ELSEVIER
Marine Geology 160 (1999) 25–44
MARINE GEOLOGY
INTERNATIONAL JOURNAL OF MARINE GEOLOGY, GEOCHEMISTRY AND GEOPHYSICS
www.elsevier.nl/locate/margeo

Sedimentation processes in a tectonically active environment: the Kerkyra–Kefalonia submarine valley system (NE Ionian Sea)

S.E. Poulos [a,*], V. Lykousis [b], M.B. Collins [c], E.J. Rohling [c], C.B. Pattiaratchi [d]

[a] *Department of Geology, Section of Geography–Climatology, University of Athens, Panepistimiopoli, Zografou 15784, Athens, Greece*
[b] *National Centre for Marine Research, Institute of Oceanography, Agios Kosmas, Hellenikon 16604, Athens, Greece*
[c] *School of Ocean and Earth Science, University, Southampton Oceanographic Centre, European Way, Southampton SO143ZH, UK*
[d] *Centre for Water Research, Department of Environmental Engineering, The University of Western Australia, Nedland, WA 6009, Australia*

Received 29 October 1997; accepted 15 January 1999

Abstract

The Kerkyra–Kefalonia valley system is the northwestern extension of the Hellenic arc–trench system, representing the collision zone of the Apulian Platform and the Hellenides. The system is distinguished by two different physiographic regions: the northern part, U-shaped, and oriented NNW–SSE, with relatively gentle slopes and a wide floor; and the southern part, oriented NE–SW, V-shaped, and with much steeper side walls and a narrow floor. Both parts are formed tectonically, with the former coinciding with a collision zone, and the latter being the morphometric expression of the Kefalonia strike–slip fault. Sediments recovered in the piston cores from the region consist of fine-grained material, deposited by a variety of sedimentation processes such as: gravity-driven mass movements, associated with seismic activity (i.e., slumping, sliding, debris flows, grain flows, turbidites–seismoturbidites); and, to a lesser extent, by hemipelagic deposition. Measured near-bed currents and their associated shear stresses indicate resuspension of the material, mainly within the northern part of the valley. Sub-bottom acoustic (seismic) profiling data reveal various sedimentary provinces, related to different mechanisms of sediment accumulation: (i) the eastern margin of the Apulian Platform with hemipelagic sedimentation, together with possible advection of suspensates from the Adriatic, in response localised to seabed erosion; (ii) the western Hellenic margin, with down-slope episodic sliding and slumping, induced primarily by earthquake activity, together with an input from hemipelagic settling; (iii) the collision zone, coinciding with the northern part of the Kerkyra–Kefalonia valley system, with deposition mostly from resuspension, the occurrence of local mass gravity flows and the advection of some material from the north; and (iv) the Kefalonia strike–slip fault region, where mass gravity flows are the dominant mechanisms, related to erosion/deposition from resuspension. Overall sedimentation within the tectonically-active Kerkyra–Kefalonia valley system is characterised by the coupling of the mass gravity-driven flows, which are the predominant mechanisms, with the near-bed current regime related with resuspension phenomena and the advection of suspensates. These latter mechanisms is likely more pronounced during the winter period, when dense water masses formed in the Adriatic inflowing into the Ionian Sea. © 1999 Elsevier Science B.V. All rights reserved.

Keywords: Hellenic trench; sedimentation processes; currents; seismic profiles; core

* Corresponding author

PII: S0025-3227(99)00016-X

1. Introduction

The understanding of mechanisms of sediment transport and deposition, in different tectonic settings and under a variety of climatological/oceanographic conditions and bedrock lithologies, has extended considerably during the past two decades. However, most of our knowledge on sedimentary sequences and depositional processes and facies development originates from nearshore studies, associated usually with inactive basins and large-scale modern submarine fans and fan deltas, e.g., the Mississippi (Kosters and Suter, 1993), Amazon (Nittrouer et al., 1986), Nile (Sestini, 1989), Rhone (Got and Aloisi, 1990), and Ebro (Farran and Maldolado, 1990). In contrast, examples from offshore modern basins, formed in tectonically-active regions (collision zones, rifting areas, trench–arc systems) are limited and relate to: the Bengal Foreland basin (Biswas and Agrawal, 1992); the eastern Taiwan region (Dorsey, 1988); to the west of the Kermadec trench and arc (Bay of Plenty, New Zeland) (Lewis and Pantin, 1984); the Tanganyika Trough, East African rift system (Bouroullec et al., 1991); the Californian borderland, an active strike–slip setting in the USA (Thornton, 1984); and the South Barbados tectonic accretional prism (Griboulard et al., 1996). Especially in the Mediterranean basin depositional processes have been investigated in: the northwestern Mediterranean margin (Bellaiche, 1993); the Medriff Corridor, Mediterranean Ridge (Fusi et al., 1996); the Hellenic trench–arc system (Stanley et al., 1978; Got et al., 1981; Got, 1984); and the active rift setting of the Gulf of Corinth (Greece) (Papatheodorou et al., 1993; Dart et al., 1994; Fusi et al., 1996).

Furthermore, turbidite systems ('a body of genetically related mass flow and turbidity current facies and facies associations that were formed in virtual stratigraphic continuity' (after Mutti and Normark, 1987)) which have formed in such environments have attracted both scientific and socio-economic interest. Thus, turbidite reservoirs, identified in more than 80 sedimentary basins in the world (Weimer and Link, 1991), will be a major petroleum exploration target into the 21st century. At the same time, such deposits are related often to offshore hazards, associated with structures and seabed cable failures.

The Hellenic arc–trench system (eastern Mediterranean Sea) is part of the Alpine–Himalayan mountain system; this is one of the major structural features of the earth. This Alpine-type belt was formed initially by an oceanic–continental interaction, that ultimately became an interaction between two continental masses, i.e., the African and Eurasian plate (Moores and Twiss, 1995). Thus, the Hellenic arc–trench system, one of the world's most tectonically active zones, provides a unique environment to study a variety of active sedimentological processes.

The present investigation examines past and present sedimentation processes, together with and sedimentary facies formation in modern marine basins, controlled by active tectonics and during the last post-glacial period. The study is undertaken on the basis of the integration of syntheses of interdisciplinary and 'unique' geophysical, hydrographical and sedimentological data sets (see below). The objectives of the investigation are to: distinguish between the various mechanisms of sediment transport and deposition; identify the various sediment source areas and transport pathways; investigate depositional features (e.g., turbidite systems), in the different tectonic settings of the region, i.e., continental collision, dextral strike–slip fault, and arc–trench system; establish the coupling between tectonically-induced mass gravity-driven flows and the hydrodynamic regime (e.g., bottom currents); and, finally, identify different sedimentary provenances, on the basis of the prevailing processes.

2. Study area

The study area, located within the northeastern part of the Ionian Sea, lies immediately to the south of the Otranto Strait, which forms the boundary between the Adriatic and Ionian Seas (Fig. 1). The area consists basically of the Kerkyra–Kefalonia submarine valley system, extending parallel to the Greek continental shelf and slope. The longitudinal axis of the valley trends in a NNW–SSE direction, up to the northwest of Kefalonia Island; here, it becomes NE–SW in its orientation (Fig. 2). Water depths range from around 1000 m in the north, to in excess of 3000 m at the areas' southerly limit.

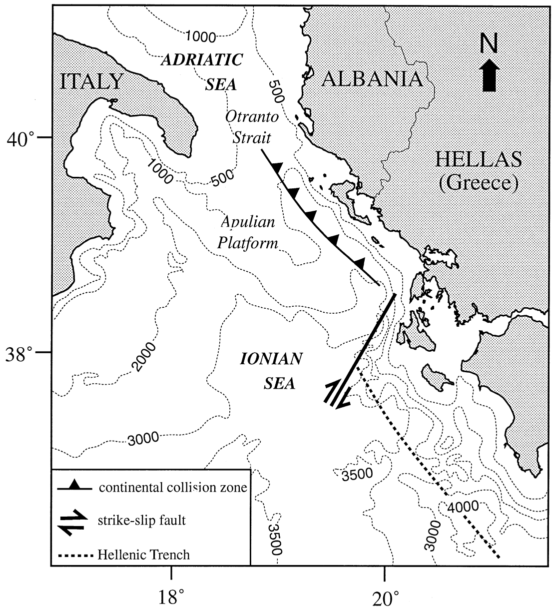

Fig. 1. Structurally-controlled bathymetry (in metres) of the study area (based upon Underhill, 1989).

Tectonically, the Kerkyra–Kefalonia valley system is the northwestern extension of the Hellenic arc–trench system (Fig. 1). Moreover, the northern part of the valley (trending NNW–SSE) represents the convergence (collision) zone between the Apulian Platform and the Outer Hellenides (the Paxos and Ionian Geotectonic Zones), while the southern part (oriented ENE–WSW), follows the strike–slip Kefalonia fault. This fault connects the previous Apulian–Albano–Greek collision zone, with the Ionian subduction zone to the south (LePichon and Angelier, 1979).

The overall structural and stratigraphic geological configuration of the region is characterised by the presence of reverse faults and thrust folds, active since the Miocene (Mercier et al., 1976; Monopolis and Bruneton, 1982; Brooks and Ferentinos, 1984). Structurally-deformed unconsolidated sedimentary sequences, of highly variable thickness, overlie indurated strata of Cretaceous/Miocene age, including evaporites from the Messinian (Blanpied and Stanley, 1981). The regional tectonics involves complex slip patterns, inferred from high seismicity, with intense shallow earthquake motions particularly pronounced in western Greece; this is the most seismically-active area in Europe. For example, more than 110 earthquakes of 5–6 Richter, some 20 earthquake of 6–7 Richter scale and three earthquakes >7 Richter (IGME, 1989) have been reported between 1900 and 1986, for the Ionian Sea (from Kerkyra to Zakynthos) and the adjacent Greek mainland. Such motions are expected to generate peak ground accelerations of 20–30% g in the southern part of the Kerkyra–Kefalonia valley system (especially along the Kefalonia strike–slip fault), decreasing to 10–15% g towards the northern part of the region (Makropoulos and Burton, 1985).

Recent sedimentation within the NE Ionian Sea has been studied in general terms, through the use of 3.5 kHz seismic reflection profiles and the analysis of cores (Perissoratis and Rossi, 1990). Mass movements were found to influence considerably the sedimentation processes, while core analysis from the southernmost part of the Kerkyra–Kefalonia valley system has indicated gravitational depositional mechanisms, i.e., slides, debris flows and turbidity currents, generated over short distances of the seabed. Lykousis (1991) and Ferentinos (1992), investigating seafloor failures in the Hellenic arc, have identified various triggering mechanisms, such as, earthquake-induced ground accelerations, of over 0.1 g; steep slopes, with gradients up to 40°; ‘weak’ sediment layers (glide planes), e.g., gas-saturated sediments, hemipelagic mud sheets of low shear strength, and sapropelic layers. Finally, detailed sedimentological investigations undertaken to the south of the study area relate to the Hellenic trench (Got et al., 1977; Got et al., 1981; Got, 1984) and the valley/canyon system of the Zakynthos channel (Ferentinos et al., 1985; Cramp et al., 1987; Anastasakis and Piper, 1991).

The regional pattern of surface water circulation is from the southeast, towards the northwest, along the western Greek coastline (Nittis et al., 1993); bottom waters move generally towards the south (Fabricius and Schmidt-Thome, 1972). A similar circulation pattern has been described for the Otranto Strait by Ferentinos and Kastanos (1988) and Gacic et al. (1996). A significant process within the region is the formation of dense water masses in the Adraitic Sea, during the winter; these flow subsequently towards the Ionian Sea, through the Otrando Strait,

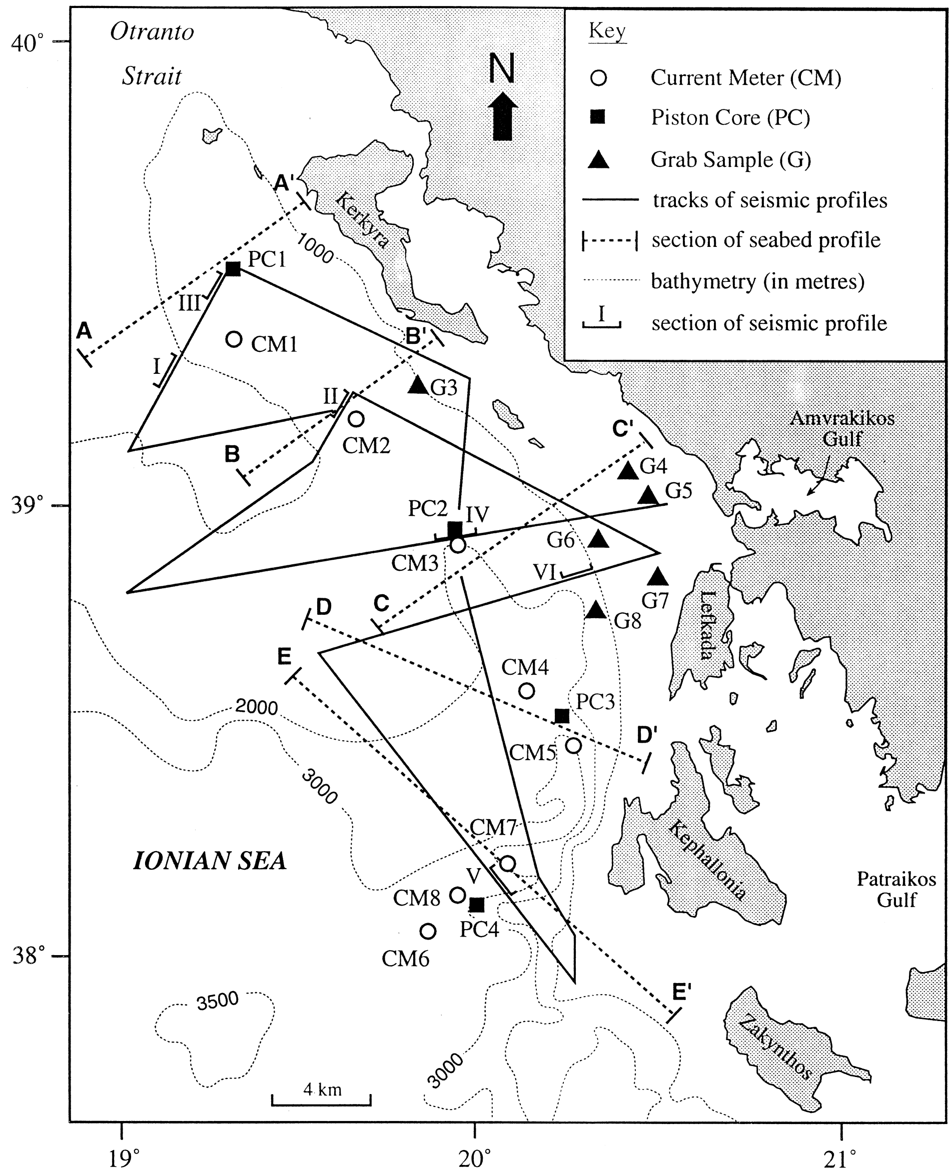

Fig. 2. Location of seismic profiles, current metre stations, piston cores and grab samples (bathymetry is based upon an hydrographic chart (1:1,175,000) published by the Hellenic Navy Hydrographic Service, Athens, 1992).

inducing strong near-bed currents (Bignami et al., 1991; Gacic et al., 1996). Furthermore, the surface waters, in contrast to these deeper waters (originating from the Adriatic Sea), are lacking in suspended sediments and nutrients (Civitazese et al., 1994; Rabitti et al., 1994). Finally, the tidal range over the area is insignificant, varying from 5 cm on neaps up to 35 cm during springs (Tsimplis, 1994).

3. Data collection and methodology

The data analysed were collected during RRS *Charles Darwin* Cruise 14/86 (between 4th and 15th July, 1986) and include: some 125 line km of geophysical (3.5 and 7 kHz high-resolution seismic profiles); Day grab (7) surficial sediment samples, from the Greek continental shelf/slope; piston cores

(4, ranging from 0.54 to 5.9 m in length); and data collected from (8) Aandera self-recording current metre mooring arrays, deployed along the axis of the Kerkyra–Kefalonia valley system (over a 10- to 11-day period). During the sampling programme, the weather conditions were relatively stable, with winds < 4 Beaufort. The positions of the high-resolution sub-bottom seismic lines, together with the sampling and mooring locations, are shown in Fig. 2.

The continuous 3.5 kHz high-resolution reflection profiles have been analysed according to the methods proposed by Damuth (1975), Mitchum et al. (1977) and Embley and Morley (1980). These approaches distinguish between different sediment sequences and depositional conditions based upon the analysis of correlatable reflections, successive reflectors, and associated unconformities.

Particle size analysis was undertaken on all the grab samples and selected sub-samples abstracted from the cores. The sand fraction (> 62.5 μm) was separated from the mud, using wet sieving; the remaining sediment was divided further into silt and clay (< 4 μm), with the use of a Sedigraph 5100. Where sufficient sand fraction was available, dry sieving was used to determine its size distribution. The organic carbon contents, of the (bulk) grab samples and from the sub-samples taken along the piston cores, were determined using an elemental analyser (Carlo Erba EA1108); this followed treatment with concentrated hydrochloric acid, for the removal of the carbonate. Because of the potential for contamination of AMS ^{14}C dating or oxygen isotope stratigraphy, only biostratigraphic correlation with a central Mediterranean reference core (Jorissen et al., 1993) was used for the age assignments (see text). Such a dating technique relies upon prominent changes in the 'total' planktonic foraminiferal fauna.

Current speed and direction were sampled every 2 min, while the threshold of movement of the (Savonious) rotors used on the metres was 1.7 cm s^{-1}. Analysis of the current metre data has been undertaken in terms of the statistical characteristics of the Eulerian observations. Furthermore, the erosional ability of the observed bottom currents has been investigated, through the calculation of the near-bed shear stresses induced by the maximum and mean near-bed (< 5 m) current activity. Shear stresses associated with all the near-bed current metres were derived using the equation proposed by Sternberg (1972): $\tau_c = \rho C_D u_z^2$ where ρ is the density of seawater; u_z is the current velocity; C_D is the drag coefficient, equal to $[0.4/\ln(z/z_o)]^2$; z is the distance above the seabed; and z_0 is the bed roughness which is equal to grain diameter (D_{50}) for flat (plane) beds. Threshold values used in the analyses have been derived from field and laboratory investigations, published elsewhere, for sediments of different grain sizes.

4. Results and interpretation

4.1. Seabed morphology

The Kerkyra–Kefalonia submarine valley system is a major linear depression, which runs parallel to the margin of the northwestern Greek mainland (that of the Ionian Islands) (Fig. 2). The system consists of two distinctive physiographic units: the northern part, with the axis trending 330°N; and the southern part, oriented 240°N. The northern part is some 140 km in length and incorporates water depths of between 900 m (in the vicinity of the Otranto Strait) and 3000 m (to the west of the island of Lefkada); the southern part is about 60 km in length, with water depths ranging from 3000 to 3600 m.

Bathymetric sections across the longitudinal axis of the valley (Fig. 3) reveal a change from a wide U-shape, to a narrow V-shape, between the northern and southern part of the valley system. Similarly, the floor of the northern part of the valley is somewhat flat, with gradients about 1:100. The widths vary from 3000 m to less than 500 m, towards the southern part of the valley system. The axial slope of the valley varies from 1:100 (to the north) to 1:80 (towards the south). The eastern side of the valley consists of the western continental shelf and slope of the Greek mainland and the Ionian Islands. In general, the shelf break lies at water depths of between 180 and 220 m. The continental slope gradients range from 1:10 to 1:35 and from 1:3 to 1:10, over the northern and southern parts, respectively. The western side of the valley, forming the southeastern submarine extension of the Apulian Platform, is characterised by more gentle slopes, ranging from 1:40 to 1:80; higher gradients are associated with the southern part of the valley.

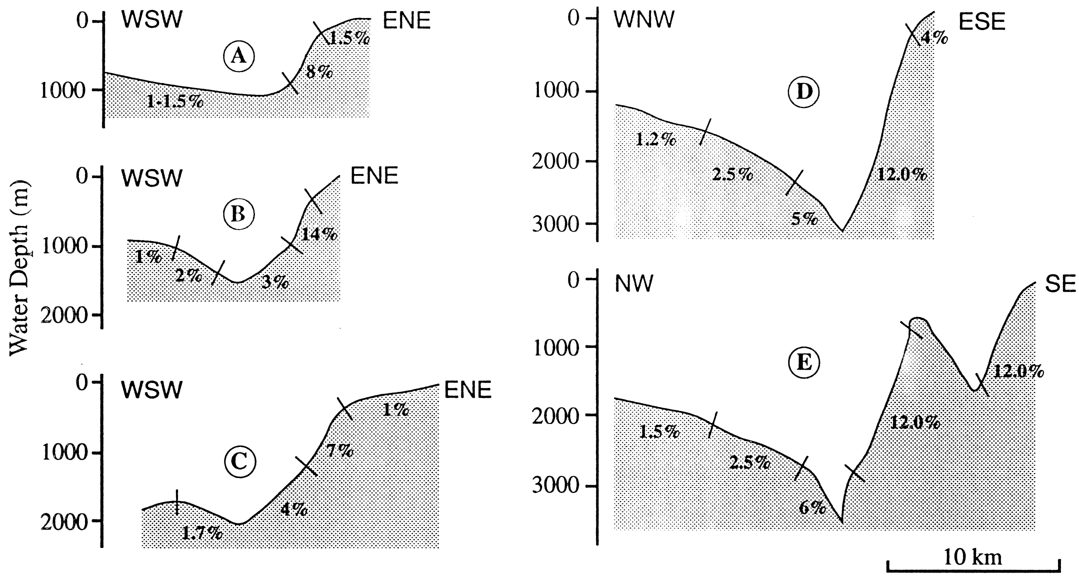

Fig. 3. Transverse bathymetric profiles of the Kerkyra–Kefalonia valley system based upon bathymetric chart (1:250,000), published by the Hellenic Navy Hydrographic Service, Athens, 1988 (for locations of cross-sections, see Fig. 2).

The continental shelf, extending up to an average water depth of 200 m, has an average width of some 15 km and a slope-gradient of 1:35–1:70 (to seawards of the western Greek mainland). The shelf is less than 1 km wide and is steeper than 1:25 off the western coast of the Ionian Islands.

4.2. Lithoacoustic stratigraphy

The lithoacoustic profiles obtained from the submarine extension of the Apulian Platform display sheet-drape 'seismic' facies, with sub-parallel and generally low amplitude continuous and stratified reflectors (Fig. 4; Section I). The thickness of these concordant acoustic facies varies from 10 to 25 m, representing Upper Quaternary sediments; these were deposited in a relatively deep hemipelagic environment. In fairly extensive regions over the Apulian Platform, the parallel seismic faces are distorted slightly by the synsedimentary geodynamic evolution of the Apulian, forming a high amplitude symmetric or asymmetric wavy configuration of the acoustic reflectors of the seabed (Fig. 4; Section I). This configuration is similar to that described elsewhere, for an extensional back-arc regime (i.e., Gulf of Patras, Cornelisse et al., 1991), implying probably rotational 'extensional' faulting. Towards the eastern margin of the Apulian Platform, parallel reflectors display a very small angle offlap termination towards the seafloor; this suggests weak and probably localised erosional processes. Below, another seismic sequence may be faintly distinguished, incorporating deformed reflectors, and toplapping to the upper sheet-drape seismic unit. This pattern is consistent with an older (Middle/Lower-Pleistocene) intense (extensional) geotectonic event (rotation–folding–tilting). The feature represents, possibly, the characteristics of an extensional back-arc area, similar to that suggested for the greater Hellenic back-arc area (Mercier et al., 1976), reported earlier for the Central Aegean Sea (Taymaz et al., 1991) and described recently by Lykousis et al. (1995).

Seismic profiles obtained from the relatively steeper southwestern marginal slopes of the Apulian Platform (the western side-walls of the Kerkyra–Kefalonia valley) show very strong bottom reflectors, without sub-bottom reflections or weak discontinuous near-bottom reflectors offlapping to the seabed (Fig. 4; Section II). This physiographic region is clearly erosionally-truncated and is subject to synsedimentary resuspension and/or non-accumulation processes; this is in response to possible bottom current activity (as there are no indications of any sediment mass gravity processes). The seabed of the northeastern part of the Apulian Platform margin

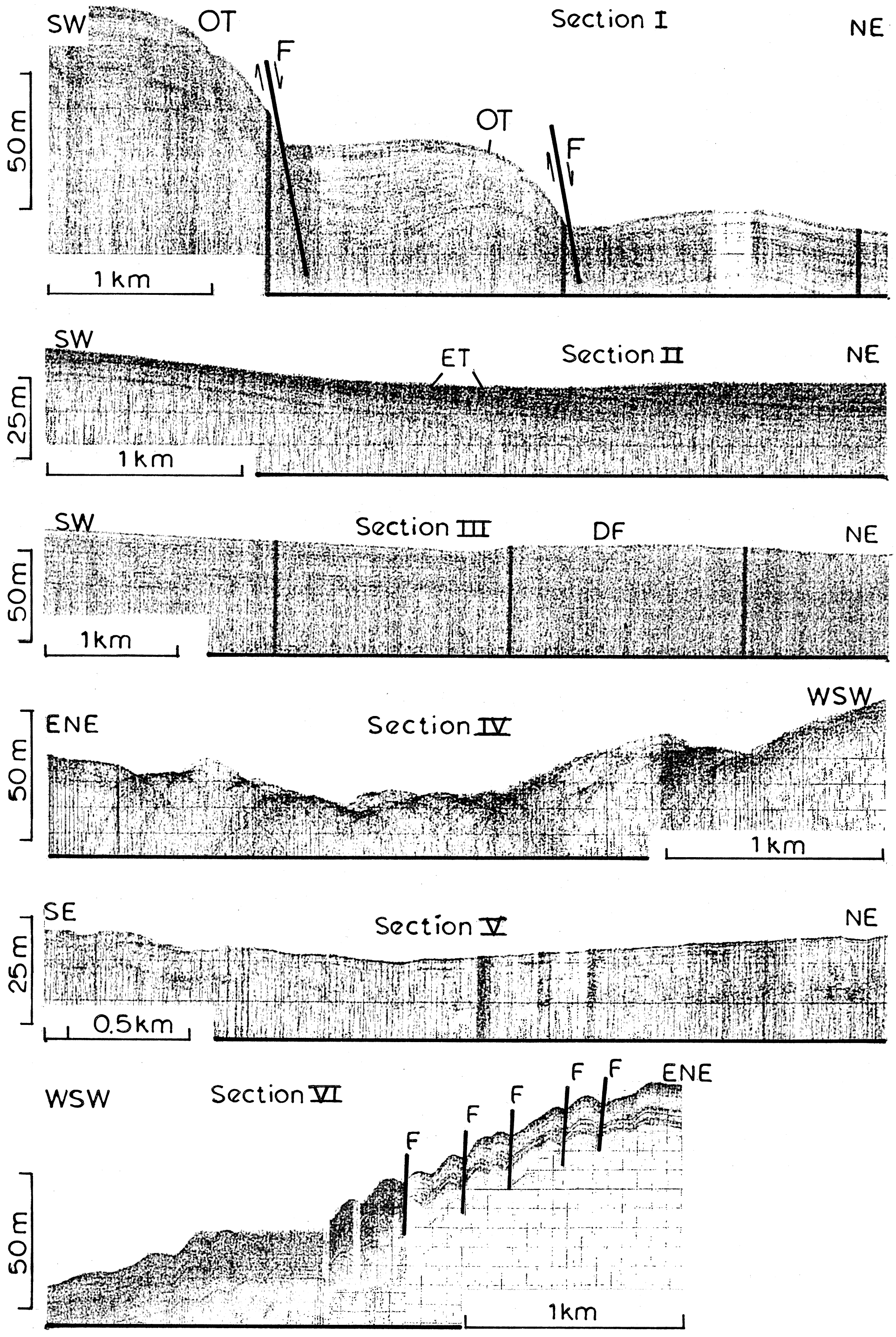

Fig. 4. 3.5 kHz sub-bottom seismic profiles along sections I–VI (for locations, see Fig. 2). F = fault; OT = offlap termination; ET = erosional trancate; DF = debris flow.

(characterised by lower gradient slopes) together with the adjacent northern entrance of the Kerkyra–Kefalonia valley consist of parallel sub-bottom reflectors (Fig. 4; Section III). These reflectors are interrupted, within the Kerkyra–Kefalonia valley, by mass flow episodic events (mudflows, debris flows); these are indicated by the massive chaotic sub-surface reflections. Farther to the south, within the upper part of the valley, the parallel sub-bottom reflectors display small angle toplap termination to the sea-bottom. This pattern is the result of weak erosional-resuspension processes, which probably prevail over the area, coupled with mass gravity flows initiated from the steep slopes of the Island of Kerkyra.

Seismic profiles, inclined almost perpendicular to the axis of the central part of the Kerkyra–Kefalonia valley-system, consist of medium amplitude and irregular overlapping hyperbolic reflectors; there is an absence of distinct sub-bottom reflectors (Fig. 4; Section IV). This particular type of seismic reflection denotes a highly irregular bottom, perhaps resulting from turbidity current erosion of older (compacted) sediments on the valley floor. Further, present-day near-bed flows, as indicated by measurements obtained from a current metre array (CM3) deployed nearby, are in excess of 30 cm s^{-1}; these have the potential to initiate erosion of the seabed (see below).

The 3.5 kHz profiles obtained from the narrow southern part of the valley floor (the Kefalonia strike–slip fault) consist of an indistinct semi-prolonged bottom echo, with zones of strong semi-prolonged discontinuous and parallel sub-bottom reflectors (Fig. 4; Section V). These reflectors alternate with zones of hummocky, chaotic or diffuse

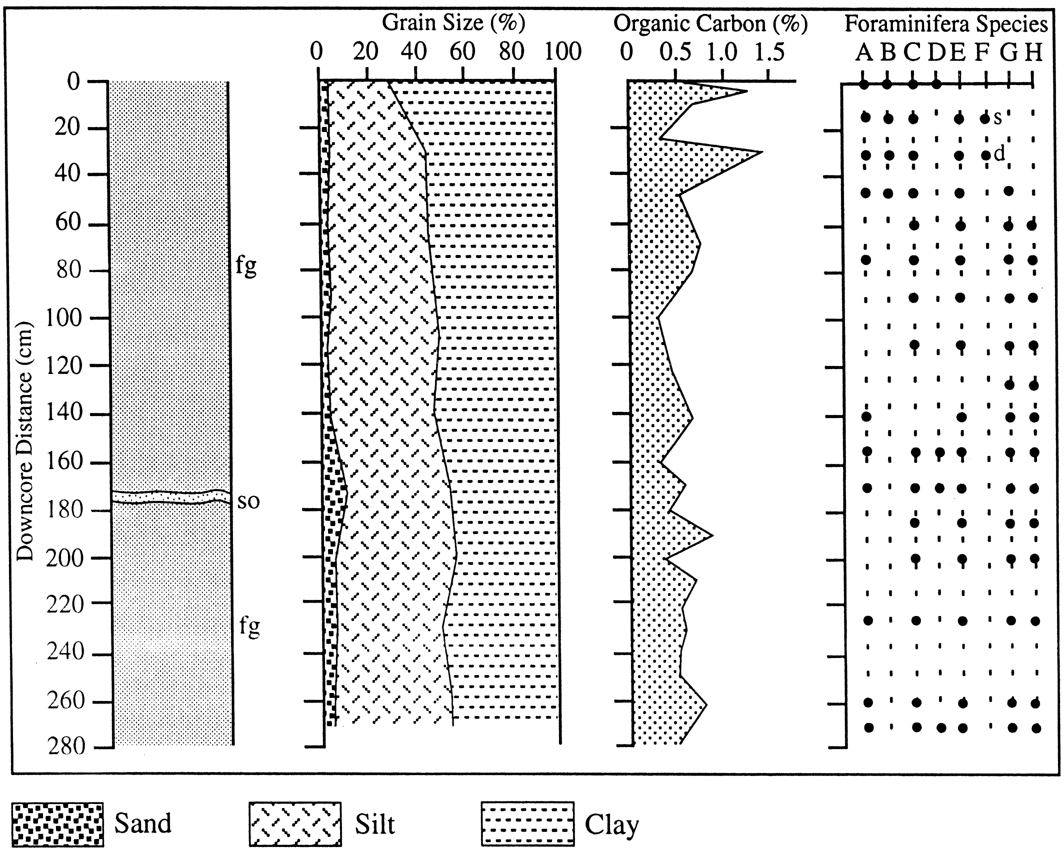

Fig. 5. Vertical distribution of the sedimentological characteristics of PC1 (for location, see Fig. 2). fg = fine-grained; so = sandy horizon; A = *G. ruber*; B = *G. inflata*; C = *Globigerina bulloides*; D = *Globigerinita glutina*; E = *Neogloboguadrina*; F = *G. truncatulinoides* (s: sinistral coiling; d: dextral coiling); G = *G. scitula*; H = *Globigerina quinqueloba*.

('mushy') sub-bottom reflections (cf. Damuth, 1975), usually indicating debris flows. High amplitude overlapping hyperbolic reflectors often appear below this lithostratigraphic sequence, indicating an irregular substratum morphology. This pattern of seismic reflection configuration commonly denotes deposition from sediment mass flows, particularly turbidities, debris and grain flows; these, in turn, are related to the irregular bottom topography.

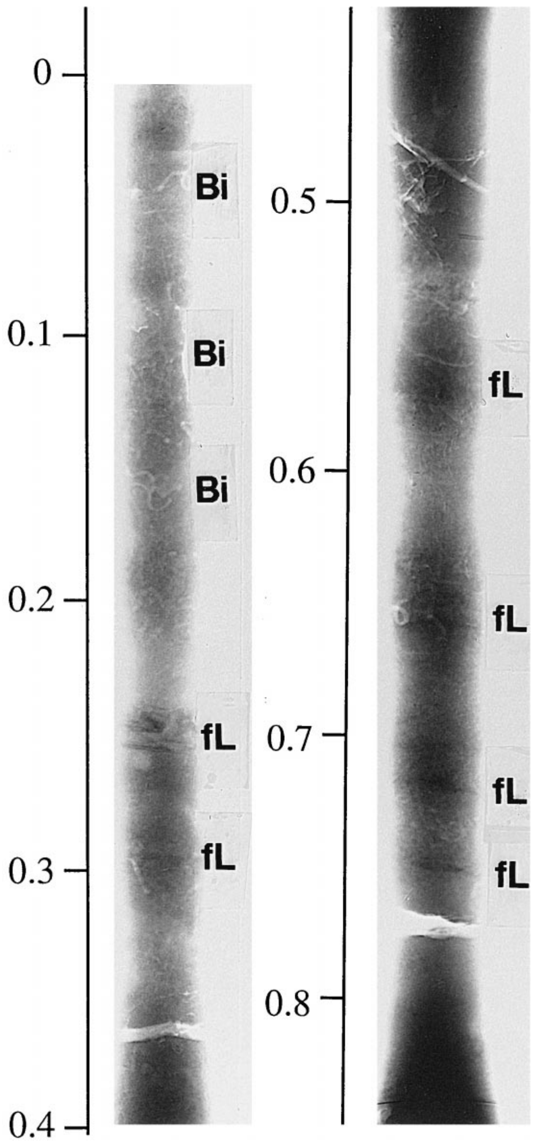

Fig. 6. X-ray radiograph along a split section (the upper 40 cm) of PC1 (downcore distance in metres). Bi = bioturbation; fL = faintly laminated.

The eastern and steeper sidewalls of the Kerkyra–Kefalonia valley-system (especially at the Kefalonia escarpment), in relation to the precipitous and irregular topography, display characteristic high-amplitude overlapping hyperbolic reflections. In contrast, thick parallel and stratified sub-bottom reflectors characterise the slope to the west of Amvrakikos Gulf (Fig. 2); these suggest high sedimentation rates, related possibly with prodeltaic deposition along the western Greek mainland, during low-stands of sea level; this has been described in relation to the neighbouring Gulfs of Patras and Corinth (Piper and Panagos, 1981; Piper et al., 1990). Such stratified reflectors are affected commonly by gravity growth faults, at the shelf break and on the upper slope (Fig. 4; Section VI); these are an indication of gravity-induced deformation (seismically-activated) during an initial, probably 'pre-slumping', stage. Such instabilities are common within the modern prodelta slopes of the seismically-active continental shelves of western Greece (Lykousis, 1991; Ferentinos, 1992, 1993). The seafloor features here resemble: contemporaneous faults and slumps, observed on the shelf off the South Pass of the Mississippi Delta (Coleman and Prior, 1981); a slump near Eureka–California (Lee et al., 1981); and slumps identified in the Gulf of Alaska (Carlson et al., 1980).

4.3. Sediments

4.3.1. Lithology and biostratigraphy [1]

4.3.1.1. Piston core 1 (PC1). This particular core (total length, 586 cm) was recovered from the northeastern part of the Kerkyra–Kefalonia submarine valley, in a water depth of 1160 m. The distribution of grain size and organic carbon content along the upper 280 cm of the core, are shown on Fig. 5. The sedimentary material presented in the core is dominated by silt and clay, while only a single layer (at 170 cm downcore) is associated with a high percentage of sand (9.3%); this can be attributed to a proportionally high percentage of broken shells (mainly bivalves). Dinoflagellates are relatively

[1] Note: based upon analysis of the piston cores (for location, see Fig. 2).

abundant in the upper section of the core, but are absent below 80 cm. The abundance of foraminifera and nannofossils appears, in general, to decrease with depth.

X-radiographic analysis of split sections of the upper 40 cm of the core (Fig. 6) shows an almost structureless hemipelagic mud; this is commonly bioturbated, with pyritized burrows in a matrix that incorporates a series of faintly-laminated mud deposits. The lamination displays poorly defined basal contacts, extending up to several centimetres in thickness.

Biostratigraphic analysis reveals a strong dominance, at 15 cm, of the left-coiling variety of *Globorotalia trunctulinoides*; this suggests that, at this level, sediments are younger than 11.7 ka BP (cf. Jorissen et al., 1993). Such an inference is supported by the absence of *Globorotalia scitula* and *Turborotalita quinqueloba* in the upper three samples analysed (Fig. 5). At 30 cm, *G. truncatulinoides* is predominantly right-coiled, suggesting that the 11.7 ka BP coiling-change is located at a depth of between 15 and 30 cm in this core. The substantial presence of both *G. scitula* and *T. quinqueloba*, at 60 cm, suggests that this horizon is older than about 12.7 ka BP. The continued high abundance of *G. scitula* and *T. quinqueloba*, combined with the continued absence of *Globorotalia inflata* and low abundance of *Globorotalia ruber* farther downcore, suggests that the base of the core PC1 is dated well within the last glacial phase. In the eastern Mediterranean, *G. inflata* is known to have been previously of substantial abundance, before about 30 to 35 ka BP (Jorissen et al., 1993). Using this age-limit for the base of the core, an overall sedimentation rate of around 10 cm ka^{-1} has been derived. Approximate dating of the upper part of the core would indicate that sedimentation rates are closer to 25 cm ka^{-1}, suggesting that the core base only reaches down to about 20 ka BP. Biostratigraphy of PC1 does not really provide a means to specify the date for the base of the core, but the derived sedimentation rate exceeds the general values for the abyssal plain of the eastern Mediterranean (by a factor of between 4 and 10).

4.3.1.2. Piston core 2 (PC2). The core was recovered from the middle of the northern part of the Kerkyra–Kefalonia valley system, from a water depth of 1815 m. This relatively coarse-grained short core (80 cm in length) does not display any apparent textural vertical trend, while particular sediment sequences cannot be recognised (Fig. 7). Sediment horizons or layers of various thickness and lithologi-

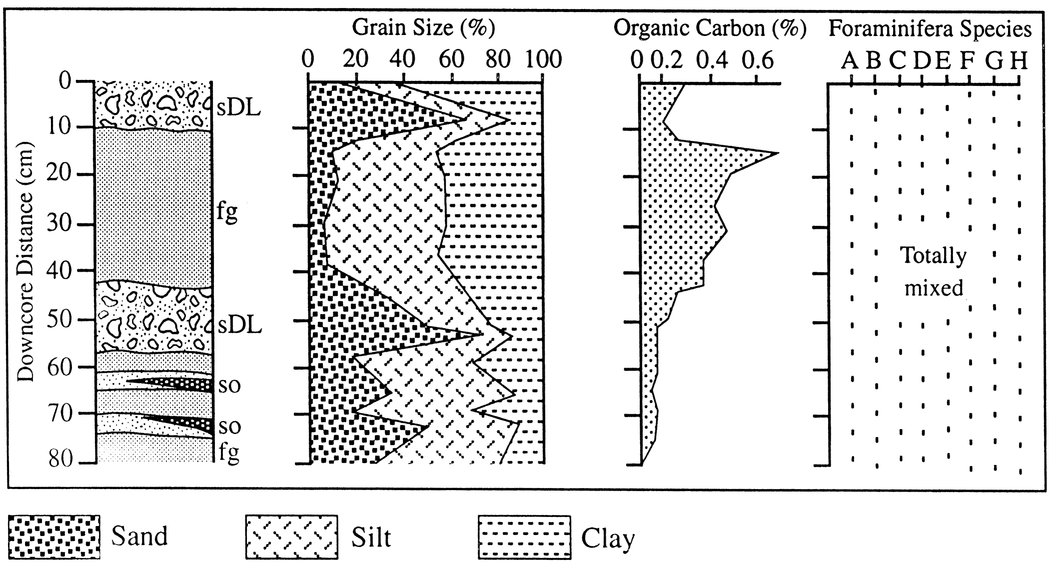

Fig. 7. The vertical distribution of various sedimentological parameters in PC2 (for location, see Fig. 2). sDL = sandy debris layer; fg = fine grained material; so = sandy horizon (for foraminifera species, see capture of Fig. 5).

cal composition (mostly bioclastic sand, with a high silt content) appear throughout the core; these are sharp contacts, often layered intrusions, of aggregates (mostly mud clasts).

Organic carbon contents range from < 0.1% up to 0.66%, over the majority of the core length, the values range between 0.14% and 0.2%. Moreover, the lower organic carbon content is related with the coarser-grained material. Such correlation may be due to relatively higher accumulation rates of the terrigenous inputs, supported also by the lower foraminifera (nannofossil and dinoflagellate) content and the increase in quartz and feldspar.

Much of the data suggest that the sediments contained within the core record resuspension events, followed by deposition, and/or mass flows; the latter interpretation is supported by the presence of bioclastic material, typical of shelf origin and/or the product of in-situ winnowing processes. In addition, the biostratigraphy of the core, characterised by the absence of any species succession, indicates that sediment is mixed; this is the result of re-deposition, attributed either to turbidity currents and/or near-bed current activity. The graded discrete sandy-bed turbidites (on the basis of their sedimentary structures and the presence of glauconite, which occurs normally in shallower water deposits) indicate the turbiditic character of the depositional processes.

4.3.1.3. Piston core 3 (PC3). PC3 (total length, 489 cm) was recovered from a water depth of 2830 m, to the west of the island of Lefkada (Fig. 2). Unfortu-

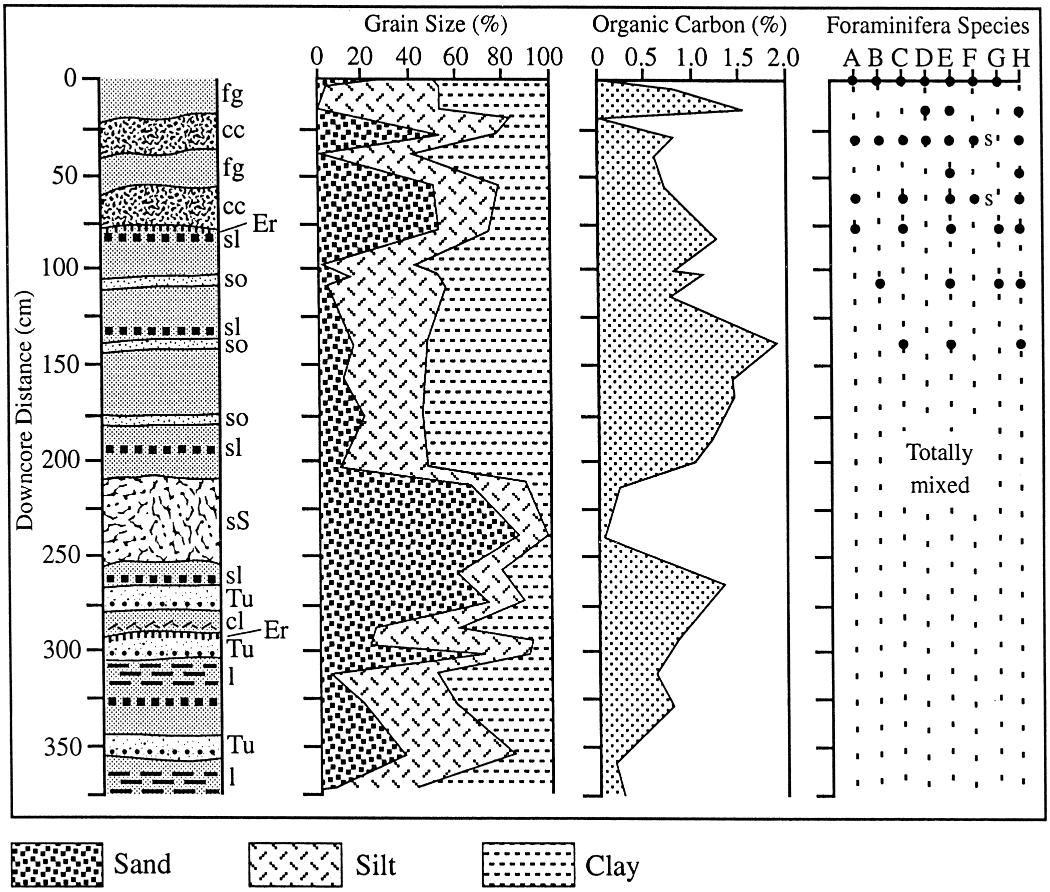

Fig. 8. The vertical distribution of various sedimentological parameters in PC4 (for location, see Fig. 2). fg = fine grained material; cc = chalk clasts; Er = erosional surface; sl = sapropelic (possibly) horizons; sS = foraminifera sands; cl = cross-lamination; Tu = turbidite; l = lamination (for foraminifera species, see capture of Fig. 5).

nately, the core material from this recovery was not available to the authors. Nevertheless, preliminary examination revealed that the core was rather uniform, i.e., olive grey/green colour and high in silt/sand content, throughout its length. The increase in relatively coarse-grained material content (silt and sand), combined with the presence of a fragment of conglomerate at its surface, indicates that the core was recovered from an environment characterised by mass gravity movement.

4.3.1.4. Piston core 4 (PC4). The core was recovered from a water depth of 3442 m (Fig. 2), from the eastern flank of southern part of the Kerkyra–Kefalonia valley system. There is a great variation in the proportion of sand along the length of the core, ranging from 0.09% to 86.6% (Fig. 8). The sandy horizons contain very coarse-grained material (> 500 μm). The largest particles (3–5 cm in diameter) consist mostly of chalk clasts, transported from the shelf down to this depth (i.e., 3500 m). Organic

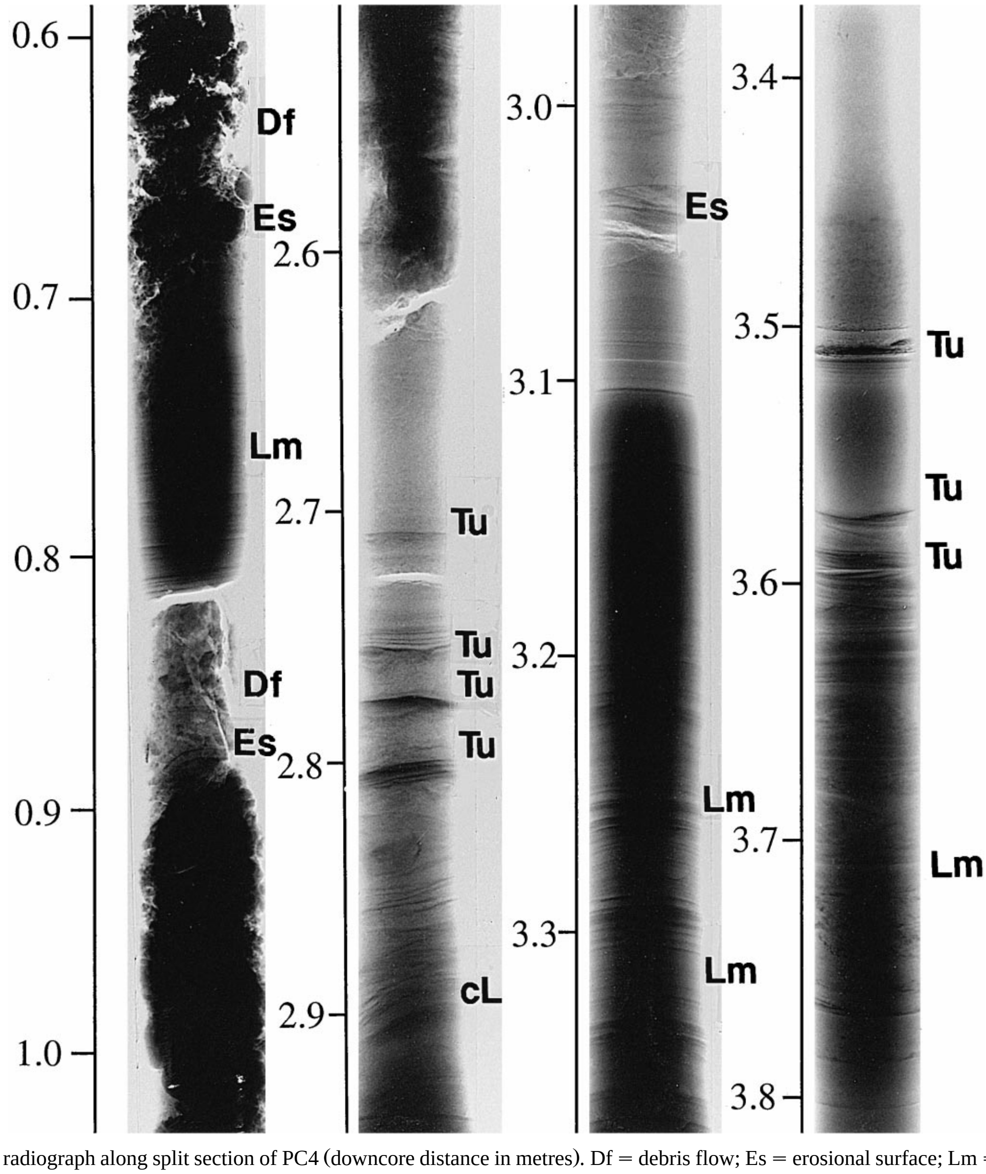

Fig. 9. X-ray radiograph along split section of PC4 (downcore distance in metres). Df = debris flow; Es = erosional surface; Lm = lamination; Tu = turbidite.

carbon levels range from between 0% and 2.02%, most of the values are $< 1\%$. In several of the layers (e.g., 83–87, 138–140, 192–194, 204–206 and 336–340 cm), the sediment is olive grey (5YR 4/2) in colour and contains a high organic carbon content ($> 1\%$). These layers could represent either re-worked sapropelic horizons, or parts of such horizons, which became separated during periods of disturbance.

The biostratigraphic investigation has revealed a mixture of species, at various levels within the core. Samples recovered from the top of the core are indicative of the Early Holocene, however, there is no indication of the exact time of sediment deposition. Discoasters, dinoflagellates, foraminifera and nannofossils are all present here; these become scarce towards the middle and bottom of this core, where the foraminifera are abundant. But, there are two sections within the core where they account for almost all of the material present; these are foraminiferal sands, towards the top (between 75 and 107 cm), and at the base (between 194 and 277 cm) of the core.

At 30 cm and (less prominently) down to 75 cm, *G. truncatulinoides* is predominantly left-coiling; this suggests that the sediments are younger than 11.7 ka BP (cf. Jorissen et al., 1993), representing an average sedimentation rate of the order of 6 cm ka^{-1}. Around the 75 cm level, there appears to be a change, from sediments dominated by *G. ruber* to those dominated by *G. scitula* and *T. quinqueloba*. This upward transition records probably the change from glacial to interglacial conditions, thus corroborating the late deglacial age (11.7 ka BP) inferred above. However, the biostratigraphy of PC4 is much less obvious than that of PC1 (see previously), because the fauna typical of glacial and interglacial intervals occur in varying proportions and are mixed throughout the core. From 140 cm downward, the faunas appear to be homogeneously mixed; no marked biostratigraphic horizons can be distinguished. In the upper 140 cm, the mixing seems less intensive, but is still prominent. In summary, it is difficult to establish sedimentation rates for this particular core (PC4), although a tentative estimate of the order of 6 cm ka^{-1} is suggested, for the upper 75 cm of the core.

The core consists of a variable vertical succession of distinct lithofacies; these are mostly turbiditic sequences, without any vertical trend (as shown in Fig. 8 and by the X-radiograph shown as Fig. 9). In the upper part of the core, the sediment consists of faintly or finely-laminated muds, interpreted as debris flow deposits interbedded by massive sandy–silty horizons. Turbidites vary both in grain size (either coarse- or fine-grained material) and in thickness (to a few tens of centimetres); they display, also, characteristically sharp bases, often with cross-lamination and (locally) erosional contacts, indicating re-working of older turbiditic deposits by turbidity currents.

Turbidites are triggered mostly on the steep Kefalonia slopes by earthquakes, within an area that is the most seismically-active in the Mediterranean. Seismoturbidites have been reported previously for the Zakynthos and Strofades basins (Anastasakis and Piper, 1991); these are located a few tens of kilometres to the south of the study area (Fig. 1). The faintly or finely-laminated muds are characterised by thin (1–5 mm) parallel laminae and the absence of any bioturbation of the sediments. Since suspended sediment input from the ephemeral rivers of Kefalonia is negligible, the laminated muds present were likely to have been deposited from turbidity flows originating from resuspension processes. Debris flow deposits (Fig. 9) appear as an admixture of stiff mud clasts, within a matrix of silty mud, without any

Table 1
Grain size and organic carbon content of the surficial sediments (for sample locations, see Fig. 2)

	Grain size (%)			Mz (μm)	σ_I	Organic carbon (%)
	Sand	Silt	Clay			
P1	1.5	28.7	69.8	1.05	2.7	0.36
P2	8.4	24.2	67.4	2.09	2.2	0.38
P3	0.8	33.7	65.5	2.58	2.0	
P4	1.5	28.2	70.3	0.42	4.7	0.23
G2	5.8	26.7	67.4	1.82	2.1	0.30
G3	5.3	26.2	68.5	1.59	2.1	0.47
G4	3.6	31.6	64.8	1.70	2.7	0.50
G5	7.9	28.9	63.2	1.95	2.2	0.59
G6	14.3	22.3	63.4	1.59	2.6	0.53
G7	18.8	23.9	57.3	1.82	2.4	0.52
G8	2.5	30.2	67.3	1.82	2.3	0.36

Note: (Mz) is graphic mean and (σ_I) is inclusive graphic standard deviation (after Folk, 1980). Both Mz and σ_I refer to the fine-grained material (< 62.5 μm).

Table 2
Statistical parameters relating to current measurements (for mooring locations, see Fig. 2)

Station	D[a] (m)	Z[b] (m)	Current speed					Residual current speed		
			Zero (%)	Minimum (cm s^{-1})	Maximum (cm s^{-1})	Mean (cm s^{-1})	Standard deviation	Speed	Direction (°)	Neumann[d] factor (%)
CM1	1170	100	00[c]	0.0	29.6	24.6			–	–
		30	14	0.0	46.1	25.7	10.0	14.0	221	67
		10	16	0.0	60.2	29.4	11.9	17.1	208	71
		4	17	0.0	58.6	28.9	11.6	17.0	202	72
		3	15	0.0	53.9	27.9	10.6	16.6	195	72
CM2	1395	30	74	0.0	39.0	24.4	7.7	3.5	321	60
		5	88	0.0	47.6	28.6	7.4	1.0	254	26
CM3	1860	100	00[c]	0.0	28.9	18.1	6.6	–	–	–
		30	49	0.0	30.4	15.5	5.6	5.5	348	73
		10	66	0.0	32.7	17.9	6.1	4.0	002	78
		4	45	0.0	32.0	15.1	5.9	6.1	326	83
		3	48	0.0	31.2	16.3	5.4	7.2	334	92
CM4	2400	30	05	0.0	38.6	21.2	7.1	12.1	185	65
		5	00	11.3	53.3	31.3	8.5	22.7	177	77
CM5	2945	100	93	0.0	13.2	09.8	1.6	0.5	014	99
		30	88	0.0	15.6	10.3	3.0	1.3	332	93
		10	76	0.0	21.0	11.7	3.8	3.0	315	97
		4	79	0.0	19.5	11.3	4.3	1.8	328	72
		3	81	0.0	17.1	10.0	3.3	1.5	319	82
CM6	3645	30	07	0.0	51.3	16.5	6.9	12.6	262	99
		5	07	0.0	46.3	14.9	6.2	13.7	240	99
CM7	3120	5	100	0.0	0.0	0.0	–	0.0	–	–
CM8	3200	30	100	0.0	0.0	0.0	–	0.0	–	–
		10	100	0.0	0.0	0.0	–	0.0	–	–
		4	99.9	0.0	2.9	2.7	0.4	–	–	–
		3	96.5	0.0	3.6	2.3	0.3	0.1	70	98

[a](D) is water depth of the mooring (in metres).
[b](Z) is the height above seabed (in metres).
[c]Due to a rotor malfunction, the data obtained from CM1 (100 m) and CM3 (100 m) had a useful data record of only 18 and 21 h, respectively. Hence, residual analysis could not be undertaken for the former current meters and those recording zero speed.
[d]'Neumann' or stability factor indicative of the steadiness of current direction (after Ramster et al., 1978).

stratification; they range, in thickness, from about 5–15 cm. Seismo-tectonically induced instabilities of Pleistocene muddy sediments, on the precipitous Kefalonia slope (slumps, gravity flows, etc.), may be expected to be the initiating mechanism for such debris flow deposits.

4.3.2. Surficial sedimentary texture [2]

Seabed sediments are represented by (7) grab samples obtained from the eastern side (G2, G3 and G8) of the Kerkyra–Kefalonia valley and the shelf/slope region of the western Greek mainland and the Ionian islands (G4–G7). Grain size distributions show little difference between the samples (Table 1); the sediment texture is essentially clay, according to the nomenclature of Folk (1980). Moreover, at all the stations, the distribution of fine-grained sediment (<62.5 μm) is unimodal in character, with a graphic mean (Mz) of about 9ϕ. The sand percentages range from 2.5% to 7.9%; exceptions are samples G6 and G7, where the sand content is 14.3% and 18.9%, respectively. Examination of the sand fraction shows that it is comprised of mainly fine-grained sand, with only a few particles >500 μm in size; these are large aggregates, rock fragments, fish remains and shells. Such a composi-

[2] Note: based upon analysis of grab samples (for location, see Fig. 2).

tion indicates the terrigenous origin of most of the coarser-grained material. Organic carbon contents range from 0.3% to 0.6%, with the higher values ($>$ 0.5%) associated with the shallower water regions.

4.4. Near-bed currents (and sediment resuspension)

Near-bed current measurements obtained along the main axis of the valley system are represented by observations taken at 3 (or 4), 5, 10, 30 and 100 m above the seafloor. In Table 2 are listed: the maximum recorded values; the mean (not including zero values, i.e., that below the threshold of movement of the rotor (1.7 cm s^{-1})); and the standard deviation of the current speeds. The residual current velocities and directions are presented in the table, together with the Neumann Factor (which describes the persistency of the flow). In addition, averaged hourly current observations (speed and direction), at various levels above the seabed, are presented as a series of stick-plots (Fig. 10).

Current activity at the bottom of the valley is non-persistent and highly variable, in terms of both speed and direction. The currents are persistent at station CM1, but in different directions; they are continuous, in the same direction, at CM4 and CM6

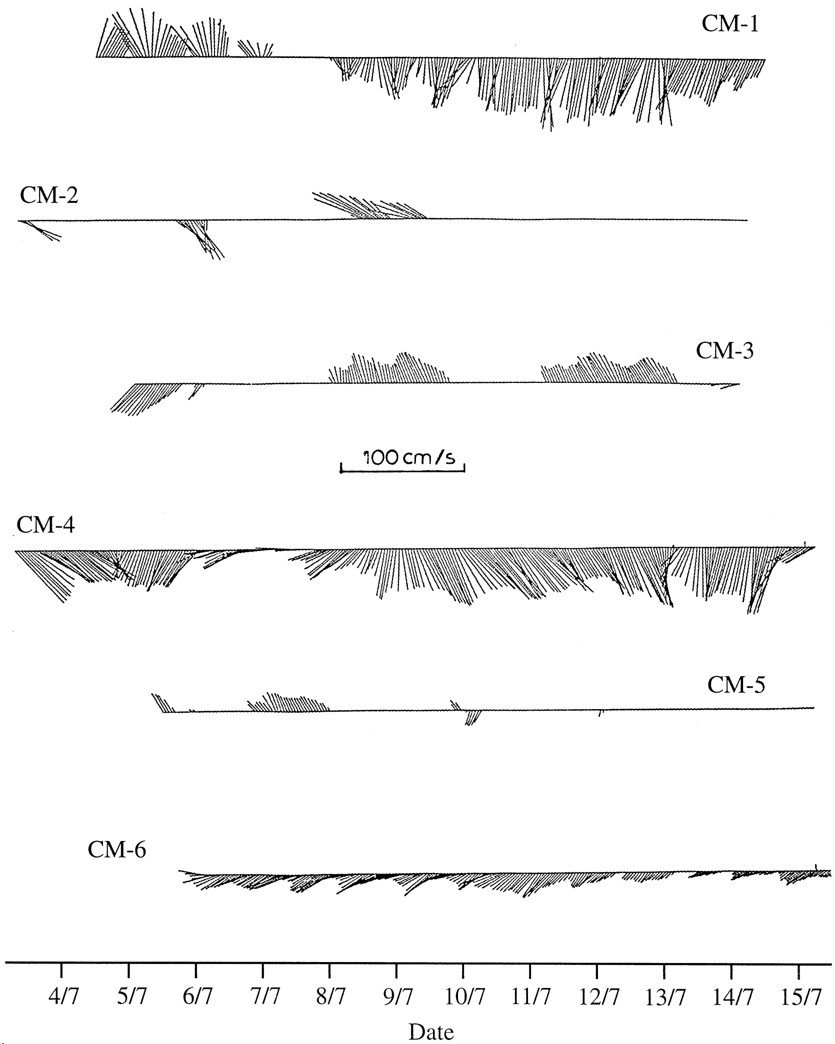

Fig. 10. Time-series of averaged hourly current speeds and directions at six current metre locations (with time in Julian days).

Table 3
Estimated critical shear stress values (for method of determination, see text)

	Z[a] (m)	Velocity (cm s^{-1})		Shear stress (N m^{-2})		Grain size[b] (mm)
		Maximum	Mean	Maximum	Mean	
CM1	3	53.9	27.9	0.21	0.06	0.00105 (P1)
CM2	5	47.6	28.6	0.17	0.06	0.00159 (G3)
CM3	3	31.2	16.3	0.08	0.02	0.00209 (P2)
CM4	5	53.3	31.3	0.22	0.08	0.00258 (P3)
CM5	3	17.1	10.0	0.02	0.01	0.00258 (P3)
CM6	5	46.3	14.9	0.13	0.01	0.00042 (P4)
CM7	5	0.0	0.0			
CM8	3	3.6	2.3	0.001	0.0	0.00042 (P4)

[a](Z) is the height above seabed (in metres).
[b]In parenthesis is denoted the nearest surficial seabed sediment sample, for the establishment of threshold conditions.

(for locations, see Fig. 2). The mean current speed varies from 15 to 31 cm s^{-1}. The maximum observed values range from 30 to 60 cm s^{-1}, with the exception of CM5 (19 cm s^{-1}). In general, the maximum observed currents increase towards the south, in the deeper waters of the valley system.

Further, there is no evidence of a steady flow (in terms of speed and direction) occurring along the axis and near the bottom of the valley system; such variability in the currents appears to be consistent within the lower 30 m of the water column, at all of the stations. Only CM1 and CM4, located at the head and within the lower reaches of the northern part of the Kerkyra–Kefalonia valley system, respectively, record southerly flow; this is similar to the regional flow patterns observed by other investigators (Fabricius and Schmidt-Thome, 1972; Ferentinos and Kastanos, 1988) Moreover, Gacic et al. (1996) have observed a near-bed southerly flow at the northern 'entrance' to the valley, during winter/early spring (in 1994). The same authors have stated that current activity, in general, is more pronounced in winter, rather in summer. Consequently, the currents measured as part of the present investigation may be expected to be stronger and more consistent during the winter/early spring period; at this time, their activity covers, probably, the majority of the Apulian Platform (Fig. 1).

The estimated shear stresses for data collected at all the near-bed current metre stations are listed in Table 3, together with the mean grain size (in μm) of the adjacent seafloor sediments. The maximum shear stresses vary between 0.92 (CM5) and 0.21 N m^{-2} (CM1); mean values range from 0.01 to 0.06 N m^{-2}. Critical shear stresses exceeding 0.1 N m^{-2}, when applied to flat bed sediments of a grain size (mean grain size $D_{50} < 2$ μm) similar to that in the study area, are associated with erosion or resuspension phenomena (Cohmault, 1971; Harrison and Owen, 1971; Sheng, 1984; Mehta, 1988; Cornelisse et al., 1991).

Maximum near-bed shear stresses (> 0.13 N m^{-2}) indicate the presence of resuspension phenomena at all of the mooring sites, except in the vicinity of stations CM5 and CM8 stations (Table 3). The highest values (> 0.2 N m^{-2}) are attributed to stations CM1 and CM4. On the other hand, the *mean* current velocities are unable to cause resuspension (perhaps with the exception of CM4, where the shear stresses are around 0.08 N m^{-2}). These observations are in accordance with the information provided by the acoustic profiles collected from the northern part of the Kefalonia–Kerkyra valley system (Fig. 4); here, the depositional features are related also to erosional and resuspension phenomena. In contrast, the measured current velocities and shear stresses associated with the southern and narrow part (the Kefalonia strike–slip fault) of the system (CM7 and CM8) do not indicate erosion, in response to any near-bed current activity.

5. Discussion

The study area, located within the northernmost part of the Hellenic trench, comprises three main morphotectonic units: the eastern margin of the Apulian Platform; the western margin of the Outer Hellenides; and, located between them, the Kerkyra–Kefalonia valley system. The latter system is formed by a continental collision zone, to the north, and a strike–slip fault to the south.

Overall, the morphometric configuration of the Kerkyra–Kefalonia valley system has resulted from the regional geotectonic evolution. In general, it is uneven and asymmetrical, with the eastern flank being much steeper and associated with the high mountains of the Albano–Greek mainland (Fig. 3). Furthermore, the northern part is a U-shaped with relatively gentle slopes and a wide floor, representing the continental collision zone of the Apulian Platform and the Outer Hellenides. In contrast, the southern part is V-shaped with steeper side walls and narrow floor (similar to a 'canyon-type' configuration), interpreted as the morphometric expression of the Kefalonia strike–slip fault (Fig. 1); this is the northeastern limit of the Hellenic trench representing the transition from subduction of oceanic crust in the south, to continental collision in the north. The aforementioned geomorphological structures, a continuous valley type depression, can be compared with those of the Hellenic trench. Here two major fault systems, lying almost perpendicular to one another, have resulted to the formation of a succession of deep 'isolated' basins along the axis of the subduction zone (the Zakynthos, Matapan and Ptolemy basins).

Lithoacoustic profiles, obtained from the eastern margin of the Apulian Platform, indicate a synsedimentary geodynamic evolution; this is controlled by its eastwards compression–collision with the Hellenides. On the other hand, the observed high amplitude symmetric or asymmetric wavy configuration of the acoustic profiles indicate a rotational 'extensional' phase characteristic of a back-arc area. This observation is in accordance with that of Doutsos and Frydas (1994), i.e., that the Apulian Platform is affected by limited, mostly normal, deformation. The associated shortening along the collision zone must be absorbed in the convergence zone, immediately to the west of the island of Kerkyra and related to the rapid uplift (> 3 mm year^{-1}) of the outer block of the Hellenides. In this region, hemipelagic depositional processes dominate, with some of the sedimentary material originating from the Adriatic Sea and being transported by the general southerly (mostly near-bed) water flow. The latter is associated with dense water formation in the Adriatic, during winter; it subsequently flows towards the Ionian Sea, through the Otranto Strait. Thus, near-bed current activity is expected to be much stronger during the winter period, in comparison to those observed in summer (as part of the present investigation) 1986, along the norther part of the valley system. Hence, during the winter period the stronger near-bed currents are expected to be capable of eroding and resuspending the fine-grained sediments of the seabed.

It may be speculated that some combination of depositional mechanisms is acting along the western continental margin of the Outer Hellenides, especially off the island of Kerkyra where the slopes are steeper. Such processes include mass gravity motion, seafloor erosion (associated with resuspension) and some hemipelagic sedimentation. In particular, the seafloor offshore from the entrance to Amvrakikos Gulf (see Fig. 2) is characterised by higher sedimentation rates; these possibly represent Late Pleistocene prodeltaic deposition (at lowered sea level). These sedimentary sequences are affected by gravity growth faults, within the shelf-break/upper slope area. The eastern flank of the northern part of the Kerkyra–Kefalonia valley system presents a seismically-activated gravity-induced deformation; this is probably an initial 'pre-slumping' stage. Farther to the south, the sedimentation mechanisms related to the Kefalonia strike–slip fault, mostly its eastern and steeper side, are dominated by intense mass gravity processes, e.g., seismoturbidites, slumps and debris flows, as indicated by sediments recovered (in PC4) (Fig. 8). Hemipelagic sedimentation plays only a minor role over this particular area.

Within the deeper parts of the valley system, along the collision zone, compressional forces predominate; the seafloor is covered mostly by turbiditic sequences (especially in the southern part). Here, the near-bed current regime represents a general southerly residual flow. The current velocities (CM2 and CM3) relate to shear stresses on the seafloor that are capable of resuspending surficial sediments. Further, this current activity becomes more intense in the vicinity of CM4 and CM5. Thus, over the western flank of the lower reaches of the Apulian margin, sedimentation is characterised by the presence of weak and perhaps local erosional processes and/or resuspension events. There is no indication of any sediment mass gravity processes (Figs. 4 and 5). In contrast, along the other side of the system (the lower reaches of the Hellenides margin) there is evidence of mass flow episodic events, such as mudflows and debris flows. To the west of the island of Kerkyra, there is evidence of relatively weak erosional resuspension processes; these are combined with mass gravity flows, initiated on the steeper Kerkyra slopes. In the souther part of the valley system, current activity (CM6, CM7, and CM8) is rather weak and is unable to induce resuspension. Some current activity may occur over the relatively less steep western flank of the valley, which consist of the lower reaches of the Apulian Platform.

The rate of sediment accumulation in the study area is difficult to estimate accurately, because of seabed resuspension and intense mass gravity processes. At the northern entrance of the Kerkyra–Kefalonia valley system, the foraminifera along core PC1 indicate a low rate of deposition of 10–25 cm ka^{-1}; for comparison, this is 4–10 times higher than the average deposition rate over the abyssal regions of the eastern Mediterranean basin.

6. Conclusions

Tectonism controls the morphological characteristics of the Kerkyra–Kefalonia valley system: a continuous asymmetrical and uneven U-shaped valley, representing the continental collision zone of the Apulian Platform and the Outer Hellenides; together with a narrow and steep-sided asymmetrical and uneven V-shaped valley, representing the dextral strike–slip fault (the northeastern limit of the Hellenic trench).

The upper (Plio–Pleistocene) sedimentary sequences of the system represent, in general, stratigraphic characteristics of a compressional phase. In the case, however, of the eastern promontory of the Apulian Platform the presence of normal faulting in the sequences indicates the action of extensional forces, similar to those of the back-arc basins of the Aegean Sea.

The stratigraphy of the surficial sedimentary cover of the valley system is affected by various types of gravity-driven mass movements, while its floor consists mostly of turbiditic deposits. These processes are most pronounced along the eastern flank of the valley system, associated with its steep slopes and the presence of canyons.

In this tectonically-active region and especially over the northern part of the valley system, modern sedimentation processes include the action of near-bed currents; the latter are associated with the dense water formation in Adriatic Sea, especially during the winter period. These currents can act as a mechanism for the resuspension and dispersal of sedimentary material.

Acknowledgements

The authors are grateful to the captain and crew of the NERC research vessels, *RRS Charles Darwin*, for their assistance with the data collection. Mrs. Kate Davis is thanked for her preparation of the figures. Thanks are extended to John Milliman and his colleagues (Virginia Institute for Marine Studies, USA) for improvement (enhancement) of original geophysical records and, in particular, Prof. D.J.W. Piper (Geological Survey of Canada, Bedford Institute of Oceanography) for his detailed and constructive review of the original manuscript submitted.

References

Anastasakis, G., Piper, D.J.W., 1991. The character of seismoturbidites in the S-1 sapropel, Zakynthos and Strofadhes basins, Greece. Sedimentology 38, 717–733.

Bellaiche, G., 1993. Sedimentary mechanisms and underlying tectonic structures of the northwestern Mediterranean margin, as revealed by comprehensive bathymetric and seismic surveys. Mar. Geol. 112 (1–4), 89–108.

Bignami, F., D'Archino, R.D., Montebello, O., Salusti, E., 1991. New observations on bottom currents in the Southern Adriatic and Ionian Seas (eastern Mediterranean Sea). Ann. Geophys. 9, 227–232.

Biswas, S.K., Agrawal, A., 1992. Tectonic evolution of the bengal foreland basin since the Early Pliocene and its implication on the development of the Bengal Fan. In: Recent Geoscientific Studies in the Bay of Bengal and the Andaman Sea. Papers Presented in the Seminar Held on October 9–11, 1990 at Calcuta. Geol. Surv. India Spec. Publ. No. 29, pp. 5–19.

Blanpied, C., Stanley, D., 1981. Uniform mud (unifites) deposition in Hellenic trench, eastern Mediterranean. Smithsonian Contrib. Mar. Sci. 13, 40.

Bouroullec, J.L., Rehault, J.P., Rolet, J., Tiercelin, J.J., Mondeguer, A., 1991. Quaternary sedimentary processes and dynamics in the northern part of the Tanganyika trough, east African rift system. Evidence of lacustrine eustatism?. Bull. Cent. Rech. Explor. Prod. Elf. Aquitaine 15 (2), 343–368.

Brooks, M., Ferentinos, G., 1984. Tectonics and sedimentation in the Gulf of Corinth and the Zakynthos and Kefallina channels, western Greece. Tectonophysics 101, 25–54.

Carlson, P.R., Molnia, B.F., Wheeler, N.C., 1980. Seafloor geologic hazards in O.C.S. Lease Area 55, Eastern Gulf of Alaska. Proceedings, 12th Offshore Technology Conference, Houston, TX, Vol. 1, pp. 563–603.

Civitazese, G., Bregant, I., Luchetta, A., Ruffini, S., 1994. Hydrochemistry of the Otranto Strait. Nutrients and oxygen distributions in winter 1994. First Workshop of the Mediterranean Targeted Project, Barcelona, 21–23 Nov., pp. 91–95.

Cohmault, P., 1971. Determination experimentele du debit solide d'erosion dues sediments fins cohesive. 14th IAHh Congress, Paler D2, Paris, pp. D2.1–D2.8.

Coleman, J.M., Prior, P.B., 1981. Subaqueous sediment instabilities: the offshore Mississippi river delta. In: Bouma, A., Sangrey, D., Coleman, J., Prior, D., Trippet, A., Dunlap, W., Hooper, J. (Eds.), Offshore Geologic Hazards. AAPG Educational Course Notes Series 18, pp. 5.1–5.53.

Cornelisse, J.M., Kuisper, C., Winterwerp, J.C., 1991. Erosion and deposition characteristics of natural muds. Delft Hydrolycs Report No. 26, Netherlands, 28 pp.

Cramp, A., Collins, M.B., Wakefield, S.J., 1987. Sedimentation in the Zakynthos channel—a conduit link to the Hellenic trench, eastern Mediterranean. Mar. Geol. 76, 71–87.

Damuth, J.E., 1975. Echo character of the western equatorial Atlantic floor and its relationship to the dispersal and distribution of terrigenous sediments. Mar. Geol. 18, 17–45.

Dart, C.J., Collier, R.E.L.l., Gawthorpe, R.L., Keller, J.V.A., Nichols, G., 1994. Sequence stratigraphy of Pliocene–Quaternary synrift, Gilbert-type fan deltas, northern Peloponesos, Greece. Mar. Petrol. Geol. 11 (5), 545–560.

Dorsey, R.J., 1988. Provenance, evolution and unroofing history of a modern arc–continent collision: Evidence from petrography of Plio–Pleistocene sandstones, eastern Taiwan. J. Sediment. Petrol. 58 (2), 208–218.

Doutsos, T., Frydas, D., 1994. The Corfu thrust (Greece). C. R. Acad. Sci. Paris 318 (II), 659–666.

Embley, R.W., Morley, J.J., 1980. Quaternary sedimentation and paleoenvironmental studies off Namibia (South–West Africa). Mar. Geol. 36, 183–204.

Fabricius, F., Schmidt-Thome, P., 1972. Contributions to recent sedimentation on the shelves of the southern Adriatic, Ionian and Syrtis Seas. In: Stanley, D.J. (Ed.), The Mediterranean Sea: A Natural Sedimentation Laboratory. Dowden, Hutchinson and Ross, Stroudsburg, PA, pp. 333–343.

Farran, M., Maldolado, A., 1990. The Ebro continental shelf: quaternary seismic stratigraphy and growth patterns. Mar. Geol. 95, 289–312.

Ferentinos, G., 1992. Recent gravitative mass movements in a highly tectonically active arc system: the Hellenic arc. Mar. Geol. 104, 93–107.

Ferentinos, G., 1993. Offshore geological hazard in the Hellenic arc. Mar. Geotechnol. 9, 261–277.

Ferentinos, G., Kastanos, N., 1988. Water circulation patterns in the Otrando Strait, eastern Mediterranean. Continent. Shelf Res. 8–9, 1025–1041.

Ferentinos, G., Collins, M.B., Pattiaratchi, C.B., Taylor, P.G., 1985. Mechanisms of sediment transport and deposition in a tectonically active submarine valley/canyon system: Zakynthos Straits, NW Hellenic trench. Mar. Geol. 65, 243–269.

Folk, R.L., 1980. Petrology of Sedimentary Rocks. Hemphill, Austin, TX, 182 pp.

Fusi, N., De-Larderel, G.A., Borello, A., Amelio, O., Castradori, D., Negri, A., Rimoldi, B., Sanvoisin, R., Tarbini, P., Cita, M.B., 1996. Marine geology of the Medriff Corridor, Mediterranean Ridge. Island–Arc 5 (4), 420–439.

Gacic, M., Kovacevic, V., Manca, B., Papageorgiou, E., Poulain, P.M., Scarazzano, P., Vetrano, A., 1996. Thermocline properties and circulation in the Otrando Strait. In: Briand, F. (Ed.), Dynamics of Mediterranean straits and Channels. CIESM Science Series No. 2, Bulletin de l' Institut oceanographique, Monaco, No. special 17, pp. 117–145.

Got, H., 1984. Sedimentary processes on the west Hellenic arc margin. In: Stow, D.V.A., Piper, D.J.W. (Eds.), Fine Grained Sediments, Vol. 15. Blackwell Scientific Publications, Oxford, Geological Society Special Publication, pp. 169–183.

Got, H., Aloisi, J.C., 1990. The Holocene sedimentation on the ulf of Lions margin: a quantitative approach. In: Monaco, A., Biscaye, P.E., Pocklington, R. (Eds.), Particle Fluxes and Ecosystem Response on a Continental Margin: The Mediterranean Experiment. Continent. Shelf Res. 10 (9–11) pp. 841–855.

Got, H., Stanley, D.J., Sorel, D., 1977. Northwestern Hellenic arc: concurrent sedimentation and deformation in a compressive setting. Mar. Geol. 24, 21–36.

Got, H., Monaco, A., Vitton, J., Brambati, A., Catani, G., Masoli, M., Pugliese, N., Zucchi-Stolfa, M., Belfiore, A., Gallo, F., Mezzadri, G., Vernia, L., Vinci, A., Bonaduce, G., 1981. Sedimentation on the Ionian active margin (Hellenic arc)—provenance of sediments and mechanisms of deposition. Sediment. Geol. 28, 243–272.

Griboulard, R., Gonthier, E., Drezen, E., Faugeres, J.C., Bobier, C., Foucher, J.P., 1996. South Barbados tectonic accretionary prism: atlas of acoustic imagery of morphostructures associated to the active argilokinetic tectonic. Aquitaine–Ocean Takence–France University–Bordeaux-1, No. 2, 78 pp.

Harrison, A.J.M., Owen, M.W., 1971. Siltation of fine sediments in estuaries. Proceedings of the 14th IAHH Congress, Paris, paper D1, 24 pp.

IGME (Institute for Geological and Mineralogical Exploration), 1989. Seismotectonic Map of Greece (1:500,000), IGMR, Athens.

Jorissen, F.J., Asioli, A., Borsetti, A.M., Capotondi, L., de Visser, J.P., Hilgen, F.J., Rohling, E.J., van der Borg, K., Vergnaud-Grazzini, C., Zachariasse, W.J., 1993. Late Quaternary central Mediterranean biochronology. Mar. Micropaleontol. 21, 169–189.

Kosters, E.C., Suter, J.R., 1993. Facies relationships and systems tracts in the Late Holocene Mississippi delta plain. J. Sediment. Petrol. 63, 727–733.

Lee, H.J., Edwards, B.D., Field, M.E., 1981. Geotechnical analysis of a submarine slump, Eureka, CA. Proceedings of the 13th Offshore Technology Conference, Houston, TX, pp. 53–59.

Le Pichon, C., Angelier, J., 1979. The Hellenic Arc and Trench system: a key to the neotectonic evolution of the Eastern Mediterranean area. Tectonophysics 60, 1–42.

Lewis, K.B., Pantin, H.M., 1984. Intersection of a marginal basin with a continent: structure and sediments of the bay of Plenty, New Zealand. In: Kokelaar, B.P., Howells, M.F. (Eds.), Marginal Basin Geology: Volcanic and Associated Sedimentary and Tectonic Processes in Modern and Ancient Marginal Basins. Spec. Publ. Geol. Assoc. No. 16, pp. 121–135.

Lykousis, V., 1991. Submarine slope instabilities in the Hellenic arc region, northeastern Mediterranean Sea. Mar. Geotechnol. 10, 83–96.

Lykousis, V., Anagnostou, C., Pavlakis, P., Rousakis, G., Alexandri, M., 1995. Quaternary sedimentary history and neotectonic evolution of the eastern part of central Aegean Sea, Greece. Mar. Geol. 128, 59–71.

Makropoulos, K., Burton, P., 1985. Seismic hazard in Greece: II. Ground acceleration. Tectonophysics 117, 259–294.

Mehta, A.J., 1988. Laboratory studies on cohesive sediment deposition and erosion. In: Dronkers, J.J., van Leussen, W. (Eds.), Physical Processes in Estuaries, pp. 427–445.

Mercier, J.L., Carrey, E., Phillip, H., Sorel, D., 1976. La neotectonic plio–quaternaire de l'arc Egeen externe et la mer Egee et ses relations avec la seismicite. Bull. Soc. Geol. Fr. XVIII, 355–372.

Mitchum, R.M., Vail, P.R., Thompson, S., 1977. Seismic stratigraphy and global changes of sea level: Part 2. The depositional sequences as a basic unit for stratigraphic analysis. In: Payton, C.E. (Ed.), Seismic Stratigraphy—Applications to Hydrocarbon Exploration. Mem. Am. Ass. Petrol. Geol. 26, 53–62.

Monopolis, D., Bruneton, A., 1982. Ionian Sea (western Greece): its structural outline deduced from drilling and geophysical data. Tectonophysics 83, 227–242.

Moores, E.M., Twiss, R.J., 1995. Tectonics. W.H. Freeman, New York, 415 pp.

Mutti, E., Normark, W., 1987. Comparing examples of modern and ancient turbidite systems. Problems and concepts. In: Leggett, J., Zuffa, C. (Eds.), Marine Clastic Sedimentology: Concepts and Case Studies. Graham and Trotman, pp. 1–38.

Nittis, K., Pinardi, N., Lascaratos, A., 1993. Characteristics of the summer 1987 flow field in the Ionian Sea. J. Geophys. Res. 98 (C6), 10171–10184.

Nittrouer, C.A., Kuehl, S.A., DeMaster, D.J., Kowsmann, R.O., 1986. The deltaic nature of Amazon self sedimentation. Bull. Geol. Soc. Am. 97, 444–458.

Papatheodorou, G., Hassiotis, T., Ferentinos, G., 1993. Gas-charged sediments in the Aegean and Ionian Seas, Greece. Mar. Geol. 112, 171–184.

Perissoratis, C., Rossi, S., 1990. Study of the recent sedimentation at the northeast Ionian Sea with the help of the 3.5 kHz sub-bottom profiler. Bull. Geol. Soc. Greece XXI, 83–102.

Piper, D.J.W., Panagos, A.G., 1981. Growth patterns of the Archeloos and Evinos deltas, western Greece. Sediment. Geol. 28, 111–132.

Piper, D.J.W., Stamatopoulos, L., Poulimenos, G., Doutsos, T., Kontopoulos, N., 1990. Quaternary history of the Gulfs of Patras and Corinth, Greece. Z. Geomorph. N. F. 34 (4), 451–458.

Rabitti, S., Boldrin, A., de Lazzari, A., Turchetto, M., 1994. Suspended matter distribution and dynamics in the Otranto Strait (Feb.–Mar. 1994). First Workshop of the Mediterranean Targeted Project, Barcelona, 21–23 Nov., pp. 139–144.

Ramster, C.A., Hughes, D.G., Furness, G.K., 1978. A 'steadiness' factor estimating the variability of residual drift in current metre records. Deutch. Hydrol. Zeits. 31, 230–236.

Sestini, G., 1989. Nile delta: a review of depositional environments and geological history. In: Whateley, M.K.G., Pickering, K.T. (Eds.), Deltas: Sites and Traps for Fossil Fuels. Oxford Blackwell Scientific Publications, Geological Society special Publication No. 41, pp. 99–127.

Sheng, P.Y., 1984. Modelling bottom boundary layer and cohesive sediment dynamics in estuarine and coastal waters. In: Mehta, A.J. (Ed.), Lecture Notes on Coastal and Estuarine Studies, No. 14, Estuarine Cohesive Sediment Dynamics. Proceedings of the Workshop on Cohesive Sediment Dynamics, FL, Springer, pp. 76–71.

Stanley, D.J., Knight, J., Stuckenarth, R., Catani, J.P., 1978. High sedimentation rates and variable dispersal patterns in the western Hellenic trench. Nature 273, 110–113.

Sternberg, R.W., 1972. Predicting initial motion and bed-load transport of sediment particles in the shallow marine environment. In: Swift, D.J.P., Duane, D.B., Pilkey, O.H. (Eds.), Shelf Sediment Transport: Process and Pattern. Dowden, Hutchinson and Ross, Stroudsberg, pp. 61–82.

Taymaz, T., Jackson, J., McKenzie, D., 1991. Active tectonics of the north and central Aegean Sea. Geophys. J. Int. 106, 433–490.

Thornton, S.E., 1984. Basin model for hemipelagic sedimentation in a tectonically active continental margin: Santa Barbara basin, California continental borderland. In: Stow, D.A.V., Piper, D.J.W. (Eds.), Fine Grained-Sediments: Deep Water Processes and Facies. Geol. Soc. Spec. Publ. No. 15, pp. 377–394.

Tsimplis, M.N., 1994. Tidal Oscillations in the Aegean and Ionian Seas. Estuar. Coastal Shelf Sci. 39, 201–208.

Underhill, J.R., 1989. Late Cenozoic deformation of the Hellenide foreland, western Greece. Bull. Geol. Soc. Am. 101, 613–634.

Weimer, P., Link, M.H., 1991. Seismic facies and sedimentary processes of submarine fans and turbidite systems. Springer, New York, 414 pp.