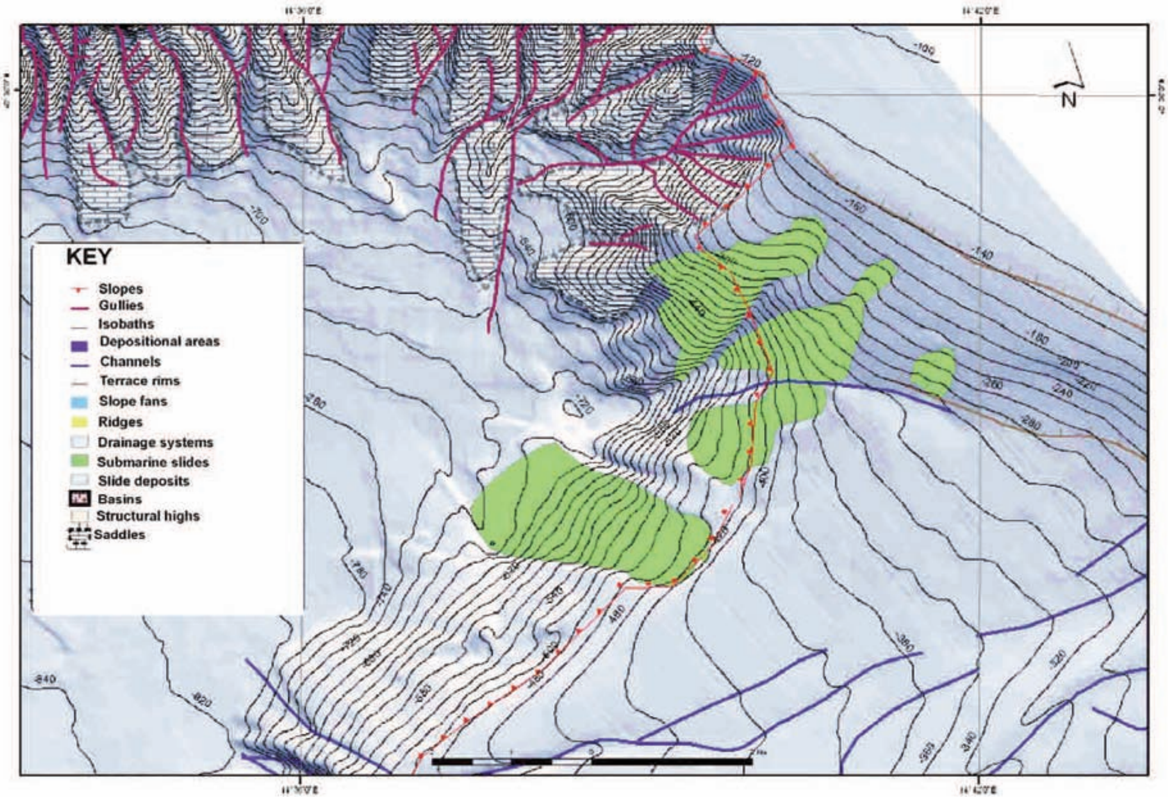

Figure 15 Detailed Digital Terrain Model of three important submarine landslides, identified in the northern sector of the Salerno Gulf.
Figura 15 Modello Digitale del Terreno di dettaglio di tre importanti frane sottomarine, identificate nel settore settentrionale del Golfo di Salerno.

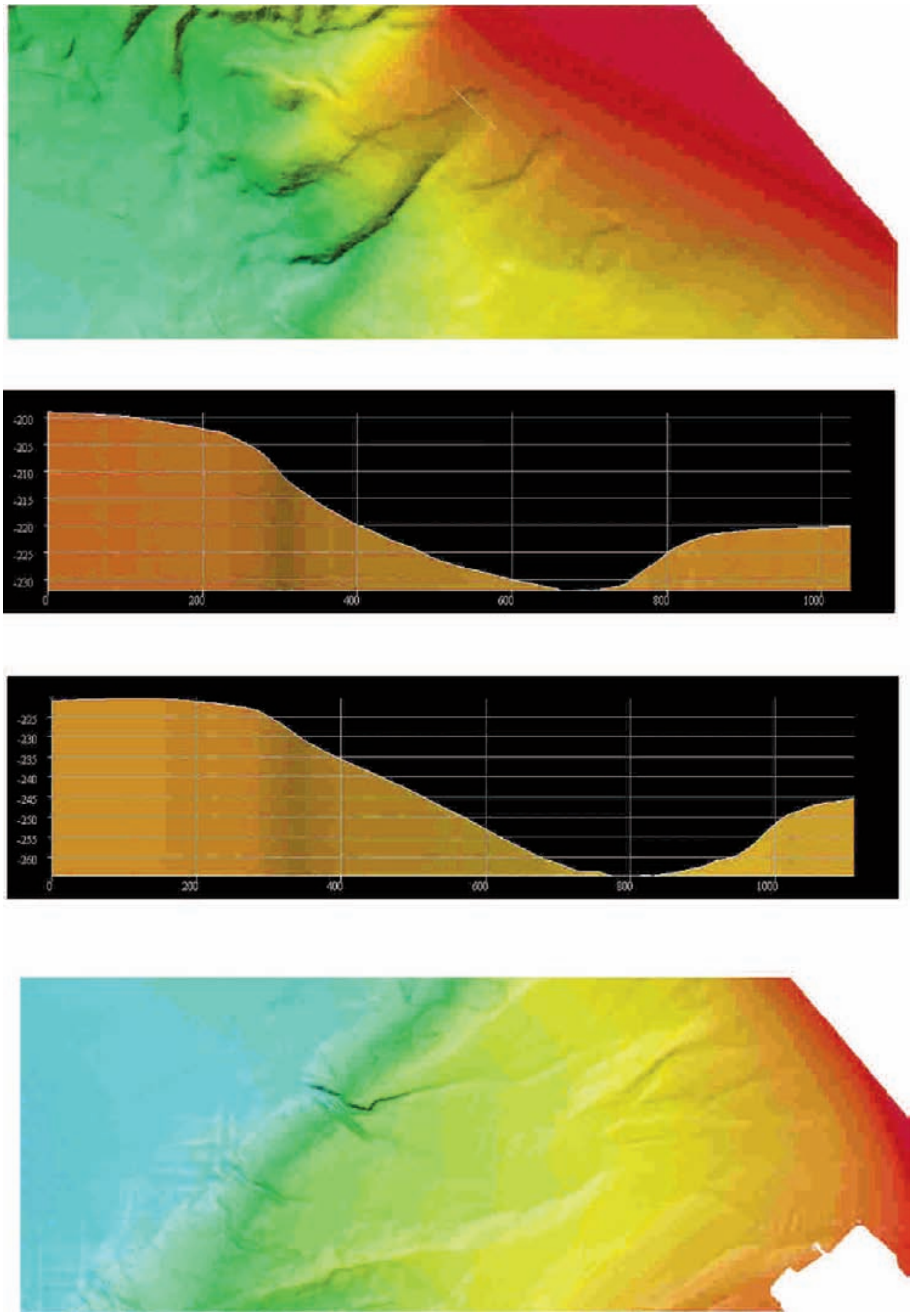

Figure 16 (a) Localization on detailed DTM of the bathymetric profiles used for the volumetric computation of submarine landslides A and B (see also fig. 15). (b) Bathymetric profiles on the slide scars A and B, respectively A-A' and B-B'. (c) Detailed Digital Terrain Model showing channels and canyons eroding the lower continental slope of the northern Salerno Gulf, feeding the surrounding bathyal plain.
Figura 16 (a) Localizzazione su un DTM di dettaglio dei profili batimetrici usati per effettuare il computo delle volumetrie delle frane sottomarine. (b) Profili batimetrici sulla nicchia di distacco. (c) Modello Digitale del Terreno di dettaglio che mostra i canali ed i *canyons* che erodono la scarpata continentale inferiore del Golfo di Salerno settentrionale, che alimentano la piana batiale circostante.

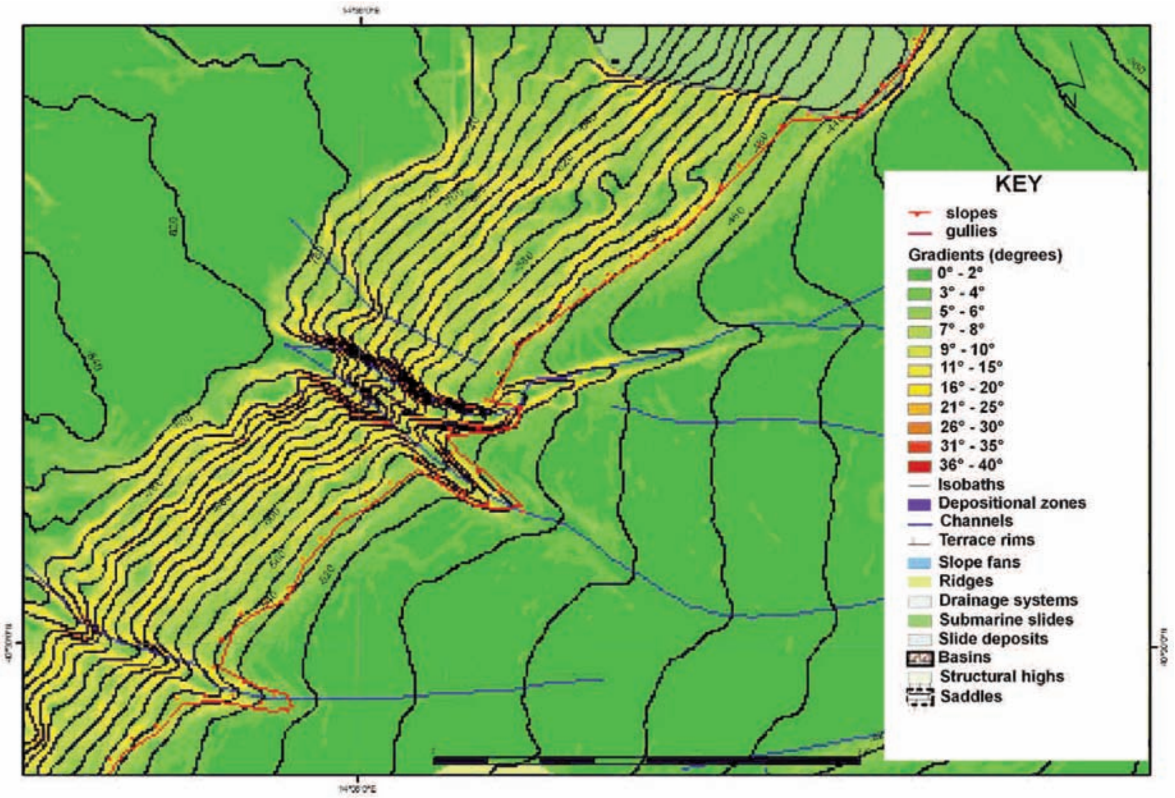

Figure 17 Detail of a bathymetric contour map showing submarine canyons off the northern Salerno Gulf.
Figura 17 Dettaglio di mappa batimetrica a *contour* che mostra i *canyons* sottomarini localizzati fuori il settore settentrionale del Golfo di Salerno.

its axis and uprises from – 1060 m to – 600 m for the first peak and to – 420 m for the second peak.
The eastern high is characterized by high gradients, reaching 35°-40° (Fig.15). On the western flank of the same high, the gradients seem to be minor; it grades into an intra-slope basin, located at water depths of – 803 m/804 m. The second high, located westwards, shows two peaks located along its axis, the northern one reaching water depths of – 340 m and the southern one of – 240 m.
Three important submarine slides, previously unknown, have been identified in the study area (Fig. 15). The northernmost one (A in Fig. 15) develops at water depths ranging from – 180 m and – 560 m for an overall length of about 3 kilometres. The second slide (B in Fig. 15) shows a length of about 3500 m and comprises an area located between the depths of – 200 m and – 440 m. The third one (C) has a slide scar of about one kilometre located at a water depth of – 430 m and corresponds to slide deposits higher than 30 m at – 700 m of water depth.
On the continental slope offshore of the Sele Plain, several well-identified channels appear, which are well illustrated by the three-dimensional reconstruction of Fig. 16. The submarine channels start from – 200 m of water depth; several drainage axes join into three main channels, reaching the slope rim, located at the – 440 m of water depth. On the slope, the channels become two canyons. The easternmost one (Fig. 16) shows pronounced rims and starts, with high gradients, from a water depth of – 520 m reaching the – 840 m of water depth. The second canyon, located 2.5 km to the south, is located in the same bathymetric interval and shows at its base a related deposit with a diameter of more than 2500 m and a maximum height of more than 30 m.

3.2 Tectonic setting and seismic stratigraphy

The Salerno Valley is a Pleistocene half-graben, whose identification and tectonic setting have been controlled by the normal fault (with a probable strike-slip component) showing an average thickness of about 1500 metres [Bartole et al. 1983; Bartole 1984; Aiello et al. 1997a; 1997b; 2007]. This fault has controlled the origin of the Salerno canyon, showing erosional processes which are still active and synsedimentary tectonics. The acoustic basement is composed of Mesozoic carbonate platform unit (penetrated by the lithostratigraphic wells "Mina 1", "Milena 1", "Margherita Mare 1") and the overlying Miocene siliciclastic units related to the "Liguride Units" and the related Miocene foredeep deposits ("Flysch del Cilento") cropping out on land in the Cilento Promontory [D'Argenio et al. 1973; 1986; Bonardi et al. 1988].

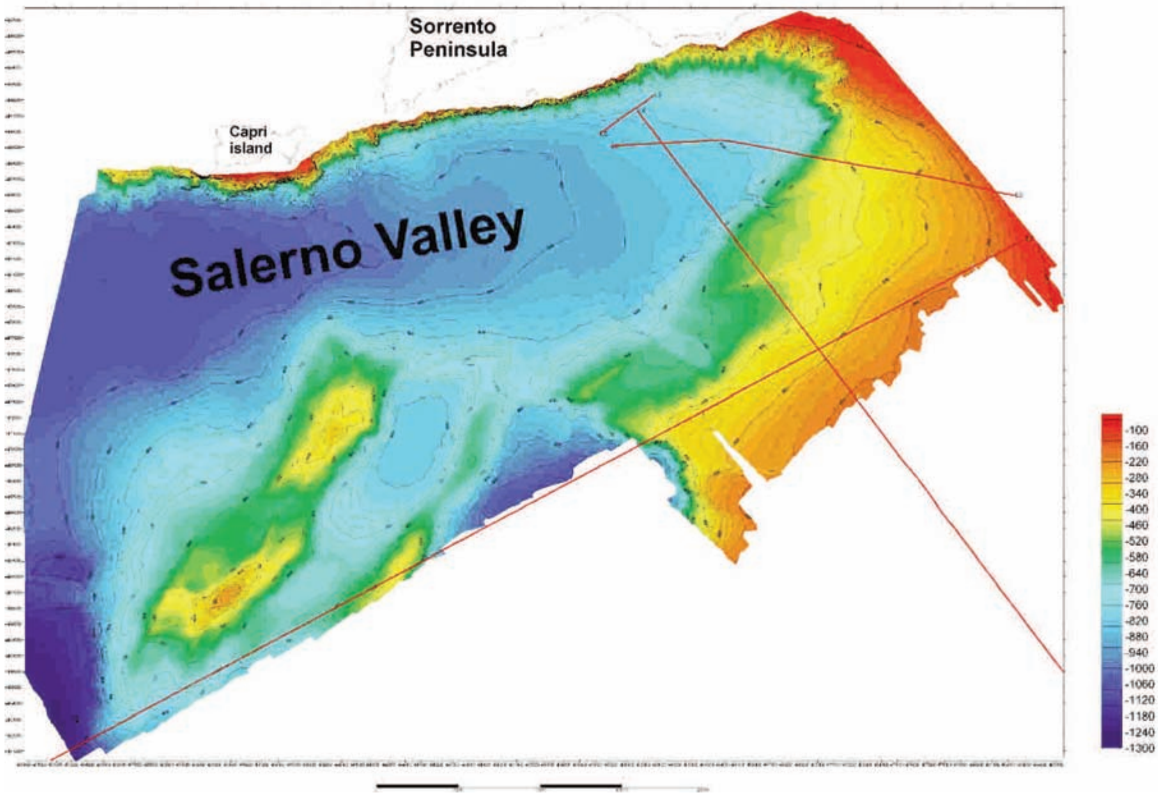

Figure 18 Digital Terrain Model of the Salerno Valley and superimposed location of multichannel seismic profiles recorded in the study area.
Figura 18 Modello Digitale del Terreno della Valle di Salerno riportante l'ubicazione dei profili sismici multicanale acquisiti nell'area in studio.

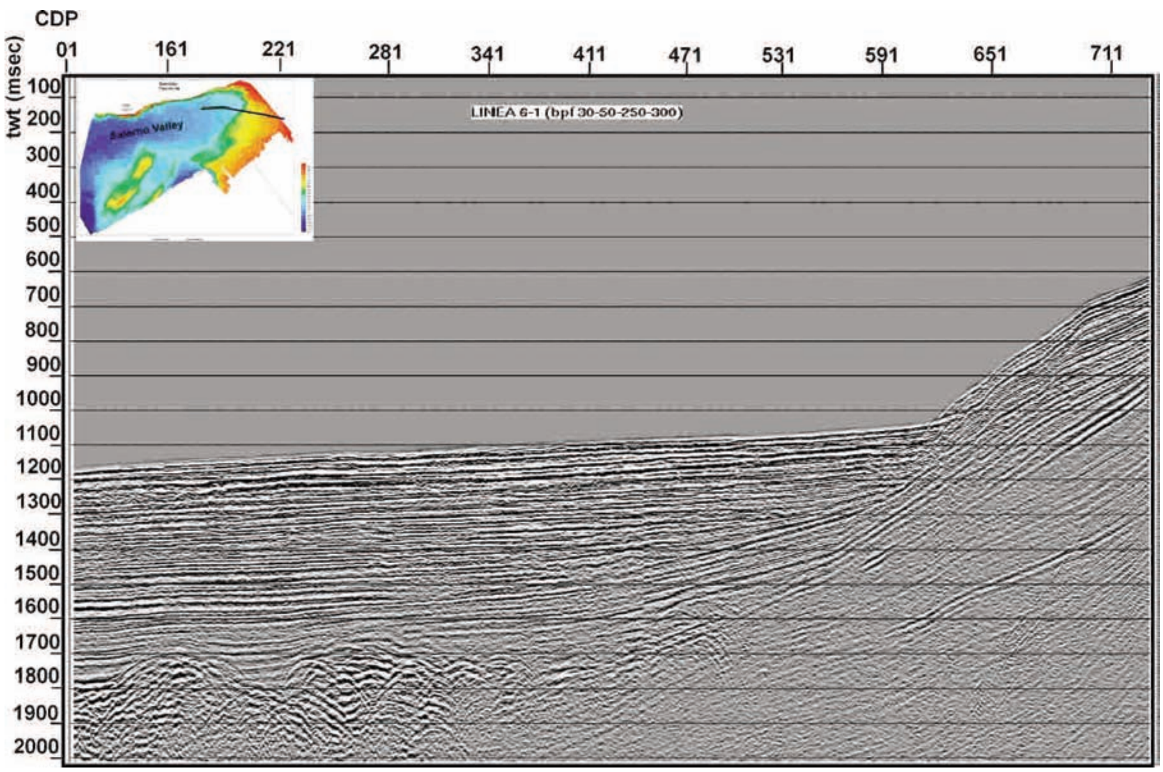

Figure 19 Multichannel seismic profile L6, acquired in the Salerno Valley during the cruise SISTERII.
Figura 19 Profilo sismico multicanale L6 acquisito nella Valle di Salerno durante la crociera oceanografica SISTERII.

The Salerno Valley shows an example of complex Quaternary filling of a tectonically-controlled sedimentary basin, registering the interactions between the effects of the glacio-eustatic sea level fluctuations, the tectonic activity in the source region and the tectonic deformation in the depositional area, lasting up to recent times. High sedimentary supply, combined with a restrict sediment dispersal, have enabled the deposition of a thick sedimentary succession, locally exceeding 3000 m of thickness. The basin filling is composed of marls and marly clays with intercalations of sands and conglomerates and then of marly clays with intercalations of thin sands (Pleistocene). The overall thickness of the Pleistocene filling of the Salerno Valley based on the offshore wells ranges between 1500 m and 2000 m (Mina 1 exploration well). In the Cilento offshore, a regional unconformity, probably related to a non-depositional and/or erosional hiatus (Pliocene is completely missing), characterises the base of the Pleistocene sequences ("Margherita Mare 1" and "Milena 1" exploration wells).

The seismic grid superimposed on the contour map of the Multibeam bathymetry is reported in Fig. 18.

The seismic profile L6 shows an E-W trending (in its first part), passing to a NNW-SSE trending (in its second part) and crosses the Salerno Valley at water depths ranging from – 900 m to – 500 m. The seismic profile shows a first part depicting the basin (i.e. the Salerno Valley) at water

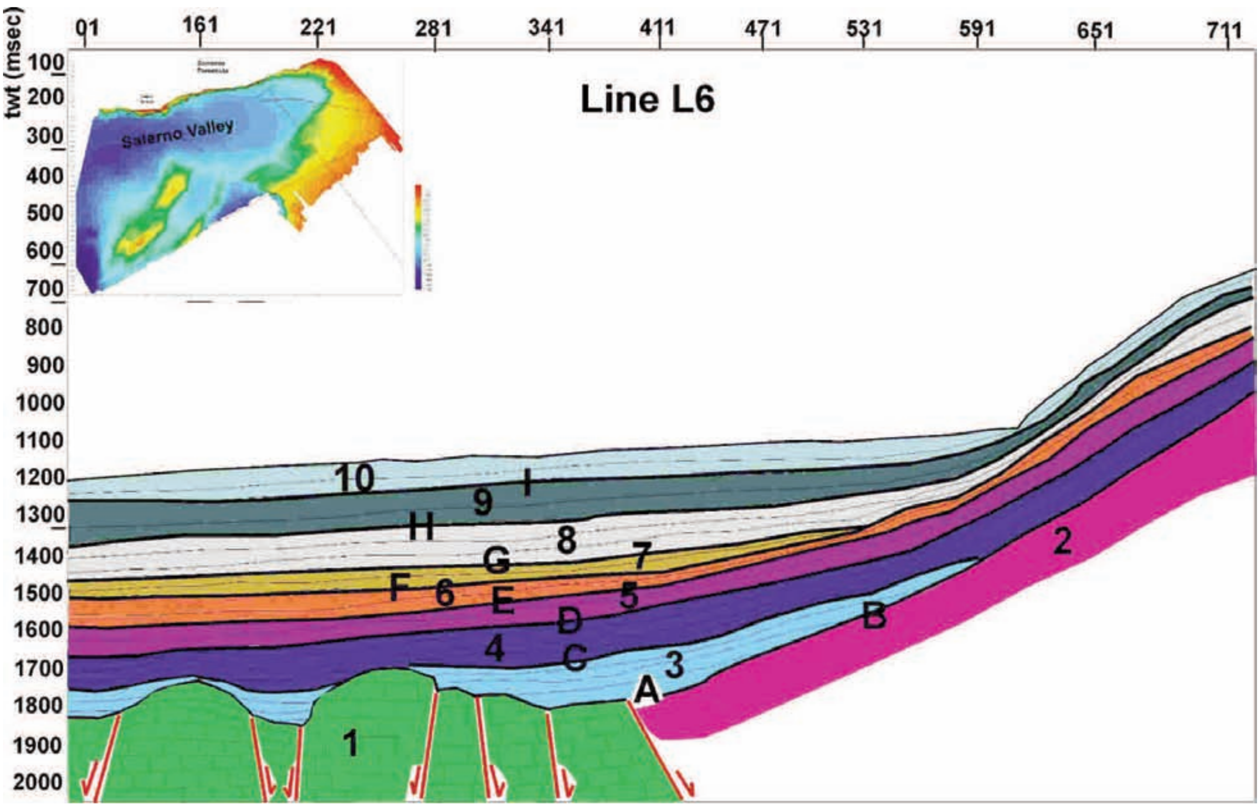

Figure 20 Geologic interpretation of multichannel seismic profile L6 (see the fig. 19 for the uninterpreted seismic profile). Key. 1: Meso-Cenozoic platform carbonates. 2: Early Pleistocene marine deposits, which can be probably attributed to relic prograding wedges. 3: First seismic sequence of the basin filling, onlapping the B unconformity (located at the top of the seismic sequence 2) and unconformably overlying the unit 1, with parallel and subparallel reflectors. 4: Second seismic sequence of the basin filling, characterised by inclined reflectors on the slope and by parallel reflectors in the basin. 5: Third seismic sequence of the basin filling, characterised by inclined reflectors on the slope and by parallel reflectors in the basin. 6: Fourth seismic sequence of the basin filling, characterised by inclined reflectors on the slope (where it is relatively thinner) and by parallel reflectors in the basin. 7: Fifth seismic sequence of the basin filling, characterised by a wedge-shaped external geometry, onlapping the F unconformity (located at the top of the seismic sequence 6). 8: Sixth seismic sequence of the basin filling, characterised by inclined reflectors on the slope and parallel reflectors in the basin. 9: Seventh seismic sequence of the basin filling, characterised by inclined reflectors on the slope and parallel reflectors in the basin. 10: Eighth seismic sequence of the basin filling, characterised by inclined reflectors on the slope and parallel reflectors in the basin.

Figura 20 Interpretazione geologica del profilo sismico multicanale L6 (in fig. 19 è riportato il profilo non interpretato). Legenda. 1: Carbonati di piattaforma meso-cenozoici. 2: Depositi marini del Pleistocene inferiore, attribuibili a cunei progradanti relitti. 3: Prima sequenza sismica nel riempimento del bacino, in onlap sull'unconformity B (posta al top della sequenza sismica 2) ed in discordanza sull'unità sismica 1, con riflettori paralleli e subparalleli. 4: Seconda sequenza sismica nel riempimento del bacino, caratterizzata da riflettori inclinati sulla scarpata e da riflettori paralleli nel bacino. 5: Terza sequenza sismica nel riempimento del bacino, caratterizzata da riflettori inclinati sulla scarpata e da riflettori paralleli nel bacino. 6: Quarta sequenza sismica nel riempimento del bacino, caratterizzata da riflettori inclinati sulla scarpata (dove si presenta relativamente più sottile) e da riflettori paralleli nel bacino. 7: Quinta sequenza sismica del bacino, caratterizzata da una geometria esterna cuneiforme, in onlap sulla unconformity F (ubicata al top della sequenza sismica 8) Sesta sequenza sismica del bacino, caratterizzata da riflettori inclinati sulla scarpata e da riflettori paralleli nel bacino. 9) Settima sequenza sismica del bacino, caratterizzata da riflettori inclinati sulla scarpata e da riflettori paralleli nel bacino. 10) Ottava sequenza sismica del bacino, caratterizzata da riflettori inclinati sulla scarpata e da riflettori paralleli nel bacino.

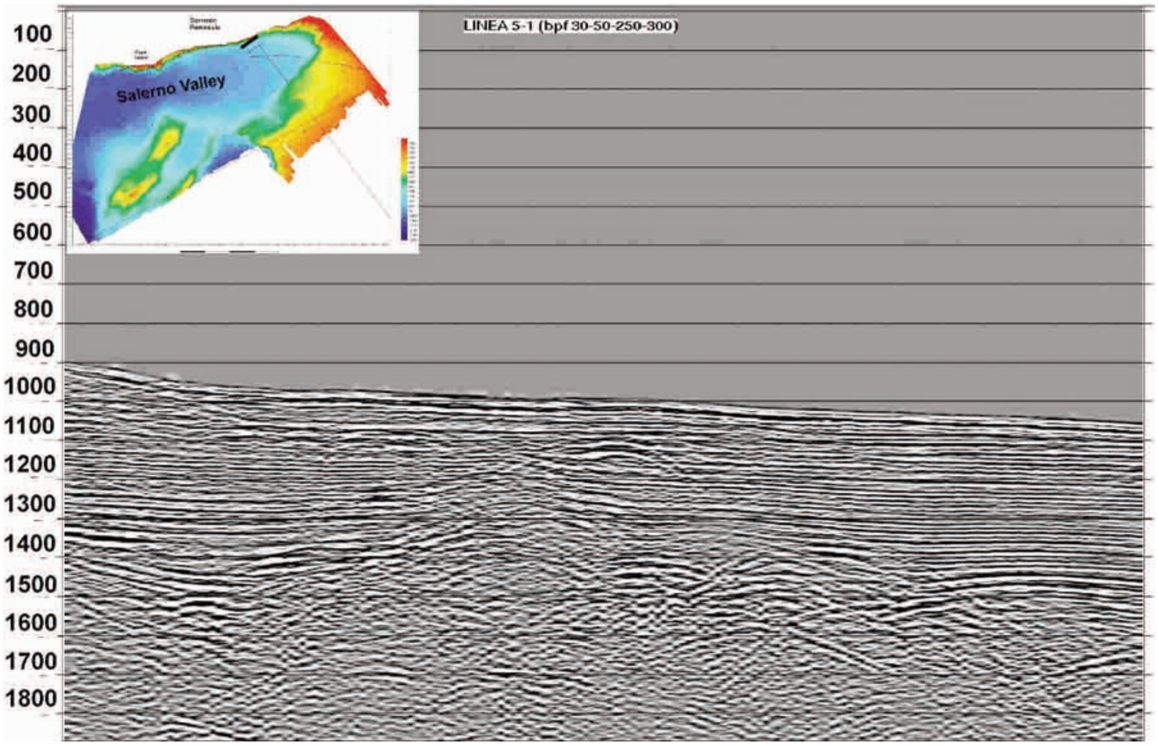

Figure 21 Multichannel seismic profile L5, acquired in the Salerno Valley during the oceanographic cruise SISTERII.
Figura 21 Profilo sismico multicanale L5, acquisito nella Valle di Salerno durante la crociera oceanografica SISTERII.

depths of about – 900 m, rising in correspondence to a break in slope located at about – 825 m to – 525 m along the flank of the slope surrounding the western sector of the Salerno Gulf (Fig. 17).

The geological interpretation of the multichannel profile L6, carried out on seismic stratigraphy criteria (Fig. 20) has enabled the identification of several seismic horizons, corresponding to significant unconformities. In particular, an important unconformity, located between 1.7 and 1.8 sec of depth (two-way travel times) has been correlated with the top of the Meso-Cenozoic carbonatic acoustic basement, widely cropping out in the Sorrento Peninsula structural high. This unconformity (also recognised on seismic profile L5) is strongly downthrown by normal faulting, and marks the top of the Meso-Cenozoic acoustic basement and the base of the Pleistocene basin filling of the Salerno Valley. The corresponding seismic horizon lacks in lateral continuity and grades towards parallel seismic reflectors, which form a thick sedimentary package along the slope.

The Pleistocene basin filling of the Salerno Valley is organised in eight seismic sequences (3 to 10 in Fig. 20) separated by unconformities (B to I in Fig. 20), for an overall thickness of about 600 msec (corresponding to about 510 m by using a seismic velocity of about 1700 m/sec for qualitative time to depth conversion). The seismic sequence 2 constitutes the oldest sedimentary drape, overlying the continental slope which bounds the eastern sector of the Salerno Gulf; it is characterized by parallel reflectors, with high amplitude and continuity. Its top corresponds to an unconformity (reflector B) identified by the onlap of the overlying seismic sequence (sequence 3 in Fig. 20). The sequence 3 corresponds to the earliest phases of the basin filling of the Salerno Valley; it is characterised by wedge-shaped external geometries overlying the A unconformity and is characterised by onlap terminations on the unconformity B. Its upper boundary corresponds to the unconformity C. The seismic sequences 4, 5 and 6 (Fig. 20) show seismic horizons with high amplitude and lateral continuity and an overall geometry corresponding to a vertically-aggrading infill, both in the basin and in the continental slope. The stratigraphic relationships in the three sequences are of paraconcordance, also in relation to the bounding unconformities. The unconformity F (Fig. 20), located at the top of the seismic sequence 6, indicates a main variation in the aggradational geometries of the basin filling and a probable variation in the depositional conditions in the sedimentary basin, probably accompanied by submarine erosion. This is evidenced by the onlap of the sequence 7 on the unconformity F (Fig. 20). The sequence 7 is characterised by parallel and continuous seismic reflectors, alternating with transparent intervals. The vertical aggradation in the sedimentary basin of the Salerno Valley and on the slope laterally bounding the basin also continues in cor-

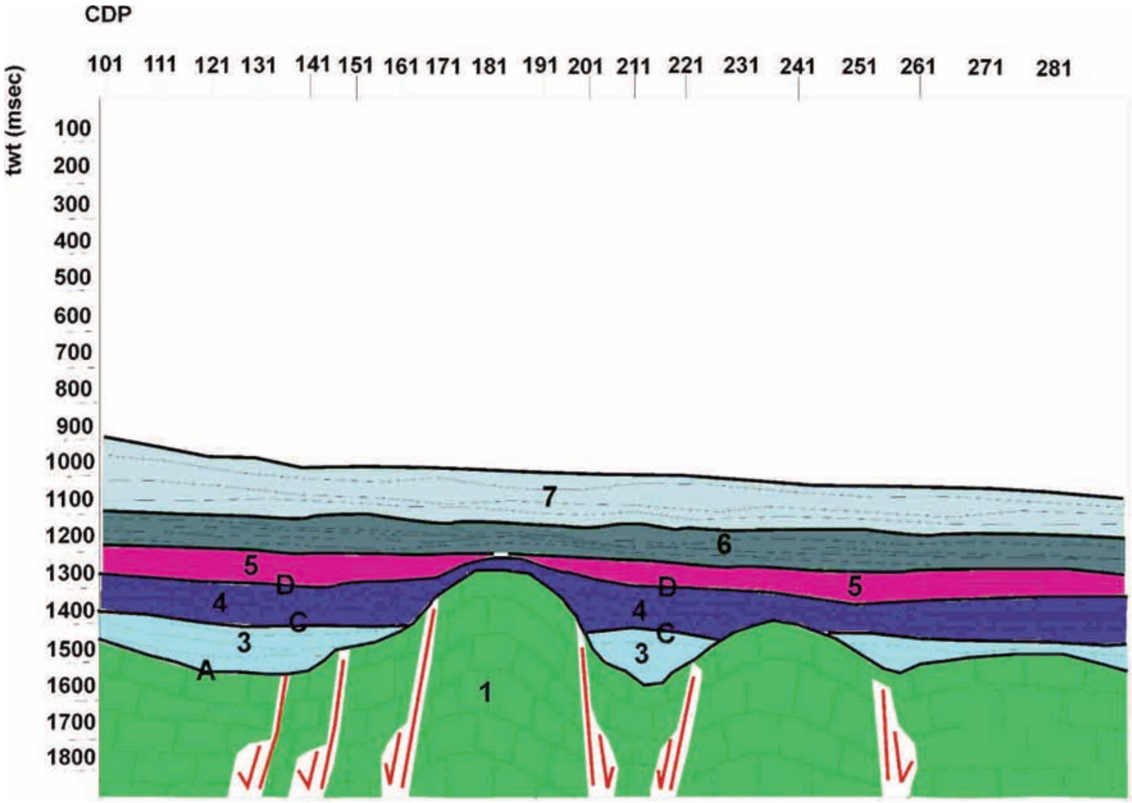

Figure 22 Geologic interpretation of the multichannel seismic profile L5 (see the fig. 21 for the uninterpreted profile). Key. 1: Acoustic basement, corresponding to Meso-Cenozoic platform carbonates. 3: First seismic sequence of the basin filling, characterised by parallel to subparallel seismic reflectors, unconformably overlying the A unconformity. 4: Second seismic sequence of the basin filling, characterised by parallel to subparallel seismic reflectors, thinning in correspondence to structural highs of the acoustic basement. 5: Third seismic sequence of the basin filling, characterised by parallel to subparallel seismic reflectors, thinning in correspondence to structural highs of the acoustic basement and onlapping the D unconformity. 6: Fourth seismic sequence of the basin filling, characterised by parallel to subparallel seismic reflectors. 7: Fifth seismic sequence of the basin filling, characterised by parallel to subparallel seismic reflectors.
Figura 22 Interpretazione geologica del profilo sismico multicanale L5 (si veda la fig. 21 per il profilo non interpretato). Legenda. 1: Basamento acustico, corrispondente ai carbonati di piattaforma meso-cenozoici. 3: Prima sequenza sismica del riempimento del bacino, caratterizzata da riflettori sismici paralleli e subparalleli, che ricopre in discordanza l'unconformity A. 4: Seconda sequenza sismica del riempimento del bacino, caratterizzata da riflettori da paralleli a subparalleli, che si assottiglia in corrispondenza di alti strutturali del basamento acustico carbonatico. 5: Terza sequenza sismica del riempimento del bacino, caratterizzata da riflettori da paralleli a subparalleli, che si assottiglia in corrispondenza di alti strutturali del basamento acustico carbonatico e ricopre in onlap l'unconformity D. 6: Quarta sequenza sismica del riempimento del bacino, caratterizzata da riflettori sismici da paralleli a subparalleli. 7: Quinta sequenza sismica del riempimento del bacino, caratterizzata da riflettori sismici da paralleli a subparalleli.

respondence to the seismic sequences 8, 9 and 10, showing an overall thickness of about 300 msec. The blanking of the acoustic signal in correspondence to localised seismic intervals indicates the occurrence of chaotic intervals, probably corresponding to resedimented deposits, triggered by submarine instabilities, occurring in the sedimentary filling of the Salerno Valley.

The seismic profile L5 shows an E-W trending and crosses the Salerno Valley in a sector located at approximately – 750 metres of water depth (Fig. 21), as evidenced by the integrated interpretation of Multibeam bathymetry and multichannel seismics.

The geological interpretation of the multichannel profile L5 (Fig. 22) shows four main seismic sequences separated by significant seismic horizons, corresponding to regional unconformities (A C D). A strong seismic horizon, located at depths ranging between 1.5 and 1.6 sec, is presumably interpreted as the Meso-Cenozoic unconformity (A in Fig. 20), located at the top of platform carbonates, extensively cropping out in correspondence to the Capri island-Sorrento Peninsula structural high. The platform carbonates, Meso-Cenozoic in age ("Campania-Lucania carbonate platform" Auct.) are downthrown southwards in correspondence to the regional master fault Capri-Sorrento Peninsula, bounding southwards the Sorrento Peninsula and controlling the formation of a tectonic slope, located southwards of the Sorrento Peninsula (see also the paragraph on the morpho-bathymetric analysis). The sequence 1 is interpreted as the Meso-Cenozoic platform carbonates (Fig. 20). In fact, it is probable that in the sector of the Salerno Valley crossed by the line L5, there a strong reduction or a total absence of the Neogene sequences related to the "Flysch del Cilento"

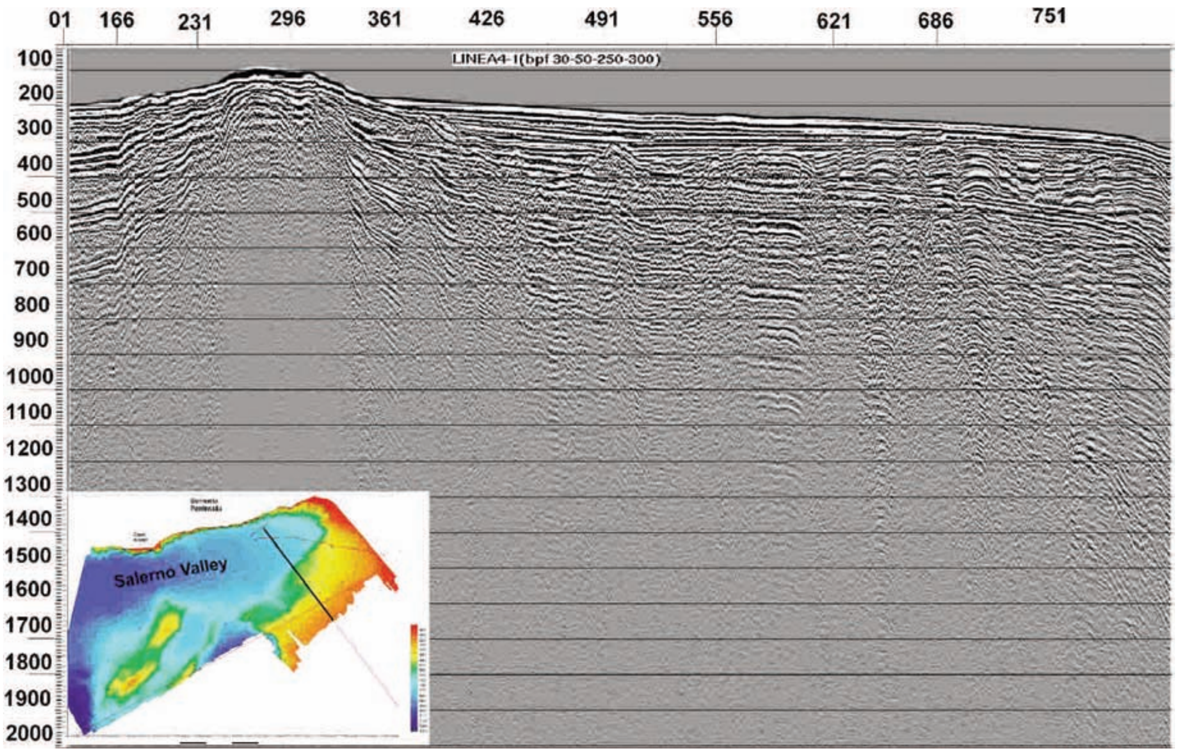

Figure 23 Multichannel seismic profile L4 acquired in the Salerno Gulf parallel to the Tyrrhenian shoreline.
Figura 23 Profilo sismico multicanale L4 acquisito nel Golfo di Salerno parallelamente alla linea di costa tirrenica.

Auct. [Bonardi et al. 1988], which have been recognised on the continental shelf surrounding the southern sector of the Salerno Gulf and the Cilento Promontory (see also the geological interpretation of the profile L4).
Third seismic sequence of the basin filling, characterised by parallel to subparallel seismic reflectors, thinning in correspondence to structural highs of the acoustic basement and onlapping the D unconformity. 6: Fourth seismic sequence of the basin filling, characterised by parallel to subparallel seismic reflectors. 7: Fifth seismic sequence of the basin filling, characterised by parallel to subparallel seismic reflectors.
The seismic sequences numbered as 3-7 (Fig. 22; see also Fig. 20) refer to the Pleistocene sedimentary filling of the Salerno Valley, with an average thickness of 0.5 sec in this distal sector of the basin. These sequences are characterised by parallel to subparallel seismic reflectors, highly continuous, typical of a distal marine sedimentation composed of alternating sands and shales. It is worth noting the occurrence of intervals characterised by chaotic seismic facies, suggesting the presence of turbiditic episodes, probably triggered by the tectonic activity. The latter one is evidenced by the occurrence of normal faults having a little vertical throw, involving the top of the Meso-Cenozoic sequence (A reflector), located at the top of the sequence named as 1.
The seismic profile L4 runs on the continental shelf of the Salerno Valley at water depths ranging from 150 m to 250 m with a NNW-SSE trending, parallel to the shoreline of the Salerno Gulf (Fig. 23).
The seismic interpretation has enabled the distinction of several sequences, probably Pleistocene in age, strongly deformed by normal faulting, delineating a structural framework characterised by structural highs and sedimentary basins. These sequences overlie an acoustic basement probably correlated with the "Flysch del Cilento" Auct. (Fig. 21).
The seismic section L4 (Fig. 23) is characterised by the occurrence of a structural high, in correspondence of which a pattern of normal faults bounding the flanks of the structure both towards NNW and towards SSE can be recognised. The chaotic seismic facies observed in correspondence to the high and its stratigraphic position suggest that it is composed of Neogene terrains correlated with the "Flysch del Cilento" Auct., widely cropping out in the adjacent emerged sectors of the Southern Apennines [Bonardi et al., 1988]. As known from the literature data, these terrains are characterised by alternating turbiditic sands and shales and have been intensively deformed by compressional tectonics during the deformational phases of the Apenninic chain and, successively, by the extensional tectonics, during the phases of differential neotectonic uplift enabling the formation of horst and graben structures in the whole Apenninic margin. The structural high represents, perhaps, a high of the acoustic basement (FC in Fig. 24).
It is worth noting that the structural high, cropping out at

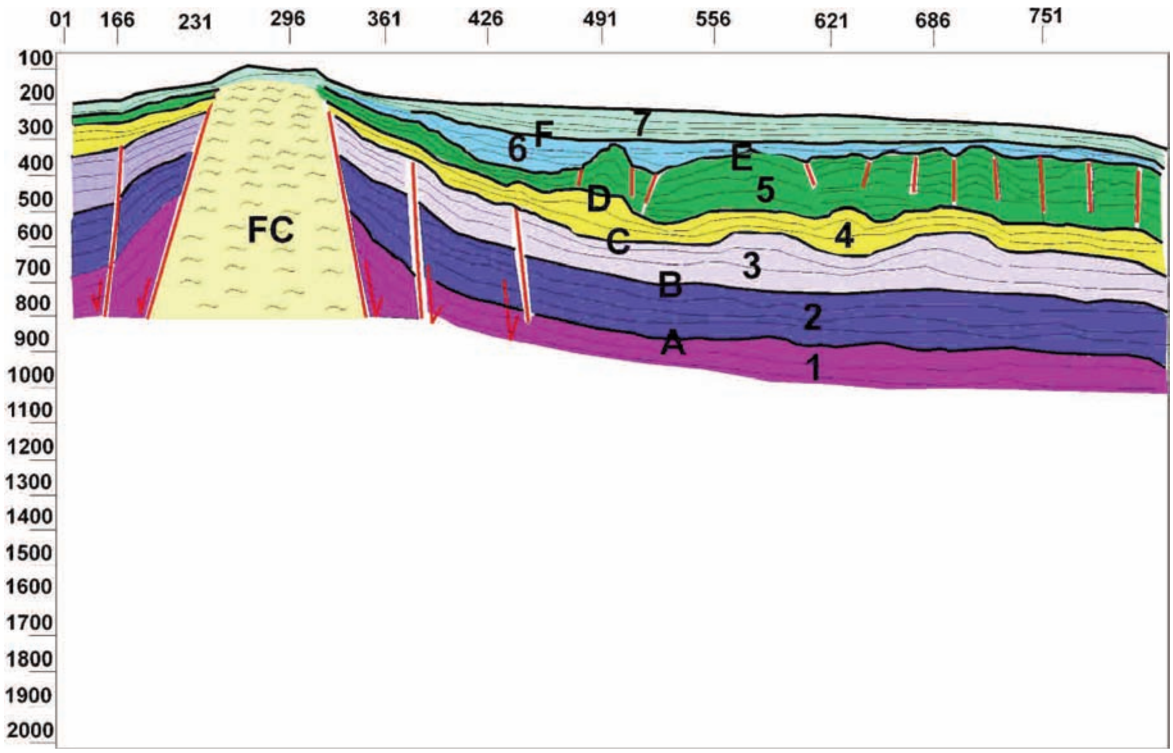

Figure 24 Geologic interpretation of the multichannel profile L4 (see fig. 23 for the uniterpreted seismic profile). Key. FC: Acoustic basement (Cenozoic siliciclastic deposits related to the "Flysch del Cilento" Auct.). 1: Seismic unit of the Pleistocene basin filling, in lateral contact with the acoustic basement along normal faults, characterised by parallel to subparallel seismic reflectors. 2: Seismic unit of the Pleistocene basin filling, in lateral contact with the acoustic basement along normal faults, characterised by parallel to subparallel seismic reflectors. 3: Seismic unit of the Pleistocene basin filling, in lateral contact with the acoustic basement along normal faults, characterised by parallel to subparallel seismic reflectors. 4: Seismic unit of the Pleistocene basin filling, onlapping the flanks of the structural high of the Cenozoic acoustic basement and characterised by parallel seismic reflectors and slight thickness variations. 5: Seismic unit of the Pleistocene basin filling, onlapping the flanks of the structural high of the Cenozoic acoustic basement and characterised by parallel to subparallel seismic reflectors, slightly deformed by normal faulting. 6: Seismic unit of the Pleistocene basin filling, onlapping the flanks of the structural high of the Cenozoic acoustic basement, infilling intra-basinal depressions with bi-directional onlaps. 7: Late Pleistocene-Holocene seismic unit, characterised by low angle progradational reflectors, cropping out at the sea bottom.

Figura 24 Interpretazione geologica del profilo sismico multicanale L4 (si veda la fig. 23 per il profilo non interpretato). FC: Basamento acustico (depositi silicoclastici cenozoici collegati al "Flysch del Cilento" *Auct.*). 1: Unità sismica del riempimento pleistocenico del bacino, in contatto laterale con il basamento acustico lungo faglie dirette, caratterizzata da riflettori sismici da paralleli a subparalleli. 2: Unità sismica del riempimento pleistocenico del bacino, in contatto laterale con il basamento acustico lungo faglie dirette, caratterizzata da riflettori sismici da paralleli a subparalleli. 3: Unità sismica del riempimento pleistocenico del bacino, in contatto laterale con il basamento acustico lungo faglie dirette, caratterizzata da riflettori sismici da paralleli a subparalleli. 4: Unità sismica del riempimento pleistocenico del bacino, in onlap sui fianchi dell'alto strutturale del basamento acustico cenozoico e caratterizzata da riflettori sismici paralleli e da deboli variazioni di spessore. 5: Unità sismica del riempimento pleistocenico del bacino, in onlap sui fianchi dell'alto strutturale del basamento acustico cenozoico e caratterizzata da riflettori sismici da paralleli a subparalleli, debolmente dislocata da faglie dirette. 6: Unità sismica del riempimento pleistocenico del bacino, in onlap sui fianchi dell'alto strutturale del basamento acustico cenozoico, che riempie depressioni intra-bacinali con configurazioni di onlap bidirezionale. 7: Unità sismica del Pleistocene superiore-Olocene, caratterizzata da riflettori progradanti a basso angolo, affiorante al fondo mare.

the sea bottom (between the CDP points 250 and 420), where it is overlain by a drape of recent sediments, characterised by sub-horizontal seismic reflectors for an overall thickness of 70 msec, has induced the deformation of the sea bottom itself. Then, the morphology of the sea bottom in the area affected by the occurrence of the high shows a structural control. The pattern of normal faults controlling the deformation of the structural high is characterised by a couple of main faults and by some secondary faults having a trending parallel to the main fault. These secondary faults downthrow both the acoustic basement and the first two underlying Pleistocene sequences, delineating the sedimentary basin of the Salerno Gulf. This downthrowing is evident both towards NNW and towards SSE, delineating two zones of sedimentary basin, whose filling is characterised by almost five seismic sequences, separated by tectonic unconformities, significant at a regional scale and corresponding to main seismic reflectors, identified at a scale of the whole seismic section. The top of the structural high seems to be eroded, indicating that it has been affected by probable phases of differential uplift and erosion, determining the formation of an erosional surface, probably polycyclic, at the top of the structure and at the base of the recent sediments (Figs. 23-24).

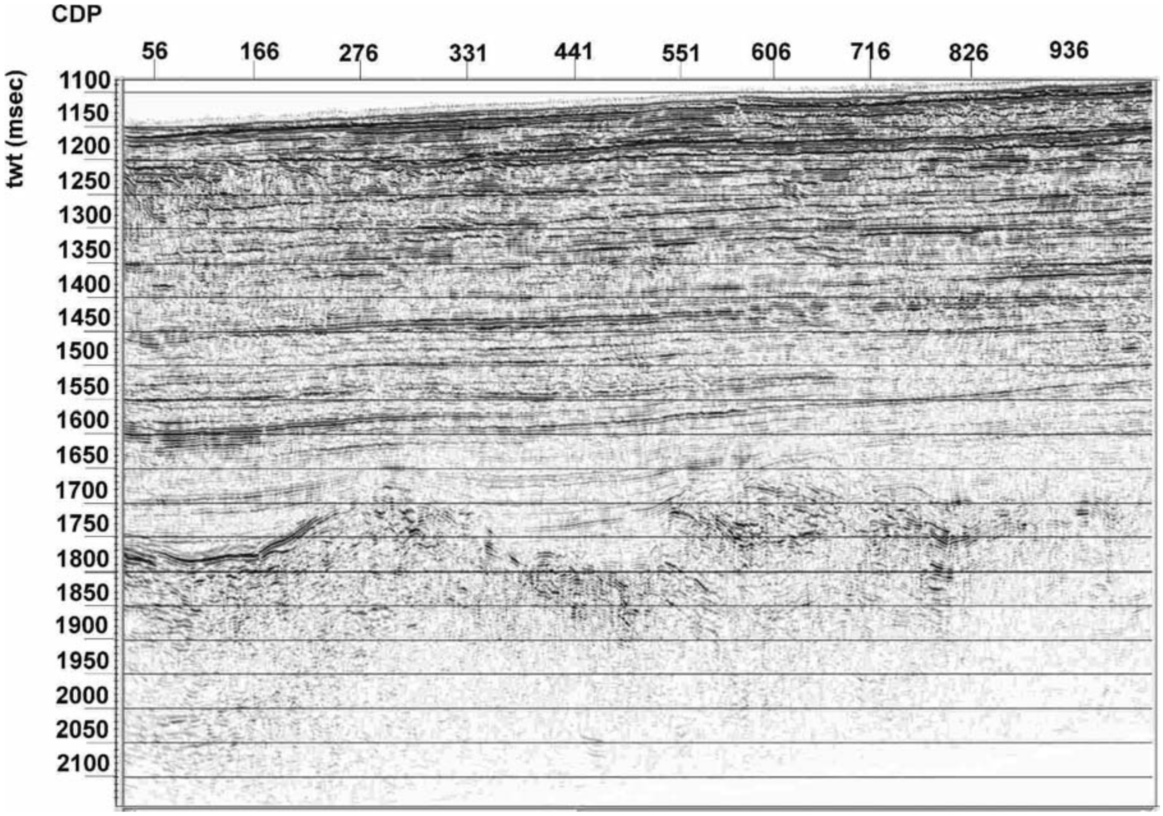

Figure 25 Detail of the multichannel seismic profile L6 showing the Meso-Cenozoic unconformity.
Figura 25 Dettaglio del profilo sismico multicanale L6 mostrante la *unconformity* meso-cenozoica.

The recognised seismic sequences delineate the stratigraphic and structural framework of the sedimentary basin occurring in correspondence to the Salerno Gulf. A first strong seismic horizon (A in Fig. 26) recovered at depth of 0.8 sec is interpreted as an unconformity surface, representing the base of the first sequence, characterised by discontinuous and subparallel seismic reflectors. The seismic horizon overlies the structural high of the Meso-Cenozoic acoustic basement. The overlying sequence (sequence 3 in fig. 26) appears involved in wedging processes, due to synsedimentary tectonics, presumably simultaneous with the activity of normal faults along the Meso-Cenozoic acoustic basement. The top of the seismic sequence coincides with a strong horizon located at about 0.75 sec of depth, onlapping the flank of the structural high uprising to 0.4 sec of sediments. A second seismic sequence shows characteristics similar to those of the first sequence. It is bounded at the base and at the top by strong seismic horizons, with characteristics of unconformity and involved in wedging in correspondence to the high.

A strong horizon with erosional characteristics, evidenced by an angular unconformity with respect to the underlying seismic reflectors, has been recognised at depths ranging between 0.65 sec and 0.35 sec. The reflector constitutes also the base of a seismic sequence intensively deformed by subvertical faults having little throw and an average thickness of 100 msec. The top of the sequence is deeply eroded; the erosion acted in a differential way, determining the formation of deep incised valleys between the blocks of the sequence itself, corresponding to the footwalls of the fault blocks. Over this sequence another seismic sequence has been recognised, characterised by continuous reflectors, showing configurations of bidirectional onlaps and of low angle downlaps. They represent sedimentary filling deposited in the incised valleys, coincident with the footwalls of the fault block of the underlying sequence. The top of the sequence corresponds to an evident erosional truncation, approximately sub-horizontal and located at depths of about 0.3 sec. This unconformity may be linked with the erosional truncation corresponding to the eustatic low correlated to the isotopic stage 5e (occurred about 18 ky B.P.) [Martinson et al. 1987].

The last seismic sequence which has been recognised, occurring in outcrop at the sea bottom, is characterised by seismic reflectors having high continuity and amplitude, representing typical facies of distal filling of the sedimentary basin. The occurrence of continuous horizons, typically with horizontal strikes, suggests the occurrence of alternating sands and shales, deposited on a sea bottom of continental shelf, surrounding the Sele Plain.

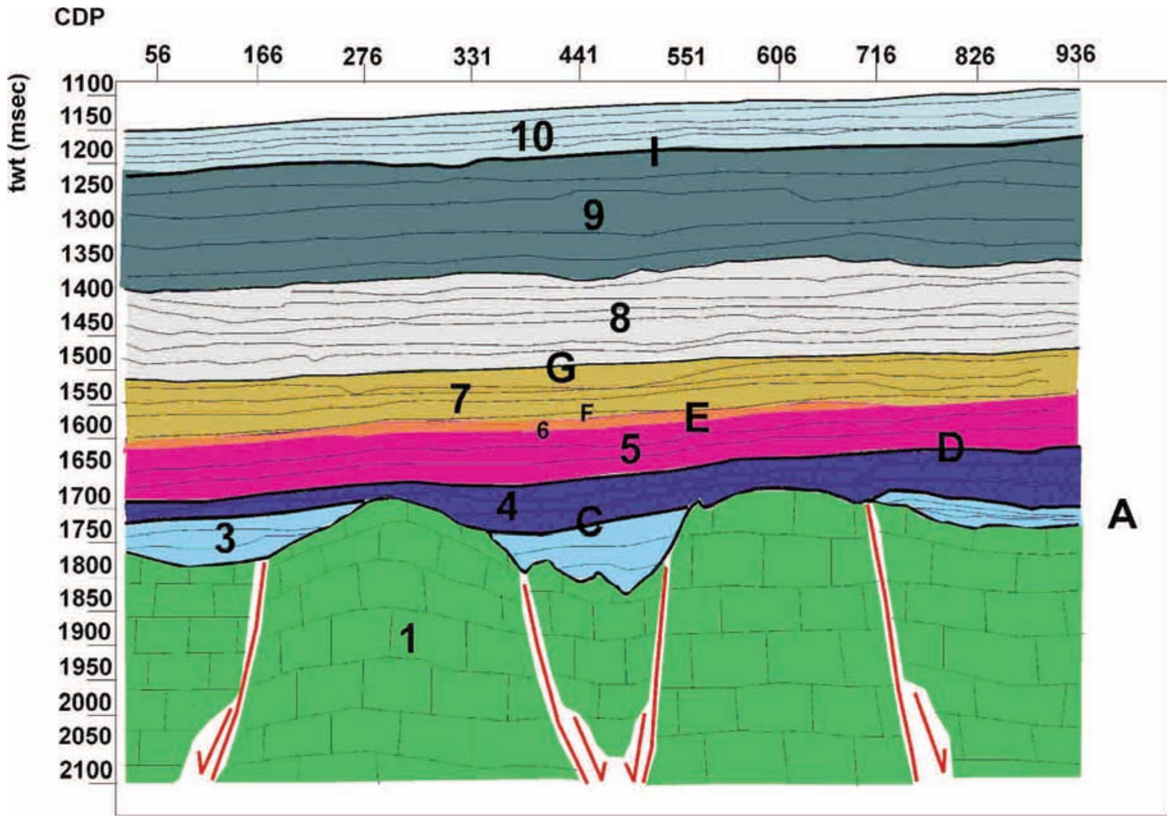

Figure 26 Geologic interpretation of the detail of the L6 seismic profile (see fig. 25 for the uninterpreted seismic profile). Key. 1: Meso-Cenozoic platform carbonates. 3: First seismic unit of the basin filling, overlying the A unconformity (located at the top of the seismic sequence 1). 4: Second seismic sequence of the basin filling, characterized by parallel seismic reflectors. 5: Third seismic sequence of the basin filling, characterized by parallel seismic reflectors. 6: Fourth seismic sequence of the basin filling, characterised by parallel seismic reflectors. 7: Fifth seismic sequence of the basin filling, characterized by parallel to subparallel seismic reflectors. 8: Sixth seismic sequence of the basin filling, characterised by parallel to subparallel seismic reflectors.
Figura 26 Interpretazione geologica del dettaglio del profilo sismico L6 (per il profilo non interpretato si veda la fig. 25). Legenda. 1: Carbonati di piattaforma meso-cenozoici. 3: Prima unità sismica del riempimento del bacino, che ricopre la discordanza A (ubicata alla sommità della sequenza sismica 1). 4: Seconda sequenza sismica del riempimento del bacino, caratterizzata da riflettori sismici paralleli. 5: Terza sequenza sismica del riempimento del bacino, caratterizzata da riflettori sismici paralleli. 6: Quarta sequenza sismica del riempimento del bacino, caratterizzata da riflettori sismici paralleli. 7: Quinta sequenza sismica del riempimento del bacino, caratterizzata da riflettori sismici da paralleli a subparalleli. 8: Sesta sequenza sismica del riempimento del bacino, caratterizzata da riflettori sismici da paralleli a subparalleli.

4. Discussion

Particular attention has been paid to the geological interpretation of the multichannel profile L6, on which an important unconformity has been identified (Figs. 25-26). The erosional unconformity, located at depths ranging between 3000 and 3500 metres (Figs. 25-26), is located at the top of the acoustic basement and is strongly downthrown in correspondence to normal faults. The unconformity is interpreted as the top of Meso-Cenozoic carbonatic sequence, widely cropping out in the adjacent emerged sector, in correspondence to the Sorrento Peninsula structural high. A thick basin filling develops on the unconformity ("the Salerno Valley"), having an average thickness of about 3000 m, probably Pleistocene in age.
The seismic sequences in correspondence to the Salerno Valley are involved by strong wedging and synsedimentary tectonics, particularly in correspondence to a complex, NW-SE trending morpho-structural high, which is evidenced well on the high resolution DTM of the Multibeam bathymetry (fig. 6). The morpho-structural high is located in correspondence to a straight break in slope, marking also the passage to the bathyal sectors, having water depths ranging between – 750 m and – 1100 m. The seismic sequences of the Salerno Valley are also characterised by chaotic seismic facies, alternating with parallel and continuous seismic reflectors, suggesting the occurrence of episodes of gravity mass transport, alternating with normal marine sedimentation. Submarine gravity instabilities are also evident at the sea bottom based on the geological interpretation of the Digital Terrain Model of the Multibeam bathymetry. Moreover, the geophysical data have given interesting, new evidence on deformational styles in the Salerno Valley, characterised by the occurrence of NNW-SSE trending structural trends.

Wide antiformal structures, parallel to the Tyrrhenian shoreline, are interpreted as the result of the envelopment of low angle normal faults.

The tectonic setting of the Salerno Valley is strongly controlled by two main listric normal faults, i.e. the Capri-Sorrento Peninsula master fault, showing a WSW-ENE trending and bounding southwards of the Sorrento Peninsula and the Capo D'Orso master fault, showing a NE-SW trending. Several high-angle normal faults, parallel to the Capri-Sorrento master fault, have been developed in correspondence to the shoreline of the Sorrento Peninsula [Tozzi and Capotorti 1988; Milia and Torrente 1997].

Several minor faults, parallel to the Capri-Sorrento Peninsula master fault are evident from the analysis of seismic profiles, both synthetic and antithetic to the Capo D'Orso normal fault. Wide antiformal structures with ENE-WSW axes, involving the Pleistocene seismic sequences have been interpreted as roll-over mechanisms, resulting from the envelopment of listric normal faults. This evidence concurs with previous studies on the tectonics and the crustal structure of the Campania and Sicily continental margins [Pepe et al. 2000; Milia et al., 2003].

Outcrop and subsurface geological data on the Campania continental margin reveal the presence of NE-SW faults; E-W faults and NW-SE faults. In particular a complex pattern of faults displacing the Southern Apennine thrust belt was identified at the Campania continental margin on the basis of geological mapping [Servizio Geologico Nazionale 1959; 1965a; 1965b; 1966; 1969 and unpublished data] and mesostructural analyses [Gars and Lipman 1984; De Rita and Giordano 1996; Milia and Torrente 1997]. NE-trending faults dipping towards the SE were the main structural features and gave rise to asymmetrical extensional structures, i.e. half-grabens filled with Quaternary deposits and tilted blocks dipping towards the NW [Mariani and Prato 1988].

The Salerno Valley is one of these half-graben, filled with a Quaternary sedimentary wedge that overlies a Meso-Cenozoic substratum (Figs. 19 and 20). To the north of the Salerno Valley, the NE-trending ridge of the Sorrento Peninsula corresponds to an uplifted fault block dipping towards the northwest and bounded by a normal fault dipping towards the southeast.

An older extensional event occurred along NW-SE faults and was followed by the main extensional event linked to the

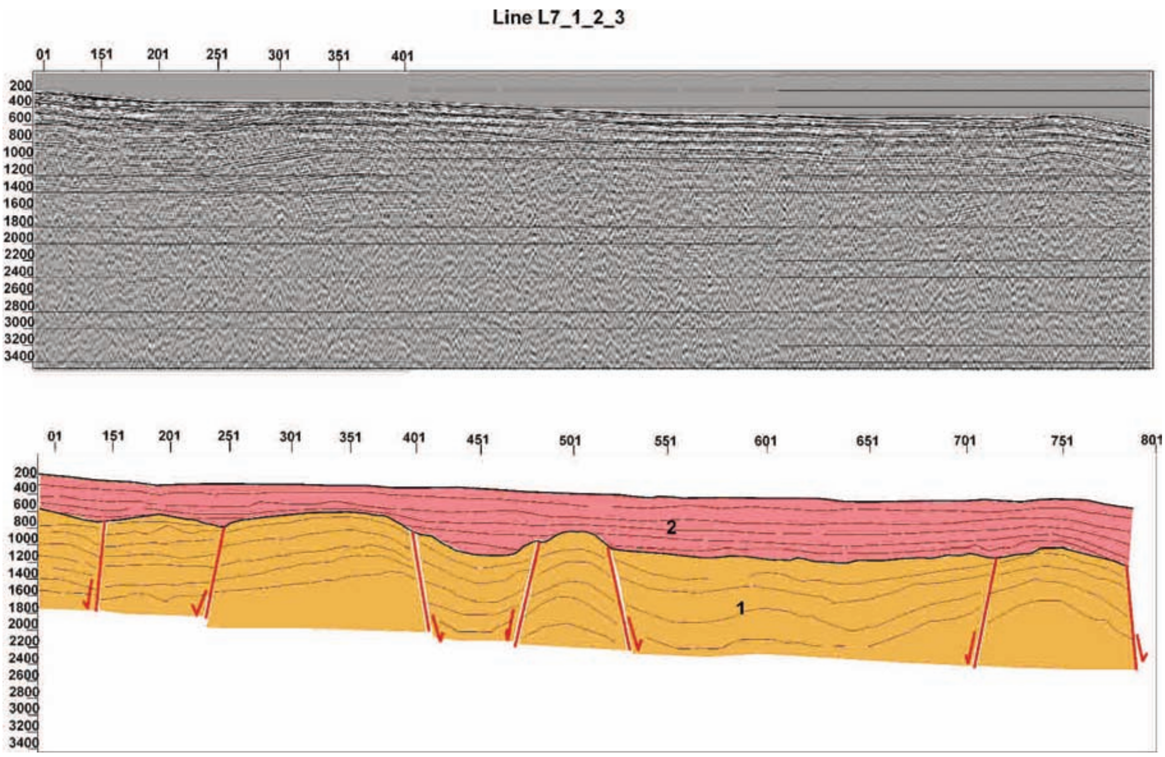

Figure 27 Multichannel seismic profile recorded in the Salerno Gulf parallel to the Tyrrhenian shoreline and showing the roll-over anticlines which characterize the deformational patterns of the Pleistocene deposits of the Salerno Gulf. Key. 1: (Orange). Seismic sequence of the Middle-Late Pleistocene, characterized by parallel to subparallel seismic reflectors, deformed in correspondence to antiformal structures (roll-over anticlines), which are fossilised by the unconformity localised at the top of the seismic sequence. 2: (Red). Seismic sequence of the Late Pleistocene-Holocene, relatively undeformed, characterized by parallel to subparallel seismic reflectors.

Figura 27 Profilo sismico multicanale acquisito nel Golfo di Salerno parallelamente alla linea di costa tirrenica e mostrante le anticlinali a *roll-over* che caratterizzano gli stili deformativi dei depositi pleistocenici della Valle di Salerno. Legenda. 1 (Arancio): Sequenza sismica del Pleistocene medio-superiore, caratterizzata da riflettori da paralleli a subparalleli, deformata in corrispondenza di strutture antiformi (anticlinali da *roll-over*), che appaiono suturate dalla discordanza localizzata alla sommità della sequenza sismica. 2: (Rosso). Sequenza sismica del Pleistocene superiore-Olocene, relativamente indeformata, caratterizzata da riflettori sismici da paralleli a subparalleli.

activity of NE-SW normal faults. The latter tectonic events were active between 700 and 400 ky, producing half-grabens filled by more than 5 km of Quaternary deposits. The stratigraphic signature of these tectonic events corresponds to a Lower Pleistocene marine unconformity-bounded unit overlain by Middle and Late Pleistocene rocks belonging to a transgressive-regressive cycle.

Previous crustal sections on the Campania continental margin have displayed an asymmetric linked fault system characterised by a 10-12 m deep main detachment level, listric normal faults and rollover anticlines [Milia et al. 2003]. The calculated values of extension (e=0.25) is higher than the regional estimates of the Tyrrhenian margin, i.e. on the continental margin off northern Sicily, where lower values of extension have been calculated based on multichannel reflection seismics [Pepe et al. 2000]. In this case, the overall structure of the margin is also controlled by extension, which caused crustal thinning and widespread normal faulting. Extension began in Late Tortonian times and caused the opening of the Cefalù basin controlled by a northward dipping listric fault. Messinian stretching affected most of the future margin and provoked a widening of the basin and normal faulting in the north. Break-up took place in the Late Pliocene and was followed by the deposition of post-rift Pleistocene sediments [Pepe et al. 2000].

5. Conclusion

The Multibeam bathymetric survey has evidenced the high gradients of the continental slope and the occurrence of strong erosional processes, partly still active, mainly at the toe of the slope, where a dense network of erosional channels is evident. The geologic interpretation of seismic profiles has evidenced the tectonic activity along the fault escarpment as a triggering cause for submarine instability processes during the Late Pleistocene-Holocene. This is evidenced also by slump deposits, characterised by a chaotic acoustic facies, intercalated in the distal basin filling of the Salerno Valley. On the contrary, in the distal sectors of the Valley, where the deposition prevails, the shallower sector of the valley shows hints of erosional processes in correspondence to the Salerno canyon and evidence of recent tectonic deformations as antiforms and high-angle normal faults, interpreted in a regional framework as hints of intense erosional tectonics, lasting up to recent times [Aiello et al. 1997a; 1997b].

The morpho-bathymetric data have been recorded by using the Multibeam RESON 8160, a low-frequency Multibeam echosounder particularly suitable for deep sea bottoms. A Digital Terrain Model covering an area of 1600 square kilometres, extending to the north-west from the southern coast of the Capri island to the south-east to the mouth of the river Sele has been produced.

As is evident from the Multibeam data, the continental shelf of the Salerno Gulf shows a marked asymmetry proceeding from north to south, reflecting the different structural domains of this segment of Apenninic margin. The variable extension, of the depth of the shelf break and of the average steepness are in fact controlled by the structural and geologic framework of the shelf margin areas [Bartole et al. 1984; Sacchi et al. 1994], more than the glacio-eustatic variations during the Pleistocene [Trincardi and Field 1992; Ferraro et al. 1997; Buccheri et al. 2002].

The continental slope surrounding the Salerno Valley is characterised by structural depocenters with a NW-SE (Apenninic) trending, originated by the extensional phases related to the Tyrrhenian basin [Trincardi and Zitellini 1987; Malinverno and Ryan 1986], alternating with morpho-structural highs, adjacent to intra-slope basins, where the gravity instabilities are frequent and tectonically-controlled. In particular, the geologic interpretation of the DTM evidences the occurrence of two complex morpho-structural highs which are bounded, on their western flank, by a wide intra-slope basin, NE-SW trending, located on the – 700 m of water depth (Fig. 9).

The geological interpretation of the DTM of the Salerno Gulf shows also the northern sector of the continental shelf (to the left in Fig. 9), which constitutes the seaward prolongation of the Sele graben, where the prograding units generated by the Sele river delta are evident. Based on commercial seismic profiles collected by the AGIP oil company, tied to lithostratigraphic data of deep exploration wells, the tectonic setting of the area has been interpreted as deriving from a half-graben structure, controlled by SW-NE trending listric normal faults, probably reactivated by compressional phases responsible for phenomena of basin inversion [Sacchi et al., 1994]. The acoustic basement of the Salerno Valley is represented by Meso-Cenozoic platform carbonates, widely cropping out onshore in correspondence to the structural high Capri-Sorrento Peninsula under the valley [Aiello et al. 1997a; 1997b].

To the north of the mouth of the river Sele the continental shelf narrows to a maximum extension of 10-12 km and is characterised by average gradients (0.5-1.5%) and by a shelf break having a constant depth of – 120 m throughout the northern sector of the Gulf. In the southern sector of the Salerno Gulf the marine areas include a shelf sector developing with low gradients up to a water depth of – 250 metres and representing a structural high, which has emerged since the Middle Miocene [Sacchi et al. 1994]. The pre-Pliocene basement is represented by two imbricated thrust sheets, the Cilento/Liguride Units [Bonardi et al. 1988] and the Alburno-Cervati Units [D'Argenio et al. 1973]. The high sedimentary supply due to the river Sele and its tributaries, draining more than 7000 km2 of emerged areas, and the tectonic subsidence of the Campania continental margin have

determined the progradation of the continental shelf during the lowstand phases, relative to the sea level lowstand of the Pleistocene last glacial.
The geological interpretation of the DTM (Fig. 12) reveals that in the northern zone of the investigated area, the morphological framework is controlled by tectonic structures; a narrow continental platform and a steep escarpment, tectonically controlled, characterise the whole marine belt surrounding the southern Sorrento Peninsula. In the eastern sector of the area the DTM interpretation, coupled with seismic stratigraphy, shows an extended continental platform, whose stratigraphic architecture is conditioned by the progradation of forced regression sedimentary wedges supplied by the river Sele.
The presented DTM is particularly interesting when referred to the continental slope, NE-SW oriented (Fig. 10); the slope starts from the rim of the Dohrn canyon, borders the Capri island and then is oriented parallel to the Sorrento Peninsula, for an overall length of about 60 kilometres. The trending of the escarpment is irregularly articulated in promontories and embayments, reflecting the main structural trends occurring on land in the Capri island. The high gradients of the slope confirm a tectonic control along the regional fault Capri-Sorrento Peninsula, strongly downthrowing the Meso-Cenozoic carbonates of the acoustic basement, with an average throw of about 1500 m. Moreover, the interpretation of the DTM has shown that the slope south of the Sorrento Peninsula is eroded by several gullies, alternating with morpho-structural highs. The gullies probably constitute the continuation of the drainage network occurring offshore in the Sorrento Peninsula. The acoustic response of the isobaths and the overall seismo-stratigraphic evidence suggest that the slope shows a rock lithology and then it probably represents a carbonatic escarpment, originated by the seaward prolongation of the Meso-Cenozoic carbonates, cropping out in the Sorrento Peninsula.
Among the morpho-structures, the NNW-SSE trending morpho-structural highs occurring in the south-western slope of the Salerno Valley are of particular relevance. The interpretation of multichannel seismic profiles running on these structures (Fig. 28) has revealed that they represent relic morphologies of the Middle-Late Pleistocene continental shelf, characterised by prograding strata with eroded topsets and preserved clinoforms. The structures are truncated

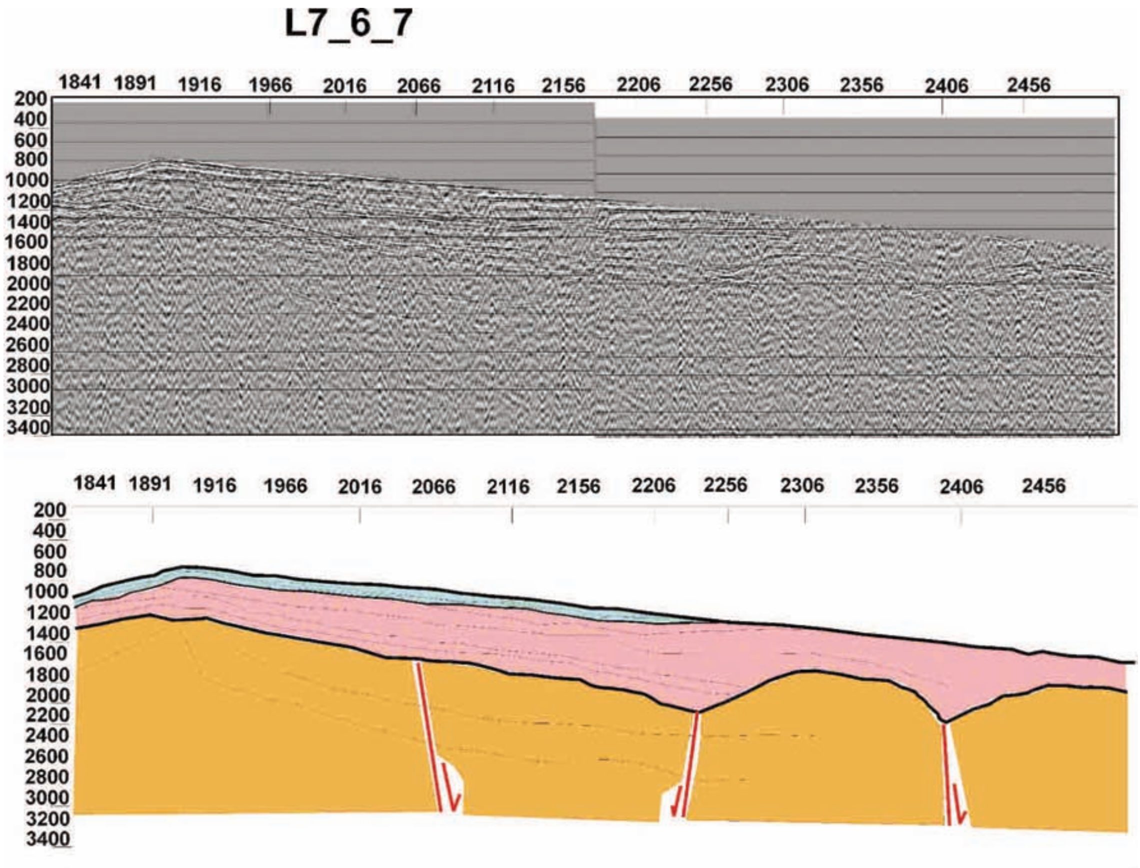

Figure 28 Detail of the multichannel seismic profile L6_L7 crossing the morpho-structural high which bounds westwards the Salerno Valley and corresponding geologic interpretation. The low-angle erosional truncations of the Pleistocene reflectors in corresponding to the morpho-structural high suggest its possible interpretation as a relic morphology of the Middle-Late Pleistocene continental shelf.
Figura 28 Dettaglio del profilo sismico multicanale L6_L7 passante sull'alto morfostrutturale di scarpata che delimita verso ovest la Valle di Salerno e corrispondente interpretazione geologica. Le troncature erosive a basso angolo dei riflettori pleistocenici in corrispondenza dell'alto morfostrutturale suggeriscono una sua possibile interpretazione come un relitto morfologico della piattaforma continentale di età medio-tardo pleistocenica.

at their top by an erosional unconformity (Fig. 28), probably corresponding to the sea level lowstand of the isotopic stage 5e, which is well documented in all the continental margins of Southern Italy [Aiello and Budillon 2004]. The two morpho-structural highs are separated by an intra-slope basin, actually infilled by sediments; several minor depocenters have also been identified.

Several seismo-stratigraphic units and related unconformities have been distinguished in the Salerno Valley based on the geological interpretation of multichannel reflection profiles (Figs. 19-28). The overall seismo-stratigraphic framework suggests a tectono-sedimentary evolution of a half-graben basin, whose individuation has been controlled, during the Early Pleistocene, by the master fault Capri island-Sorrento Peninsula, bounding the southern margin of the Sorrento Peninsula. This fault has a vertical throw of 1500 metres and has downthrown the Meso-Cenozoic carbonates, forming the acoustic basement of the sedimentary basin, under the Salerno Valley.

The geological interpretation of the seismic profile L6, carried out based on the seismic stratigraphy criteria, has allowed the identification of an important unconformity, located at about 1.7 and 1.8 sec of depth (corresponding to about 3000-3500 metres) and correlated with the top of the Meso-Cenozoic carbonatic sequence, widely cropping out onshore in the structural high of the Sorrento Peninsula (Fig. 19, 20, 25 and 26). This unconformity bounds upwards the carbonatic acoustic basement, which is strongly lowered by normal faulting and marks the base of the Pleistocene basin filling of the Salerno Valley. An erosional and/or depositional hiatus lasting from the Early Cenozoic (inferred age of the underlying carbonatic terrains) and the Early Pleistocene (inferred age of basin formation and deposition of the first sediments of the basin filling) is related to this unconformity.

Eight seismic sequences and related unconformities have been identified in the Pleistocene basin filling of the Salerno Valley, for a combined thickness of about 500 m (Fig. 19-20). The first sequences (units 2 and 3 in Fig. 16) represents the early stages of the basin filling and are characterised by wedging geometries indicating synsedimentary tectonics corresponding to the master fault that identified the half-graben basin, probably up to the Middle Pleistocene. A normal trend of subsidence and filling of the sedimentary basin is shown by the upper sequences, characterised by a very pronounced vertical aggradational component. The occurrence of chaotic intervals, interpreted as gravity transport deposits and intercalated at several stratigraphic levels in the sedimentary succession, suggests that the tectonic activity lasted up to the Late Pleistocene in the offshore adjacent to the sedimentary basin, probably in correspondence to NNW-SSE trending normal faults. This evidence, perhaps, is confirmed by the tectonic setting of the morpho-structural highs and related intra-slope basins in the south-eastern offshore of the area.

References

Aiello G. and Budillon F., (2004). *Lowstand prograding wedges as fourth-order glacio-eustatic cycles in the Pleistocene continental shelf of Apulia (southern Italy)*. In: Cyclostratigraphy. Approaches and Case Histories. (Ed. by B. D'Argenio, A.G. Fischer, I. Premoli Silva, H. Weissert and V. Ferreri) SEPM Special Publication 81, 215-230.

Aiello G. Budillon F. de Alteriis G. Di Razza O. De Lauro M. Marsella E. Pelosi N. Pepe F. Sacchi M. Tonielli R., (1997a). *Seismic exploration of the perityrrhenian basins in the Latium-Campania offshore*. Abstract. Int. Cong. International Lithosphere Program Task Force "Origin of the Sedimentary Basins", Torre Normanna (Palermo, Italy), June 1997.

Aiello G. Budillon F. de Alteriis G. Ferranti L. Marsella E. Pappone G. Sacchi M., (1997b). *Late Neogene tectonics and basin evolution of Southern Italy Tyrrhenian margin. Abstract*. Int. Cong. International Lithosphere Program Task Force "Origin of the Sedimentary Basins", Torre Normanna (Palermo, Italy), June 1997.

Aiello G. Budillon F. Cristofalo G. D'Argenio B. de Alteriis G. De Lauro M. Ferraro L. Marsella E. Pelosi N. Sacchi M. Tonielli R., (2001). *Marine geology and morphobathymetry in the Bay of Naples*. In: Structures and processes of the Mediterranean Ecosystems. (Ed. by F.M. Faranda, L. Guglielmo, G. Spezie), 1-8, Springer-Verlag, Italy.

Aiello G. Angelino A. Marsella E. Ruggieri S. Siniscalchi A., (2004). *Carta magnetica di alta risoluzione del Golfo di Napoli*. Bollettino della Società Geologica Italiana, 123, 333-342.

Aiello G. Angelino A. D'Argenio B. Marsella E. Pelosi N. Ruggieri S. Siniscalchi A., (2005). *Buried volcanic structures in the Gulf of Naples (Southern Tyrrhenian sea, Italy) resulting from high resolution magnetic survey and seismic profiling*. Annals of Geophysics, 48, 1-15.

Aiello G. Di Fiore V. Marsella E. D'Isanto C., (2007). *Stratigrafia sismica e morfobatimetria della Valle di Salerno*. Proc. 26th National Congress GNGTS, Extended Abstract, Rome, Italy, December 2007, 495-498.

Bartole R., (1984). *Tectonic structure of the Latian-Campanian shelf (Tyrrhenian sea)*. Bollettino di Oceanologia Teorica Applicata, 2, 197-230.

Bartole R. Savelli D. Tramontana M. Wezel F.C., (1983). *Structural and sedimentary features in the Tyrrhenian margin off Campania, Southern Italy*. Marine Geology, 55, 163-180.

Bonardi G. Amore F.O. Ciampo G. De Capoa P. Miconnet P. Perrone V., (1988). *Il Complesso Liguride Auct.: stato* *delle conoscenze e problemi aperti sull'evoluzione pre-appenninica ed i suoi rapporti con l'Arco Calabro*. Memorie della Società Geologica Italiana, 41, 17-35.

Buccheri G. Capretto G. Di Donato V. Esposito P. Ferruzza G. Pescatore T. Russo Ermolli E. Senatore M.R. Sprovieri M. Bertoldo M. Carella D. Madonia G., (2002). *A high resolution record of the last deglaciation in the southern Tyrrhenian sea: environmental and climatic evolution*. Marine Geology, 186, 447-470.

D'Argenio B. Pescatore T. Scandone P., (1973). *Schema geologico dell'Appennino meridionale (Campania e Lucania)*. Accademia Nazionale dei Lincei, 183, Atti del Convegno "Moderne Vedute sulla Geologia dell'Appennino", Roma.

D'Argenio B. Ortolani F. Pescatore T.S., (1986). *Geology of the Southern Apennines*. Geologia Applicata e Idrogeologia, 6, 135-161.

D'Argenio B. Aiello G. de Alteriis G. Milia A. Sacchi M. Tonielli R. Budillon F. Chiocci F.L. Conforti A. De Lauro M. D'Isanto C. Esposito E. Ferraro L. Insinga D. Iorio M. Marsella E. Molisso F. Morra V. Passaro S. Pelosi N. Porfido S. Raspini A. Ruggieri S. Terranova C. Vilardo G. Violante C., (2004). *Digital Elevation Model of the Naples Bay and adjacent areas, Eastern Tyrrhenian sea*. Atlante di Cartografia Geologica scala 1:50.000 (progetto CARG), Servizio Geologico d'Italia (APAT), 32nd International Congress "Firenze 2004", Editore De Agostini, Italy.

De Rita D. and Giordano G., (1996). *Volcanological and structural evolution of Roccamonfina volcano (Italy): origin of the summit caldera*. In: Volcano instability on the Earth and other planets (Eds. W.J. Mc Guire A.P. Jones J. Neuberg), Geol. Soc. Spec. Publ. 110, 209-224.

Fabbri A. Gallignani P. Zitellini N., (1981). *Geologic evolution of Mediterranean margins*. In: Sedimentary basins of the Mediterranean margins (Ed. F.C. Wezel), 101-126.

Ferraro L. Pescatore T.S. Russo B. Senatore M.R. Vecchione C. Coppa M.G. Di Tuoro A., (1997). *Studi di geologia marina sul margine tirrenico: la piattaforma continentale tra Punta Licosa e Capo Palinuro (Tirreno meridionale)*. Bollettino della Società Geologica Italiana, 116, 473-485.

Gars G. and Lippman M., (1984). *Nouvelles donneès néotectonique dans l'Apennin campanien (Italie du sud)*. CR Acad Sci Paris 298 (II-11), 495-500.

IHO Special Publication n. 44, (1998). *Standards for Hydrographic Surveys*. 4th Edition International Hydrographic Bureau, Munchen.

Malinverno A. and Ryan W.B.F. (1986). *Extension in the Tyrrhenian sea and shortening in the Apennines as a result of arc migration driven by sinking of the lithosphere*. Tectonics, 5, 227-245.

Mariani M., Prato R. (1988). *I bacini neogenici costieri del margine tirrenico: approccio sismico-stratigrafico*. Memorie della Società Geologica Italiana, 41, 519-531.

Marsella E. Aiello G. Angelino A. Bruno P.P.G. Di Fiore V. Giordano F. Pelosi N. Siniscalchi A. D'Isanto C. Ruggieri S. (2002). *Shallow geological structures and magnetic anomalies in the Gulf of Naples (Southern Tyrrhenian sea, Italy). An integrated analysis of seismic and magnetometric profiles*. Bollettino di Geofisica Teorica Applicata, 42 (1/2), 292-297.

Martinson D.G. Pisias N.G. Hays J.D. Imbrie J. Moore T.C. Shackleton N.J., (1987). *Age dating and the orbital theory of the ice ages: development of a high resolution 0 to 300.000 year chronostratigraphy*. Quaternary Research, 27, 1-29.

Milia A. and Torrente M.M., (1997). *Evoluzione tettonica della Penisola Sorrentina (margine peritirrenico campano*. Bollettino della Società Geologica Italiana, 116, 487-502.

Milia A. Torrente M.M. Russo M. Zuppetta A., (2003). *Tectonics and crustal structure of the Campania continental margin: relationships with volcanism*. Mineralogy and Petrology, 79, 33-47.

Patacca E. Sartori R. Scandone P., (1990). *Tyrrhenian basin and Apenninic arcs: kinematic relations since Late Tortonian times*. Memorie della Società Geologica Italiana, 46, 45-68.

Pepe F. Bertotti G. Cella F. Marsella E., (2000). *Rifted margin formation in the south Tyrrhenian sea: a high resolution seismic profile across the north Sicily passive continental margin*. Tectonics, 19 (2), 241-257.

Sacchi M. Infuso S. Marsella E. (1994). *Late Pliocene-Early Pleistocene compressional tectonics in the offshore of Campania*. Bollettino di Geofisica Teorica Applicata, 36, 141-144.

Secomandi M. Paoletti V. Aiello G. Fedi M. Marsella E. D'Argenio B. Rapolla A., (2003). *Analysis of the magnetic anomaly field of the volcanic district of the Bay of Naples, Italy*. Marine Geophysical Researches, 24, 207-221.

Servizio Geologico Nazionale, (1959). *Geological Map of Italy "Sorrento-I. di Capri" 196 Sheet*. Rome, Istituto Poligrafico e Zecca dello Stato, scale 1:100.000.

Servizio Geologico Nazionale, (1965a). *Geological Map of Italy "Amalfi" 197 Sheet*. Rome, Istituto Poligrafico e Zecca dello Stato, scale 1:100.000.

Servizio Geologico Nazionale, (1965b). *Geological Map of Italy "Gaeta" 171 Sheet*. Rome, Istituto Poligrafico e Zecca dello Stato, scale 1:100.000.

Servizio Geologico Nazionale (1966). *Geological Map of Italy "Caserta" 172 Sheet*. Rome, Istituto Poligrafico e Zecca dello Stato, scale 1:100.000.

Servizio Geologico Nazionale (1969). *Geological Map of Italy*

"Salerno" 185 Sheet. Rome, Istituto Poligrafico e Zecca dello Stato, scale 1:100.000.

Siniscalchi A. Angelino A. Ruggieri S. Aiello G. Marsella E. Sacchi M., (2002). *High resolution magnetic anomaly map of the Bay of Naples*. Bollettino di Geofisica Teorica Applicata, 42, 99-104.

Tozzi M. and Capotorti F., (1988). *Tettonica trascorrente della Penisola Sorrentina*. Memorie della Società Geologica Italiana, 47, 235-249.

Trincardi F. and Field M.E., (1992). *Collapse and flow of low-stand shelf margin deposits: an example from the Eastern Tyrrhenian, Italy*. Marine Geology, 105, 77-94.

Trincardi F. and Zitellini N. (1987). *The rifting of the Tyrrhenian basin*. Geomarine Letters, 7, 1-6.

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