Mediterranean Marine Science

Vol 1, No 1 (2000)

Holocene palaeoceanographic evolution of the Iskenderun bay, South-Eastern Turkey, as a response to river mouth diversions and human impact

S. SPEZZAFERRI, D. BASSO, H. KORAL

doi: 10.12681/mms.3

To cite this article:

SPEZZAFERRI, S., BASSO, D., & KORAL, H. (2000). Holocene palaeoceanographic evolution of the Iskenderun bay, South-Eastern Turkey, as a response to river mouth diversions and human impact. *Mediterranean Marine Science*, *1*(1), 19–44. https://doi.org/10.12681/mms.3

Mediterranean Marine Science
Vol. 1/1, 2000, 19-43

Holocene palaeoceanographic evolution of the Iskenderun Bay, South-Eastern Turkey, as a response to river mouth diversions and human impact

S. Spezzaferri[1], D. Basso[2] and H. Koral[3]

[1] Geologisches Institut, ETH-Zentrum, Sonneggstrasse 5, 8092 Zurich, Switzerland
e-mail: silvia@erdw.ethz.ch.

[2] Dipartimento di Scienze della Terra, Via Mangiagalli 34, 20133 Milano, Italy
e-mail: daniela.basso@unimi.it

[3] Department of Geology, Istanbul University, Avcilar 34850 Istanbul, Turkey
e-mail: h_koral@hotmail.com

Manuscript received: 7 July 1999; accepted in revised form: 3 January 2000

Abstract

A quantitative study of benthic foraminifera, sediment texture and composition from two cores was performed to unravel the environmental evolution of the Iskenderun Bay (eastern Turkey) in the Holocene. Core 29 (NE Iskenderun Bay) consists of clay and silt from the top of the core down to 35 cm with dominant bioclasts (coral Cladocora caespitosa) from 35 cm down to the bottom of the core. Core 92, located near an ancient Ceyhan River mouth (Yumurtalik), consists of sandy and silty sediment passing to homogeneous clay and silt at about 48 cm from the top. Several grab samples show very coarse biogenic detritus covered by a centimetric veneer of sandy silt and clay. Radiocarbon dating of corals, molluscs and algae from core 29 and five selected grab samples, the sediment and foraminiferal study indicate that at least three pulses of muddy sedimentation occurred in the bay. (1) An older pulse (about 3700 yrs BP) related to the large-scale forest clearing (Beysheir Occupation Phase). (2) Another pulse coincides with a major delta progradation of the Ceyhan River at about 2140 years BP. (3) A younger pulse follows the diversion of the Ceyhan River mouth toward Yumurtalik, from the Middle Age to 1935.

Species interpreted as tolerant of low salinity indicate that the influence of the Ceyhan was minor when the river drained directly into the Mediterranean Sea (approximately 2000 years BP) and progressively increased when the river diverted towards Yumurtalik.

Keywords: Holocene, Iskenderun, Ceyhan River, Palaeoenvironmental evolution, Benthic foraminifera, Human impact.

Introduction

During the years 1993-1995, an Avicenne Project (EU) among Italy, Israel and Turkey was aimed to develop and test a new method of biological monitoring of marine pollution using benthic foraminifera from the Iskenderun Bay (eastern Turkey) and Haifa and Atlit Bays along the Israeli coast (Yanko, Kronfeld & Flexer, 1994; Basso *et al.* 1994; Bresler & Yanko, 1995). Sampling cruises were carried out in these three bays in

Summer 1994 and were repeated in Winter 1995.

This project also provided the opportunity to study the biological and environmental evolution of the Iskenderun Bay in the Holocene (Fig. 1a). For this purpose, cores were taken at key points within the bay: Core 29, located in an area of intense, recent, anthropogenic impact, and Core 92, located in front of the ancient Ceyhan River mouth. A multidisciplinary study including quantitative analyses and statistical treatment of data of benthic foraminifera, sediment texture and calcium carbonate content, radiocarbon dating of corals, molluscs and algae and stable isotopes (oxygen and carbon) of benthic and planktonic foraminifera was performed on two of these cores (Cores 29 and 92). Radiocarbon dating and faunal investigations were carried out also on Grab Samples 30, 67, 116 and 139.

Geological and physiographic setting

The Iskenderun Bay is a relatively long, narrow and shallow basin extending NE along the easternmost Mediterranean coast of Turkey (Fig. 1a). The maximum depth along the main axis of the bay is about 70 m, gradually deepening SW, toward the open sea, where the depth reaches about 90 m. The south-eastern flank of the bay is steeper than the north-western one. Along the south-western coast of the bay there is a delta formed by the abandoned mouth of the Ceyhan River. This river is the major source of terrigenous sediments into the bay. The shape and the structure of the bay is controlled by the position and direction of a number of quaternary faults, which reflect the active tectonic framework of the region (AKSU *et al*., 1992). The bay is seismically active and located on a major strike-slip fault, the Eastern Anatolian Fault. Local, gentle elevations or weak depressions of the bottom are formed by horsts and grabens generated by this fault system (AKSU *et al.*, 1992; KORAL, 1995). Changes in the bathymetry are in turn responsible for local irregularities in the distribution of sediments (KORAL, 1995).

Historical documentation

The Adana basin, filled with Neogene-Quaternary deltaic sediments, represents the onshore extension of the Cilicia and Iskenderun Basins (Fig. 1b). Since the Neolithic time (approximately 8500 years BP) through the pre-Hittites time (3000-4000 years BP) until the present day, the Adana Basin was occupied by numerous human settlements, especially along the coasts, where evidence can be found in the large number of burial mounds in the delta plain (AKSU *et al.*, 1992).

The Ceyhan River occupies the eastern part of the Adana Basin and displays intensive meandering and a complex channel history. Aerial photographs and historical data show a complex progradational history for its delta at least for the last 2000 years (AKSU *et al.*, 1992).

Documents from the classical time report that the Ceyhan River drained directly into the Mediterranean Sea, outside the bay. We also know that the southern hill of the Misis Mountain, located along the coast in the eastern part of the Adana Basin (Fig. 1b), was an island and that its northern portion was blanketed by the Ceyhan River delta progradation at about 2000 yrs BP (Strabo, Book, XIV. 5.16 as in JONES, 1949).

During the Middle Age, the Ceyhan River mouth diverted towards the more eastern Yumurtalik mouth inside the Iskenderun Bay. This mouth was active until 1935 (RUSSEL, 1954; AKSU *et al.*, 1992). Unfortunately, no information about the timing of other Ceyhan River mouth diversions is available from the historical literature.

Materials and methods

The field work was carried out with the Turkish research vessel K. Piri Reis during June 1993 (Cruise AVI-II-93). Ship positioning

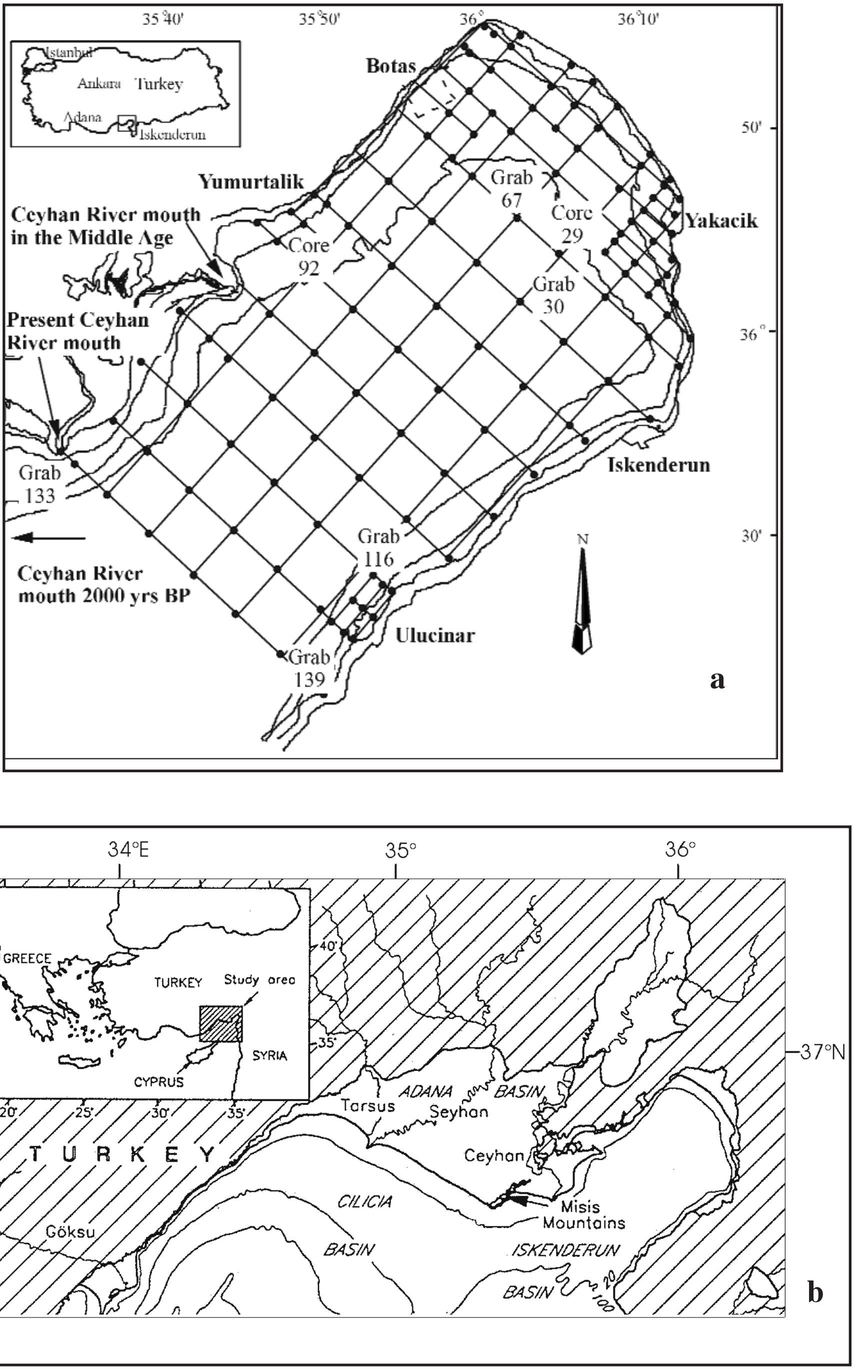


Fig. 1a,b: (a) Map of the Iskenderun Bay (eastern Turkey) showing the location of Cores 29 and 92 and grab samples mentioned in the text and sampled during the spring of 1993. Black dots indicate the position of all the stations sampled during the same cruise. (b) Map of the Adana, Cilicia and Iskenderun Basin (modified from AKSU *et al.*, 1992).

and station depths were obtained by GPS.

Coring was performed with gravity corer in selected stations along the coast of the Iskenderun Bay where high sedimentation rate was expected. Cores recovered at Sites 29 (water depth 39 m) and 92 (water depth 24 m) revealed significant lithological variations and were studied in more detail (Fig. 1a).

Samples for faunal investigation were soaked in distilled water, washed under running water through 40-150 □m, 150-250 □m and 250-500 □m and > 500 □m mesh sieves to separate the larger, smaller and eventual juvenile specimens. Each fraction was dried at room temperature and weighed. The percent abundance of each dried fraction over the total sediment was calculated and abundance curves were constructed (Fig. 2). Fractions were also used to obtain more precise indications on the dominant grain size and to identify eventual variations in abundance of the single fractions which may be related to sorting and/or displacement as in use for planktonic foraminifera (Premoli Silva, Castradori & Spezzaferri, 1993; Spezzaferri, 1995). The three size fractions obtained were related to the grain size categories as follows: < 40□m = silt and clay, 40-150 □m = very fine to fine sand and silt, 150-250 □m = fine sand, 250-500 □m = medium sand, > 500 □m = medium and coarse sand.

Samples were then re-assembled for qualitative and quantitative study. For the quantitative study, three hundred specimens of benthic foraminifera were counted for each sample. Abundance of each species is reported in Tables 1-2. The calcium carbonate content was measured on bulk samples using a modified Bernard calcimeter (Fig. 2).

Fifty to one hundred specimens of very small-sized *Bulimina aculeata* (benthic foraminifer) and 10 to 20 specimens of Globigerinoides ruber (planktonic foraminifer) were picked, whenever possible, from each sample for stable isotope analyses. Oxygen and carbon isotopes were measured using a PRISM Mass Spectrometer in the Stable Isotope Laboratory of the Geological Institute of the ETH-Zurich. The isotope data, corrected following the procedure of Craig (1957) modified for a triple collector and relative to the international standard Pee Dee Belemnite (PDB), together with the data of weight of size fractions and carbonate content are given in Table 3.

Radiocarbon dating of macrobenthos (about 40 g per sample) was performed at the Rome University "La Sapienza", Department of Physics, and results have been calibrated with the Radiocarbon Calibration Program Rcv.3.0 (Stuiver & Reimer, 1993) and rounded in function of the error (Table 4). Throughout the text data are expressed as years BP, for uniformity.

Results

Core 29

Core 29 was recovered along the coast of Yakacik at a water depth of 39 m (Fig. 1a). The sediments consist mainly of greenish-grey clay and silt from the top of the core down to 35 cm sharply passing to dominant bioclasts from 35 cm to the bottom of the core. At about 5 cm from the top (Fig. 2), a concentration of molluscs includes the bivalves *Nucula sulcata*, a strictly mud loving species, *Nuculana pella* and *Corbula gibba* exclusive characteristic of bottoms influenced by sedimentary instability (Peres & Picard, 1964). From about 35 cm down to the bottom of the core dominant remains were observed of a colony of the coral *Cladocora caespitosa*, apparently in life position, accompanied by randomly distributed *Arca noae* (bivalve mollusc). This well developed coral colony required clear water and low muddy input: therefore, both macrobenthic assemblages and the sediments indicate a dramatic change in the sedimentary regime of this site.

The curve obtained from the >500 □m size fraction shows a general decrease moving

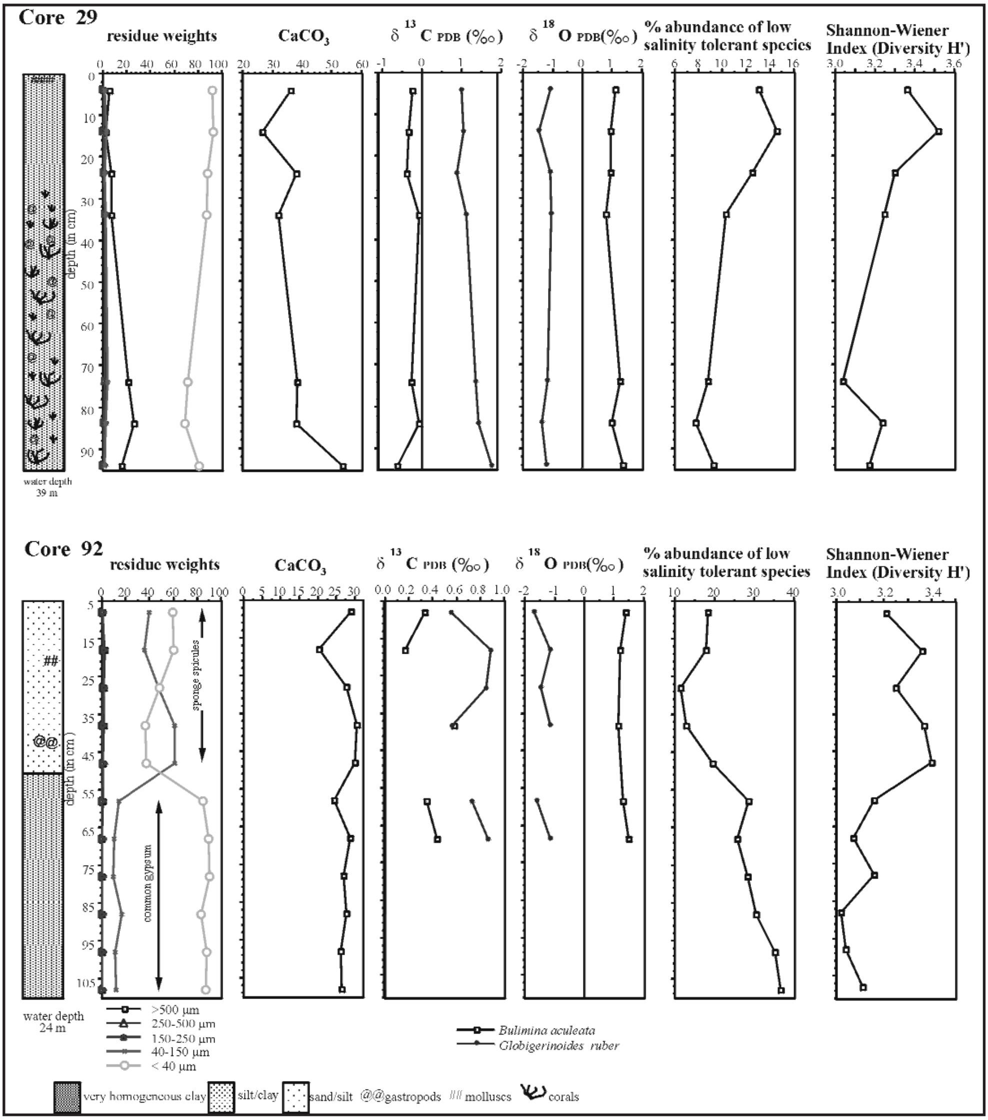


Fig. 2: Plots of residues weight, calcium carbonate content, oxygen and carbon isotopes, percent abundance of low salinity tolerant species, Shannon-Wiener Index (H') through the cores. Higher H' indicate higher species diversity.

up the core (Fig. 2) with values ranging from 27 to 2%. In the uppermost 35 cm of the core this variation is due to the lower abundance to absence of small coral fragments. The curve of the <40 □m size fraction shows an opposite trend, with clay and silt increasing from the bottom to the top of the core.

Calcium carbonate content varies from 26.69 to 53.65 wt % and follows the curve of the > 500□m size fraction. High values are due to abundant biogenic remains throughout. Only at about 84 cm, the higher value of the >500 □m size fraction corresponds to a low value of the calcium carbonate content (Fig. 2).

The □^{18}O of the benthic foraminifera from Core 29 does not show any significant trend and ranges from 0.79‰ to 1.35‰.

TABLE 1-2

Quantitative distribution of benthic foraminifera in samples from Cores 92 and 29, Iskenderun Bay (eastern Turkey). Ninety-four species of benthic foraminifera were identified in the eighteen studied samples.

Core 92	8-9	18-19	28-29	38-39	48-49	58-59	68-69	78-79	88-89	98-99	108-109
Adelosina cliarensis	17	15	8	20	28	21	25	23	38	15	18
Adelosina duthiersi	1			3	3	2			2		1
Adelosina italica				4	2	2	1		1		1
Adelosina mediterranensis	6	6	2	4	6	1	2	8	4	6	7
Adelosina sp.1	6	6	6	4	4	5	3	4	5	3	3
Ammonia beccarii	29	40	44	31	21	24	36	40	26	38	32
Ammonia gaimardi	21	14	19	17	18	15	17	21	20	14	8
Ammonia parkinsoniana				4	9	15	9	10	15	20	25
Ammonia tepida	11	4		6	7	10	7	6	7	3	1
Asterigerinata mamilla	5	6	3	2	1	4	4				2
Astrononion stelligerum	8	5	10	6	9	9	4	3	10	3	10
Bolivina punctata		10	5	2	1	1	1	10	2	9	4
Brizalina alata				1			1				
Brizalina dilatata									1		
Brizalina spathulata		1									
Bulimina aculeata	1	10	15	2	2	5	4	5		1	
Bulimina elongata	3	13	5	1	3	2		1			
Conorbella paterlliformis		2	5								2
Cornuspira involvens		1	2	2	1						1
Coscinospira hemprichii		3	1	1	1						
Cycloforina rugosa	4	1	1	1	1						
Cycloforina tenuicollis	3	3		1	1			1		1	
Elphidium crispum	22	11	22	27	15	26	26	13	13	11	11
Elphidium macellum	14	3	10	7	5	20	11	10	15	6	7
Elphidium pauciloculum						1					
Elphidium sp. 4	13	5	2	5	8		2	3	4		4
Elphidium sp. 5						1	1	3	3	9	6
Elphidium cuvilleri					5	7	4	10	13	6	15
Eponides concameratus											1
Fursenkoina acuta		1						4		2	
Guttulina lactea	1										
Gyroidina soldanii							1				
Hainesina depressula	7	10	6	2	6	8	13	25	6	33	25
Hyalinonetrion gracillium					1	5				1	
Lachlanella bicornis	1							1			1
Lenticulina cultrata							1				
Melonis barleanum				1	2		1				
Miliolinella labiosa	5	5	8	7	12			2	1	4	1
Miliolinella elongata		2	6	1	2					3	3
Miliolinella subrotunda		17	13	14	12	9	5	9	6	15	6
Neopeonides bradyi	14	14	12	9	9	15	22	11	5	10	7
Neouvigerina porrecta subs.A		1									
Nodophtamidium antillarum	1	1		1							
Nonionella turgida		1			3		1	1	4	1	1
Nonionides grateloupi			4	1	4		4	8	2	1	1
Peneroplis planatus	1	2	2	2	2			1			
Planorbulina mediterranensis	1	1			1			1			
Porosononion subgranosum	26	23	19	20	27	43	43	34	51	48	44
Pseudotriloculina oblonga	2	5	5	3	2	1				1	
Quinqueloculina bosciana		1	1								
Quinqueloculina jugosa						1					
Quinqueloculina laevigata	2	3	1	2	6	5	4	2	6	6	2
Quinqueloculina seminula			4	2	2	2	2				2
Quinqueloculina viennensis		1				2		1	2		2
Reussella spinulosa	14	9	4	8	8	4	6	5	2	3	4
Rosalina bradyi	4	3	4	1	2	3		3		3	
Rosalina globularis							6				1
Rotomorphina? involuta						2	1				
Sigmoilinita costata	1										
Siphonaperta agglutinans	5	10	7	12	10	3	6	3	5	3	3
Siphonaperta aspera						1	1	3			
Siphonaperta irregularis	1	1	6	7	1	1	1				
Sorites orbiculus				1							
Spiroculina tenuiseptata											1
Spiroloculina ornate tricarinata	7	7	5	17	9	3	7	3	5	4	2
Textularia bocki	21	19	24	15	22	15	4	10	12	14	15
Triloculina affinis	1	2									
Triloculina marionii	10	6	7	11	9	7	13	10	8	10	16
Triloculina plicata									1		
Triloculina serrulata	1										
Triloculina tricarinata			3	5	1	1			3	2	1
Triloculina trigonula	7	5	1	4				1	1		
Vertebralina striata	2	1	1	3	2	1	2				

Core 29	3-5	13-15	23-25	33-35	73-75	83-85	93-95
Adelosina cliarensis	7	7	12	10	20	8	7
Adelosina duthiersi	6	5	8	5	2		5
Adelosina elegans						1	
Adelosina italica	1	5					
Adelosina mediterranensis	5	10	13	10	3	10	16
Adelosina sp.1	3	6	3	5	9	10	6
Ammonia beccarii	16	14	21	25	25	13	6
Ammonia gaimardii	12	5	1	3		2	1
Ammonia tepida	8	6	4	1			
Asterigerinata mamilla	9	16	15	30	39	43	47
Astrononion stelligerum	18	5	11	7	7	17	7
Bolivina variabilis	7	4	3	11		4	3
Brizalina spathulata			1				
Brizalina italica			1				
Bulimina elongata	4	9	2				
Bulimina aculeata	15	4	2	2		5	
Cassidulina laevigata	2						
Conorbella patelliformis	18	10	17	5	7	3	2
Cornuspira involvens	5	5	3	1	2	3	
Cymbaloporetta sp.1						1	
Elphidium crispum	21	31	26	24	26	10	35
Elphidium macellum	13	9	3	9	6	8	9
Elphidium sp.5	4	4	5	1	1		3
Elphidium jenseni				1			
Eponides concameratus	1	3	2	2		1	1
Fissurpolymorphina williamsoni	3	1					
Fursenkoina acuta						1	1
Globocassidulina subglobosa		1		1			2
Haynesina depressula	2	4	2	9	2	5	4
Haplophragmoides sp.							1
Lachlanella bicornis					3	3	7
Lachlanella undulata	3	5	6	8	15	17	19
Lachlanella variolata				1	1		
Lobatula lobatula		4	3	4	2	1	3
Melonis barleeanum		3	7				
Miliolinella labiosa					2		1
Miliolinella subrotunda	1	6		2	5	10	7
Miliolinella webbiana						1	1
Neoeponides bradyi	17	8	6	12	19	5	8
Nonionella turgida			1			2	
Nonionoides grateloupi	2	7					
Peneroplis pertusus	7	4	4				
Planorbulina mediterranensis					2	5	6
Porosononion subgranosum	21	19	20	15	23	15	22
Pseudotriloculina oblonga	1	2	1	3	1	4	2
Pyrgo elongata						1	
Quinqueloculina bosciana	3					7	3
Quinqueloculina laevigata							3
Quinqueloculina parvula				1			
Quinqueloculina seminula		1	1				
Quinqueloculina viennensis		1	1	2			
Rectuvigerina phlegeri						3	
Reussella spinulosa	2	5	3	1	14	12	11
Rosalina bradyi	15	11	13	20	9	24	19
Sigmoilinita costata	2	6	10	3		3	3
Siphonaperta agglutinans	5	5	1	1	14	2	8
Siphonaperta irregularis						1	
Siphonina reticulata	3	2	4	5			
Sphaerogypsina globula					3	1	4
Spiroloculina dilatata	1	1					
Spiroloculina excavata				1			
Spiroloculina ornata tric.	2	3	1	2	5	2	2
Textularia bocki	14	16	29	21	16	35	32
Triloculina marioni	20	19	20	22	16	10	13
Triloculina plicata			2	1	8	12	16
Triloculina tricarinata	1	4	4	6	1	2	
Triloculina trigonula	5	6	9	6			
Valvulineria bradyana							1
Vertebralina striata	1	7	2	1			

TABLE 3

Residues weight, calcium carbonate content, carbon and oxygen isotope ratios (‰, PDB) of planktonic and benthic foraminifera from Cores 29 and 92.

Core 29

Sample (in cm)	weight of dry sediment	>500 (wt in gr.)	250-500µm (wt in gr.)	150-250µm wt (in gr.)	40-150µm (wt in g.)	<40µm (wt in gr.)	CaCO3 (wt %)	δ 13C benthic foram.	δ 18O benthic foram.	δ 13C plankt foram	δ 18O plank. foram.	Shannon-Wiener Index (H')
3-5	24,91	1,30	0,13	0,24	0,35	22,89	36,23	-0,23	1,10	1,01	-1,08	3,36
13-15	54,56	1,15	0,62	0,51	1,57	50,71	26,69	-0,33	0,96	1,04	-1,45	3,52
23-25	65,79	4,66	1,03	0,73	1,15	57,87	37,95	-0,37	0,94	0,88	-1,07	3,30
33-35	69,24	4,92	1,50	0,89	1,40	60,53	32,05	-0,06	0,79	1,12	-1,04	3,25
73-75	53,03	11,16	1,20	0,92	1,95	37,80	38,47	-0,26	1,28	1,36	-1,19	3,04
83-85	31,72	8,36	0,38	0,25	0,71	22,02	37,99	-0,06	0,97	1,42	-1,38	3,24
93-95	38,63	6,13	0,45	0,17	0,51	31,37	53,65	-0,61	1,35	1,75	-1,22	3,17

Core 92

Sample (in cm)	weight of dry sediment	>500 (wt in gr.)	250-500µm (wt in gr.)	150-250µm wt (in gr.)	40-150µm (wt in gr.)	<40µm (wt in gr.)	CaCO3 (wt %)	δ 13C benthic foram.	δ 18O benthic foram.	δ 13C plankt foram	δ 18O plank. foram.	Shannon-Wiener Index (H')
8 9	51,10	0,04	0,16	0,22	20,10	30,58	28,90	0,33	1,38	0,56	-1,69	3,21
18-19	77,92	1,57	0,32	1,38	27,54	47,11	20,44	0,17	1,20	0,89	-1,16	3,36
28-29	71,26	1,15	0,32	1,22	34,08	34,49	27,69	-	-	0,85	-1,47	3,25
38-39	78,48	1,15	0,28	0,57	47,85	28,63	30,60	0,58	1,14	0,57	-1,16	3,37
48-49	70,99	0,69	0,30	0,46	43,31	26,23	30,06	0,56	1,42	0,47	-1,53	3,40
58-59	51,47	0,32	0,08	0,04	7,37	43,66	24,28	0,35	1,31	0,73	-1,58	3,16
68-69	48,07	0,09	0,04	0,08	4,78	43,08	28,80	0,43	1,50	0,87	-1,13	3,07
78-79	46,65	0,12	0,03	0,15	4,29	42,06	26,86	-	-	-	-	3,16
88-89	47,66	0,03	0,03	0,07	7,95	39,58	27,70	-	-	-	-	3,02
98-99	45,90	0,04	0,05	0,18	5,02	40,61	26,25	-	-	-	-	3,04
108-109	42,53	0,02	0,08	0,10	5,10	37,23	26,37	-	-	-	-	3,11

The δ^{18}O of planktonic foraminifera is rather invariant throughout with a slight more negative excursion at 18-19 cm from the top of the core. Values range from -1.04‰ to -1.45‰ (Fig. 2, Table 3).

The Carbon isotope record shows a trend toward less positive values for planktonic foraminifera with the δ^{13}C ranging from 0.88‰ to 1.75‰. Benthic foraminifera display a δ^{13}C values slightly more positive up to Sample 33-35 cm and then slightly more negative to the top of the Core, the δ^{13}C ranges from -0.06‰ to -0.61‰ (Fig. 2, Table 3).

Core 92

Core 92 was recovered along the coast of Yumurtalik at a water depth of 24 m (Fig. 1). It consists of homogeneous greenish-grey clay and soft fine sand and silt passing to stiffer and finer silty clay from about 50 cm downward. Only the curves of the finer size fractions (40-150µm and <40µm) show significant variations with values ranging from 11.9 to 60.9% and 36.94 to 90.16% respectively (Fig. 2). The curve of the 40-150 µm size fraction displays a general trend toward increasing values from the bottom to the top with a sharp positive excursion up to the 60 % at about 50 cm from the top. The reversed trend is shown by the curve of the <40 □m size fraction.

Both patterns reflect higher abundance of fine sand and silt in the uppermost 50 cm of the core.

The values of the calcium carbonate content vary from 20.44 to 30.6 wt % without significant variations. Its curve is similar and mostly parallel to that of the 40-150 □m components (Fig. 2).

Siliceous sponge spicules are commonly present from the top of the core down to Sample 48-49 cm. In Samples 59-59 cm to 88-89 cm, gypsum is a common component of the 40-150 □m to >500 □m size fractions, whereas in Sample 98-99 cm wood fragments are abundant and gypsum is absent.

The isotope record is not complete for Core 92. Suitable specimens for isotopic analyses were not available especially in the lowermost 60 cm. Missing data include the interval where the lithologic change is observed within the core. The values of the □^{18}O of both planktonic and benthic foraminifera do not show any significant variations. The more positive values of the □^{13}C, occurring in Samples 15-18 cm and 35-38 cm, are about 0.5 and 0.3‰ respectively (Tab. 3).

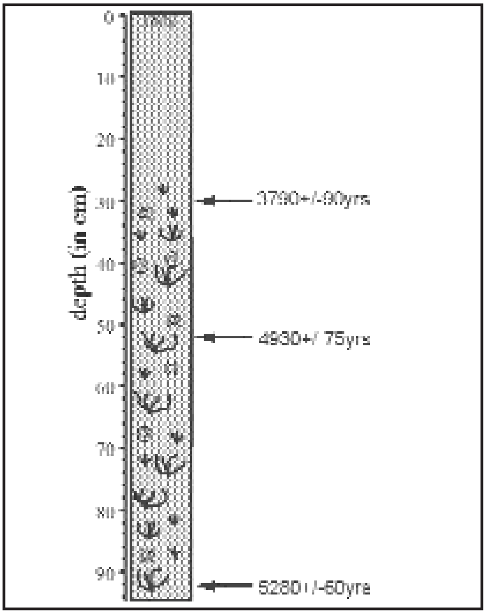


Fig. 3: Radiocarbon dating of corals from Core 29.

Radiocarbon dating

The dramatic changes in the sedimentary regime observed in Core 29 was also observed in other parts of the Iskenderun Bay, such as Site 139 (water depth 12 m), located along the coast south of Ulucinar and Site 16 (water depth 58 m) sampled during the second cruise in winter 1995 in front of the Iron Steel Complex (Yakacik). In particular, at Site 139, a grab sample revealed that in this part of the Bay a few centimetres of clayey mud cover a much coarser substratum consisting of mollusc shells and fragments of bioclasts (BASSO *et al.*, 1994). Moreover, some hard-bottom related faunas were found in predominantly muddy bottom (Grab Sample 30, water depth 46 m and Grab Sample 67, water depth 49 m). Radiocarbon analyses were performed to unravel the time when the lithological change occurred.

Cladocora caespitosa from Core 29, calcareous algae and *Spondylus* (bivalve mollusc) from Grab Sample 116, *Spondylus* from Grab Sample 30, mixed molluscs from the coarse substratum from Grab Sample 139 and calcareous algae and corals from Grab Sample 67 were analysed. The results are summarized in Fig. 3 and Tab. 4.

TABLE 4
Radiocarbon dating of macrofauna and macroflora from the Iskenderun Bay.

Sample	W. depth (m)	Fossil	Calibrated Age (yrs BP)
Grab 116A	40	Algae	500+/-25
Grab 116A	40	*Spondylus*	475+/-30
Grab 30	46	*Spondylus*	300+/-50
Grab 139	12	molluscs	2140+/-90
Core 29,25-35 cm	39	corals	3790+/-90
Core 29,45-50 cm	39	corals	4930+/-75
Core 29, 100 cm	39	corals	5280+/-60
Grab 67	49	algae-corals	830+/-70

Statistical treatment

The univariate and multivariate quantitative statistical treatment were applied to the quantitative data of benthic foraminifera using the software PRIMER (Plymouth Marine Laboratory).

The Shannon-Wiener Diversity Index (H') expresses the degree of species diversity within each sample and can be related to the environmental stress (WARWICK & CLARKE, 1995) (Fig 2). In particular, diversity declines where sea and fresh water meet, although these waters may be highly productive and support dense populations of some species (KINNE, 1971; LASSERRE, 1992). For the multivariate statistical treatment, abundance data of benthic foraminifera have been double-square root transformed (no standardization, no species reduction), in order to limit the contribution of most abundant, ubiquitous species and simplify the interpretation of the data structure (FIELD *et al.*, 1982).

The obtained data have been used for a hierarchical agglomerative clustering based on Bray-Curtis similarity (Fig. 4). On the basis of the same similarity matrix, the eighteen samples collected along Cores 29 and 92 have been ordinated by MDS (non-metric MultiDimensional Scaling) (Fig. 5). Clusters identified both in the dendrogram and in the MDS plot, at the same similarity level, have been further investigated through the similarity term analysis, in order to highlight the contribution of each species to the total average similarity within each group (and dissimilarities between different groups).

At the 75% level of Bray-Curtis similarity, 5 clusters separate (1 to 5 in Figs. 4, 5).

Cluster 1 groups the four upper samples of Core 29 (average similarity = 81.79%, Fig. 4, Tab. 5).

Fifteen species account for about 51% of the average similarity within this cluster (Fig. 4). They are, in order of decreasing contribution: *Elphidium crispum*, *Triloculina marionii, Porosononion subgranosum, Ammonia beccarii, Textularia bocki, Rosalina bradyi, Asterigerinata mamilla, Conorbella patelliformis, Neoeponides bradyi, Adelosina cliarensis, Adelosina mediterranensis, Astrononion stelligerum, Triloculina trigonula, Elphidium macellum and Adelosina duthiersi.*

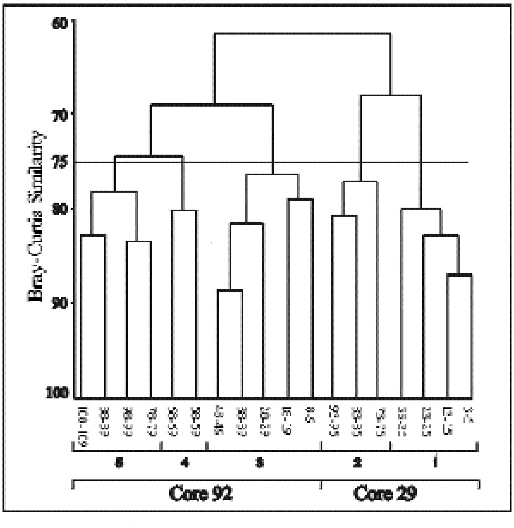


Fig.4: Hierarchical agglomerative clustering of the samples from Cores 29 and 92, based on the Bray-Curtis similarity. Each cluster groups the samples which share a similar benthic foraminiferal assemblage. Note that the sequence of samples in dendrograms is arbitrary because vertical lines can be visualized as threads holding samples which are free to rotate in an horizontal plane (FIELD *et al.*, 1982).

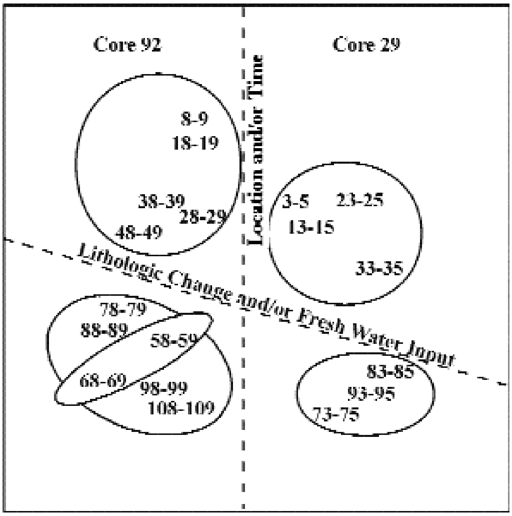


Fig. 5: Non-metric MultiDimensional Scaling (MDS) plot, with a stress of 0.11, of the Samples from Cores 29 and 92 recovered in the Iskenderun Bay. The ordination by MDS is an iterative procedure to represent "distance" of samples from a multidimensional space on the base of rank dissimilarities, therefore, sample position in the MDS may not correspond to that in the dendrogram. The stress represents the distortion involved in compressing the data to a small number of dimensions (FIELD *et al.*, 1982).

Cluster 2 groups the three lower samples of Core 29 (average similarity = 78.15%, Fig. 4, Tab. 5).

Twelve species account for about 50% of the average similarity within this cluster (Fig. 4, Tab. 5). They are, in order of decreasing contribution: *A. mamilla, T. bocki, P. subgranosum, Lachlanella ondulata, E. crispum, R. bradyi, Reussella spinulosa, T. marionii, Triloculina plicata, A. beccarii, A. cliarensis* and *A. stelligerum.*

Cluster 3 groups the five upper samples of Core 92 (average similarity = 78.94%, Fig. 4, Tab. 5).

Fourteen species account for about 50% of the average similarity within this cluster (Fig. 4, Tab. 5). They are, in order of decreasing contribution: *A. beccarii, P. subgranosum, T. bocki, Ammonia gaimardi, E. crispum, A. cliarensis, N. bradyi, T. marionii, Siphonaperta agglutinans, Spiroloculina ornata tricarinata, A. stelligerum, R. spinulosa, Miliolinella labiosa* and *E. macellum.*

Cluster 4 groups two samples from the middle part of Core 92 (average similarity = 79.96%, Fig. 4, Tab. 5). Six species account for about 50 % of the average similarity within this cluster. They are, in order of decreasing contribution: *P. subgranosum, A.beccarii, E. crispum, A. cliarensis, N. bradyi* and *A. gaimardi.*

Cluster 5 groups the four lower samples of Core 92 (average similarity = 32.19%, Fig. 4, Tab. 5). Twelve species account for about 50 % of the average similarity within this cluster. They are, in order of decreasing contribution: *P. subgranosum, A. beccarii, A. cliarensis, A. parkinsoniana, Haynesina depressula, A. gaimardi, E. crispum, T. bocki, T. marionii, E. cuvilleri, E. macellum* and *Miliolinella subrotunda.*

The ecology of the most relevant species identified by statistics is summarized in Table 6 (further information can be obtained, among others, in: LE CALVEZ & LE CALVEZ, 1958; BLANC-VERNET, 1969; BLANC-VERNET *et al.*, 1979; REISS & HOTTINGER, 1984; SGARRELLA et al., 1983; SGARRELLA *et al.,* 1984; AMORE *et al.,* 1988; CIMERMAN *et al.*, 1988; SGARRELLA, MONTCHARMONT-ZEI, 1993; COPPA *et al.,* 1994; LANGER, 1998; BASSO & SPEZZAFERRI, subm., CITA *et al.,* 1980; SPEZZAFERRI *et al.,* 1998).

TABLE 5

List of species and statistical parameters of Cluster 1-3 and 5. Since Cluster 4 groups two species only, statistical parameters were not calculated.

Cluster 1	Average similarity = 81.79			
	Avg. Ab.	Avg.	Perc.	Cum%
E. crispum	25,50	3,40	4,13	4,13
T. marioni	20,25	3,30	3,98	8,11
P. subgranosum	18,75	3,10	3,84	11,95
A. beccarii	19,00	3,10	3,77	15,72
T. bochi	20,00	3,10	3,77	19,49
R. bradyi	14,75	2,90	3,54	23,03
A mamilla	17,50	2,90	3,51	26,54
C. patelliformis	12,50	2,60	3,18	29,72
N. bradyi	10,75	2,60	3,13	32,85
A. cliarensis	9,00	2,60	3,13	35,97
A. mediterranensis	9,50	2,50	3,10	39,07
A. stelligerum	10,25	2,50	3,02	42,09
T. trigonula	6,50	2,40	2,89	44,98
E. macellum	8,50	2,40	2,88	47,86
A. duthiersi	6,00	2,30	2,85	50,71

Cluster 2	Average similarity = 78.15			
	Avg. Ab.	Avg.	Percent	Cum%
A. mamilla	43,00	4,30	5,50	5,50
T. bochi	27,67	3,60	4,63	10,13
P. subgranosum	20,00	3,50	4,45	14,57
L. ondulata	17,00	3,40	4,34	18,92
E. crispum	23,67	3,30	4,25	23,16
R. bradyi	17,33	3,10	4,03	27,19
R. spinulosa	12,33	3,10	4,01	31,20
T. marionii	13,00	3,10	3,98	35,17
T. plicata	12,00	3,00	3,80	38,97
A. beccarii	14,67	2,90	3,67	42,63
A cliarensis	11,67	2,80	3,59	46,23
A. stelligerum	10,33	2,80	3,55	49,78

Cluster 3	Average similarity = 78.94			
	Avg. Ab.	Avg.	Perc.	Cum%
A. beccarii	33,00	3,50	4,47	4,47
P. subgranosum	23,00	3,30	4,19	8,65
T. bochi	20,20	3,20	4,04	12,70
A. gaimardi	17,80	3,10	3,93	16,63
E. crispum	19,40	3,10	3,87	20,50
A. cliarensis	17,60	2,90	3,68	24,18
N. bradyi	11,60	2,80	3,49	27,67
T. marionii	8,60	2,50	3,21	30,89
S. agglutinans	8,80	2,50	3,17	34,06
S. ornata tric.	9,00	2,50	3,11	37,16
A. stelligerum	7,60	2,40	3,10	40,26
R. spinulosa	8,60	2,40	3,10	43,36
M. labiosa	7,40	2,40	3,02	46,38
E. macellum	7,80	2,30	2,91	49,28

Cluster 4	Average similarity = 79.9
P. subgranosum	
A beccarii	
E. crispum	
A. cliarensis	
N. bradyi	
A. gaimardi	

Cluster 5	Average similarity = 32.19			
	Avg. Ab.	Avg.	Perc.	Cum%
P. subgranosum	44,25	4,40	5,53	5,53
A. beccarii	34,00	4,10	5,15	10,68
A. cliarensis	23,50	3,60	4,49	15,18
A. parkinsoniana	17,50	3,30	4,19	19,37
H. depressula	22,25	3,30	4,18	23,55
A. gaimardi	15,75	3,20	4,06	27,61
E. crispum	12,00	3,20	4,05	31,66
T. bochi	12,75	3,20	4,04	35,71
T. marionii	11,00	3,00	3,82	39,52
E. cuvilleri	11,00	3,00	3,73	43,25
E. macellum	9,50	2,90	3,58	46,83
M. subrotunda	9,00	2,80	3,52	50,35

Discussion

Although the archaeological documentation from the Adana Basin and Iskenderun area is rich, the Late Holocene paleobiological and paleoenvironmental history of the bay is not well known. This study is addressed to obtain information about the biotic response to the major paleoceanographic and geographic changes which occurred in this area during the last 4000 years.

The Iskenderun Bay is characterized by a complex system of microenvironments degrading one into each other without distinct boundaries. A recent investigation revealed that the distribution of living benthic foraminifera in the Bay is essentially controlled by the substratum. Only in areas with higher fresh water input the substratum plays a minor role (BASSO & SPEZZAFERRI, subm.).

Core 92 contains relatively homogeneous sediments. Core 29, on the contrary displays a drastic change in substratum, from coarse to muddy, however, the distribution of benthic foraminifera only weakly reflects the changes in the substratum with relatively more abundant coarser-bottom loving species from Sample 93-95 cm up to Sample 73-75 cm (Tabs. 2,5).

Therefore, in both cores, the distribution of the benthic species depends also on other different environmental parameters beside the substratum.

It is known that benthic foraminiferal assemblages recovered in front of river mouths are generally poorly diversified and consist of species that can tolerate low salinity water (Sgarrella *et al.,* 1983, Sgarrella, Montcharmont-Zei 1993). Some species, such as *Ammonia tepida* are reported also from brackish and lagoonal environments (Cita *et al.,* 1980; Spezzaferri *et al*., 1998). Living benthic foraminiferal assemblages in front of the present Ceyhan River mouth are monospecific and consist of a few specimens of *Ammonia tepida* only (Basso & Spezzaferri, subm.). Combining the data from the literature and the distribution of benthic foraminifera in the Iskenderun Bay (Basso & Spezzaferri, subm.) we have interpreted the species listed in Table 7 as tolerant of low salinity. The multivariate statistical treatment of quantitative data allowed to represent the classification of the samples of the two cores with a hierarchical agglomerative cluster based on the Bray-Curtis similarity matrix (Fig. 4). The two clusters separated for Core 29 represent the benthic foraminiferal assemblages of the muddy bottom (Cluster 1) and hard or detritic bottom (Cluster 2) respectively. They are also characterized by different abundances of the low salinity tolerant species (Table 7) with higher abundance in Cluster 1 (from 3-5 cm to 33-35 cm). The terrigenous input increases in correspondence with the lithologic change as shown by the decreasing trend of the calcium carbonate content. Stable isotopes values are rather invariant throughout, with the exception of a variation in the trend of the $\square^{13}$C and $\square^{18}$O of planktonic foraminifera which become gradually and slightly more negative upward.

These lines of evidence indicate a slight increase in fresh water influence and terrigenous input from about 35 cm, in correspondence with the lithologic change, up to the top of Core 29.

Bulimina spp. and *A. gaimardi* commonly occur in muddy bottoms possibly characterized by low oxygen and high organic matter contents which reflect fluvial influence (Jorissen, 1988; Asioli, 1996). Higher abundances of these forms at the top of Core 29 also support the hypothesis of increasing fresh water input and more stressed bottom conditions.

Circulation patterns due to seasonal local winds as described by Yilmaz *et al*. (1992), Latif *et al*. (1989) should account for this indirect and slight increased influence of fresh water in the inner part of the bay.

Three clusters separate for Core 92. Cluster 3 includes the benthic foraminiferal assemblages characteristic of sandy sediment with variable abundances of mud-loving species throughout. Clusters 4 and 5 include predominantly mud-loving species, whereas, species characteristic of sandy and silty sediments are present as minor components. In particular Cluster 4 seems to be transitional between Cluster 3 and 5. The trend of the calcium carbonate content suggests that the terrigenous input was high throughout, however a slight decrease is observed in correspondance of Samples 28-29 cm to 48-49 cm.

The low salinity tolerant species show an opposite trend than that one observed for Core 29, their abundance is higher in the lower part of the core, and decreases towards the top (Fig. 2, Tab. 7). The variability of the benthic foraminiferal assemblages along Core 92 has been examined through the Shannon-Wiener diversity index H' (Fig.2, Tab. 2). Increasing levels of environmental stress are generally considered to decrease diversity (Warwick & Clarke, 1993). In particular, a freshwater inflow in a marine environment is associated with a decrease in benthic diversity (Kinne, 1971). The Shannon-Wiener diversity Index shows a drastic increase in diversity in Core 92 between sample 58-59 cm and 48-49 cm upward.

These data indicate that the benthic assemblages in the lower part of Core 92 (from the bottom up to about 50 cm) underwent an environmental stress probably originated by fresh water influence and terrigenous input due to a more direct impact of

TABLE 6

Ecology of selected species from the Iskenderun Bay. DC = Coastal detritic; SGCF = coarse sand substratum with bottom current influence; VTC = Circalittoral and terrigenous muddy bottoms (Peres & Picard, 1964).

Species	**environment**	**substratum** (as in the literature)	**substratum** (as in the Iskenderun Bay)	**Comments**
A beccarii	infralittoral, rarely circalittoral	fine infralittoral sand, detritic circalittoral	sand	
A. cliarensis	infralittoral	sand with Amphioxus, DC	silt and fine sand	keeled with depth
A. mamilla	infralittoral	Posidonia prairies and DC	fine and medium sand	
A. duthiersi	infra-circalittoral	sand and gravel	silt and sand	
A. gaimardi	infralittoral-upper circalittoral	mud sand and detritic sand	no clear trend with grain size	low oxyg. and abundante org. matter
A. mediterranensis	infralittoral	algal prairies	mud	
A. parkinsoniana	infralittoral, rarely circalittoral	fine infralittoral sand, detritic circalittoral	silt and fine sand	low salinity, river mouths
A. stelligerum	infralittoral, rarely circalittoral	sand	fine to coarse sand	
A. tepida	infralittoral, rarely circalittoral	fine infralittoral sand, detritic circalittoral	mud and fine sand	low salinity, river mouths
B. elongata	infra-circalittoral	mud and muddy sand	silt and fine sand	low salinity, river mouths
E. crispum	infra-circalittoral	sand, detritic circal. sand, sand with Amphioxus	silt and very fine sand	
E. cuvilleri	infra-upper circalittoral	muddy sands	mud and fine sand	low salinity, river mouths
E. macellum	infralittoral-upper circalittoral	mud and sand with algae, Posidonia and Cymodocea	mud and fine sand	
C. patelliformis	infralittoral	sand, SGCF	medium and coarse sand	
H. depressula	infralittoral and bay bottoms	VTC	mud and silt	low salinity, river mouths
L. ondulata	infralittoral- upper circal.	algal prairies and DC	coarse sand	rarely found alive
M. labiosa	-	-	silt and fine sand	
M. subrotunda	infralittoral	mud	silt and fine sand	
N. bradyi		mud	mud and sand	
P. mediterranensis	infralittoral	Posidona and Cymodocea prairies, coralligenous	sand	low salinity, river mouths
P. subgranosum	infra-circalittoral	sand with Cymodocea, VTC and DC	mud	low salinity, river mouths
Q. seminula	infra-circalittoral	mud and muddy sand	silt and fine sand	low salinity, river mouths
R. bradyi	infralittoral, rarely circal.	Posidonia prairies, detritic circal., rarely DC	fine to coarse sand	
R. spinulosa	infralit. - circalittoral	VTC	silt and fine sand	
S. agglutinans	infralittoral only	algal prairies, Cymodocea rarely on sand	fine sand	very fragile
S. ornata tricarin	infralittoral	Posidonia prairies	silt and fine sand	
T. bochi	infralittoral	mud	silt and very fine sand	
T. marionii	infra-circalittoral	algal prairies, Cymodocea	no clear trend with grain size	
T. plicata	infralittoral	Posidonia prairies	medium to coarse sand	
T. trigonula	infralittoral -upper circalittoral	mud and sand, Cymodocea	mud	low salinity, river mouths

TABLE 7
Average percent abundance of the species in each cluster with its respective standard deviation (std.).

Species	Cluster 1		Cluster 2		Cluster 3		Cluster 4		Cluster 5	
	Average	Std.	Average	Std.	Average	Std.	Average	Std.	Average	Std.
A. parkinsoniana	0,00	0,00	0,00	0,00	0,84	1,29	3,95	1,39	5,67	2,11
A. tepida	1,55	0,97	0,00	0,00	1,78	1,39	2,80	0,69	1,38	0,90
B. elongata	1,22	1,25	0,00	0,00	1,79	1,51	0,33	0,47	0,08	0,16
E. cuvilleri	0,00	0,00	0,00	0,00	0,32	0,72	1,81	0,69	3,57	1,30
H. depressula	1,40	1,10	1,12	0,45	2,03	3,67	3,46	1,17	7,18	3,67
Q. seminula	0,16	0,19	0,00	0,00	0,52	0,55	0,66	0,00	0,16	0,33
P. mediterranensis	0,00	0,00	1,31	0,58	0,20	0,18	0,00	0,00	0,08	0,16
P. subgranosum	6,15	0,83	6,15	1,42	7,53	1,17	14,17	0,03	14,34	2,43
T. trigonula	2,13	0,58	0,00	0,00	1,12	0,96	0,00	0,00	0,16	0,19
Total of low salinity tolerant species	12,62	1,77	8,58	0,76	15,97	3,59	27,18	2,03	32,63	3,88

the Ceyhan River.

In normal marine conditions the fresh water input may produce a depletion in both ^{13}C and ^{18}O and therefore □^{13}C and □^{18}O become more negative (KROON, 1988; ARIZTEGUI *et al.* 1996). At the same time their positive values, and in particular that of the □^{13}C, reflect high productivity (KROON, 1988). Although the resolution is very low in samples from Cores 29 and 92, no significant variations toward more negative values are observed in the oxygen and carbon isotopes record of both planktonic and benthic foraminifera. In particular, this is observed at Site 92 which is located in front of the Ceyhan River mouth, where marine phytoplankton bloom as a response to higher amount of nutrient input by river discharge, may have balanced the oxidation of terrestrial organic matter, and therefore, the isotopic values. The presence of siliceous sponge spicules in this core supports the presence of high fertility conditions (YILMAZ *et al,* 1992).

Based on these observations we can interpret the Multi Dimensional Scaling (MDS) plot, that represents the samples along the real ecological gradients, which control and are represented by the distribution of the biota. Samples from the two cores are vertically separated (different location of the two cores within the bay) and ordered along a vertical gradient that we interpret as being the different depositional environment and/or the geologic time. The second oblique gradient is interpreted as being the lithological change and/or the fresh water input (Fig. 5).

Temporal framework

Radiocarbon ages indicate that the last *Cladocora caespitosa* (Core 29) in living position is as old as 3790+/- 90 yrs BP. The age of the molluscs recovered in the lower part of Grab Sample 139, taken along the south-western coats of the bay, indicates that the coarse bottom persisted at least until 2140+/-90 yrs BP. In the same area, a biodetritic bottom covered by muddy sediments (Grab Sample 116) displays a younger age of about 500+/-25 to 475+/-30 yrs BP (algae and *Spondylus* respectively). In the north eastern part of the bay, *Spondylus*, algae and corals are also found as sparse components covered by muddy sediments of Grab Sample 67 and 30, indicate that a hard to very coarse detritic bottom persisted from 830+/-70 to 300+/-50 years BP in some areas of the bay.

Based on these data we may assume that different major increases in the muddy sedimentation occurred in the Iskenderun Bay: an "older phase", at 3790 and 2140 yrs BP, reflected by the age of the hard to coarse biogenic bottoms observed under the mud at sites 29 and 139, and a "younger phase", between 830 and 300 yrs BP, represented by sites 67, 30 and 116.

Considering separately the north-eastern side and the southernmost coast of Iskenderun Bay, we observe that the shallowest hard/coarse bottoms (Core 29 in the NE and Grab Sample 139 in the S) were covered by during the "older phase". The "younger phase" of increasing muddy sedimentation is recorded at deeper sites (30, 67 and 116). At sites 67 and 30, at comparable depth (49 and 46 m), the coarse detritic bottom was covered by muddy sediments at about 830 and 300 yrs BP respectively. Station 67 is about 5 km closest to the Middle Age-1935 Ceyhan River mouth (on a straight line) than station 30 and 116, and therefore, we may assume that this pulse of muddy sedimentation was due to the diversion of the Ceyhan River mouth in the inner part of the bay in the Middle Age and gradually proceeded from its proximal to its distal part.

Palaeoenvironmental and geological remarks

FAIRBANKS (1989) and TRINCARDI *et al.* (1994;1996) identified in the Mediterranean Sea a transgressive system trend starting from the last glacial maximum (about 120 meters below the present sea level) with rapid overall maximun sea level rise at about 5000 yrs BP.

In the Adana Basin (Fig. 1b), drained by the Ceyhan River, burial mounds are absent only within a narrow strip of land along the present-day coast. This suggests that the Adana plain never underwent a complete inundation and that the amplitude of the transgression in the eastern Mediterranean was minor (ERINC, 1978; AKSU *et al.* 1992) and/or that the sea level rise was compensated by a tectonic uplift (KORAL *et al.*, 1997).

According to AKSU *et al.* (1992), seaward delta progradation may occur sometimes also during high sea-level stand when the delta, occasionally and temporarily, reestablishes a dynamic equilibrium with the environment, caused either by stillstand of the sea level or by increased rate of sedimentation. This observation supports the historical documentation of a strong delta progradation which blanketed part of the Misis Mountains at about 2000 years (JONES, 1949; AKSU *et al.,* 1992; TRINCARDI *et al.*, 1996).

Why the coral colony stopped its growth and drowned? *Cladocora caespitosa* is an hermatipic mediterranean coral with a depth distribution limited by the symbiotic zooxanthellae. It prefers clear, shallow waters down to 50 m maximum, and normally disappears after pollution and/or increase of mud input (ZIBROWIUS, 1980). Pollen records and archaeological studies identified a progressive climatic desiccation along the Mediterranean coasts between 6000 and 4000 yrs BP. In addition, we know that complex societies emerged around 4000 yrs BP (ROBERTS, 1989). The anthropogenic effect resulted in a drastic change in the natural vegetation all over the eastern Mediterranean. This event called Beysehir Occupation Phase (BOP) is clearly detectable in pollen diagrams (VAN ZEIST, WOLDRING & STAPERT 1975). The Beysehir pollen diagram dated the maximum of the BOP from 3200 to 2000 BP, on the basis of uncalibrated ^{14}C dates, which would be ca. 200 years older after calibration (BARUCH, 1994). During the BOP the natural forest components (conifer and deciduous oak in western Anatolia, evergreen oak in the Levant), were drastically replaced by cultivated trees and plant taxa characteristic of disturbed habitats. This large-scale forest clearing lasted from 3500 to about 1500 yrs BP and was accompanied by significant soil erosion (ROBERTS, 1989; BARUCH, 1994).

We can conclude that combined effect of direct and/or indirect human impact upon a fragile environment, which was stressed by desiccation processes and soil erosion on land, was probably responsible for increased terrigenous and muddy sediments input into the sea, and therefore, caused the drowning of the *Cladocora caespitosa* colony.

The north-western part of the Bay underwent a different paleoenvironmental evolution. Since no direct age control is available for the sediments from Core 92, we can only speculate on the timing of the lithological change. This change in lithology at about 50 cm from the top of the core coincides also with the drastic variation in abundance of low salinity tolerant species and is reasonably related to a variation in the influence of the Ceyhan River.

At present, the Ceyhan River drains a basin of 20,466 km^2 and transfers to the sea about 5462 x 103 tons of sediments per year (AKSU *et al.* 1992). These data have been collected after the damming of the middle reach of the Ceyhan River between 1956 and 1972, and suggest a very high rate of sedimentation for the area proximal to the river mouth also in the present days. From the historical documentation we know that in the Middle Age, the Ceyhan River mouth diverted towards Yumurtalik, located in the inner north-western part of the Bay and this mouth was still active until 1935.

Site 92 is located exactly in front of the Middle Age-1935 river mouth. We can reasonably assume that the sedimentation rate was much higher before the damming, and therefore, interpret the sediments from the lower part of Core 92 as remarkably much younger than those from Core 29. Thus, we can conclude that the diversion of the Ceyhan River from the Middle Age-1935 river mouth to the present one was responsible for the lithological change and the drastic variation in abundance of low-salinity tolerant species.

Conclusions

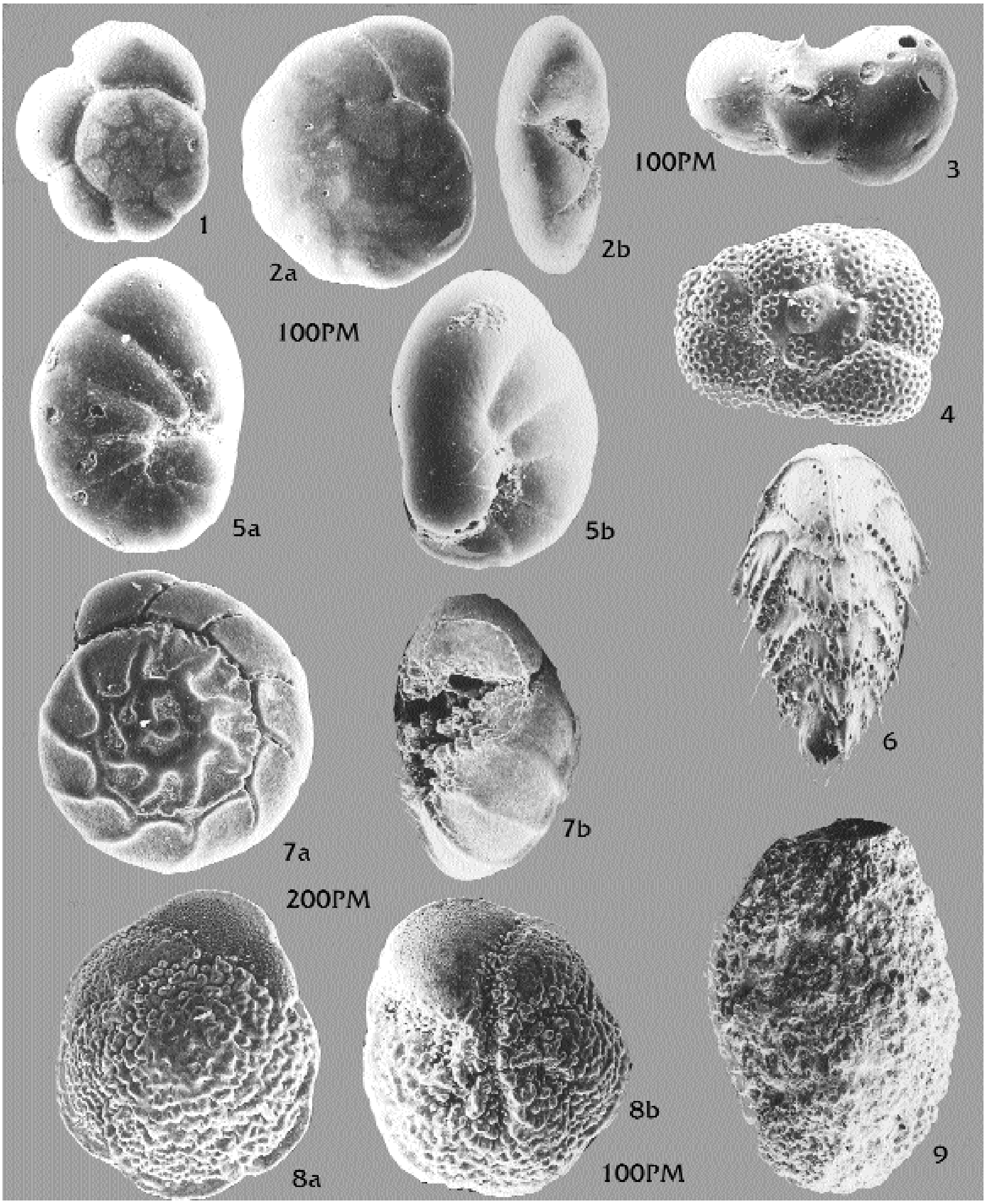
In conclusion, variations of the sedimentary regime were identified in the Iskenderun Bay in the Late Holocene. In particular, we identify 3 pulses of increased muddy sedimentation (two within the "older phase" and one in the "younger phase") which are related to different mechanisms. The oldest pulse produced the arrest of the growth of the *Cladocora caespitosa* colony at about 3790 years. We suggest that this was caused by the human impact on natural vegetation (Beysehir Occupation Phase), progressive desiccation and consequent soil erosion. Another old pulse along the southern coast of the Bay coincides with a major delta progradation episode of the Ceyhan River at about 2140 years BP.

A younger pulse occurred in the deeper parts of the bay and coincide with the diversion of the Ceyhan River mouth toward Yumurtalik in the Middle Age (Grab 67). Muddy sedimentation progressively increased also in other areas of the bay (Grab 116, 500 years) and lasted until 300 years BP (Grab 30), as a result of the shift of depocenters in response to lobe-shifting of the river-mouth.

The influence of the Ceyhan River on the benthic assemblages from the inner north eastern part of the bay (Core 29) was minor when the river drained directly into the Mediterranean Sea outside the bay (approximately 2000 years BP) and progressively increased when the river mouth started its diversion towards the inner part of the bay. The circulation system also allowed the penetration of fresh water towards the inner part of the Bay.

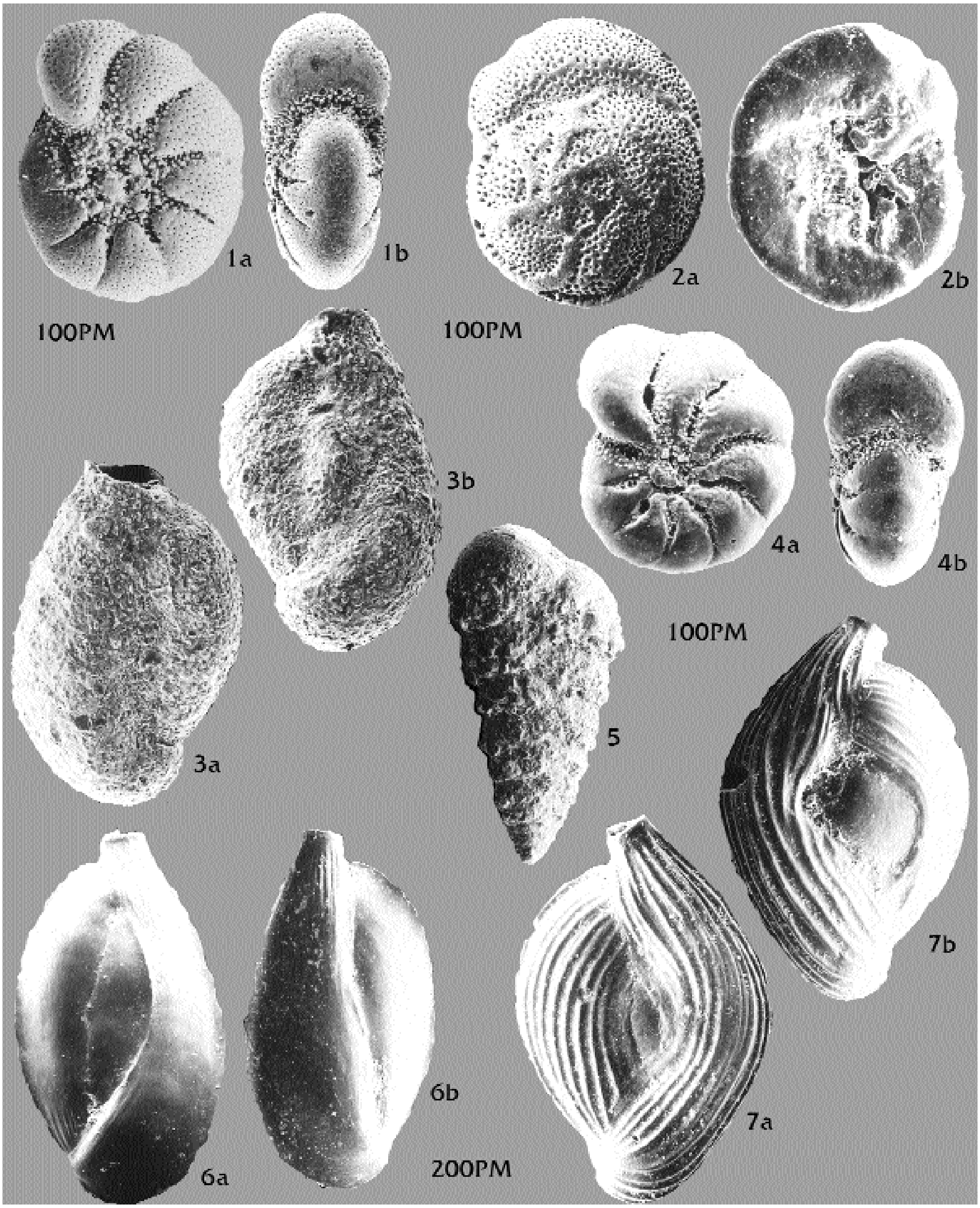
The sediments from Core 92 are interpreted as much younger than those ones from Core 29 owing to the high rate of sedimentation close to the Ceyhan River mouth. We suggest that the variation of the sedimentary regime and the benthic foraminifera response, especially in the nortwestern part of the Iskenderun Bay are predominantly due to the Ceyhan River mouth diversions between the Middle Age and the present.

Plate 1



Benthic foraminifera from the Iskenderun Bay.
1. *Ammonia tepida* Cushman, Sample 92, 58-59 cm. Spiral view.
2a-b. *Ammonia parkinsoniana* (d'Orbiny), Sample 92, 58-59 cm. (a) Spiral view, (b) side view.
3. *Miliolinella labiosa* (d'Orbiny), Sample 92, 48-49 cm. Side view.
4. *Planorbulina mediterranensis* d'Orbigny, Sample 92, 48-49 cm. Unattached side.
5a-b. *Nonionella turgida* (Williamson), Sample 92, 48-49 cm. (a) Spiral view, (b) umbilical view.
6. *Reussella spinulosa* (Reuss), Sample 92, 58-59 cm. Edge view.
7a-b. *Ammonia gaimardi* (d'Orbigny), Sample 92, 58-59 cm. (a) Spiral view, (b) side view.
8a-b. *Neoeponides bradyi* (Le Calvez), Sample 92, 58-59 cm. (a) Spiral view, (b) umbilical view.
9. *Siphonaperta aspera* (d'Orbigny), Sample 92, 78-79 cm. Side view.

Plate 2



Benthic foraminifera from the Iskenderun Bay.
1a-b. *Porosononion subgranosum* (Egger), Sample 92, 58-60 cm. (a) Side view, (b) face view.
2a-b. *Rosalina bradyi* Cushman, Sample 92, 8-9 cm. (a) Spiral view, (b) umbilical view.
3a-b. *Siphonaperta agglutinans* (d'Orbigny), Sample 92, 58-59 cm. Side view.
4a-b. *Elphidium pauciloculum* (Cushman), Sample 92, 58-59 cm. (a) Side view, (b) face view.
5. *Textularia bocki* Hoeglund, Sample 92, 28-29 cm. Side view.
6a-b. *Adelosina cliarensis* (Heron-Allen and Earland), Sample 92, 28-29 cm. (a, b) Side view.
7a-b. *Adelosina* cf. *mediterranensis* Le Calvez, Sample 92, 28-29 cm. (a, b) Side view.

Acknowledgements

The authors are grateful to the crew of the R/V K. Piri Reis for their help during the cruise AVI II-93 and the Institute for Marine Science and Technology of Izmir for providing the instrumentation on board. Thanks to two anonymous referees for their fruitful revision and useful comments on the text. A warm thank is due to Andrea Passagnoli for calcium carbonate analyses and to Maureen Padden and Stefano Bernasconi for their assistance with the stable isotope measurements. A special thank to Prof. S. Improta (Universita "La Sapienza" - Roma) for providing the radiocarbon dating. SEM photographs by Agostino Rizzi, CSGAQ, CNR, Italy. We are very grateful to the European Union (Avicenne Initiative 92, Contract AVI CT92-0007) for the financial support which allowed this research to become possible.

Financial support was provided to Daniela Basso and Hayrettin Koral by Contract AVI CT92-0007 and to Silvia Spezzaferri by Contract AVI CT92-0007, the European Science Foundation, the European Consortium for Ocean Drilling and ETH-Zurich.

List of species

Species are listed by Genus in alphabetical order. References are made to the most reliable illustrations reported in the literature. The generic and specific concept of CIMERMAN & LANGER (1991), HOTTINGER, HALICZ & REISS (1993), SGARRELLA & MONCHARMONT-ZEI (1993), SPROVIERI & HASEGAWA (1990), HASEGAWA, SPROVIERI & POLUZZI (1990) are retained.

Ammonia parkinsoniana (d'Orbigny) (See SGARRELLA & MONCHARMONT-ZEI, 1993, pl. 20, fig. 3-4)

Adelosina cliarensis (Eron-Allen and Earland) (See Cimerman and Langer, 1991, pl. 18, figs. 1-4)

Adelosina duthiersi Schlumberger (See CIMERMAN & LANGER, 1991, pl. 18, fig. 8)

Adelosina italica (Terquem) (See SGARRELLA & MONCHARMONT-ZEI, 1993, p. 179, pl. 7, figs. 13-14)

Adelosina mediterranensis Le Calvez (See CIMERMAN & LANGER, 1991, pl. 19, figs. 1-16)

Adelosina sp. 1 (See CIMERMAN & LAN-GER, 1991, p. 28, pl. 21, figs. 1-4)

Ammonia beccarii (Linneo) (See CIMERMAN & LANGER, 1991, pl. 87, figs. 3-4)

Ammonia gaimardi (d'Orbigny) (See SGARRELLA & MONCHARMONT-ZEI, 1993, pl. 20, fig. 7-8)

Ammonia tepida Cushman (See CIMER-MAN & LANGER, 1991, pl. 87, figs. 10-12)

Asterigerinata mamilla (Williamson) (See CIMERMAN & LANGER, 1991, pl. 82, figs. 1-4)

Astrononion stelligerum (d'Orbigny) (See CIMERMAN & LANGER, 1991, pl. 84, figs. 13-15)

Bolivina variabilis (Williamson) (See CIMERMAN & LANGER, 1991, pl. 61, figs. 7-8)

Brizalina punctata (d'Orbigny) (See ELLIS & MESSINA, 1949, v. 8)

Brizalina alata (Seguenza) (See SPROVIERI & HASEGAWA, 1990, pl. 3, figs. 7-8)

Brizalina dilatata (Reuss) (See CIMERMAN & LANGER, 1991, pl. 62, figs. 2)

Brizalina italica (Cushman) (See ELLIS & MESSINA, 1949, v. 8)

Brizalina spathulata (Williamson) (See CIMERMAN & LANGER, 1991, pl. 62, figs. 3-5)

Bulimina aculeata d'Orbigny (See SGARRELLA & MONCHARMONT-ZEI, 1993, pl. 15, fig. 1)

Bulimina elongata d'Orbigny (See CIMERMAN & LANGER, 1991, pl. 64, figs. 3-8)

Cassidulina laevigata d'Orbigny (See CIMERMAN & LANGER, 1991, pl. 63, figs. 1-3)

Conorbella patelliformis (Brady) (See CIMERMAN & LANGER, 1991, pl. 73, figs. 1-3)

Cornuspira involvens Reuss (See CIMERMAN & LANGER, 1991, pl. 15, figs. 407)

Coscinospira hemprichii Ehrenberg (See CIMERMAN & LANGER, 1991, pl. 47, figs. 8-11)

Cycloforina rugosa (d'Orbigny) (See

CIMERMAN & LANGER, 1991, pl. 28, figs. 3-4)

Cycloforina tenuicollis (Wiesner) (See CIMERMAN & LANGER, 1991, pl. 28, figs. 5-6)

Cymbaloporetta sp.1 (See CIMERMAN & LANGER, 1991, pl. 80, figs. 1-5)

Elphidium cuvilleri Levy (See SGARRELLA & MONCHARMONT-ZEI, 1993, pl. 20, fig. 13)

Elphidium macellum (Fichtel and Moll) (See CIMERMAN & LANGER, 1991, pl. 89, figs. 9)

Elphidium crispum (Linneo) (See CIMER-MAN & LANGER, 1991, pl. 90, figs. 1-16)

Elphidium jenseni (Cushman) (See CIMERMAN & LANGER, 1991, pl. 92, figs. 1-3)

Elphidium pauciloculum (Cushman) (See SGARRELLA & MONCHARMONT-ZEI, 1993, pl. 22, fig. 1-3)

Haynesina sp. 1 (CIMERMAN & LANGER, 1991, pl. 83, figs. 5-8)

Elphidium sp. 5 (See CIMERMAN & LANGER, 1991, pl. 91, figs. 8-10)

Elphidium sp.4 (See CIMERMAN & LANGER, 1991, pl. 91, figs. 5-6)

Eponides concameratus (Williamson) (See CIMERMAN & LANGER, 1991, pl. 65, figs. 11-14)

Fissupolymorfina williamsoni (Terquem) (See CIMERMAN & LANGER, 1991, pl. 58, figs. 1-4)

Fursenkoina acuta (d'Orbigny) (See CIMERMAN & LANGER, 1991, pl. 67, figs. 1-2)

Globocassidulina subglobosa (Bradyi) (See HASEGAWA *et al.* 1990, pl. 4, figs. 5-6)

Guttulina lactea (Walker and Jacob) (See COLOM 1974, pl. X fig. 205-206)

Gyroidina soldanii d'Orbigny (See HAEGAWA *et al,* 1990, pl. 5, figs. 13-15)

Haynesina depressula (Walker & Jacob) (See CIMERMAN & LANGER, 1991, pl. 83, figs. 1-4)

Hyalinonetrion gracillimum (Seguenza) (See CIMERMAN & LANGER, 1991, pl. 55, figs. 1-2)

Lachlanella bicornis (Walker and Jacob emend. Haynes) (See CIMERMAN & LANGER, 1991, pl. 29, figs. 1-3)

Lachlanella undulata (d'Orbigny) (See CIMERMAN & LANGER, 1991, pl. 30, figs. 3-6)

Lachlanella variolata (d'Orbigny) (See CIMERMAN & LANGER, 1991, pl. 31, figs. 1-12)

Lenticulina cultrata (Momfort) (See CIMERMAN & LANGER, 1991, pl. 53, figs. 5-6)

Lobatula lobatula (Walker and Jacob) (See CIMERMAN & LANGER, 1991, pl. 75, figs. 1-4)

Miliolinella elongata Kruit (See CIMER-MAN & LANGER, 1991, pl. 37, figs. 8)

Miliolinella labiosa (d'Orbigny) (See CIMERMAN & LANGER, 1991, pl. 38, figs. 1-3)

Miliolinella subrotunda Montagu (See CIMERMAN & LANGER, 1991, pl. 38, figs. 4-9)

Miliolinella webbiana (d'Orbigny) (See CIMERMAN & LANGER, 1991, pl. 39, figs. 1-3)

Melonis barleanum (Williamson) (See SGARRELLA & MONCHARMONT-ZEI, 1993, pl. 26, figs. 1-2)

Neoeponides bradyi (Le Calvez) (See HOTTINGER, HALICZ & REISS, 1993, pl. 146, figs. 8-12)

Neouvigerina porrecta (Brady) subspecies A (See HOTTINGER, HALICZ & REISS, 1993, pl. 128, figs.1-6)

Nodophtalmidium antillarum (Cushman), (See HOTTINGER, HALICZ & REISS, 1993, pl. 23, figs. 4-7)

Nonionella turgida (Williamson) (See CIMERMAN & LANGER, 1991, pl. 84, figs. 6-8)

Nonionides grateloupi (d'Orbigny) (See HOTTINGER, HALICZ & REISS, 1993, pl. 195, figs. 4-13)

Peneroplis pertusus (Forskal) (See CIMERMAN & LANGER, 1991, pl. 49, figs. 1-8)

Peneroplis planatus (Fichtel and Moll) (See CIMERMAN & LANGER, 1991, pl. 50, figs. 1-6)

Planorbulina mediterranensis d'Orbigny (See CIMERMAN & LANGER, 1991, pl. 78, figs. 1-8)

Porosononion subgranosum (Egger) (See SGARRELLA & MONTCHARMONT-ZEI 1993, pl.21, fig.1-2)

Pseudotriloculina laevigata (d'Orbigny) (See CIMERMAN & LANGER, 1991, pl. 39, figs. 8-12)

Pseudotriloculina oblonga (Montagu) (See CIMERMAN & LANGER, 1991, pl. 40, figs. 1-4)

Pyrgo elongata (d'Orbigny) (See CIMERman & Langer, 1991, pl. 41, figs. 6-8)

Quinqueloculina bosciana d'Orbigny (See Cimerman & Langer, 1991, pl. 33, figs. 5-7)

Quinqueloculina jugosa Cushman (See Cimerman & Langer, 1991, pl. 33, figs. 12-14)

Quinqueloculina laevigata d'Orbigny (See Cimerman & Langer, 1991, pl. 33, figs. 8-11)

Quinqueloculina parvula Schlumeberger (See Cimerman & Langer, 1991, pl. 34, figs. 6-8)

Quinqueloculina seminula (Linneo) (See Cimerman & Langer, 1991, pl. 34, figs. 9-12)

Quinqueloculina viennesis Le Calvez and Le Calvez (See Sgarrella & Montcharmont-Zei 1993, pl. 7, fig. 8)

Rectuvigerina phlegeri Le Calvez (See Sgarrella & Moncharmont-Zei, 1993, pl. 16, figs. 3-4)

Reussella spinulosa (Reuss) (See Cimerman & Langer, 1991, pl. 66, figs. 5-8)

Rosalina bradyi Cushman (See Sgarrella & Moncharmont-Zei, 1993, pl. 17, figs. 4-5)

Rosalina globularis d'Orbigny (See Sgarrella & Moncharmont-Zei, 1993, pl. 17, figs. 7-8)

Rotomorfina ? involuta Parker (See Sgarrella & Montcharmont-Zei 1993, pl. 19, figs.1-3)

Sigmoilinita costata (Schlumberger) (See Cimerman & Langer, 1991, pl. 45, figs. 1-6)

Siphonaperta agglutinans (d'Orbigny) (See Cimerman & Langer, 1991, pl. 25, figs. 1-3)

Siphonaperta aspera (d'Orbigny) (See Cimerman & Langer, 1991, pl. 25, figs. 4-6)

Siphonaperta irregularis (d'Orbigny) (See Cimerman & Langer, 1991, pl. 26, figs. 4-6)

Siphonina reticulata (Czjek) (See Cimerman & Langer, 1991, pl. 73, figs. 11-16)

Sorites orbiculus Ehrenberg (See Cimerman & Langer, 1991, pl. 51, figs. 1-5)

Sphaerogypsina globula (Reuss) (See Sgarrella & Montcharmont-Zei 1993, pl. 23, fig. 6)

Spiroloculina dilatata d'Orbigny (See Cimerman & Langer, 1991, pl. 22, figs. 5-8)

Spiroloculina excavata d'Orbigny (See Cimerman & Langer, 1991, pl. 23, figs. 1-3)

Spiroloculina ornata d'Orbigny var. tricarinata Le Calvez (See Cimerman & Langer, 1991, pl. 23, figs. 4-7)

Spiroloculina tenuiseptata Brady (See Cimerman & Langer, 1991, pl. 24, figs. 6-9)

Textularia bocki Hoeglund (See Cimerman & Langer, 1991, pl. 10, figs. 3-6)

Triloculina affinis d'Orbigny (See Hottinger, Halicz & Reiss, 1993, pl. 66, figs. 1-3)

Triloculina marionii Schlumberger (See Cimerman & Langer, 1991, pl. 43, figs. 1-5)

Triloculina plicata Terquem (See Cimerman & Langer, 1991, pl. 43, figs. 8-10)

Triloculina serrulata McCulloch (See Hottinger, Halicz & Reiss, 1993, pl. 65, figs. 1-9)

Triloculina tricarinata d'Orbigny (See Cimerman & Langer, 1991, pl. 44, figs. 3-4)

Triloculina trigonula (Lamark) (See Hottinger, Halicz & Reiss, 1993, pl. 69, figs. 41-10)

Valvulineria bradyana (Fornasini) (See Cimerman & Langer, 1991, pl. 67, figs. 8-10)

Vertebralina striata d'Orbigny (See Cimerman & Langer, 1991, pl. 16, figs. 1-5)

References

Aksu, A.E., Ulug, A., Piper, D.J.W., Konuk, Y.T., Turgut, S., 1992. Quaternary sedimentary history of the Adana, Cilicia and Iskenderun basin: Northeast Mediterranean Sea. *Mar. Geol.,* 104, 55-71.

Amore, F.O., Barra, D., Ciampo, G., Taddei Ruggiero, E., Russo, G.F., Sgarrella, F., 1988. Paleoecologia dei depositi terrazzati de La Starza (Pozzuoli), In: E., Robba (Editor), Proceedings of the Fourth Symposium on Ecology and Paleoecology of Benthic Communities, *Mus. Reg. Sc. Nat.,* Torino, 455-499.

Ariztegui, D., Chondrogianni, C., Wolf, G., Asioli, A., Terranes, J., Bernasconi, S., McKenzie, J., 1996. Paleotemperature and paleosalinity history of the Meso Adriatic Depression (MAD) during the Late Quaternary: a stable isotopes and alkenones study. In: P. Guilizzoni & F. Oldfield (Editors), Paleoenvironmental Analysis of Italian Crater Lake and Adriatic Sediment (PALICLAS), *Mem. Ist. It. Idrobiol.*, 55, 218-230.

Asioli A., 1996. High resolution foraminifera biostratigraphy in the Central Adriatic basin during the last deglaciation: a contribution to the PALICLAS project. In: P. Guilizzoni & F. Oldfield (Editors), Paleoenvironmental Analysis of Italian Crater Lake and Adriatic Sediment (PALICLAS), *Mem. Ist. It. Idrobiol.,* 55, 197-217.

Balossi, M., 1994. Applicazione e verifica di un metodo per la valutazione automatica dei parametri paleo-ambientali nelle rocce sedimentarie. Publication Agip, SpA.

Baruch, U., 1994. The Late Quaternary pollen record of the Near East. In: O.Bar-Yosef & R.S. Kra (Editors), Late Quaternary Chronology and Paleoclimates of the Eastern Mediterranean, *Radiocarbon*, 103-119.

Basso, D., Spezzaferri, S. (subm.). The distribution of benthic foraminifera in the Iskenderun Bay (eastern Turkey): A statistical approach. *Bull. Soc. Paleont. Ital.*

Basso, D., Spezzaferri, S., Yanko, V., Koral, H., Avsar, N., 1994. Cruise AVI-II 93: preliminary data from the Iskenderun Bay (Turkey). *Rend. Fis. Acc. Lincei,* 9(5), 233-245.

Blanc-Vernet, L., 1969. Contribution a l'etude des foraminiferes de Mediterranee. *Recl.Trav. Stn. Mar. Endoume,* 64 (48), 315 pp.

Blanc-Vernet, L., Clairefond P.P., Orsolini, P., 1979. La mer Pelagienne - Les Foraminiferes. *Geol. Medit*., 6, 1.

Bresler, V., Yanko, V., 1995. Chemical ecology: a new approach to the study of living benthic epiphytic foraminifera. *J. Foram. Res.,* 25, 267-279.

Cimerman, F., Langer, M.R., 1991. Mediterranean Foraminifera. *Slovenska Academia Znanosti in Umetnosti,* Ljubljania, 119 pp.

Cimerman, F., Drobne, K., Ogorelec, B., 1988. L'association de foraminiferes benthiques des vases de la Baie de Veliko Jezero sur l'Ile de Mljet et de la falaise Lenga, ouverte vers la mer (Adriatique moyenne). Benthos 86, 3eme Symposium International sur les Foraminiferes Benthiques. *Revue de Paleobiologie, Museum d' Histoire Naturelle*, Geneve, 2, 741-753.

Cita, M.B., Vismara-Schilling, A., Bossio, A., 1980. Stratigraphy and paleoenvironment of the Cuevas del Almazora Section (Vera Basin). A re-interpretation. *Riv. It. Paleont. Strat.,* 86, 215-240.

Coppa, M.G., Russo, B., Siani, G., 1994. The Holocene foraminiferal assemblages of the continental margin between Agropoli and Capo Palinuro (Tyrrhenian Sea, Italy), In: R. □atteucci, M.G. Carboni, & J.S. Pignatti, (Editors), Studies on Ecology and Palaeoecology of Benthic Communities, Proceedings of the 5th Paleobenthos Symposium, Roma, September 28-30, 1992. *Boll. Soc. Paleont. Ital.,* 2, 67-91.

Craig, H., 1957. Isotopic standards for carbon and oxygen and correction factors for mass-spectrometric analysis of carbon dioxide. *Geochem. Cosmochem. Acta*, 12, 133-149.

Earland, A., 1936. Additional records from the Weddel Sea sector from material obtained by the S.Y. Scotia. *Discovery Reports,* XIII, 70 pp.

Ellis, B.F., Messina, A., 1949. Catalogue of Foraminifera. *Am. Mus. Nat. Hist.* Micropaleont. Press., New York.

Erinc, S., 1978. Changes in the physical environment in Turkey since the end of the last glacial. In W.C. Brice (Editor), The environmental history of the Near and Middle East since the last Ice Age. Academy Press, London, 87-110.

Fairbanks, R.G., 1989. A 17000 year glacioeustatic sea level record: influence of glacial melting rates on the Younger Dryas event and deep ocean circulation. *Nature*, 342, 637-642.

Field, J.G., Clarke, K.R., Warwick, R.M, 1982. A practical strategy for analysing multispecies distribution patterns. *Mar. Ecol. Prog. Ser.,* 8, 37-52.

Hasegawa, S., Sprovieri, R., Poluzzi, A., 1990. Quantitative analyses of benthic foraminiferal assemblages from Plio-Pleistocene sequence in the Tyrrhenian Sea, ODP Leg 107. In K.A. Kasten, J. Mascle et al., Proc. ODP Sci. Results, 107, College Station, TX (Ocean Drilling Program), 461-478.

Hottinger, L., Halicz, E., Reiss, Z., 1993. Recent foraminifera from the Gulf of Aqaba, Red Sea. *Slovenia Akademija Znanosti in Umetnosti,* Ljubljania, 179 pp.

Iyiduvar, O., 1986. Hydrographic characteristic of Iskenderun Bay. MSc. Thesis, Institute of Marine Sciences, Middle East Technical University, Turkey, 157 pp.

Jones, H.L., 1949. The Geography of Strabo. Harvard Univ. Press, London.

Jorissen, F.J., 1988. Benthic foraminifera from the Adriatic Sea: Principles for phenotypic variation. *Utrecht Micropal. Bull.*, 37, 176 pp.

Koral, H., 1995. Sedimentological study: sediments of Iskenderun Bay in the context of regional structures. In: AVICENNE Annual Report 1995, Benthic foraminifera as indicators of heavy metal pollution- A new kind of biological monitoring for the Mediterranean Sea, 217-223.

Koral, H., Kronfeld, J., Avsar, N., Vogel, J., 1997. Tectonic uplift of Iskenderun Bay (northeastern Mediterranean Sea) during Late Pleistocene-Holocene time. *European Union Geosciences* (EUG), 9, 406.

Kroon, D., 1988. The planktic □^{13}C record, upwelling and climate. In: G.J.A. Brummer, D. Kroon (Editors), Planktonic foraminifers as tracer of ocean-climate history. VU Uitgeverij, Amsterdam, 335-346.

Langer, M.R., 1998. Recent epiphytic foraminifera from Vulcano (Mediterranean Sea).*Rev. Paleobiol*. Vol. Spec. 2, Benthos 86, 827-832.

Lasserre P., 1992. The role of biodiversity in marine ecosystems. In Biodiversity and global change (Solbrig, van Emden & van Oordt Eds.) IUBS Press, monograph n. 8, Paris, 221 p.

Latif, M.A., Ozsoy, E., Saydam, C., Unluata, U., 1989. Oceanographic Investigation of the Gulf of Iskenderun. A. Annual Report, Middle East Technical University, Institute of Marine Sciences.

Le Calvez, J., Le Calvez Y., 1958. Repartition des foraminiferes dans la Baie de Villafranche, I- Miliolidae. XXXV Ann. Inst. Ocean.

Mangano G., Violanti, D., 1992. Foraminiferiattuali in sedimenti infralitorali e circalitorali a nord di Messina (Sicilia, Italia). *Riv. It. Paleont. Strat.* 98(3), 371-378.

Peres, J.M., Picard, J., 1964. Noveau manuel de bionomie benthique de la mer Mediterranee. *Recl. Trav. Stn. Mar. Endoume.* 31(47), 137 pp.

Premoli Silva, I., Castradori, D., Spezzaferri, S. 1993. Calcareous nannofossil and planktonic foraminifer biostratigraphy of Hole 810C (Shatsky Rise, Northwestern Pacific). In: J.H. Natland, M.A. Storm, et al., Proc ODP, Sci. Results, 132: College Station, TX (Ocean Drilling Program), 15-36.

Reinhardt, E.G., Patterson, R.T., Schrider-Adams, C.J., 1994. Geoarchaeology of the ancient harbour of Cesarea Maritima, Israel: evidence from sedimentology and paleoecology of benthic foraminifera. *J. Foram. Res.*, 24(1), 37-48.

Reiss, Z., Hottinger, L., 1984. The Gulf of Aqaba, ecological micropaleontology. *Ecological studies* 50. Springer, Berlin, Heidelberg, 354 pp.

Roberts, N., 1989. The Holocene an environmental history. Blackwell Publ. Ltd., Univ. Press. Cambridge.

Russel, R.J., 1954. Alluvial morphology of Anatolian rivers. *Ann. Assoc. Am. Geogr*., 44, 363-391.

Sgarrella F., Moncharmon -Zei, M., 1993. Benthic foraminifera in the Gulf of Naples (Italy): systematic and autoecology. *Boll. Soc. Paleont. Ital.,* 32, 145-264.

Sgarrella, F., Barra, D., 1984. Distribuzione dei foraminiferi bentonici nel Golfo di Salerno (Basso Tirreno, Italia). *Boll. Soc. Nat*. Napoli, XCIII.

Sgarrella, F., Barra, D., Improta, A., 1983. The benthic foraminifers of the Gulf of Policastro (Southern Thyrrhenian Sea, Italy). *Boll. Soc. Nat.* Napoli, XCII.

Spezzaferri, S., 1995. Planktonic foraminiferal paleoclimatic implications across the Oligocene /Miocene transition in the oceanic record (Atlantic, Indian and South Pacific). *Palaeogeogr. Palaeoclimatol. Palaeoecol.*, 114, 43-74.

Spezzaferri, S., McKenzie J.A., Cita, M.B., 1998. The Miocene/Pliocene boundary in the Eastern Mediterranean: Results from ODP Leg 160, Sites 967 and 969, In: A.H.F. Robertson, K.-C. Emeis, C. Richter A., & Camerlenghi A. (Editors), Proc. ODP, Init. Reports, College Station, TX (Ocean Drilling Program), 8-23.

Sprovieri, R., Hasegawa, S., 1990. Plio-Pleistocene benthic foraminifer stratigraphic distribution in the deep-sea record of the Thyrrhenian Sea (ODP Leg 107). In: K. A. Kastens, J. Mascle, et al. (Editors), Proc. ODP, Sci. Res., 107: College Station, TX (Ocean Drilling Program), 429-459.

Stuiver, M., Reimer, P.J., 1993. A computer program for radiocarbon age calibration. *Radiocarbon*, 35, 215-230.

Trincardi, F., Cattaneo , A., Asioli, A., Correggiari, A , Langone, L., 1996. Stratigraphy of the late-Quaternary deposits in the central Adriatic Basin and the record of the short-term climatic events. In: P. Guilizzoni, & F. Oldfield, Paleo - environmental Analysis of Italian Crater Lake and Adriatic Sediment (PALICLAS). *Mem. Ist. It. Idrobiol,* 55, 39-70.

Trincardi, F., Correggiari, A., Roveri, M., 1994. Late Quaternary trangressive erosion and deposition in a modern epicontinental shelf in the Adriatic semienclosed basin. *Geo-*

Mar. Letters, 14, 41-51.

VAN ZEIST, W., WOLDRING, H., STAPERT, D., 1975. Late Quaternary vegetation and climate of southwestern Turkey. *Palaeohistoria* 17, 53-143.

WARWICK, R.M., CLARKE, K.R., 1993. Increased variability as a symptom of stress in marine communities. *J. Exp. Mar. Biol. Ecol.*, 172: 215-226.

YANKO, V., KRONFELD, J., FLEXER, A., 1994. Response of benthic foraminifera to various pollution sources: implications for pollution monitoring. *J. Foram. Res.,* 24, 1-17.

YILMAZ, A., BAESTURK, O., EDIGER, D., YLMAZ, K., HATIPOGLU, E., 1992. Eutrophication in Iskenderun Bay, north-eastern Mediterranean. Science of the Total Environment, Elsevier, 705-717.

ZIBROWIUS, H., 1980 Les Scleractiniaires de la Mediterranee et de l'Atlantique nord oriental, *Mem. Inst. Ocean.,* Monaco, 11.