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Paleontologia. — *Cruise AVI-II 93: preliminary data from the Iskenderun Bay (Turkey).* Nota di DANIELA BASSO, SILVIA SPEZZAFERRI, VALENTINA YANKO, HAYRETTIN KORAL e NIYIAZI AVSAR, presentata (*) dal Corrisp. M. B. Cita.

ABSTRACT. — Preliminary results obtained by the AVI-II Cruise in the Iskenderun Bay (south-eastern Turkey), are presented. The Avicenna Project aims to verify the possibility of using benthic foraminifera for low-cost monitoring of heavy metal pollution. About one-hundred and forty grab samples and four cores were collected ranging in depth from 7 to about 85 m, CTD data were also collected at all stations. A more detailed sampling was performed close to the possible main pollution sources: iron-steel complex, fertilizer industry, pipe-terminal, harbour, towns. Chemico-physical conditions in the Bay are controlled mainly by the general circulation pattern, and by the fresh water inflow from the Ceyhan River. The sediments mostly consist of silty clays in the deepest area of the bay, of silty sands at shallower depth, above 45 m. Qualitative observations on macrobenthos allowed to identify biocoenoses and thanatocoenoses related to the coastal detritic (DC), coastal terrigenous mud (VTC) and coralligenous (C) assemblages. Evidence from cores and some grab samples revealed a dramatic environmental change from hard bottom communities dominated by the coral *Cladocora caespitosa* to the present-day muddy bottoms assemblage.

KEY WORDS: Pollution; Benthic assemblages; Iskenderun Bay.

RIASSUNTO. — *Crociera AVI-II 93: dati preliminari dalla Baia di Iskenderun (Turchia).* Si presentano i risultati preliminari raccolti durante la Crociera AVI-II 93 nella Baia di Iskenderun (Turchia sudorientale). Il Progetto Avicenna ha lo scopo di verificare la validità dell'uso dei foraminiferi bentonici come indicatori dell'inquinamento da metalli pesanti. Sono stati effettuati 4 carotaggi e circa 140 bennate a profondità comprese tra i 7 e gli 85 m. In corrispondenza di ogni stazione sono stati misurati i valori di pressione, temperatura e conduttività lungo la colonna d'acqua, con sonda CTD. In prossimità delle possibili fonti di inquinamento – complesso siderurgico, industria di fertilizzanti, terminale dell'oleodotto, strutture portuali, centri urbani – è stato eseguito un campionamento più fitto. Le acque dolci immesse dal Fiume Ceyhan e le particolari condizioni di circolazione all'interno della Baia risultano essere gli elementi chiave che influenzano le caratteristiche fisico-chimiche osservate. I sedimenti della zona più profonda della baia consistono principalmente di argille siltose, mentre sopra i 45 m si rinvengono prevalentemente sabbie siltose. Le osservazioni qualitative sul macrobenthos hanno permesso di identificare biocenosi e tanatocenosi correlate al Detritico Costiero (DC), Fanghi Terrigeni Costieri (VTC) e «coralligeno» (C). Le osservazioni effettuate sui campioni rivelano un drastico cambiamento da associazioni di fondo duro, dominate dal corallo *Cladocora caespitosa* alle attuali associazioni caratteristiche dei fondi fangosi circalitorali.

INTRODUCTION

The aim of this study is to verify the efficacy of using benthic foraminifera for the monitoring of heavy metal pollution. Benthic foraminifera reflect pollution in the sea water in modifying chemical composition of tests as well as their general morphologies, producing abnormalities. At the same time, the composition of the assemblages, test density, species diversity, spatial distribution of species are strongly controlled by environmental conditions and therefore, they may also reflect the degree of pollution (Yanko *et al.*, 1994). Two cruises were planned and performed in 1993 within the AVI-

(*) Nella seduta del 12 febbraio 1994.

CENNA Project, supported by the European Community. The first cruise, AVI-I, was performed in Haifa and Atlit Bays along the Israeli coast in mid-May, 1993, on the R/V Shikmona of the Israel Oceanographic and Limnologic Research Institute, Haifa. The second (AVI-II) was performed in the Iskenderun Bay, south-eastern Turkey, on R/V K. Piri Reis of the Institute of Marine Sciences and Technology, Eylul University of Izmir, in early June 1993.

These two spring cruises will be followed by others, to be carried out in the same areas in September-October, 1994.

General features of the Iskenderun Bay

Very little is known on the Iskenderun Bay, consisting in a narrow and elongated embayment located in the easternmost part of the Mediterranean Sea along the Turkish coast (fig. 1). It deepens gradually toward the open sea, where it reaches about 90 m depth. Major morphological features include the Ceyhan River delta at the western side of the bay. The natural meandering of this river originated a wide lagoonal area which borders a large embayment, delimited on its southern side by the old Ceyhan River mouth. Minor features are a number of stream mouths scattered along the coast. The bay is weakly asymmetric, showing a sharper deepening on its southern side. This appears to be correlated to the main circulation

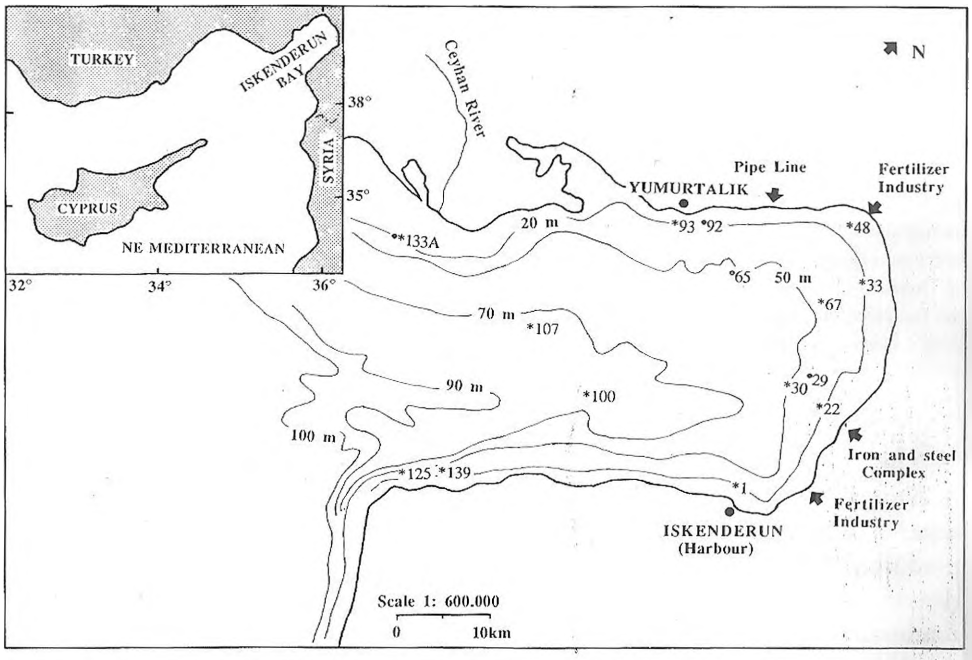

Fig. 1. – Location map of the Iskenderun Bay. Numbers with black spots indicate the position of cores; numbers with asterisks are referred to relevant grab samples.

pattern, producing an inflow close to the southern side of the bay and an outflow along its northern coast (Iyiduvar, 1986; Ylmaz *et al.*, 1992).

The bay is surrounded by a number of towns, and is intensely industrialized as compared with other parts of the Mediterranean coast of Turkey. Industrial facilities are mainly iron and steel complexes, fertilizer industries, a pipe line terminal (crude oil), petroleum loading stations, and a very busy harbour, discharging their wastes into the bay without any control, protection and treatment. The sea water in the Gulf of Iskenderun is, therefore, affected by different kinds of pollutants owing to such intense and uncontrolled discharge. Moreover, doubling of the population during summer months adds to pollution in the region. Thus, different kinds of pollution can be identified in the bay: heavy metal pollution due to the presence of a large iron-steel complex, high concentration of nitrate and phosphate due to the presence of two fertilizer industries, petroleum pollution related to the presence of petroleum processing and manufacturing facilities, and finally domestic sewege due to several densely populated towns and cities along the coast (Saydam *et al.*, 1984; Salihoglu *et al.*, 1987).

Materials and methods

Bottom sediments containing benthic foraminifera were recovered in about 140 stations located on a 3.5 miles grid by a 10 l Van Veen grab and in 4 stations by gravity corer. Sampling was denser along the coast, near the industries (0.75 miles grid) (tab. I). Sampled sites range in water depth from 7 to about 85 m. These samples were treated in a 4% formaline solution with sea water buffered with 20 grams of $Na_2B_4O_7$ (Na-borate) hydrate per liter. This procedure was used in order to prevent dissolution of calcium carbonate (Boltowskoy and Wright, 1976) and to preserve the citoplasm of living specimens.

Samples of macrobenthic flora and fauna were taken in order to sketch a preliminary distribution of benthic communities present in the area. Living benthic specimens (including foraminifera, algae, molluscs) were treated with a 4% buffered formaline solution. Where crustaceans were found, they were put in 80% alchool solution with marine water. Dead molluscs and algae were sampled from 0.6 1 of sediment and sieved through 2 mm mesh. In silty-clay samples, where macrofauna was very dispersed, qualitative observation and picking of specimens were performed.

Each grab was also subsampled for grain size, organic carbon, calcium carbonate and isotope analyses.

Coring was performed only in stations close to pollution sources along the coast, where high sedimentary rate of finest particles was previously observed in grab samples. Cores were recovered at station 29, 92, 65 and 133A (fig. 2). Two cores were taken for each site, one was opened on board, described, photographed and sampled each 10 cm, for heavy metals detection and benthic foraminiferal content. The second of the two raised cores was preserved untouched for X-rays analyses of sedimentary structures.

Since industrial discharges are expected to modify natural parameters of the sea

TABLE I. – *Latitude, longitude, and water depth of the investigated stations in the Iskenderun Bay.*

Stations	lat. N	long. E	depth (m)
1	36°35.89	36°09.69	18
2	36°37.50	36°07.80	53
3	36°37.77	36°09.77	51
4	36°38.18	36°10.80	19
5	36°38.74	36°11.79	27
6	36°39.74	36°10.26	51
7	36°39.15	36°12.49	11
8	36°40.43	36°12.44	7
9	36°40.69	36°11.40	31
10	36°41.38	36°11.79	10
11	36°40.72	36°08.93	56
12	36°41.77	36°10.09	42
13	36°42.31	36°10.67	32
14	36°42.85	36°11.63	8
16	36°41.67	36°07.52	57
17	36°42.76	36°08.75	44
18	36°43. 38	36°09.38	32
19	36°43.88	36°10.01	23
20	36°44.49	36°10.61	12
21	36°45.05	36°11.10	10
22	36°49.92	36°11.64	8
23	36°46.59	36°11.93	8
24	36°47.19	36°11.15	15
25	36°46.71	36°10.50	17
26	36°46.13	36°09.95	16
27	36°45.50	36°09.29	23
28	36°44.92	36°08.80	29
29	36°44.17	36°08.14	39
30	36°07.40	36°07.31	46
31	36°45.97	36°07.26	40
32	36°47.05	36°08.54	27
33	36°48.20	36°09.67	18
34	36°48.82	36°10.51	6
35	36°49.83	36°09.01	14
36	36°49 24	36°08.27	20
37	36°48.10	36°07.28	37
38	36°49.14	36°05.78	41
39	36°50.28	36°07 22	22
40	36°50.73	36°07.81	16
42	36°52.40	36°06.96	8
43	36°51.19	36°05.81	24
44	36°49 95	36°04.61	42
45	36°50 08	36°01.72	46
45A	36°51.25	36°03.11	38
46	36°52.14	36°04.44	20
47	36°53.13	36°05.45	8
48	36°54.67	36°02.22	8
49	36°54.46	36°01.96	10
50	36°53.13	36°00.51	23
51	36°52.00	35°59.04	35
52	36°53.30	35.57.67	21
53	36°53.89	35°59.25	18
54	36°55.25	36°00.07	8
56	36°54.20	35°58 58	11
57	36°53.30	35°57.33	9
59	36°51.26	35°54.88	8
60	36°50.78	35°55.07	18
61	36°49 68	35°56.43	42
62	36°50.71	35°57.87	41
63	36°50.79	36°00.51	43
64	36°49.74	35°59.40	47
65	36°48.72	35°58.05	51
66	36°47 69	35°59 19	54
67	36°47.59	36°04 98	49
68	36°45.70	36°01.98	60
69	36°43 67	36°04.74	60
70	36°39 50	36°05.00	68
71	36°41.60	36°02.20	68
72	36°43.49	35°59 54	63

Stations	lat. N	long E	depth (m)
73	36°45.43	35°56.77	56
74	36°47.56	35°54.06	41
75	36°48.88	35°52.22	9
76	36°46.78	35°49.62	10
77	36°46.26	35°50.32	21
78	36°45.33	35°51.65	42
79	36°43.34	35°54.55	56
80	36°41.38	35°56.82	60
81	36°39.38	35°59.70	70
82	36°37.20	36°02.49	70
83	36°35.03	36°05.20	37
84	36°34.45	36°06.32	11
85	36°32.85	36°03.04	13
86	36°34.95	36°00.02	71
87	36°37.01	35°57.26	73
88	36°38.95	35°54.49	68
89	36°40.89	35°52.00	62
90	36°43.00	35°50.20	48
91	36°44.17	35°50.44	45
92	36°45.40	35°49.10	23
93	36°45.96	35°48.12	10
94	36°45.52	35°45.79	12
95	36°44.65	35°47.02	22
96	36°43.08	35°44.52	22
97	36°40.84	35°46.68	56
98	36°38.74	39°49.44	69
99	36°36.77	35°52.11	73
100	36°34.91	35°54.80	76
101	36°32.70	35°57.54	63
102	36°30.64	36°00.64	11
103	36°28.56	35°57.50	12
104	36°30.42	35°54.84	52
105	36°32.47	35°52.23	78
106	36°34.41	35°49.25	76
107	36°36.60	35°46.80	72
108	36°38.50	35°44.00	62
109	36°40.79	35°41.04	21
110	36°38.29	35°38.76	13
111	36°36.22	35°41.34	55
112	36°34.41	35°44.26	75
113	36°32.25	35°46.85	79
114	36°30.35	35°49.71	82
115	36°28.27	35°52.47	52
115A	36°27.16	35°51.26	55
116	36°27.65	35°53.46	40
117	36°27.26	35°53.88	31
118	36°27.00	35°54.27	16
119	36°26.15	35°53.63	14
120	36°25.55	35°53.48	7
121	36°26.04	35°52.79	23
122	36°26.71	35°52.13	43
123	36°25.27	35°52.59	21
124	36°24.58	35°52.15	12
125	36°24.88	35°51.58	24
126	36°25.50	35°50.84	49
127	36°25.87	35°50.11	64
128	36°27.97	35°47.30	82
129	36°29.97	35°44.48	80
130	36°32.10	35°42.02	76
131	36°34.15	35°39.35	44
132	36°35.02	35°37.85	19
133	36°33.08	35°34.56	11
133A	36°32.67	35°35.17	22
134	36°31.86	35°36.65	61
135	36°29.80	35°39.31	76
136	36°27.86	35°42.09	82
137	36°25.84	35°44.97	85
138	36°23.71	35°47.73	79
139	36°22.35	35°49.96	12

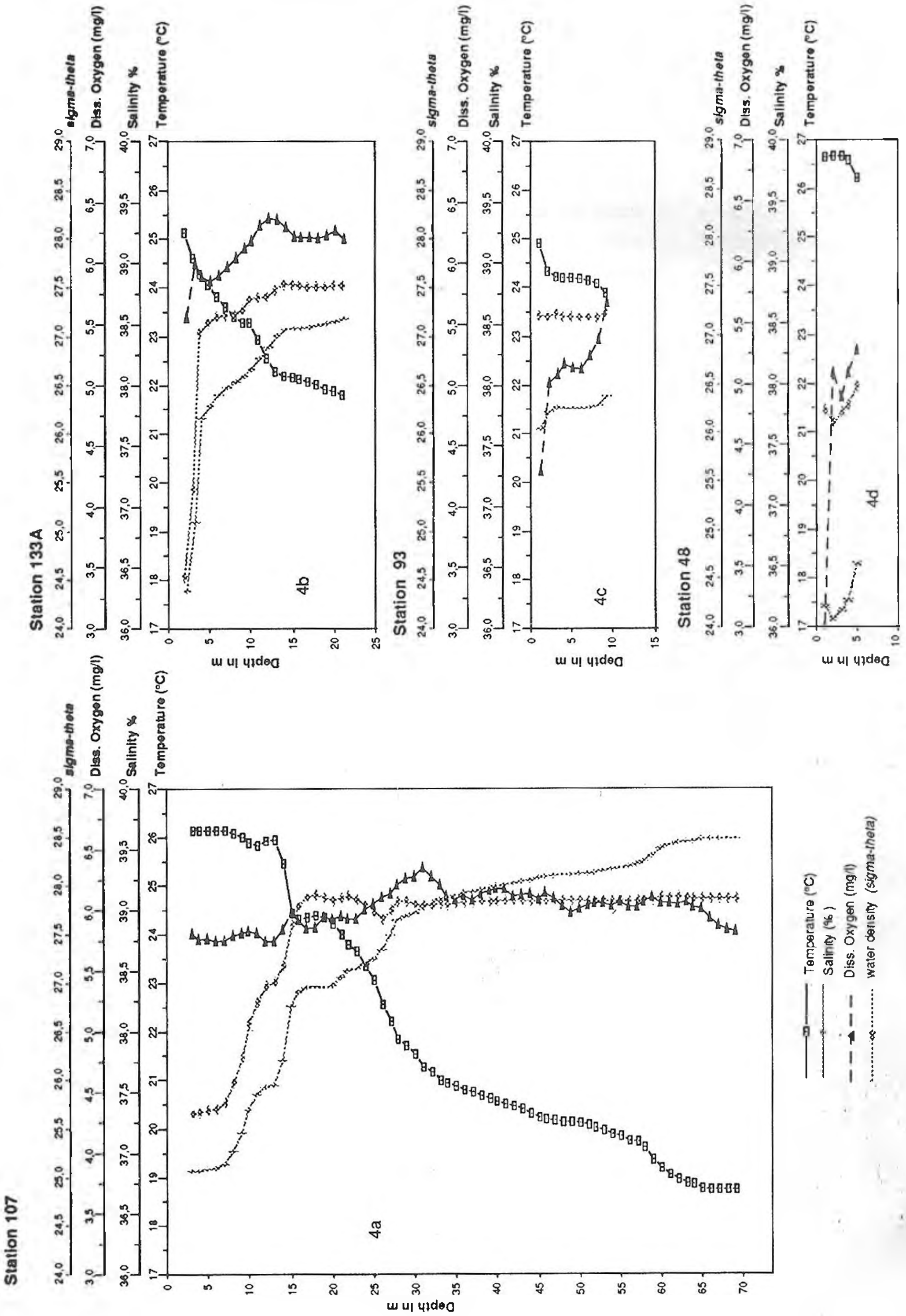

Fig. 2. – Chemico-physical data recorded in the Iskenderun Bay.

water, *i.e.* pH, temperature, salinity, water density and dissolved oxygen (DO), these measurements were taken for each of the 140 sampled stations. A pH meter Beckman *f*20 was used to measure pH of water taken close to the bottom. CTD equipment was provided by the Institute of Marine Sciences and Technology of Izmir.

Chlorophyll-α sampling was performed at three different levels of the water column: 5, 10 and 20 m from the sea surface. Water samples were taken by Niskin bottles rosette. Two liters of sea water for each depth were filtered through Gelman Sciences GN-6, 0.45 micron filters with a diameter of 47 mm. At the end of each filtering operation 1 ml of $MgCO_3$ (Magnesium Carbonate) was added to the sample water in order to preserve the chlorophyll-α until the processing in the laboratory. The filters were then frozen.

Preliminary results

1. Chemico-physical results

Eight stations were chosen as examples of spring oceanographic conditions. They are located along the coast, and in the deeper part of the Bay (tab. I).

The deepest profile was obtained at Station 107 (fig. *2a*). The steepest thermocline and pycnocline are located between 12-30 m depth. A rapid decrease in temperature (about 5 °C) corresponds to a rapid increase in density and salinity below 10 m depth. Dissolved oxygen ranges from about 5.7 to 6.2 mg/1, reaching its maximum at about 30 m depth.

Salinity values in the surface layer (about 37.3‰) are lower than those usually recorded in the Eastern Mediterranean, ranging from 38 to over 39‰ (Miller *et al.*, 1970; Stanev and Friederich, 1991). These lower values can be due to a fresh water tongue coming from the Ceyhan River. The fresh water input is still more evident at station 133a (fig. *2b*) where salinity and density are as low as 36.4‰ and 24.4 *sigma-theta* respectively.

Further inside the Bay, Station 93 is located in front of the town of Yumurtalik (fig. *2c*). The shallow water associated with uncontrolled seawage discharge probably produce the decrease of oxygen concentration in the sea water (4.3 mg/l at the surface).

Station 48 (fig. *2d*), located in the inner part of the Bay, is close to the Fertilizer Industry and to a small stream; the very high temperature recorded here (over 26.6 °C) together with the local and minor fresh water input are probably the causes of the lowest recorded water density (lower than 25 *sigma-theta*). It is likely that the fertilizer complex discharges nutrient-rich wastes and organic matter at sea. The oxidation of these compounds may be at the origin of the very low oxygen concentration.

Station 33 (fig. *3a*) represents the normal sea-water conditions along the coast.

Station 22 (fig. *3b*) is located in front of the iron-steel complex. All observed variables follow the same pattern discussed for station 48; however values are less extreme, since there is poor evidence of fresh-water input and oxidation processes.

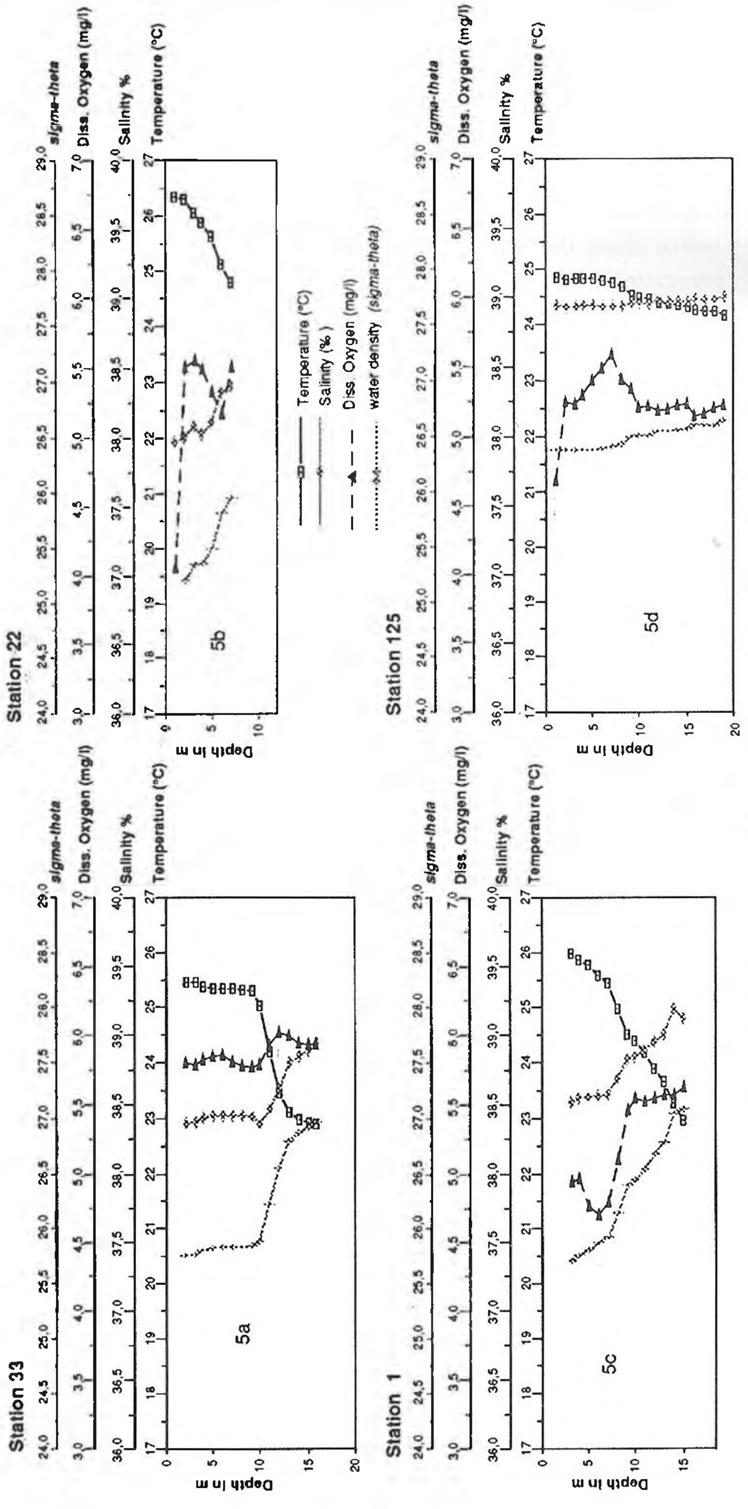

Fig. 3. – Chemico-phisical data recorded in the Iskenderun Bay.

Station 1 (fig. *3c*) located in front of the Iskenderun Harbour, shows a distinct decrease in oxygen concentration with a minimum at 5 m depth. Temperature values are slightly higher than that observed at station 33 taken as standard.

Along the southern coast, close to the connection with the open sea, station 125 (fig. *3d*) shows a water column with very homogeneous hydrological conditions. We already pointed out that the pattern of circulation of the sea-water in the bay shows a main inflow along the southern coast. It is likely that stronger currents exist in this area, generating the observed mixing in the water column, and allowing

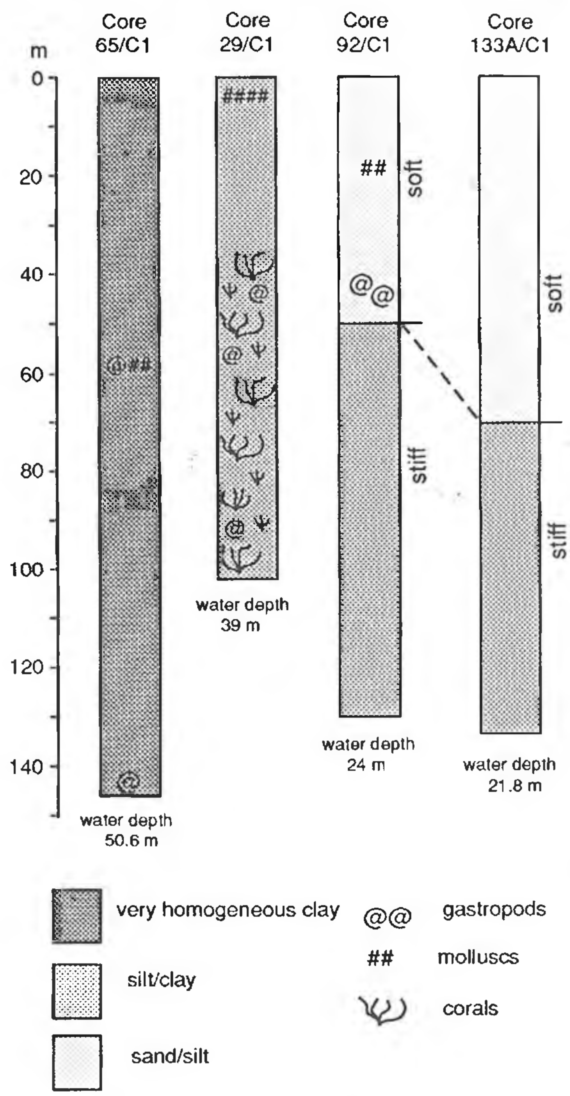

Fig. 4. – Lithologic log of the four cores recovered in the Iskenderun Bay.

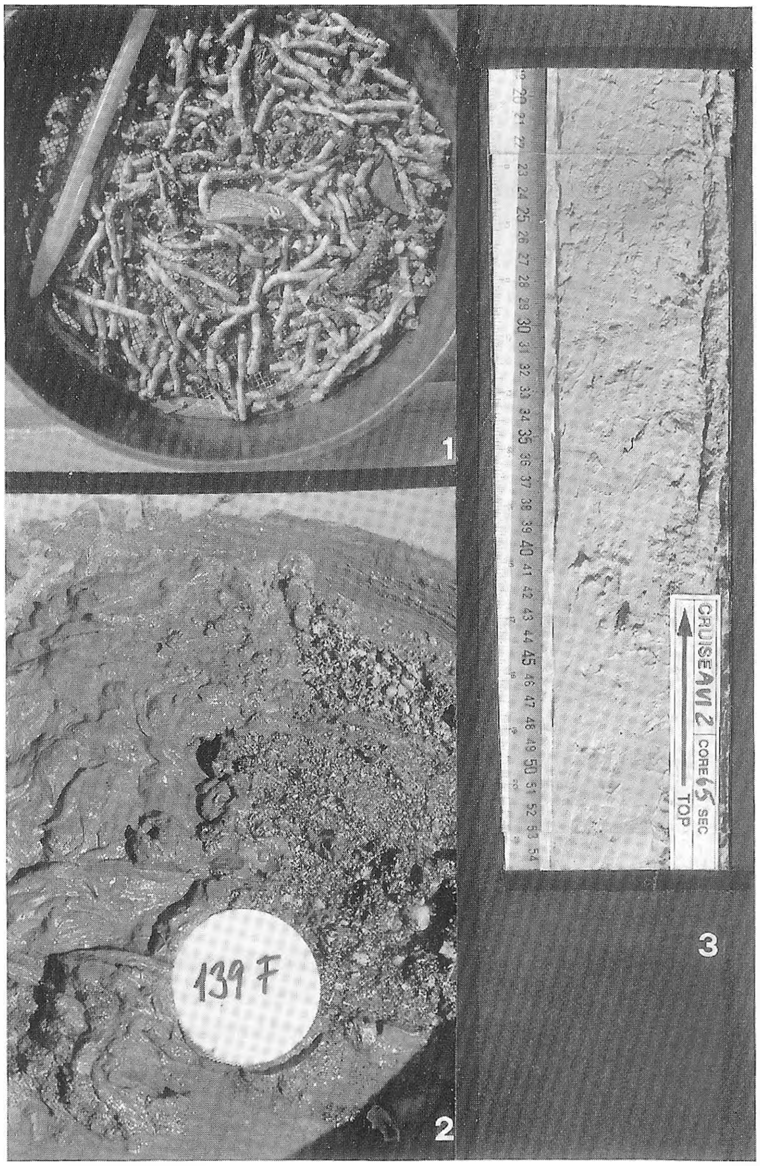

Fig. 5. – 1. *Cladocora caespitosa* and the mollusc *Arca noae* Core AVI II - 29, 35-70 cm; 2. Detail of Grab AVI II - 139 representing the transition from coarse sediment containing abundant biogenic remains (on the right) and the present day muddy sediment (on the left); 3. Detail of Core AVI II - 65. The homogeneous sediment consists of sandy-mud.

the development of current-loving macrobenthic assemblages such as the coralline-rich detritic bottom (see point 3).

2. Sediment distribution in space and time

A qualitative investigation of sediments grain size allowed to sketch a preliminary map of distribution of the sediments in the bay.

The recovered sediments mostly consist of silty clays. They are distributed in the deepest area of the bay, deeper than 45 m depth. Silty sands are recovered at shallower depth (above 45 m) and are common along the north-eastern coast, and in front of Yumurtalik. Coarse gravelly sediments are confined to the south-eastern side of the bay.

2.1 Description of cores

Cores were raised at four sites (29, 65, 92 and 133A).

Core 29 (figs. 1, 4), was recovered in front of the iron-steel complex of Yakacik, at a water depth of 39 m (3644.17N, 3608.14E). This core contains mainly greenish-grey clay and silt (5Y5/1) with abundant bioclasts. At the top of the core is observed a concentration of probably living molluscs, mainly bivalves in life position. Rare large bivalves (*Arca noae*) are randomly distributed along with very abundant remains of the coral *Cladocora caespitosa* (fig. 5:1). This assemblage is drowned under 35 cm of homogeneous mud, indicating a drastic change in sedimentary regime.

Such change is not evident in the other cores. Core 92 recovered along the coast of Yumurtalik at a water depth of 24 m, Core 133 recovered close to the mouth of River Ceyhan at a water depth of 21.8 m and Core 65 recovered in front of the Botas oil pipe terminal, at a water depth of 50.6 m are more homogeneous (fig. 4). Sediments consist of homogeneous greenish-grey clay (5Y5/1) (Core 65) and soft, coarser sandy silt sharply passing to stiffer and finer silty clay (Cores 133 and 92). Biogenic remains are rare and randomly distributed.

Since the sedimentary rate in the Iskenderun Bay is not known, and faunal assemblages do not provide information about the age of the deeper sediments recovered, we can only assume that they were deposited during the Holocene until radiocarbon dating will be available.

3. Living macrobenthic assemblages and fossil remains: ecologic significance

Living flora was mainly located along the southern coast, in front of Ulucinar, at depth ranging from about 12 to 51 m. Two different situations were observed. The first was characterized by multidecimetric concretions of coralline red algae (fig. 6:1), corresponding to the «coralligenous» hard bottom (= C; Pérès and Picard, 1964); the second was a soft bottom of coarse biogenic gravel mainly composed by branched free living corallinacean species and abundant molluscan remains, referable to the coastal de-

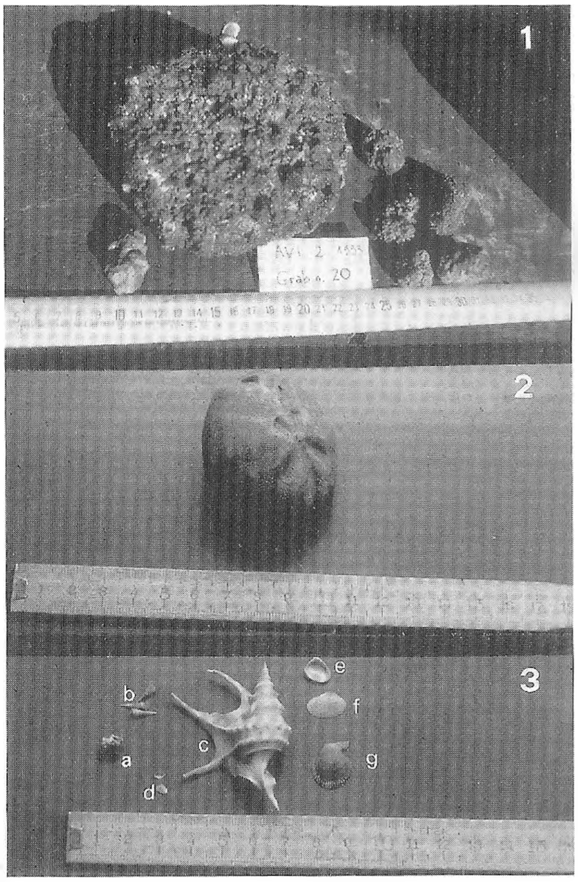

Fig. 6. – 1. Corallinacean rhodoids from Grab AVI II - 20; 2. Dead specimen of *Brissopsis lyrifera* recovered in Grab AVI II - 98; 3. Macrofaunal thanatocoenosis recovered in Grab AVI II - 86. *a*) *Sertella* sp. (Bryozoa); *b*) *Turritella communis*; *c*) *Aporrhais pespelecani*; *d*) *Corbula gibba*; *e*) *Nucula sulcata*; *f*) *Abra alba*; *g*) *Chlamys varia*.

tritic community (= *DC*; Pérès and Picard, 1964). The presence of these two communities corresponds to the coarsest sediments recovered in the area, and also with the main direction of the inflowing water (Iyiduvar, 1986; Ylmaz *et al.*, 1992).

It is likely that, due to the particular hydrological conditions, this area would be scarcely polluted.

Apparently, no macroflora lives in most part of the bay, where muddy sediments dominate.

Living molluscs were also very rare in the same sediments. Along a transect parallel to the southern coasts, at about 80 m depth, dead specimens of *Aporrhais pespelecani, Turritella communis*, and *Acanthocardia echinata* were found in most samples. *Aporrhais pespelecani* is recorded in mixed sediments (coastal detritic/muddy detritic communities), or in sandy muds (Pérès and Picard, 1964), while *T. communis* is characteristic of the terrigenous mud community (*VTC*; Pérès and Picard, 1964). Along another transect parallel to the northern coasts, at about 70 m depth, almost all samples contained remains of Spatangoida and dead shells of *Turritella*; at least in two grab samples (100 and 107 at a water depth of 76 m and 72 m respectively) these Spatangoida (*Brissopsis lyrifera*) have been found living. In several other grab samples dead specimens of *B. lyrifera* have been found (fig. 6:2). *Brissopsis lyrifera* is a mud-loving species, frequently found in muddy bottoms of the bathyal zone (Pérès and Picard, 1964). These observations lead to hypothesize an evolution of the bottoms over about 45 m depth, from sandy muds tentatively related to the muddy detritic community (= *DE*; Pérès and Picard, 1964), to the present-day terrigenous mud bottoms (= *VTC*). The assemblage characterized by *T. communis* and *B. lyrifera* was also found on clay-silt bottoms at 60-80 m, in the Haifa Bay, along the Israeli coast (Tom and Galil, 1991), and related to the coastal terrigenous mud biocoenosis of Picard (1965) (fig. 6:3).

At the easternmost end of the bay, in some grab samples (es. Grab 30, water depth 46 m; Grab 67, water depth 49 m) the bivalve *Spondylus* sp., and large bryozoan colonies typical of hard bottom, were drowned by sandy mud. Fossil hard bottom assemblages of these grab samples are correlatable with corals observed in Core 29; thus these observations provide further evidence of gradual and progressive drowning of a pre-existing hard bottom. A similar situation was observed in front of Konacik, at Station 139, located at only 12 m depth. Here the grab sample showed a coarse biogenic sand, mainly composed by mollusk shells, covered by few centimeters of silty clay (fig. 5:1).

The dramatic change in the sedimentary regime of the area, from hard bottoms or coarse sediments to mainly muddy sediments may be due to intense human activity occurring in the neighbouring territories (Basso *et al.*, 1990); alternatively, Holocene sea-level rise can be taken into account. Radiometric age determinations now in progress will hopefully clarify the issue.

Acknowledgements

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