Journal of Coastal Research	9	3	609–627	Fort Lauderdale, Florida	Summer 1993

Beach Material and its Transport in Accordance with the Predominant and Prevailing Wave Directions on Some Shores in Northern Greece

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ABSTRACT

PYÖKÄRI, M. and LEHTOVAARA, J.J., 1993. Beach material and its transport in accordance with the predominant and prevailing wave directions on some shores in northern Greece. *Journal of Coastal Research*, 9(3), 609–627. Fort Lauderdale (Florida) ISSN 0749-0208.

Fifty-one profiles across eight beaches on the coasts of the Chalkidiki Peninsula and the island of Thassos in northern Greece were surveyed. Nine sediment samples were collected from each profile, three samples from each environment: the inshore, foreshore and backshore. The directions of seasonal and net littoral drifts were observed on the shores.

All the studied beaches are low-carbonate beaches, where the texture and mineral composition of beach sediments display some degree of local variation. On the Chalkidiki beaches sediments consist mainly of coarse sand, being moderately sorted, symmetrical or negatively skewed and slightly leptokurtic. Their mineral compositions are closely related to the nearby exposed parent rocks or bluffs on the shores. Quartz and feldspar consist of approximately 85% of the mineral contents of the beach sands. The sediments of Golden Beach on Thassos are, on the contrary, fine sand, which is almost well-sorted, symmetrical and very leptokurtic. Its texture and mineral content indicate a close relationship to the mineral suite of the old Pleistocene-Holocene sand on the northern Aegean shelf. Quartz, gypsum and high-Mg calcite are the most common minerals in this sand.

The direction of net littoral drift on the studied shores is mainly determined by the predominant waves approaching from the direction of the greatest fetch. These same waves also considerably determine the direction of seasonal littoral drift in the swash and surf zones, while the direction of seasonal drift in the beach zone in winter is mostly caused by the prevailing waves and wind.

ADDITIONAL INDEX WORDS: *Beach sediments, composition, texture, provenance, sand transport, fetch, predominant waves, prevailing waves, Chalkidiki Peninsula, Thassos, northern Greece.*

INTRODUCTION

The western part of the Chalkidiki Peninsula is low and belongs to the Vardar eugeosynclinal trough (Figures 1 and 2), which was a major basin of sedimentation in this area during the Mesozoic and Tertiary (MELENTIS, 1977; ROBERTSON and DIXON, 1984). The central and eastern parts belong to the structurally complex Serbo-Macedonian zone and Circum Rhodope Belt, which lie between the Vardar zone and the Rhodope Massif (KATSIKATSOS, 1977; KOCKEL *et al.*, 1977; ROBERTSON and DIXON, 1984). These zones are dominated by mountain ranges with peaks 500-2,000 m in height consisting of magmatic rocks (gabbros, diorites, granites), the mafic and ultramafic plutones of the Chalkidiki ophiolites, schists, gneisses, phyllites, marbles and sandstones (KOCKEL *et al.*, 1977; DIXON and DIMITRIATIS, 1984). Short rivers run from the mountain ranges down to the coasts and form there small coastal plains.

The island of Thassos consists of metamorphic rocks (gneisses, schists, marbles, dolomites) and breccio-conglomerates and it is regarded as a part of the Rhodope Massif (MELENTIS, 1977; ZACHOS, 1982; LYBÉRIS and SAUVAGE, 1983; LYBÉRIS, 1984) (Figures 1 and 2). The island is mountainous, the highest peak being 1,200 m. Many small rivers discharge from the mountains into the sea.

There have been a large number of different studies in recent years dealing mainly with ophiolites of the Chalkidiki Peninsula (*e.g.* KOCKEL *et al.*, 1977; DIXON and DIMITRIATIS, 1984) and some with the evolution of the northern Aegean shelf (*e.g.* LE PICHON *et al.*, 1984; PERISSORATIS and MITROPOULOS, 1989). Nothing has hitherto been published on the Macedonian coasts and beach sediments. This work forms part of the geographical and sedimentological studies carried out by the author (M.P.) on the coasts of the Eastern

92035 received 2 April 1992; accepted in revision 29 May 1992.

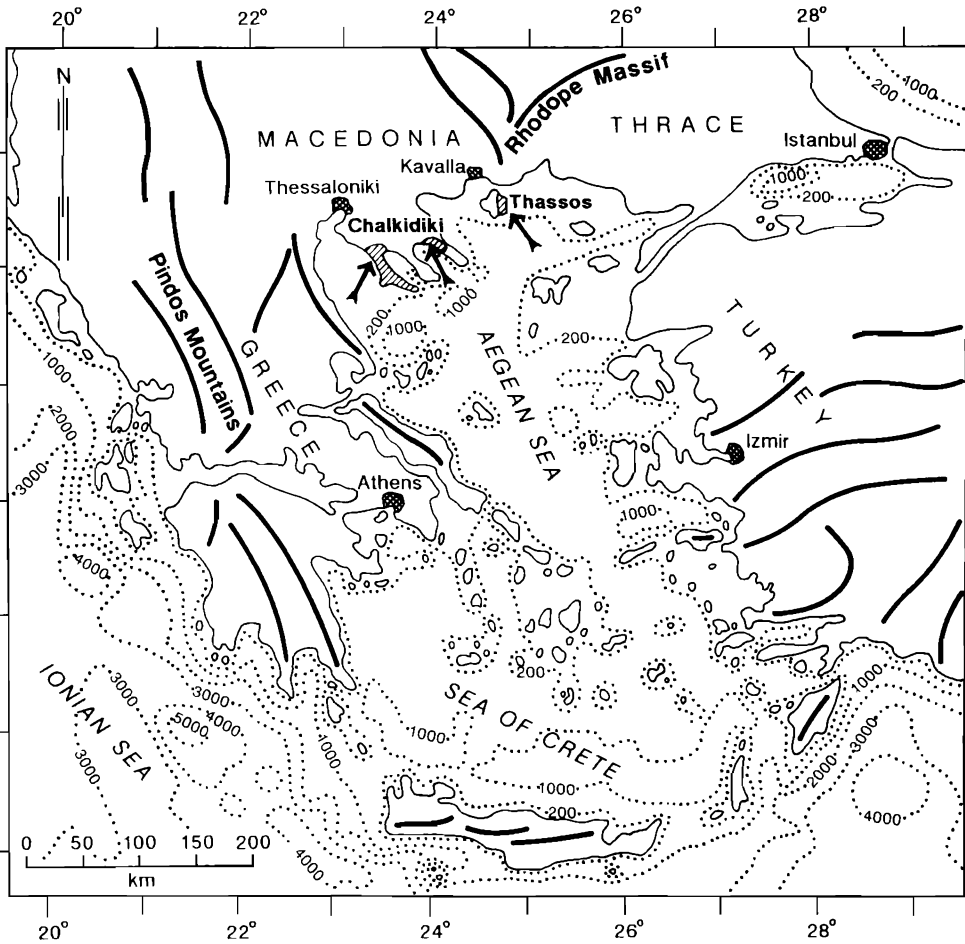

Figure 1. Map of the Aegean Sea, showing areas discussed in text. Arrows indicate the studied areas.

Mediterranean Sea in 1982–1991. Although the survey and sampling were done during July–August in 1989 and of short duration, it seems that what has been presented is a common summer situation on these shores.

Winds and Coastal Processes

In the northern Aegean Sea in summer the winds blow from N or NE (Kendrew, 1953; Markgraf, 1961; Blake *et al.*, 1987) called Etesians or Meltemi (Figure 2). They are remarkably steady in direction (50–70 percent frequency) and light or moderate, occasionally rising to gale force. Winds from SE or S in April, May and July are more common on the coasts of the Chalkidiki Peninsula than on the coasts of the island of Thassos, where the winds are northeasterly through the summer (Markgraf, 1961).

In winter the general winds blow from N-NE, but winds from S are not very rare (Kendrew, 1953; Markgraf, 1961) (Figure 2). These winds are cyclonic, more variable in force and direction than the summer winds. Near coasts they have a tendency to blow along shore, as the summer winds sometimes also do. Winter winds are moderate to strong with occasional gales. On the Macedonian coast gales are sometimes very strong when cold air sweeps down the valleys from the highlands (Kendrew, 1953). In general, gales are more frequent and winds more easterly on Thassos than those which blow on the Chalkidiki coasts (Markgraf, 1961).

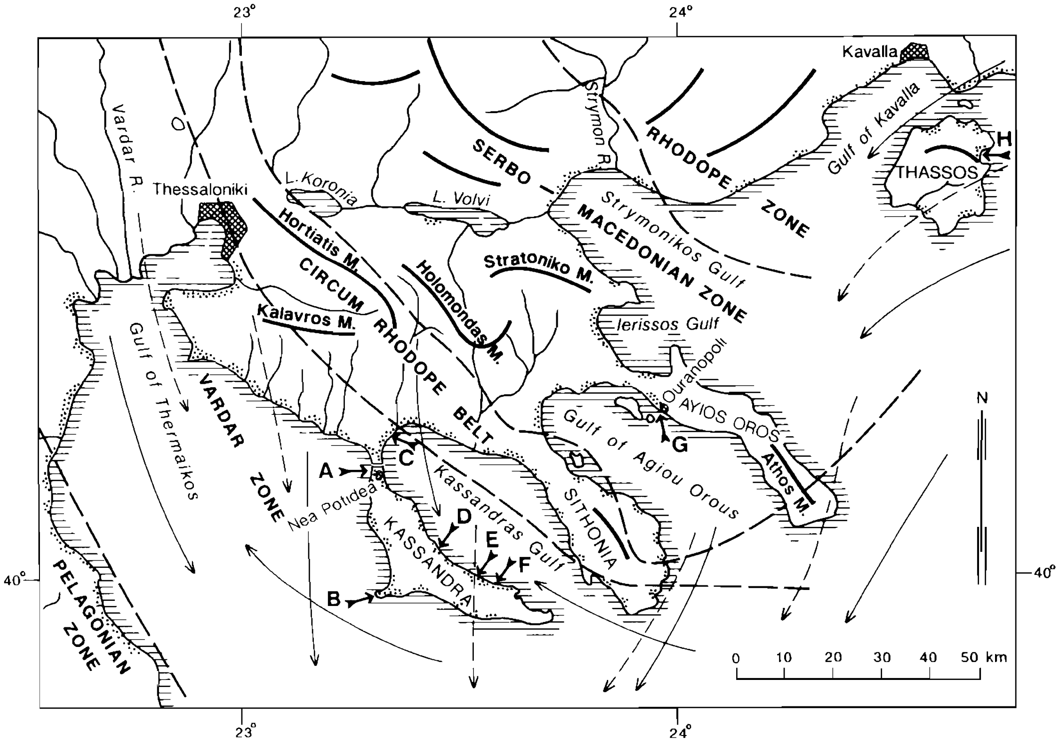

Figure 2. Locations of the beaches studied on Chalkidiki Peninsula and the island of Thassos. (A) Nea Potidea Beach, (B) Posidi Beach, (C) Aghios Mamas Beach, (D) Kallithea Beach, (E) Hanioti Beach, (F) Pefkohori Beach, (G) Ouranopoli Beach, (H) Golden Beach. Unbroken arrows show the directions of prevailing winds in summer, broken arrows in winter.

The approach of prevailing waves is, in general, from NNW-NNE, while predominant waves come from SW-SE (Figures 1 and 2) during cyclonic winds in winter and mainly gharbi winds (scirocco) in summer. These southern winds are moderate to strong and can cause a rise of several feet in sea level on the Macedonian coast (KENDREW, 1953) more than the tidal oscillation of 30–40 cm (RYAN *et al.*, 1966). Waves up to 6 m high may be formed especially south of the 'fingers' of the Chalkidiki Peninsula and the island of Thassos. On the eastern coast of Thassos prevailing waves come from NE-E and predominant waves from E-SE (Figures 1 and 2).

Aims of the Study

The purpose of this investigation is to study the relationship between the sedimentary characteristics and composition of mineral assemblages in present coastal deposits and those of the exposed parent rocks on the coasts of the Chalkidiki Peninsula and the island of Thassos, and also how prevailing and predominant winds and waves have affected this material and how the direction and length of the fetch influence transport. Therefore the texture, mineral composition and transport of beach material were studied on different types of beaches and attempts made to relate these properties to the nature of source materials found on the coasts and to determine the directions of seasonal and net littoral drifts. These results are also important for a general understanding of onshore and longshore beach-sand migrations and how such processes control littoral-sand mineralogies.

PHYSICAL SETTING OF THE STUDY AREAS

The areas studied on the Chalkidiki Peninsula and on the island of Thassos comprise the coasts of the Kassandra Peninsula, the western coast of the Ayios Oros Peninsula at the neck of the peninsula and the shores of Potamias Bay on the eastern coast of Thassos (Figures 1 and 2). The southern point of the Kassandra Peninsula consists of an ophiolite massif (BIZON *et al.*, 1969; KOCKEL *et al.*, 1977; SMITH and SPRAY, 1984; SPRAY *et al.*, 1984), but it is predominantly composed of conglomerates, siltstones, sandstones, shales, marls, clays, limestones and limestone breccias (BIZON *et al.*, 1969; KOCKEL *et al.*, 1977; ROBERTSON and DIXON, 1984). The peninsula is low, the highest hills being only 350 m. There are no rivers, only small seasonal streams that run down to the coast. The western coast of the Kassandra Peninsula consists largely of bluffs of loose material, cliffs of loose sedimentary rocks and rocky shores without cliffs. The size and profile of the beaches vary greatly from small pocket beaches or narrow sand-gravel beaches at the base of cliffs or bluffs (*e.g.* Nea Potidea Beach) to several kilometre-long beaches with a well-developed berm and backshore (*e.g.* Posidi Beach). The eastern coast is flatter and consists of several long well-developed beaches with a berm (*e.g.* Aghios Mamas and Pefkohori Beaches) as well as beaches with a bluff (*e.g.* Kallithea Beach).

The eastern peninsula, Ayios Oros, is mountainous and the highest peak, Mt. Athos, reaches 2,000 m. It consists of rocks of the Serbo-Macedonian zone, at the neck of the peninsula mainly of granites and granodiorites (KOCKEL *et al.*, 1977, DIXON and DIMITRIATIS, 1984). The western coast is rocky and cliffed with some boulders on the shoreline. Beaches do not occur until northwest of Ouranopoli town, where they are still small and lie mostly under a bluff or a cliff.

The eastern coast of the island of Thassos is also mainly rocky and cliffed. The rocks around Potamias Bay consist of a metamorphic Potamias series: dolomites, marbles, gneisses and schists (ZACHOS, 1982). Beaches are pocket or bay-head beaches (*e.g.* Golden Beach).

Beaches Sampled

Eight different types of beaches were selected on the basis of configuration (bay-head or straight beach), profile (cliff, bluff or dunes) and the length of the fetches in the directions of prevailing or predominant waves as key areas for study of the transport of beach sediments and their provenances (Figure 2, beaches A–H). Each of the selected beaches represents one of the main types which occur on the area.

Nea Potidea Beach

Situated on the western coast of the Kassandra Peninsula at its narrowest point, it is a typical narrow, straight beach, delimited landwards by a 10–20 m high bluff (Figure 3A) consisting of loose sandy shales (Figure 4). The width of the backshore varies along the shore; at points it is even absent and the bluff falls abruptly to the foreshore. The foreshore is narrow, the beach face slope being 5°–6°. The inshore is rather wide (Figure 5A) with a longshore bar about 30 m from the shoreline. The open fetches are to SSW-WNW (Figures 1 and 2).

Posidi Beach

Posidi Beach is situated 25 km south of Nea Potidea Beach consisting of the shores of a promontory, which continues as a point bar into the sea (Figure 3B). The beach is limited landwards by small dunes or a bluff. The width and gradient of the beach vary, being greatest (12°–15°) on the foreshore of the bar beach where there are also two berms and some beach ridges. The inshore is narrow and deepens rapidly (Figure 5B). On this very exposed promontory ESE-WSW fetches dominate on the southern shore and the NW fetch on the northern shore (Figures 1 and 2).

Aghios Mamas Beach

Aghios Mamas Beach is a 10 km-long, smoothly curving beach at the head of Kassandras Bay (Figure 3C). The beach is delimited at places by 1–2 m-high bluffs or dunes, and the backshore widens towards the north. Landwards from the dunes lies a 0.5–1 km-wide marsh with small salt lakes. The foreshore is narrow, the inclination of beach face being 5°–7°. The inshore is wide with 1 or 2 parallel bars about 20–30 m and 50–60 m from the shore-

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Figure 3. Sampling sites on Chalkidiki Peninsula and Thassos. The numbered lines on the beaches show the sites of surveyed beach profiles and places where sediment samples were taken from three different shore zones. (A) Nea Potidea Beach, (B) Posidi Beach, (C) Aghios Mamas Beach, (D) Kallithea Beach, (E) Hanioti Beach, (F) Pefkohori Beach, (G) Ouranopoli Beach, (H) Golden Beach.

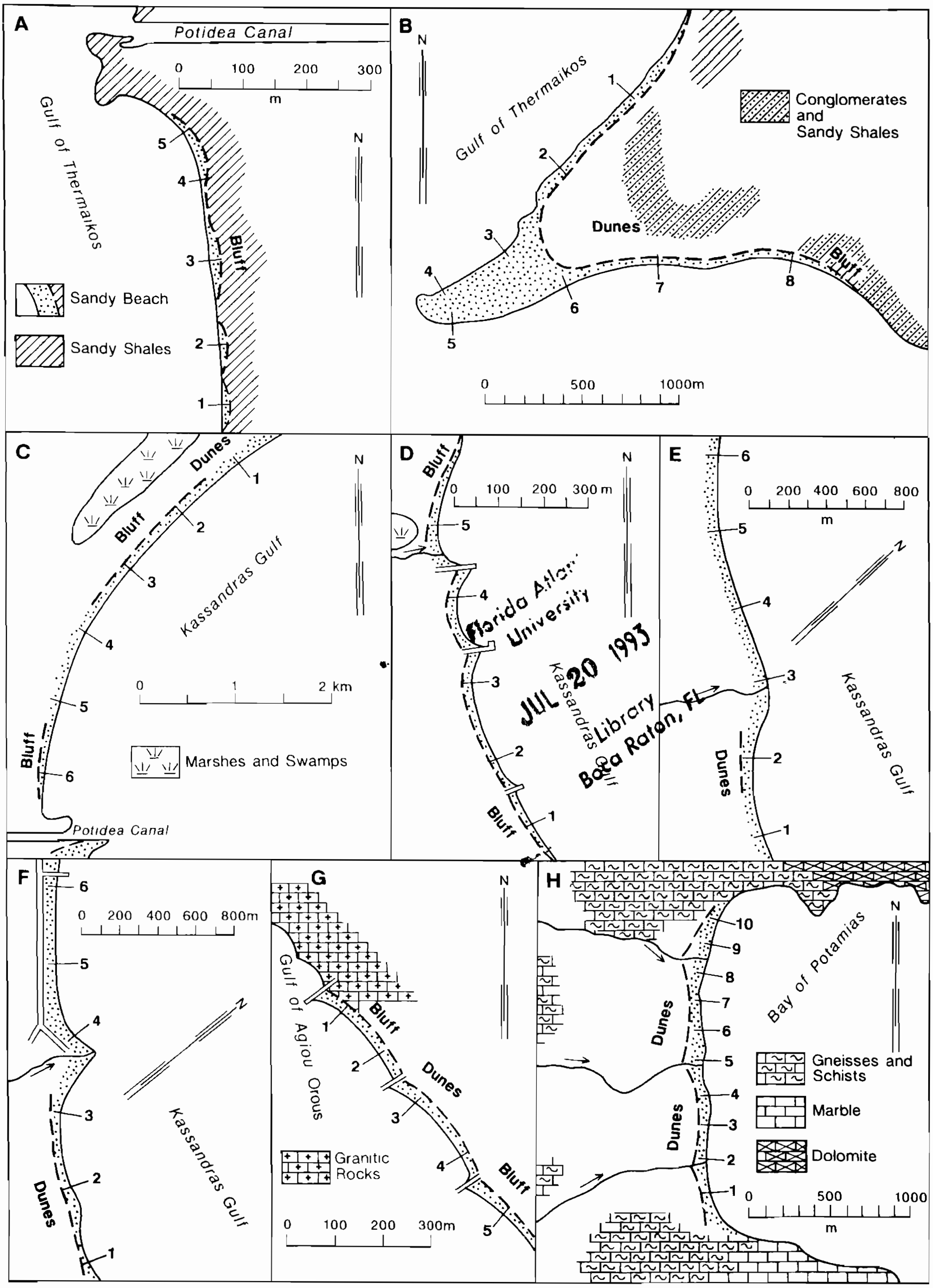

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Figure 4. Coastal bluff on the southern part of Nea Potidea Beach shows evidence of strong erosion and landsliding. The bluff is of soft Mio-Pliocene deposits composed mainly of sandy red shales. The inshore slopes gently towards the sea.

line (Figure 5C). Here the only long fetch is SE (Figures 1 and 2). The surveyed area is the southern part of the beach.

Kallithea Beach

Kallithea Beach is a 1.5 km-long beach 20 km south of Nea Potidea town on the eastern coast of the Kassandra Peninsula. The beach is delimited by 1–7 m-high bluffs at both ends (Figure 3D). The foreshore is narrow, the beach slope being 7°–10°. The backshore is wide in the central part of the beach, but the inshore is wide along its length with crescent bars (Figure 5D). The open fetches are predominantly ESE (Figures 1 and 2).

Hanioti Beach

Hanioti Beach is a nearly straight beach 10 km southeast of Kallithea Beach on the same coast continuing towards SE as Pefkohori Beach (Figure 3E). The backshore is wide, delimited at some places by dunes. The foreshcre is narrow, the inclination seawards being 7°–10°. The inshore is rather wide (Figure 5E). There is influence of the only long fetch possible, from ESE (Figures 1 and 2).

Pefkohori Beach

Pefkohori Beach is very similar to Hanioti Beach, but the fetch is limited in all directions (Figures 1 and 2). Low dunes and small berms composed of gravel and pebbles are, however, here more common than on Hanioti Beach (Figures 3F and 5F).

Ouranopoli Beach

Ouranopoli Beach is located on the western coast of the Ayios Oros Peninsula, 0.5 km northwest of Ouranopoli town. The beach is limited landwards by a 0.5–1 m-high bluff or only vegetation (Figure 3G). The backshore and inshore are wide and rather gentle. The foreshore is narrow, the inclination of beach face being 5°–8° (Figure 5G). On this beach the SSE fetch dominates (Figures 1 and 2).

Golden Beach

It is a 2 km-long bay-head beach on the eastern coast of the island of Thassos. The beach is de-

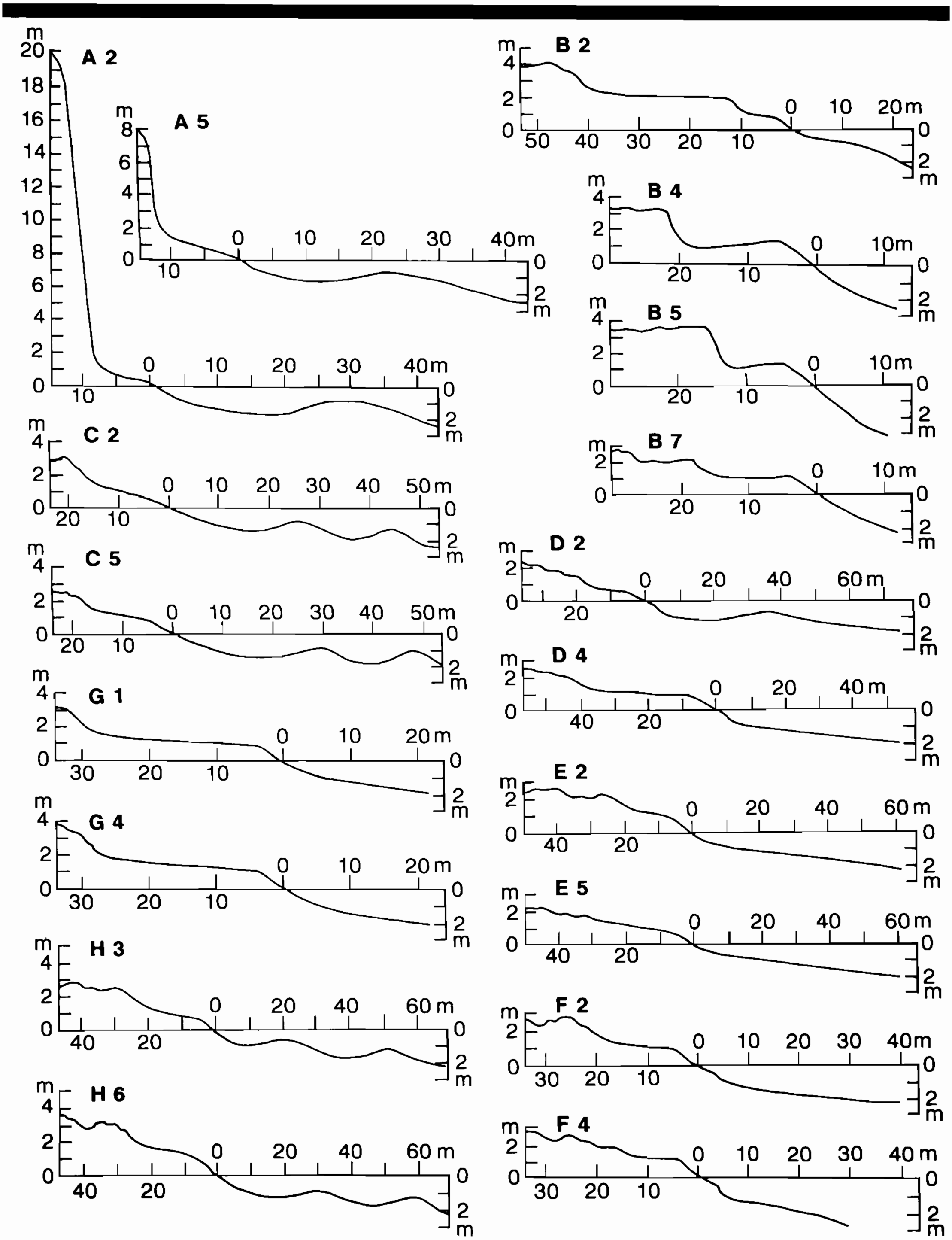


Figure 5. Shore profiles from the studied beaches on Chalkidiki Peninsula and Thassos. Locations A–H and profile numbers are the same as in Figure 3.

limited landwards by 0.5–2 m-high dunes, through which three small seasonal rivers discharge from the mountains into the bay (Figure 3H). The northern and southern shores of Potamias Bay are rocky and cliffed. The inshore is wide with two parallel bars, the first approx. 30 m and the second about 60 m from the shoreline (Figure 5H). The backshore is rather wide but the foreshore is narrow, its slope being 6°–8°. The open fetches are to NE–SE (Figures 1 and 2).

METHODS

Beach profiles on the eight key areas (Figures 3 and 5) were measured with a levelling instrument. Surface samples were collected from the beaches with a small cylinder during July–August 1989 when the weather was typical of the Aegean summer without storms (MARKGRAF, 1961). They were collected at each site along a survey line from three environments: from the surf zone at a depth of 1 m, from the swash zone on the foreshore, and from the beach above the swash zone on the backshore. Three samples were taken from each zone at each site. The samples were sieved at ¼-phi intervals. Grain-size analysis was made using the methods of FOLK (1966) and the grain-size parameters of FOLK and WARD (1957).

The mineral composition of beach material at each location was studied by using a multiple split of the combined grain samples. The grains of this sample were epoxy-impregnated thin-sectioned and scrutinized under a polarising microscope. At least two traverses were made across the slide, and every grain (200 or more grains) which intersected the cross hairs was counted. The carbonate content of beach material at each location was determined by dissolving five multiple splits of the combined grain samples in cold dilute (10%) hydrochloric acid, which dissolved all carbonates. The carbonate minerals and gypsum in beach sand were determined by common staining techniques (FRIEDMAN, 1959; PYÖKÄRI and LEHTOVAARA, 1990) combined with a microscopic study of both thin sections and unmounted combined grain samples.

Variation in the textural parameters of samples (MCLAREN and BOWLES, 1985; PYÖKÄRI and LEHTOVAARA, 1987), the direction of sand movement on the bottom in the surf and swash zones, floating bottles on the surface and other observations were used to determine the direction of seasonal littoral drift and the direction of littoral transport (beach drift and longshore drift) during the study. The mineral composition of beach material and some geomorphic indicators (*e.g.* long and massive structures interrupting littoral drift, beach width and beach slope) were used to determine the direction of net littoral drift (*cf.* TAGGART and SCHWARTZ, 1988).

RESULTS

The textural parameters of the material from each of the key areas are given in Table 1. The proportions of non-carbonate and carbonate material in the beach sediments are presented in Tables 2 and 3. The fact that the proportions of carbonates on the same beach in these tables are very similar (differences are only 0.0–2.3%), although they were arrived at in basically different ways, indicates that the results are reliable.

Texture of Beach Sediments

Shore material on the studied beaches consists of grains ranging from very fine sand to coarse gravel, coarse sand occurring most frequently in the materials with fine sand common in the beach zone and gravel in the surf and swash zones (Figure 6, Table 1).

The mean grain size (M_z) of the beach materials is coarsest on Posidi Beach and finest on Golden and Kallithea Beaches (Table 1). In general, the mean grain size is coarsest in surf-zone materials and finest in beach-zone materials. Sorting (σ_I) also varies from moderately sorted (most beaches) to poorly sorted (Pefkohori Beach) (Table 1). Among the three shore-zone materials sorting is best (well sorted) in the beach-zone sediments of Nea Potidea and Golden Beaches and in the surf-zone sediments on the southern shore of Posidi Beach and poorest in surf-zone sediments on Pefkohori and Ouranopoli Beaches. In general, sorting is best in beach-zone materials and poorest in surf-zone materials.

Skewness values (Sk_I) in the shore materials show nearly symmetrical distribution except for the sediments on Kallithea Beach and on the southern shore of Posidi Beach, which are negatively skewed (Table 1). The mean values for the different shore-zone materials, in general, also reveal almost symmetrical distributions. Sediments are, however, sometimes negatively skewed in beach-zone and swash-zone materials and often positively skewed in surf-zone materials. As to kurtosis values (K_G), the materials on the studied beaches are mesokurtic or leptokurtic with the exception of Golden Beach, where sediments are

Table 1. *Mean grain size (M_Z), degree of sorting (σ_I), skewness (Sk_I), and kurtosis (K_G) of shore sediments in the shore zones at eight locations on Chalkidiki Peninsula and the island of Thassos.*

	M_Z (ϕ)	σ_I	Sk_I	K_G	
Location and Material	*$\bar{x} \pm m$	$\bar{x} \pm m$	($\bar{x} \pm m$)	$\bar{x} \pm m$	†n
Nea Potidea Beach					
Beach zone	+1.55 ± 0.04	0.38 ± 0.01	+0.05 ± 0.03	0.95 ± 0.05	15
Swash zone	+0.99 ± 0.13	1.03 ± 0.11	−0.05 ± 0.10	1.35 ± 0.02	15
Surf zone	−0.31 ± 0.20	1.14 ± 0.15	+0.21 ± 0.09	0.94 ± 0.06	15
All zones	+0.74 ± 0.12	0.85 ± 0.08	+0.07 ± 0.05	1.08 ± 0.04	45
Posidi Beach					
Northern shore					
Beach zone	−0.87 ± 0.17	0.58 ± 0.04	−0.24 ± 0.06	1.22 ± 0.04	12
Swash zone	−1.28 ± 0.13	0.68 ± 0.05	−0.10 ± 0.06	1.08 ± 0.07	12
Surf zone	−1.83 ± 0.08	1.19 ± 0.03	+0.11 ± 0.04	0.65 ± 0.03	12
All zones	−1.33 ± 0.10	0.81 ± 0.05	−0.08 ± 0.04	0.98 ± 0.05	36
Southern shore					
Beach zone	−1.08 ± 0.12	0.70 ± 0.00	−0.42 ± 0.01	1.28 ± 0.07	12
Swash zone	−1.43 ± 0.20	0.56 ± 0.04	−0.31 ± 0.04	1.33 ± 0.13	12
Surf zone	−2.81 ± 0.04	0.45 ± 0.02	+0.24 ± 0.06	1.10 ± 0.06	12
All zones	−1.83 ± 0.11	0.57 ± 0.02	−0.17 ± 0.06	1.24 ± 0.05	36
Aghios Mamas Beach					
Beach zone	+1.20 ± 0.14	0.53 ± 0.04	−0.17 ± 0.02	1.11 ± 0.06	18
Swash zone	−0.87 ± 0.05	1.02 ± 0.06	−0.31 ± 0.05	1.03 ± 0.04	18
Surf zone	+1.49 ± 0.22	0.54 ± 0.08	+0.18 ± 0.05	1.12 ± 0.05	18
All zones	+0.61 ± 0.15	0.70 ± 0.05	−0.10 ± 0.04	1.08 ± 0.03	54
Kallithea Beach					
Beach zone	+1.31 ± 0.09	0.66 ± 0.06	−0.18 ± 0.02	1.13 ± 0.05	15
Swash zone	+1.41 ± 0.06	0.59 ± 0.06	−0.21 ± 0.05	1.25 ± 0.04	15
Surf zone	+1.37 ± 0.19	0.80 ± 0.17	−0.08 ± 0.06	1.17 ± 0.09	15
All zones	+1.36 ± 0.07	0.68 ± 0.06	−0.15 ± 0.03	1.18 ± 0.04	45
Hanioti Beach					
Beach zone	+0.41 ± 0.06	0.72 ± 0.05	−0.06 ± 0.04	1.36 ± 0.09	18
Swash zone	−0.97 ± 0.16	0.67 ± 0.02	−0.04 ± 0.02	1.09 ± 0.03	18
Surf zone	−1.69 ± 0.09	1.06 ± 0.06	−0.03 ± 0.02	0.90 ± 0.05	18
All zones	−0.75 ± 0.14	0.82 ± 0.04	−0.04 ± 0.02	1.12 ± 0.04	54
Pefkohori Beach					
Beach zone	+0.44 ± 0.14	0.77 ± 0.07	−0.21 ± 0.04	1.29 ± 0.07	18
Swash zone	−0.25 ± 0.13	1.15 ± 0.16	−0.17 ± 0.07	0.93 ± 0.04	18
Surf zone	−1.55 ± 0.15	1.40 ± 0.07	+0.23 ± 0.07	0.85 ± 0.03	18
All zones	−0.46 ± 0.14	1.14 ± 0.07	−0.05 ± 0.04	1.02 ± 0.04	54
Ouranopoli Beach					
Beach zone	+0.74 ± 0.07	0.70 ± 0.02	+0.07 ± 0.05	0.96 ± 0.05	15
Swash zone	+0.20 ± 0.22	0.85 ± 0.08	−0.21 ± 0.08	1.59 ± 0.18	15
Surf zone	−0.96 ± 0.18	1.26 ± 0.11	−0.13 ± 0.04	0.87 ± 0.03	15
All zones	−0.01 ± 0.13	0.94 ± 0.06	−0.09 ± 0.04	1.14 ± 0.08	45
Golden Beach					
Beach zone	+1.79 ± 0.05	0.40 ± 0.02	−0.04 ± 0.05	1.67 ± 0.12	40
Swash zone	+1.31 ± 0.18	0.50 ± 0.06	+0.07 ± 0.05	1.48 ± 0.09	40
Surf zone	+1.50 ± 0.22	0.78 ± 0.11	+0.05 ± 0.04	1.52 ± 0.09	40
All zones	+1.53 ± 0.10	0.56 ± 0.04	+0.03 ± 0.03	1.56 ± 0.06	120

*$\bar{x} \pm m$ = mean ± standard error of the mean
†n = number of samples

Table 2. *Percentages of carbonates and non-carbonates in shore material on Chalkidiki Peninsula and the island of Thassos.*

Location and Zones	Non-carbonates (%) *x̄ ± m	Carbonates (%) *x̄ ± m	†n
Nea Potidea Beach			
Beach zone	90.5 ± 0.2	9.5 ± 0.2	2
Swash zone	93.6 ± 0.5	6.5 ± 0.5	2
Surf zone	86.3 ± 0.4	13.8 ± 0.4	2
All zones	90.1 ± 1.2	9.9 ± 1.2	6
Posidi Beach			
Beach zone	89.7 ± 0.2	10.3 ± 0.2	2
Swash zone	87.5 ± 0.4	12.5 ± 0.4	2
Surf zone	88.2 ± 0.3	11.8 ± 0.3	2
All zones	88.4 ± 0.4	11.6 ± 0.4	6
Aghios Mamas Beach			
Beach zone	95.7 ± 0.2	4.3 ± 0.2	2
Swash zone	93.3 ± 0.3	6.7 ± 0.3	2
Surf zone	94.7 ± 0.3	5.3 ± 0.3	2
All zones	94.6 ± 0.4	5.4 ± 0.4	6
Kallithea Beach			
Beach zone	98.9 ± 0.3	1.2 ± 0.3	2
Swash zone	97.0 ± 0.3	3.0 ± 0.3	2
Surf zone	96.9 ± 0.2	3.1 ± 0.2	2
All zones	97.6 ± 0.4	2.4 ± 0.4	6
Hanioti Beach			
Beach zone	99.3 ± 0.1	0.7 ± 0.1	2
Swash zone	98.2 ± 0.1	1.8 ± 0.1	2
Surf zone	98.8 ± 0.2	1.2 ± 0.2	2
All zones	98.8 ± 0.2	1.2 ± 0.2	6
Pefkohori Beach			
Beach zone	97.2 ± 0.2	2.8 ± 0.2	2
Swash zone	94.3 ± 0.3	5.7 ± 0.3	2
Surf zone	97.1 ± 0.3	2.9 ± 0.3	2
All zones	96.2 ± 0.5	3.8 ± 0.5	6
Ouranopoli Beach			
Beach zone	99.4 ± 0.1	0.6 ± 0.1	2
Swash zone	98.5 ± 0.1	1.5 ± 0.1	2
Surf zone	99.3 ± 0.1	0.7 ± 0.1	2
All zones	99.1 ± 0.2	0.9 ± 0.2	6
Golden Beach			
Beach zone	94.9 ± 0.4	5.1 ± 0.4	2
Swash zone	95.8 ± 0.4	4.3 ± 0.4	2
Surf zone	81.6 ± 0.5	18.4 ± 0.5	2
All zones	90.8 ± 2.6	9.2 ± 2.6	6

*x̄ ± m = mean ± standard error of the mean
†n = number of samples

very leptokurtic. The mean values for kurtosis in beach-zone materials are, in general, leptokurtic and in swash-zone materials lepto- or mesokurtic. Surf-zone materials are mainly platy- or mesokurtic but with a few exceptions leptokurtic (Table 1).

Composition of Beach Sediments

The sediment material of combined splits from the studied beaches revealed a small carbonate fraction (1–12%) in the beach sediments, the carbonate content being smallest in the sediments of Hanioti and Ouranopoli Beaches (approximately 1%) and largest on Posidi and Golden Beaches (about 12% and 10%) (Tables 2 and 3). The composition of carbonate minerals shows a dominance of low-Mg calcite in the sediments of Posidi, Aghios Mamas, Hanioti and Pefkohori Beaches, while high-Mg calcite characterizes the carbonate content on Nea Potidea, Kallithea and Golden Beaches (Table 3). Calcite particles are rounded (see POWERS, 1953) on Posidi Beach, subrounded on Aghios Mamas and Pefkohori Beaches and sub-angular (partly angular) on the other beaches. The roundness of the low-Mg calcite particles is, in general, little better than that of high-Mg calcite clasts.

The proportions of dolomite, magnesite and aragonite in the beach materials are low (Table 3). Most of the dolomite clasts occur in the sediments of Golden Beach (2.2%). The overall roundness of the mineral grains of these carbonate species does not differ essentially from those of calcite clasts except on Posidi Beach, where their roundness is poorer. Aragonite clasts are commonly angular or sub-angular pieces of shelly or other biogenic material.

Non-carbonates in the beach sediments constitute the major part (88–99%) of the samples (Tables 2 and 3). The non-carbonate grains are, in general, rather more poorly rounded than the carbonate clasts. They are angular or sub-angular, but the grains on Nea Potidea, Posidi and Ouranopoli Beaches are even very angular with sharp edges. The roundness is, however, somewhat better on the beaches of the eastern coast of the Kassandra Peninsula and especially on Golden Beach on Thassos, where some quartz clasts are even sub-rounded or rounded.

The non-carbonate minerals are characterized by quartz grains in the sediments on Golden Beach (71.4%) and quartz (56.0–67.2%) and feldspar (14.2–38.1%) clasts on the other beaches (Table 3). In addition to these minerals there are also small amounts of muscovite (0.3–7.2%) and epidotes (0.6–6.8%) and a tiny quantity of gypsum on most of the beaches with the exception of Golden Beach, where gypsum is the second commonest mineral (8.0%). Small amounts of biotite, chlorites, amphiboles, titanite, haematite and limo-

Table 3. *Mineral composition of combined sand samples at eight locations on Chalkidiki Peninsula and the island of Thassos. (1) Nea Potidea Beach, (2) Posidi Beach, (3) Aghios Mamas Beach, (4) Kallithea Beach, (5) Hanioti Beach, (6) Pefkohori Beach, (7) Ouranopoli Beach, (8) Golden Beach.*

	Locations							
Minerals	1	2	3	4	5	6	7	8
Non-carbonates*	91.0	87.4	94.6	97.9	99.0	94.1	99.4	88.5%
Quartz	62.6	66.8	67.2	61.4	65.8	58.5	56.0	71.4%
Feldspar	15.6	14.2	20.2	22.7	21.3	26.0	38.1	3.9%
Muscovite	1.9	4.3	2.8	2.6	7.2	3.6	0.3	1.0%
Biotite	—	—	—	—	—	—	0.9	0.4%
Chlorite	—	—	0.4	—	—	—	—	—%
Pyroxenes	8.1	—	—	3.2	—	—	—	3.2%
Amphiboles	1.8	—	—	—	—	—	—	—%
Epidote	0.9	1.9	3.0	6.8	4.2	4.7	1.8	0.6%
Titanite	—	—	—	1.1	0.5	1.2	—	—%
Haematite	—	—	0.9	—	—	—	0.4	—%
Limonite	—	—	—	—	—	—	1.8	—%
Gypsum	0.1	0.2	0.1	0.1	—	0.1	0.1	8.0%
Carbonates*	9.0	12.6	5.4	2.1	1.0	5.9	0.6	11.5%
Low-Mg calcite	2.4	10.3	2.4	0.6	0.7	3.1	0.1	3.9%
High-Mg calcite	3.8	0.5	0.8	1.0	0.1	1.4	0.2	5.1%
Aragonite	0.4	0.1	0.8	0.1	0.1	—	0.1	0.2%
Dolomite	0.8	0.4	0.3	0.3	0.1	1.1	0.1	2.2%
Magnesite	1.6	1.3	1.1	0.1	—	0.3	0.1	0.1%
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0%

*These calculations are based on 200–300 grains, the distribution of the carbonates and gypsum by counting 1,000–2,000 grains from stained batches.

nite occur on some beaches. Pyroxenes are, however, rather common (8.1%) in the sediments of Nea Potidea Beach.

DISCUSSION

The nature of beach sediments on the Chalkidiki Peninsula and the island of Thassos shows certain distinct patterns which can be related to adjacent coastal rocks, to coastal orientation and coastal processes, and in particular to predominant and prevailing waves (Figure 2).

The textural properties of the beach sediments on most of the beaches studied (coarse, moderately sorted, symmetrical or negatively skewed and slightly leptokurtic) (Table 1) suggest a few local sources (*cf.* FOLK and WARD, 1957; GREENWOOD, 1969; VISHER, 1969) and not very great transport (*cf.* SUNAMURA and HORIKAWA, 1972; JACOBSEN and SCHWARTZ, 1981; TAGGART and SCHWARTZ, 1988). The textural properties of the sands on Golden Beach (fine, nearly well-sorted, symmetrical and very leptokurtic), however, indicate a longer transport of material in littoral drift (*cf.* KOMAR, 1976; SELF, 1977; JACOBSEN and SCHWARTZ, 1981; TAGGART and SCHWARTZ; 1988) or, more probably, the old age of this sand.

Provenances of Beach Sediments

The mineral content of beach sands on the shores of the Kassandra Peninsula correlates well with that of the strata (clays, shales, sandy siltstones, sandstones, marls, conglomerates, breccio-conglomerates, limestone breccias) (BIZON *et al.*, 1969; KOCKEL *et al.*, 1977) that are exposed along the coasts and subject to wave erosion. The lower unit under these sedimentary rocks consists of massive strata of reef limestone and calcturbidites which are exposed only on the southern point of the peninsula (BIZON *et al.*, 1969; KOCKEL *et al.*, 1977; MUSSALLAM and JUNG, 1986).

The beaches studied, excluding Hanioti and Pefkohori Beaches, are delimited landward by bluffs (Figure 3). The mineral analysis at each of the beaches can be related to the composition of the bluffs or nearby exposed rocks (*cf.* KOCKEL *et al.*, 1977). The mineral suites of these strata are rich in such light minerals as quartz, feldspar and muscovite, which also dominate the content of beach sands (Table 3). Sources of epidote, amphiboles and titanite occurring in the sands are probably metamorphosed impure calcareous rocks. Especially on the eastern shore, there are sandy clays, shales and siltstones consisting of mica and

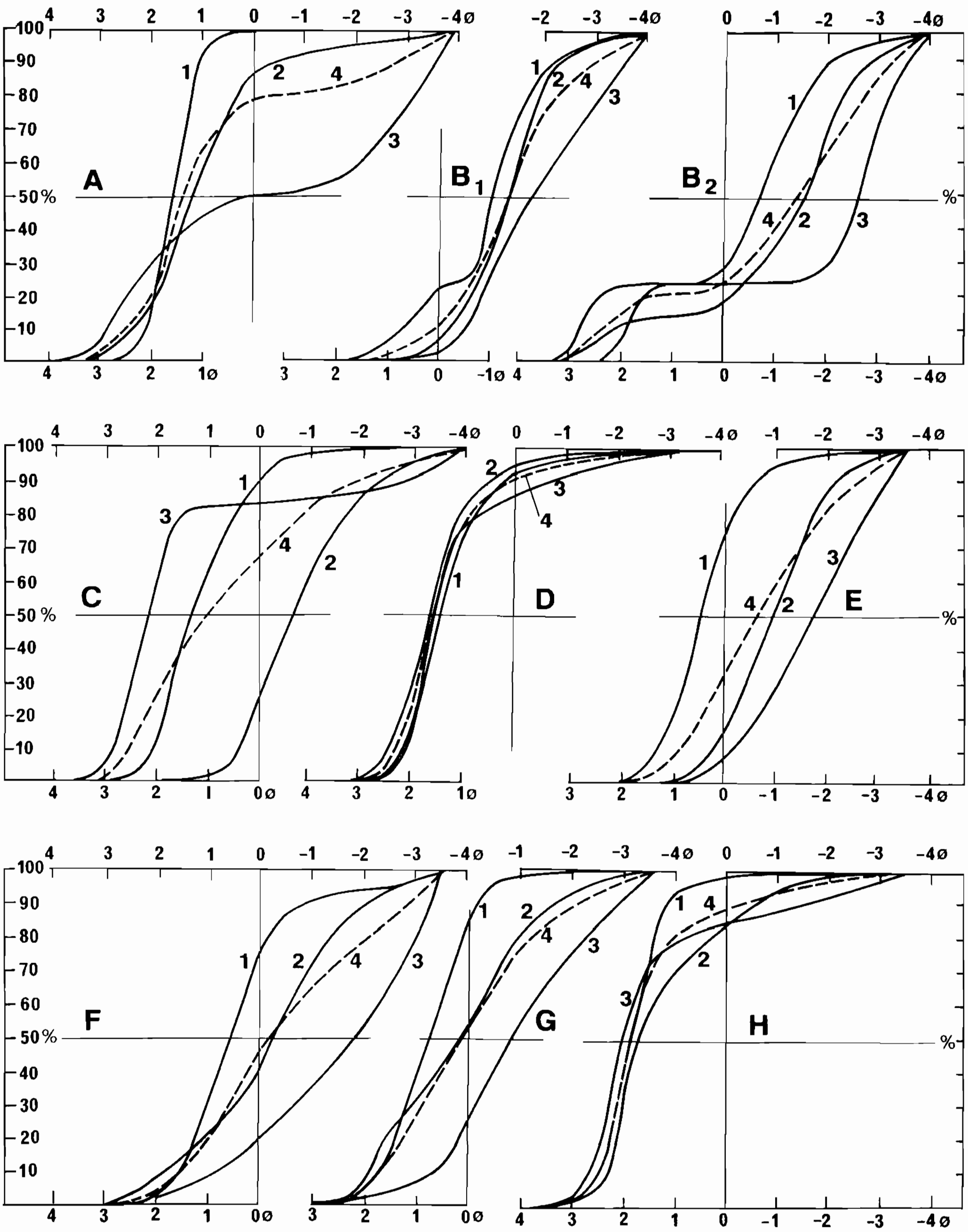


Figure 6. Cumulative log-normal grain-size curves of the studied materials on the eight beaches on Chalkidiki Pensinsula and Thassos. Locations A–H are as in Figure 2 (B_1 is the northern shore and B_2 the southern shore of Posidi Beach) and the numbers of samples as in Table 1. (1) Beach zone material, (2) swash zone material, (3) surf zone material, (4) total material.

marble concretions (BIZON *et al.*, 1969), which may be the sources of these minerals. The origin of pyroxenes (mainly diopside) is probably metamorphosed impure blocks of dolomites. Chlorites are alteration products of ferromagnesian minerals in low-grade regionally metamorphosed rocks in the area and haematite is a common mineral in sediments (*cf.* BIZON *et al.*, 1969; MUSSALLAM and JUNG, 1986).

The beaches of the Kassandra Peninsula are low-carbonate beaches, the highest carbonate concentrations occurring on the beaches of the western coast (Posidi and Nea Potidea Beaches) and lowest on Kallithea and Hanioti Beaches (Tables 2 and 3) on the eastern coast. The sources of carbonate material (low-Mg calcite, dolomite, magnesite) are the underlying limestone strata and limestone, and marble and dolomite concretions in the clays, shales and siltstones (*cf.* BIZON *et al.*, 1969). However, part of the carbonates, consisting of skeletal debris dominated by mollusc and foraminifera particles, is produced on the adjacent shelf. This recent carbonate sand is a major source of aragonite and high-Mg calcite and a minor source of low-Mg calcite (*cf.* PYÖKÄRI and LEHTOVAARA, 1987, 1990, 1991). The less stable carbonates (aragonite and high-Mg calcite, Table 3) occurring in this sand are most common on Posidi Beach. A small gypsum fraction (0.1–0.2%) may derive from clays and limestones.

The poor roundness of non-carbonate particles, in general, also indicates that sands on the beaches of the Kassandra Peninsula are local. The somewhat better roundness of the particles on the eastern shore is probably caused by the facts that this coast is straighter than the western coast and that there are fewer bluffs and cliffs. Thus the material on the eastern coast seems to be transported along shore somewhat longer distances than on the western coast. Where carbonate particles reveal a dominance of low-Mg calcite (Posidi, Aghios Mamas, Hanioti and Pefkohori Beaches), roundness is also better than on beaches where high-Mg calcite and aragonite dominate (Kallithea and Nea Potidea Beaches). This marine shelly sand is angular or sub-angular. The typical minerals (olivine, hypersthene, augite, hornblende, biotite) of the ophiolite complex situated at the end of the Kassandra Peninsula (BIZON *et al.*, 1969; KOCKEL *et al.*, 1977) are also absent from the studied beach sands, which indicates that the distances over which shore materials are transported are not particularly great and that the sources of beach material are local strata.

The mineral composition of Ouranopoli Beach at the neck of the Ayios Oros Peninsula (Figures 1 and 3G) also reflects well the mineral composition of local granites and granodiorites (KOCKEL *et al.*, 1977; MUSSALLAM and JUNG, 1986) (Table 3), but the beach sand is somewhat enriched with quartz. The carbonates consist mainly of shelly gravel. Beach material is coarse, nearly poorly sorted (Table 1) and grains angular or even very angular with sharp edges. All this suggests that the shore material originates from the adjacent bluffs and cliffs and that the transport distances are short.

The mineral content of beach sands on Golden Beach in Potamias Bay on the island of Thassos differs, however, from the mineral suite of the rocks (muscovite schists, biotite gneisses, dolomite, marble) (ZACHOS, 1982) of the drainage basins of the rivers which run from the mountains. Amphiboles (actinolite and tremolite) and titanite are absent and feldspars, muscovite, biotite, pyroxenes and epidotes are rare (Table 3). All these minerals are common in the local rocks. High-Mg calcite and aragonite derived from the shelf also make up nearly half of the carbonates. The low-Mg calcite, dolomite and magnesite come, however, from the dolomite cliff on the northern shore and marble cliff on the southern shore of Potamias Bay (Figure 3H). The large fractions of quartz (88.5%), gypsum (8.0%) and high-Mg calcite (5.1%), and the scarcity or absence of the above-mentioned minerals indicate that the main source of sands is the shelf, the old Pleistocene and Holocene sand (PERISSORATIS and MITROPOULOS, 1989), which originated, when sea level lay about 120 m below its present level. Most parts of the quartz grains show evidence of modification by abrasion in a subaqueous environment; the surfaces are pitted and scratched, and the sharp edges have been rounded to a moderate degree. Thus, it seems that these grains were enriched, reworked and moderately rounded in a shallow-marine environment prior to their deposition on the present beaches when the water level was lower (*cf.* LYBÉRIS and BIZON, 1981; PERISSORATIS and MITROPOULOS, 1989). A minor part of the quartz grains are, however, rather unrounded with some sharp edges. This quartz may be river-borne sediment, the source of which is the schists and gneisses of inland Thassos. The gypsum fraction (8.0%) derives from evaporites

Table 4. *Dependence of the direction of littoral drift on the directions of prevailing and predominant winds.*

Littoral Drift	Prevailing Wind In Winter r_s	Prevailing Wind In Summer r_s	Predominant Wind (greatest fetch) r_s
Seasonal drift			
Beach zone	+0.52*	+0.27	−0.05
Swash zone	+0.15	+0.43°	+0.51*
Surf zone	−0.05	+0.09	+0.56*
All zones	+0.16	+0.15	+0.42°
Net littoral drift	−0.11	−0.14	+0.71**

r_s = Spearman's coefficient of rank correlation, arranged according to the effects of the waves on the shore.
° = correlation symptomatical
* = correlation fairly significant
** = correlation significant

of Messinian age situated in the bottom successions of the sea around Thassos (CHIOTIS, 1984; LE PICHON *et al.*, 1984; MEULENKAMP, 1985; PERISSORATIS and MITROPOULOS, 1989).

Transport of Material and the Direction of Littoral Drift

It seems that longshore transport along the Chalkidiki coasts determines the composition of beach sediments, because the orientation of the shoreline is nearly straight or slightly curving (with some exceptions on the western coast of the Kassandra Peninsula), so that movement may be several kilometres. The coasts of Thassos are, on the contrary, rocky and irregular, sediment transport is compartmentalized and longshore transport is short. The coasts are full of small or large coves with pocket beaches, which act as local sediment traps (*cf.* PYÖKÄRI and LEHTOVAARA, 1991).

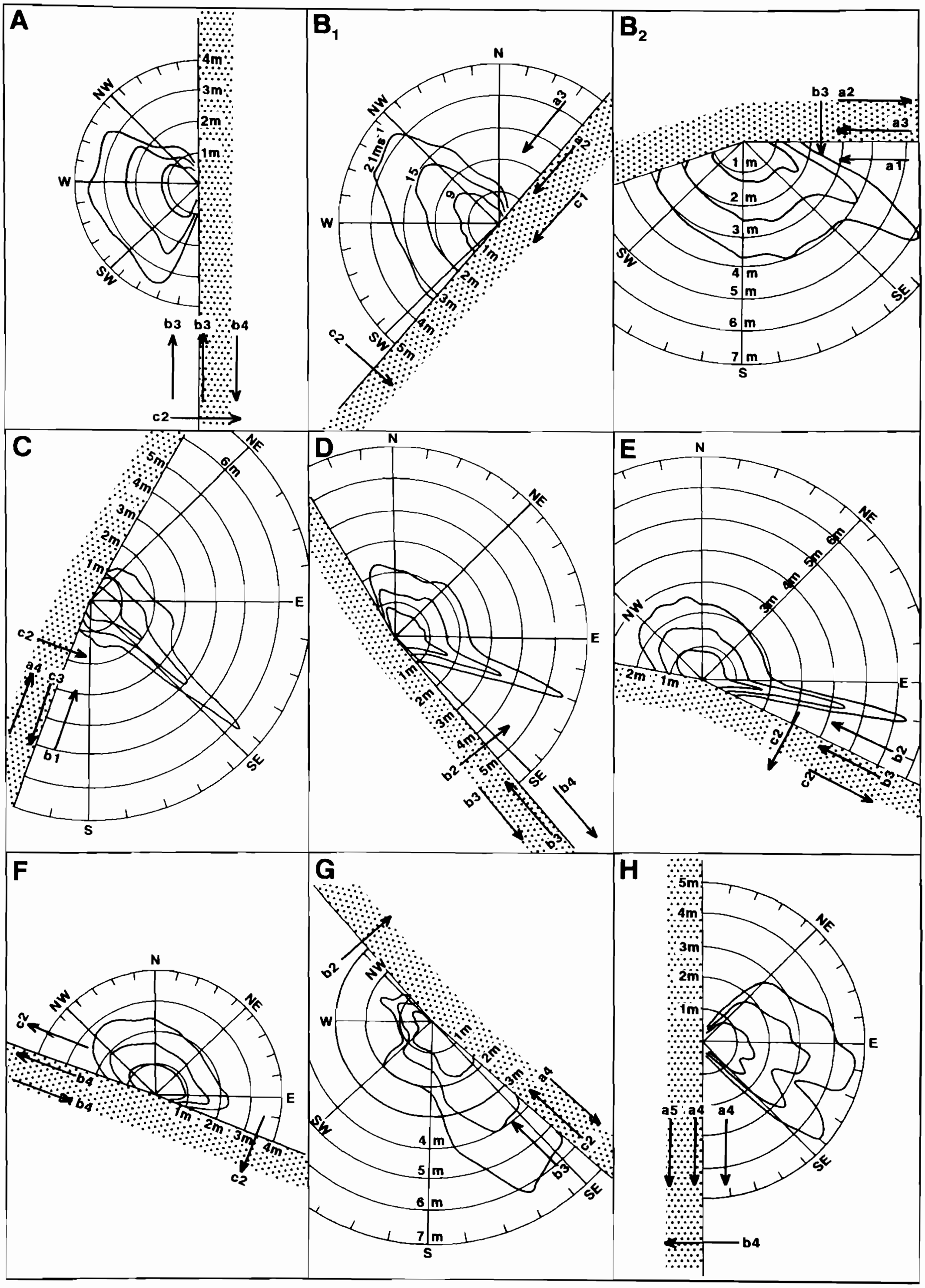
In explaining the directions of material movement on the Chalkidiki and Thassos shores, we must remember that the samples collected from the swash zone reflect the situation on the day they were collected and those from the surf zone a longer period (some days). Samples taken from the beach zone, however, probably reflect the situation during winter storms (or some other earlier extreme events), when waves reach this zone. This study was founded mainly on the following principles as to the direction of littoral drift: the most common wave direction (prevailing wind), the most effective wave direction (predominant wind) and the length of fetch. For Chalkidiki shores, the longest wind fetch is at most 330 km and for Golden Beach on Thassos 170 km, but in most cases the fetch is much less than 100 km. Using Spearman's coefficient of rank correlation in testing the direction of littoral drift to the directions of prevailing wind and predominant wind (longest fetch), we obtained the correlations shown in Table 4.

The transport of material on Nea Potidea Beach on the western coast of the Kassandra Peninsula seems to be northwards in the surf and swash zones and southwards in the beach zone (Figure 7A). Predominant waves (mostly swells) come to this coast from SW, where the fetch is greatest (75 km). There are also high bluffs on the southern part of the beach at the beginning of the drift sector (Figure 3A) which show evidence of strong erosion and landsliding (Figure 4). Net littoral drift also seems to be northwards, because the backshore widens in this direction and sediment is accumulated on the southern side of jetties. The fetch is shortest in the north, which is the direction of the prevailing wind both in summer and winter (Figure 2). The southward transport in the beach zone is probably caused by a strong NW wind in winter (*cf.* KENDREW, 1953). Deposition occurs on the northern part of the beach and the bar (Figure 5A).

The movement of material on the northern shore of Posidi Beach (Figure 7B) is caused by the prevailing northerly winds and waves, which reach the shore at angles of 30°–60°. This is a very efficient angle (KING, 1972) and forces shore material to move SW. On the southern shore seasonal littoral drift is westwards in the surf and swash

→

Figure 7. Wind forecast diagrams for the studied beaches on Chalkidiki and Thassos. Estimated wave heights (in metres) for minimum wind durations (velocities 9 msec^{-1}, 15 msec^{-1}, and 21 msec^{-1}) according to fetch conditions. The directions of littoral drift (beach drift and longshore drift) in the three shore zones and transport of sediments normal to the shore along the studied lines on the beaches are indicated by arrows (a = exclusively, b = mostly, c = mainly). The transport of sediments in the direction of the arrow is very strong (5), strong (4), moderate (3), weak (2) or very weak (1). Locations A–H as in Figure 2 and B_1 and B_2 as in Figure 6.


A
NW
W
SW
4m
3m
2m
1m
b3
b3
b4
c2
B1
N
NW
W
SW
21ms-1
15
9
a3
c1
c2
1m
2m
3m
4m
5m
B2
b3
a2
a3
a1
SW
SE
S
1 m
2 m
3 m
4 m
5 m
6 m
7 m
C
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E
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1m
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c2
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E
SE
1m
2m
3m
4m
5m
a5
a4
a4
b4

zones caused by both the prevailing and predominant winds from SE in summer (Figure 7B). In the beach zone the material has been transported eastwards, probably during a severe winter storm when the wind directions are more variable (MARKGRAF, 1961). The storm berms are seen in Figure 5B. According to geomorphic indicators net littoral drift seems to be westwards on the southern shore of Posidi Beach (the point of the bar also curves NW, Figure 3B) and to the southwest on the northern shore. The southern shore is slightly erosional and the northern shore depositional.

The movement of material on the eastern shore of the Kassandra Peninsula is caused by both the prevailing and predominant winds. The predominant waves reach the shore from SE-E where the largest fetch (210–330 km) is situated (Figure 7C–F), but the sector of efficient waves is very narrow, about 10°. The NW movement in the surf and swash zones on Pefkohori and Hanioti Beaches is caused both by the prevailing and predominant waves, which come in the same direction on to these beaches in summer (Figures 2 and 7E and F). On Kallithea Beach this same direction of littoral transport is seen in the swash zone (Figure 7D) and on Aghios Mamas Beach in the surf and beach zones (Figure 7C). The movement on these beaches is probably caused only by the predominant waves (swells), which come from SE-E. The prevailing wind is northerly both in summer and winter (Figure 2) and, especially in winter, causes material to be transported SE in the beach zone during severe winter gales, as seen in Figure 7D–F. The transport of shore material northwards in the beach zone on Aghios Mamas Beach is to be expected, because the fetch is very short to the N-NE (Figures 2 and 7C). The movement is caused by large southeasterly swells or storm waves, which have rushed up on to the beach zone. The beaches on the eastern shore of the Kassandra Peninsula are somewhat erosional (Figure 7C and D), deposition occurring on the bars, as on Aghios Mamas and Kallithea Beaches (Figure 5C and D), or on the beach, as Hanioti and Pefkohori Beaches (Figures 7E and F and 5E and F). The increasing width of the beaches towards NW and sedimentation of sand on the SE side and erosion on the NW side of the jetties would appear to indicate a northwesterly direction of net littoral drift on the eastern coast of the Kassandra Peninsula (Figure 8).

The littoral drift in the surf and swash zones on Ouranopoli Beach appears to be NW (Figure 7G) and has been caused exclusively by predominant waves approaching from SSE, where the fetch is longest (330 km) (Figure 2). The prevailing wind is from the north both in summer and winter. The SE drift of material in the beach zone has been generated in a situation when waves, probably during a severe winter storm, have approached from WNW and reached the beach zone. The marks of this movement on the upper beach may be older than one year. According to geomorphic indicators the net littoral drift is NW. Sand accumulates somewhat on Ouranopoli Beach (Figure 7G), caused partly by the jetties which break the littoral drift.

On the eastern coast of the island of Thassos the direction of transported beach material correlates well with the direction of the prevailing wind, which is from NE both in summer and in winter (Figure 2). Material moves in all the shore zones southwards (Figure 7H). The longest fetches are, however, in the SE-E directions (100–160 km), but material does not move northwards because the fetches in the direction of the prevailing wind (NE-E) are large enough (50–100 km) to generate large waves which move material on the shore southwards and carry old Pleistocene-Holocene sand (PERISSORATIS and MITROPOULOS, 1989) from the shelf and deposit it on to the beach.

When the means of the samples from each site and in each studied area were tested in the direction of transport and normal to the shore (Figure 7) using Student's t-test, the grain-size parameters differed highly significantly in 66–83%, significantly in 3–14% and fairly significantly in 1–3% of all the cases in Figures 3 and 7. Thus the directions of littoral drift and onshore–offshore transport would seem reliable.

In general, the directions of net littoral drift on the studied shores seem to be largely dependent on the directions of the greatest wind fetches (or predominant wind and waves). The correlation (0.71) in Table 4 is significant. A good correlation has been observed between the greatest fetch and net littoral drift direction in some other studies, too (*e.g.* TAGGART and SCHWARTZ, 1988). The direction of the greatest fetch also seems to determine to a large extent the direction of seasonal littoral drift on the shores in the swash and surf zones; the correlations (0.51 and 0.56) are fairly significant. A fairly significant correlation (0.52) is also between the direction of the prevailing wind

Figure 8. Kallithea Beach on the eastern coast of Kassandra Peninsula. The direction of net littoral drift (beach drift) in the swash zone towards NW is seen as an accumulation of sediment on the updrift side and erosion on the downdrift side of the jetty. Accumulation and erosion near other jetties outside the photo area are similar.

in winter and the direction of seasonal littoral drift in the beach zone.

Thus, it seems that the direction of the greatest fetch (predominant wind and waves) on Chalkidiki shores is the most significant factor determining the direction of littoral drift. In winter the direction of the prevailing wind also largely determines the direction of material movement in the beach zone. The direction of the prevailing wind in summer does not seem to determine the direction of material movement on the shore. The correlations are not significant, but the correlation in the swash zone is, however, symptomatic (0.43).

CONCLUSIONS

The following conclusions are drawn on the basis of this study of the texture, mineral composition, provenance, transport and causes of the transport on some beaches of the Chalkidiki Peninsula and the island of Thassos in northern Greece:

(1) Textural and mineralogical analyses of beach sands on the Chalkidiki beaches do not show any particularly great variation (with the exception of grain size) and also display patterns that are consistent with the coastal geology and the processes acting on these coasts. The most complex coastal area, Golden Beach on Thassos, however, exhibits this complexity in the mineral content and texture of its beach material (Table 3).

(2) The beach material on the Chalkidiki beaches shows a fairly broad range of grain size, consisting mainly of coarse sand; it is moderately sorted, symmetrical or negatively skewed and slightly leptokurtic (Table 1). The sands on Golden Beach on Thassos are, however, fine, nearly well-sorted, symmetrical and very leptokurtic.

(3) The mineral content of beach sediments on the Chalkidiki beaches suggests that the main sources of the sands are the eroded adjacent cliffs, bluffs and rocky shores. A small part of carbonates are derived from the nearby sea bottom carried on to the beach by waves. High-Mg calcite and

aragonite are typical minerals in this sand (Table 3).

(4) The mineral content and grain-size parameters of the beach sediments on Golden Beach on Thassos indicate that the main source of the clastic material here is old Pleistocene-Holocene sand from the Northern Aegean shelf. The mineral suite of beach materials does not correlate well with the mineral contents of the coastal rocks and the drainage basins of the rivers, but it correlates well with that old sand. The high quartz, gypsum and high-Mg calcite contents indicate marine origin (Table 3). The quartz grains are also finer and more rounded than quartz clasts on the other beaches.

(5) The direction of net littoral drift on the studied beaches on the Chalkidiki Peninsula and the island of Thassos is mainly determined by the predominant waves and wind (the direction of the greatest fetch). The direction of seasonal drift is also largely caused by these waves and this wind in the swash and surf zones (beach drift and longshore drift) while the direction of seasonal drift in the beach zone (beach drift) in winter is mainly determined by the prevailing waves and wind (Table 4).

ACKNOWLEDGEMENTS

The writers wish to thank Mrs. Leena Kiiskilä, who drafted the figures in final form, Mr. Turkka Puisto, who prepared thin sections for microscopic study, Mr. Christopher Grapes, who corrected the English text, and Mr. Heikki Pyökäri, who helped in collecting the samples. This study was supported by a Docent Scholarship at Turku University awarded to Dr. Mauri Pyökäri in 1988. Without this financial help we would not have been able to make our study.

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□ RÉSUMÉ □

On a réalisé 51 profil sur 8 plages des côtes de la péninsule de Chalkidiki et l'ile de Thassos au Nord de la Grèce. Neuf échantillons de sédiments ont été recueillis pour chaque profil, trois pour chaque environnement: avant plage, bas de plage, tête de plage. Les directions saisonnière et de la dérive nette ont été observées.

Toutes les plages étudiées sont faiblement carbonatées, la texture et la composition minéralogique peut localement varier. Les sédiments des plages de Chalkidiki sont grossiers, modérément triés, symétriques ou d'asymétrie négative et légèrement leptocurtiques. Leur composition minéralogique est trés liée à la roche mére des falaises voisines exposées. Les sables de plage sont contitués à environ 85% de quartz et de feldspath. Les sables de Golden Beach sur Thassos, sont au contraire fins, bien triés, symétriques et trés leptocurtiques. Leur texture et leur composition minéralogique montrent une forte relation avec celle des sables pléistocènes et holocénes du Nord du plateau Egéen. Le quartz, le gypse et une forte teneur en calcite à manganèse caractérisent ce sable.

La direction de la dérive littorale est conditionnée par l'angle d'approche prédominant de la houle par rapport au plus grand fetch. Ces vagues déterminent aussi la direction du courant saisonnier dans la zone de déferlement. Ce courant est surtout causé l'hiver par les houles et les vents dominants.—*Catherine Bousquet-Bressolier, Géomorphologie E.P.H.E., Montrouge, France.*

□ RESUMEN □

En ocho playas de las costas de la Península de Chalkidiki y la isla de Thassos, en el norte de Grecia, se midieron 51 perfiles de playa. Sobre cada perfil se tomaron nueve muestras de sedimentos, tres para cada uno de los ambientes, el costero, la anteplaya y la playa posterior. La dirección estacional y la deriva litoral neta fueron observadas en cada una de las playas.

Todas las playas estudiadas poseen bajos contenidos de carbonatos, donde la textura y la composición mineral de los sedimentos de playas presentan algún grado de variación local. Sobre las playas de Chalkidiki los sedimentos consisten principalmente en arenas gruesas, con una moderada clasificación, con un sesgo negativo o simétrico y ligeramente leptocurtósica. Sus composiciones minerales se hallan estrechamente relacionadas a las rocas madres expuestas en las proximidades o las escarpas sobre las playas. El 85% del contenido mineral de las arenas de estas playas consisten en cuarzo y feldespato. Los sedimentos de Golden Beach en Thassos son, por el contrario, arenas finas, muy bien clasificadas, simétricas y muy leptocurtósica. Sus texturas y contenido de mineral indican una estrecha relación con el mineral contiguo de la arena antigua del Pleistoceno-Holoceno sobre el norte de la plataforma de Aegean. El cuarzo, el yeso y la Mg-calcita son los minerales más comunes en estas arenas.

La dirección neta de la deriva litoral sobre las playas estudiadas es determinada por la aproximación de las olas dominantes a partir de la dirección del máximo campo de acción de las olas. Estas olas son las que determinan la dirección de la deriva litoral estacional en las zonas de lavado y rompiente, mientras la dirección de la deriva litoral en la zona de la playa en invierno es producto de las olas y los vientos dominantes.—*Néstor W. Lanfredi, CIC-UNLP. La Plata, Argentina.*