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CURRENT ACTIVITY IN THE THERMAIKOS GULF CONTINENTAL MARGIN, IN RELATION TO MODERN SEDIMENTATION PROCESSES

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ABSTRACT

The area under investigation represents the NW continental margin of the Aegean Sea i.e. the Thermaikos Gulf and the associated NW Sporades Basin. Surficial seabed sediments are of terrigenous origin whilst in terms of grain size, offshore sediments maybe distinguished into silty sediments that cover the northern and western part of the Gulf; clayey that cover the floor of the Sporades basin and relict sands that cover mainly the central and eastern part of the self. Current meter measurements from different water depths were obtained from 10 stations on the shelf, shelf/break, within canyons and in the Sporades Basin. Surface currents over the period of the investigation are dominated by inertial currents generated by wind events. Inertial period currents also dominate the near-bed currents on the continental shelf and in Sporades Basin. On the canyon slope, however, tidal currents are the dominant ones; these relate to the amplification of the internal tide, within the submarine canyon. Measured near-bed currents are below the threshold for sediment movement in the case of flat seabeds, although they are capable to inhibit deposition of the settling clayey particles. This contributes also to a further offshore dispersal of riverine sediments. Moreover, increased bed roughness due to benthic activity can cause resuspension for lower current speeds.

1 INTRODUCTION

The Thermaikos Gulf represents the NW continental margin of the Aegean Sea that leads into the deep Sporades Basin. Morphologically, it includes (Figure 1): the continental shelf (Thermaikos Plateau) that is wide and steeps gradually to water depths of about 130 m (shelf brake); the continental slope, which is steep and reaches the deep Sporades basin at water depths of some 1000 m, with irregular morphology, due to the presence of two submarine canyon-valley systems and a marginal plateau; and the deep (>1100 m) Sporades Basin. Furthermore, two main canyon systems are present: one to southwest with an ENE-WSW orientation and one to the north of the study area trending almost from West to East.

Surficial seabed sediments are of terrigenous origin, supplied mainly by the Axios, Aliakmon and Pinios rivers, whilst in terms of grain size, offshore sediments may be distinguished into three principal categories (Fig. 2): (i) muddy sediments (Mud, mostly clayey) with very small percentage of sand (<5%) that cover the northern and western part of the Gulf and the Sporades Basin; (ii) muddy Sand (relict sands) that cover mainly the central and eastern part of the self; and, (iii) sandy Mud that is also present as shown on Figure 2 (Karageorgis & Anagnostou, 2001).

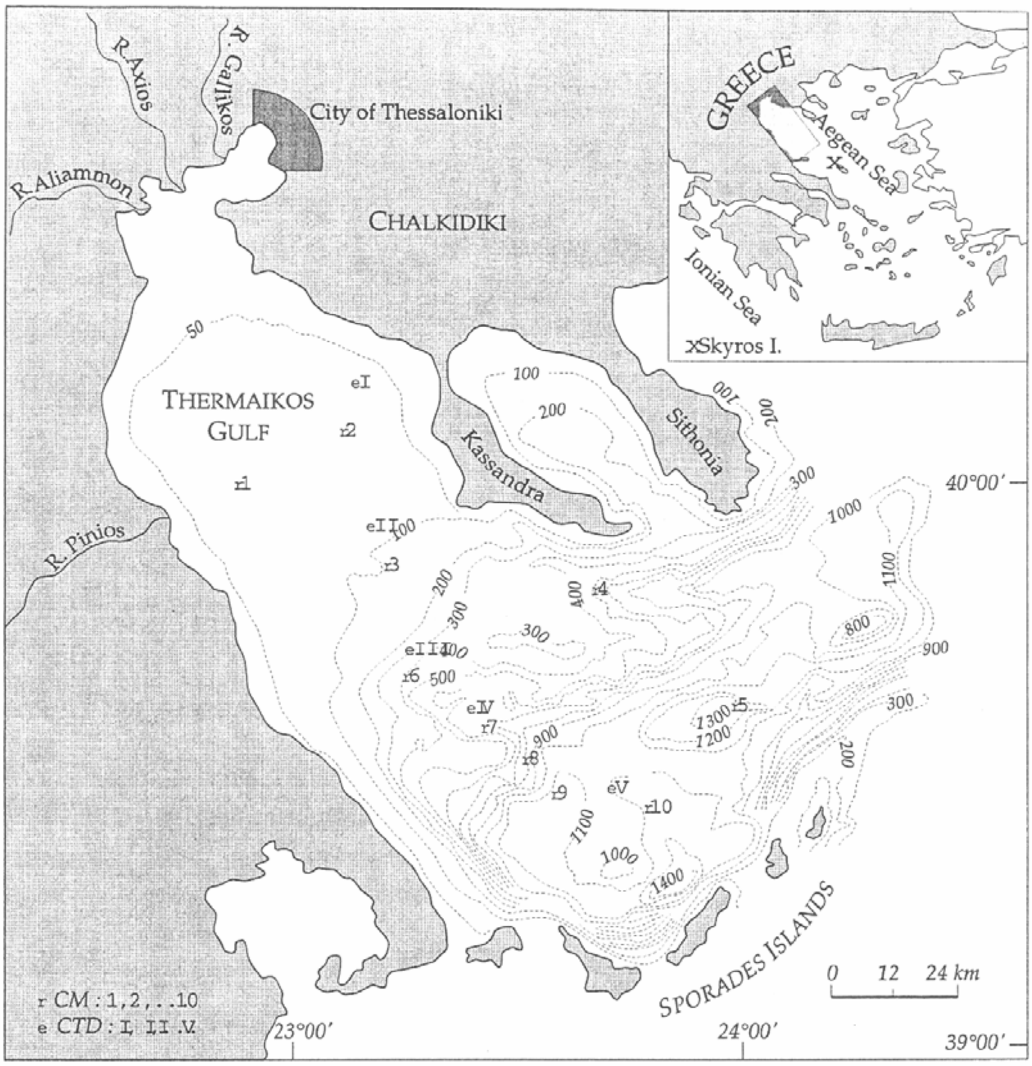

Figure 1. Bathymetry and locations of current meter moorings (in latin letters). Positions pointed with r 1-6 denotes locations of current meter measurements and those pointed with e I-V CTD measurements obtained for instrument calibration.

2 DATA SET

The main part of the oceanographic data set analysed in this study was collected during the RRS Discovery (cruise 137) undertaken between May 23rd and June 1st of 1983.

Current meter measurements from different water depths were obtained from 10 stations (Table 1; for locations see Fig. 1). Meteorological data (atmospheric pressure, with wind speed and direction) from Skyros island (Sporades Basin) were provided by the Meteorological Service of Greece. Sea level fluctuations at the port of Thessaloniki, for the period of the cruise, have been kindly provided by the Hellenic Hydrographic Service (Athens).

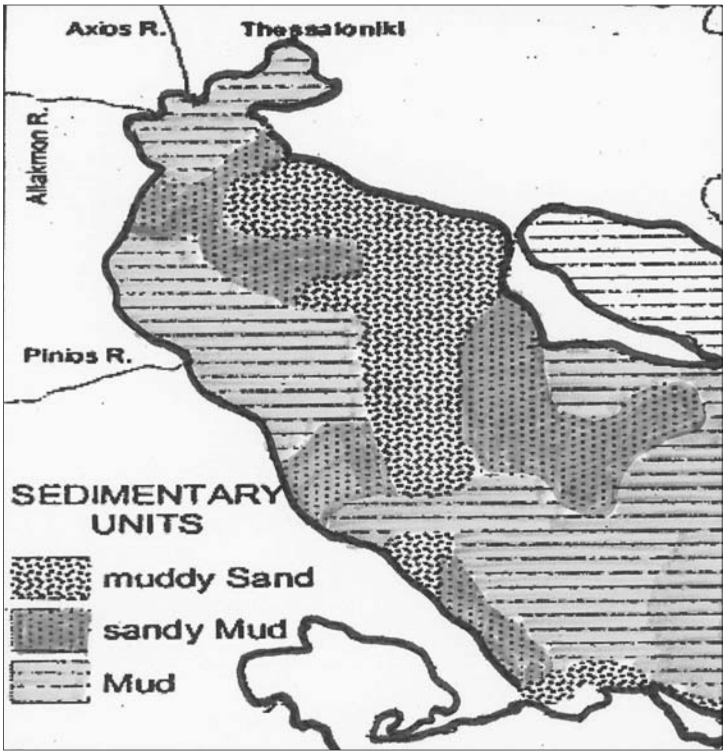

Figure 2. Generalised seabed sedimentology (deduced from Karageorgis & Anagnostou 2001).

Table 1. Water depth of current meter deployment and period of useful data (s: surface; b: bottom).

Station[1]	Water depth (m)	Height above bed (m)	Period of useful data	
			Start time	Finish time
CM 1s	75	50	01:00 26/5/83	16:10 01/6/83
CM 1b	75	5	01:00 26/5/83	16:10 01/6/83
CM 2s	85	50	01:00 27/5/83	18:30 01/6/83
CM 2b	85	5	01:00 27/5/83	18:30 01/6/83
CM 3s	105	95	21:00 25/5/83	12:35 01/6/83
CM 3b	105	5	21:00 25/5/83	12:35 01/6/83
CM 4b	500	5	09:00 23/5/83	17:25 30/5/83
CM 5b	1380	5	14:00 23/5/83	03:00 31/5/83
CM 6b	330	5	20:00 24/5/83	09:55 01/6/83
CM 7s	680	610	17:00 24/5/83	05:05 01/6/83
CM 7b	680	5	17:00 24/5/83	05:05 01/6/83
CM 8b	850	5	17:00 24/5/83	05:05 01/6/83
CM 9s	1100	1040	12:00 24/5/83	15:50 31/5/83
CM 9b	1100	5	10:00 24/5/83	13:25 31/5/83
CM 10b	1150	5	17:00 23/5/83	09:30 31/5/83

3 RESULTS AND DISCUSSION

Currents

Atmospheric pressure at Thessaloniki (inner Thermaikos Bay) and Skyros island (Sporades Basin) together with the sea level fluctuations at the port of Thessaloniki and the wind field at Skyros are presented on Figure 3. During the measurement period there were two low pressure (LP) systems (about 1005 hPa) passing through the area. Furthermore, during the first low pressure system that was associated with southerly winds, a depression of sea level in inner Thermaikos Bay occurred. In contrast, during the passage of the second LP system, which was associated with weaker northerly winds, the mean sea level remained unaffected.

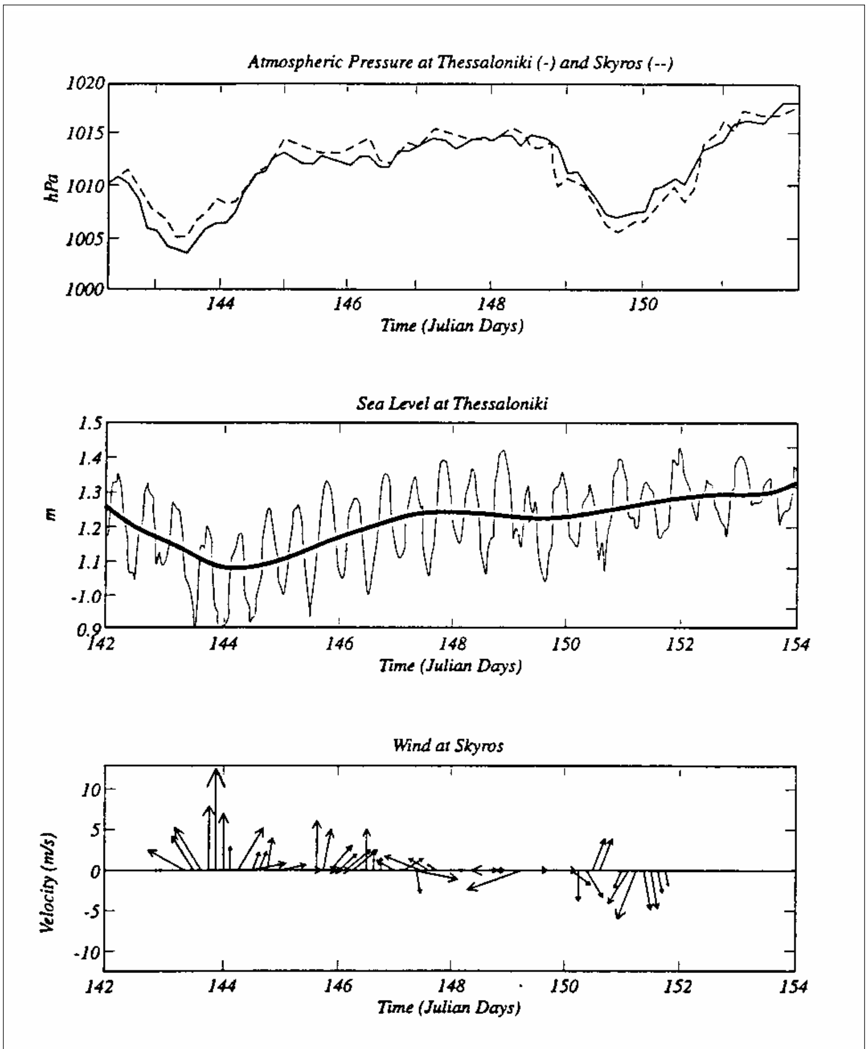

Figure 3 Variations of atmospheric pressure (Mikra airport), sea level fluctuations (port of Thessaloniki) and wind data (Skyros island).

On Table 2 the results of current meter analyses in terms of minimum, maximum and mean velocity together with the residual flow direction are listed. It is clear that a complex current structure existed in the region with considerable variability which possibly associated with atmospheric forcing. The surface flow shows a more complex structure, and in particular there does not seem to be a direct response to changes in the wind field. Especially the pass of the 2nd LP system seems to have a minor only effect on the near surface current with possibly only the exception of the CM3 which ceases after the presence of the 2nd LP. The bottom currents show a relatively more consistent pattern with those placed in deeper waters (e.g. canyon axis) to present a general flow from Thermaikos Gulf to the Sporades Basin. In terms of residual drift, CM1 flows to the south whilst CM2 and CM3, located at the eastern side of the Gulf, present an eastward and northward water movement. Bottom residual drift is generally southwards with the exception of CM7 and CM5 which flow to WSW.

Besides reversals to the residual flows are observed in the case of CM 1, 2 & 3 (shelf) and at CM 4 (see Figure 1). The short length of the observational period (5-7 days) prohibits us from a thorough explanation of the observed water movement.

Table 2. Current velocities and direction of residual flow.

Stanion	Readings below threshold (%)	Current speed cm/s			Residual flow direction (degrees)
		min	max	mean	
Surface					
CM 1	20	<1.70	15.78	6.50	171
CM 2	27	<1.70	12.98	6.50	79
CM 3	40	<1.70	18.86	9.34	336
CM 7	00	7.10	22.78	14.55	65
CM 9	01	<1.70	30.90	14.41	182
Bottom					
CM 1	32	<1.70	08.22	4.23	126
CM 2	01	<1.70	08.78	4.99	146
CM 3	32	<1.70	07.10	3.97	134
CM 4	28	<1.70	07.38	3.92	89
CM 5	14	<1.70	08.50	4.43	271
CM 6	16	<1.70	08.78	4.99	225
CM 7	43	<1.70	07.10	3.68	275
CM 8	33	<1.70	18.02	7.79	136
CM 9	00	<1.70	11.02	5.43	164
CM 10	00	2.62	07.94	5.53	187

Mechanisms of current generation

In order to investigate the mechanisms of current generation spectral analysis was performed, although the short period of data collection (5-6 days) could only lead to indicative results. In general, the energy spectrum of velocity fluctuations can be divided into four bands: a high frequency (<10 h); a semi-diurnal (tidal) (10-15 h); an inertial (15-25 h); and, wind (>30 h). The names of these bands designate the likely principal contributors to the fluctuations, but not necessarily the only ones; thus, the band of frequencies >30 h can be also attributed to forces other than that related to wind action, whilst the inertial band could contain the diurnal tide.

In accordance to the above, the predominant frequencies at all (near surface and near bed) of the shelf region (water depths <100 m) are of inertial period (18.6 -18.8) with the semidiurnal and wind components to be of secondary importance. Near bed currents and especially those flowing at water depths >300 m (e.g. along the canyon axis and in Sporades Basin) are dominated by the tidal (semi-diurnal) frequencies, whilst a fluctuation of frequency about 80 h (CM 4, 6 & 9) is also present. Besides, a more recent investigation by Estournel et al (pers. commun.) has revealed the presence of upwelling and downwelling flows at the sides of the western canyon.

Current activity in relation to modern sedimentation

Near-bed current activity is relatively low, with mean and maximum values of less than 8 cm/s and 12 cm/s, respectively; these values are similar to those observed previously (in June, 1986) by Balopoulos et al. (1987) and they are not capable of reworking the surficial seabed sediments, in the case that hydraulic bed roughness is introduced (theoretically) only by grain size (5.3-7Φ).
On the other hand, the associated shear velocities are an order of magnitude higher than the final settling velocities of suspensates with grain diameter >5 Φ; thus, near-bed flows are capable, at least, of inhibiting the deposition of the allochthonous suspended material in the form of individual particles and/or as flocculated material with sizes <2 Φ (Gibbs, 1985). On the assumption of increased bed roughness (10-25 mm), related to the observed biological benthic activity (Lykousis &

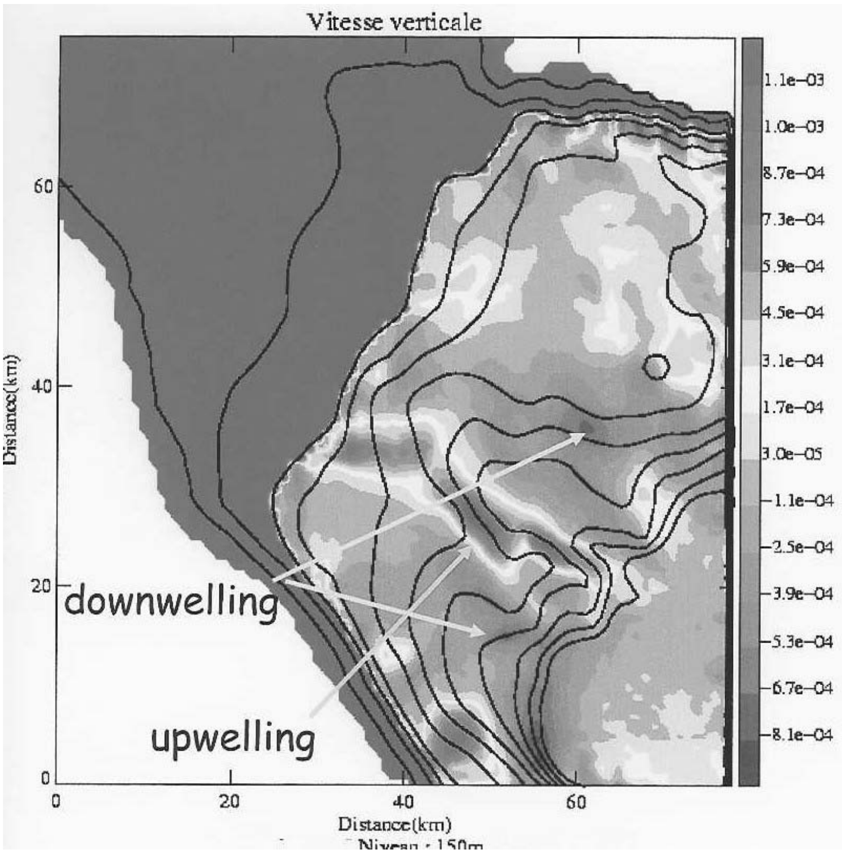

Figure 4. Vertical water movements (upwelling / downwelling) (Estournel G., pers.commun.)

Collins, 1987) the near-bed water movements (with velocities >6 cm/s) are found to be able to re-suspend the surficial bottom sediments (Poulos, 2001). Hence, near-bottom nepheloid layers observed in the area, during June 1987 (Durrieu de Madron et al., 1992), and more recently (see Fig. 5) by Karageorgis and Anagnostou (2003) may attributed, at least partially, to the reworking of surficial bottom sediments by near bed currents; likewise the southward observed flow along the east coast causes advection of suspensates (mostly riverine in origin) from the Thermaikos Plateau to the slope and farther to the deep Sporades basin (cf. Lykousis and Chronis 1989; Poulos et al.,

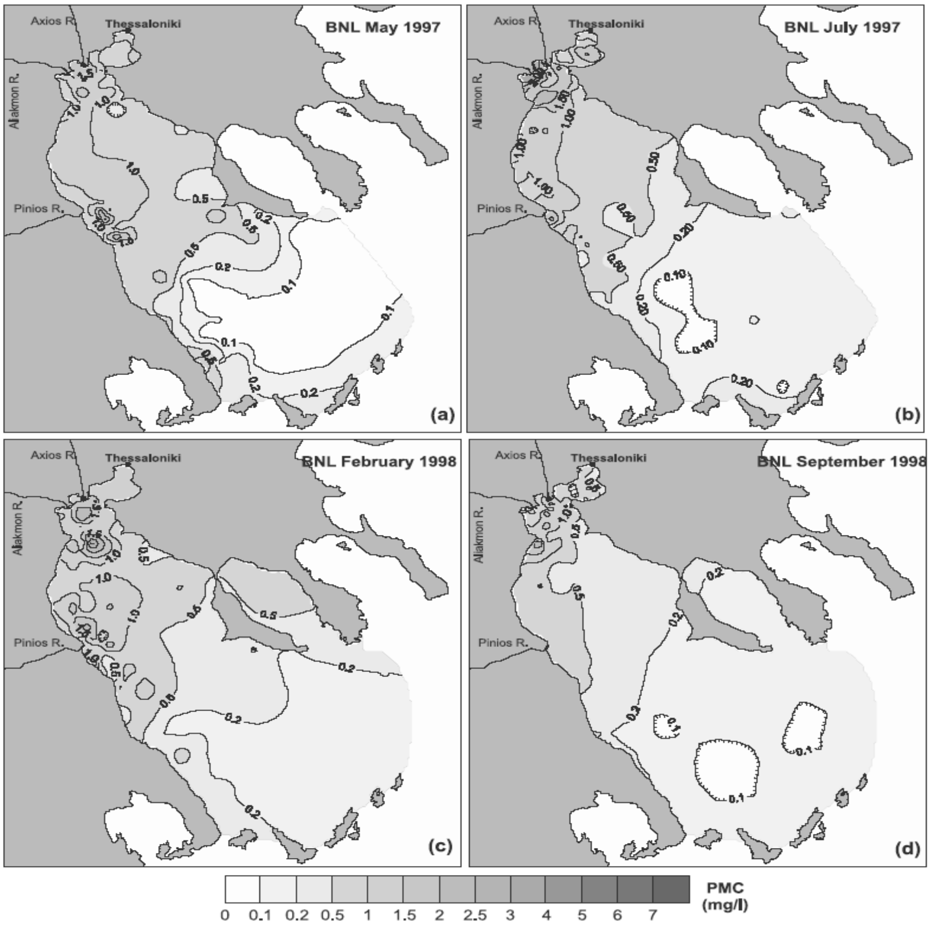

Figure 5. Spatial distribution of benthic nepheloid layer over the margin of the Thermaikos Gulf (abstracted from Karageorgis & Anagnostou, 2003).

2000). In addition, intermediate nepheloid layers observed in June 1986 at the slope area (mostly at shelf-break area) and within the canyon slopes (Durrieu de Madron et al., 1992) may be explained by the water movements induced by the aforementioned upwelling events and/or the breaking of internal waves and the amplification of the tidal signal due to seabed geomorphology.

4 CONCLUSIONS

The currents at the continental margin of the outer continental shelf of Thermaikos Gulf and in Sporades Basin are in general low with maximum velocities near sea surface and 5 m above bed of <31 cm/s and 11 cm/s, respectively. The residual flow direction is generally to the south along the western coast and to the north along the eastern coast and central part pf the continental shelf.

The continental shelf currents (surface and near-bed) are primarily wind generated, having an inertial period of approx. 18.7 hrs. However, currents at tidal (semidiurnal) frequencies dominate flows in the submarine canyons, indicating amplification of the tidal signal. Air-sea interaction processes associated to the thermohaline circulation pattern over the region might also be able to induce upwelling/downwelling phenomena along the canyon slopes.

The measured maximum speeds of near-bed currents (<12 cm/s) are not able to cause resuspension in the case of a theoretically flat seabed. But, with increase hydraulic roughness (>10 mm) due to the biogenic activity currents with velocities >6 cm/s could erode the bottom sediments. Sediment resuspension at the shelf-break and along the slope of the canyons may also be initiated by extreme events such as, internal tidal bores and turbidity flows. Finally, the overall weak water movements are able to inhibit the final settling of suspansates contributing, therefore, to their differential deposition and offshore dispersal.

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