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Grain size distribution, clay mineralogy and chemistry of bottom sediments from the outer Thermaikos Gulf, Aegean Sea, Greece

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Abstract

The Thermaikos Gulf constitutes the NW part of the North Aegean Sea and is limited eastward from the Chalkidiki Peninsula and westward from the Pieria Prefecture. Its plateau covers an area of 3,500 km^2. The mechanisms responsible for the grain size distribution into the Gulf, the clay mineralogy and the chemistry of some bottom sediments from the outer Thermaikos Gulf, are examined.

Source mixing during transportation, flocculation, differential settling processes and organic matter appear to be the main mechanisms for the distribution of clay minerals in shallow waters. All grain size fractions studied present a wide range of values confirming the extreme variations of the discharged load and the variability in marine processes. Plagioclases predominate over K-feldspars, while quartz is the most abundant mineral present. In addition, micas, chlorites, amphiboles and pyroxenes exist as primary and/or accessory minerals in all samples. Among clay minerals, illite predominates over smectite and smectite over chlorite (+ kaolinite). The ordered interstratified phase of I/S, with 30-35% S layers, is present in the 2-0.25μm fraction. The randomly interstratified phase of I/S, with 50% S layers, is present in the <0.25μm fraction. On average the clay mineral content of the studied samples is: 48% I, 23% S, 17% Ch (+K) and 12% others for the 2-0.25μm fraction and 50% I, 30% S and 20% Ch (+K) for the <0.25μm fraction. All these minerals are the weathering products of the rocks from the drainage basins of the rivers flowing into the Gulf, as well as of the Neogene and Quaternary unconsolidated sediments of the surrounding coasts. The terrigenous input, the water mass circulation and, to a lesser extent, the quality of the discharged material and the differential settling of grains, control the grain size distribution within the outer Thermaikos Gulf. The chemical composition of the analysed samples is generally in agreement with their mineral composition and signifies their terrigenous origin presenting discretely clastic character.

Keywords: Clay mineralogy; Thermaikos Gulf; Aegean Sea.

Introduction

During weathering of a wide range of rocks, dissolution of primary minerals and formation of new mineral phases takes place within a weathering profile. Factors controlling the intensity of the weathering processes are climate (temperature and rainfall), topography, tectonics, mineralogical and physical characteristics of parent rocks, organisms, etc.

In middle latitude regions, mild temperatures, rainfall ranging from 50 to 100cm/yr and chemical weathering predominate (CHAMLEY, 1989). The resulting soils typically exhibit a brown colour that tends to become reddish in the warmer areas (i.e. red Mediterranean soils). In the sub-humid region of the Mediterranean, degradation is moderate. In lowland areas, where the rainfall is between 30 and 50cm/yr, the ions removed from primary silicates during humid seasons are re-concentrated during dry seasons giving genesis to discrete and interstratified clay minerals. In temperate areas, clastic illite is the predominant clay mineral, signifying low to medium intensity of weathering processes (WEAVER, 1989).

The general scarcity of clay sized sediments in shallow water, due to winnowing through the action of waves, tides and currents, contrasts with the huge accumulations of argillaceous deposits in the rest of the oceans. Where they do occur, source mixing during transportation, flocculation and differential settling processes appear to be the main mechanisms for their distribution (GRIFFIN *et al.*, 1968; CHAMLEY, 1989). Additionally, CHAMLEY (1989) suggests that the aggregation of clay particles by marine organic matter appears to be a widespread phenomenon, mainly responsible for the rapid sinking of land-derived materials. Clay is mainly incorporated in faecal pellets and other mucous matter within the surface water masses where high planktonic productivity develops seasonally.

Preferential settling of smectite and expandable mixed minerals represents a common phenomenon in the western Mediterranean Sea. CHAMLEY (1971), MONACO (1971) and ROUX & VERNIER (1977) report a frequent increase of expandable minerals at an increased distance from the shore of the Gulf of Lions. In the Adriatic Sea, mechanical sorting and flocculation account for the distribution of clay suites derived from the Po R. and other rivers (VENIALE *et al.*, 1972; TOMADIN & BORGHINI, 1987).

The Thermaikos inner Gulf is a semi-enclosed embayment (depths <35m) within the north-western Aegean Sea (POULOS *et al.*, 1996b). The wave activity, the near bed currents, the prevailing climatic conditions, the extreme variations of the discharged load, as well as the grain size and the mineralogical composition of the suspended load, control the grain size distribution in the Thermaikos Gulf (POULOS *et al.*, 2000). The central and eastern Thermaikos Gulf seabed is covered by relict sands (sand content up to 80%), with very little silt content (LYKOUSIS *et al.*, 1981; LYKOUSIS & CHRONIS; 1989, KARAGEORGIS & ANAGNOSTOU, 2001).

In this study the grain size distribution, the clay mineralogy and the chemistry of some bottom sediments from the outer Thermaikos Gulf are examined. In addition, the mechanisms responsible for the grain size distribution into the Gulf are investigated.

Study area

Physical Geography

The plateau of the Thermaikos Gulf, extends up to the isobath of 200m, and covers an area of 3,500km^2 (LYKOUSIS *et al.*, 1988). The main rivers flowing into the Gulf are: Gallikos, Axios, Aliakmon and Pinios. The Gulf constitutes the NW part of the North Aegean Sea and is limited eastward from the Chalkidiki Peninsula and westward from the

Pieria Prefecture. Gradually the Gulf narrows northward and finally ends in the inner Gulf on the coast of which the city of Thessaloniki is built (Fig. 1).

Characteristics of the rivers flowing into the Gulf are given in Table 1. The total drainage basin of all rivers (and their tributaries) is about 45,000km^2 and their total deltaic area is 662km^2. The total mean annual water discharge and the total mean annual suspended sediment load of all four rivers, is 11X10^6 m^3 and 57X10^6 tons/yr, respectively.

The bathymetry of the Gulf was studied from the nautical charts of the area with scales 1:50,000 and 1:250,000 (X.E.E. 31, X.E.E. 255) of the Hydrographic Service. The relief of the Gulf seabed, as well as of the surrounding area, is smooth with a very low gradient; thus, the Gulf seabed is almost flat. The water depth, even at large distances from the coast, is low

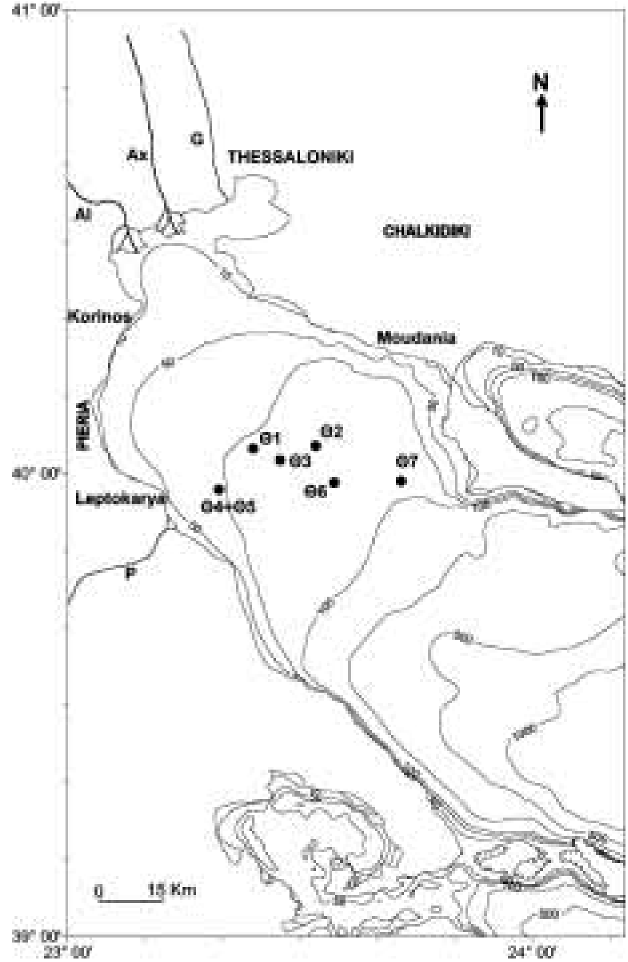

Fig. 1: Sample collection positions. G = Gallikos, Ax = Axios, Al = Aliakmon, P = Pinios.
Letters and indexes denote sample collection positions: Θ_4=0-10cm, Θ_5=80-90cm and Θ_6=0-10cm are bottom core samples, Θ_1, Θ_2, Θ_3 and Θ_7 are bottom grab samples.

Table 1
Characteristics of the rivers flowing into the Thermaikos Gulf
(PSILOVIKOS & HAHAMIDOU, 1987; POULOS et al., 1996a & 2000).

River	Delta type	D	L	B	I	S	M	W	S.S.L.
Gallikos	Bird foot	80	60	930	53	43	4	1.2	1.5
Axios	Bird foot	393	275	23,750	43	49	8	5.0	24.3
Aliakmon	Bird foot	120	240	9,250	15	76	9	2.3	15.0
Pinios	Radial	69	175	10,750	18	76	6	2.6	16.2

D = delta area (km^2), L = total length of main river branches (km), B = area of drainage basin (km^2), I = igneous rocks (%), S = sedimentary rocks (%), M = metamorphic rocks (%), W = mean annual water discharge ($X10^9$ m^3), S.S.L. = mean annual suspended sediment load ($X10^6$ t).

and does not exceed 36m in the inner Gulf (16m on average) and 92m in the outer Gulf, for latitude higher than 40° N. A bottom ridge at 22m depth separates the two parts of the Gulf. The bottom gradient is less than 2%. After the isobath of the 22m an elongated undersea platform exists at an average depth of 65m with a NW to SE direction.

Oceanography-Climatology

The overall water circulation pattern in the Thermaikos Gulf is characterised by northerly water movement, from the central and eastern part of the Gulf and southerly movement along its western part, resulting in a cyclonic hydrodynamic circulation (KARAGEORGIS & ANAGNOSTOU, 2003). The prevailing climate (winds and pressure systems) appears to control the surface water circulation, while near-bed current measurements reveal a general moderate (<15cm/s) southerly flow, i.e. offshore, toward the deep water Sporades Basin (POULOS *et al.*, 1996a & 2000).

According to the data of the Meteorological Station of Aristotle University the catchment areas of the rivers that discharge into the Gulf, as well as its coastal area, present average annual rainfall of 45.5cm (period 1930-1990) and the predominant winds have mainly NE (25%), N (13%) and SW (10%) directions. The calm period is 52%.

Geology

The marine and terrigenous area of the study belongs geotectonically to the Peonia Zone. This Zone represents part of the ancient Tethys Sea. The sedimentary formations of the Thessaloniki plain have Miocene to Pleistocene age. The Pliocene in this area exists both in brackish and terrigenous phase (MARINOS, 1965). The Pleistocene sediments nonconformably overlay the Pliocene ones. In addition, Neogene and Quaternary sediments (especially red clayey breccia silts) are found on the east and west coasts of the Gulf. During the period of Upper Miocene – Pliocene intense volcanic activity took place north of the Gulf (Almopia). In addition, during the period of Pliocene – Quaternary the passages of the Aliakmon and Pinios rivers opened and large quantities of clastic sediments were discharged into the Gulf. Today, the main supplying sources of the inner Thermaikos Gulf are the rivers Axios and Aliakmon. However, the composition of the transported materials differs substantially because the Axios flows mainly through igneous (especially ophiolites) and sedimentary formations (92%) and the Aliakmon through sedimentary formations (76%) (Table 1). The mean particle size of the discharging material is about 250μm. During the last 10,000 years the sedimentation rate in the western part of the Gulf was nine times higher than in the eastern part (CHRONIS, 1986; POULOS *et al.*, 1996a & 2000).

Geologically, the Thermaikos Gulf and the Plain of Thessaloniki constitute a large graben with a NW to SE direction, the formation of which started in the Early Miocene. After

Pliocene a sea transgression took place. However, during Alluvium the recharging of fluvial deposits with the simultaneous continental movements resulted gradually in the present land morphology (PSILOVIKOS, 1987).

Materials and Methods

Bottom surface samples and short gravity bottom cores were collected from the Thermaikos Gulf (Fig. 1 & Table 2) using a Dietz La Fond bottom sampler and an 1.5m long Benthos Inc. gravity corer, from the R/V 'PYTHEAS' of the Hydrographic Service, Hellenic Navy. The position of the sample stations was determined by a 'TRISPONDER' positioning system. Four surficial and three core samples were selected for this study (Fig. 1).

Prior to mineralogical analysis the samples were dried overnight in an oven at about 65°C and then were disaggregated by use of an agate mortar and pestle. Disaggregation was done gently in order to retain, as much as possible, the intrinsic grain sizes of the samples. A 20g split of the <2mm fraction of each sample was subjected to the following chemical treatments (JACKSON, 1979) to remove the non-silicate phases: 1N sodium acetate-acetic acid buffer solution (pH = 5.0) in a water-bath at 75-80°C for 30 min with intermittent stirring for carbonate removal; 30% H_2O_2 in a water-bath at 75-80°C for 2.5 hours to remove organic matter and Mn-oxides; and 1M $NaHCO_3$-0.3M sodium citrate buffer solution (pH = 7.3) to which 2g of $Na_2S_2O_4$ were added, during digestion in a water-bath at 75-80°C for 15 min with intermittent stirring, to remove free Fe-oxides and interlayer Fe- and Al-hydroxides.

The cleaned residues were separated into four consecutive size fractions (250-20, 20-2, 2-0.25 and <0.25μm) by gravity settling and centrifugation and were dried overnight in an oven at about 65°C. X-ray diffraction was performed on a Philips diffractometer with Ni-filtered CuK_α radiation. Both randomly oriented samples and samples with preferred orientation were scanned over the interval 3-43° 2θ at a scanning speed 1°/min. All the oriented mounts were reanalysed after glycolation to distinguish the expandable mineral phases. Some of the glycolated mounts were heated for 2.5 hours at 550°C for chlorite detection. Semi-quantitative estimates of the amounts of quartz, plagioclase, orthoclase, calcite, dolomite and total clays, as well as of the amphiboles and pyroxenes are based on peak heights and intensity factors on XRD patterns of randomly oriented powder samples, using the methods of SCHULTZ (1964) and PERRY & HOWER (1970). XRD patterns taken from preferentially oriented and glycolated samples were used for the semi-quantitative estimation of clay mineral phases

Table 2
Grain size distribution (wt. %) of the samples analysed.

Sample	Water depth (m)	C.O.I.[1] (%)	250-20 (μm)	20-2 (μm)	2-0.25 (μm)	<0.25 (μm)	Class[2]
Θ_1	75	25	17	26	14	18	sM
Θ_2	78	32	24	18	11	15	mS
Θ_3	78	30	14	25	13	18	sM
Θ_4	75	26	8	29	16	21	sM
Θ_5	75	16	65	7	6	6	mS
Θ_6	90	28	22	23	11	16	sM
Θ_7	85	14	76	4	3	3	mS

[1] Total percentage of Carbonates + Organics + Iron oxides and iron and aluminum hydroxides.
[2] Classification according to FOLK (1974); sM=sandy Mud, mS=muddy Sand.
Other symbols as in Figure 1.

using specific reflections and intensity factors (MOORE & REYNOLTS, 1997).

Chemical analyses were performed on a JSM-840 electron microprobe, equipped with a LINK system energy dispersion analyser. Operating conditions were: accelerating voltage 15kV, beam current 3nA, surface electron beam 1μm diameter and counting time 100 seconds.

Results

Grain size distribution

The grain size distribution of the samples after chemical treatments is given in Table 2. No relationship between water depth and grain size distribution is noticed. From these data it is concluded that the amount of the sum of carbonates + organic matter + iron oxides and iron and aluminum hydroxides is high (14-32%). The majority of this belongs to carbonates. Stereoscopic examination of the untreated samples reveals the extensive presence of shell fragments.

According to the FOLK (1974) classification, the studied outer Gulf seabed sediments may be characterised as sandy Muds (sM) and muddy Sands (mS).

XRD analysis

The results of XRD analysis of the different size fractions after chemical treatments are given in Table 3. Different minerals in variable proportions are concentrated in different grain size fractions. In the two coarsest fractions (250-20μm and 20-2μm), quartz and feldspars predominate. Among the feldspars plagioclases exceed significantly. The presence of dolomite and calcite in the two coarsest fractions is due to their incomplete dissolution after the first chemical treatment for carbonate removal. Amphiboles and pyroxenes exist in small amounts in all samples. Micas and chlorites are the predominant phyllosilicate minerals in the two coarsest fractions. The total clays percentage in these two fractions is significantly high, denoting the extensive presence of clay minerals. In addition, quartz, feldspars and amphiboles are present in significant amounts (12-17%) in the coarse clay fraction (2-0.25μm).

Illite is the most abundant clay mineral present in both clay fractions (2-0.25μm and <0.25μm), but with small range of values (44-52%). Smectite is present in both clay fractions, but in the <0.25μm fraction a significant increase in content is observed. Chlorite (+ kaolinite) occurs in both clay fractions with small range of values (16-3%). Ordered illite/smectite (I/S) with 30-35% smectite layers is present in the 2-0.25μm fraction. Randomly interstratified I/S with 50% smectite layers is present in the <0.25μm fraction.

On average, the clay mineral content in the studied outer Gulf seabed sediments is: 48% illite, 23% smectite, 17% chlorite (+ kaolinite) and 12% other minerals in the 2-0.25μm fraction and 50% illite, 30% smectite and 20% chlorite (+ kaolinite) in the <0.25μm fraction.

Chemical analysis

The chemical composition of three of the examined samples is given in Table 4. It is generally in agreement with their mineral composition. The coarse fraction (250-20μm) in comparison to fine fraction (<0.25μm) is richer in SiO_2 and CaO signifying the extensive presence of non-clay minerals. The reverse trend is noticed for Al_2O_3, Fe_2O_3 and H_2O (included in L.O.I.). The weight percentage of TiO_2 and MnO remains constant in both fractions. Finally, the fine fraction (<0.25μm) is richer in the alkalies (Na and K) and Mg signifying the extensive presence of phyllosilicate minerals.

Discussion

The high percentage of C.O.I. indicates an environment of low oxidation potential (Eh) during the weathering processes. All grain size fractions present a wide range of values confirming the extreme grain and particle variations of the discharged load and signifying

Table 3
Mineralogical composition (wt. %) of separated size fractions (μm) of the samples analysed.

Sample	Size	C	D	Q	Pl	Or	Am	Px	T.cl	I	S	Ch
Θ1	250-20		6	36	40	8	tr		10			
	20-2		6	34	17	7	5	6	25			
	2-0.25			3	3	3	4		87	50	19	18
	<0.25								100	52	28	20
Θ2	250-20	5	4	44	16	10	3	4	14			
	20-2		8	27	18	9	6	7	25			
	2-0.25			4	4	4	3		85	49	20	16
	<0.25								100	48	30	22
Θ3	250-20	2	5	37	28	9	4	3	12			
	20-2	4	6	32	17	7	5	6	23			
	2-0.25			3	4	3	4		86	50	19	17
	<0.25								100	47	30	23
Θ4	250-20		6	46	20	7	4	4	13			
	20-2		6	30	15	7	6	7	29			
	2-0.25			4	3	3	4		86	49	21	16
	<0.25								100	48	32	20
Θ5	250-20	6	28	44	14	3	tr		5			
	20-2	5	9	22	12	7	6	8	31			
	2-0.25			6	3	4	4		83	44	23	16
	<0.25								100	52	30	18
Θ6	250-20	tr	6	51	32	4	tr		7			
	20-2		9	30	15	6	5	7	28			
	2-0.25		tr	4	5	4	3		84	44	24	16
	<0.25								100	50	30	20
Θ7	250-20	2	3	33	45	4	3		10			
	20-2		9	28	14	7	5	7	30			
	2-0.25			5	4	3			88	47	25	16
	<0.25								100	52	31	17

C = calcite, D = dolomite, Q = quartz, Pl = plagioclase, Or = orthoclase, Am = amphiboles, Px = pyroxenes, T.cl = total clays, I = illite, S = smectite, Ch = chlorite (+ kaolinite), tr = traces. Other symbols as in Figure 1.

a mild intensity of weathering of parent rocks on land. The coarse grains are subangular and present medium sorting. These characteristics signify their textural immaturity. In addition, the extensive presence of feldspars and ferromagnesian minerals (Table 3) also confirm their mineralogical immaturity.

The extensive presence of medium to fine grain sands at two positions Θ5(core sample) and Θ7(grab sample) are due to relict sands. Such sands in the Thermaikos Gulf have been detected previously by CHRONIS (1986), LYKOUSIS & CHRONIS (1989) and KARAGEORGIS & ANAGNOSTOU (2001). In addition, relict sands exist in the Strymonikos Gulf (PEHLIVANOGLOU & SOURI-KOUROUMBALI, 1987) and the Evoikos Gulf (KARAGEORGIS *et al.*, 2000).

The origin of all silicate minerals is terrigenous. They are the weathering products of parent rocks from the drainage basins of the rivers, as well as of the surrounding coasts. Micas as primary minerals and chlorites, amphiboles and pyroxenes as accessory minerals exist in these rocks. The abundance of clay minerals in the Gulf sediments is due to the presence of the above minerals, as well as to the feldspars from the alteration of which they are formed. The origin of both carbonate minerals (dolomite and calcite) is mostly

Table 4
Chemical composition (wt. %) of some sample fractions (μm) analysed.

Sample →	**Θ1**		**Θ5**		**Θ6**	
Size →	**250-20**	**<0.25**	**250-20**	**<0.25**	**250-20**	**<0.25**
SiO_2	72.87	48.41	68.43	45.30	69.56	46.37
TiO_2	0.42	0.34	0.22	0.30	0.32	0.34
Al_2O_3	10.64	18.53	8.56	16.49	10.06	17.90
Fe_2O_3	2.83	9.48	2.74	8.86	2.91	9.40
MnO	0.05	0.05	0.06	0.05	0.05	0.06
MgO	2.51	4.12	4.06	4.23	3.20	4.33
CaO	3.22	0.49	6.22	1.19	4.30	0.66
Na_2O	3.06	4.81	2.23	6.00	2.90	4.43
K_2O	1.60	2.18	1.54	2.40	1.74	2.39
P_2O_5	0.10	0.37	0.08	0.26	0.67	0.65
L.O.I.	2.41	11.11	5.79	14.44	4.00	13.12
Total	99.71	99.89	99.93	99.52	99.71	99.65

L.O.I. = Loss on ignition. Other symbols as in Figure 1.

biogenic. Recent bibliography confirms the presence of tiny dolomite crystals in some shells (TUCKER, 2001).

Illite, smectite and chlorite (+ kaolinite) are the minerals, which predominate in the clay fractions. In addition, interstratified illite/smectite occurs in significant amounts in the same fractions. The illite, smectite and chlorite (+ kaolinite) contents of the Gulf sediments are due to the very large suspended load of the rivers derived from the weathering of parent rocks in the drainage basins. In addition, some of the clay minerals are derived from the weathering of unconsolidated Neogene and Quaternary coastal sediments. The weathering of all these rocks supplies at least $57X10^6$ tons/yr of suspended material into the Thermaikos Gulf (Table 1). The Evros River is the largest supplier of continental detritus ($8.5X10^6$ tons/yr) to the offshore area (NE Aegean Sea), which is then dispersed westward along the coast by local currents (PERISSORATIS *et al.*, 1987; PEHLIVANOGLOU, 1995; POULOS & CHRONIS, 1997).

Chlorite (+ kaolinite) content expresses the strong climatic dependence controlled by the intensity of hydrolysis of parent rocks, which occur in the drainage basins. The low content of kaolinite, however, may be due to unfavourable climatic and physicochemical conditions, as well as to the detrital origin, rapid transport and deposition of the weathered material in the Gulf. Furthermore, the presence of amphiboles observed even in the coarse clay fractions confirms the limited reworking and weathering of the primary ferromagnesian minerals because of the high river discharge over short time periods and rapid deposition in the Gulf. Finally, the significant presence of the interstratified illite/smectite confirms the limited reworking and weathering of the primary minerals during their transport and deposition from the drainage basins to the Gulf.

LYKOUSIS *et al.* (1981) studying bottom sediments of the inner Thermaikos Gulf found that their average clay mineral composition is: 50% illite, 34% smectite and 16% kaolinite (+ chlorite).

In addition, CONISPOLIATIS (1983) studying bottom sediments from the inner Thermaikos Gulf found that illite is the most abundant (40-65%) clay mineral and smectite follows with 10 to 40%. The presence of kaolinite and chlorite is limited. According to the same authors the same trend is noticed for all bottom sediments of the North Aegean Sea.

CHRONIS (1986) estimated that smectite predominates over the rest of the clay minerals in front of the pro-delta platform and close to the coast at depths not exceeding 30m in the Thermaikos Gulf. The abundance of smectite may be enhanced by the high Fe and organic content of the terrigenous input, as well as by the physicochemical conditions of the seawater (i.e. salinity, temperature, pH and Eh), which result in rapid flocculation and settling of smectite flocks.

KARAGEORGIS & ANAGNOSTOU (2003) studying the seasonal variation of the suspended particulate matter in the northwest Aegean Sea suggest that the total particulate standing crop is (484-830)X10^3 tons.

According to CONISPOLIATIS & PERISSORATIS (1987) the clay mineral distribution in the Ierissos Bay is mainly related to the rock composition of the drained land and to the dispersion by currents. The average clay mineral content of this Bay is: 63% illite, 20% smectite, 9% kaolinite and 8% chlorite. Also, a low content of mixed-layer illite/smectite is detected in some samples.

In the Strymonikos Gulf the illite content in the clay fraction varies between 45% and 73%, with higher values close to the Strymon delta, while smectite varies between 11% and 38% and kaolinite between 6% and 15% (CONISPOLIATIS, 1984).

The average clay mineral composition of Neogene sediments from drilling cores (depths 1,780 to 3,550m) in the Nestos delta is: 51% mixed-layer illite/smectite, 28% discrete illite and 21% kaolinite (+ chlorite) (TSIRAMBIDES, 1983).

The average clay mineral composition of the bottom sediments from the Alexandroupolis Gulf is: 52% illite, 33% smectite and 15% chlorite (+ kaolinite). Mixed-layer illite/smectite was also detected in traces in some samples (PEHLIVANOGLOU, 1995; PEHLIVANOGLOU *et al.*, 2000).

The recent sediments of the Thermaikos Gulf have adopted their characteristic zone distribution in response to the coastal topography, the water circulation, and the prevailing climate in the region (POULOS *et al.,* 2000). To a lesser extent the quality of the discharged material and the differential settling of grains, are additional factors controlling the clay and non-clay minerals' distribution in the Gulf. Finally, the composition and dispersal of the suspended load of the rivers into the Thermaikos Gulf is controlled by the prevailing seasonal meteorological conditions at their catchment areas and the coastal area.

The aggregation and distribution of clay particles in the Thermaikos Gulf is least controlled by the organic content of the terrigenous input because its presence is limited (Table 2). TRONTSIOS (1991) and PEHLIVANOGLOU (1995) studying respectively Paleogene and Modern river sediments discharged into the Alexandroupolis Gulf, estimated their organic content as very low (2%) .

The chemical composition of the examined samples is generally in agreement with their mineral composition. The coarse fraction (250-20μm) in comparison to fine fraction (<0.25μm) is richer in SiO_2 and CaO signifying the extensive presence of non-clay minerals. The fine fraction (<0.25μm) is richer in the alkalies (Na and K) and Mg signifying the extensive presence of phyllosilicate minerals. The chemical composition of both fractions of the examined outer Gulf seabed samples signifies their terrigenous origin presenting discretely clastic character.

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