BULLETIN OF THE
MINERAL RESEARCH AND EXPLORATION

Foreign Edition **1999** **Number : 121**

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Mineral Res. Expl. Bul., 121, 1-18, 1999

MORPHOLOGY AND SEDIMENTARY FACIES OF ACTUAL KOCASU AND GÖNEN RİVER DELTAS, MARMARA SEA, NORTHWESTERN ANATOLIA

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ABSTRACT.- In the southern coastal zone of the Sea of Marmara (northwestern Turkey), two important rivers. Kocasu and Gönen, debouch into the sea, with a distance of less than 80 km from each other. The discharge and transport of appreciable amounts of sediment load are due to the prevailing semi-arid climate with wet-winter seasons. The sedimentary input of Kocasu and Gönen rivers have produced two quite morphologically different delta systems. The Gönen river delta is lobate and fluvial-dominated with sediment accumulation having a progradation of 5.5 km and subaerial plain of 28 km^2 totally. The meandering distributary channels and a number of small lagoonal lakes are the main elements of the delta plain. The input of sediment is abundantly bedload and has resulted in the development of a triangular delta plain, with a slight shifting towards the east. A step-like scarp at 6 m altitude divides the plain into two parts. Two drillings of DSI at apex of the delta show that overall deltaic sequence is 65 m thick, however delta plain sediments are generally 6 m thick. The Kocasu delta is characterized as a highly mud-dominated delta, a specimen of a destructive, curvi-linear delta type. It is a wave-dominated river delta with a 3.5 km of progradation and a subaerial plain of 48 km^2. The present Kocasu delta has only one straight, major channel. The extensive lateral growth of the delta is provided by wave actions, mostly created by northeasterly winter winds. Fluvial sediments on the delta plain are limited extent. Consequently, actual fluvial sedimentation on the delta plain is low and, two lagoonal lakes, swamps, cheniers, dunes and a long sandy beach are the basic morphological elements of delta plain. A step-like morphology at 4 m altitude, similar to that of Gönen river delta, separates the delta plain to a relatively older and a younger formations. Total thickness of the deltaic sediment body is estimated to be 55-60 m by graphic correlations. Both deltas abound in active right lateral strike-slip faults and their depositional areas were limited by bedrocks on the seashore. Limitation is very typical and sharp in the Kocasu delta due to the presence of fault scarps on the Palaeozoic metamorphics. Geomorphology of drainage areas shows that the modern Kocasu and Gönen river deltas are synchronique deposits and they must have began to develop in early Holocene. The step-like morphology on delta plains may indicate a global sea-level fall to the present level, most probably since the last climatic optimum. Later, local sea-level changes in Kocasu area took place, creating long cheniers in swamp sediments by the activity of the faults on the sea shore. The present-day sea-level has been seen at still-stand period for the last millenia.

INTRODUCTION

Deltas are depositional systems where balance of erosion and transportation between coast and hinterland were established and big amount of sediments were deposited resulting from this balance. Various kinds of deltas are formed by wide range of factors such as climate of drainage area morphology and tectonism, inclination of shoreface and effective energy (Coleman and Roberts, 1988; Orton and Reading, 1993). So, both old and recent deltas give information about the conditions affecting on the coast and hinterland. As the information of recent deltas can be easily observed, they represent geology of actual situation and help the interpretation of old delta facies (Whateley and Pickering, 1989; Oti and Postma, 1995). Kocasu and Gönen river deltas are good examples of this kind of things. Because these deltas have recently developed at the southern coast of Marmara sea representing at least late Quaternary evolution. In this study actual morphology and sedimentary facies and the process of these deltas will be given.

Physiography of the sea of Marmara that is the depositional area of the Kocasu and Gönen river deltas are almost well-known (Özsoy et al., 1986; Beşiktepe, 1991; Ergin et al. 1991, 1994, 1996), There are many discussion on the opening, formation and Quaternary evolution of the sea of Marmara and they are still disputed (Ardel, 1957; Stanley and Blanpied, 1980; Barka and Kadinsky-

Cade, 1988; Şengör et al., 1985; Emre et al., 1997a. Görür et al., 1997a, *b)* However there are different opinions on the Neogene and Quaternary evolution of the southern Marmara region (Emre et al., 1997 a. *b,* 1998). Aspects of this study are deltas with records of at least Quaternary evolution and their three-dimensional interpretation may explain the development of the sea of Marmara.

Kocasu delta (Figs. 1 and 2) is a mud-dominated, lobate type, wave-dominated delta and is approximately 80 km far from Gönen delta, in the E. Latter is also lobate type and fluvial dominated delta (Figs. 1 and 3). Sedimentary facies of both deltas are partly similar to each other. The aim of this study is to discriminate facies distribution in terms of their geometry and to explain their similarity and differences with the processes. In fact, available data about these deltas cover some description of coastal morphology of the sea of Marmara (Ardel, 1957, 1968; Erinç, 1957; Erol, 1969, 1991). However, systematic information has been collected after the studies of National Marine Research Programme (Kazancı et al., 1997 a, b).

Although the drainage areas of the Kocasu and Gönen river deltas are under the effect of tectonism (Şaroğlu et al., 1987; Emre et al., 1997a) the deltas have developed at the margin of active fault scarps (Figs. 2 and 4). By these features Kocasu and Gönen deltas are good examples reflecting direct results of sea-level changes, not only showing sediment supply by tectonic effects. This situation which is frequently seen on fan deltas but not on fluvial deltas, is an important feature discriminating Kocasu and Gönen deltas from others. For this reason, effects of tectonism on the delta plain facies will be explained

INVESTIGATION METHOD

Field studies in the Kocasu and Gönen deltas were carried out in 1996. Firstly, boundaries of facies have mapped by using aerial photographs and samples of each facies have been collected for routine sedimentological analysis. Unexposed areas have been mapped as recent or old swamps based on vegetation. On the other hand, changes in facies were tried to consider using the correlation of old topographic maps, landsat images and aerial photographs. Interpretati6n on the delta front and offshore of the delta has been gained from previous studies. Information about bed load transportation onto the delta and annual discharge of rivers has been taken from EİE sources for years of 1993 and 1996. After this, authors have calculated rainy and dry periods, maximum and minimum suspended load, denudation and total load by the comparison available meteorological data (Tables 1 and 2). During the calculations, ElE stations of 210, 317 and 321 have been used (Fig. 1). These stations are 10-25 km back of deltas. As there is not any important tributary, the data collected from these stations have been accepted as real discharge. However the real discharge and suspended load can also be much more than available data (Table 2).

BACKSHORE FEATURES AFFECTING DELTA FORMATION

Southern Marmara region of which is the drainage area of the Kocasu and Gönen deltas is more rainy than the average of Turkey although it has semi-arid climatic conditions (Table 1). Rainy periods extend from December to April, approximately 450 mm/yr., and it is also considerably windy (average 8 m/hr). Average rain in dry period (May to November) is 236 mm/year and it is not windy (average velocity 2-4 m/s). Although the rainy period tends to be summertime in the last decade, it does not affect average value. According to Bandırma and Çanakkale stations it has been understood that intermediate and strong winds trough the year come from 25° NE in 60 percent (Meteorological Bulletin, 1974, 1984). It is thought that wind directions are mostly controlled by regional morphology and particularly Dardanelles and Bosphorus (Özsoy et al., 1986; Beşiktepe, 1991). It can also be assumed that delta progradation is limited in the same period of the winds which they distribute sediments, although the rains supplying sediments into the deltas increase in wintertime.

The Kocasu and Gönen river gain the water of

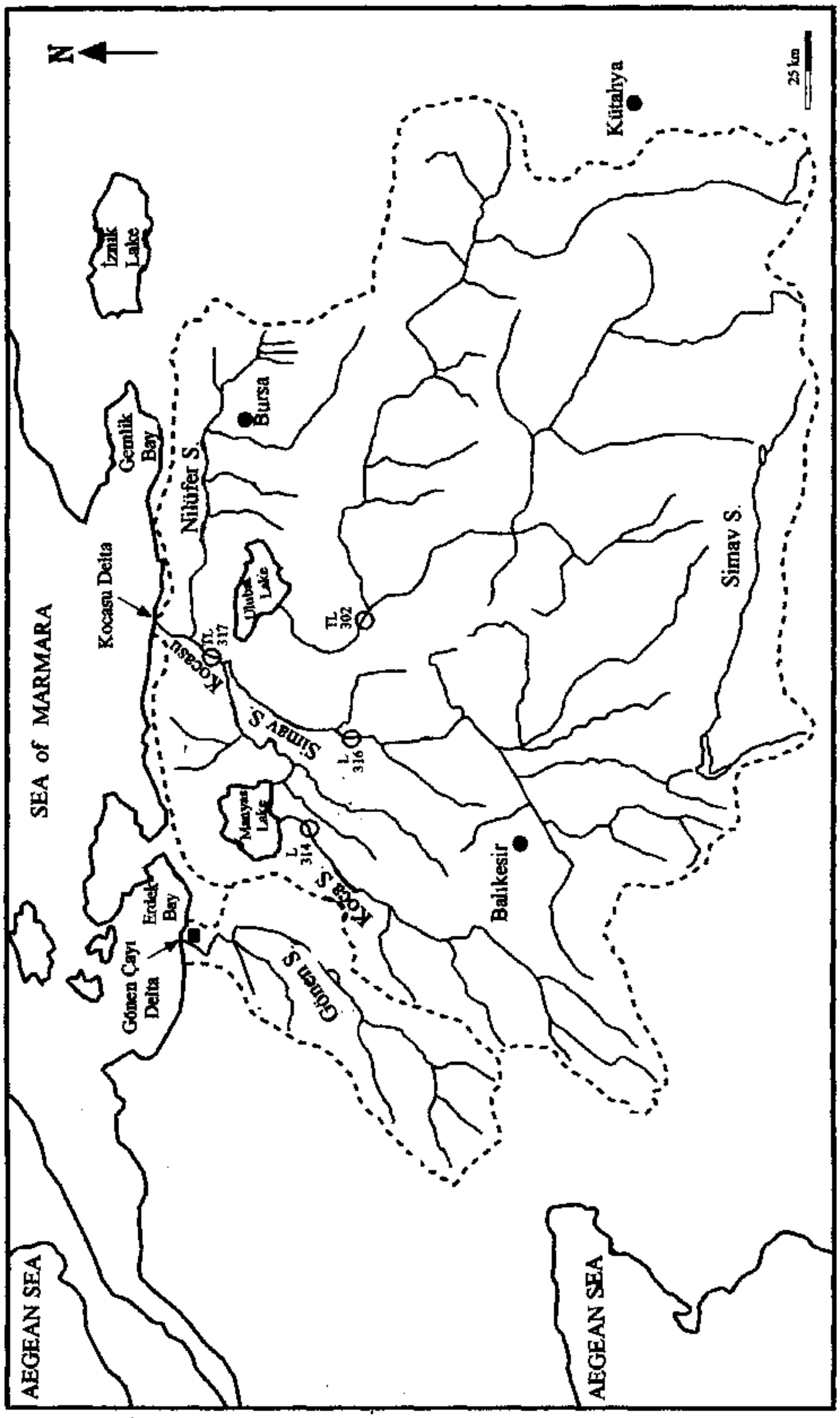

Fig.1- Drainage networks of the southern Marmara deltas. 317 EIE observation station, DSI drilling site.

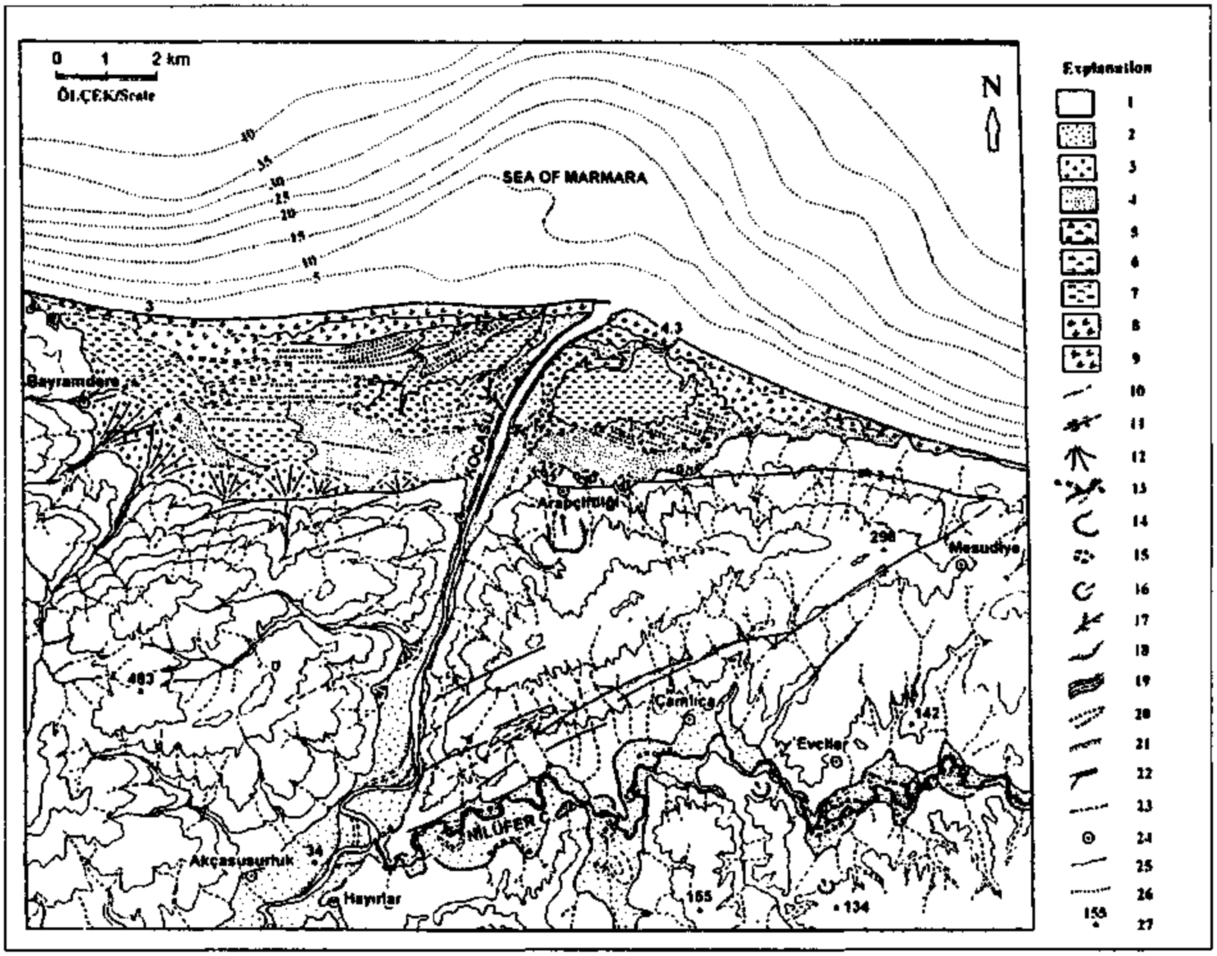

Fig. 2- Quaternary geology and geomorphology map of the Kocasu delta. 1, Denudation area surrounding the delta, 2, Flood plain sediments, 3, Alluvial fan sediments, 4, Sandy delta sediments, 5, New marsh sediments, 6, Old marsh, 7, Lagoon, 8, Actual coastal dune, 9, Old coastal dune, 10, Contact, 11, fault (arrows show the direction of movement, - and + point out downthrown and upthrown sides respectively), 12, Alluvial fan, 13, a) abandoned channel, b) present channel, 14, Old meander scar, 15, cut-off meander, 16, Landslide, 17, crevasse, 18, point-bar deposit, 19, river and its levee, 20, Beach ridges, 21, Beach, 22, Spit, 23, boundary of old and new delta, 24, settlement, 25, isohips (with 100 m interval), 26, isobath, 27, spot height.

2/3 of whole southern Marmara region and some part of northern Aegean region (Fig. 1). Drainage network is mainly rectangular in the E, reflecting tectonic control, and is linear in the W (Fig. 1).

Kocasu

The length of main course of this river is 321 km and its drainage area covers 27600 km^2. Simav, Orhaneli, Mustafakemalpasa and Nilüfer creeks and Kocaçay are main tributaries of Kocasu. Ulubat and Manyas lakes are depositional areas on these courses. Beside, there are two water irrigation ponds on the Simav river which are a kind of sedimentary site.

Mainly Neogene aged sedimentary and volcano-sedimentary units are exposed in the Kocasu drainage basin and soil formation is quite well developed. Drainage network is respectively dense, topography is mature and morphological incision is much. The river follows some fault-lines on pre-Neogene rocks, which are less exposed and topography is quite wild. Valley slopes have high angles except plains.

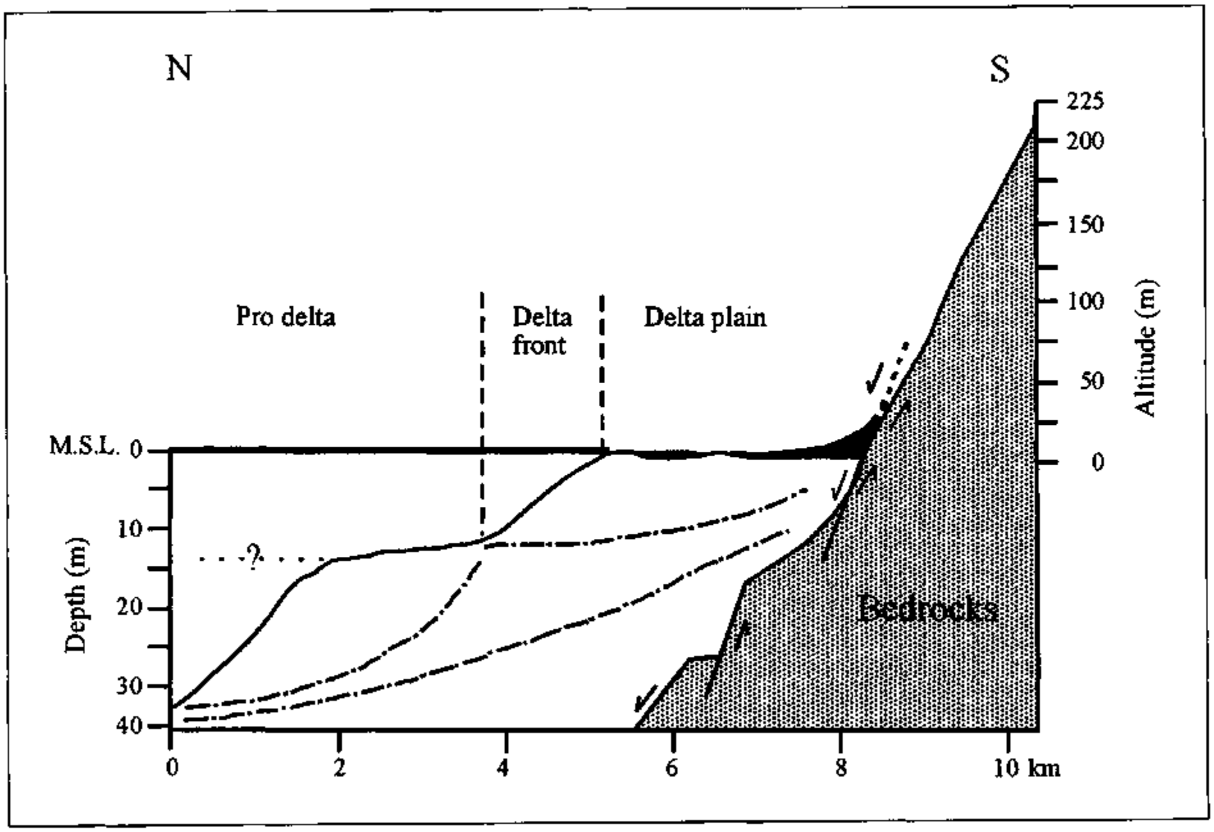

Fig. 3- Subaquaeous and aeral part of the Kocasu delta. Notice the platform at the 10-15m deep. ? and dotted truncated line shows probable and deltaic occurrence related to sea level.

Based on long term observation, discharge of Kocasu is 158 m^3/sec. During the last 28 years, maximum discharge is 1322 m^3/sec while the minimum is 7.07m^3/sec (EIE, 1996). This difference reflects semi-arid climate and floody discharge. In the proximal section of the delta, at the EİE station No.317, Kocasu river carries much suspended load, not bed load (Table 2). The main reason of this case is that bed load is hold in meanders and the lakes of Manyas and Ulubat. Very large alluvial fillings in the lower parts of the rivers and the existence of deltas in these lakes give an idea that this situation has started since the late Pleistocene (Emre et al., 1997b).

Kocasu river parses away 8 km length Karacabey gorge before it reaches the sea of Marmara. This gorge has been dissected in mefa morphic rocks in E-W direction. In fact this gorge is unique passage of southern Marmara region's drainage due to steep coast between Gemlik and Bandırma and it has very important role on local morphology (Erinç, 1957; Emre et al., 1997 *a, b).* The gorge is 150-1500 m wide and its floor was flattened by alluvium of Kocasu. The course of the river has cut the infillings 1.5-4.5 m depth in a narrow meander. However, to the S., Kocasu river runs at 2 m, near the EiE station 317, some 16 km far from the sea of Marmara. In this distance it runs very quietly. Nilüfer creek, joins the Kocasu river at the entrance of the gorge, has a drainage network reflecting neotectonic effects (Erkal and Emre, 1997). This river carries bed load in rainy period while it is a relict channel of Bursa area in arid time.

Gönen river

This river, forming Gönen delta and reached to Erdek gulf, has a main course and three tributaries

Table 1- Climatological features of the southern Marmara region (Meteoroloji Bülteni, 1984) BUR=Bursa, BAN= Bandırma, ÇAN= Çanakkale Meteorology stations, TEK= Tekirdağ, F= Florya, ORT= Average, F=Florya, Figures in paranteses indicate observation periods for rain and temperature.

Stations and Measurments		M o n t h s J	F	M	A	M	J	J	A	S	O	N	D	Annual
BUR	Precipitation (50 years)	92.0	77.6	74.2	61.4	51.8	30.3	24.6	19.9	41.0	58.9	81.0	107.5	720 mm total
BUR	Temperature (52 years)	5.1	6.1	8.1	12.6	17.3	21.6	24.1	23.8	19.7	15.4	11.2	7.3	14.4 (°C) av.
BAN	Precipitation (31 years)	98.3	84.3	70.6	51.3	33.7	25.0	13.7	15.3	34.2	66.1	91.7	121.3	705.7 mm total
BAN	Temperature (31 years)	5.2	6.2	7.5	11.9	16.6	21.0	23.4	23.5	20.1	15.6	11.4	7.6	14.2 (°C) av.
ÇAN	Precipitation (50 years)	97.6	71.5	66.5	39.6	28.9	23.3	11.2	8.4	23.7	45.6	85.6	105.0	606.9 mm total
ÇAN	Temperature (50 years)	5.9	6.5	8.0	12.3	17.2	21.8	24.6	23.9	19.7	15.6	11.8	81.0	14.6 (°C) av.
ORT	Precipitation (mm)	96.0	77.8	70.4	50.8	38.1	26.2	16.5	14.5	33.0	56.9	86.1	111.3	677.6 mm total
ORT	Temperature (°C)	5.4	6.3	7.8	12.3	17.0	21.9	24.0	23.7	21.2	14.8	11.4	77.0	14.4 (°C) av.
Wind		Humid period (N+D+J+F+M), total = 441.6 mm/year												
		Dry period (A+M+J+A+S+O), total = 236 mm												
TEK	Wind	Annual average wind speed 4 m/s												
F	Wind	Strong wind speed 8-25 m/s												
In Bandırma and Çanakkale 25° NE wind form the 60 % of annual blowns of the region														

(Fig. 1). Its drainage basin covers 2174 km^2 with main course in 134 km length and the elevation is 850 m at the source. The main channel has been cut into valleys in accordance with the Yenice-Gönen fault while tributaries follow the Sarıköy and Pazarköy faults (Şaroğlu et al., 1992). Gönen river has much step-like profile longitudinally. Its average discharge at the EİE station 210, is 14.2 m^3/sec (Table 2). Maximum and minimum water flows are 911 m^3/sec and 0.024 m^3/sec respectively. Lithological features of its drainage basin are similar to that of Kocasu river with the difference of more widely Neogene volcanics exposure.

Gönen river passes a wide flood plain around Gönen and Sarıköy and reaches to the sea of Marmara via a gorge forming entrenched meanders (Fig. 4). The thickness of alluvium is about 50 m in this flood plain which is bordered by active faults (Şaroğlu et al., 1992). This thickness is similar to that of the Karacabey plain.

Sediment supply of the Kocasu and Gönen

Table 2- Data for the drainage basin, hydrological regime and delta averages of the Kocasu and Gönen deltas

Characteristics	Kocasu	Gönen River
DRAINAGE BASIN		
area (km^2) 27600	2174	
main course length (km)	321	134
INCLINATION		
Inc. in channel (%)	0 08	0,11
Inc. in delta (%)	0.00113	0.00166
DISCHARGE		
Measurment site	EİE Station No 317, 321	EİE Station No 210
annual average dis. (m^3/s)	158,5	17
minimum (m^3/sn)	7,07	0,024
maximum (m^3/s)	1322	911,0
SEDIMENT TRANSPORT		
Suspended load (%)	90	92
Bed load (%)	IO	8
Dry season consentration aver. (ppm)	103.6	67.3
Humid season consentration aver. (ppm)	276.7	122.4
Total sediment tsansport (ton/ years)	364-486 million	45-53 million
In humid period	5.468	0.841
In dry period	0.423	0.0172
DELTA DIMENSIONS		
Max. coastal length (km)	21	13
Delta plain (km^2)	48	28
Progradation (km)	3,5	5,5
WIND REGIME		
Character	Normal	Normal
Main Direction in summer	Generally SW	Generally SW
Main Direction in winter	NE	NE
Max.-Min. wave length	2-0.5	2-0.5
CURRENT REGIME		
Tidal	?	?
Longshore	?	?
Other	?	?

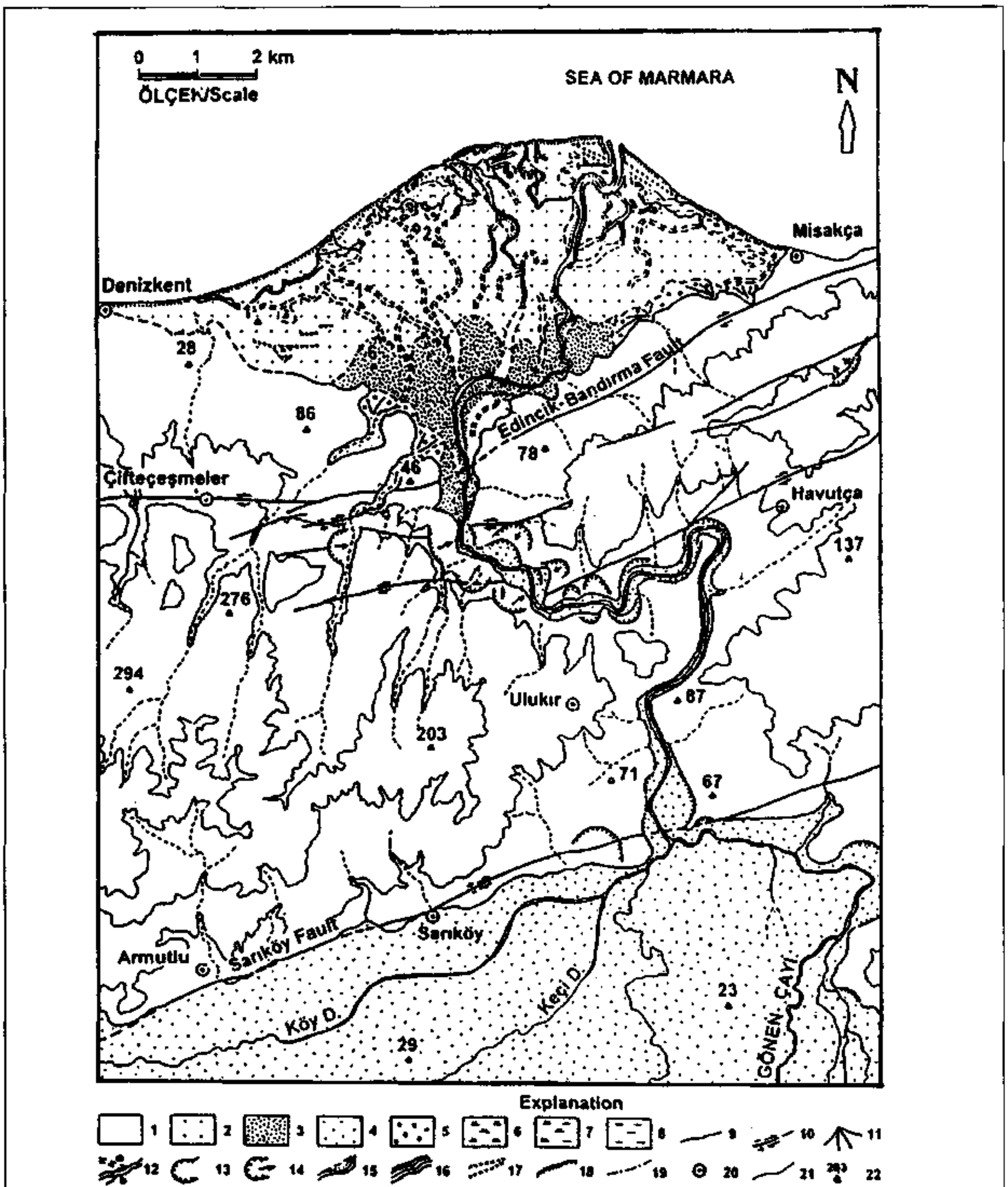

Fig. 4- Quaternary geology and geomorphology map of Gönen delta. 1, Denudation area surrounding the delta, 2, New delta sediments, 3, Old delta sediments, 4, Flood plain sediments, 5, Alluvial fan deposits, 6, New marsh, 7, Old delta, 8, Lagoon, 9, Contact, 10, fault (arrow show the direction of movement, - and + indicate downthrown and upthrown sides respectively), 11, alluvial fan, 12, a) abandoned channel, b) present channel, 13, old meander scar, 14, landslide, 15, point-bar deposit, 16, river and its levee, 17, beach ridge, 18, beach, 19, boundary between old and new delta, 20, settlement, 21, isohips (100 m at interval), 22, spot height.

deltas seem to that it is dependent on rainy/snowy wintertime (Tables 2 and 3). Denudation between rainy and dry seasons in the Kocasu watershed area is 0.072-0.0056 ton/km^2/yr while it is 0.141-0.003 ton/km^2/yr in the Gönen drainage basin. On the other hand sediment load in dry seasons can be neglected (Table 3). Although they are in the same climatic belt, sediment supply from the denudation is twice in comparison to Kocasu. The reason of this difference is due to that drainage basin of the Gönen river is close to technically active belt and the main channel and tributaries of the river are located in the active fault zone. Although its drainage basin is relatively small, high amount sediment supply of the Gönen delta explains that why the Gönen delta has progradated more than Kocasu delta and has formed a distinctive lobate coast along the sea of Marmara. Additionally hold of bed load by the lakes creates sediment supply against the Kocasu delta.

KOCASU DELTA

Physiography

Actual Kocasu delta has been progradating in front of a fault scarp and in an area surrounded by basement rocks (Fig. 2). It is not clear that how the İmralı island some 20 km in the north, gulfs of Gemlik and Bandırma in the E and W respectively, have changed marine dynamic elements and have affected delta evolution. The river forming the Kocasu delta reaches to the sea of Marmara at a single mouth via 8km length Karacabey gorge that is incised into basement rocks. Its areal deltaic plain is about 48 km^2

Coastal length of Kocasu delta is 21 km and its geometry gets closer in E-W direction, which is 3.5 km through the largest axis. Kocasu river flows in a narrow channel turning to the right and divides the delta into two parts (Fig. 2). Except some seasonal cracks/crevasses, it does not have any recent and/or active distributary channel. The length of Kocasu river on the delta is 4.5 km and the western part is bigger than the other. Maximum delta progradation is near the actual mouth (Fig. 2). There are two irregular shaped lagoons at the two sides of the main channel and their geometry can change from time to time. Aerial part of 0.5-1 m in elevation is widely exposed. Maximum height of the delta is 4 m near Bayramdere village in the W while the maximum height in the E is 2 m where it is juxtaposed a fault (Fig. 2).

Except the active part where there is its main channel, other coastal zone is 2-250 m width beach consisted of fine to medium sand. Grain size of beach sand in this part is homogeneous but it gets coarser towards the W (Sayılı et al., 1997). Kocasu delta does not have a subaqueous platform compared to deltaic plain. Unfortunately its submarine topography could not be understood owing to some technical problems. Bathymetric values of Akbulut and Algan (1985) given in fig.2 are based on some limited measurements. However a step-like morphology can be seen in front of the active delta at 14m depth (Fig. 2 and 3).

Boundary of delta front and delta shore is not clear as depth and topography. It is considered that front of active delta is not large because of being more clayey sediment beyond -6 and -8 metres (Akbulut and Algan, 1985).

Table 3- Denudation estimation in the drainage basins of the Kocasu and Gönen river deltas (Data based on EİE sediment observations).

Streams	Drainage Area (km^2)	Denudation rate ton/km^2/year	Total sediment loss ton/year
Kocasu	27600	0.0723-0.0056	1995.4-154.4
Gönen	2174	0.141-0.003	306.9-6.3

Elements and sediments of delta plain

As is the same in many deltas, surface of the Kocasu delta is partly covered by vegetation, of which some of them are cultural and the others are hydrophilic and "all these are obstacles for transportation. However it is interesting that distribution of vegetation is concordant with deltaic elements and sedimentary facies. Based on this feature and areal photographs the delta plain could be mapped in detail (Fig. 2). It should be reminded that although surface elements of whole deltas are generally similar to each other their dimensions and aerial position could be changeable (Wright, 1985; Reading and Collinson, 1996).

Delta plain elements of the Kocasu delta are main course and its barrier, two crevasses, two lagoonal lakes, active and inactive marshes, N-S directed flood plain, beach ridges and beach (Fig. 2). Although alluvial fans are not included into delta elements in their origin nine alluvial fans have also been mapped. Their dimensions get larger from east to right. However beach ridges (Cheniers) among these deltaic elements are distinctive with their position. These beach ridges are 30-100 cm in height, 150-500 m in length broad ridges with clayey fillings and are parallel to the actual shoreline (Fig. 2). They are old coastal bars and/or old beaches in origin and are located in lagoons or marine marshes due to sea level rise (Elliot, 1978; Reineck and Singh, 1980). As they have not sunk into the swamp deposits and their elongations are still being kept, it reflects a limited sea-level rise and/or very new occurrence. Beach ridges, being kept and mapped are eight in number. So it can be suggested that sea level has been changed recently at least eight stages. Other element of the delta plain is ripples that are in different type and dimension. The orientation of these ripples is 20-30° NE-SW that reflects the concordance with the dominant winds of the region (Table 1).

Sediments of the Kocasu deltaic plain can be divided as old and new/recent deltaic sediments. This is morphologically very clear at 2 m height of the old deltaic sediments. At these heights covered by cultural vegetation, soil cover in 0-20 cm thick can be seen and Karacabey-Bayramdere highway follows this boundary. There are recent delta plain sediments at 0-2 m height, in front of the 2-4 m height terrace level formed by old delta plain (Fig.2). Although this boundary is not a stratigraphic contact, it shows a delta progradation stage. The surface of new deltaic sediments is bare, underground water-level is considerably hfgh and mostly covered by hydrophilic plants. Towards the east of delta, nowadays cultivation is a human activitiy.

Most of the sediments subject to this investigation are more or less affected by marine processes. Results of deposition controlled by terrestrial and denudational effects are alluvial fans, river embankments and flood plain sediments and their distribution is relatively limited (Fig. 2), but old marshes; they cover large area, are controlled by marine water inputs. These old marshes have these features especially in rainy stages. Although very large and thick alluvial sediments are characteristics in river dominated deltas (Hoeksta 1989; El-Sohby et al., 1989) alluvial sediments on this delta covering 48 km^2, are limited amount. In fact in big deltas there is a parallelism between delta drainage basin, delta plain-water discharge and delta cover-delta coast. If delta surface gets larger alluvial sediments also get thicker (Coleman and Roberts, 1989) but the reason of this reverse situation in the Kocasu's both in old and new sediments, is not to be developed distributary channels. It is most likely that the river forming the delta cannot be moved laterally due to very narrow Karacabey gorge and also delta plain is surrounded by active faults and basement rocks.

Sediments of the Kocasu delta plain are not very different in view of textural features. They are generally consisted of silts and there is sorting in beach sediments. In other sedimentary area gravels, sands, silts and clays are mixed. Rate of organic material is very low and it gives dark colour. Sedimentary deposits and/or facies that can be differentiated in the delta are given below.

a) Sand fades.- This facies can be seen along the 5-150 m wide coast except the mouth of active delta. Medium-fine sand is dominant and grain size gets coaser from east to west. Some marine shell fragments can also be seen but heavy mineral concentration is distinctive in fine sediments (Sayılı et al., 1997).

Coastal dunes behind the beach, up to 750 m wide locally, have beach sand features but they have been contaminated by recent disposals. Owing to selection by aeolian effects, grain size of coastal dunes is coarser than beach sediments and they are medium size. Original topography has been demolished in some places resulted from sandy material taken for construction.

Another depositional site where the sandy facies can be observed, are sandy, ridges in marshes. In these deposits fine and very fine sands are dominant and also there is abundant shell fragments. In most cases they are mixed with fine (silt-clay) sediments and they are dark coloured.

Sandy old deltaic sediments are oxided in some places. They are already covered by vegetation and have shell fragments. Grain size of these sediments is heterogenous and fine gravels (pebbles) have also been included.

Deltaic elements given in figure 2 are beach, actual and coastal dunes, sandy deltaic sediments and marshy sandy ridges. These sediments are originally bed-load of Kocasu river that they were deposited as mouth bar sediments, and are resulted from the selection of wave and current action and deposition occurred in different places. In fact this is a normal situation in all fluvial dominated deltas and forms architecture of deltaic facies (Scruton 1960; Galloway, 1975; Wright, 1985; Postma, 1990). There is mineralogical similarity in whole facies body having quartz, feldspar, and rock fragments and heavy minerals.

b) Silty clay fades.- This facies is consisted" of fine sediments and silt/clay ratio cannot be discriminated easily. This facies is locally composed of clayey silt, silty clay or clay. The facies has" been mapped as old and actual marshes, lagoonal lakers, flood plain and levee sediments (Fig. 2). These,sediments which are suspended load, can be intruded into lagoons in dry seasons and deposition occurs in rainy seasons. Marsh sediments are blueish-greenish-blackish gray in colour where they are dark gray in flood plain and levee sediments. Unfortunately role of very dense disposals transported by Nilüfer river could not be understood on the effect of facies colour. However it is supposed that blueish colour of the marsh deposits is dependent on this way.

Facies relations and delta progradation

Dominant physiography of the Kocasu delta that waves control deposition is reflected by old and new beach, marsh sand ridges parallel to shoreline. According to classifications (e.g. Galloway, 1975; Elliot, 1978; Orton, 1988) this delta is 'wave dominated river delta'.

Although sand facies covers relatively small area in the delta plain, it seems to be bigger as a volume. Sediment thickness of the actual delta plain is only 4 m above mean sea level and old sandy deltaic sediments are dominant between the heights of 2-4 m (Fig. 2). This position is distinctive in two ways: Deposition is sandy type although actual bedload is not too much and delta progradation is smaller in comparison to having a big watershed area. However in most deltas there is an opposite development (Coleman and Roberts, 1989). Many sea-level changes and wave dominance in the region should cause such a development.

Deltaic section, which was formed by submarine topography and delta plain, depicts that there is 45-55 m thick sequence (Fig. 3). It is supposed that maximum thickness can be observed if it is drilled near the actual active delta. This sequence probably represents delta complex in terms of the data of many sea-level changes. Suddenly happened sea-level rises may cause decrease in sediment thickness resulted from the erosion of some deltaic sediment. For example there are some sea-level rises in the present Caspian Sea since the late Pleistocene, their periods are being getting smaller (e.g. 15 years periods for the last century and they cause some deltaic recedes in the Reşt delta (Zubakov, 1993; Gülbabazade, 1997).

GÖNEN RIVER DELTA

Gönen river delta has been progradating in the Erdek gulf which is surrounded by Kapıdağ peninsula in the E, and Avşa and Paşalimanı islands in the N (Figs. 1 and 4). Being sheltered by the Erdek gulf is not known well but it may cause a barrier against the NNE directed winds (Table 1). Density currents that are characteristic of the sea of Marmara (Beşiktepe, 1991; Ergin et al., 1994) are undoubtedly affected by these natural barriers.

Physiography

Gönen river delta like Kocasu delta, surrounded by basement rocks but these surrounded rocks do not form a wild topography (Fig. 4). There is right-lateral active Edincik-Bandırma fault and Sarıköy fault to the S (Fig. 4). Drainage network of the Gönen river has been affected by these faults that form a 8 km length antecedent valley with incised meanders as a result of uplift between the faults (Şaroğlu et al, 1987; Emre et al., 1997a). The incised meanders are important data indicating neotectonic activity in the back of the delta (Fig. 4).

Length of Gönen delta coast is 13 km and its progradation amount is 5.5 m. The delta covers 28 km^2 in aerial extent (Table 1). Gönen delta has a lobate delta form with a diversion slightly towards NE. Activity of the delta progradation is toward the tilting. Main channel of Gönen river is oriented toward the right after the formation of meander. After this meander it turns to N and right before reaching the sea. There are also three active distirubutary channels. However many abandoned channels form the surface morphology of the delta plain. Lagoons have been formed at the mouths of the old and new distributary channels. The shape of these lakes is changeable and some of these are dry except rainy periods. Hydrophilic plants cover through some lakes.

Gönen delta shows step-like topography with two steps (Fig. 4). Backward part of this delta is 6 m height and covers one fourth of whole delta. But the other part of the delta forming actual delta plain is dissected by distributary channels up to 1,5 m depth (Fig. 4). Maximum height in this part is 2 m and forms the western part of the delta with abandoned channel forms. These abandoned channels have been shifted from W to E (Fig. 4).

Unfortunately the data about the subaqueous part of the delta have not been gained. Boundaries of the delta front and off the delta are not clear. However bathymetric map prepared by SHOD (Turkish Navy Oceanographic Department) shows the 15-30 m depth few km off the delta. In view of this data it is supposed that subaqueous part of the delta is considerable. On the other hand if the submarine topography of the Erdek gulf is interpreted existence of a submarine valley with its gentle topography can be thought. This topography should have been formed in the last sea-level drop in Marmara sea region and it is most likely to be old Gönen valley developed on the present shelf.

Elements and sediments of delta plain

Grassy plants cover aerial part of the Gönen delta and top of the old deltaic sediments has been transferred to cultural area. Surface of new deltaic sediments close to land, is pasture while the closer site to the sea is covered by reed. Many deltaic plain elements are many distributary channels, and lagoons that are terminals for the distributary channels. Between distributary channels there is flood plain. However parts of flood plain are distinctive if they are close to main channel. Actual delta coast is 1-15 m width with coarse sand, but it is 30 m width near Denizkent. The beach has some sandy patches as distributary channels or lagoonal inlets have cut it.

Gönen river delta plain up to 2 m has an alluvial character except the lagoonal and beach sites. Main and distributary channels transport fine gravel-fine sand while silt-clay size material is transported in the flood plain. Sedimentation on the old delta plain is up to 2-6 m height, forming small size alluvial fans. Old delta sediments have medium-fine sediments with many shell fragments. There is occasionally gravely and silty/clayey levels.

During the fieldwork it was not possible to collect samples from the lagoons but it is thought that they are similar to marshy and lagoonal sediments of the Kocasu delta. It is noteworthy that beach sediments are gravel-coarse sand size while old beach sediments at the back of the coast are medium to fine sand. Grain compositon is heterogeneous. Actual coast with coarse grain is gray-dark colour owing to existence of large amount rock fragments. Not only rock fragments and also feldspar and mafic minerals are abundant in sands. Quartz is quite rare as amount as feldspar. This case is a result of having quite close source area sand total load of Gönen river is transported to the sea of Marmara, except in plains. In fact Gönen delta has been developed rather than Kocasu due to its small watershed area and it has formed a lobe.

Delta progradation

Gönen delta is a fluvial dominated classical delta (Galloway, 1975) because of having lobate geometry and alluvial sediments on the actual delta plain. Much of totally calculated 5.5 km progradation (2/3) seems to be formed in accordance with actual sea level (Fig. 4). It is clear that there are many distributary channels with main channel and this case is thought that right lateral Edincik-Bandırma fault has affected it. Tilting of delta plain and shifted delta mouth to the E, support this idea (Fig. 4). Erdek gulf sheltered against the winds and gently inclined topography in this gulf (maximum depth is 46 m) seem to that rapid delta progradation has been supported by these factors.

Sediment thickness of the Gönen delta is considerably less than its progradation. At two drilling sites (DSI A101168 and A101681) it has been reached to 64 and 42 m depth and reddish Neogene rocks were cut under these depths (Fig. 5). Deltaic sediments are composed of washed up sands and silt-clay interbeddings with shell frag"-ments and gravels (Fig. 5). Sands most likely represent old mouth bars while fine sediments reflect bays and lagoons between distributary channels. These sands are not sorted and it should be result of rapid sedimentation.. The step-like morphology, which is distinctive for discrimination of old and new deltaic area, shows that there was a sea-level drop during the delta progradation. The same case for the Kocasu delta, indicate that sea-level drop occurred in whole Marmara sea basin, not happened due to local tectonism.

DISCUSSION AND CONCLUSIONS

Although Kocasu and Gönen deltas are different from each other with their dimensions, geometry, basement topography and development processes (Table 2), their position which are developed in basement rocks bounded area and deposited in front of active fault scarps, is similar (Figs. 2 and 4). Thickness of their sedimentary sequences is same (Figs. 3 and 5). Drainage networks and developments at the back of these deltas are also same.

Kocasu delta is a wave-dominated delta with its triangular in shape, 45-55 m thick sedimentary sequence, and maximum 4m height. Marine processes have controlled its delta plain sediments. Tectonic setting of this delta is being on the downthrown side of an E-W trending right-lateral oblique fault. As the main channel forming this delta is limited with Karacabey gorge, distributary channels on the deltaic plain cannot be developed. However Gönen river delta is a fluvial-dominated, lobate type delta with 55-65 m thick sediments. Fluvial processes control delta plain of this delta and there is many distributary channels on it. This classical fluvial delta is located in an area sheltered by right-lateral fault and close to wave effective zone. Drainage area of the Gönen river delta is small but its progradation is much (Figs. 2 and 4, Table 2). Based on comparison of deltas and their elements some results can be given as follows:

1- Main channels and their tributaries forming these deltas form the whole drainage of the southern Marmara region. Reaching to the sea of the drainage network occur these two main channels via the Karacabey gorge. It is known that actual drainage in the region was mainly established in the late Pliocene and developed with some deformations due to tectonism (Emre et al., 1997a; Erkal

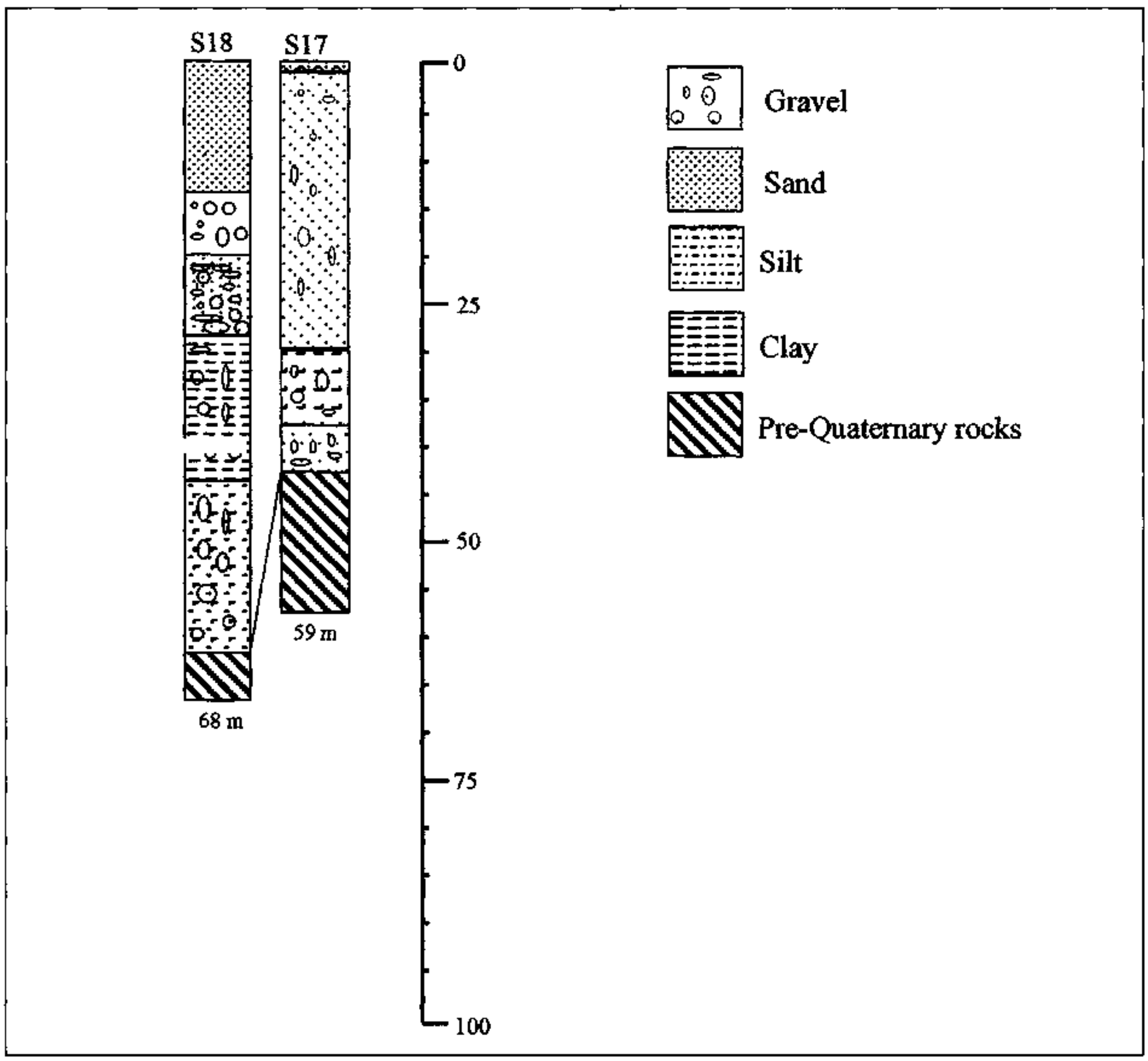

Fig. 5- Sequential features of Gönen river delta (DSİ drilling no. A-10, 11680-11681).

and Emre, 1997; Emre et al., 1998). Available data show that Kocasu was flowing into endoreic basin in Karacabey-Mustafakemalpasa area in early-middle Pleistocene but both Kocasu and Gönen rivers were flowing towards the Sea of Marmara in other times (Emre et al., 1997b). Thickness of this internal basin is less when it is compared to Kocasu drainage basin and sediment influx. It is supposed that there should have been thick sedimentary sequences in these two deltas but thickness of the deltaic sequences are not too much (50-65 m) and delta lobes are smaller or have not been developed. In case of erosion-sedimentation processes it is understood that these deltas are very young. When they are compared to morphostratigraphy of closer plains, aerial parts of the deltas have been deposited in Holocene.

2- It is supposed that there are Pleistocene aged old deltaic sediments deposited below or off the present deltaic sequences when the sea-level was dropped. Besides, it can be observed that remnants of old deltaic deposits which they have been formed during the high sea-level periods are seen as terraces along the coast. Unfortunately data on the second alternative and the sea-level between Karabiga and Gemlik reached up to higher than actual mean sea-level could not be gained. This situation covering the delta evolution, supports that the sea of Marmara settled down in the Erdek gulf and Bandırma-Gemlik corridor in the Holocene (Emre et al., 1997a). Because, Kocasu and Gönen deltas are similar to each other in their present position. However the deltas have different palaeogeographic evolution based on the place of their old deltaic systems. This should be owing to different submarine topography.

3- It is observed that there are some step-like morphology at 2-4 and 0-2 meters and 2-6 and 0-2 meters in Kocasu and Gönen deltas respectively. Based on this step-like morphology it is possible to understand the existence old and new deltaic sedimentation stages. Of course, old deltaic sediments indicate higher sea-levels. Additionally more data can be submitted on this subject. Firstly, Kocasu and Gönen rivers were cut into 4.5 m deep in the old deltaic sediments. Secondly, some notches in the basement rocks in the E of Kocasu delta are in the same level with the old deltaic sediments. So it points out that sea-level rise was in global scale as this features have been observed in two deltas with a distance of 80 km from each other (Figs. 2 and 4). It can be said that the sea of Marmara was 4-6 m higher than present sea-level in the beginning of delta evolution.

4- Quite thin delta plain sediments both in Kocasu and Gönen delta show that delta development is young, particularly new delta evolution means that sedimentation has started probably in late Holocene, but it has also been affected by tectonism. The fault behind the Gönen delta has affected deltaic prism oriented to the E rather than sea-level. However dextral fault controlling Kocasu delta is an oblique fault (Fig. 2), caused marine floods and drownings because of drops in the N. Parallel sandy ridges in marsh sediments are evidence af this event. Reason of dominant marine processes in the delta should be tectonism. This event happening at least eight times formed sand ridges indicating delta progradation, marshes showing marine floodings respectively.

5- Bed load is less but suspended load is much in the Kocasu delta at present. Sandy facies are products of rapid fluvial erosion due to high thalweg following global sea level drop. At present the river transports more suspended load at about the base level along the 30 km from the Ulubat lake. This can be explained that sea-level is increasing.

6- Existence of deltas buttressed by active faults and surrounded by basement rocks are quite rare. Therefore effects of active faults reflect on delta plain elements on the Kocasu and Gönen river deltas. On the other hand strike-slip faults have not affected sea-level. This is quite good example for interpretation of old sequences.

7- Marsh sandy ridges in Kocasu delta plain can be helpful for fault mechanism of oblique faults. They are suitable places for palaeoseismic studies on the North Anatolian fault forming Bandirma-Gemlik corridor where many pull-apart basins have developed. The deltas also have very rare late Holocene deposits for this purpose.

8- It is understood that site for deltaic deposition surrounded by basement rocks has not affected delta progradation too much. Surrounded by basement rocks is clear in the Kocasu delta while it is weak in the Gönen river delta but delta progradation in these two deltas are vice versa. So it can be thought that longshore currents are not important on the bed load transportation of the sea of Marmara.

Kocasu and Gönen river deltas are good examples to understand deltaic sedimentation as much as geological evolution of the sea of Marmara. In point of denudation-transportation-deposition processes view there are many discordance in the drainage evolution of the river, which have formed the deltas. In this study state-of-arts of the deltas has been evaluated in particular attention of regional geology and geomorphology. The interpretation can be made clear if they are correlated with the drillings and submarine geophysical studies and it may help to understand Quatermary palaegeographic evolution of the southern Marmara region.

ACKNOWLEDGEMENTS

This study is part of project numbered YDABÇAG 426/G and 598/G, titled "National Marine Geology and Geophysics Programme" carried out by TÜBİTAK, MTA and universities. The editor and referees of this journal kindly improved this paper.

Manuscript received April 20, 1998

REFERENCES

Akbulut, A.O. and Algan. I.M., 1985, Kocasu Çayı ağız kesiminde denizalti depolarmin bazı sedimantolojik özellikleri. İst. Üniv. Deniz Bil. ve Cogr. Enst. Bült., 2, 145-154.

Ardel, A., 1957, Marmara Denizi'nin tesekkülü ve tekamülü. Türk Cografya Dergisi, 17, 1-14

———, 1968, Turkiye Kıyılarının teşekkül ve tekamülüne toplu bir bakış, Türk Cografya Dergisi, 24/25, 1-6

Barka, A.A. and Kadinsky-Cade, K., 1988, Strike-slip fault geometry in Turkey and its influence on earthquake activity. Tectonics, 7, 663-684.

Beşiktepe, T.T., 1991, Some aspects of the circulation and dynamics of the Sea of Marmara, Ph.D. Thesis, Inst. Marine Sciences. METU, 195 pp., İçel.

Coleman, J.M. and Roberts, H.H., 1988, Deltaic coastal wetlands. In: Coastal Lowlands Geology and Geotechnology (ed. by W.J.M. Van der Linden, S.A.P.L. Cloeting, J.P.K. Kaasschieter, J. Vanderberghe, W.J.E. Van der Graaf and J.A.M Van der Gun) Kluwer Acad. Pub., 1-24, Dordrecht.

El Sohby, M.A., Mazen, S.O., Abou-Shook, M. and Bahr, M.A., 1989, Coastal development of Nile Delta. In: Coastal Lowlands Geology and Geotechnology (ed. by W.J.M. Van der Linden, S.A.P.L. Cloeting, J.P.K, Kaasschieter, J.P.K, J. Vanderberghe, W.J.E. Van der Graaf and J.A.M. Van der Gun). Kluwer Acad. Pub., 175-180, Dordrecht

Elektrik İşleri Etüd İdaresi (EİE), 1993 Türkiye akarsularında sediment gözlemleri ve Sediment taşınım miktarları. EİE Genel Müdürlüğü, Yayl. no. 93-59. Ankara

———,1996, 1992 Su Yılı Akım Değerleri, EİE Genel MüdürlüğüYayl No: 95-25, Ankara

Elliot, T., 1978, Deltas. In: Sedimentary Environments and Facies (ed. by H.G. Reading) Elsevier, 97-142, New york

Emre, 6., Kazancı, N., Erkal, T., Karabıyıkoğlu M. and Kuşçu, L, 1997a, Ulubat ve Manyas Gollerinin Oluşumu ve Yerleşim Tarihçesi. TÜBİTAK YDABÇAG 426/G Raporu (Koord: N. Kazancı ve N. Görür) Ankara, 116-134

———,———,———, Görmüş, S., Görür, N., Kuşçu, L, Karabıyıkoğlu, M. and Keçer, M., 1997b, Ulubat ve Manyas göllerinin oluşumu ve Güney Marmara'nın Kuvaterner evrimi. Marmara Deniz Araştırmaları Workshop-III (2-3 Haz. 1997). TÜBİTAK-MTA-ÜNİVERSİTE Ulusal Deniz Araştırmaları Programı (Koor. N. Görür), Genişletilmiş Bildiri Özetleri, 23-27, Ankara.

———, Erkal, T., Tchepalyga, A., Kazancı, N., Keçer. M. and Ünay, E., 1998, Doğu Marmara'nın Neojen-Kuvaterner'deki Evrimi. MTA Bull., 120, 233-258.

Ergin, M., Saydam, C., Baştürk, S., Erdem, E. and Yörük. R., 1991, Heavy metal concentration in surface sediments from the two coastal inlets (Golden Horn Estuary and İzmit Bay) of the northeastern Sea of Marmara. Chem. Geology, 91, 269-285.

———, Bodur, M.N., Yıldız M., Ediger, D., Ediger, V., Yemencioğlu, S. and Eryılmaz-Yücesoy, F., 1994, Sedimantation rates in the Sea of Marmara; a comparison of results based on organic carbon-primary productivity and 210 Pb dating. Continental Shelf Research, 14, 1371-1387.

———, Kazancı N., Varol B., İleri Ö. and Karadenizli L.. 1996, Late Quaternary depositional enviroments on the southern Marmara shelf. Turkish Journal of Marine Sciences, 2, 83-92.

Erinç, S., 1957, Karacabey Boğazı, İst. Üniv. Coğr. Enst. Derg., 8, 95-99.

Erkal, T. and Emre, Ö., 1997, Nilüfer Çayı (Bursa) Drenajının Kuruluşu ve Evrimi: Tektonizma-Drenaj İlişkileri Marmara Denizi'nin oluşumu ve Neojen-

Kuvaterner'deki evrimi. Güney marmara bölgesinin Neojen ve Kuvaterner evrimi. TÜBİTAK YDABÇAG 426/G Raporu (Koord: N. Kazancı ve N. Görür) Ankara 1-22.

Erol, O., 1969, Çanakkale Boğazı çevresinin jeomorfolojisi hakkında on not. Coğr. Araşt. Derg., 2, 53-71.

————, 1991, Türkiye kıyılarında terkedilmiş tarihi limanlar ve bir gevre sorunu olarak kıyı çizgisi değişimlerinin önemi. İ.Ü. Deniz Bil. ve Coğr. Enst. Bült., 8, 1-44.

Galloway, W.E., 1975, Process framework for describing the morphologic and stratigraphic evaluation of deltaic depositional systems, In: Deltas, Model for Exploration (ed. by M.L. Broussard). Houston Geol. Soc., 87-98, Houston, Texas, USA

Görür, N., Çağatay, M.N., Sakınç, M., Sümengen, M., Şentürk, K., Yaltırak, C. and Tchepalyga, A., 1997a, Origin of the Sea of Marmara as deduced from the Neogene to Quaternery paleogeographic evolution of its frame. Intern. Geology Review, 39, 342-352.

———and—————; 1997b, Marmara Denizi'nin oluşumu ve Neojen-Kuvaterner'deki evrimi. Güney Marmara bölgesinin Neojen ve Kuvaterner evrimi. TÜBİTAK YDABÇAG 426/G Raporu (Koord: N. Kazancı ve N. Görür) Ankara 1-22.

Gülbabazade, T., 1997, Anzeli Gölü (KD İran) civarındaki Kuvaterner istifinin incelenmesi (Doktora Tezi), A.l). Fen bilimleri Enst., Ankara 121 pp. (Unpubl).

Hoekstra, P., 1989, The development of two major Indonesian river deltas: morphology and sedimentary aspects of the Solo and Porong deltas, East Java. In: Coastal Lowlands:" Geology and Geotechnology (ed. by W.J.M. Van der Linden, S.A.P.L. Cloeting, , J.P.K. Kaasschieter, J. Vanderberghe, W.J.E. Van der Graaf and J.A.M. Van der Gun). Kluwer Acad. Pub., 143-160, Dordrecht.

Kazancı, N., Bayhan, E., Süleyman, N. Şahbaz, A., İleri, Ö., Özdoğan, M., Temel, A. and Ekmekçi, E., 1997a, Manyas Gölü ve güncel tortulları: TÜBİTAK YDABÇAG-426/G no.lu proje raporu (Koord. N. Kazancı ve N. Görür) Ankara, 192-243.

————, N., Emre, 6., Erkal, T., Görür, N., Ergin, M. and ileri, Ö., 1997b. Kocasu ve Gönen deltalarının* Morfolojisi ve Tortul yapısı: TÜBİTAK YDABÇAG-' 426/G no.lu proje raporu (Koord. N. Kazancı ve N. Görür) Ankara, 140-169.

Meteoroloji Bülteni, 1974, Ortalama, Ekstrem Sıcaklık ve Yağıs Değerleri Bülteni. Devlet Meteoroloji İşleri Genel Müdüğrlüğü, Başbakanlık Basimevi, Ankara.

————, 1984, Ortalama, Ekstrem Sıcaklık ve Yağış Değerleri Bülteni Devlet Meteoroloji İşleri Genel Müdürlüğü, Başbakanlık Basimevi, Ankara

Orton, G.J., 1988, A spectrum of Middle Ordovician fan deltas and braid plain delta, North Wales: a consequence of varying flourise clastic input, In: Fan Deltas; Sedimentology and Tectonic Settings (ed. by W. Nemec and R.J. Stell). Blackie Pub., Glasgow 23-49.

————, and Reading, H.G., 1993, Variability of deltaic processes in terms of sediment supply with particular emphasis on grain size. Sedimentology. 40. 475-512.

Oti, M.N. and Postma, G. (Eds.), 1995, Geology of Deltas. Balkema Pub. Comp., Rotterdam 480.

Özsoy, E., Oguz T., Latif, M.A. and Ünlüata, Ü.. 1986. Oceanography of the Turkish Straits. First Annual Report, Inst. Marine Sciences, METU, 1, İçel 269.

Postma, G., 1990, Depositional architecture and facies of river and fan deltas: a synthesis. In:Coarse-Grained Deltas (ed. by A. Colella and D.B.Prior). IAS. spec. Pub. 10; 13-28.

Reading, H.G. and Collinson, J.D., 1996, Clastic Coast. (Ed. H.G. Reading), Sedimentary Environments: Processes, Facies and Stratigraphy Blackweil. London; 154-231.

Reineck, H.E and Singh, I.E., 1980, Depositional Sedimentary Environments (2nd Ed.), Springer Verlag, Berlin, 439.

Sayılı, İ.S., Ergin, M., Şahbaz, A., Özdoğan, M., Varol, B.. İleri, 6., Bayhan, E., Görmüş, S., Turan. S.D. and Soydemir, Ö., 1997, Kocasu deltası plajı kıyı tortullarının sedimantolojik ve mineralojik özellikleri. TÜBİTAK YDABÇAG-426/G -no.lu proje raporu (Koord. N. Kazancı ve N. Görür) Ankara. 170-191.

Scruton, P.C., 1960, Delta building and the deltaic sequence. In: Recent Sediments. Northwest Gulf of Mexico (ed. by F.P. Shepard, F.B. Phleger and Tj.H. van Andel). AAPG Pub., Tulsa, 82-102.

Stanley, D.J. and Blanpied, C., 1980. Late Quaternary water exchange between the eastern Mediterranean and the Black sea. Nature, 285, 537-541.

Şaroğlu, F., Emre, Ö. and Boray, A., 1987. Türkiye'nin Aktif Fayları ve Depremsellikleri, MTA Rep. no: 8174 (Unpublished). Ankara

————;————and Kuşçu, İ., 1992. Türkiye Diri Fay Haritası, MTA publ., Ankara.

Şengör, A.M.C., Görür, N. and Şaroğlu, F., 1985, Strike-slip faulting and related basin formation in zones of tectonic escape: Turkey as a case study. In: Strike-slip deformation, basin formation, and sedimentation (ed. by K.T. Biddle and N. Christie-Blick). Soc. Econ. Paleont. Mineral. Spec. Publ.. 37, 227-264.

Whateley, M.G.K. and Pickering, K.T. (Eds.), 1989, Deltas; Sites and Traps for Fossil Fuels. Geol. Soc. Pub. No: 41, Blackwell, Oxford.

Wright, L.D., 1985, River Deltas, In: Coastal Sedimentary Environments 2nd (ed. by R.A. Davies). Springer Verlag, New York 1-76.

Zubakov, V.A., 1993, The Caspian Sea level oscillations in the geological past and its forecast. Russian-Meteorology and Hydrology Bull.. 8, 65-70.