DIGITAL ELEVATION MODEL OF THE NAPLES BAY AND ADJACENT AREAS, EASTERN TYRRHENIAN SEA

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ABSTRACT. An extensive, high-resolution bathymetric survey has recently portrayed the continental shelf-slope system of the Campania region, South Italy (Eastern Tyrrhenian Sea). Bathymetric data were acquired between 1997 and 2002, using multibeam systems with an average vertical resolution of ≤ 0.25 % of water depth and a position accuracy of ≤ 10 m. The survey data have been successively merged with a Digital Terrain Model (DTM) created from topographic maps of the onshore coastal area and islands of the Bay of Naples, into a Digital Elevation Model (DEM) based on a homogeneous grid with cell spacing of 20 m.
The shaded-relief colour scale map of the Bay of Naples we present in this study, provides new, detailed information on morphology of the coastal region of Campania. This continental margin displays evidence of the interplay between tectonics and volcanism and their interference with sedimentary processes during the latest Neogene and Quaternary.
Major morphological features revealed by the 3-D digital maps are: 1) the system of marine canyons (Dohrn and Magnaghi) that cut the continental slope at a depth between 250 m and 1100 m; 2) the funnel-shaped marine slope system of the Ischia volcanic structure; 3) the onshore-offshore volcanic field of the Campi Flegrei; 4) the rugged seafloor area (with diameter of ca 2 km) off the town of Naples (Banco della Montagna), caused by active uplift of small-scale volcaniclastic diapirs (pyroclastic lumps); 5) debris-flow/avalanche deposits on the inner continental shelf of the Eastern Bay of Naples, evolved from the pyroclastic products of the Vesuvius.

Keywords: Tyrrhyenian Sea, multibeam bathymetry, digital elevation model, continental margin, submarine canyon, debris avalance, pyroclastic diapir

RIASSUNTO Un esteso rilievo batimetrico di alta risoluzione è stato realizzato recentemente in corrispondenza del sistema piattaforma-scarpata del margine continentale Campano nel Tirreno orientale. I dati batimetrici sono stati acquisiti tra il 1997 ed il 2002 utilizzando ecoscandagli multifascio (sistemi multibeam) con risoluzione verticale ≤ 0.25 % della profondità d'acqua e posizionamento con errore inferiore a 10 m. I dati raccolti sono stati utilizzati per la realizzazione di una griglia di dati batimetrici con maglia di 20 m. Il grid batimetrico è stato poi integrato con dati digitali di terreno (DEMs), di eguale risoluzione, derivati da carte topografiche dell'area costiera e delle isole Campane.
La carta batimetrica digitale con rilievo a luci ed ombre ed il modello 3-D qui illustrati forniscono nuove informazioni sulla morfologia di dettaglio del margine continentale della Campania che mostra nel suo complesso una chiara evidenza dell'interazione tra processi tettonici, vulcanici e sedimentari durante il Neogene superiore - Quaternario. Gli elementi morfologici principali evidenziati dai dati batimetrici sono: 1) i sistemi di canyon sottomarini (Dohrn and Magnaghi) che dissecano la scarpata continentale tra circa 250 m e 1000 m di profondità; 2) la scarpata continentale dell'apparato vulcanico dell'Isola di Ischia; 3) una serie di banchi vulcanici al largo del distretto vulcanico dei Campi Flegrei (ad es. Ischia, Miseno, Penta Palummo, Nisida); 4) un'area dal rilievo irregolare, del diametro in pianta di circa 2 km, al largo della città di Napoli (Banco della Montagna), legata alla emergenza al fondo mare di piccole strutture diapiriche in depositi vulcanoclastici pomicei; 5) accumuli sottomarini da debris-flow/avalanche di masse piroclastiche vesuviane parzialmente inserite nel margine orientale del Golfo di Napoli.

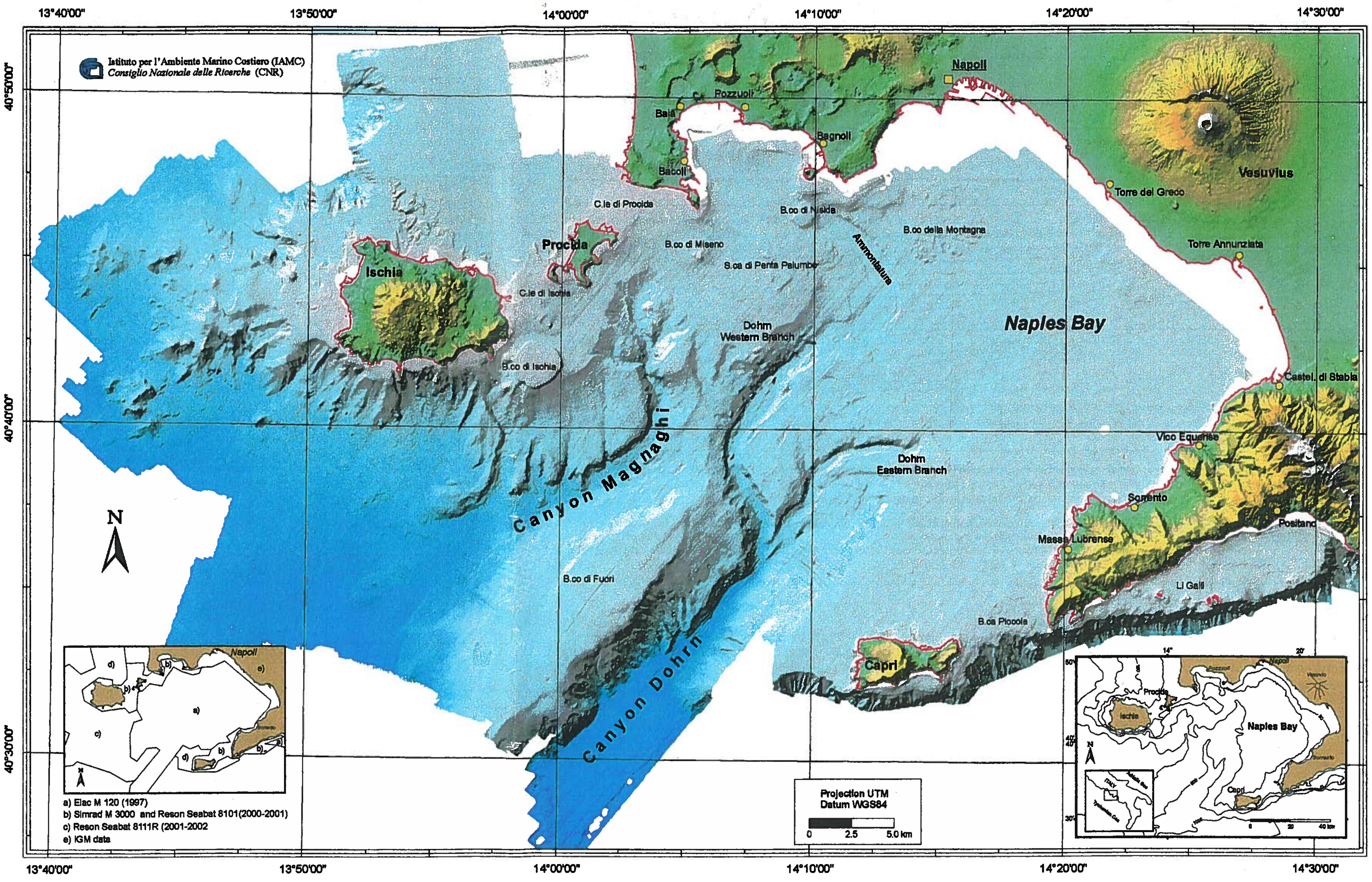

Fig. 1. Shaded relief map of the Bay of Naples and adjacent areas based on digital elevation data
Rilievo a luci ed ombre del modello batimetrico e topografico digitale del Golfo di Napoli e delle circostanti aree costiere

1. AIMS

This study is part of a long-term project focused on extensive bathymetric survey of selected segments of the Tyrrhenian continental shelf. On-going research activities include acquisition of digital data of the Earth and seafloor surface elevation in order to obtain high resolution digital model and maps of the Campania continental margin and adjacent areas. This is a heavily populated segment of the Italian coastal zone that is subject to severe environmental threat due to intense anthropic activity.

The aims of the research program include:

- Acquisition of high resolution digital bathymetric data on the Italian economic zone (continental shelf-slope system) of the Eastern Tyrrhenian Sea and digital topography of the coastal zone;
- Study of morpho-structural features and related geologic processes along the Eastern Tyrrhenian continental margin.
- Creation of merged 3-D digital maps of onshore topography and offshore bathymetry imaged as a unique habitat, to be used as a tool for a Geographic Information System (GIS) based study or application.
- Use of accurate marine DEMs for numerical modeling of oceanographic processes and sediment and pollutant transport, geological mapping, assessment of submarine slide potential, location of the surface expression of active faults, identification of offshore disposal sites, as well as monitoring of biological processes and benthic habitats.

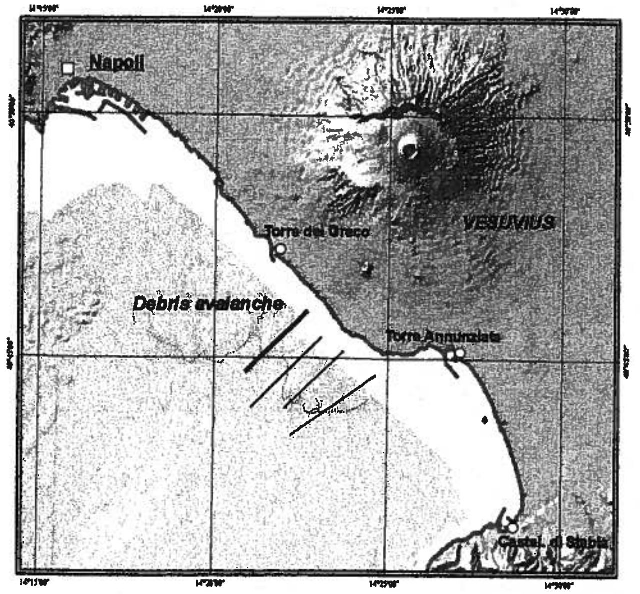

Fig. 9. Shaded relief map of the Vesuvian area with indication of the debris avalanche offshore Torre del Greco and Torre Annunziata, with location of the interpreted sparker profile shown in Fig. 10 (thick line) and subbottom (CHIRP) profiles shown in Fig. 11 (thin lines).

Rilievo a luci ed ombre dell'area vesuviana con indicazione dell'area di debris avalanche al largo tra Torre del Greco e Torre Annunziata ed ubicazione del profilo sparker di Fig. 10 (linea spessa) e dei profili subbottom di Fig. 11 (linee sottili).

6. THE MORPHOLOGY OFFSHORE VESUVIUS VOLCANO

Hummocky seafloor morphology has been documented at water depth of 30 and 100 m on the continental shelf, offshore Somma-Vesuvius volcano. Sub-bottom (CHIRP) profiles acquired parallel to the coast show this morphology draped landward by younger sediments (Figs 9 and 10). The seaward termination of this surface in the multibeam bathymetry displays an irregular pattern characterised by elongated lobes that lie perpendicular to the coast (Milia et al., 1998, 2003). Seismic sections across this area display a seismic unit (DA1) characterised by chaotic facies that terminate seawards with a steep, 60 m-high scarp. This unit lies above an erosional unconformity on top of the the Campania Ignimbrite (35 ka BP). The top of unit DA1 features a staircase morphology with flat surfaces overlain by marine sediments. At its seaward margin unit DA1 is covered by a progradational seismic unit characterised by a toplap surface dipping seaward with depths of 130-145 m. Because the toplap surface marks the sea level position at the time of its deposition and the sea level reached a depth of approximately 130 m during the last glacial maximum that occurred at 18 ka BP (Bard et al., 1996), the unit DA1 is here considered as emplaced at 18 ka in a subaerial environment. Its stratigraphic position is confined above the unconformity overlying unit CI and below the wedge that formed during the sea level lowstand. The unit DA1 is hence interpreted as the debris avalanche that led to the collapse of Monte Somma at 18 ka, shortly before the "Pomici di Base" eruption (Fig. 11).

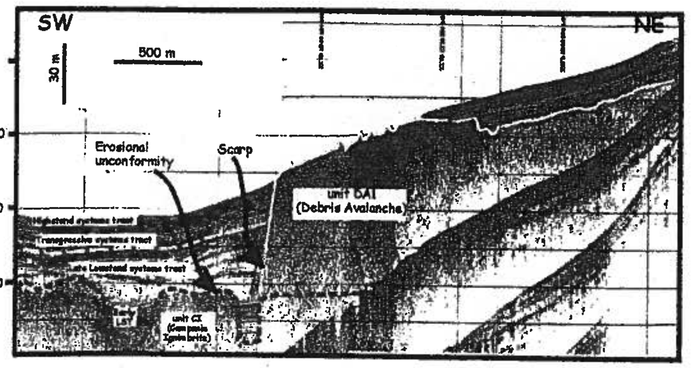

Fig. 10. Geologic interpretation of a sparker seismic profile offshore the Vesuvius. See Fig. 9 for location.

Interpretazione di un profilo sparker attraverso l'area al largo del Vesuvio. Vedi Fig. 9 per l'ubicazione del profilo.

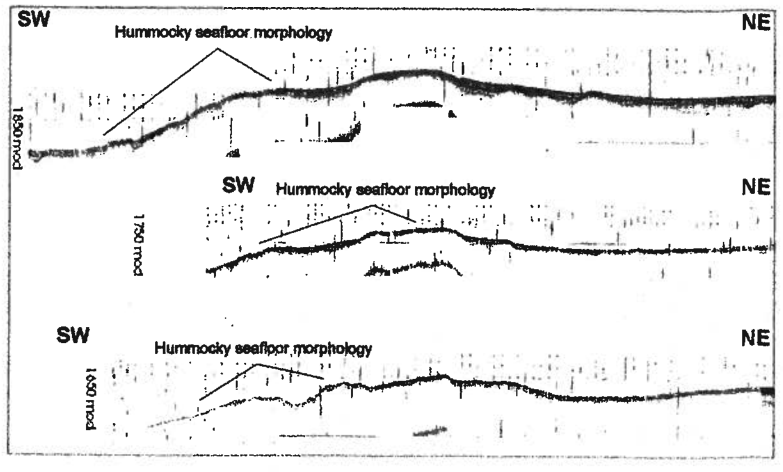

Fig. 11. Subbottom (CHIRP) profiles showing hummoky seafloor morphology off the Vesuvius debris avalanche. Location of profiles is shown in Fig. 9.

Profili subbottom (CHIRP) al largo del Vesuvio che illustrano la morfologia ondulata del fondo mare in corrispondenza del debris avalanche. L'ubicazione dei profili è riportata in Fig. 9.

7. PYROCLASTIC DIAPIRS

Diapiric structures consisting of massive volcaniclastic deposits have been recently discovered beneath the sea floor a few kilometers offshore the town of Naples (Eastern Tyrrhenian Sea). High-resolution (sparker 1.5-4 kJ) and very high-resolution (sub-bottom CHIRP) single-channel seismic reflection profiles show these pyroclastic diapirs (pyroclastic lumps) rising through the uppermost Pleistocene - Holocene deposits and dramatically deforming the sea floor over a quasi-circular area of ca 2 km in diameter (Figs 12 and 13) (Sacchi et al., 2000; Aiello et al., 2001).

The pyroclastic lumps of the Naples Bay are rooted in the uppermost layers of a large volcanic unit, several tens of meters beneath the sea floor. Chemical analysis and $^{40}Ar/^{39}Ar$ dating of the pumice collected from gravity core samples demonstrates that the pyroclastic deposits forming the diapirs derive from the products of widespread eruptions of Latest Pleistocene-Earliest Holocene, mostly including the "Neapolitan Yellow Tuff" (15 Ka BP) (Insinga et al., 2000; Insinga, 2003) (Fig. 14).

The key factors controlling the dynamic system include: 1) the viscosity of the ascending pyroclastic material, 2) the density of the overlying deposits, 3) the density contrast between these structures and the overlying sediments, 4) the initial width of the individual diapiric structures. The modelled rates of uplift of pyroclastic lumps are in the order of several mm/yr (Sacchi et al., 2000).

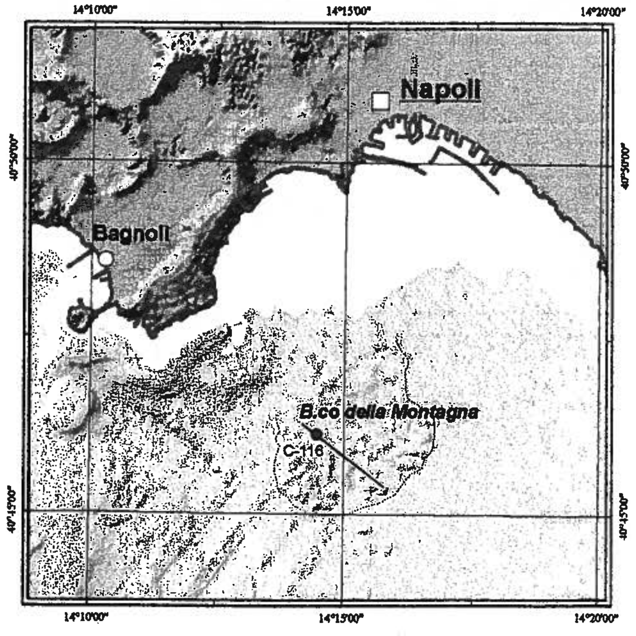

Fig. 12. Shaded relief map of the continental shelf-slope offshore Naples. The rugged seafloor morphology of the Banco della Montagna area is due to the recent uplift of diapiric structures that developed at depth within uppermost Quaternary pumiceous deposits.

Rilievo a luci ed ombre della piattaforma continentale-scarpata al largo della città di Napoli. La morfologia irregolare dell'area del Banco della Montagna è dovuta alla risalita tardo-quaternaria di diapiri pomicei che deformano il fondo mare.

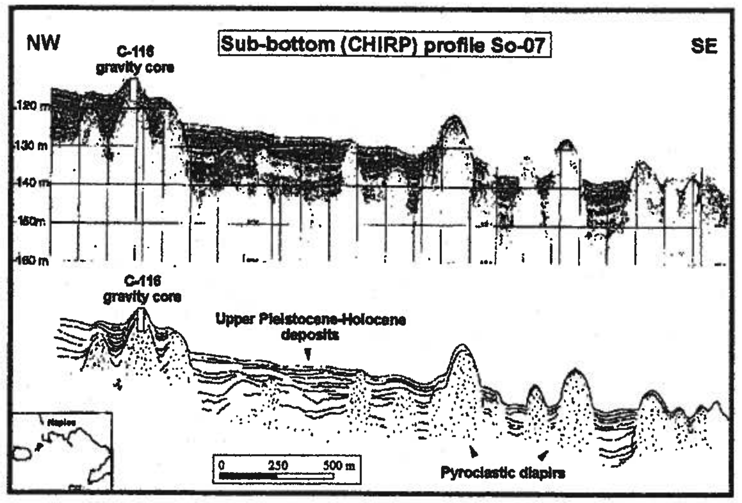

Fig. 13. Subbottom (CHIRP) profile across the pyroclastic diapirs of the Banco della Montagna, and location of the gravity core C-116 used for calibration of seismic data. Location of profile is shown in Fig. 12.

Profilo subbottom (CHIRP) attraverso i diapiri piroclastici del Banco della Montagna ed ubicazione del carotaggio C-116 utilizzato per la calibrazione del dato geofisico. La traccia del profilo è ubicata in Fig. 12.

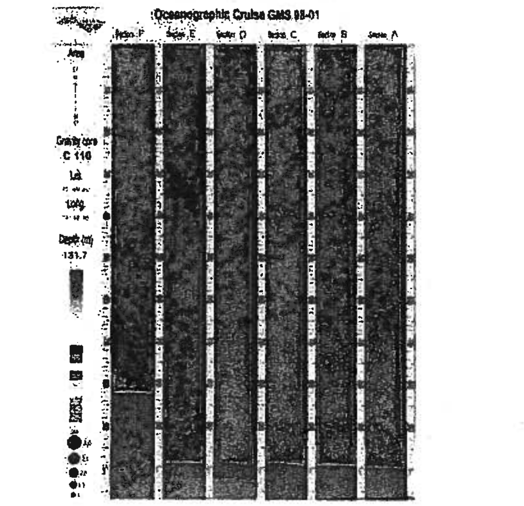

Fig. 14. Gravity core C-116 sampled a succession of sand-sized marine deposits interbedded or chaotically mixed with pumice layers. See Fig. 12 for location.

Il carotaggio a gravità C-116 ha campionato una successione di sedimenti marini sabbiosi intercalati o caoticamente frammisti a materiale pomiceo. Vedi Fig. 12 per l'ubicazione della stazione di campionamento.

8. CONCLUSION

The Naples Bay and adjacent areas represent a very mobile segment of the hinge zone between the Southern Apennines fold and thrust belt and the Tyrrhenian basin. This area is characterized by intense tectonic and volcanic activity during the Quaternary and may be regarded as a privileged natural laboratory to study recent and active morphologic and sedimentary processes and their relation with the geodynamic evolution of the region.

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Late Pleistocene - Holocene seismic stratigraphy

The Dohrn canyon exposes along its walls hundreds of meters of a Middle-Late Pleistocene prograding wedge, formed by clastic and volcaniclastic sediments and genetically related to the paleo-Sarno fluvial system. A major morphostructural high (Banco di Fuori) separates the Dohrn canyon from the Magnaghi canyon (Fig. 1). It consists of a Mesozoic carbonate block resulting from regional uplift and tilting of the acoustic basement, cropping out in the structural highs of the Sorrento Peninsula and Capri Island (Fusi et al., 1991; Milia and Torrente, 1999; Aiello et al., 2001).

The location of the Dohrn eastern branch and evidence from seismic stratigraphy suggest a genetic link between the activity of the Dohrn canyon and the Sarno paleo-delta during sea level lowstands. The deltaic system of the paleo-Sarno river has directly fed the continental slope areas during the lowstand phases of Middle-Late Pleistocene, giving rise to a wide prograding wedge, deeply incised by the Dohrn canyon. This is suggested also by the occurrence of two non-volcanic highs located near the heads of the Dohrn canyon. Seismic stratigraphy reveals that they consist of deltaic sediments characterized by clinoform patterns and related to the distal part of a prograding wedge fed by the paleo-Sarno river mouth. These highs, having an elevation with respect to the surrounding depth in the order of 20-30 m, represent relic morphologies of the Middle-Late Pleistocene continental shelf (Aiello et al., 2001). Seismic evidence suggests that this erosional phase predates the onset of the Campania Ignimbrite (> 35 ka) (Cinque et al., 1997; Milia, 1998, 2000).

Submarine canyon evolution

Morphobathymetric and seismostratigraphic evidences are important for the understanding of submarine canyon formation, since sediment flows, according to recent models on submarine canyon evolution, may repeatedly trigger retrogressive failures (Pratson and Coakley, 1996). Canyon formation may be interpreted reconciling morphological evidences for headward canyon erosion by mass wasting, with the stratigraphic evidence of canyon inception by downslope-eroding sediment flows. As already suggested, the canyon evolution may be seen as a transition from "youthful" to "mature" morphology (Farre et al., 1983). The youthful stage begins with extensive slope failures. Retrogressive mass wasting of continental slope sediments along the failure headwall leads to the formation and upslope extension of relatively straight, steep-walled chute. If this headward migrating chute breaches the shelf break, the canyon taps into a new sediment source of outer shelf sands and enters into a mature phase of evolution. Failure of shelf sediments in the vicinity of the canyon head initiates coarse-grained turbidity currents, which become an important agent of erosion by down-cutting the canyon and creating a sinuous thalweg (Twichell and Roberts, 1982; Farre et al., 1983; Pratson and Coakley, 1986; Talling, 1998).

5. IMAGING AND SAMPLING OF THE ISCHIA MARINE DEBRIS AVALANCHE

One of the most destructive forms of volcanic behaviour has only recently received scientific attention. This is the catastrophic, sudden collapse of a sector of the volcanic edifice that generates debris-avalanche deposits and leaves amphitheater-like craters. Generally subaerial collapse (as that of Mt. St. Helen, USA in 1980) are one order of magnitude smaller than those occurring over large volcanic islands in the ocean, as Hawaai or Canary islands (Moore et al., 1994; Masson et al., 2002).

The island of Ischia represents only the emerged top (about 30 %) of a major, E-W trending volcanic ridge that separates two sectors of the continental shelf: the Gulf of Gaeta to the northwest and the bay of Naples to the southeast, with deeper and rough sea-floor topography (Alessio et al., 1996; Bruno et al., 2002). Ischia consists of alcali-trachitic lavas and pyroclastites dating back to 150 ka (Rittmann,

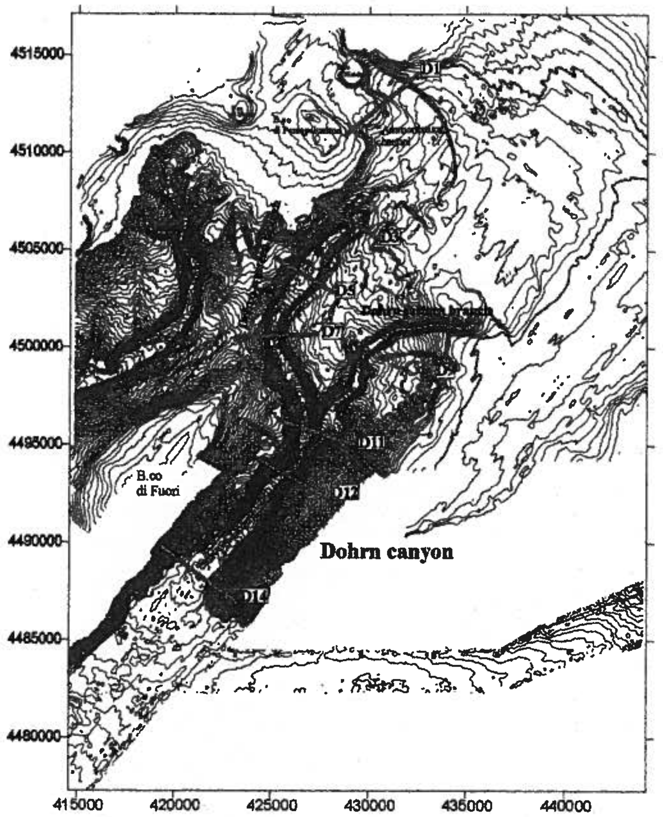

Fig. 4. Simplified map of the central sector of the Bay of Naples with location of bathymetric profiles illustrated in Fig. 5.
Carta schematica del settore centrale del Golfo di Napoli con ubicazione dei profili batimetrici di Fig. 5.

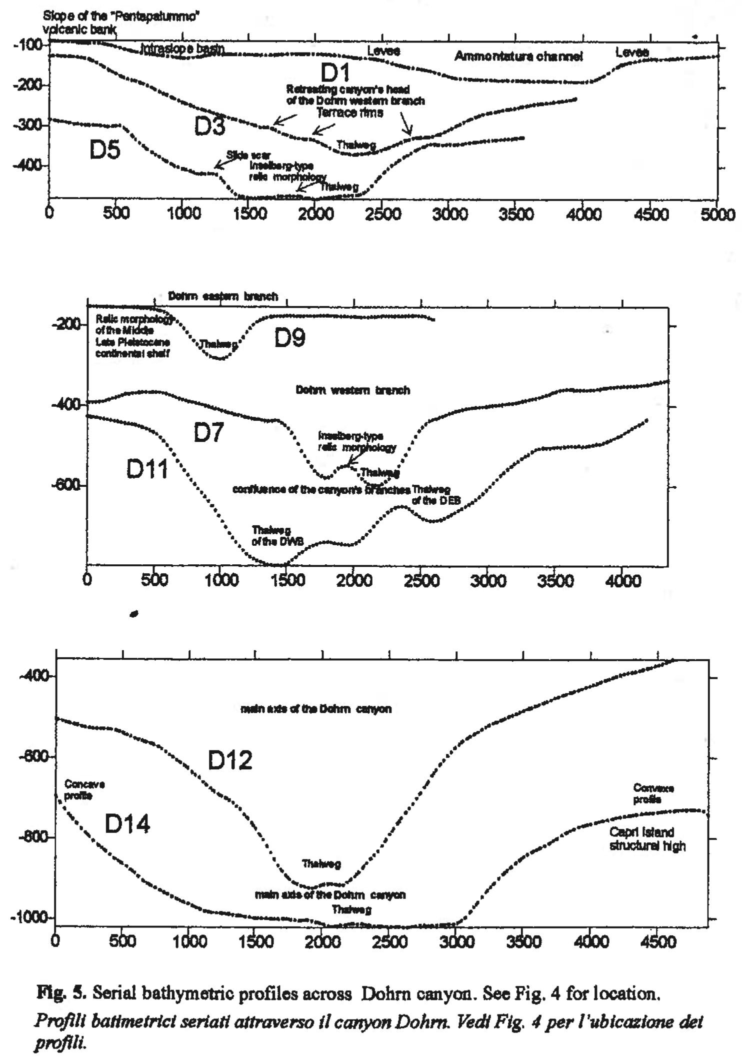

Fig. 5. Serial bathymetric profiles across Dohrn canyon. See Fig. 4 for location.
Profili batimetrici seriati attraverso il canyon Dohrn. Vedi Fig. 4 per l'ubicazione dei profili.

1930; Gillot et al., 1982). The southern offshore of the island is characterised by extremely narrow shelf areas, followed by a very steep upper slope carved by several active canyons (Marsella et al, 2001; de Alteriis e Toscano; 2003, Budillon et al., 2003a).

The hypothesis that the Ischia volcano might have undergone subaerial and/or submarine sector collapse during its history (Luongo et al., 1991) has been recently reproposed on the basis of a deep-tow survey (TOBI instrument, Southampton Oceanography Centre, UK) carried out over the southern offshore in the 300-1100 bathymetric range (TiVoll Cruise, Chiocci et al., 1998). The acoustic data collected during that cruise revealed a debris avalanche extending some 50 km in the southern offshore down to the 1000-1100 m isobath (Figs 6 and 7). Further surveys, in 2000 and 2002 showed "hummocky" topography in the western and northern offshore in the 0-150 bathymetric range (Budillon et al., 2003b).

Side-Scan-Sonar records over the southern Ischia debris avalanche have shown that the blocks are mostly located on the lower slope (between 500 and 1100 m waterdepth). Block size ranges from a few meters to more than 100-200 m with major boulder raising 25-40 m above the sea-floor (de Alteris et al., 2001; Chiocci et al. 2002).

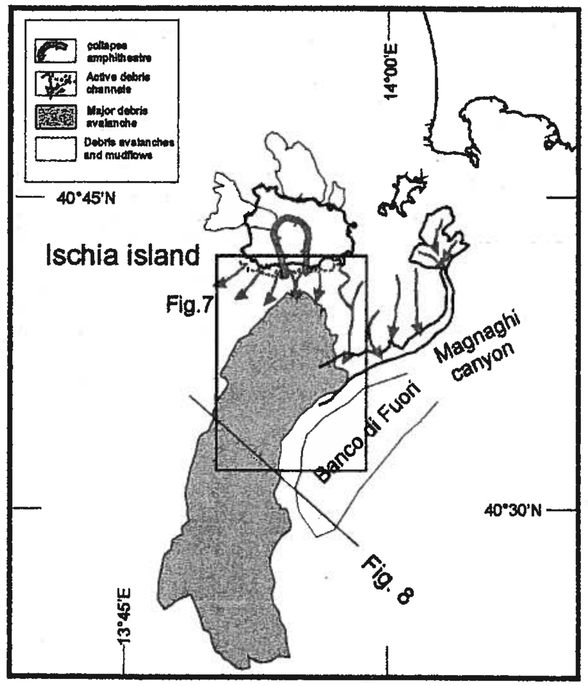

Fig. 6. Morphologic sketch-map of the continental slope south of the Ischia Island with indication of the debris avalanche deposits.
Schema morfologico della scarpata continentale meridionale dell'Isola Ischia che illustra i depositi da debris avalanche.

Based on seismic profiles only a tentative appraisal of the Ischia debris avalanche thickness may be at the moment proposed, due to high energy backscatter over the hummocky topography. On the contrary, seismics clearly shows that the eastern edge of the debris avalanche has been confined by the Banco di Fuori morpho-structural high (Fig. 8). Sampling the Ischia debris avalanche at about twenty coring and dredging stations recovered: a) post-avalanche 0.5-1 m thick hemipelagic mud in turn incorporating some air-fall tephra layers; b) the DA matrix, consisting of slightly consolidated sandy groundmass, at times still plastic,

Fig. 7. Side Scan Sonar (TOBI) image showing the rugged seafloor morphology of the Ischia debris avalanche. See Fig. 6 for location.
Sonogramma Side Scan Sonar (TOBI) illustrante la morfologia accidentata del fondo mare nell'area del debris avalanche di Ischia. Vedi Fig. 6 per l'ubicazione di questa immagine.

including heterogeneous lithic assemblages; c) small (submetric) blocks consisting of both volcano-sedimentary siltstones at times with typical jigsaw cracks and more or less altered trachytic lava, scoriae and welded tuffs; d) a debris flow consisting of a mud-supported deposit including extremely heterogeneous volcanic and sedimentary clasts and representing the heteropic, distal facies of the DA matrix.

The Ischia southern collapse may be regarded as < 10 ky on the basis of thickness of the post-avalanche hemipelagic drape, and the average sedimentary rate in turn calibrated on well known tephra layers in the offshore.

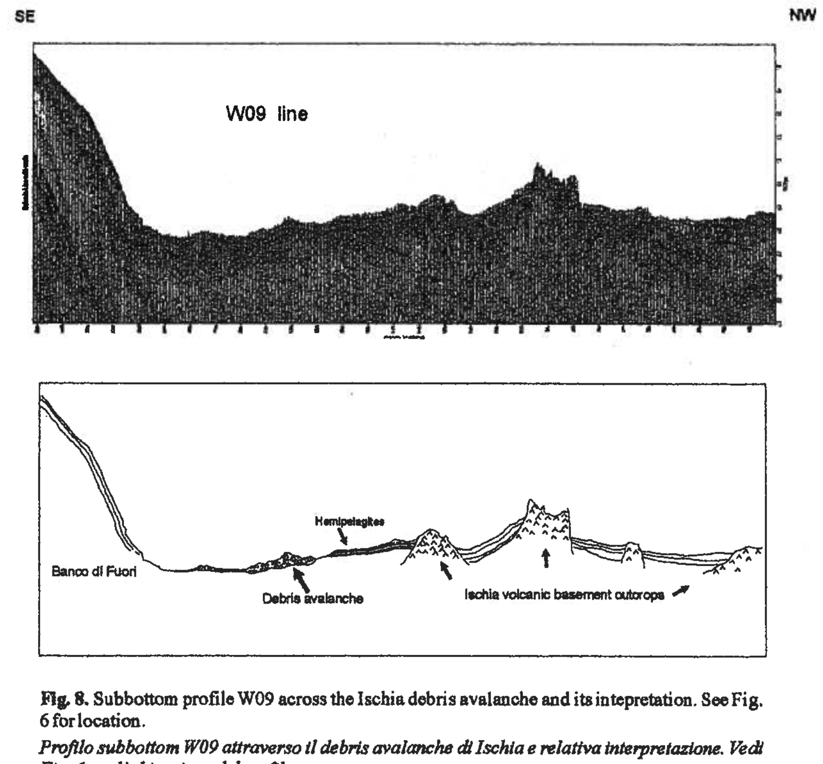

Fig. 8. Subbottom profile W09 across the Ischia debris avalanche and its intepretation. See Fig. 6 for location.
Profilo subbottom W09 attraverso il debris avalanche di Ischia e relativa interpretazione. Vedi Fig. 6 per l'ubicazione del profilo.

2. MATERIAL AND METHODS

Today, swath or "multibeam" bathymetry is recognized as one of the most effective methods for marine surveying. It provides almost full sea-floor coverage over relatively short acquisition times and does not imply extensive interpolation of data like the classic single-beam echo-sounders. An advantage of this a method is the possibility of generating a Digital Elevation (or Terrain) Model (DEM) of the real bathymetry with a resolution that is dependent both on the intrinsic characteristics of the echo-sounder and the water depth.

Unlike topographic surveys onland the compilation of a marine DEMs normally requires a longer process both during the acquisition and the processing phase. There are three main sources of error and noise systematically associated with multibeam datasets: those related to the monitoring of the vessel and echo sounder motion (navigation, pitch, roll, heave, yaw), those associated with poor acoustic signal (especially on lateral beams); those due to oceanographic factors (water sound velocity, tides, swell). In the Mediterranean some of these disturbance factors, such as tides and oceanic swell, are negligible, unless very high resolution is required, like in the case of detailed surveys (scale > 1:10.000) and very shallow water.

Echo-sounders are normally suited for a given bathymetric range with transducer's frequency varying from hundreds of kHz (shallow water surveys) to tens of kHz (full oceanic depth). While vertical resolution depends on the transducer's frequency and water sound velocity only, the horizontal resolution is typically depth-dependent and referred to as the "footprint", i.e. the seafloor area covered by each acoustic beam. The echo sounder systems employed during the 1997-2002 surveys off the bay of Naples and their characteristics are listed in Tab. 1.

Most marine DEMs are based on regularly spaced soundings arranged in symmetrical x,y,z matrices called grids. When navigation route patterns are relatively homogeneous there is no particular need for choosing DEMs other than symmetrical. Each grid is characterized by an elementary square cell unit; the adopted cell size must take into account the limits imposed by the average footprint.

The DEM of Fig.1 is based on a 20x20 m cell and results from the integration of different grids, each characterized by variable cell size ranging from 2.5x2.5 m in the shallow areas (water depth < 50m) to 25x25 m at greater depths. The marine part of the DEM has been merged with a digital terrain model of the coastal area, derived by 1:25.000 topographic maps, having the same cell size. Despite the loss of resolution in shallow water areas, the 20x20 m matrix revealed to be adequate in detecting the most prominent (larger than a few tens of meters) topographic and bathymetric features of the coastal zone.

Tab. 1. Characteristics of the echo sounder systems employed for the bathymetric survey of the Bay of Naples.
Caratteristiche tecniche dei sistemi multibeam utilizzati per il rilievo batimetrico del Golfo di Napoli.

Echo-sounder	Simrad EM 3000	Reson SeaBat 8101	Reson SeaBat 8111	Elac Bottomchart MkII
frequency	300 kHz	240 kHz	100 kHz	50 kHz
Swath sector	130°	150°	150°	150°
N° of beams/ping	127	101	101	126
Vertical resolution at 1500 m/sec	0.5 cm	0.6 cm	1.5 cm	3 cm
Footprint diameters at 10/100/1000/3000 m depths	0.17/1.7	0.26/2.6	0.26/2.6/26	0.2/2/20/62
Coverage	Up to 10 times water depth	1.8 to 7.4 times water depth	1.8 to 7.4 times water depth	2 to 8 times water depth

3. GEOLOGIC SETTING

The eastern margin of the Tyrrhenian Sea is characterized by a number of basins that evolved during the latest Neogene - Quaternary across the structural boundary between the Apennine fold and thrust belt and the Tyrrhenian back-arc extensional area (Fig. 2). These basins, among which the present-day Bay of Naples, formed in response to large-scale orogen-parallel extension and associated transtensional tectonics that accompanied the anti-clockwise rotation of the Apenninic belt and lithospheric stretching in the central Tyrrhenian basin (Sacchi et al., 1994; Ferranti et al., 1997).

The Campania segment of the peri-Tyrrhenian structural belt hence displays characters of a passive continental margin, where Quaternary orogen-parallel extension caused the formation of half-graben systems (e.g. Volturno Bay, Naples Bay, Salerno Bay) and intervening structural highs (e.g. Sorrento Peninsula, M. Massico) that trend perpendicular to the main axis of the Apennine thrust belt (Mariani e Prato, 1988; Sacchi et al., 1994; Milia and Torrente, 1999).

Quaternary extension along the Campania segment of the southern Apennine - Eastern Tyrrhenian hinge zone caused in turn the onset of intense volcanism. Major volcanic centers are represented by the Somma-Vesuvius, Ischia Island and the district of the Campi Flegrei with its numerous vents both onshore and offshore the Bay of Naples. Recent morphologic evolution of the Bay of Naples has been significantly controlled by sea-level changes and consequent base-level fluctuation during the last glacio-eustatic cycles (Milia, 1999).

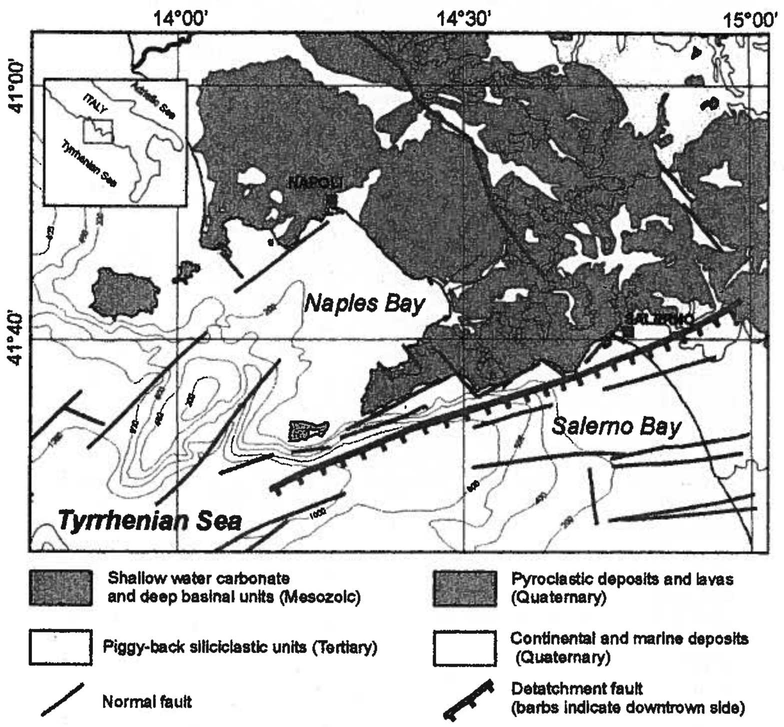

Fig. 2. Tectonic sketch-map of western Campania Apennines.
Carta tettonica schematica dell'Appennino campano occidentale.

4. THE DOHRN CANYON: A FOSSIL DRAINAGE SYSTEM IN AN ACTIVE VOLCANIC AREA

The Dohrn and Magnaghi canyons originate from the shelf break of the Bay of Naples off the Phlegrean Fields volcanic complex, located along the 140 m isobath. The course of the Dohrn canyon lower section is likely to be controlled by some morphostructural lineaments, i.e. the Banco di Fuori and Capri structural highs. Both the Magnaghi canyon and the Dohrn western branch display morphological evidence of retreating canyon heads (Figs 1 and 3).

The upper Dohrn canyon section consists of two major curved branches. The western branch cuts deep into the shelf through a 1.5 km wide and 20-40 m deep channel (Ammontatura) characterized by flat thalweg and asymmetrical levees. The Ammontatura channel probably represents an incised valley subsequently filled by younger deposits and predates the onset of the most recent volcanic edifices in the Gulf of Pozzuoli, as suggested by its abrupt termination towards the Nisida submarine vent. The width of the canyons ranges from a few hundred meters to more than 1 km; their depth ranges from 250 m at the shelf edge to some 1300 m at the junction with the bathyal plain; the slope of canyon walls attains some 35° in the steepest sectors. The Dohrn eastern branch (DEB) shows a meandering trend and develops from the shelf break of the Sorrento Peninsula, located along the 120 m isobath. The Dohrn western branch (DWB) is broader and deeper than the eastern one. The two branches do not join, being the eastern branch suspended over the western one (Figs 4 and 5).

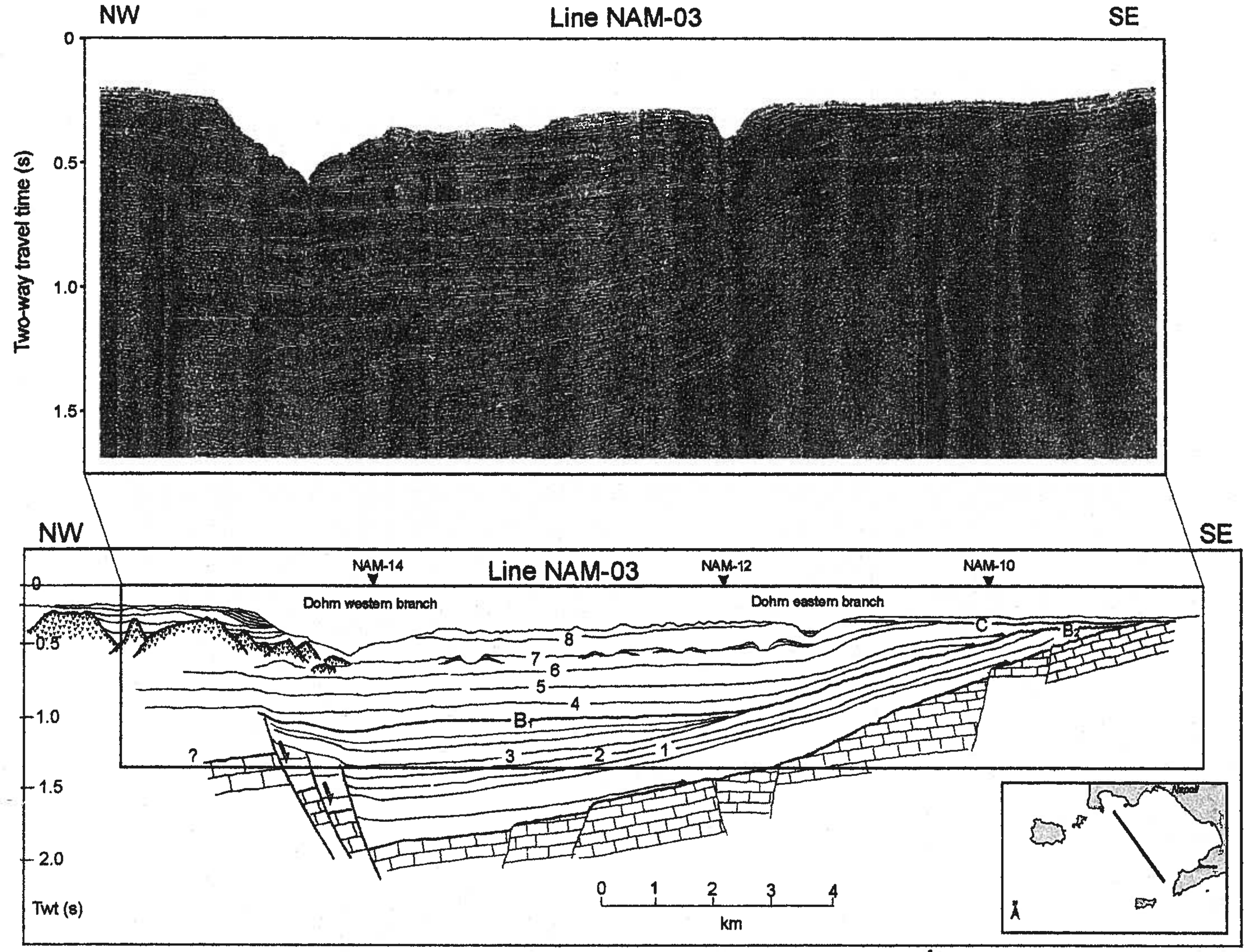

Fig. 3. Line drawing of seismic profile NAM3 crossing the Gulf of Naples from the Ischia and Procida islands offshore to the Sorrento Peninsula offshore and showing the stratigraphic relationships between the seismic sequences. Units 1-3 are interpreted as a wide, relic prograding wedge with eroded topsets and preserved clinoforms, probably Early Pleistocene in age. Units 4-8 are interpreted as a Late Pleistocene prograding wedge fed by the paleo-Sarno river mouth.

Interpretazione del profilo sismico NAM-03 che attraversa il Golfo di Napoli dalle isole di Ischia e Procida al largo di Sorrento ed illustra i rapporti stratigrafici tra le unità sismiche riconosciute. Le unità 1-3 corrispondono ad un cuneo sedimentario progradante inattivo, con topset erosi, e clinoformi ancora riconoscibili, di proabile età Pleistocenica Inferiore. Le unità 4-8 sono interpretate invece come un cuneo progradante alto-pleistocenico alimentato dalla foce del paleo-Sarno.

Canyon morphology

In general, V-shaped erosional profiles characterize the upper section of the Dohrn canyon, while U-shaped profiles develop in the lower, rectilinear section. V-shaped profiles prevail in the retreating head of the DW, and rapidly evolve into U-shaped profiles towards the meandering sector of the canyon. V-shaped profiles may be again detected in the sector of the DWB, close to the confluence between the two branches (Fig. 5). Large round-shaped morphologies at the bottom of the DWB and in the confluence area, close to the present-day thalweg of the canyon system are likely to represent remnants of the eroded substrate rather than slide blocks.

The geological scenario of the Dohrn canyon seems typical of a "mature" morphology, as suggested also by the occurrence of at least three phases of incision and terracing that predate the development of the present-day thalweg. Section D3 shows terrace rims respectively located at 300 m and 340 m waterdepth. These morphological evidences suggest at least two phases of activity and the retreat of the canyon's head. Well-developed terrace rims (at least five) were identified on bathymetric profiles (Fig. 5). Recent phases of canyon filling are testified by U-shaped morphologies in the meandering sector of the DWB and in the terminal sector of the canyon.

Drainage system

A dense network of previously unknown tributary channels, controlling sediment transport towards the surrounding areas of the continental slope, feeds the canyons. Two main tributary channels develop from the shelf break of the Phlegrean volcanic banks (located along the 140 m isobath) across the continental slope between the Dohrn and Magnaghi canyons. Some of these channels trend NW-SE and seem to be fault-controlled (Chiocci et al., 1998). Unactive tributary channels suspended over the main branches of the canyon testify phases of rapid re-incision, when the feeding from lateral sources was switched off, thus forming suspended valleys (Aiello et al., 2000).

Gravity instability processes

Several submarine slides and scars are evident on the canyon walls, especially along the western flank of the DWB as well as on the continental slope. Factors known to control submarine slides include loading of underconsolidated deposits due to rapid burial, slope oversteepening consequent to deep linear erosion, earthquakes and sea-level changes (Saxov and Nieuwenhuis, 1982; O'Leary and Dobson, 1992). This appears to be a significant issue to address, due to the potential risk of anomalous waves on the coastal zone, originated by submarine instability. Most slide scars involving the Dohrn canyon appear to be concentrated along the right flank of the Dohrn western branch. However, the Dohrn eastern branch does not appear to be involved in extensive gravitative instability compared to the western one. Moreover, slide scars are evident by bathymetric profiles also in the proximity of the present-day thalweg of the canyon.