Z. Geomorph. N. F.	Suppl-Bd. 73	167–180	Berlin · Stuttgart	Juni 1989

The clay mineralogy and geochemistry of the recent surface sediments of İskenderun Bay as indicators of terrestrial provenance

by

SELİM KAPUR, Adana, SUNGU L. GÖKÇEN, İzmir, CEMAL SAYDAM, Erdemli, MUZAFFER ŞENOL, Adana, SUAT SENOL, ADANA, and CUMALİ KARAMAN, Adana

with 4 figures and 1 table

Abstract. The comparison of clay mineral populations and geochemical properties of land samples with marine surface sediments of the Bay of İskenderun reveal the source materials of the surface sediments and confirms conclusion on provenance obtained from Landsat imagery. The occurrence of an ancient terrace and a former mouth of the River Ceyhan is also deduced from the clay mineral distribution particularly the presence of palygorskite which is an indicator of Pleistocene (pluvial/interpluvial) climatic conditions.

Introduction and scope

The importance of clay minerals in the determination and interpretation of paleoclimates and provenances of continental and marine formations has been long demonstrated and studied (e.g. ATAMAN & GÖKÇEN 1975, SINGER 1984). Marine sediments of the Atlantic, Pacific and Arctic Oceans as well as the Mediterranean Sea in relation to clay mineral assemblages, provenances have been studied in detail by BISCAYE (1965), CHAMLEY et al. (1977), CHAMLEY (1979,1980), CHAMLEY & DIESTER-HAASS (1979), and DARBY (1978).

Surface sediments and sediment cores from the Eastern Mediterranean have been examined in detail by VENKATARATHNAM & RYAN (1971), and EVANS (1971) studied the sedimentation in the Seyhan delta area (Southern Turkey) with special reference to 14 C ages, determining an age of 3200–3800 BP for formation of the lower part of the Seyhan Plain. The studies completed following EVANS (1971) pointed out the importance of sediments introduced by the Turkish rivers, as well as giving data on ages of formations and detailed chemical and mineralogical properties of sediments. However those studies did not produce any detailed information on the pedological, mineralogical and geological characteristic of the land adjacent the Mediterranean Sea, which would contribute to the offshore sediments.

Sampling of the marine surface sediments used in this paper was carried out the board of R/V Bilim, during sample collection for pollution and oceanographic studies by the Middle East Technical University, Erdemli. The aim of this study is to determine the clay mineral distribution as well as the chemistry of the surface sediments of the İskenderun bay, which was not studied earlier, in order to relate the

0044-2798/89/0073-0167 $ 3.50

results to predetermined data concerning land or soils, geological formations, clay minerals, erosion, and coastal geomorphological changes. These data were collected during 1947–1975 from aerial photography (FAO-UNESCO 1974, MERMUT 1978, DINÇ et al. 1986, TSCS 1972, 1973, 1981, OAKES 1957, SCHMIDT 1961, TÜRKMEN 1974, MTA 1975, EROL 1983, and BAL 1984) as well as from Landsat imagery, and revealed surface sediment tongues occurring on the eastern flank of the bay and probably related to the Pliocene old river terraces overlain by regosols on the eastern side of the bay (MSS band 4, image of 7 may 1975).

Geological – pedological framework of the surrounding land areas

The sedimentary succession exposed in the Çukurova region includes late Oligocene and Miocene strata, overlain by Pliocene-Quaternary sediments and basaltic lavas of the Adana and İskenderun subbasins. Two main lithostratigraphic units have been recognized, the İsalı and Karataş Formations of lower and middle Miocene in age (SCHMIDT 1961, KELLING et al. 1987). A third unit, Kızıldere Formations (Tortonian) present in the southeastern part of the region, is broadly correlative with the Kuzgun Formation of the Adana subbasin (GÖKÇEN et al. 1988).

LEGEND AND EXPLANATIONS

- Al*2 - Alluvial Soils, Fluvisols deposited from Basaltic material. Holocene (Halloysite dominant ~50 %, smectite 20-30 %, ~30-50 % glauconite in coostal sands)
- Al - Alluvial Soils, Fluvisols, Holocene (smectite dominant ~ 80-90 % of kaolinite and illite)
- A.F. - Alluvial Fan material, Fluvisols, Holocene (Kaolinite dominant ~50 %, illite ~30 %, smectite ~20 %)
- Ve - Vertisol, Pleistocene basalt including Ve*3 (smectite dominant ~ 80 %)
- M.R.D - Mediterranean Red and Reddish Brown Soils, Luvisols and or Cambisols, Villafranchian (usually smectite, accasionally illite, kaolinite dominant aloungwith lower amounts of palygorskite)
- M.R.D+C*4 Mediterranean Red Soil with Calcrete formation, Villafranchian So river terrace (Erol, 1984)
- Rg* - River Ceyhans ancient terrace with Regosols on Villafranchian calichified (calcrete) conglomerates in Pliocene units
- Rg - Regosol, Miocene-Pliocene (smectite dominant 60 % with palygorskite ~20-40 %)
- Rd - Rendzina, Miocene-Pliocene (smectite dominant ~60 % with polygorskite ~ 20-40 % especially at Rd*5 6 overlying the Gölovası deposits)
- Rk - Ranker Cretaceous (smectite dominant ~60 %)

(1 1': Cross-section lines in Fig. 3; after Türkmen 1974)

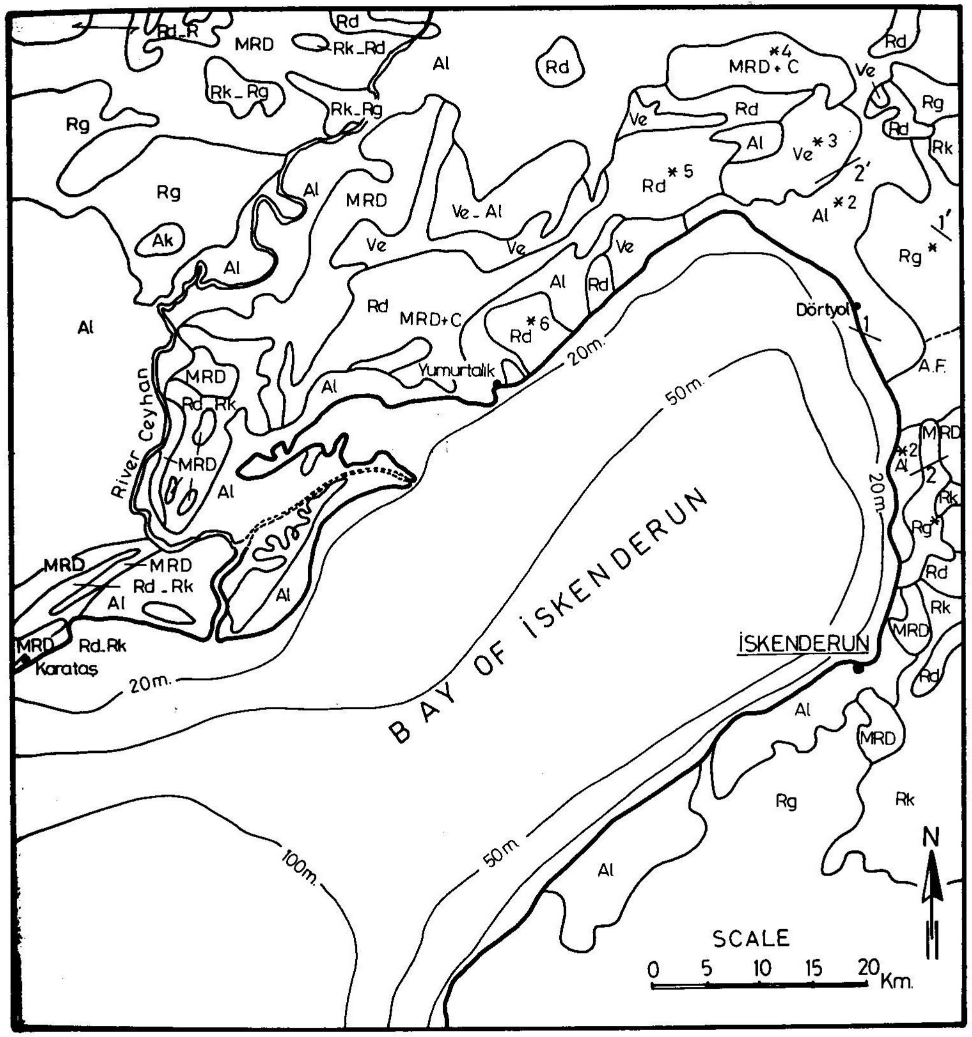
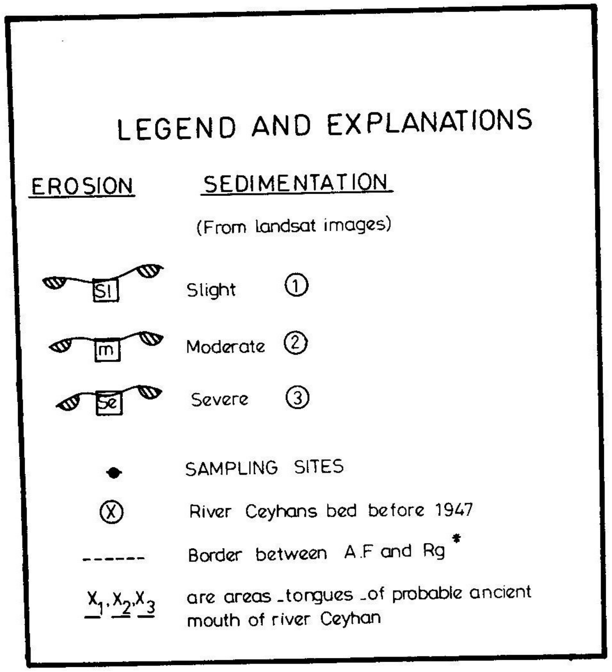


Fig. 1. Litho-pedological units and the clay minerals of the Çukurova Region Coastel areas (Revised after BAL 1984, DINÇ et al. 1986, EROL 1983, FAO-UNESCO 1974, MERMUT 1978, MSS Band 4, image of 7 may 1975, MTA 1975, OAKES 1957, TSCS 1972, 1973 and 1981, TÜRKMEN 1971).

Sequence in the Adana – İskenderun area are dominated by steep northwesterly dips, contrasting with the gentle dips of Neogene strata in the Adana and Iskenderun subbasins. Profiles across the east-northeast/west-southwest trending complex reveal a characteristic arrangement marked by packets (up to 2300 m thick) of steeply dipping strata with younger rocks to the northwest. These packets are separated by strike-parallel zones of mesoscale, subhorizontal, northwest facing folds, many of which are associated with major reverse faults and thrusts (KELLING et al. 1987, GÖKÇEN et al. 1988).

The superficial deposits of the Adana Basin mostly comprise Holocene alluvial (with deep smectite-rich soils) to Pliocene marine clay sediments (with highly smectitic deep to shallow Brown Alluvial Soils) as well as Pleistocene aged basalts forming Vertisols (dark brown to black cracking highly smectitic soils) on the west, whereas the eastern coast is mostly surrounded by Holocene alluvial dark brown to brown highly smectitic soils as well as minor parts of Regosols on Mio-Pliocene materials and Plio-Pleistocene Red Soils (Fig. 1). The probable old river terrace of the river Ceyhan is Plio-Pleistocene in age, with shallow regosols (Rg*) (Fig. 2) overlying highly calcified (calcrete) conglomerates. TÜRKMEN (1974) has determined the continuation of the old Pliocene river bed (crossections of 1–1′ and 2–2′ of Fig. 3), under the Holocene alluvium (Al*) located between the regosols (Rg*) and the Mediterranean Sea as well as the Mediterranean Red Soils (Fig. 1). The northern continuation of the old terrace of the Ceyhan River is most probably covered by the Pleistocene



basalts and later by the transported Pleistocene-Holocene Dark Brown-Black Soils (Ve*3) and the transported Mediterranean Red Soils overlying massive calcretes formed upon Mio-Pliocene clay deposits located close to the northern border of the Vertisols-Ve*3 of basaltic origin.

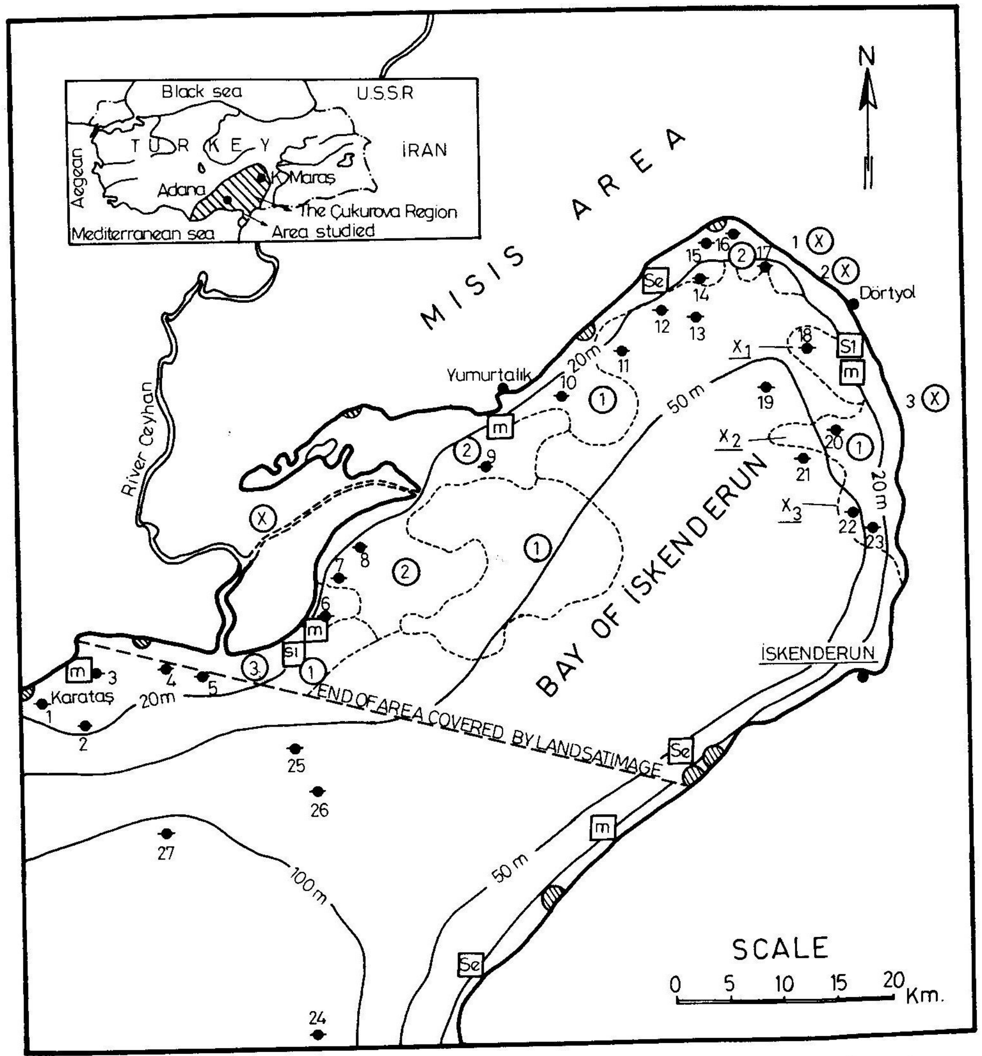


Fig. 2. Sample locations, erosion and sedimentation levels and coastal geomorphology of the study area.

Sampling of the marine surface sediments

Grab samples of the surface sediments for clay mineralogy, and elemental analysis were taken at all the sample localities shown in Fig. 2, using a Van Veen grab sampler. Depth ranges were 0–20 m (samples 1, 2, 3, 4, 5, 15, 16,); 20–50 m (samples 6, 7, 8, 9, 10, 11, 12, 13, 14, 17, 18, 20, 23); 50–100 m (samples 19, 21, 22, 25, 26); and over 100 m (samples 27 and 24).

Field sampling on land and data compilation

Soil and sediment samples of continental and marine origin to be analysed for clay and very fine sand size minerals were collected from all horizons of the selected profiles belonging to representative soil classes determined by OAKES (1957). Elemental analysis were obtained from MERMUT (1978), and DINÇ et al. (1986) for the sites. Erosional effects by erosion classes of the coast of the Iskenderun Bay were obtained from the Turkish Soil Conversation services (TSCS 1981) Erosion Map of Turkey 1/1.000.000. Geological data which marked the soil data closely (soil classes/boundaries), were taken from the 1/500.000 and 1/250.000 scaled maps of the Mineral Research and Exploration Institute of Turkey (MTA 1975). Levels of marine surface sedimentations as well as the probable ancient mouths of the Ceyhan River were observed from MSS Band 4, Landsat images of 7 May 1975. BAL's (1984) calculations using aerial photographs taken at different periods (1947–1975) of the sedimentation areas in the Bay of Iskenderun were also taken into consideration in interpreting the effect of land sources on the marine sedimentation.

The geology and Pliocene-Pleistocene stratigraphy of the probable old river terrace of the Ceyhan, which coincides with the Rg* soil class at the north eastern part of the surroundings of the Bay of Iskenderun, and which is on the eastern flank of the XI and X2 sedimentation tongues (probable old river sediments), were taken from the regional geological maps scaled 1/100.000 (TÜRKMEN 1974). He also undertook detailed field surveys of soils and surface geology, and collected additional soil and sediment samples (two surface soil samples 1⊗ and 3⊗ and one sand size beach sediment 2⊗ from varying soil types and beach sediments of the Alluvium A1*2 and three soil samples from a calchified Pliocene, hard calcrete profile of the regosols -Rg*- for the confirmation of the existence of the old river bed (Fig. 2). The geomorphological units of the land area surrounding the bay were taken from EROL (1984) and correlated in the field with the above mentioned geologcial and soil maps. Changes occurring in the formation of the delta of the Ceyhan River following the shift of its bed to its recent position by the State Hydraulic Works (D.S.I.) since 1956, were taken from BAL (1984) and incorporated in Fig. 1 and Fig. 2 respectively.

Sand and clay size mineralogy and total elemental analysis

Clay mineral (2 µm) determination of land samples as well as marine surface sediments were conducted following JACKSON (1979) on randomly oriented suspension slides by M++ Glycerol (room temp.) and K+ (rom temp. 550°C heated) saturations, using a Philips diffractometer with a Ni-filter and Cu Kα radiation, in order to determine soil-geological formation provenances of the surface sediments from the Bay of Iskenderun, very fine sand minerals (50–100 µm) were determined optically for the confirmation of the basaltic origin of the Alluvial sediments on the eastern flank of İskenderun Bay. Quantitative total elemental analyses of the marine surface sediments for Fe, Mn and Zn were carried out following A.S.A. (1965), using a Pye-Unicam SP 90 Atomic Absorption Spectrophotometer after total digestion of the samples in hydrofluoric-nitric-perchloric acids. Varying amounts of Fe is accepted as a measure for colour (especially for-rubefaction-reddending in the Pleistocene pluvials/interpluvials and thus maturity of soils in subtropical to tropical and subhumid to humid regions (REVEL 1972, MILLOT 1970, DARBY 1975, KAPUR 1975).

High amounts of Zn is a characteristic element for matureolder-soils along with increasing amounts of amorphous or poorly crystalline clay mineral materials, whereas high Mn has been determined to be an indication of material transported from Mio-Pliocene clayey deposits following accomplishment of numerous analysis of total Mn in Miocene – Pliocene (Neogene) clayey deposits of Southern Turkey. These include clayey deposits which are responsible of the formation of the Rendzinas (Rd*5 and Rd*6) occurring northeast and west of Yumurtalık town.

Results and discussion

As seen in Fig. 2, a moderate phase (2) of sedimentation continuing to depths of 0–20 m and 20–50 m in the Bay of İskenderun occurs off a slight to moderate erosion affected part of the coast (TSCS, 1981). This indicates that contemporary erosion on this part of the coast is not the cause of the Lands at determined sedimentation, but that this is cause of the deposition in the old bed of the Ceyhan, most probably bringing materials from the northern part of the Çukurova region; i.e. the Tertiary limestones, Reddish and Brown Soils formed from this material as well as materials from the Alluvial parts along the Ceyhan course. The clay minerals determined at sites (nos: 6, 7, 8, 9) corresponding to the moderately eroded coast and moderately sedimented shallower parts of the coast being between 20–50 m depth, dominantly comprised kaolinite, illite and chlorite at equal amounts followed by lesser amounts of smectite (Table 1) compared to the clay minerals of the surface sediments located between Karataş (Fig. 1) and the present mouth of the Ceyhan river, indicating that the source materials were transported mostly from the Tertiary limestones and the materials formed from them, which dominantly contain koalinite and illite with lesser amounts of smectite.

Smectite is the dominant clay mineral in the Karataş-Ceyhan river mouth sites (no's: 1, 2, 3, 4, 5; Table 1) indicating an occurrence of a recent-alluvial depositional material most probably transported from the Holocene alluvium occurring along the bed of the Ceyhan. The alluvium of the Ceyhan has been determined to be highly smectitic (90% smectite, Fig. 1) in profiles studied between the coast and the northmost part (Fig. 3) of the river bed, with much lesser amounts of other clay minerals (app. 10% kaolinite and illite together). The end of the Landsat covered area at the mouth of the present Ceyhan shows rapid sedimentation and moderate erosive effects. The sedimentation is most probably due to the erosion material transported by the Ceyhan which flows almost dark brown with suspended clay material in the winter and seasons following heavy rainfall in the area studied which is semiarid, subhumid.

Iron (%) and manganese (ppm) of site 5 which is located near the recent mouth of the Ceyhan (Fe: 0,71; Mn: 450) and sites 7 (Fe: 0,75; Mn: 450), 9 (Fe: 0, 84; Mn: 440) which most probably are the materials sedimented by the previous mouth of Ceyhan as well as the iron of site 6 (0,86) are almost identical indicating sedimentation of similar kind of clayey material to the two different mouths of the Ceyhan. Still the amount of Zn (ppm) is much higher at site 5 (30) compared to sites 6 (19), 7 (17) and 9 (17). The higher amount of Zn in site 5 can be attributed to the pollution of the Ceyhan River from 1956–1982.

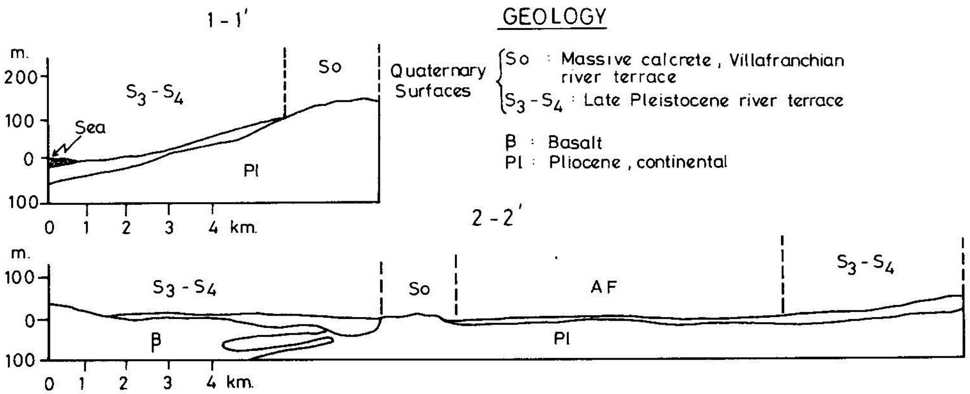


Fig. 3. Cross sections 1–1′ and 2–2′ showing the geologcial units and river terraces (after TÜRKMEN 1974), modified using EROL's (1984) Quaternary surface desination (legend as Fig. 1).

The sedimentary material transported by the recent bed of the Ceyhan has probably affected sites 4 and 5 since highly crystalline smectite is determined in both, differing from smectites of sites 1, 2 and 3 (Table 1). The effect of the Ceyhan sedimentation can probably be traced as far as sites 4 and 5 as shown Fig. 4a and b produced by BAL (1984) to show the depositon of material between 1947–1975. The absence of Zn (0 ppm) in site 1 may seem to be confirmative to recent pollution caused by the Ceyhan in the material of site 5 (Zn: 30 ppm) and its environment, as well as probably being of a different source material compared to the material in sites 7 and 9 due to their higher contents of Mn (450, 440 ppm respectively) and especially lower amounts of Zn (17 ppm in both).

The northward continuation of the coast towards Yumurtalık as seen in Fig. 2 is a slightly to moderately sedimented area. This sedimentation is most probabyl partly due to the moderate present day erosive effect, resulting to sedimentation of the highly clayey marine Mio-Pliocene Gölovası deposits forming the Alluvial, Rendzina and Mediterranean Red Soils of the corresponding land area. The surface sediments taken from sites 10 and 11 are dominantly smectitic followed by kaolinite,

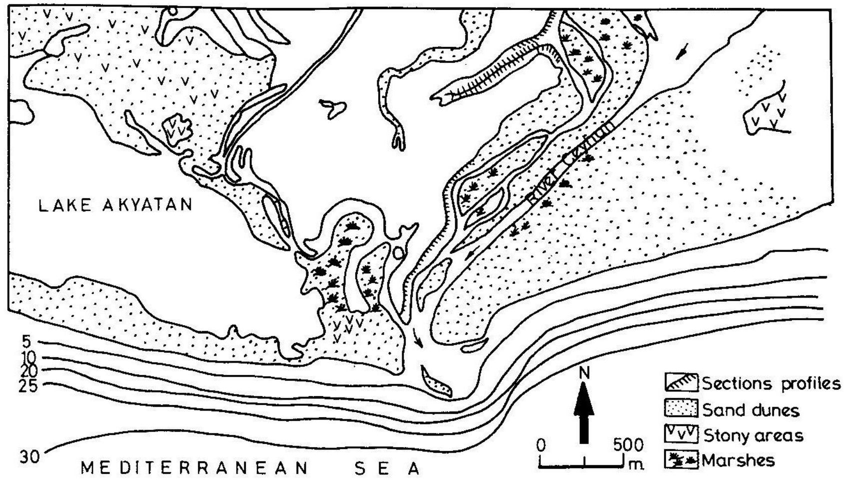


Fig. 4a. The Ceyhan Delta in 1947. (After BAL 1984).

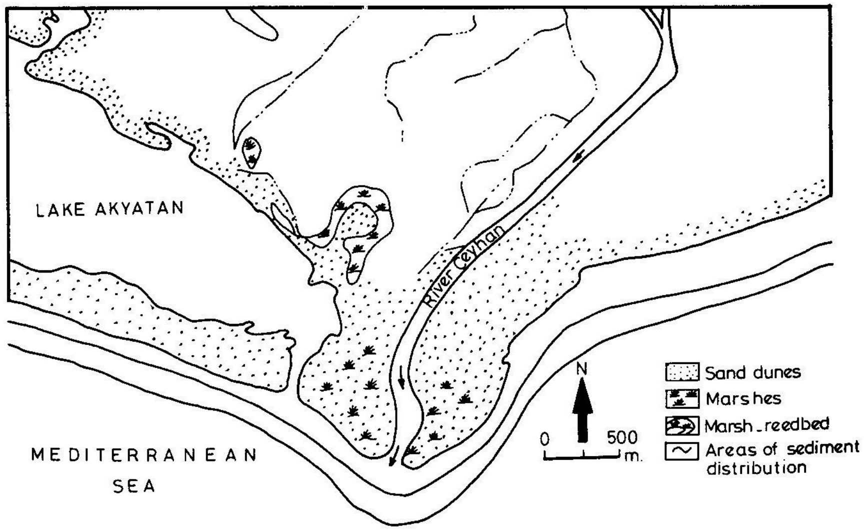


Fig. 4b. The Ceyhan Delta in 1975. (After BAL 1984).

Table 1 Semi-quatitative clay mineral distribution of the surface sediments.

Sample	S(18A°) d	S(18A°) c	I(10A°) d	I(10A°) c	K(7.2A°) d	K(7.2A°) c	C(14A°) d	C(14A°) c	P(10.5A°) d	P(10.5A°) c	H(7.4A°) d	H(7.4A°) c
1	+++	+++	+++	+++	+++	+++	+++	+++	-	-	-	-
2	++	++	+++	+++	+++	+++	+++	+++	-	-	-	-
3	++	++	+++	+++	+++	+++	+++	+++	-	-	-	-
4	+++	+++	+++	+++	+++	+++	++	++	-	-	-	-
5	+++	+++	+++	+++	+++	+++	+++	+++	-	-	-	-
6	++	++	+++	+++	+++	+++	+++	+++	-	-	-	-
7	++	++	+++	+++	+++	+++	+++	+++	-	-	-	-
8	++	++	+++	+++	+++	+++	+++	+++	-	-	-	-
9	++	++	+++	+++	+++	+++	+++	+++	-	-	-	-
10	++++	+++	++	++	+++	+++	++	++	++	++	-	-
11	+++	++	++	++	++	++	-	-	-	-	-	-
12	+++	++	++	++	+++	+++	+++	+++	-	-	-	-
13	++	++	++	++	+++	+++	+++	+++	-	-	-	-
14	++++	+	++	+	+++	+++	-	-	+	+	-	-
15	++++	++	++	++	+++	+++	++	++	-	-	-	-
16	++++	+++	-	-	++	+++	-	-	-	-	+	+
17	+++	++	++	++	++++	+++	+++	++	-	-	-	-
18	+++	+++	++	+++	+++	+++	+++	+++	-	-	-	-
19	++	++	++	+++	+++	+++	+++	+++	-	-	-	-
20	+++	+++	++	+++	+++	+++	+++	+++	+	++	-	-
21	++	++	++	+++	+++	+++	+++	++	-	-	-	-
22	++	++	++	++	+++	+++	+++	+++	+	++	-	-
23	+++	++	++	++	+++	+++	+++	+++	+	++	-	-
24	+++	++	+++	+++	+++	+++	+++	+++	+	+	-	-
25	+++	++	+++	+++	+++	+++	+++	+++	-	-	-	-
26	++	++	+++	++	+++	+++	++	++	+	+	+	+
27	+++	++	+++	+++	+++	+++	+++	+++	-	-	-	-

Dominancy (d): Abundant +++; Moderate +++; Low ++; Trace +;
Crystallinity (c): High +++; Moderate ++; Poor +
S:Smectite; I:Illite; K:Kaolinite; C:Chlorite; P:Palygorskite; H:Halloysite.

illite, chlorite and palygorskite in the former, and by illite and kaolinite at the same amounts in the latter (Table 1). Chlorite is absent at site 11, whereas site 10 contains palygorskite indicating a depositional effect from the Gölovası clays containing almost equal amounts of the same clay mineral especially at the parts of Mio-Pliocene aged formations-Rendzinas (Rd*5, 6). Palygorskite has also been determined in the Persian Gulf deposits by STOFFERS & ROSS (1979) who regard it as an indicator of continental depositon. Site 11 occurs outside the sedimentation area mapped on the Landsat image, thus confirming the reason for the absence of palygorskite. The small amount of sedimentation from the almost level land of Gölovası clayey deposits, forming the Rendzinas (Rd*5. 6) and the alluvium around Yumurtalık have not been effective as far as site 11, most probably due to the wave action in the bay. Sites 12 and 13 occur outside the moderate sedimentation and severe erosion boundaries and contain less smectite compared to sites 14 and 15 (which are within the above mentioned boundaries) affected by Vertisol (cracking) soils with high smectite formed from Pleistocence basalts (Fig. 2).

Presence of trace amounts of palygorskite in site 14 indicates a probable earlier sedimentation occurrence compared to the sedimentation in site 15 which could have originated from the material transported from Rendzinas (Rd*5) of the Gölovası (located north of the Vertisol-Ve) containing palygorskite (Table 1 and Fig. 1). This phenomenon is also confirmed by the higher amount of elemental Zinc in site 14 (42 ppm) compared to the Zinc determined in sites 15 (15 ppm) and 12 (19 ppm). Site 16 similarly contains abundant highly crystalline smectite with less amounts of kaolinite and trace amounts of halloysite alone indicating an origin of a typical basaltic soil (Table 1). KAPUR (1975), KAPUR et al. (1986, 1987) KAPUR & SENOL (1987), INCE & KAPUR (1985), DINÇ et al. (1986) have determined the same clay mineral compositions in soils formed basalts in south and southeastern Turkey. Al*2 (Fig. 1.) is the corresponding land area to site 16, which is also Alluvial Dark Brown Soil material of basaltic origin with moderate amounts of smectite and kaolinite with much higher halloysite (than site 16) which is most probably formed at location of Ve*3 and transported to its recent place. X-ray diffraction analysis of site 1⊗ –Al*2– revealed presence of dominant and abundant highly crystalline halloysite which is indicative of young basaltic soils as well as moderate amounts of smectite and kaolinite.

Sites 17 and 18 which are within the Landsat moderate and slight sedimentation boundaries are dominantly kaolinitic followed by lesser and equal amounts of smectite and chlorite (Table 1); again the source of material could well be attributed to transportation from the basaltic Al*2 material. The basaltic origin of Al*2 is also confirmed by presence of high amounts of opaque minerals 50%, plagioclase 15% and pyroxenes 20% in the very fine sand fraction-50-100-μm of surface samples from 1 ⊗ which is soil and 2 ⊗ which is coastal sand with glauconite determined by X-ray diffraction. Sites 18, 20, 22 and 23 are within the slightly sedimented tongues (XI, X2 and X3 in Fig. 2) corresponding to land areas of slight erosion. The low degree of erosion and slight sedimentation may be an indication of an earlier deposition as well as the presence of equal amounts and almost similarly crystalline palygorskite in sites 20, 22 and 23 (Table 1) indicating sedimentation most probably occurring from the regosol (Rg*) – the Villafranchian sedimentary materials-containing high amounts of highly crystalline palygorskite X-ray diffraction analysis of site I X revealed presence of dominant and abundant highly crystalline halloysite which is indicative of young basaltic soils (i.e. POND & EDELMAN 1960) as well as moderate amounts of smectite.

Site 3 ⊗ is similar in smectite content to site 1 ⊗ varying with higher amounts of well crystalline illite indicating a different depositional source confirming the presence of the alluvial fan (AF-determined in the field) with dominant kaolinite. Absence of palygorskite in all three sites (1 ⊗ 3 ⊗ and 2 ⊗ –the coastal sand deposit) representing the alluvium (Al*2) proves that the probable source for the sediments of x2 and x3 is the calcified Villafranchian formation overlain by Regosols (Rg*) located at the eastern flank of the Al*2 and probably forming an old river terrace of the Ceyhan. This Villafranchian formation with an overlaying shallow (10–30 cm) cover of a regosol is a vertical crossection of a calcified fluvial conglomerate which is 2–3 m deep from the surface with calcite columns forming in finer material in between the conglomerates as lenses, probably formed during the Middle and Late Pleistocene. Crossections 1–1′ and 2–2′ in Fig. 3 show presence of the Quaternary So surface (Villafranchian) (EROL 1984) confirmed by field work.

Sites 25 and 27 are of similar clay mineralogy, whereas sites 24 and especially 26 are quite different. Site 24 contains trace amounts of continental palygorskite and site 26 contains palygorskite as well as halloysite (Table 1). The variable clay mineral contents of these four sites may indicate the effect of the surface gyre mentioned earlier by VENKATARATHNAM & RYAN (1971), which seems to be most probable due to the long distances of the sites to the shores of the bay.

Concluding remarks

In addition to the provenances deduced from Landsat imagery the conclusions to be derived from the results and discussions are:

1) The sediments in the north-western part of the Bay of İskenderun are transported and deposited mainly from the probable Holocene alluvial soils, associated with the present and previous courses of the Ceyhan River, together with contributions (in the Yumurtalık area) formed by surface water transport from the Gölovası clayey deposits.

2) Sediments in the northern part of the Bay are derived from the Vertisol soils generated from basaltic bedrock and the alluvial material (Al*2) which most probably originated in soils developed on the Pleistocene basaltic area (Ve*3) located further north.

3) Sediments in the eastern part of the Bay were derived mainly from the Villafranchian calcified river terraces of the Ceyhan River (Rg*, Fig. 1) and were most probably deposited before the formation of the Holocene alluvium (Al*2).

Acknowledgement

The authors are indebted to Prof. Dr. OĞUZ EROL (Inst. of Geography and Marine Sci., Univ. of Istanbul) for his guiding hand for the understanding of the concept of Quaternary geology in the Çukurova Region (Southern Turkey); Prof. Dr. URAL DİNÇ (Univ. of Çukurova, Adana) and Mr. Y. BAL (General Directorate of

Mapping, Ankara) for their permission on the publication of the regional soil classes and two figures for the sedimentation of River Ceyhan in this paper.

Special thanks are due to the Prof. Dr. K. M. CLAYTON (Norwich-U.K.), Prof-Dr. G. KELLING (Keefe-U.K.) and Prof. Dr. H. BREMER (Köln-W.Germany) for their editorial contributions to the earlier version of this article.

References

A.S.A. (American Society of Agronomy (1965): Methods of Soil Analysis. part 2, chemical and microbiological properties. – E.A.Black (Ed.) ağro, no 9, 1572 pp., Madison, USA.

ATAMAN, G. & S. L. GÖKÇEN (1975): Determination of source and paleoclimate from the comparison of grain and clay fractions in sandstones: a case study. – Sediment. Geol. **13:** 81–107.

BAL, Y. (1984): Coastline changes of the Eastern Mediterranean region of Turkey. – M. Sc. Thesis, Gradutate School of Sci. Univ. Çukurova, 67 pp., Adana. [In Turkish-Unpublished]

BISCAYE, B. E. (1965): Mineralogy and sedimentation of Recent Deep Sea clays in the Atlantic Ocean and adjacent seas and oceans. – Geol. Soc. Am. Bull. **76:** 803–832.

CHAMLEY, H. (1979): North Atlantic clay sedimentation and paleoenvironment since the late Jurassic. – In: M. TALWANI, M. HAY & W. B. RYAN (Eds.): Deep Drilling Results in the Atlantic Ocean: Continental Margins and Paleoenvironment. – Maurice Ewing Ser. 3, Am. Geophys. Union, pp. 342–361.

– (1980): Clay sedimentation and paleoenvironment in the area of Daito Ridge (northwest Phillippine Sea) since the Early Eocene. – In: G. VEDRIES KLEIN, K. KOBAYASHI et al.: Initial Reports DSDP 58. – U.S. Gov. Print. Off., pp. 688–690. Washingtion. DC, U.S.A.

CHAMLEY, H. & L. DIESTER-HAASS (1979): Upper Miocene to Pleistocene climates in northwest Africa deduced from terrigenous components of site 379 sediments (leg 47A DSDP). – In: W. B. F. RYAN, J. C. SIBUET et al.: Initial Reports DSDP 47. – U.S. Gov Print, Off. **4:** 641–646 Washington DC, U.S.A.

CHAMLEY, H., L. DIESTER-HAASS & H. LANGE (1977): Terrigenous material in East Atlantic sediment cores as an indicator of northwestern African climates. – "Meteor" Forchs-Ergeben., Reihe C, **26:** 44–59.

DARBY, D. A. (1975): Kaolinite and other clay minerals in Arctic Ocean sediments. – J. Sediment. Petrol. **45:** 272–279.

DİNÇ U., S. SENOL, S. KAPUR, M. SARI, V. ÇAVUŞGİL & E. SCHLICHTING (1986): Genesis and classification of the cotton belt soils of the Seyhan and Berdan deltas according to soil Taxonomy. – Hohenheim Univ. – Çukurova Univ. Project, 38 pp., 6 Encl., Adana. [Unpublished Turkish Report]

EROL, O. (1983): Historical changes on the coastline of Turkey. – In: E. C. F. BIRD, P. FABBRI (Eds.): Coastal Problems in the Mediterranean Sea. – Proc. Sym. Geograph. Union. Com. Coastal Envir., pp. 95–108, Bologna-Italy.

– (1984): Soil forming characteristic of Neogene and Quaternary formations in Turkey. – Proc. I. Nat. Clay Symp., pp. 22–28, Adana.

EVANS, G. (1971): The recent sedimentation of Turkey and the adjacent Mediterranean and Black Sea: a review. – In: A. S. CAMPBELL (ed.): Geology and History of Turkey. – Petrol. Expl. Soc. Libya, pp. 385–400.

FAO-UNESCO (1974): Soil map of the world. Vol. 1. legend. – Unesco, Paris, 59 pp.

GÖKÇEN, S. L., G. KELLING, N. GÖKÇEN & P. A. FLOYD (1988): Sedimentology of a late Cenozoic collisional sequence, the Misis Complex, Adana, Southern Turkey. – Sediment. Geol. **59** (3/4): 205–235.

İNCE, F. & S. KAPUR, (1985): Microstructure formation in vertic soils formed on basaltic parent rocks of southeastern Turkey. – Turk. J. Agricult. Forestry (Doğa), TÜBİTAK, Serie B, **9:** 52–56.

JACKSON, M. L. (1979): Soil chemical analysis. – An Adv. Course, Publ. by the author, 895 pp., Madison, Winsconsin, U.S.A.

Kapur, S. (1975): A pedological study of three soils From Southern Turkey. – Ph. D. Thesis, Unpubl. 113 pp., Univ. of Aberdeen.
Kapur, S., V. S. Çavuşgil & E. A. Fitzpartic (1987): Soil-Calcrete (Caliche) relationship on a Quaternary Surface of the Çukurova Region, Adana (Turkey). – Soil micromorphology, Ed. by N. Fderoff, L. M. Bresson & M. A. Courty, pp. 597–603.
Kapur, S., V. Dinç & H. Özbek (1986): Microbiology of basaltic soils of Southern Turkey. – Transaction of the XIII. Congress of the Int. Soil. Sci. Soc., pp. 1558–1559, Hamburg.
Kapur, S. & M. Şenol (1987): Calcrete-Soil relationships and clay minerals of basaltic volcanites of the Yumurtalık area (Southern Turkey). – Proc. 3rd Nat. Clay Symposium. Ankara (in press).
Kelling, G., S. L. Gökçen, P. A. Floyd & N. Gökçen (1987): Neogene tectonics and plate convergence in the Eastern Mediterranean; new data from Southern Turkey. – Geology **15:** 425–429.
Millot, G. (1970): Geology of Clays. – Masson et Cie., Paris, 425 pp.
MTA (Mineral Exploration and Res. Inst. (1975): Explanatory text of the geologcial map of the Turkey (Hatay). – MTA., pub, 96 pp., Ankara.
Mermut, A. (1978): Soils of the Ceyhan-İskenderun area. – Univ. of Ankara, Fac. of Agriculture, Publ. No. **697,** 54 pp., Ankara.
Oakes, H. (1957): Soil map of Turkey. – Min. of Agr. Soil Con. and Fram Irr. Div. Pub. no. **1,** 180 p., Ankara.
Pons, L. J. & C. H. Edelman (1960): A Soil Survey of the Köyceğiz-Dalaman area. – Publ. Soil Fer. Res. Inst. Publ., 105 pp., Ankara.
Revel, J. C. (1972): Recherche sur l'origine de la rubefaction de Terres Rouge Mediterrannes. – Universite Paul Sabatier de Toulouşe, Toulouse, 104 pp.
Schmidt, G. C. (1961): Stratigraphic nomenclature of the Adana Petroleum area. – Publ. Petrol. Office **6:** 47–63.
Singer, A. (1984): The paleoclimatic interpretation of clay minerals in sediments-a review. – Earth-Sci. Rev. **21:** 251–293.
Stoffers, P. & D. A. Ross (1979): Late Pleistocene and Holocene mentation in the Persian Gulf-Gulf of Oman. – Sediment. Geol. **23:** 181–208.
TSCS (Topraksu) (1972): Soil sources inventory of the Hatay Province. – Gen. Dir. Topraksu, Publ. no 161, Rep. no. 33, 20 pp.
– (1973): Soils of the Ceyhan Basin. – Gen. Dir. Topraksu, Publ. no. 285., Rep. no. 36, pp. 69–86.
– (1981): Erosion map of Turkey. – Gen. Dir. Topraksu, Publ. no 547, Rep. no. 64, 32 pp.
Türkmen, G. (1974): Hydrogeological investigation report of the Dörtyol-Erzin Plain. – Rep. Turk. Min. Energy Natur. Rese. Publ., 42 pp., Ankara.
Venkatarathnam, K. & W. B. F. Ryan (1971): Dispersal patterns of clay minerals in the sediments of the Eastern Mediterranean Sea. – Marine Geol. **11:** 261–282.

Addresses of the authors: Prof. Dr. Ing. S. Kapur, Department of Soil Science, Çukurova University, Adana, Turkey. Prof. Dr.-Ing. S. L. Gökçen, Institute of Marine Sciences and Technology, Dokuz Eylül University, İzmir, Turkey. Doc. Dr. C. Saydam, Institute of Marine Sciences, Middle East Technical University, Erdemli, Turkey. Dipl.-Ing. M. Senol, Mineral Research and Exploration Institute, MTA, Adana, Turkey and Geological Engineering Dept., Çukurova University, Adana–Turkey. Doc. Dr. S. Şenol, Department of Soil Science, Çukurova University, Adana, Turkey. Dipl.-Ing. C. Karaman, Department of Soil Science, Çukurova University, Adana, Turkey.