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PREFACE

This special issue has been prepared for the papers which were presented in the 4th European Ostracodologists Meeting at Çukurova University in Adana, on 5-8 July 1999.

After Germany (Frankfurt), Scotland (Glasgow) and France (Paris) meetings, Turkey welcomed Ostracodologists to the 4th European Meeting. The scientific theme is: Studies on Ostracoda. The aim of the Meeting was to bring together ostracodologists (Paleontologists and Zoologists) from different countries to discuss their problems and fascinations with Ostracoda.

30 delegates attended to the Meeting. By countries these were: Australia 1 (Dr. K.G. McKenzie), Canada 1 (Dr. Q. Siddiqui), Egypt 2 (A. M. T. Elewa and accompanying person), India 1 (Dr. A. Bhandari), Great Britain 1 (Dr. M. Keen), Poland 2 (Dr. J. Szczechura and Dr. E. Olempska), Russia 1 (Dr. N. Aladin), Spain 3 (Dr. A. Baltanas, P. Alcorlo, L. Arqueros), Sweden 1 (Dr. S. Majoran), Turkey 17 (Dr. N. Sönmez-Gökçen, Dr. A. Nazik, Dr. Ü. Şafak, Dr. C. Tunçoğlu, Dr. M. Duru, Dr. S. Altınışlı, Dr. C. Kubanç, Dr. O. Kulköylüoğlu, Dr. H. Sarı, Dr. N. Avşar, Dr. K. Gürbüz, Dr. M. Kılıç, O. Özuluğ, N. Kubanç, G. Öğrünç, U. Işık, N. Akça).

Opening Ceremony of the meeting started in the morning of July 5th, 1999. Also, the scientific sessions started on July 5th, 1999 in the afternoon, and lasted July 6th, 1999. A keynote address, 19 oral and 5 posters were presented during the meeting. 11 papers of them were published in Proceeding Book. The following day, a field excursion was organized to the Tertiary Adana Basin. Guidebook by Drs. Kemal Gürbüz and Nuran Sönmez-Gökçen, guided by Dr. Gürbüz. Participants visited a considerable variety of marine and non-marine facies and fossiliferous beds including corals, pelecypods, gastropods, plant fossils as well as planktic forams and ostracods.

The new president and vice-president of European Ostracodologists were elected at the Closing Session. Dr. Atike NAZİK (Turkey) was elected as a President and Dr. Angel BALTANAS (Spain) was elected as a Vice-President of EO.

I would particularly like to thank Prof. Dr. Can ÖZŞAHİNOĞLU (Rector), Prof. Dr. A. Hamit SERBEST (Dean of Eng.&Arch.Faculty), Prof. Dr. Aziz ERTUNÇ (Previous Head of Geology Dept.) and Prof. Dr. Fikret İŞLER (Present Head of Geology Dept.). Their support and encouragement for this Meeting is deeply appreciated by the Organizing Committee. Also, the Organizing Committee would like to express their acknowledgment to Prof. Dr. Mesut ANIL and his colleagues for the presentation of this volume.

Dr. Atike NAZİK
Meeting Secretary



4th European Ostracodologists Meeting
6 July 1999 - Adana, TURKEY

ACKNOWLEDGEMENTS

The Organizing Committee of the 4th European Ostracodologists Meeting is grateful to following Foundations and Institutions for their practical support and some funding:

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INTRA-CLONAL SHAPE VARIABILITY IN THE NON-MARINE
OSTRACOD *HETEROCYPRIS BARBARA* (CRUSTACEA, OSTRACODA)

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ABSTRACT: *Environmental factors such as temperature are known to affect growth process in non-marine ostracods. Accordingly, the occurrence of changes in shape due to environmental cues is expected but poorly documented. Here we assess changes occurring in a clonal lineage –genetically uniform– of the non-marine ostracod *Heterocypris barbara*. Adult carapace size and shape have been analysed for a series of ostracods raised under controlled conditions for three environmental factors (two levels each): photoperiod - 16:8 and 8:16 (L:D) - , temperature - 10°C and 20°C - and conductivity - 6 and 20 m S cm⁻¹ . Relative influence of each of those factors and the interactions between them are described. Implications for the reconstruction of palaeoenvironments and for evolutionary ecology of parthenogenetic ostracods are discussed.*

1. INTRODUCTION

A central paradigm in ecomorphology is the link between an organism's morphology (phenotype) and its ecology (resource use and fitness) (Wainwright 1994). Performance, the ability of the organism to cope with the environment, is determined by its design. And, as far as the environment is not constant but fluctuates, it is assumed that adaptive pressures will favour some kind of flexible response, called *phenotypic plasticity*, in physiological, behavioural and development processes at the organism level. So, a single genotype might result in different phenotypes according the changing external conditions. The phenotypic response pattern of a single genotype is called *reaction norm*. In spite of those clear-cut definitions, phenotypic plasticity is still difficult to assess in the field, because of confounding effects due to other sources of phenotypic variability, mainly (a) random effects in biochemical and physiological processes at the individual level; and (b) genotypic differences among individuals.

A fruitful approach to measure phenotypic plasticity would be to exclude other sources of variability. Random individual variation, by its own nature, cannot be avoided. But between-genotype variability can be removed by performing observations on genetically identical individuals; an aim that can be achieved using clones of parthenogenetically reproducing organisms. In addition, lab experiments,

as compared to field experiments, are expected to provide a more clear pattern (although less realistic) of phenotypic change because some important environmental variables, including habitat structure and trophic resources, can be kept under control. Non-marine ostracods seem ideal model organisms for such an endeavour. Many species include populations which reproduce through obligate parthenogenesis; and due to their small size (0.5-2 mm) and short life span (frequently 1-3 months) they can be adequately cultured in the lab.

Among the many phenotypic traits that could be analysed for detecting patterns of phenotypic plasticity we here focus on morphological traits. More precisely, we explore variability in carapace size and shape within a clone of the palaearctic species *Heterocypris barbara* (Gauthier & Brehm, 1928). Instead of looking at the limbs, which are morphologically more diverse and complex structures, we analyse some aspects of carapace morphology. Our attention is devoted to the carapace because (i) as Benson (1981) states: "[...] the design of the carapace (of the ostracod) represents a direct interface between the animal and surrounding stresses"; and (ii) the carapace fossilise so well that if changes in environmental signals do consistently translate into changes in carapace features, then it would be possible to detect such environmental changes in the past by examining ostracod carapaces.

The range of environmental conditions

the organism can confront in the field is extremely large and involves a large set of variables. However, neither all of them are equally meaningful nor they all affect carapace morphology. There is evidence that some environmental variables such as temperature, oxygen content, salinity, water chemistry, depth, sediment texture and food supply are of overwhelming importance (Bodergat 1983, Carbonel et al. 1988). Previous experimental work, however, have dealt with just one or two of those variables at a time (Van Harten 1975, 1996, Martens 1985, Rossi 1990, 1993, Yin 1997).

Therefore, the aim of this paper is to describe, within a clone of a non-marine ostracod, the phenotypic plasticity in carapace size and shape when exposed to a range of environmental conditions resulting from the combined effect of temperature, conductivity and photoperiod.

2. MATERIAL AND METHODS

The experimental organism is the non-marine ostracod *Heterocypris barbara*. It is widely distributed in Europe, mainly in the circum-mediterranean region and, accordingly, has a wide ecological tolerance ranging from freshwater to saline habitats (Santamaría et al. 1992, Baltanás et al. 1996). Both parthenogenetic and syngamic populations are known, but for the aims of this work an all-female population from Retamar lake (La Mancha, central Spain) was selected. The lake is a temporary shallow calcium-sulphate

dominated water body (Otero 1998).

Animals sampled from the lake (February '97) were used to set up a stock culture which was maintained in the lab for more than a year. Given that multiple clones frequently coexist in a single water body (Havel et al. 1990, Havel & Hebert 1993, Rossi & Menozzi 1990) and that they can significantly differ in fitness (Rossi & Menozzi 1990, 1993) ten females were randomly selected from the stock culture (May '98) and placed isolated in separate wells of tissue culture plates ($\phi = 3.5$ cm, height = 1.5 cm). This procedure was developed in order to choose a lineage which could perform well enough under the experimental conditions (high fecundity, short generation time, high survival rates). This preliminary experiment was run under the following conditions: 16L:8D- photoperiod; 20°C- room temperature; and 5.6 mS cm⁻¹ – conductivity. All individuals were checked and the medium of their containers renewed on a daily basis (except for weekends). Experimental animals were reared in water from the lake and fed with *Tolypothrix tenuis* (Cyanobacteria) cultured on a BG-11 medium.

Among those females which survived experimental conditions, one showing high fecundity and early reproduction was selected as founder of the experimental clonal lineage. Eggs laid by this 'mother' were monitored and transferred to individual culture wells as soon as they hatched. This first

generation was split into eight sub-sets, each with a different combination of environmental conditions (see Table 1). Instead of using this animals for the experiment, they were kept under controlled conditions until they themselves laid eggs. This was to reduced transgenerational phenotypic plasticity, the so called *maternal effects* through which the environment experienced by the mother can affect the phenotypic variation of the offspring (Mousseau & Fox 1998). Therefore, new-borns of the second generation were used as experimental individuals (24 replicates per experiment, table 1).

These cultures were maintained until ostracods reached the adult stage and die. Adult ostracods were then dissected and their valves cleaned and placed over micro slides to be observed under a microscope. Those valves that were broken or decalcified were excluded from the analysis. Valve outlines were recorded using a semi-automatic image analysis system. Cartesian co-ordinates gathered in this way were analysed using Elliptic Fourier analysis in order to obtain a series of Fourier coefficients (20 harmonics, 4 coefficients each) which summarises the outline shape in a quantitative way. The elliptic Fourier

Table 1. Factorial experimental design. Each experiment was run with 24 replicates. Final number of valves analysed are indicated under N (LV-left valves; RV-right valves).

Experiment	N	Temperature	Conductivity	Photoperiod
1(<i>tcP</i>)	18(LV)/17(RV)	10°C (t)	5.6 mS cm ⁻¹ (c)	16L:8D (P)
2(<i>tcp</i>)	7(LV)/8(RV)			8L:16D (p)
3(<i>tCP</i>)	11(LV)/16(RV)		20 mS cm ⁻¹ (C)	16L:8D (P)
4(<i>tCp</i>)	8(LV)/11(RV)			8L:16D (p)
5(<i>TcP</i>)	17(LV)/16(RV)	20°C (T)	5.6 mS cm ⁻¹ (c)	16L:8D (P)
6(<i>Tcp</i>)	20(LV)/23(RV)			8L:16D (p)
7(<i>TCP</i>)	13(LV)/19(RV)		20 mS cm ⁻¹ (C)	16L:8D (P)
8(<i>TCp</i>)	17(LV)/21(RV)			8L:16D (p)

coefficients were normalised for size, orientation and starting point. Co-ordinates for the left valves were previously transformed to produce a mirror image directly comparable with

right valve outlines.

Length, height and outline area were measured on each specimen as estimates of size. Differences in mean size among experiments were evaluated by

performing a three-factor analysis of variance, where the factors considered (two levels each) were temperature, conductivity and photoperiod. Factor levels were selected within the known range of tolerance of the species. Codes for each level and factor are also included in Table 1. Left valves and right valves were analysed apart as they are not independent from each other.

If, despite homogeneous genetic control over development, environmental conditions affect ostracod shape in some specific way then we expect a coherent pattern of shape variation among the various experiments - this means that variability between experiments is expected to be higher than variability within experiments. This last type of variability is identified as developmental 'noise' at the individual level. To test this hypothesis the pattern in shape variation among different experiments was assessed using discriminant function analysis. This method provides a set of canonical functions which discriminate as well as possible between groups that are known *a priori* (Manly 1994). In our case, the groups are the eight experiments. For this analysis, left and right valves were again considered apart, this time to check whether or not both valves undergo similar changes in shape under the same conditions. Of course, it is presumed from the beginning that if both valves change their shapes dissimilarly, it will probably result in malfunction and fitness reduction for the organism.

3. RESULTS

A total of 242 valves (131 right valves and 111 left valves) out of 384 (belonging to the 192 experimental ostracods) were measured for size and their shapes recorded. Few of the experimental animals did not reach maturity (less than 6%), so those lost data were mainly due to bad preservation of the valves or accidents while manipulating them. There were also some valves poorly calcified which become deformed during the process of drying before measuring.

Given that all size-related variables are highly correlated (Table 2), three-factor analysis-of-variance was performed only on outline area measurements.

Table 2. Correlation coefficients (Pearson) between size measurements in both right (upper diagonal) and left (lower diagonal) valves.

	Length	Height	Area ^{1/2}
Length	-----	.962 (***)	.987 (***)
Height	.946 (***)	-----	.990 (***)
Area ^{1/2}	.986 (***)	.983 (***)	-----

Three-factor interaction was statistically significant for both left and right valves. ($F_{LV(1,103)} = 13.43$, $p < 0.001$; $F_{RV(1,123)} = 24.15$, $p < 0.0001$). This implies that the factors considered are not independent in their effects on ostracod size and, thus, precludes from analysing them individually (Underwood 1996). Observed average sizes range from nearly 1 mm² (~1.5mm long;

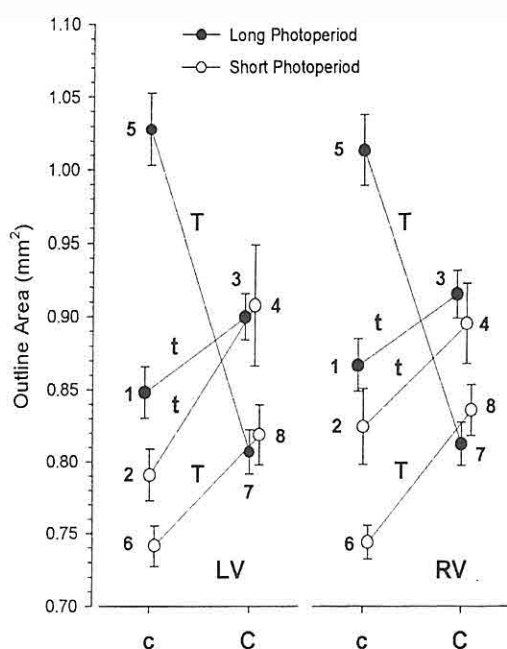


Figure 1. Average adult sizes and their standard errors for each of the eight experiments (see Table 1 for experiment number and code).

experiment 5 - TcP) to 0.7 mm² (~1.24 mm long; exp. 6 - TcP) (see Fig. 1). Long photoperiod, low temperature, and high conductivity seem to result in larger adult ostracod size, except for experiments 5 and 7 which behave in a completely opposite direction. Could it be that those results are affected by some kind of experimental or measurement error? After having carefully checked all the experimental procedures and having analysed other life-history traits in those organisms (Alcorlo et al. in prep) we consider those observations are reliable, so dramatic increase in size under conditions such as in exp-5 must be

6

further discussed.

Discriminant function analysis was rather successful showing that it is possible to separate the experimental groups (and valve side) on the basis of their shape. In figure 2, the mean shapes (left and right valves) corresponding to each of the 8 experiments are plotted. Those average shapes are the representatives of each group and are computed by averaging the harmonic coefficients (shape variables) elementwise. The first four canonical functions explain 71% percent of the variance in the raw data (Fig. 2). The main patterns observed are:

- first discriminant function separates left valve shapes from right valve shapes, meaning that differences in shape between left and right valves are more substantial than differences in shape between different treatments.
- Within the morphospace defined by discriminant functions, left valves are more spread, i.e. are more variable in shape, than right valves (Fig. 2A).
- The distribution of the 'right valve' groups along the second discriminant function is paralleled by the 'left valve' groups. Left and right valves undergo similar shape changes when developed under similar conditions (see Fig. 2A).
- Two main groups can be distinguished according valve shape (second discriminant function): low temperature experiments (1-2-3-4) and high temperature experiments (5-6-7-8).

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However, no clear pattern related to either conductivity or photoperiod emerges.

- Among experiments with high temperature (20°C), experiment-5 (TcP) is neatly separated from all the others (Fig. 2A).

4. DISCUSSION

When growing under different environmental conditions some morphological traits of *Heterocypris barbara* show variability well beyond

what can be considered random individual variation. For instance, regardless of which valve is considered (left or right), there is a 40% increase in size (measured as outline area) from individuals in experiment-6 (TcP) to those in experiment-5 (TcP). Interestingly, both experiments only differ in the length of the photoperiod with which the ostracods were grown. Differences in size between other experiments are also significant, although less dramatic in magnitude. However,

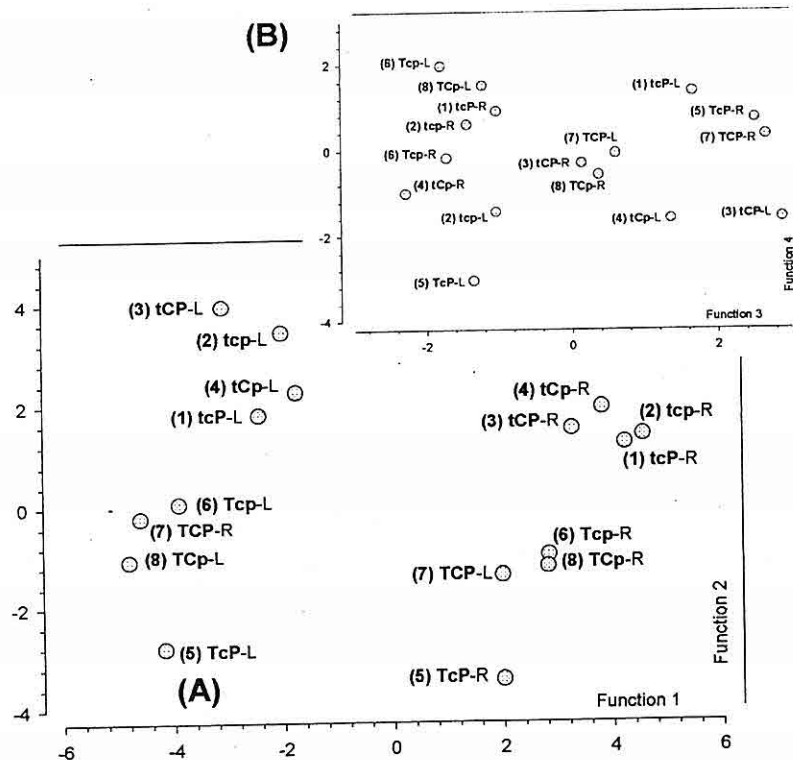


Figure 2. Plot of ostracod shapes in the 8 experiments, left (L) and right (R) valves, against their values for canonical discriminant functions. The first two functions (A) account for 55 % of variance in the original data; the third and fourth functions (B) explains an additional 16 %

morphological responses seem to be driven not by one factor alone but by the combination of the three used here (temperature, conductivity and photoperiod). Complex influences produce complex responses, a corollary which sounds quite reasonable although it significantly limits our capacity for doing generalisations. This is somewhat disappointing as if each environmental factor would induce a single, recognisable effect in ostracod morphology we could trace changes in such factors by simply tracking changes in ostracod carapace morphology. This would be of invaluable help for studying past environments. Due to the extensive fossil record of ostracods, their carapaces could be approached morphometrically to retrieve the fingerprints of past environmental events.

There are no experiments to our knowledge that had explored morphological changes in ostracod carapace under the influence of more than two controlled environmental conditions. Martens (1985) summarises (his Table 1) a good number of studies (including lab and field experiments) on ostracod growth which paid attention to carapace size. None of those studies controlled (or measured) more than two environmental factors at a time (mainly temperature, sometimes salinity or pH). The existence of complex, not easily predictable responses brings some light to understand why there is contradictory evidence in the literature concerning the specific effect of some environmental

factors. Increases in conductivity (or salinity), for instance, are documented to increase carapace size in *Limnocythere inopinata* (Yin 1997) and *Cyprideis torosa* (Van Harten 1975, 1996); but seem to have no effect in *Mytilocypris henricae* (Martens 1985). Temperature, which is by far the factor which has been most heavily studied concerning its influence on carapace morphology, have also rendered divergent observations. There is an assumed association between low temperature and larger body size in ectotherms, including microcustaceans like the ostracods (Green 1956, Rossi & Menozzi 1990). Martens (1985) found such relationship in the Australian ostracod *Mytilocypris henricae* when raised in a temperature range of 10° to 25°C. But Yin (1997) could not detect any kind of response to temperature in his lab cultures of *L. inopinata*. Our experiments with *H. barbara* show that low temperatures result in larger individuals most of the time but, when conductivity and photoperiod combine adequately with high temperature then the largest individuals are raised.

An attempt to measure the effect of temperature not only in size but also in carapace shape is that of Reyment et al. (1988) who concluded that possibly temperature (or some other seasonal factor) is the primary cause of variability in the shape of the carapace. Our results agree with theirs as changes in shape are mainly related, although not exclusively, to changes in temperature among experiments (Fig. 2).

Most of the data available in the literature concerning the relationship between carapace shape and environmental fetures refer to populations which are either sexually reproducing or multi-clonal (Carbonel et al. 1988). This means that what is measured is not the response of a single genotype but an average response across a variety of genotypes; i.e. variability at the population or species level. The point of interest, nevertheless, is whether morphological polymorphism is environmentally cued (ecophenotypic) or due to evolutionary-genetic durable forces (Reyment 1988). For instance, Danielopol (1980) associates six major shape types among the Candoninae with degrees of harshness and stability in their habitats, concluding that observed shapes are likely adaptive traits selected to increase species performance and fitness. Tétar (1982) also links shape variability in *Eucypris virens* (Jurine) to microevolutionary processes and considers that different shape types are genetically fixed at the population level. A different conclusion, that shape features are not genetically fixed but ecophenotypic, is raised by Broodbakker (1983a, b, 1984) after analysing carapace shape of several *Heterocypris*, *Hemicypris* and *Strandesia* species living in the Antillean Islands.

In this controversy between ecophenotypic effects and genetically fixed traits there is, notwithstanding, a third option frequently neglected: phenotypic variability can be genetically

coded but with an environmentally cued expression. If such is the case, and it seems to be a rather frequent case, the so-called reaction norm becomes a main subject for natural selection to act upon (Schlichting & Pigliucci 1998). Certainly not all patterns of plasticity in morphological traits are adaptive (Travis 1994). And, in addition, causal relationships between morphological traits and ecology are difficult to assess. But having shown that phenotypic plasticity exists in *H. barbara* it would worth to look for further evidence on the meaning of those subtle changes in carapace shape.

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STUDIES ON SOME IMPORTANT OSTRACOD GROUPS FROM THE PALEOGENE OF EGYPT

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ABSTRACT: *The relationships of some important species related to the genera **Paracosta**, **Loxoconcha**, **Leguminocythereis** and **Uroleberis** from the Paleogene deposits of Egypt have been revised. The achieved results are encouraging toward producing a monograph on the Paleogene ostracods of Egypt.*

*Detailed study of these genera revealed the distinction of a phylogenetic series within the genus **Paracosta** (**Paracosta palaeomokattamensis-Paracosta mokattamensis**). Moreover, the studied **Loxoconcha** species that were thought to represent a phylogenetic series by some authors assumed in this study to represent two species inherited from one ancestor, while the third from another ancestor. On the other hand, the studied Middle Eocene **Leguminocythereis** species are an example of the so-called environmentally cued polymorphism. Whereas, the studied species previously referred to the genus **Uroleberis** assumed in this study to represent the genera **Uroleberis** and **Foveoleberis**. Overall, **Paracosta mokattamensis praemokattamensis** seems to be a good stratigraphic indicator of the Lower/Middle Eocene boundary.*

1. INTRODUCTION

Species related to the genera *Paracosta* Siddiqui 1971, *Loxoconcha* Sars 1866, *Leguminocythereis* Howe & Law 1936 and *Uroleberis* Triebel 1958 show some incredulity in their taxonomy, stratigraphic distribution as well as evolution in the Paleogene of Egypt. As a result, a detailed study of these species and their relations to each others within each genus is urgent to solve these problems as a step toward publishing a complete monograph on the Paleogene ostracods of Egypt.

The genus *Paracosta* was established by Siddiqui (1971) to represent those ostracods with normally developed four longitudinal ridges and reticulation. The type species of *Paracosta*; *Costa* (*Paracosta*) *declevi* Siddiqui 1971; was described by Siddiqui from the Upper Eocene of Pakistan as a new subgenus based on the presence of a fourth ventral ridge intercalated between third ridge and ventral margin. This fourth ridge is better observed on the right valve. Keen et al. (1994) stated that although five closely related genera have previously been described (*Reticulina* Bassiouni, 1969; *Paracosta* Siddiqui, 1971; *Paleocosta* Benson, 1977; *Archeocosta* Al Bashir & Keen, 1984; *Reymenticosta* Bassiouni & Luger, 1990), but the genus *Paracosta* has become the most widely used of these genera. Three species and subspecies of *Paracosta* seem to represent a phylogenetic trend in the Paleogene of Egypt: *Paracosta palaeomokattamensis* Bassiouni & Luger

1990, from the Middle Paleocene of southern Egypt; *Paracosta mokattamensis* *praemokattamensis* (Bassiouni 1969a), from the Early Eocene of Jordan; and *Paracosta mokattamensis* (Bassiouni 1969b) from the Middle Eocene of Gebel Mokattam. These species exhibit a gradual change in morphologic characters with time. One of the authors (A. E.) recognized specimens referred to *Paracosta mokattamensis praemokattamensis* from the Early Eocene strata of the Minia Formation in southern Egypt. While specimens represent *Paracosta mokattamensis* were recognized from the Eastern Desert and Nile Valley by different authors. *Paracosta palaeomokattamensis* was recognized by Bassiouni & Luger (1990) from the Dakhla Formation of southern Egypt. The phylogenetic trend of these species should be established to reach a suitable conclusion about this important group of ostracods in the Paleogene of Egypt.

On the other hand, Sars (1866) introduced the genus *Loxoconcha* to represent ostracods with almond-shaped carapaces that having a straight dorsal margin and sinuous venter. This genus has been represented in the Middle Eocene strata of Egypt by three main species: *Loxoconcha pseudopunctatella* Cronin & Khalifa 1979, from the Gebel El Mereir in the Eastern Desert; *Loxoconcha mataiensis* Khalifa & Cronin 1979, from the Gebel El Sheikh Fadl, 5 km east Beni Mazar city on the Nile Valley; and *Loxoconcha*

vetustopunctatella Bassiouni et al. 1984, from Wadi El Rayan south of Fayoum. Bassiouni et al. (1984) in their study on the ostracod assemblages of Fayoum, have recognized some specimens that show transitional characters between *Loxoconcha vetustopunctatella* and *Loxoconcha pseudopunctatella*, therefore, they considered that the first species is the ancestor of the second. In 1994, Bassiouni et al. recorded the first species at horizons equivalent and sometimes higher than those of the second species, consequently, they rejected the aforementioned opinion. The authors observed that *Loxoconcha vetustopunctatella* and *Loxoconcha mataiensis* have many similar morphologic characters (closely similar shape in dorsal view for example). A part of the present study is devoted to clarify the morphologic relationships among these three species to explicate their phylogeny during the Paleogene time.

The genus *Leguminocythereis* was established by Howe & Law (1936) to represent the bean-shaped ostracods with subparallel dorsum and venter (for more details see Moore, 1961). Boukhary et al. (1982) stated that they think about a phylogenetic relationship between *Leguminocythereis lokossaensis*, *Leguminocythereis dandaraensis*, *Leguminocythereis hassani*, *Leguminocythereis praesadeki* and *Leguminocythereis sadeki* in the Paleogene of Egypt. It is very important to show if that opinion is true or there is some doubt about this relationship.

Triebel (1958) introduced the genus *Uroleberis* to represent ostracods with marked accommodation groove in the left valve and a small posterior caudal process coupled with a rather characteristic shape. This genus has been represented in the Paleogene strata of Egypt by four main species: *Uroleberis triebeli* Bassiouni & Luger 1990, from the Late Paleocene to Early Eocene of southern Egypt and *Uroleberis wahati* Bassiouni & Luger 1990, from the Early Eocene of southern Egypt; *Uroleberis striatopunctata* Ducasse 1967, in Elewa (1994), from the Middle Eocene of the El Sheikh Fadl-Ras Gharib stretch in the Eastern Desert; and *Uroleberis curta* Boukhary and Guernet 1993 (in Boukhary et al. 1993), from the Middle Eocene of Mingar El Rayan south of Fayoum. These four species were referred to the genus *Uroleberis* despite the difference of some of them in ornamentation and shape of caudal process than the type species of this genus: *Uroleberis parnensis* (Apostolescu 1955). It is necessary to reveal if these species belong to *Uroleberis* or could be referred to another genus.

2. MATERIAL AND METHODS

The studied species and subspecies were collected by the authors from different localities in Egypt (Fig. 1). However, data describing few species were collected from published literature.

Specimens used in the present study, except for *Leguminocythereis dandaraensis* and *Leguminocythereis*

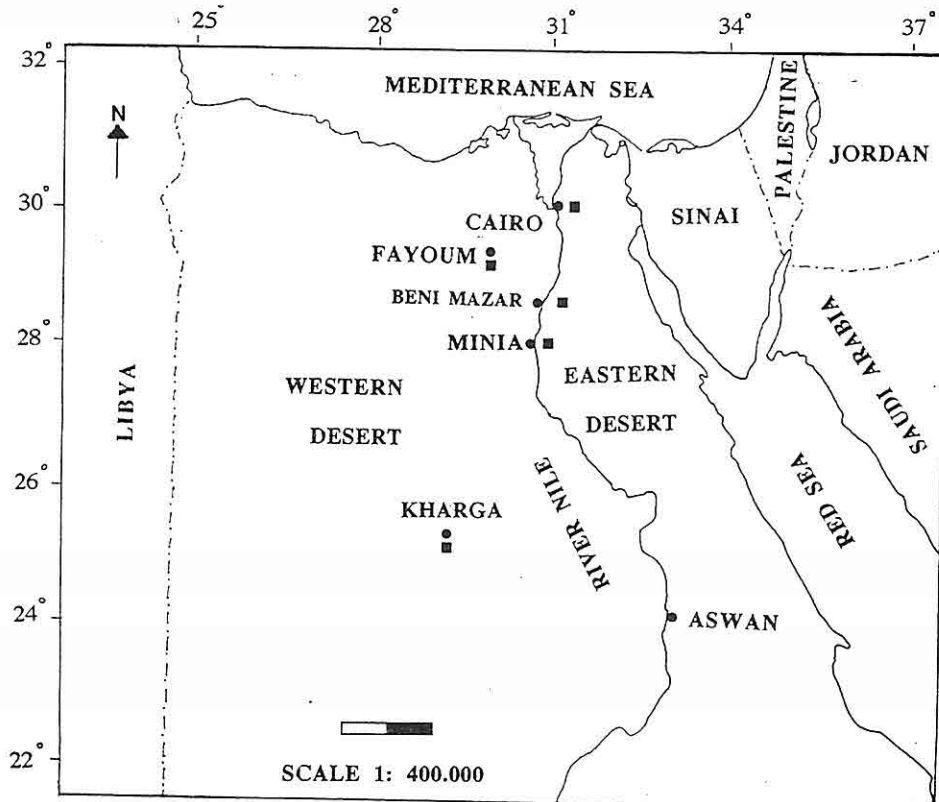


Figure 1. Location map of the studied species. Black squares are locations of species

hassani, are deposited in the Geology Department, Faculty of Science, Ain Shams University in Bassiouni's collection and the Geology Department, Faculty of Science, Minia University in Elewa's collection. Illustrations in Figures 2, 4, 6 & 7 are small sized photocopies copied from published literature.

3. RESULTS AND DISCUSSION

In the following lines the authors try to demonstrate if any phylogenetic trends

are present within species of every genus of the studied taxa, and if not what relation exists.

3.1. *Paracosta* Siddiqui 1971

Paracosta palaeomokattamensis Bassiouni & Luger 1990 is a common species in the Middle Paleocene strata of southern Egypt. It has a medium size carapace with subrectangular to suboval shape in lateral view. Bassiouni & Luger (1990) stated that this species differs from *Paracosta mokattamensis* and




Species	characters		
	<i>Paracosta mokattamensis</i>	<i>Paracosta praemokattamensis</i>	<i>Paracosta palaemokattamensis</i>
			
	Medium in size	Small to medium in size	Medium in size
	Subrectangular	Subrectangular	Subrectangular to suboval
	Broadly rounded	Broadly rounded	Broadly rounded
	Obtusely angular	Obtusely angular	Strongly acute
	Straight	Straight	Straight
	Straight	Straight	Gently curved
	Weakly developed	Weakly developed	Weakly developed
	At eye-spot	At eye-spot	At eye-spot
	Fine reticulation & ribs	Smooth with minor ribs	Ribs & minor nodes
	As for the genus	As for the genus	As for the genus
	Prominent	Prominent	Prominent
	0.87	0.77	0.85
	0.42	0.40	0.43
	0.75	0.72	0.77
	0.45	0.40	0.43

Figure 2. The main morphologic characters of the studied *Paracosta* species.

Paracosta mokattamensis
praemokattamensis by its smaller size, more acute posterior margin and different ornamentation.

Paracosta mokattamensis
praemokattamensis (Bassiouni 1969a) was first identified by Bassiouni (1969a) from the Lower Eocene of Jordan and

was considered by him to be the ancestor of *P. mokattamensis*. Elewa (1998) recognized this species in the lower Eocene of the Minia Formation at its type locality opposite to Minia city in southern Egypt.

Paracosta mokattamensis (Bassiouni 1969b) is the first identified species of

the studied *Paracosta* species. Bassiouni (1969b) identified this species from the Eocene (Bartonian) of Gebel Mokattam in Cairo. Recently, Elewa (1994) recognized this species in the Middle Eocene strata of the El Sheikh Fadl-Ras Gharib stretch in the Eastern Desert. It seems that the species identified by Khalifa & Cronin (1979) as *Costa berggreni* is a synonym of *Paracosta mokattamensis*.

The aforementioned species are closely similar in morphologic characters but with slight differences. The main differences are the variation in size that decreases with time from Middle Paleocene to the Early Eocene and increases again towards the Middle Eocene (Fig. 2), the broadening of the posterior end from the Middle Paleocene toward the Middle Eocene and the ornamentation which changes from smooth with ribs and minor nodes in the Middle Paleocene to fine reticulation with ribs in the Middle Eocene. It seems that these three species and subspecies represent a phylogenetic series (*Paracosta palaeomokattamensis*-*Paracosta mokattamensis*) (Fig. 3). Unlikely, the Egyptian ostracods show affinities between Paleocene and Lower Eocene ostracods rather than Middle Eocene ones. However, a survival strategy attempt occurs in the studied *Paracosta* species at the Lower/Middle Eocene boundary. It is translated by the small size of the individuals belonging to *Paracosta mokattamensis praemokattamensis* as compared with

sizes of its assumed ancestor *Paracosta palaeomokattamensis* and assumed descendant *Paracosta mokattamensis*, as well as its resemblance to the Middle Eocene species (*Paracosta mokattamensis*) in most characters, except size and ornamentation, if compared with the Middle Paleocene species (*Paracosta palaeomokattamensis*).

3.2. *Loxoconcha* Sars 1866

The genus *Loxoconcha* Sars, 1866 (type species: *Cythere rhomboidea* Fischer, 1855) has a medium to large carapace which is rhomboidal or ovate in lateral view, often with a compressed posteroventral marginal area. Its ornamentation is usually concentrically arranged pitting or reticulation. Sexual dimorphism is conspicuous in this genus where males are more elongated and with straighter margins than females. Species of this genus have been distributed from Cretaceous to Recent.

In a preliminary study of the phylogenetic relationships between the above mentioned three species belonging to the genus *Loxoconcha* from the Middle Eocene strata of Egypt, some attitudes of their shape changes through ontogeny were compared. From a phylogenetic viewpoint, *Loxoconcha pseudopunctatella* and *Loxoconcha vetustopunctatella* are considered by Bassiouni et al. (1984) to represent a phylogenetic series. Microscopic observations of "A" to "A-5" stages for each of the three species displayed that

OSTRACOD GROUPS FROM THE PALEOGENE OF EGYPT

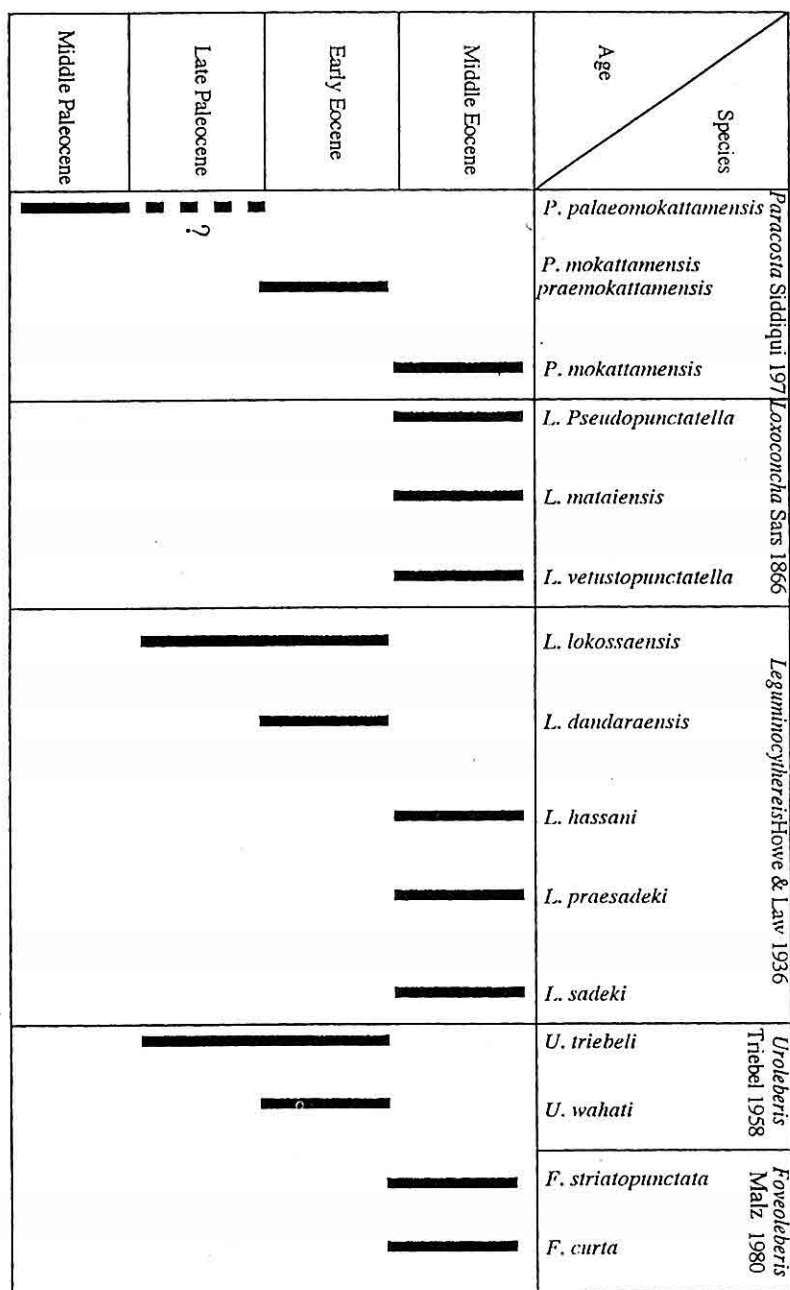


Figure 3. Range chart of the species studied in the present work.

Loxoconcha pseudopunctatella and *Loxoconcha vetustopunctatella* are much more alike in shape at later stages than earlier stages in their ontogeny. Moreover, they are recorded at equivalent horizons in the studied sequences. In comparison, *Loxoconcha pseudopunctatella* offers convergent trajectories with *Loxoconcha mataiensis* in the juvenile stages and divergent trajectories in the adults. On the other hand, the highly evolved stages of *Loxoconcha mataiensis* follow similar trajectories with the early adolescent stages of *Loxoconcha vetustopunctatella*. Furthermore, Figures 4 & 5 show the main morphologic characters of the studied species as well as their outlines, and Figure 3 their stratigraphic distribution. These results indicate that *Loxoconcha pseudopunctatella* and *Loxoconcha mataiensis* could be evolved from a common ancestor, while *Loxoconcha vetustopunctatella* is thought to be inherited from another ancestor.

3.3. *Leguminocythereis* Howe & Law 1936

As it was mentioned above, Boukhary et al. (1982) thought that a phylogenetic relationship exists between *Leguminocythereis lokossaensis*, *Leguminocythereis dandaraensis*, *Leguminocythereis hassani*, *Leguminocythereis praesadeki* and *Leguminocythereis sadeki* in the Paleogene of Egypt. Any phylogenetic trend should be associated with time

progress. *Leguminocythereis lokossaensis* was named by Apostolescu (1961) from the Late Paleocene and Early Eocene of Togo (West Africa); it may be the ancestor of this group in the Paleogene of Egypt, but the problem exists in the Middle Eocene species. Bassiouni (1969c) identified *Leguminocythereis sadeki* as a new species from the Eocene of Helwan near Cairo. This species, which is thought by Bassiouni et al. (1984) to be a representative of the late Lutetian, was recognized by Elewa et al. (1996) at levels equivalent to the planktonic foraminiferal zone *Globigerinatheka subconglobata* Interval Zone of the Middle Lutetian (P11). Likewise, *Leguminocythereis praesadeki* Boukhary et al. 1982 was recognized by different authors within the *Globigerinatheka subconglobata* Interval Zone (P11) through the *Morozovella lehneri* Interval Zone (P12) to the *Truncorotaloides rohri* Interval Zone (P14). Boukhary et al. (1982) found *Leguminocythereis hassani* Khalifa & Cronin 1979 almost at the same levels. While, Khalifa & Cronin (1979) assigned this species, together with the whole ostracod assemblage of the El Sheikh Fadl section, a Late Lutetian age based on the associated planktonic foraminifers. Accordingly, the three species occur at the same levels within the Middle Eocene strata of Egypt. Concerning morphologic characters, Boukhary et al. (1982) mentioned that *Leguminocythereis praesadeki* is an intermediate form




Species		characters	
<i>Loxocncha pseudopunctatella</i>		<i>Loxocncha mataiensis</i>	
<i>Loxocncha veispunctatella</i>			
Small in size	Small in size	Very small in size	Carapace
Subquadrate	Rhomboidal	Subrhomboidal	Lateral view
Rounded	Truncate	Broadly rounded	Anterior margin
With caudal process	With caudal process	With caudal process	Posterior margin
Straight	Straight	Straight	Dorsal margin
Strongly convex	Convex	Convex	Ventral margin
More tapering posteriorly	More tapering posteriorly	Ovoid	Dorsal view
Anteriorly	Anteriorly	Anteriorly	Maximum height
Pits	Pits	Pits	Ornamentation
Invisible	Invisible	Invisible	Eye-spot
Prominent	Prominent	Prominent	Sexual dimorphism
<div>0.425</div> <div>0.25</div>		<div>0.50</div> <div>0.250</div>	
<div>0.39</div> <div>0.25</div>		<div>0.40</div> <div>0.275</div>	
<div>0.35</div> <div>0.175</div>		<div>0.35</div> <div>0.25</div>	
<div>H (mm)</div> <div>L (mm)</div>		<div>H (mm)</div> <div>L (mm)</div>	
<div>Males</div>		<div>Females</div>	
<div>Dimensions</div>		<div>Dimensions</div>	

Figure. 4. The main morphologic characters of the studied *Loxoconcha* species.

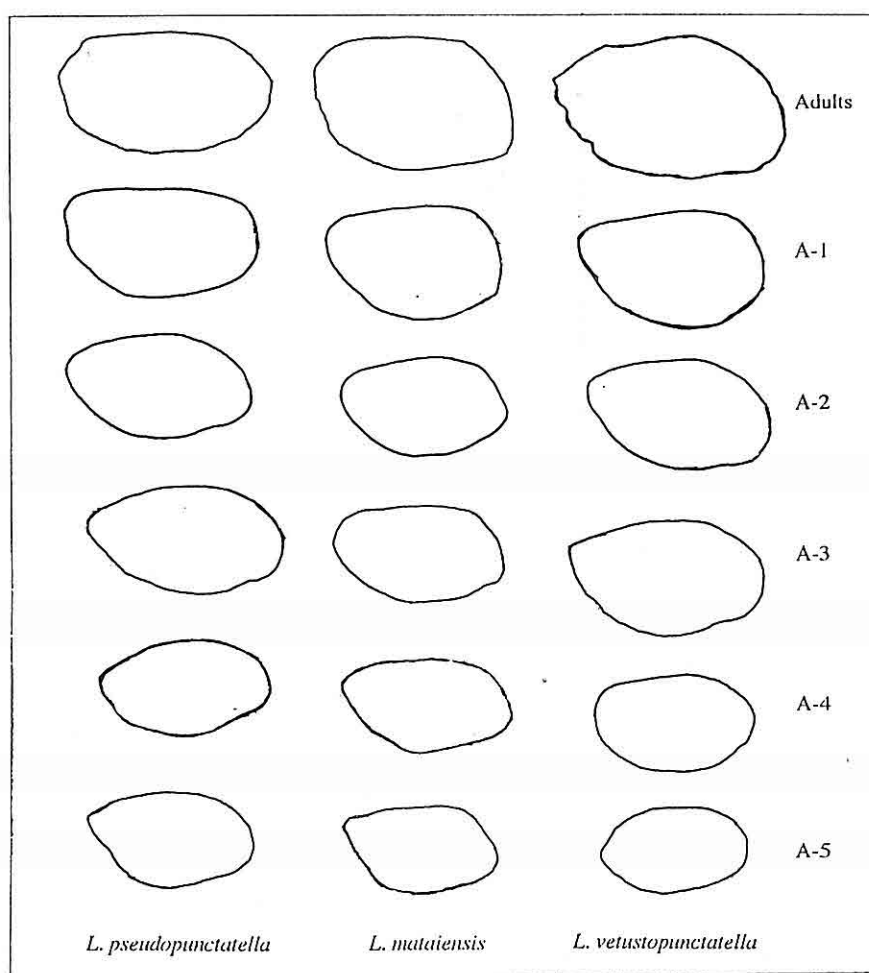


Figure. 5. Outlines of the studied *Loxoconcha* species. All specimens are right side view of carapaces drawn under x 200.

1-3: Adults, 4-6: "A-1" stages, 7-9: "A-2" stages, 10-12: "A-3" stages, 13-15: "A-4" stages, 16-18: "A-5" stages.

1, 4, 7, 10, 13, 16. *Loxoconcha pseudopunctatella*, all from the Midawara Formation of Wadi El Rayan, Fayoum area.

2, 5, 8, 11, 14, 17. *Loxoconcha mataiensis*, all from the Maghagha Formation of a section opposite to Beni Mazar city, on the western bank of the Nile Valley.

3, 6, 9, 12, 15, 18. *Loxoconcha vetustopunctatella*, all from the Midawara Formation of Wadi El Rayan, Fayoum area.

between *Leguminocythereis hassani* and *Leguminocythereis sadeki*, where the ventral side of *Leguminocythereis praesadeki* is less concave than *Leguminocythereis hassani* while that of *Leguminocythereis sadeki* is nearly straight. In addition, they noted that reticulation forms longitudinal ridges more and more prominent from *L. hassani* to *Leguminocythereis praesadeki* to *Leguminocythereis sadeki*. Reymont (1991) stated that a kind of an ornamental polymorphism consists of regular versus breached reticulations. He added that this type occurs in species of *Brachycythere* and *Leguminocythereis*. Peypouquet et al. (1986) argued that the strength of ornament is related to CaCO_3 saturation in the water during ecdysis, and considered the agradation-degradation phenomenon as an example of environmentally cued polymorphism. Nevertheless, Keen et al. (1994) pointed out that it is not certain whether the variation in ornament is true polymorphism or an ecophenotypic character. Clark (1976) concluded that any feature that gains expression in the phenotype must perforce have a genetic basis. Whereas, Reymont (1988) stated that at least some of the ornamental variations could be an expression of environmentally cued polymorphism.

Khalifa & Cronin (1979) identified 13 carapaces as *Leguminocythereis hassani* from the Middle Eocene rocks of the Maghagha Formation at Gebel El Sheikh Fadl east of Beni Mazar city on the Nile Valley. While, Elewa et al. (1995)

recognized *Leguminocythereis praesadeki* from the same formation. They concluded that this formation was deposited under shallow marine conditions with more or less reduced salinity. More recently, Elewa et al. (1996) distinguished *Leguminocythereis sadeki* from the Middle Eocene deposits of the Gehannam Formation at Fayoum. They declared that the Gehannam Formation was deposited under middle neritic to upper bathyal deep marine environment.

In conclusion, the gradual regularity in reticulation expressed by gradual prominence of the longitudinal ridges from *Leguminocythereis hassani* to *Leguminocythereis praesadeki* to *Leguminocythereis sadeki* (Fig. 6) may be related to gradual increase in depth and salinity (environmentally cued polymorphism). Therefore, these three species are nothing more than three morphs of one species that is *Leguminocythereis sadeki* (the first identified species in the series) (Fig. 3).

3.4. *Uroleberis* Triebel 1958

Neale & Singh (1988), in their study on the problems associated with the genus *Uroleberis*, divided the species belonging to this genus into five groups according to ornamentation, caudal process and eye tubercle. Group I (unnamed group) with reduced caudal process; group II (*Uroleberis* group) with smooth surface and typical caudal process; group III (*Foveoleberis* group) represents the highly pitted and foveolate forms; group

Species	characters		
	Carapace	Lateral view	Anterior margin
<i>Leguminocythereis sadeki</i>	Medium in size	Subovoid	Broadly rounded
<i>Leguminocythereis praesadeki</i>	Medium in size	Subovoid	Broadly rounded
<i>Leguminocythereis hassani</i>	Medium in size	Subovoid	Broadly rounded
			Narrowly rounded
			Convex
			Concave anteriorly
			Present
			At mid-length
			Reticulation & prominent ridges
			Holamphidont
			0.80
			0.45
			0.80
			0.45
			1.01
			0.54
			H (mm)
			L (mm)
			Dimensions

Figure 6. The main morphologic characters of the studied *Leguminocythereis* species.

IV (unnamed group) characterizes the foveolate-reticulate species with or without eye tubercle; and group V (*Ornatoleberis* group) for those species with heavy valves, almost vertical posterior margin and have tendency to pustulose ornamentation.

In the present study, *Uroleberis triebeli* Bassiouni & Luger 1990 and *Uroleberis wahati* Bassiouni & Luger 1990 have almost the same characters as group II (Figs. 3 & 7), therefore it is obvious that they belong to the genus *Uroleberis*. On the other hand, *Uroleberis striatopunctata* Ducasse 1967 and

Uroleberis curta Boukhary and Guernet 1993 show characters closely similar to group III (Figs. 3 & 7). As a result, they should be referred to the genus *Foveoleberis* Malz, 1980.

4. CONCLUSIONS

Detailed study of some important species belonging to the genera *Paracosta*, *Loxoconcha*, *Leguminocythereis* and *Uroleberis* from the Paleogene of Egypt revealed the distinction of a phylogenetic series within the genus *Paracosta* (*Paracosta palaeomokattamensis* - *Paracosta*

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Figure 7. The main morphologic characters of the studied *Uroleberis* and *Foveoleberis* species.

mokattamensis). Moreover, the studied *Loxoconcha* species that were thought to represent a phylogenetic series by some authors assumed in this study to represent two species inherited from one ancestor, while the third from another ancestor. On the other hand, the studied Middle Eocene *Leguminocythereis* species are an example of the so-called environmentally cued polymorphism. Whereas, the studied species previously referred to the genus *Uroleberis* assumed in this study

to represent the genera *Uroleberis* and *Foveoleberis*. Overall, *Paracosta mokattamensis praemokattamensis* seems to be a good stratigraphic indicator of the Lower/Middle Eocene boundary.

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NON-MARINE OSTRACODA (CRUSTACEA) FROM TEMPORARY PONDS
IN THE ISOLE PELAGIE (SICILY, ITALY)

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ABSTRACT: *Ostracoda* were collected from temporary ponds on the islands of Lampedusa and Linosa in the Isole Pelagie south of Sicily during visits in 1997-1999. Six species have been identified - one Candonidae, two Cyprididae and three Cypridopsidae. Five of these are recorded for the first time from this area.

Cypria ophthalmica (Jurine, 1820) was present only on Linosa; and *Heterocypris salina* (Brady, 1868) occurred only on Lampedusa. *Cypridopsis vidua* (O.F. Müller, 1776), *Heterocypris incongruens* (Ramdhor, 1808), *Plesiocypridopsis newtoni* (Brady and Robertson, 1870) and *Potamocypris arcuata* (Sars, 1903) were found on both islands. *P. newtoni* was represented by sexual populations and *H. incongruens* by both sexual and all female populations; the other species occurred as females only.

The record of bisexual populations of *H. incongruens* is interesting. We report the morphological features of its hemipenis. However, among other characters, the outer lobe differs from that illustrated by G.W. Müller (1900) for a German population but resembles that of the males in another population of *H. incongruens* from northern Spain.

1. INTRODUCTION

We present the preliminary results of research carried out from November 1997 to March 1999 (see Materials and methods) on the Ostracoda fauna of temporary habitats on Lampedusa and Linosa, the two largest islands in the Isole Pelagie.

2. THE ENVIRONMENT

The Isole Pelagie lie in the southern Mediterranean half way between Tunisia and Sicily and rise from the northern edge of the African continental plate (Fig. 1, inset). Lampedusa (35° 30' 13" N Lat.; 12° 36' 25" E Long.) consists of Cainozoic carbonates (Agnesi and Federico, 1995), has a subtriangular shape (Fig. 1) and exhibits a subplanar surface inclined towards the southwest. It has a surface area of 20.2 km² and a maximum length of about 11 km. Linosa (35° 51' 36" N Lat.; 12° 51' 36" E Long.) is composed of Quaternary volcanics (Di Paola, 1973), has a subcircular form (Fig. 1) and a morphology characterised by the residual relief of former volcanic cones. It has a surface area of 5.2 km² and a maximum diameter of about 3 km.

The temperature/pluvial regime of the archipelago is illustrated in Fig. 2 (Fantoli, 1960; Istat, 1959-1985). Maximum temperatures are registered in August (mean 26.0 °C), while minimum temperatures occur in January (mean 13.4 °C). Rain falls mainly from October to March, with marked gaps between rains and is very low. Mean values show a maximum of only 58 mm in December.

The Isole Pelagie are without any natural bodies of permanent water and it is only in autumn and winter, following abundant and persistent rain, that water collects in small basins which, depending on their dimensions and location have a maximum duration that ranges from 20 - 30 days. At Lampedusa, ponds form virtually everywhere: in disused man-made cisterns (Fig. 3a), on flat areas from which the soil has been ablated on the northwestern part of the island (Fig. 3b); among the rocks in deep clefts that constitute fluvial relicts (Fig. 3c); in furrows formed by car tracks on the non-asphalted roads (Fig. 3d). On Linosa, water bodies form almost exclusively in man-made cisterns (Fig. 3e,f,g), because the soil, consisting essentially of volcanic ash and tuffaceous rocks, is highly permeable and rapidly absorbs any rainwater.

The dimensions of the ponds sampled varied from 20 cm to 30 m and the maximum depth was 25 cm. Minimum and maximum water temperatures were 19 and 22 °C respectively, and conductivity values were between 486-5260 µmS/cm.

3. MATERIAL AND METHODS

There were 17 sampling localities (11 on Lampedusa and 6 on Linosa), occupied during 4 visits to the islands: 3 in the season of the rains (November 1997, December 1998, March 1999) and one during a dry spell (June 1998). Pond water was collected during the rainy season visits, but in June 1998 most of

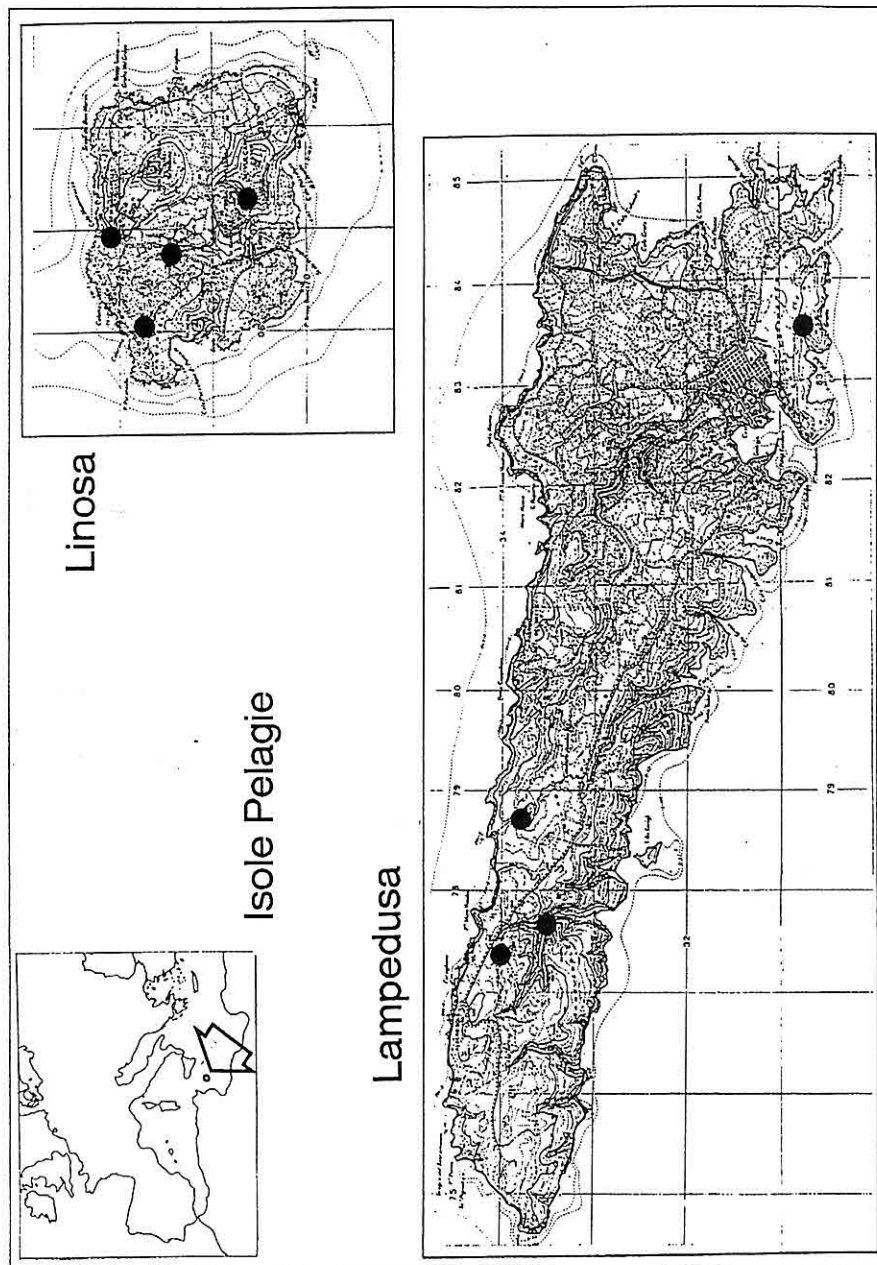


Figure 1. Topographic maps of Lampedusa and Linosa (Isole Pelagie), with sampling locations indicated.

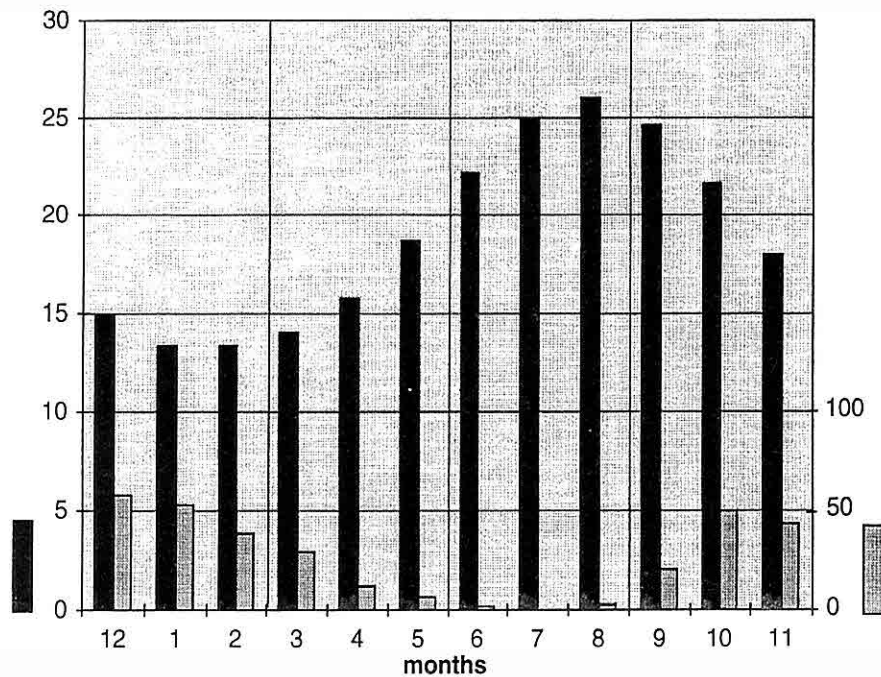


Figure 2. Isole Pelagie: temperature/pluvial regime.

the collections were of mud from pond sites (Table 1). The water samples were taken with nets having a 50 µm mesh size and the organisms thus gathered in part were fixed in 70% alcohol and in part transferred to the laboratory in vivo. The mud samples were cultured in the laboratory at Parma using Evian water.

4. RESULTS

Table 2 is the list of species found (see also Fig. 4); with the exception of *P. newtoni* these constitute their first records for both islands.

Previous work on the freshwater fauna of the Isole Pelagie was carried out in 1954-1955 (Stella, 1960) and refers to collections made during spring in water

storage tanks. The only Ostracoda identified then were *P. newtoni* at Lampedusa and *Eucypris virens* (Jurine, 1820) at Linosa. The latter has never been found by one of us (CB) during his several visits to the island.

Among the species recorded by us, only *P. newtoni* and *H. incongruens* occur as bisexual populations; at Lampedusa the latter species may also occur in all female populations.

We redescribe and reillustrate the *Heterocypris* hemipenis in the following section. Note that the outer lobe of males in a population from Girona, northern Spain differs somewhat in shape, and the bursa copulatrix of those males differs considerably from the same parts of the

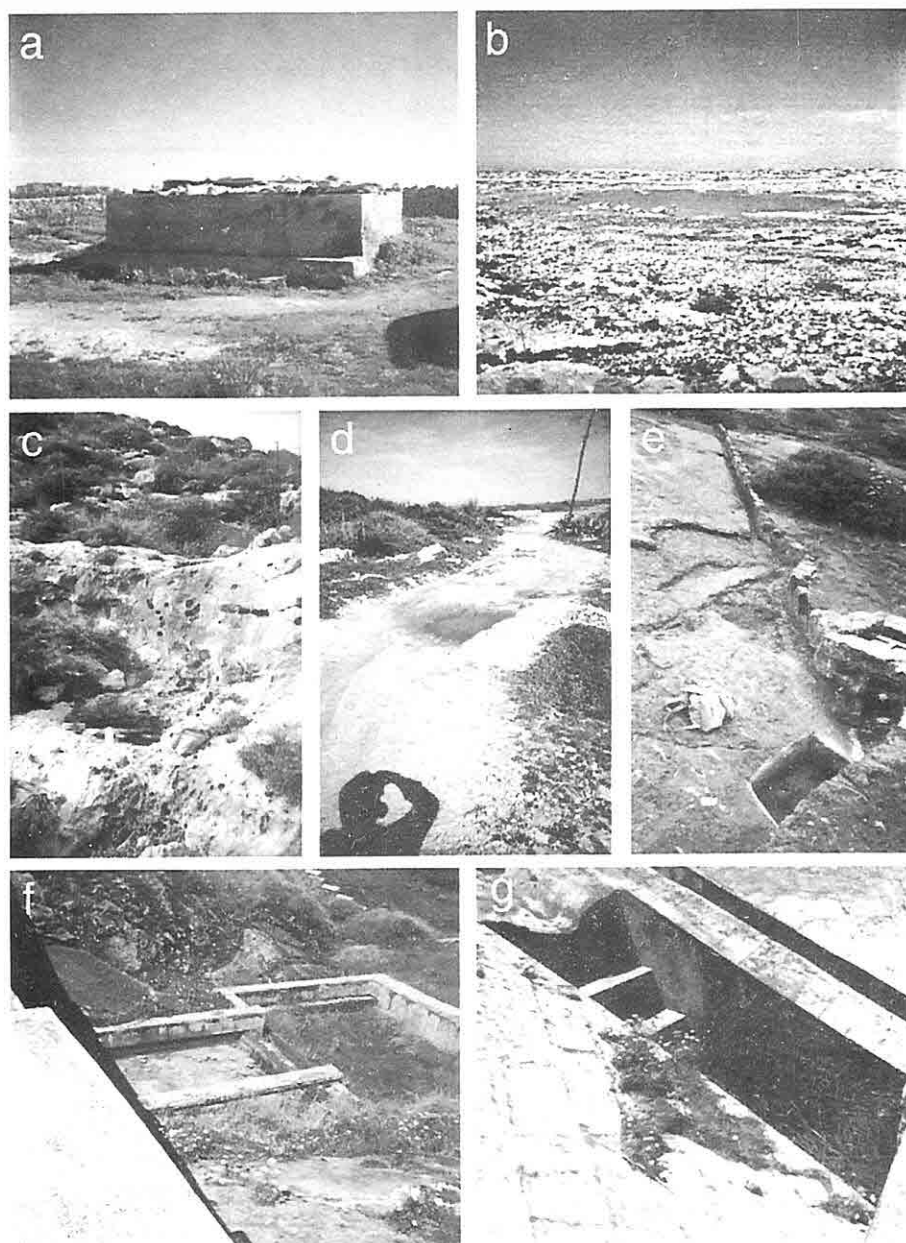


Figure 3. Lampedusa: a) man-made water cistern; b) rocky flat from which the soil has been ablated; c) declivity representing a former river channel; d) temporary pond on a non-asphalted road. Linosa: e) small cistern on an abandoned farm; f,g) large man-made cisterns.

Table 1. Sampling sites occupied at Lampedusa and Linosa from November 1997 to March 1999: w= pond water; m= mud

	1997 November	1998 June December	1999 March
Lampedusa:			
1.Cavallo Bianco A	w	m	w
2.Cavallo Bianco B	w	m	w
3.Aria Rossa A	w	m	w
4.Aria Rossa B		m	
5.Ponente (Ovile Maggiore)	w		
Vallone delle Forbice:			
6. st. A	w		w
7. st. B	w		
8. st. C1	w	m	w
9. st. C2	w	m	w
10. st. P	w	m	
11. Cala Pulcino			w
Linosa:			
1.Paranzello		m	
Mannarazza:			
2. Vascone A		w	
3. Vascone B		m	w
4. Abbeveratoio		m	w
5. Monte Vulcano		m	w
6. Fontana		w	

Table 2 . Ostracoda of Lampedusa and Linosa. (*) Includes all female populations.

	Lampedusa	Linosa
Candonidae		
<i>Cypria ophthalmica</i> (Jurine, 1820)	-----	♀ ♀
Cyprididae		
<i>Heterocypris salina</i> (Brady, 1868)	♀ ♀	-----
<i>Heterocypris incongruens</i> (Ramdhor, 1808)	♀ ♀ (*) ♂ ♂	♀ ♀ ♂ ♂
Cypridopsidae		
<i>Cypridopsis vidua</i> (O.F. Müller, 1776)	♀ ♀	♀ ♀
<i>Plesiocypridopsis newtoni</i> (Brady & Robertson, 1870)	♀ ♀ ♂ ♂	♀ ♀ ♂ ♂
<i>Potamocypris arcuata</i> (Sars, 1903)	♀ ♀	♀ ♀

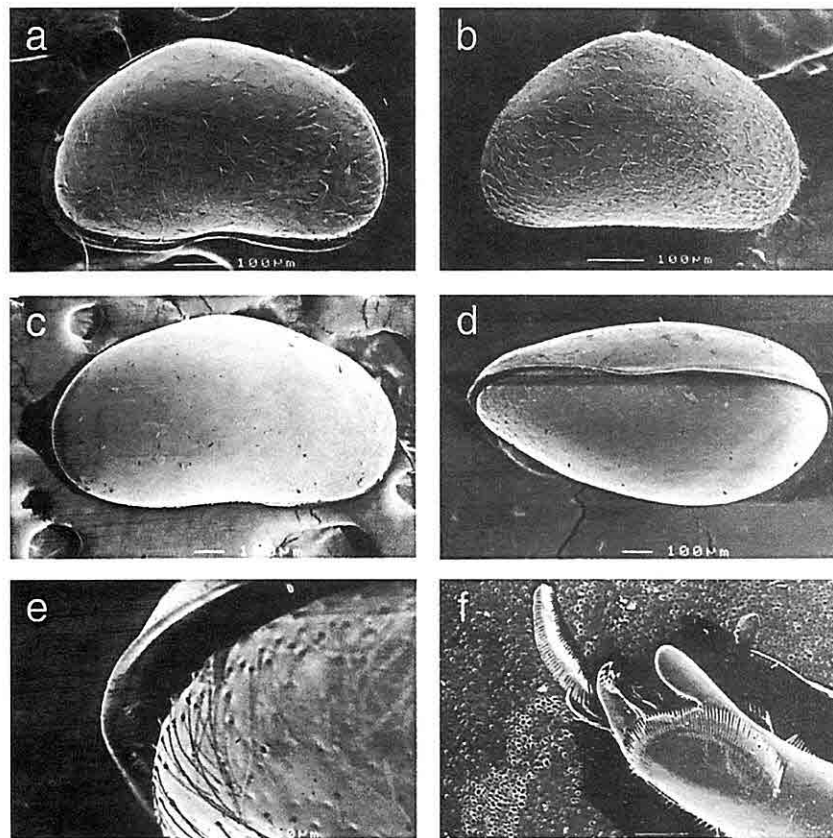


Figure 4. Ostracoda of the Isole Pelagie: a) *Plesiocypridopsis newtoni*, right valve of male; b) *Potamocypris arcuata*, right valve of female; c) *Heterocypris incongruens*, right valve of male (Lampedusa); d) *H. incongruens*, ventral view of female (Lampedusa); e) *H. incongruens*, anteroventral detail, same female as for d); f) *H. incongruens*, distal part of the P3 of a male (Lampedusa).

hemipenis in Lampedusa males (Fig. 5). We note additionally that the outer lobe of a male in a German population of *H. incongruens* (G.W. Müller, 1900) is more quadrate than the outer lobe of our Lampedusa male; Müller's illustration is inadequate to make any comparison *vis à vis* the bursa copulatrix. Future work, employing electrophoretic and

chromosome analysis, will address these issues; and also other ostracode distributions on Italian islands.

5. THE *HETEROCYPRIS* HEMIPENIS

The reproductive apparatus of ostracodes represents the 8th limb of these animals (Cohen and Morin, 1993).

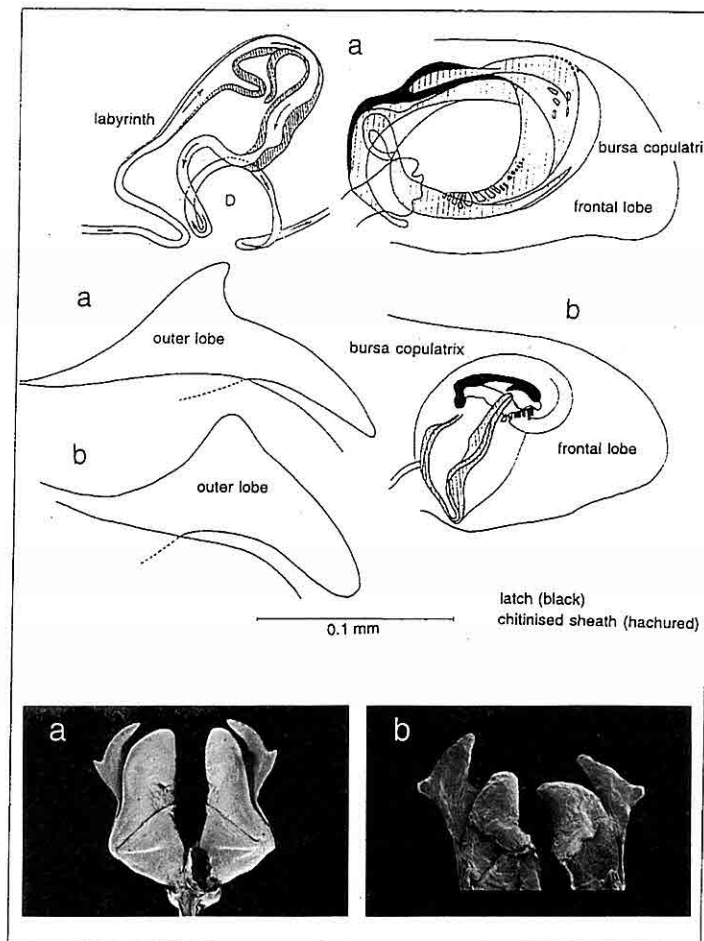


Figure 5. Characters of the hemipenes of *Heterocypris incongruens* (det. Meisch) males from: a) Lampedusa, Isole Pelagie; and b) Girona, northern Spain. Refer to discussion in the text.

This being so, the basic arrangement should generally conform to the typical crustacean model of protopod, endopod and exopod; and, ideally, it should be paired.

The hemipenes (penifera) of *Heterocypris* - and, indeed, all cypridoids and cytheroids - are consistent

with this idea. Each hemipenis comprises a proximal capsule (=protopod), bounded by the transverse fold, from which extend a terminally rounded frontal lobe (=endopod) and a smaller outer lobe (=exopod) (Fig. 5).

The frame of the capsule is strengthened by several sclerites which

converge in a ventromedial nodal zone. From this zone also extend a powerful tendinous extensor connecting to the outer lobe and other muscles connecting to the frontal lobe and parts of the capsule. The lobes themselves are conspicuously free of muscles (Fig. 5). The extensor to the outer lobe functions to facilitate abductor swing away from the inner lateral face of the frontal lobe thus enabling mating to occur, as explained below and as described for *Candona suburbana* Hoff by McGregor and Kesling (1969).

This male reproductive limb houses a convoluted spermiduct terminating in the bursa copulatrix (Fig. 5). The complete male reproductive system also includes paired accordion-like Zenkers organs (each with 32-33 tiers of irradiating spikes) and 4 coiled testes. The latter generate enormous spermatozooids - in *Heterocypris* they can be over 10 mm long, i.e. over 7 times the carapace length, which in *H. incongruens* males is about 1.3 mm. The structure of these spermatozooids is helical, behind a short pointed tip which carries the genetic information. Once thought to be sterile, they are now known to be fully functional, enabling impregnated females to produce fertile eggs which hatch out individuals of both sexes.

6. INSEMINATION

When males are ready to copulate, they mount a receptive female in the ventral/posterodorsal mating position (Cohen and Morin, 1990). The hemipenes are

extruded from the carapace (external erection of Martens (1998)); the outer lobes abduct outwards, powered by the extensors described earlier; each bursa copulatrix erects out of the inner face of the frontal lobe (internal erection of Martens (1998)), then engages in its apposite female genital lobe.

This accomplished, each accordion-like Zenkers organ energetically pumps the spermatozooids forward from the testes into the complex spermiduct. Some idea of what is involved, in energy terms, may be gained by considering the fact that the spermiduct labyrinth measures in sum about 0.5 mm (Fig. 5), whereas every *Heterocypris* spermatozoid to be pumped past it measures several mm. Study of Fig. 5 allows one to visualise that while on the compressive strokes of the Zenkers organ spermatozooids are propelled forward into the chambers of the labyrinth, the convolutions within the labyrinth itself prevent slipping back on the withdrawal strokes. Additionally, the helical structure of each lengthy sperm not only favours its compression within the hemipene spermiduct but is possibly a further factor in minimising withdrawal.

Once past the labyrinth, the sperms lodge in additional coils of the spermiduct (see Martens, 1998, Fig. 4.8), the complicated loop at D preventing slipping back. The protective chitinised sheath of the spoon-shaped bursa copulatrix incorporates a latch (Fig. 5). This appears to be species-specific and may function to maintain position of the

bursa copulatrix within the female genital lobe (McGregor and Kesling, 1969; Broodbakker, 1982).

At insemination, spermatozoids are transferred from the erect bursa copulatrix into the female spermatheca. Once there, they can move towards the uterus, to fertilise an ovum.

7. ACKNOWLEDGEMENTS

We thank: Dr. C. Meisch, (Musée national d'histoire naturelle Grand-Duché de Luxembourg) for kindly identifying samples to species; D. Boix (Dept. of Environmental Sciences, University of Girona, Spain) for providing the material from northern Spain; and the MedAirline (Lampedusa) for transport of live samples.

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OSTRACODA GENUS *ALOCOPOCYTHERE* SIDDQUI FROM THE
TERTIARY BEDS OF INDIA, WITH A NOTE ON ITS BIOSTRATIGRAPHIC
SIGNIFICANCE.

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ABSTRACT: The Ostracoda genus *Alocopocythere* Siddiqui occurs abundantly in the Tertiary beds of India and ranges in age from Early Eocene to Middle Miocene. This genus evolve rapidly and in consequence its species have relatively short stratigraphic range which make them invaluable biostratigraphic markers. In all twenty-two species of genus *Alocopocythere* have been recorded from India. Of these, thirteen species are recorded from western part of India. *A. abstracta* Siddiqui, *A. rajasthanensis* Bhandari, *A. coarctata* Siddiqui and *A. longilinea* Siddiqui are restricted to Early Eocene. *A. lunejensis* Guha ranges from Early Eocene to Early Oligocene. *A. transcendens* Siddiqui ranges from Early to Middle Eocene. *A. transversa* morph. A, is recorded from Middle Eocene and *A. transversa* morph. E is restricted to Late Eocene. While *A. fossularis* Guha ranges from Late Oligocene to Early Miocene. *A. gujaratensis* Khosla, *A. elongata* Khosla and Nagori are recorded from Early Miocene. *A. mumbaiensis* n.sp and *A. depressa* Khosla are confined to Middle Miocene. There is strong provincialism in the ostracodes of Western India and North Eastern part of India.

In the North-eastern part of India nine species of the genus *Alocopocythere* have been recorded from Middle and Late Eocene. Of these, *A. bhandarii* Neale and Singh, *A. borhollaensis* Bhandari, *A. gopinathkillaensis* Bhandari, *A. polygona* Neale and Singh, *A. talukdari* Neal and Singh are confined to Middle Eocene. *A. indica* Bhandari, *A. garoensis* Bhandari, *A. dattai* Bhandari and *A. meghalayaensis* Bhandari are restricted to Late Eocene.

On the basis of stratigraphic ranges the Early Eocene to Middle Miocene succession of western India can be divided into 10 *Alocopocythere* zones: They are: 1. *Alocopocythere rajasthanensis* Range Zone, 2. *Alocopocythere rajasthanensis Alocopocythere abstracta* Interval Zone, 3. *Alocopocythere abstracta* - *A. longilinea* Interval Zone, 4. *Alocopocythere longilinea* - *A. transcendens* Interval Zone, 5. *Alocopocythere transcendens* - *A. transversa* morph. A. Interval Zone, 6. *Alocopocythere transversa* morph. A - *Alocopocythere transversa* morph. E, 7. *Alocopocythere transversa* morph. - E. *Alocopocythere lunejensis* (Guha), 8. *Alocopocythere* - *lunejensis Alocopocythere fossularis* Inter Biohorizon, 9. *Alocopocythere fossularis* - *Alocopocythere gujaratensis* - *Alocopocythere elongata* Assemblage Zone, 10.

Alocopocythere mumbaiensis n.sp. Range Zone and Middle to Late Eocene succession of North-eastern India into five *Alocopocythere* zones: They are: 1. *Alocopocythere gopinathkillaensis* Range Zone, 2. *Alocopocythere gopinathkillaensis* - *Alocopocythere garoensis* Interval Zone, 3. *Alocopocythere garoensis* Range Zone, 4. *Alocopocythere garoensis* - *A. meghalayensis* Interbiohorizon (Poorly fossiliferous) Zone, 5. *Alocopocythere meghalayaensis* Range Zone. Evolutionary trends and biostratigraphic significance of the genus have been briefly described.

1. INTRODUCTION

The Ostracoda genus *Alocopocythere* was established by Siddiqui, 1971 for strongly reticulate Trachylebriidae in which a short, almost vertical ridge joins the eye tubercle, delimited posteriorly by a deep furrow. The genus has been reported from Paleocene to Recent and has wide geographic distribution (Siddiqui, 1983). The Tertiary ostracodes of India have been studied in detail due to active hydrocarbon exploration by Oil and Natural Gas Corporation Ltd. During the course of study of the Tertiary Ostracoda from India, the author came across a rich assemblage of the species of the genus *Alocopocythere*. In all twenty-two species of genus *Alocopocythere* have been recognized from the Early Eocene to Middle Miocene beds of India (Fig. 1). When the stratigraphic ranges of these species were plotted it was observed that some of the species of the genus *Alocopocythere* have short stratigraphic ranges which can be used as zonal markers. In this paper an attempt has been made to describe the important stratigraphically significant species of the genus *Alocopocythere* and its

significance in the biostratigraphic zonation. The genus *Alocopocythere* enable to divide Early Eocene to Middle Miocene of western part into ten *Alocopocythere* zones and Middle to Late Eocene succession of North-eastern part of India into five zones. Three distinct lineages have been established in genus *Alocopocythere* which have been described here in brief. All the figured specimens are deposited in the Repository of Paleontology Laboratory, Keshva Deva Malaviya Institute of Petroleum Exploration, Oil & Natural Gas Corporation Limited, Dehradun (UP)-India.

2. PREVIOUS WORK

The biostratigraphic significance of genus *Alocopocythere*, *Gyrocythere*, *Phalcocythere* and *Stigmatocythere* from the Early Tertiary beds of Pakistan was discussed by Siddiqui(1983). Similar attempt was made by Bhandari(1989) on biostatigraphic significance of genus *Alocopocythere* Siddiqui from the Eocene beds of Garo Hills, Meghalaya and Assam India. This genus has been widely studied in India by various

workers. Important contributions are: Lyubimova, Guha and Mohan (1960), Guha (1967, 1974), Singh and Mishra (1968), Khosla (1972, 1978), Khosla and Pant (1982), Khosla and Nagori (1989), Bhandari (1981, 1988, 1991, 1992, 1994, 1995, 1996, 1998a,b), Bhandari et al. (1990), Neale and Singh (1985), Juyal and Mathur (1990, 1992) and Bhatia and Bagi (1990).

3. BIOSTRATIGRAPHIC SIGNIFICANCE

Twenty-two species of genus *Alocopocythere* have been recognised from the (Early Eocene to Middle Miocene of India. Of these, four species are confined to Early Eocene; six species restricted to Middle Eocene; five species to Late Eocene, three species to Early Miocene and one species to middle Miocene. One species each is common to Early Eocene and Early Oligocene; Early Eocene and Middle Eocene, and Late Oligocene to Early Miocene. A detailed analysis of these are given below.

Early Eocene : The oldest known species of genus *Alocopocythere* from the Tertiary beds of India is from Early Eocene. However, in Pakistan it is reported from Paleocene and represented by *Alocopocythere rupina*. The species confined to Early Eocene of western part of India are : *Alocopocythere abstracta*, *A. rajasthanensis*, *A. coarctata* and *A. longilinea* (Fig 2). Besides these, *A. lunejensis* ranges into Early Oligocene and *A. transcendens* ranges into Middle Eocene (Siddiqui, 1983).

Middle Eocene : In the western part of India only one species designated by *A. transversa* morph. A is restricted to Middle Eocene while in the north eastern part of India, five species i.e. *A. bhandarii*, *A. borhollaensis*, *A. gopinathkillaensis*, *A. talukdari*, and *A. polygona* are restricted to Middle Eocene and are of valuable stratigraphic significance (Fig.3).

Late Eocene : The Late Eocene succession of western India is represented by one species i.e. *A. transversa* morph. E which is confined to Late Eocene. In the north eastern part of India, it is represented by *A. dattai*, *A. garoensis*, *A. indica* and *A. meghalayaensis* (Fig.3).

Early Oligocene : One taxon, *A. lunejensis* has been recorded from Early Oligocene which is continuing from Early Eocene and hence of little stratigraphic value.

Late Oligocene : Only *Alocopocythere fossularis* has been recorded which ranges upto Middle Miocene.

Early Miocene : Two species are confined to Early Miocene. They are represented by *A. elongata*, *A. gujaratensis*.

Middle Miocene : *A. mumbaiensis* n. sp. has been recorded from Middle Miocene (N9-N10 Zones) by Bhandari (1998) from Mumbai Offshore and *A. depressa* Khosla and Nagori was reported from Early Miocene (Khosla et al. 1989) in fact belongs to Middle Miocene (=N8 Zone).

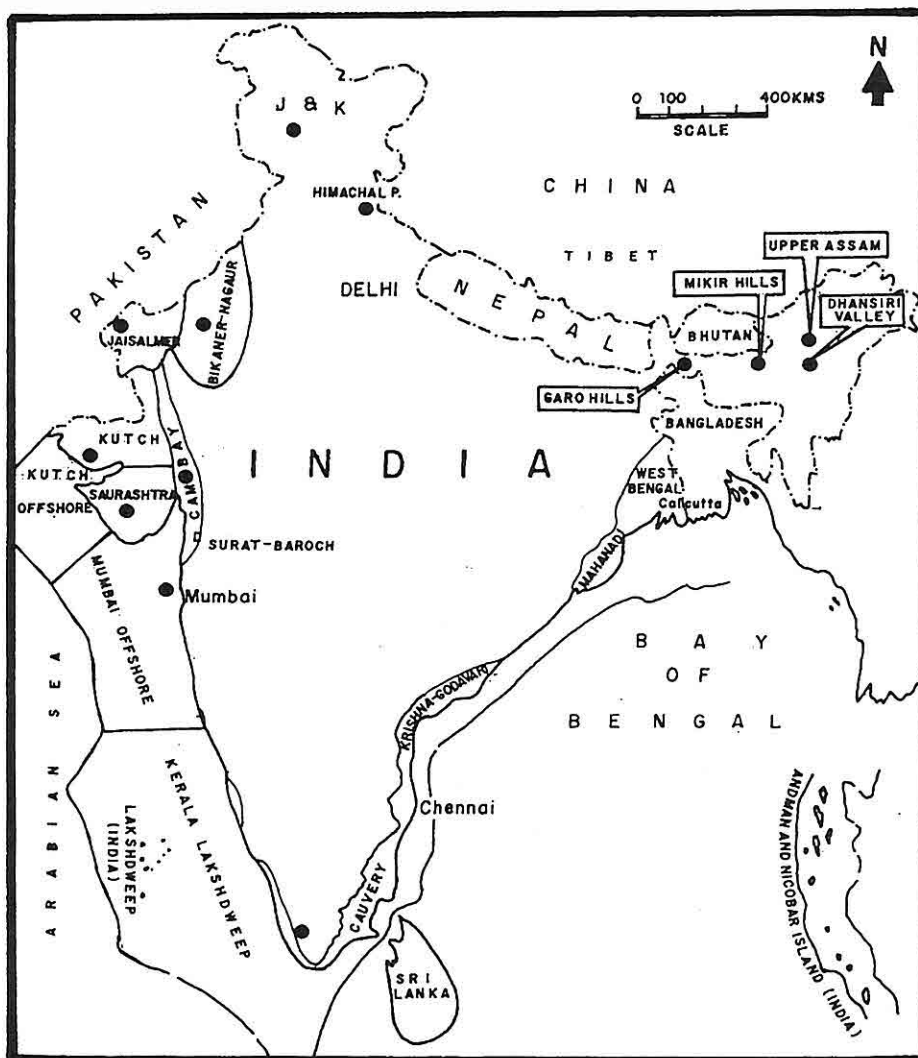


Figure 1. Paleogeographic distribution of genus *Alocopocythere* in the Tertiary beds of India.

4. PALEOZOOGEOGRAPHY

The paleozoogeographic distribution of genus *Alocopocythere* was discussed by Siddiqui (1983). In India the genus *Alocopocythere* occurs abundantly in the Tertiary beds of Cambay, Kachchh, Jammu and Kashmir, Himachal Pradesh,

Garo Hills, Mikir Hills, Upper Assam and Dhansiri Valley (Fig.1). Besides India this genus has also been reported from the Early Tertiary beds of Pakistan (Sohn, 1970, Siddiqui, 1971, 1983, Al Furaih, 1980), Tertiary beds of Burma (Gramann, 1975), Early Tertiary of Tibet,

OSTRACODA GENUS ALOCOPOCYTHERE SIDDIQUI FROM THE TERTIARY BEDS OF INDIA, WITH A NOTE ON ITS BIOSTRATIGRAPHIC SIGNIFICANCE

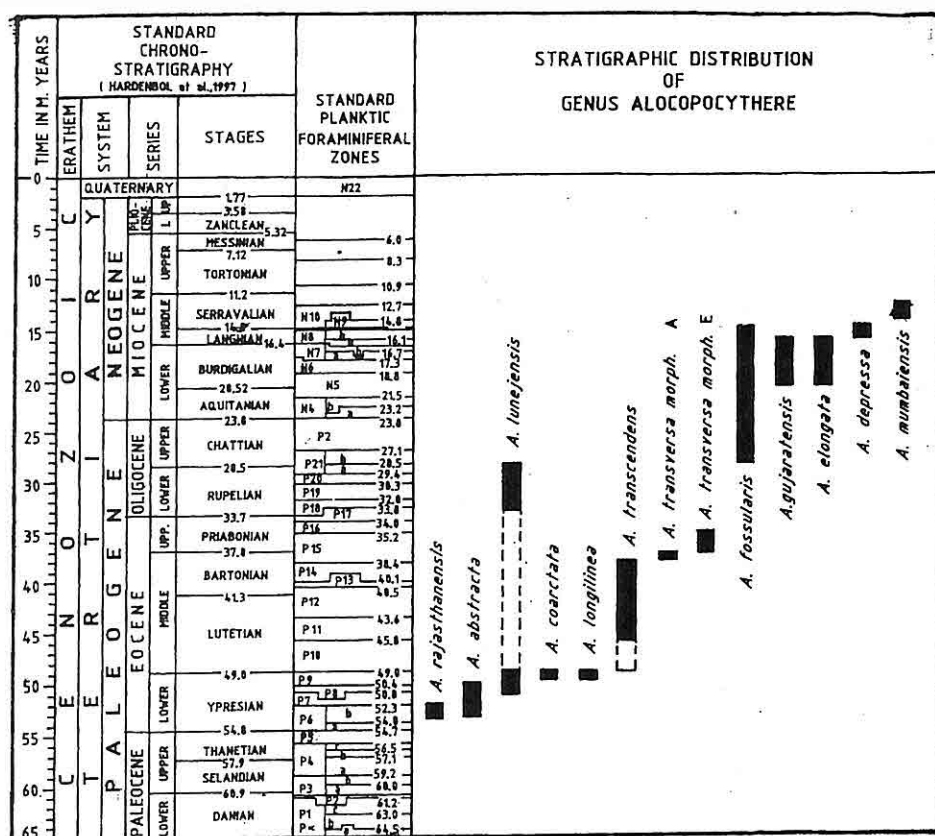


Figure 2. Distribution of genus *Alocopocythere* in the Tertiary beds of Western India.

China (Huang, 1976), Paleocene of Saudi Arabia (Al Furaih, 1980), Paleocene of ? Northwest Nigeria (Rement, 1981) and upper Eocene-Oligocene of ? Off Natal, South Africa (Dingle, 1976) (Fig.4).

5. SYSTEMATIC DESCRIPTION

Subclass OSTRACODA Latreille, 1806
Order PODOCOPIDA Muller, 1894
Suborder PODOCOPA Sars, 1866
Super family CYTHERACEA Baird, 1850
Family TRACHYLEBERIDIDAE
Sylvester-Bradly, 1948

Tribe ECHINOCYTHEREIDINE,
Hazel, 1967
Genus ALOCOPOCYTHERE,
Siddiqui, 1971.

Alocopocythere abstracta Siddiqui

Plate I, Fig. 1.

Alocopocythere abstracta Siddiqui, 1971, p.17, pl.3, figs. 5-11; pl.4, fig.11
Bhatia and Bagi, 1990, p.28, pl.1, fig.11;
- Juyal and Mathur, 1990, p.218-219, pl.2, figs.6-9; - Juyal and Mathur, 1992, p.30-32, pl.II. figs. 16-20; - Bhandari, 1996, p.32, pl.8, figs. 1-4.

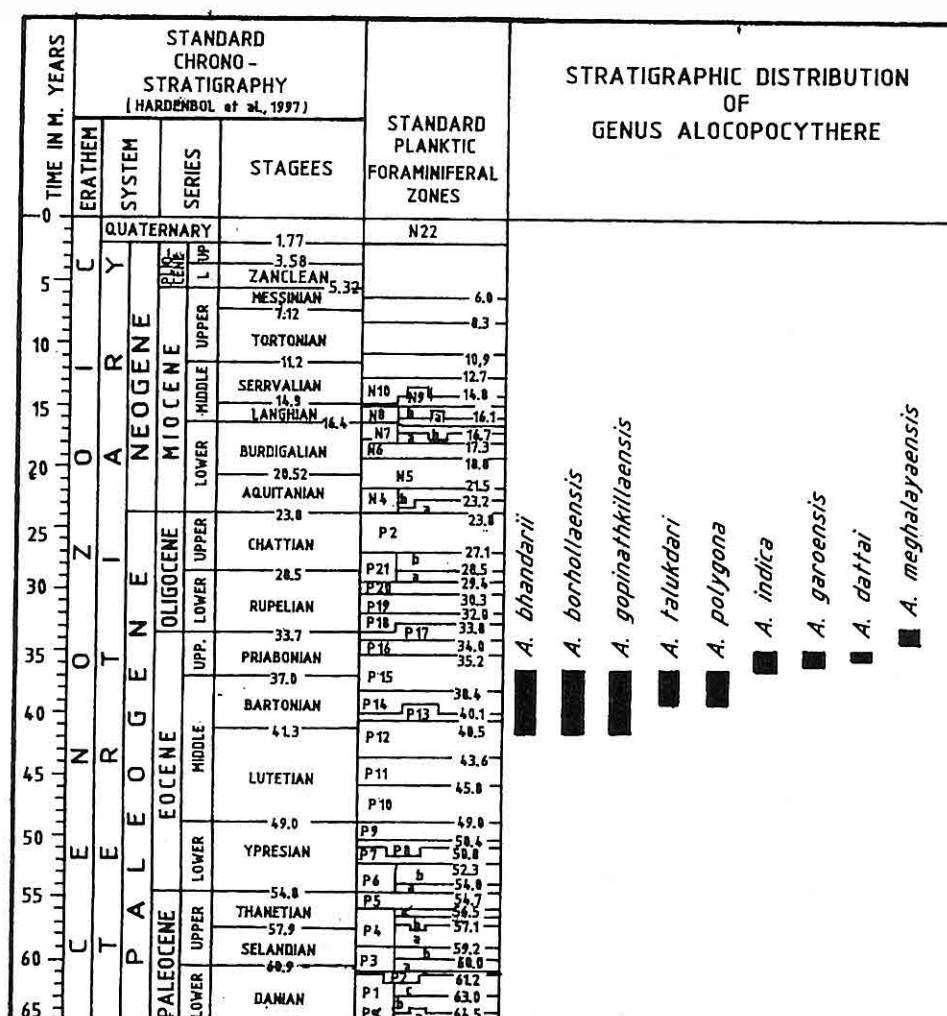


Figure 3. Distribution of genus *Alocopocythere* in the Eocene beds of North-Eastern India

Locality and horizon: Ghotaru well-B, sample 600-605m below surface, Khuiala Formation, Early Eocene.

Diagnostic characters : Carapace subrectangular in lateral view; dorsal margin sinuate; ventral margin nearly straight; anterior margin broadly and evenly rounded; posterior extremity

narrow; posteroventral margin straight; eye tubercle distinct; subcentral tubercle present but not prominent; anterodorsal furrow deep, bounded anteriorly by a short verticle ridge diagnostic of genus. Surface reticulate.

Figured specimen : Male carapace (IPE/BO2/04/6701) L.0.63mm, X 82

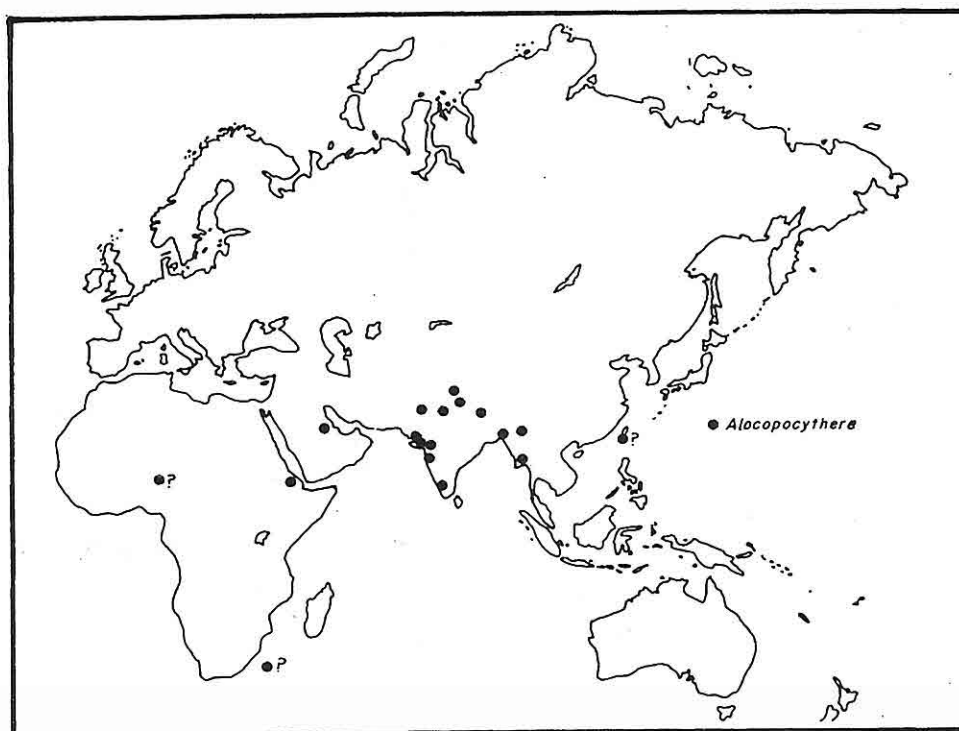


Figure 4. Geographic distribution of fossil species of genus *Alocopocythere*
(Modified after Siddiqui (1983)).

Distribution : Early Eocene of Pakistan, Jaisalmer Basin, Rajasthan, Kachchh, Cambay, Himachal and J & K.

Alocopocythere borhollaensis
Bhandari

Plate I, fig.2.

Alocopocythere borhollaensis
Bhandari, 1992, pp.54-55, pl.VIII, figs.3-4; pl.XIV, fig.4.

Locality and horizon : Borholla well-C, Dhansiri Valley, Upper Assam. Sample 2990-3000 metres below surface, grey limestone, Prang Member, Sylhet Formation, Middle Eocene.

Diagnostic characters : Carapace

bean-shaped in lateral outline. Eye tubercle distinct; subcentral tubercle faintly developed. Valve surface ornamented with coarse reticulation; anterior marginal zone flat and compressed, a low marginal rim along anterior, ventral and posterior margins.

Figured specimen : Holotype (BOS No.58) a complete carapace, L. 0.64mm, X 86

Distribution : Middle Eocene, Dhansari Valley, Upper Assam.

Alocopocythere bhandarii Neale and Singh

Plate I, Fig.3.

Alocopocythere bhandarii Neale and Singh, 1985, pp.371-372, pl.44, figs. 2-4; -Bhandari, 1992, pp.54. pl.VIII, fig.8

Locality and horizon : Borholla Well-C, Sample 2990-95m below surface Prang Member, Sylhet Formation, Middle Eocene.

Diagnostic characters : Carapace bean shaped in lateral view; valve surface strongly pitted; a short distinct rib starts above mid-ventral about one quarter height and runs upwards slightly posteriorly to mid-height; anterior marginal area smooth and compressed; subcentral tubercle weak.

Figured specimens : Female carapace (BOS No.57), L.0.56mm, X 107

Distribution : Middle Eocene, Sylhet Formation, Mikir Hills, Assam and subsurface of Borholla, Dhansiri Valley, Upper Assam.

Alocopocythere dattai Bhandari
Plate I, Fig.4.

Alocopocythere dattai Bhandari, 1981, pl.1, figs.2-3; - Bhandari, 1992, pp.55, pl.VIII, figs.5-6.

Locality and horizon : Baghmara well-A, Garo Hills, Meghalaya, sample 1280-1290m below surface, Kopili Formation, Late Eocene.

Diagnostic characters : Carapace subquadrate in lateral view. Surface ornamented with coarse reticulation, reticle meshes arranged in form of five ridges radiating from posterior of subcentral tubercle and a prominent ventral ridge sloping upwards posteriorly.

Figured specimen : Carapace, (BOS No.60) L.0.70mm, X 93

Distribution : So far recorded from the Late Eocene of Garo Hills, Meghalaya, and Upper Assam Shelf.

Alocopocythere coarctata Siddiqui
Plate I, Fig.5.

Alocopocythere coarctata Siddiqui, 1971, p.18, pl.4. figs.6-9; -Bhandari 1996, p.34, pl.9, figs.1-4.

Locality and horizon : Ghotaru well-B, sample 500-04m below surface, Khuiala Formation, Early Eocene.

Diagnostic characters : Carapace subrectangular to subquadrate appears to be compressed in lateral view; dorsal margin with a hump between protruding anterior and posterior cardinal angles; Surface finely reticulate with superimposed weak longitudinal ridges. Subcentral tubercle distinct, eye tubercle more or less distinct.

Figured specimen : Carapace (IPE/BO2/04/6703), L.0.65mm, X 88

Distribution : Early Eocene of Pakistan; Cambay Basin and Jaisalmer Basin, Rajasthan.

Alocopocythere depressa Khosla and Nagori
Plate I, fig.6.

Alocopocythere depressa Khosla and Nagori, 1989, pp.31-32, pl.5. figs. 1-5.

Locality and horizon: Sankaramangalam well-4, Kerala, sample 5/19, 40.63 m below surface, grey sticky clay with shales, Quilon beds, Early Miocene.

Diagnostic character : Carapace elongate, subrectangular in lateral view;

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dorsal margin straight anteriorly with three distinct nodes posteriorly; Eye tubercle and subcentral tubercle pronounced; a depression posterior to subcentral tubercle. Valve surface ornamented with broad shallow reticulation and a backwardly directed spine posteriorly.

Figured specimen : Carapace (No.355), L.O.76mm X 79

Distribution : Early Miocene of Kerala.

Alocopcythere elongata Khosla and Nagori

Plate I, fig.7.

Alocopcythere fossularis Khosla, 1978, pp.266-267, pl.4, fig.2 (not *Alocopcythere fossularis* (Lyubimova and Guha) in Lyubimova, Guha and Mohan, 1960, pp.40-41, pl.3, figs.7)

Alocopcythere elongata Khosla and NAGORI, 1989, pp.32-33, pl.5, figs.7-9.

Locality and horizon : Somkramangalm well 4 sample S/3, 122.83-123.74-123.74 m. below surface, grey clay with sand, Quilon beds, Early Miocene Kerala.

Diagnostic characters : Carapace elongate, sub rectangular in lateral view, dorsal margin straight anteriorly and slightly convex posteriorly. Valve surface ornamented by broad, shallow reticulation arranged in rows paralld to margins; Eye tubercle and subcentral tubercle low and a spine in posteroventral region.

Figured specimen : Carapace (No.359), L.O.90mm X 67.

Distribution : Early Miocene of Saurashtra, Kachchh, Kerala and Bombay High.

Alocopcythere fossularis (Lyubimova and Guha)

Plate I, fig.8.

Trachyleberis fossularis Lyubimova and Guha, in Lyubimova, Guha and Mohan, 1960, pp.40-41, pl.3, fig.7

Cytheretta cheropadiensis Tewari and Tandon, 1960, pp.159-160, text figs.5, figs. 4a-b.

Echinocytheris fossularis (Lyubimova and Guha) Guha, 1961, p.4, figs.5-9 Guha et.al.,1965,p.13 pl.3,fig.12.

Quadracythere fossularis (Lyubimova and Guha) Guha, 1968a, pp.215-216, pl.2, fig.20.

Alocopcythere fossularis Khosla and Nagori, 1989, pp.33-34, pl.5, fig.6

Locality and horizon : KD well A, Kutch offshore Basin, sample 450-55m below surface, Bombay Formation, Early Miocene.

Diagnostic characters : Carapace elongate and irregularly oval in lateral view; dorsal margin with wavy hump bearing five nodes along posterodorsal margin. Valve surface with deep reticulation.

Figured specimens : Female Carapace (IPE/BO2/04/7043), L.O.80 mm ,X 75.

Distribution : Early Miocene of Kachchh, Saurashtra, Kerala, Cauvery Basin and Late Oligocene to Early Miocene of Bombay High.

Alocopcythere garoensis Bhandari

Plate II, fig.1.

Alocopocythere garoensis, Bhandari, 1992, p.55, pl.IX, figs.1-2

Locality and horizon : Gopinathkilla well-A, Mahendraganj, Garo Hills, Meghalaya, India. Sample 515-520 metres below surface, greenish-grey silty shale, Kopili Formation, Late Eocene.

Diagnostic characters : Carapace subovate in lateral outline, eye tubercle and subcentral tubercle weakly, developed. Valve surface strongly reticulate, reticulate meshes arranged in rows, radiating from mid-dorsal region in upper half, and three to four longitudinal rows parallel to ventral margin in lower half, reticulate being coarse in middle and fine towards margin; marginal rim low.

Figured specimen : Holotype (BOS No.61) carapace L. 0.65mm, X 89.

Remarks : So far recorded from the Late Eocene, subsurface of Gopinath Killa Well Garo Hills.

Alocopocythere gopinathkillaensis
Bhandari

Plate II, fig.2.

Alocopocythere gopinathkillaensis
Bhandari, 1992, pp.55-56, pl.IX, figs.3-6; pl.XIV, fig.3

Locality and horizon : Gopinathkilla well-A, Mahendraganj, Garo Hills, Meghalaya, India. Sample 550-555 metres below surface, calcareous shale, Prang Member, Sylhet Formation, Middle Eocene.

Diagnostic characters : Carapace bean-shaped in lateral outline, anterior and posterior cardinal angles protruding

more particularly in left valve; anterior marginal zone compressed and flat; Valve surface ornamented with strong reticulation; 5-6 vertical ridges in posterior half; a prominent ventral ridge sloping upwards posteriorly.

Figured specimen : Holotype (BOS No.62), female carapace, L.0.71 mm, X ; Paratype II (BOS No.64) a male carapace, L.0.71mm, X 83.

Remarks : So far recorded from Middle Eocene, subsurface of Gopinathkilla Well-A, Garo Hills.

Alocopocythere gujaratensis Khosla
Plate II, fig.3.

Alocopocythere gujaratensis Khosla, 1978, p.267, pl.4, figs. 3-4.

Locality and horizon : SE-5 well, CC-2(1318-1324m), Bombay Formation, Burdigalian (Early Miocene), Bombay Offshore.

Diagnostic characters : Carapace bean shaped in lateral view, valve strongly reticulate, the meshes arranged in rows parallel to margin in ventral and posterior regions and a distinct spine in posteroventral part.

Figured specimen : Carapace, left valve view, L.0.89mm, X 65.

Distribution : Early Miocene of Saurashtra, Kerala and Mumbai High.

Alocopocythere indica Bhandari
Plate II, fig. 4.

Alocopocythere indica Bhandari, 1992, p.56, pl.IX, figs.7-8

Locality and horizon : Baghmara well-B, Mahendraganj, Garo Hills,

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Meghalaya, India. Sample 1310 metres below surface, grey shale, Kopili Formation, Late Eocene.

Diagnostic characters : Carapace bean shaped in lateral outline dorsal margin with a hump near middle and concavity on sides. Valve surface ornamented with concentrically arranged reticulation; a prominent ventral ridge, convex downwardly;

Figured specimen : Holotype (BOS No.67) a female carapace, L 0.71mm, X 84.

Remarks : So far recorded from Late Eocene, subsurface Baghmara Garo Hills, Meghalaya.

Alocopocythere longilinea Siddiqui
Plate II, figs.5-6.

Alocopocythere longilinea Siddiqui, 1971, pp.18-19, pl.4, figs.10-13; pl.5, figs.1-3,6; Bhandari, 1996, p.34, pl.10, figs.1-2.

Locality and horizon : Ghotaru well-B, sample 500-505m below surface, Khuilala Formation, Early Eocene.

Diagnostic characters : Carapace ovate in lateral view, slightly tapering towards posterior; ventral margin evenly curved; posterior extremity almost straight. Subcentral tubercle indistinct. Eye tubercle low. Surface reticulate, reticules being arranged in longitudinal lines with weak ridges; anterior and posterior marginal area flat and compressed.

Figured specimen : Carapace (IPE/B02/04/6704), L. 0.51mm, X 104

Distribution : Early Eocene of

Pakistan, Cambay Basin and Jaisalmer Basin, Rajasthan.

Alocopocythere lunejensis (Guha)
Plate II, fig.7.

Leguminocythereis lunejensis Guha, 1967, p.21, pl.I, figs. 3, 6, 8.

Alocopocythere lunejensis (Guha) Khosla and Nagori, 1892b, p.332.

Locality and horizon : One km South west of Jagira village, Bikaner District, Rajasthan, sample, J-6, Fuller's Earth, Early Eocene.

Diagnostic characters : Valve surface reticulate, reticules in the central part of the valves are concentric around indistinct subcentral tubercle, otherwise alligned parallel to margins. The alligned reticules some times give rise to thin ridges noticed along middle and dorsal margin and convex upward; posterior margin narrow and angulate.

Figured specimen : Carapace, left valve view, L.0.68 mm, X 81

Distribution : Early Eocene Cambay, Bikaner Basin Rajasthan and Early Oligocene of Cambay, Kachchh and Subsurface of Suthri-A, Kachchh.

Alocopocythere meghalayaensis
Bhandari
Plate II, Fig.8.

Alocopocythere meghalayaensis
Bhandari, 1992, p.56-58, pl.VIII, Fig.7.

Locality and horizon : Gopinathkilla well-A, Mahendraganj, Garo Hills, Meghalaya, India. Sample 365-370 meters below surface, bluish-green shale, Kopili Formation, Late Eocene.

Diagnosis : Carapace subrectangular in

lateral outline, valves almost equal; valve surface ornamented with reticulation, 4-5 oblique, curved ridges with grooves in between in posterior half; a prominent ventral ridge sloping upwards posteriorly; a low marginal rim along anterior, ventral and posterior margins.

Figured specimen : Holotype (BOS No.69) a carapace L. 0.81mm, X 64

Distribution : So far recorded from Late Eocene, Gopinathkilla well-A.

Alocopocythere mumbaiensis n.sp.

Plate III, figs.1-2.

Name : After city Mumbai, State of Maharashtra, India.

Material : Twenty-five carapaces and three open valves from Murud Depression Well-A (MDA-A), eight carapaces from Mumbai High well-A.

Locality and horizon : MDS well-A, sample 1980-85m below surface, Bandra Formation, Middle Miocene.

Diagnosis : Carapace elongate, thick shelled, valve surface ornamented by reticles, arranged concentrically; dorsal margin with 4-5 weak nodes.

Diagnostic characters : Carapace elongate, subrectangular in lateral outline; left valve slightly larger than right valve; overlapping distinct along cardinal angles; dorsal margin straight with 4-5 weak nodes; anterior and posterior cardinal angles protuded in left valve; ventral margin weakly sinuate along posteroventrally; anterior margin broad and evenly rounded; posterior margin subrounded; in dorsal view carapace biconvex with maximum width near

middle; Eye and subcentral tubercle low. Valve surface ornamented by thick reticles arranged concentrically about 4-5 longitudinal striae along posterior and ventral margins, two ridges originating from eye tubercle, one forming anterior marginal rim and other short vertical ridge joining subcentral tubercle; a deep furrow posterior to vertical ridge.

Figured specimens: Holotype (IPE/HO2/04/8001), male carapace, L.0.67mm, H.0.38mm, W.0.37 Paratype (IPE/P02/04/8002) in female carapace L.0.65mm, H.0.40mm, W.0.40mm.

Remarks : The present species resemble *Alocopocythere fossularis* (Lyubimova and Guha, 1960)) in lateral outline. Unlike present species *A.fossularis* having distinct hump along dorsal margin, anterior marginal area smooth and a well developed subcentral tubercle.

Alocopocythere polygona Neale and Singh

Plate III, Fig.3.

Alocopocythere polygona Neale and Singh, 1985, p.374, pl.45, Figs.1-3.

Locality and Horizon : Deopani traverse, sample No.13, Sylhet Formation, Mikir Hills, Assam.

Diagnostic characters : Carapace bean shaped, medium size. Valve surface with polygonal pits; anterior and posterior marginal areas rather smooth.

Figured specimen: Male carapace (IPE/HO2/03/987), L.0.56mm, X 89.

Distribution : Middle Eocene, Mikir Hills, Assam.

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Alocopocythere rajasthanensis
Bhandari

Plate III, fig.4.

Alocopocythere rajasthanensis
Bhandari, 1995, a, p.178, pl.2, figs.5-8; -
1996, p.36, pl.11, figs.1-4.

Locality and horizon : Ghotaru well-B, C.C.3, (725-730m), Khuiala Formation, Early Eocene.

Diagnostic characters : Valve surface ornamented by broad shallow reticulations, reticles are tetragonal to pentagonal in shape with a prominent sub ventral ridge sloping upward towards posterior.

Figured specimen : Holotype (IPE/H02/04/6665), male carapace, L.0.80mm, X 71

Distribution : Early Eocene , Jaisalmer Basin Rajasthan.

Alocopocythere talukdarii Neale and Singh

Plate III, fig.6.

Alocopocythere talukdarii Neale and Singh, 1985, p.374, pl.44.figs.8, 10-12.

Locality and horizon : Deopani traverse, sample No.8, Sylhet Formation, Mikir Hills, Assam.

Diagnostic characters : Carapace medium sized, valve surface ornamented with 5-6 longitudinal ridges posterior to subcentral tubercle; inter costal area pitted; dorsal margin appears convex due to convex dorsal ridge.

Figured specimen : Female carapace (IPE/P02/03/933), L.0.51mm.

Distribution : Middle Eocene, Mikir Hills, Assam.

Alocopocythere transcendens Siddiqui
Plate III, Fig.7.

Locality and horizon : 2 Kilometers south of Lakhpat village, Middle Eocene, Kutch.

Diagnostic characters : Carapace large, subrectangular in lateral view. Valve surface deeply reticulate and posteroventral margin rounded.

Figured specimen: Carapace (IPE/BO2/04/8050), L.0.64 mm, H. 0.39mm, X .110

Distribution : Middle to Early Eocene of Pakistan and Middle Eocene of Kutch, India.

Alocopocythere transversa morph.A
Siddiqui

Plate III, fig.7.

Alocopocythere transversa morph. A
Siddiqui, 1971, pp.19-20, pl.5, figs. 4, 5, 7-10; pl.6, figs. 1-4.

Genus and Species indet.5, Sohn, 1970, p.68, pl.4, figs.23-24.

Alocopocythere transversa Bhandari, 1992, p.46, pl.1, figs.5; - Bhandari, 1992, p.46, pl.1, figs.5; - Bhandari, 1996, pl.12, figs.1-2.

Locality and horizon : Kharatar well-A, sample 380-385m below surface, Bandah Formation, Middle Eocene.

Diagnostic characters : Carapace large, subrectangular in lateral view. Valve surface reticulate with three posterior transverse concentric ridges; a short ridge in anteroventral area running obliquely from anterior towards venter and a shallow groove on the dorsal side of the ridge.

Figured specimen : Open valve (IPE/ B02/04/6705), L.0.92mm, X 63.

Distribution : Middle and Late Eocene of Pakistan, Cambay Basin, and Jaisalmer Basin Rajasthan.

Alocopocythere transversa morph. E, Siddiqui

Plate III, fig.8.

Alocopocythere transversa morph.E, Siddiqui, 1971, p. 22, pl. 7., figs. 5-8; pl. 8, figs. 1-3, 5.

Genus and species indet.5, Sohn, 1970, p.68, pl.4, figs.27-29.

Alocopocythere transversa morph. E., Bhandari, 1992, p.46, pl.1, figs.67. Bhandari, 1996, pl.13, figs.1-4.

Locality and horizon : Sadewala well-A, sample 402-405m below surface, Glauconitic clays, Bandah Formation, Late Eocene.

Diagnostic characters : Carapace large, subrectangular in lateral view. Valve surface papillose with three posterior transverse concentric ridges; a short ridge in the anteroventral area running obliquely from anterior towards venter and a smooth, shallow groove on the dorsal side to the ventral ridge.

Figured specimen : Carapace (BOS No.12), L.0.90mm, X 61

Distribution : Late Eocene of Pakistan and subsurface of Jaisalmer Basin, Rajasthan.

6. BIOZONATION

On the basis stratigraphic ranges, the genus *Alocopocythere* has enable to divide the Tertiary beds of western part of India

into 10 zones (Fig. 5) and the North-eastern part of Garo Hills, Meghalaya and Upper Assam shelf, Eocene (Middle to Late Eocene) into five zones (Fig.5). The biozonation scheme proposed on the basis of *Alocopocythere* is described briefly below.

Western India

1. *Alocopocythere rajasthanensis* Range Zone

Definition : The total observable range of nominate taxon *A. rajasthanensis* Bhandari defines the extent of this zone.

Assemblage : *A. abstracta* Siddiqui, *Paragrenocythere reticulospinosa* (Sohn), *Phalcocythere sentosa* Siddiqui, *Hornibrookella chandrai* Bhandari and *Gyrocythere parvicarinata* Siddiqui etc.

Age : Early Eocene.

Remarks : This zone is equivalent to ostracode zone TOS-8, i.e. *Anommatocythere indica*- *Hornibrookella rajasthanensis* Interval Zone of Bhandari, 1996.

2. *Alocopocythere rajasthanensis* – *Alocopocythere abstracta* Interval Zone.

Definition : Defined as the Interval from Last Appearance Datum (LAD) of *Alocopocythere rajasthanensis* Bhandari to LAD of *A-abstracta* Siddiqui.

Assemblage : *Hornibrookella rajasthanensis* Bhandari, *Schizocythere bikanerensis* Khosla *Bythocypris westi* Singh and Misra, *Gyrocythere parvicarinata* Siddiqui, *Echinocythereis jaini* Khosla, *Hermanites goeli* Khosla,

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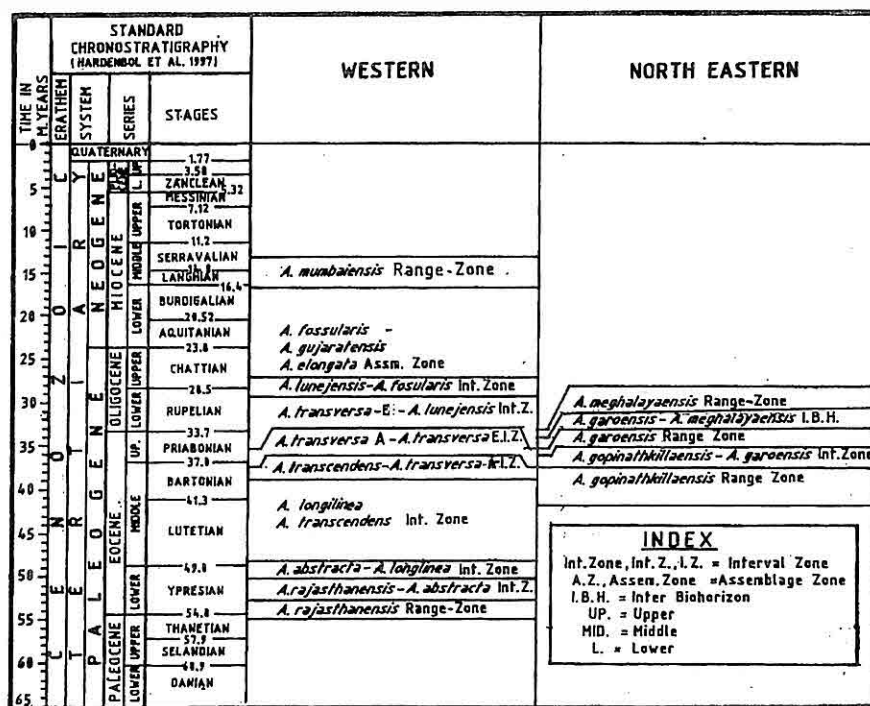


Figure 5. Biozonation proposed on the basis of genus *Alocopocythere* in the Eocene - Miocene beds of India.

Occultocythereis peristicta Siddiqui, *Paijenborchellina indica* Khosla, *P. mohani* Khosla, *Schizocythere spinosa* Guha and *Anommatocythere laqueta* Siddiqui.

Age : Early Eocene.

Remarks : This zones is equivalent to ostracode zones TOS-9 to TOS-12 of Bhandari 1996b (P7-P8 zones on planktic scale).

3. *Alocopocythere abstracta* - *A. longilinea* Interval Zone.

Defenition : Defined as the interval from LAD of *A. abstracta* Siddiqui to LAD of *A. longilinea*.

Assemblage : *A. coarctata* Siddiqui, *A. longilinea* Siddiqui, *Stigmatocythere obliqua* Siddiqui, and *Aglaioocypris ? indica* Bhandari.

Age : Latest Early Eocene (=P9 (part) on plank scale).

Remarks : This zone is equivalent to TOS-13 and TOS-14 of Bhandari, 1996b.

4. *Alocopocythere longilinea* - *A. transcendens* Interval Zone

Definition : Defined as the interval from the LAD of *A. longilinea* Siddiqui to LAD of *A. transcendens* Siddiqui.

Assemblage : *Stigmatocythere obliqua* Siddiqui, *A. transcendens* Siddiqui,

Echinocythereis (S) sahanii (Tiwari and Tandon), *Gyrocythere exaggerata* Siddiqui *Anommatocythere confirmata* Siddiqui and *Patagonacythere ? nidulus* Siddiqui

Age : Latest Early Eocene (=P9 (top) on planktic scale) to Middle Eocene.

Remarks : This zone is equivalent to ostracode zone TOS 14 (topmost part) to lower part of *Alocopocythere transversa* morph. A – *Stigmatocythere lumaria* Assemblage Zone, Bhandari 1996,b.

5. *Alocopocythere transcendens* – A. *transversa* morph. A. Interval Zone.

Definition : Defined as LAD of *A.transcendens* Siddiqui to LAD of *A.transversa* morph. A Siddiqui.

Assemblage : *Alocopocythere transversa* morph. A, *Acanthocytheris decoris* morph. A Siddiqui, *Echinocytheris (S) sahnii* (Tewari and Tandon), *Patagonacythere ? nidulus* Siddiqui.

Age : Latest Middle Eocene.

Remarks : This zone is equivalent to upper part of *Alocopocythere transversa* Morph. A. to *Stigmatocythere lumaria* Siddiqui, Bhandari, 1996b.

6. *Alocopocythere transversa* morph. A - *Alocopocythere transversa* morph. E

Definition : Defined as LAD of *A.transversa* morph A to LAD of *A.transversa* morph.E Siddiqui.

Assemblage : *Alocopocythere transversa* morph. E, *Echinocytheris (S) sparsa* Siddiqui, *Echinocythereis (S)*

multibullate Siddiqui, *Stigmatocythere lumaria* morph. B

Age : Earliest Late Eocene (=P15 on planktic scale)

Remarks : This zone is equivalent to *Alocopocythere transversa* morph. E-*Stigmatocythere lumaria* Assemblage Zone, Bhandari, 1996b.

7. *Alocopocythere transversa* morph. – E. *Alocopocythere lunejensis* (Guha)

Definition : Defined as LAD of *Alocopocythere transversa* morph. – E. to LAD of *A.lunejensis* (Guha).

Assemblage : *A.lunejensis* (Guha), *Actionocytheresis ramaniaensis* Khosla and Pant, *Archicythereis reticulata* Khosla and Pant, *Hornibrookella kutchensis* Khosla and Pant, *H. ramaniaensis* Khosla and Pant, *Stigmatocythere (Bhatiacythere) khariensis* Khosla and Pant and *Uroleberis sohni* Khosla and Pant.

Age : Early Oligocene.

Remarks : This zone is equivalent to ostracode zone *Actinocythereis ramaniaensis*, Range Zone, Khosla and Pant, 1982b.

8. *Alocopocythere lunejensis*-*Alocopocythere fossularis* Inter Biohorizon.

Definition : Defined as LAD of *Alocopocythere lunejensis* to First Appearance Datum (FAD) of *Alocopocythere fossularis* (Lyubimova and Guha).

Age : Early Oligocene to Late

Oligocene.

Remarks : This Inter-Biohorizon is devoid of genus *Alocopocythere*. It is equivalent to *Actinocythereis kutchensis* Range Zone of Khosla and Pant, 1982b and *Pokorynella* sp.-*Loocancha confinis* Interval Zone, Bhandari, 1996b.

9. *Alocopocythere fossularis* – *Alocopocythere gujaratensis* – *Alocopocythere elongata* Assemblage Zone.

Definition : The nominate taxa *Alocopocythere fossularis* (Guha), *A.gujaratensis* Khosla and *A.elongata* Khosla and Nagori are most characteristic ostracodes of this zone.

Assemblage : Beside nominate taxa, the other characteristic ostracodes of this zone are : *Archicytheris pulchra* (Lyubimova and Guha), *Hemicyprideis autonoma* (Lyubimova and Guha), *Murthya chadudopadiensis* (Lyubimova and Guha), *Neomonoceratina gajensis* Guha, *N. kutchensis* Guha, *Paijenberchillina prona* (Lyubimova and Guha).

Age : Early Miocene (Burdigalian)

Remarks : This zone is equivalent to TOS26 – TOS-28 of Bhandari, 1996b.

10. *Alocopocythere mumbaiensis* n.sp Range-Zone

Definition : Defined as a total observable range of nominate taxon *Alocopocythere mumbaiensis* n.sp.

Assemblage : *Alocopocythere mumbaiensis* n.sp, *Actionocytheris pandeyi* n.sp. *Assymitocythere* sp., *Costa*

mumbaiensis n.sp and *Pokorynella pseudoalata* n.sp.etc.

Age : Middle Miocene (N9-N10 on planktic scale)

Distribution : Mumbai Offshore.

North Eastern India

1. *Alocopocythere*

***gopinathkillaensis* Range Zone**

Definition : The total observable range of nominate taxon *A. gopinathkillaensis* Bhandari define the extent of this zone.

Assemblage : The characteristic ostracodes of this zone are : *A.bhandarii* Neale and Singh, *A.talukdari* Neale and Singh *A.gopinathkillaensis* Bhandari, *Cytheretta hastata* Neale and Singh, *P. (E) bhandarii* Bhandari, *P. (E) khoslai*, *Paracypris sahui* Bhandari, *Cytherella siddiqui* Bhandari, *Cytherella anthiformis* Neale and Singh *Semicytherura nealei* Bhandari, *Siddiquicythere dhansariensis* (Neale and Singh), *Siddiquicythere mohani* Bhandari, and *Schizocythere gujaratensis* Guha, *Paijenborchella (E) bhandarii* Neale and Singh.

Age : Middle Eocene.

Remarks : This zone is equivalent to *Siddiquicythere dhansariensis* – *A. gopinathkillaensis* Range Zone, Bhandari, 1998.

2. *Alocopocythere gopinathkillaensis*-*Alocopocythere garoensis* Interval - Zone.

Definiton : This zone is defined as the interval from LAD of *Alocopocythere gopinathkillaensis* Bhandari to FAD of *Alocopocythere garoensis* Bhandari.

Assemblage : This zone is poorly fossiliferous and yielded ostracodes namely : *Krithe oryza* Neale and Singh, *Neocyprideis bhupendri* (Singh and Misra), *Neonesidea khoslai* Bhandari and *N.shilligensis* Bhandari.

Age : Late Eocene

3. *Alocopocythere garoensis* Range zone.

Definition : The total observable range of nominate taxon *Alocopocythere garoensis* Bhandari defines the extent of this zone.

Assemblage : The characteristic ostracodes restricted to this zone are : *Alocopocythere dattai* Bhandari, *A.indica* Bhandari, *Bairdopillata chaudharii* Bhandari, *Bythoceratina* sp. *Hermanites* sp., *Hornibrookella* sp. and *Occultocythereis turaensis* Bhandari.

Age : Late Eocene.

4. *Alocopocythere garoensis*-*Alocopocythere meghalayaensis* Interbiohorizon (Poorly fossiliferous) Zone

Definition : This zone is defined as the interval from LAD of *Alocopocythere garoensis* Bhandari to FAD of *A.meghalayaensis* Bhandari.

Assemblage : This zone is poorly fossiliferous / barren. The lower part of this zone has yielded *Krithe oryza* Neale and Singh, *Neonesidea shillongensis* Bhandari *Occultocythereis raivermanii* Bhandari, *Propontocypris* (Ek.) *meghalayaensis* Bhandari while upper part of this zone is devoid of ostracodes.

Age : Late Eocene

5. *Alocopocythere meghalayaensis* Range Zone.

Definition : The total observable range of nominate taxon *Alocopocythere meghalayaensis* Bhandari defines the extent of this zone.

Assemblage : The ostracodes restricted to this zone are: *A. meghalayaensis* Bhandari, *P.(E) swaraswatiai* Sarma, *Cytherelloidea* cf. *C. chewtonensis* Haskins and *Gyrocythere* sp.

Age : Late Eocene.

Evolutionary trends in genus *Alocopocythere*

(A) *A. abstracta* – *A. transcendens* – *A. transversa* lineage

An attempt has been made in this work to establish evolutionary trends within genus *Alocopocythere*. The oldest known species of genus *Alocopocythere* is represented by *A. abstracta* which seems to be ancestral to *A.transcendens*. *A. abstracta* appears in the Early Eocene and characterised by reticulate ornamentation with posteroventral margin straight. This species evolves and gave rise to *A.transcendens* which is comparatively larger in size, surface deeply reticulate and posteroventral margin rounded. This species continues upto Middle Eocene and gave rise to *A.transversa* morph. A, which is also larger in size and develops three posterior transverse concentric ridges and a short ridge in the anteroventral area, runs obliquely from anterior towards venter.

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This species is restricted in the Middle Eocene and gave rise to *A. transversa* morph. E which is more papillose in the Late Eocene (Fig.6).

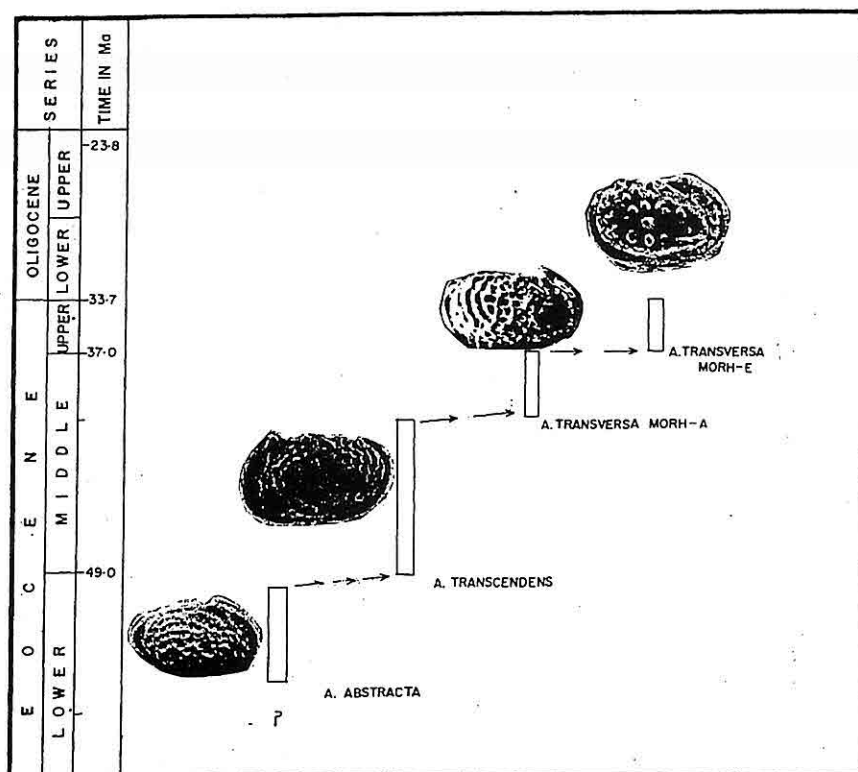


Figure 6. Postulated lineage, stratigraphical distribution of *A. abstracta*-*A. transcendens*-*A. transversa* morph-A and *A. transversa* morph-E in the Tertiary beds of western India.

(B) *A. rajasthanensis* – *A. elongata* – *A. depressa* lineage

Alocopocythere rajasthanensis seems to be ancestral form to *A. elongata*. *Alocopocythere rajasthanensis* appear in the Early Eocene and characterised by broad shallow reticulations with a prominent sub ventral ridge sloping upward towards posterior. This species evolves in the Early Miocene and gave

rise to *A. elongata* having broad shallow reticulations arranged in rows parallel to margins. Eye tubercle and sub central tubercle became low and instead of ventral ridge it has spine in posteroventral region. This further evolve and gave rise to *A. depressa* which has shallow reticles and depression posterior to subcentral tubercle and three nodes in the dorsal margin and a spine (Fig.7).

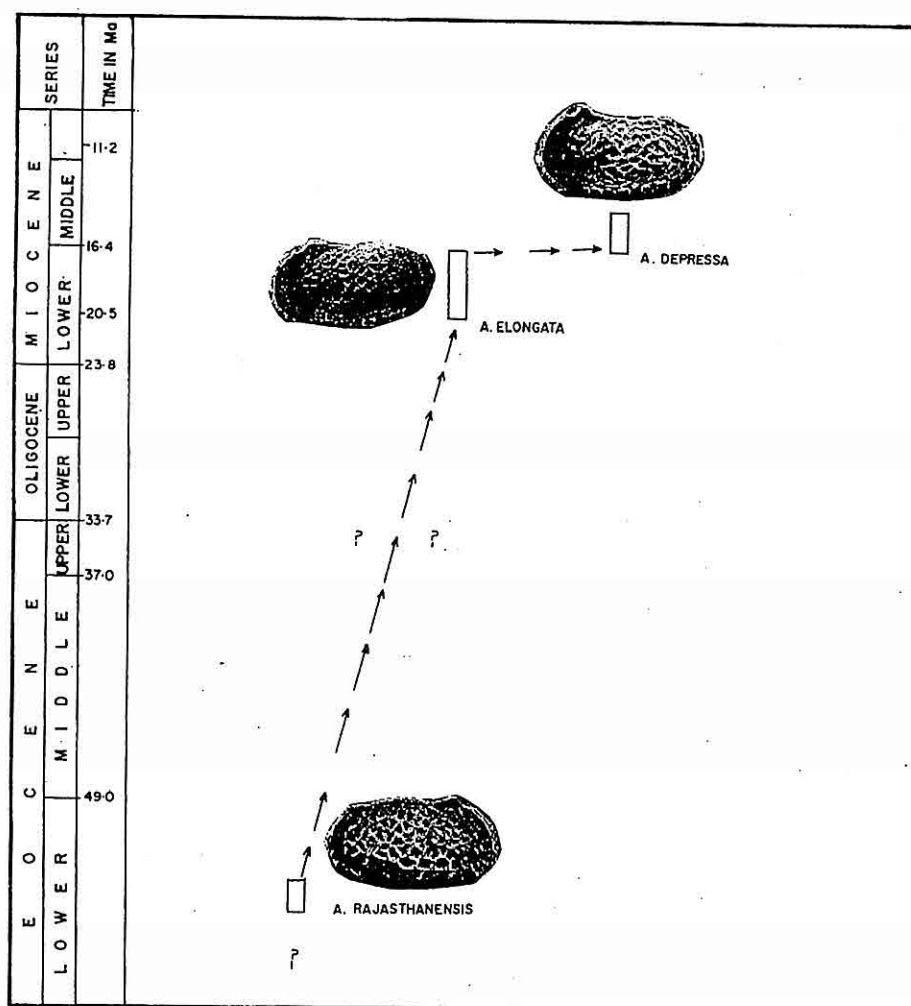


Figure 7. Postulated lineage, stratigraphical distribution of *A. rajasthanensis* -*A. elongata* and *A. depressa* in the Tertiary beds of Western India.

(C) Northeastern India

A. gopinathkillaensis – *A. indica* – *A. meghalayaensis* lineage

A. gopinathkillansis appears in the latest Middle Eocene and seems to be ancestral of *A. indica*. *A. gopinathkillaensis* is characterised by having reticulate valve surface with 5-6 verticle ridges in the

posterior half, a prominent ventral ridge sloping upwards posteriorly and anterior marginal zone flat and compressed. *A. gopinathkillaensis* evolves and gave rise to *A. indica* in the Late Eocene which has reticulate valve surface and reticles arranged in concentric pattern with ventral ridge and anterior marginal zone

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flat and compressed. This species further characterised by 4-5 oblique curved evolve and gave rise to *A. meghalayaensis* in the latest Late Eocene, ridges with grooves posteriolry and a prominent ventral ridge (Fig.8).

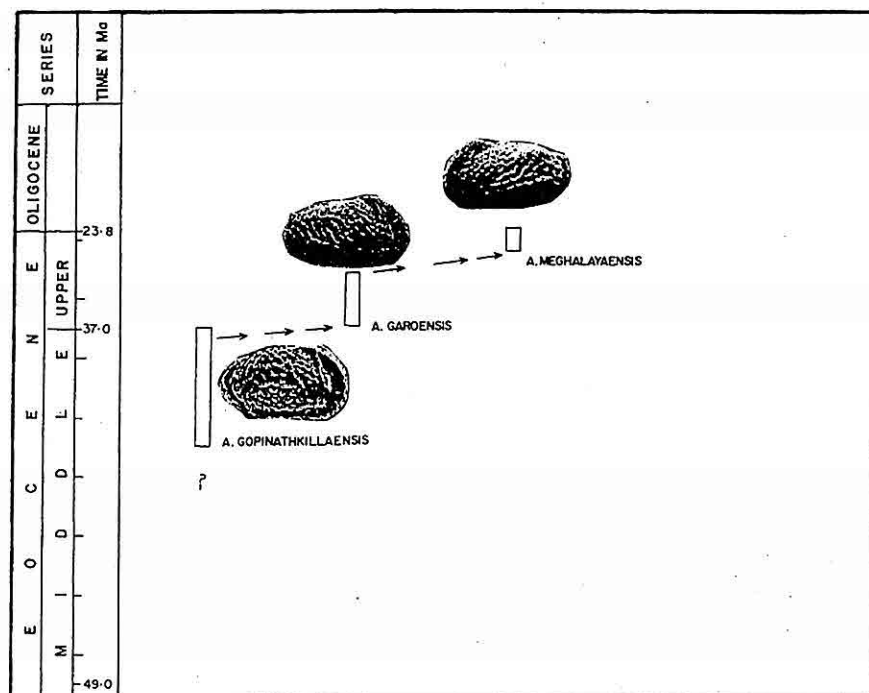


Figure 8. Postulated lineage, stratigraphical distribution of *A. gopinathkillaensis* - *A. garoensis* and *meghalayaensis* in the Eocene beds of north-eastern India.

6. ACKNOWLEDGEMENTS

The author is thankful to Director Exploration, and Executive Director (R&D), KDM Institute of Petroleum Exploration, Oil and Natural Gas Corporation Ltd. for giving permission for publication and presentation of this paper in the 4th European Ostracodologists meeting Adana, Turkey. Sincere thanks are due to Sh. K.N. Mishra G.M. (GRG), Sh. James Peters.

Dy.G.M. (Geol.) ONGC for providing necessary help and facilities during preparation of this paper and to Dr. S.C. Khosla and Dr. M.L. Nagori, Department of Geology, M.L. Sukhadia University for providing type material of ostracodes for comparison.

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PLATE – I

- Fig. 1** *Alocopocythere abstracta* Siddiqui, a male carapace, (IPE/BO2/04/6701), right valve view, X 82.
- Fig.2** *Alocopocythere borhollaensis* Bhandari, a female carapace (BOS No.58), right valve view, X 86.
- Fig.3** *Alocopocythere bhandarii* Neale and Singh, a carapace (BOS No.57), right valve view, X 107.
- Fig.4** *Alocopocythere dattai* Bhandari, a carapace (BOS No.60), right valve view, X 93.
- Fig.5** *Alocopocythere coarctata* Siddiqui, carapace (IPE/BO2/04/6703), right valve view, X 88.
- Fig.6** *Alocopocythere depressa* Khosla and Nagori, a male carapace (No.355), left valve view, X 79.
- Fig.7** *Alocopocythere elongata* Khosla and Nagori, a male carapace (No.359), left valve view, X 67.
- Fig.8** *Alocopocythere fossularis*, (Lyubimova and Guha), a female carapace (IPE/BO2/04/7043), right valve view, X 75.

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PLATE - I

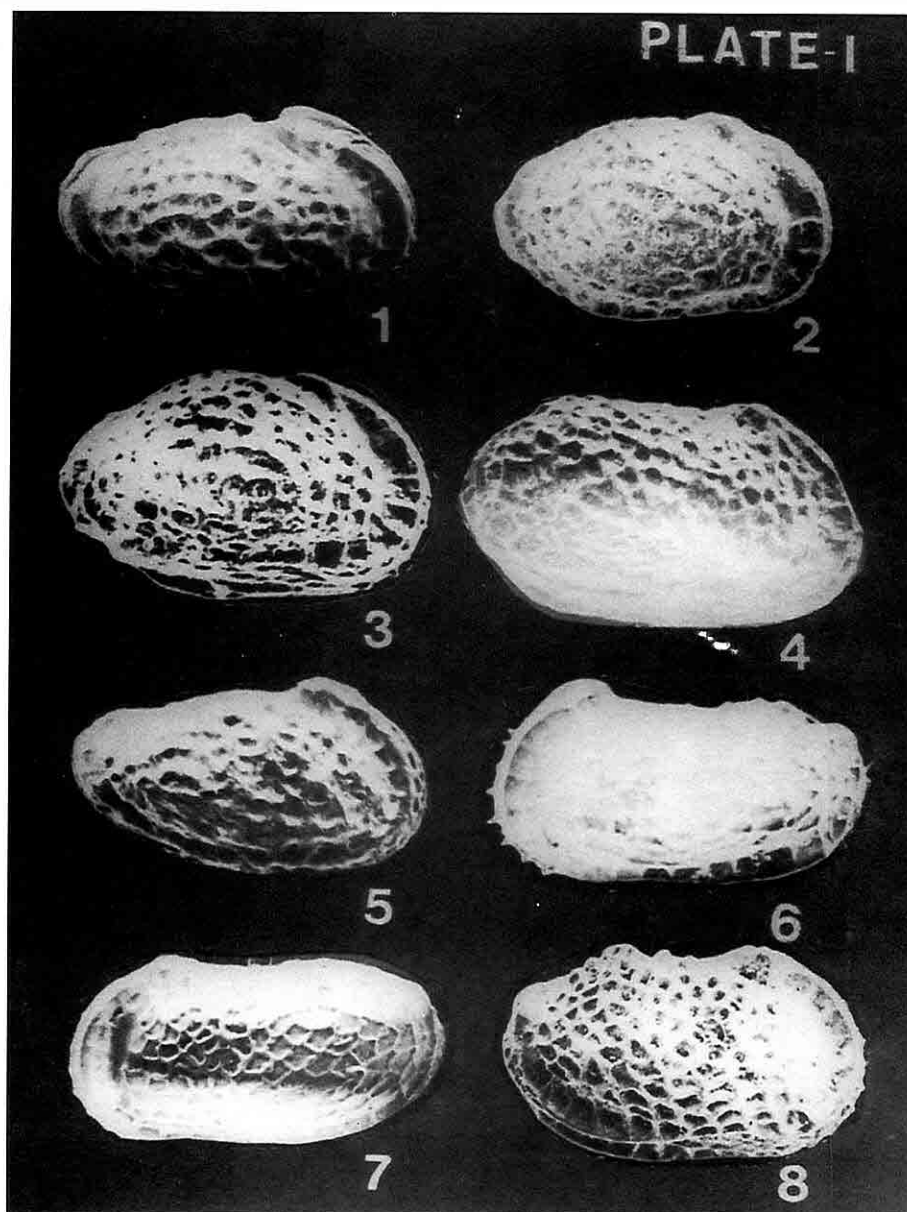


PLATE - II

Fig.1 *Alocopocythere garoensis* Bhandari, a carapace (BOS No.61), right valve view, X, 89.

Fig.2 *Alocopocythere gopinathkillaensis* Bhandari, a female carapace (BOS No.62), right valve view, X 83.

Fig.3 *Alocopocythere gujaratensis* Khosla, a carapace left valve view, X 65.

Fig.4 *Alocopocythere indica* Bhandari, a female carapace, (BOS No.67), right valve view, X 84.

Figs.5-6 *Alocopocythere longilinea* Siddiqui,

5. Carapace (IPE/BO2/04/6704), right valve view, X 104.

6. Carapace (IPE/BO2/04/670) left valve view, X 117.

Fig.7 *Alocopocythere lunejensis* Guha, a carapace, right valve view, X 88.

Fig.8 *Alocopocythere meghalayaensis* Bhandari, a carapace (BOS No.69), right valve view, X 64.

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PLATE - II

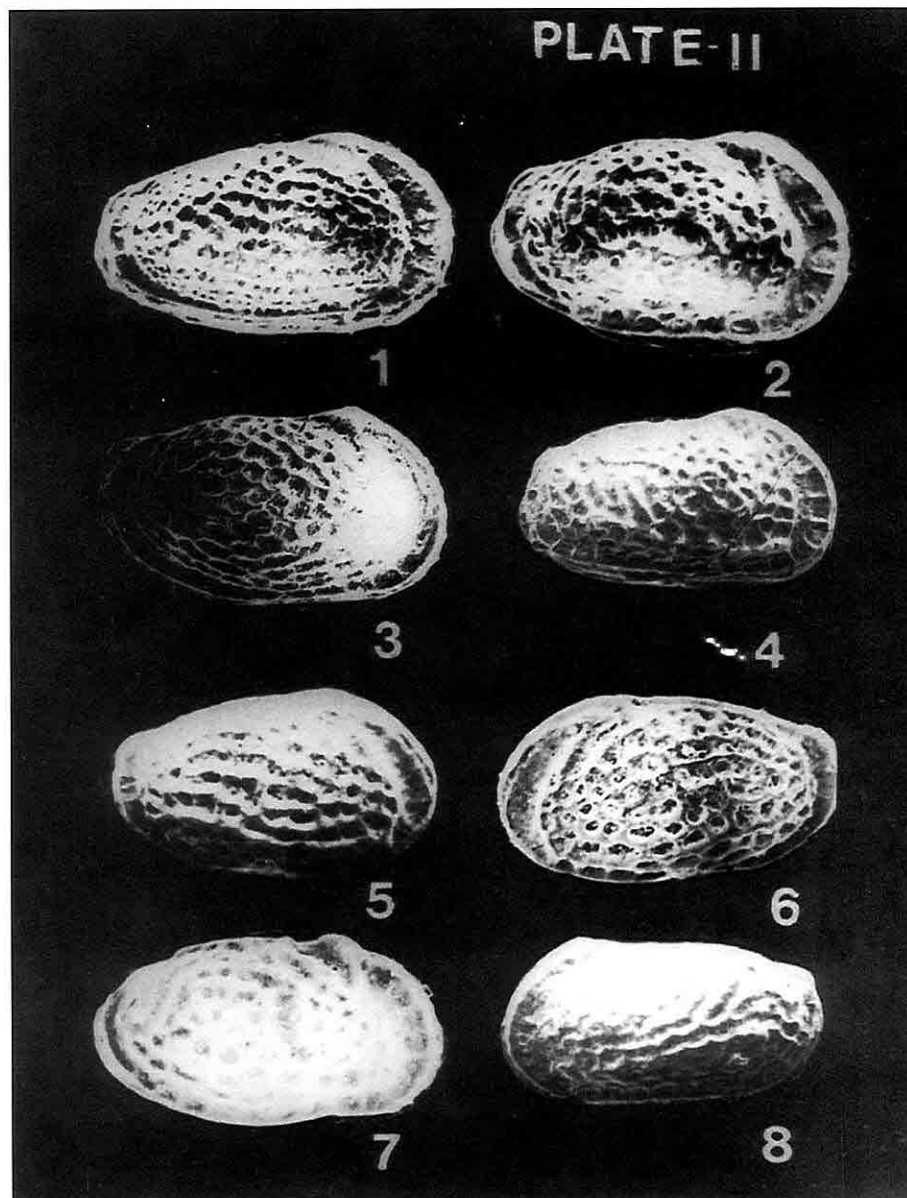


PLATE - III

Figs.1-2 *Alocopocythere mumbaiensis* n.sp.,

1. Male carapace (IPE/HO2/04/8001), right valve view, X 89.
2. Female carapace (IPE/PO2/04/8002), left valve view, X 89.

Fig.3 *Alocopocythere polygona* Neale and Singh, a male carapace (IPE/HO2/03/987), left valve view, X 89.

Fig.4 *Alocopocythere rajasthanensis*, Bhandari, a male carapace (IPE/HO2/04/6665), right valve view, X 71.

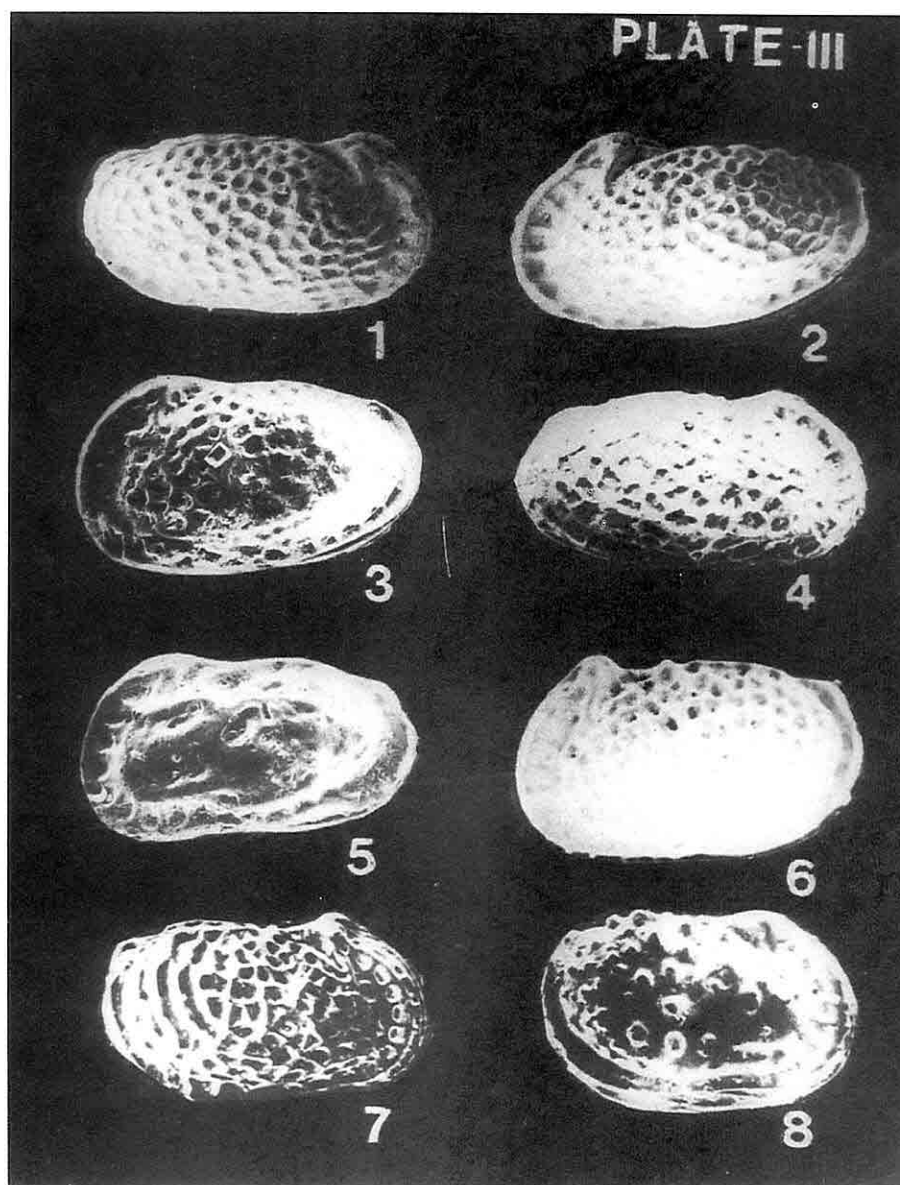
Fig.5 *Alocopocythere talukdari* Neale and Singh, a female carapace (IPE/PO2/03/933), left valve view, X 108.

Fig.6 *Alocopocythere transcendens* Siddiqui, a carapace (IPE/BO2/04/8050), left valve view, X 60.

Fig.7 *Alocopocythere transvers* morph A. Siddiqui, (IPE/BO2/04/6705), right view, X 63.

Fig.8 *Alocopocythere transversa* morph E. Siddiqui, a carapace (BOS No.12), right valve view, X 61.

PLATE - III



THE OSTRACODA (CRUSTACEA) FAUNA OF SAKARYA RIVER BASIN

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ABSTRACT: *This study was performed at the Sakarya River basin between September 1, 1995 and November 11, 1995. Materials collected from 41 stations, were evaluated and 16 species (*Ilyocypris biplicata*, *Ilyocypris gibba*, *Ilyocypris bradyi*, *Ilyocypris decipiens*, *Candona neglecta*, *Cypria ophthalmica*, *Eucypris virens*, *Prionocypris zenkeri*, *Heterocypris incongruens*, *Cyprinotus inaequalis*, *Herpetocypris chevreuxi*, *Psychrodromus olivaceus*, *Cypridopsis vidua*, *Potamocypris villosa*, *Potamocypris zschokkei* and *Tyrrhenocythere amnicola*) belonging to 12 genera were identified. All ostracod species are new record for these localities.*

1. INTRODUCTION

Anatolia is an important region in terms of its geological, ecological and zoogeographical characteristics. Geologically, Anatolia has undergone many changes, and the fauna of the region has also displayed considerable variation. During these changes, many animal species originating from different zoogeographical regions migrated to Anatolia. In particular, many animal species moved to Anatolia in the last glacial period. In this period, life conditions were appropriate for these species in Anatolia. For example, the climate was suitable for many life forms during the last Ice Age. Numerous paleontological and zoological findings in Anatolia have confirmed this theory. Nevertheless, taxonomic studies on the fauna of Anatolia have limited to a few groups up to the present time.

Recent extensive studies conducted on certain animal groups have yielded valuable information about Anatolia. The subclass Ostracoda has recently been studied. Schäfer (1954) and Hartmann (1964) conducted the first studies on the Ostracoda fauna of Anatolia.

The following studies were used for determining freshwater Ostracoda fauna in Anatolia and Thrace: Gülen (1975, 1977, 1985 a, 1985 b, 1988); Altınışalı (1988, 1993); Altınışalı & Kubanç (1990); Kùlköylüoğlu et al., (1993 and 1995); Gülen et al., (1994); Altınışalı & Yılmam (1995) and Kùlköylüoğlu (1998).

The aim of study was to contribute to

knowledge of the recent cypridid ostracod fauna of Sakarya river and their branches. Moreover, this study will contribute to the knowledge of the recent cypridid ostracod fauna of Anatolia. Our data and literature are basis for reflection on the biogeography of this group in Anatolia and adjacent areas.

2. MATERIAL AND METHODS

This study was performed in the Sakarya River basin. Ostracods were collected in shallow waters (< 1 m depth) with a Müller plankton net, and immediately fixed in 4 % formaldehyde. The benthic forms of ostracods (> 1 m depth) living in the mud were collected with a bottom sample container and special sieves were used to separate detritus and other materials. In the laboratory, samples were washed under pressurised tap water, filtered through three standard-sized sieves (of 2: 1: 0.25 mm of mesh-size, respectively) and stored in 70 % ethanol. Then, the samples were conserved in 70 % ethanol and glycerine (in a 1:1 ratio). Species identification was based on the soft body parts and valves. The permanent and temporary slides of the soft body parts were prepared with Canada Balsam and lactophenol, respectively. Valves of each species were held in micro-slides. All material were deposit in the Zoology Museum of the Biology Department, University of Istanbul, Turkey.

Study Area: Sakarya (Sangarios) River is the longest river in the north-western Anatolia. It is 824 km long. It is accepted

to have arisen from a spring called Sakaryabaşı near Çifteler district of the north-western region of Central Anatolia, but longer branches of the river, which bear various names, go downwards from the eastern slopes of Yazılıkaya plateau and Emir mountains. First it turns towards south-east, then towards north and finally meets with the Black Sea near Karasu district. In accordance with the tectonic structure it follows a route similar to shape S; it flows slowly in a plain in the upper section, faster in a narrow valley between Köroğlu and Sündiken mountains, and slower again in some plains (Pamukova and Adapazarı plains) where its lower region pass through. Sakarya river is fed by many streams and springs. The main streams which flow into this river are Porsuk stream, Ankara stream, Kirmir stream and Göksu stream which drains the waters from İnegöl and Yenişehir plains, Mudurnu stream which meets the river in Adapazarı plain, and Çark stream which drains the waters from Lake Sapanca. Since a great portion of the alluvium carried by the river have settled in Osmaneli and Adapazarı plains, which form significant settlement areas in lower region, no major delta has been formed at the mouth of the river. The river and its branches are fed by rain and snow waters. Average rate of flow is approximately 134 m³/second when it leaves Geyve strait, but rates of flow between 6 m³ and 1162 m³/second have been measured. It causes hazardous floods especially in the lower plains

because of this irregular flow regime. The highest average rate of flow is observed during April (219 m³/second) and the lowest average rate of flow is observed during October (77 m³/second). Sarıyar dam and hydro-electric power plant is set up in the middle region of Sakarya River. The material was collected from 41 stations. These stations are shown in Figure 1.

Stations

Station 1- Seydi Stream (Spring of Sakarya River), 01/09/1995, 30° 50' E- 39° 22' N

Station 2- Sakaryabaşı Spring (Spring of Sakarya River), 02 /09/95, 31° 03' E- 39° 21' N

Station 3- Bardakçı Stream (Branch Seydi Stream), 03/09/1995, 31° 12' E - 39° 29' N

Station 4- Sarısu (Branch of Seydi Stream) Stream, 03/09/1995, 31° 07' E- 39° 28' N

Station 5- Porsuk River, (Branch of Sakarya River), 16/09/95, 30° 18 'E- 39°38' N

Station 6- Yukarıçağlan Stream (Branch of Porsuk Stream), 16/09/1995, 30°28'E- 39° 44' N

Station 7- Akyurt Stream (Branch of Seydi Stream), 17/09/1995, 31° 01' E - 39° 23' N

Station 8- Şerefiye Stream (Brach of Sarısu Stream), 17/09/1995, 31° 03' E- 39° 39' N

Station 9- Sarısu Stream (Branch of Seydi Çayı), 17/ 09/1995, 30° 50' E- 39° 32' N

Station 10- Sakarya River, Yassihöyük Region, 08 /09/1995, 31° 59' E - 39° 40' N

Station 11- Porsuk Stream, Yassihöyük Region, 08/09/1995, 31° 56'E- 39° 42' N

Station 12- Ilcaözü Stream (Branch of Sakarya River), 09/09/1995, 32° 07' E - 39° 23' N

Station 13- Babayakup Stream (Branch of Ankara Stream), 09/09/1995, 32° 25'E- 39° 44'N

Station 14- Ova Stream (Branch of Ankara Stream), 10/09/1995, 32° 32' E - 40° 02' N

Station 15- Kirmir Stream, 11/09/1995, 31° 57' E- 40° 07' N.

Station 16- Aladağ Stream (Sarıyar Dam), 12/09/1995, 31° 42' E- 40° 17' N

Station 17- Kızıldere Stream, 13/09/1995, 30° 46' E- 40° 06' N

Station 18- Çolak Stream (Branch of Sakarya River), 13/09/1995, 30° 46' E- 40° 06' N

Station 19- Sakarya River, Vicinity of Vezirhan Town, 22 /09/1995, 30° 04' E - 40° 16' N

Station 20- Akçay Stream (Branch of Sakarya River), 22 / 09 / 1995, 30° 18' E - 40° 17' N

Station 21- Çakırlar Stream (Branch of Sakarya River), 23 /09/1995, 30° 33' - 40° 18' N

Station 22- Güllük Stream (Branch of Göynük Stream), 24/09/1995, 30° 42' E- 40° 29' N

Station 23- Mudurnu Stream ((Branch of Sakarya River), 25/09/1995, 31° 04' E- 40° 29' N

Station 24- Tütünlük Stream (Branch of

Mudurnu Stream), 29/09/1995, 30° 58' E- 40° 44' N

Station 25- Hanyatak Stream (Branch of Mudurnu Stream), 30/09/1995, 30° 37' E 40°31' N

Station 26- Çark Stream (Branch of Sakarya River), 01/10/1995, 30° 19'E- 40° 48' N

Station 27- Acı Elmalık Stream (Branch of Sakarya River), 02/10/1995, 30° 20'E- 40° 54' N

Station 28- Kayalar Deresi (Branch of Mudurnu Stream), 02/10/1995, 30° 29' E- 40° 43' N

Station 29- Şükriye Stream (Branch of Sakarya River), 03/10/1995, 30° 20' E- 40° 40' N

Station 30- Kanlıçay Stream (Branch of Mudurnu Stream), 03/10/1995, 30° 30'E- 40° 34' N

Station 31- Ketenli Stream (Branch of Mudurnu Stream), 04/10/1995, 30° 36' E- 40° 37' N

Station 32- Göcek Stream (Branch of Mudurnu Stream), 04/10/1995, 30° 34' E- 40° 43' N

Station 33- Sobran Stream (Branch of Porsuk Stream), 19/10/1995, 29° 57' E- 39° 44' N

Station 34-Enne Stream (Branch of Porsuk Stream), 20/10/1995, 29° 39' E- 39° 32'N

Station 35-Gelinkaya Stream (Branch of Porsuk Stream), 20/10/1995, 29° 52'E- 39° 22'N

Station 36-Alibeyköy Stream (Branch of Porsuk Stream), 21/10/1995, 30° 07'E- 39° 06'N

Station 37-Atkın Stream (Branch of

Seydi Stream), 21/10/1995, 30° 24' E-39° 20' N

Station 38- Seydi Stream (Branch of Seydi Stream), 22/10/1995, 30° 45' E-39° 30' N

Station 39- Çaltı Stream (Branch of Sakarya River), 27/10/1995, 30° 15' E-40° 03' N

Station 40- Akçasu Stream (Branch of Çatak Stream), 28/10/1995, 30° 41' E-40° 10' N

Station 41- Çatak Stream (Branch of Sakarya River), 28 /10/1995, 30° 48' E -40° 13' N

Station 42- Sarıcalar Stream (Branch of Çatak Stream), 29/10/1995, 30° 42' E-40° 18' N

3. RESULTS

The faunal composition of the Sakarya river basin revealed 16 ostracod species. The occurrence of the species at each station is summarised in Table 1.

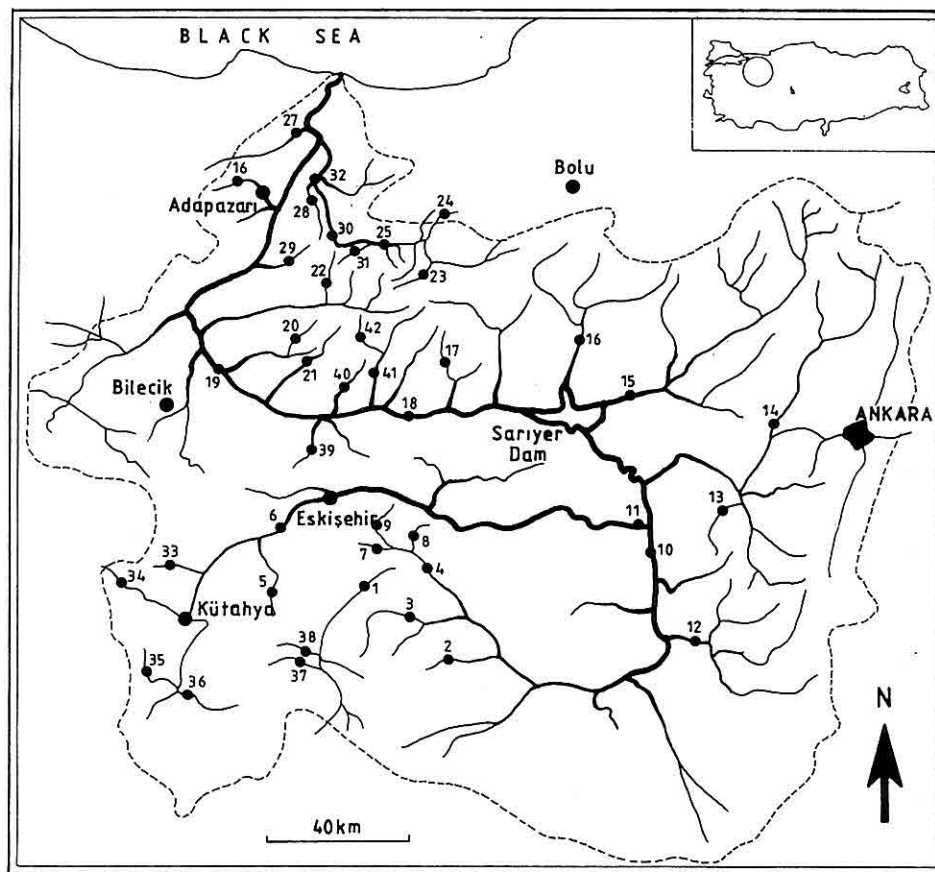


Figure 1. Sakarya river basin and stations.

Table 1. Ostracods species collected in Sakarya river basin, Turkey.

STATIONS

SPECIES	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42					
<i>Ilyocypris buplicata</i> (Koch)										+																																					
<i>Ilyocypris gibba</i> (Randohr)									+		+					+																															
<i>Ilyocypris bradyi</i> Sars	+			+		+				+					+												+																			+	
<i>Ilyocypris decipiens</i> Masi							+																																								
<i>Candona neglecta</i> Sars																																															+
<i>Cypria ophthalmica</i> (Jurine)																																															+
<i>Eucypris virens</i> (Jurine)	+														+																																+
<i>Prionocypris zenkeri</i> (Chyzer & Toth)				+	+	+		+							+																															+	
<i>Heterocypris incongruens</i> Randohr																																															+
<i>Cyprinoides inaequivalvis</i> Bronstein								+			+																																				+
<i>Herpetocypris chevreauxi</i> (Sars)																																															+
<i>Psychrodromus olivaceus</i> (Brady & Norman)	+																																														+
<i>Cypridopsis vidua</i> (O. F. Müller)								+			+				+																															+	
<i>Potamocypris villosa</i> (Jurine)											+																																				+
<i>Potamocypris zschokkei</i> (Kaufmann)	+																																														+
<i>Tyrrhenocythere amnicola</i> (Sars)									+																																						+

4. FINDINGS AND TAXONOMY

In this study, we followed the systematic keys of Hartmann and Puri (1974), Kempf (1980) and Meisch (1984 and 1985).

Class	: Crustacea
Subclass	: Ostracoda Latreille, 1806
Order	: Podocopida G.W. Müller, 1984
Suborder	: Podocopa Sars, 1866
Superfamily	: Cypridoidea Baird, 1845
Family	: Ilyocyprididae Kaufmann, 1900
Genus	: <i>Ilyocypris</i> Brady & Norman, 1889

Ilyocypris biplicata (Koch, 1838) Brady & Norman, 1889.

Material: Station 11, 20.09.1995, 2 ♀♀ ; Station 14, 26.09.1995, 2 ♀♀ .

Previous records from Turkey: Bursa and Bilecik (Gülen, 1985 a); İzmir (Altınsaçlı, 1988); İstanbul (Külköylüoğlu et al., 1993); Sinop and Samsun (Kaleli, 1993); İznik Lake and Sapanca Lake (Altınsaçlı, 1993); Terkos Lake (Altınsaçlı & Yılmam, 1993) and şamlar Lake (Külköylüoğlu, 1998).

General Distribution: Europe, North America, North Africa and Near-East Asia

Ilyocypris bradyi Sars, 1890

Material: Station 2, 01.08.1995, 15 ♀♀ ; Station 4, 01.08.1995, 15 ♀♀ ; Station 7, 01.08.1995, 4 ♀♀ ; Station 9, 13.09.1995, 2 ♀♀ ; Station 12, 20.09.1995, 2 ♀♀ ; Station 16, 01.08.1995, 1 ♀♀ ; Station 19, 26.09.1995, 4 ♀♀ ; Station 21, 26.09.1995,

2 ♀♀ ; Station 22, 26.09.1995, 5 ♀♀ ; Station 23, 26.09.1995, 1 ♀ ; Station 27, 27.09.1995, 2 ♀♀ ; Station 31, 29.09.1995, 2 ♀♀ ; Station 32, 27.09.1995, 3 ♀♀ ; Station 35, 15.10.1995, 7 ♀♀ ; Station 42, 16.10.1995, 15 ♀♀

Previous records from Turkey: Eskişehir (Gülen, 1977), Bilecik (Gülen, 1985 a), İzmir (Altınsaçlı 1988); Balıkesir (Altınsaçlı & Kubanç, 1990), İstanbul (Külköylüoğlu et al., 1993); Samsun (Kaleli, 1993); Lake İznik, and Lake Sapanca (Altınsaçlı, 1993); Amasya and Sivas (Gülen et al., 1994).

General Distribution: Europe, North Africa, Central Asia and North America.

Ilyocypris decipiens Masi, 1905.

Material: Station 7, 13.09.1995, 2

Previous records from Turkey: Zonguldak (Hartmann, 1964), Kütahya (Gülen, 1985 a); İzmir (Altınsaçlı, 1988), Lake İznik (Altınsaçlı, 1993) and İstanbul (Külköylüoğlu et al., 1993).

Known Distribution: Europe, North Africa, North America and Asia.

Ilyocypris gibba (Ramdohr, 1808) Brady & Norman, 1889

Material: Station 9, 13.09.1995, 2 ♀♀ ; Station 11, 20.09.1995, 2 ♀♀ ; Station 12, 20.09.1995, 2 ♀♀ ; Station 17, 13.09.1995, 21 ♀♀ .

Previous records from Turkey: Zonguldak, Kocaeli (Hartmann, 1964); İzmir (Gülen, 1975); Kütahya and İzmir (Gülen, 1977); Balıkesir (Gülen, 1985a); Adana (Gülen, 1988); İzmir (Altınsaçlı, 1988); Balıkesir (Altınsaçlı & Kubanç, 1990); Sapanca Lake (Altınsaçlı, 1993); Terkos Lake (Altınsaçlı & Yılmam,

1993); Amasya and Çankırı (Gülen et al., 1994) and Lake şamlar (Külköylüoğlu, 1998).

General Distribution: Europe, North Africa, North America and Near East Asia.

Family : Candonidae Kaufmann, 1900

Subfamily : Candoninae, Kaufmann, 1900

Genus : *Candona* Baird, 1845

Candona neglecta Sars, 1887

Material: Station 19, 26.09.1995, 1 ♀ ; Station 20, 26.09.1995, 1 ♀ ; 1 ♀ ; Station 24, 26.09.1995, 1 ♀ ; Station 34, 15.10.1995, 7 ♀ ; Station 39, 27.10.1995, 2 ♀ ;

Previous records from Turkey: Gaziantep (Hartmann, 1964); Kütahya (Gülen, 1977); Bilecik, İzmir, Aydın, Bolu and Zonguldak (Gülen, 1985a, b); İzmir, (Altınsaçlı, 1988); Adana (GÜLEN, 1988); İznik Lake and Sapanca Lake (Altınsaçlı, 1993); Sinop, Samsun (Kaleli, 1993) and Terkos Lake (Altınsaçlı & Yılmam, 1995)

General Distribution: Europe, Central Asia, North Africa and south-east Asia

Subfamily : Cyclopyridinae Kaufmann, 1900

Genus : *Cypria* (Zenker, 1854) Brady & Norman, 1889

Cypria ophthalmica (Jurine, 1820) Brady & Norman, 1889

Material: Station 34, 15.10.1995, 1 ♀ ; Station 38, 22.10.1995, 4 ♀ ;

Previous records from Turkey: İstanbul (Gülen, 1985a); Lake Sapanca (Altınsaçlı, 1993); Terkos Lake

(Altınsaçlı & Yılmam, 1995) and Şamlar Lake (Külköylüoğlu, 1998).

General Distribution: Europe, North Africa and North America

Family : Cyprididae Baird, 1845

Subfamily : Eucypridinae

Bronstein, 1947

Genus : *Eucypris* (Vavra, 1891)

Daday, 1900

Eucypris virens (Jurine, 1820) Daday, 1900

Material: Station 2, 01.08.1995, 2 ♀ ; Station 28, 27.09.1995, 1 ♀ ; Station 36, 15.10.1995, 1 ♀ ; Station 42, 16.10.1995, 8 ♀ ;

Previous Records from Turkey: İzmir (Gülen, 1975); Kütahya and İzmir (Gülen, 1977); İstanbul, Aydın, Muğla, Manisa, Afyon and Zonguldak (Gülen, 1985 a); Mersin, Adana and Antakya (Gülen, 1988); İstanbul (Külköylüoğlu et al., 1993); Sinop and Samsun (Kaleli, 1993); İznik Lake and Sapanca Lake (Altınsaçlı, 1993) and şamlar Lake (Külköylüoğlu, 1998)

General Distribution: Holarctic

Genus : *Prionocypris* Brady & Norman, 1896

Prionocypris zenkeri (Chyzer & Toth, 1858) G. W. Müller, 1912

Material: Station 3, 01.08.1995, 40 ♀ ; Station 4, 01.08.1995, 55 ♀ ; Station 5, 24.08.1995, 40 ♀ ; Station 6, 24.08.1995, 2 ♀ ; Station 8, 13.09.1995, 30 ♀ ; Station 14, 26.09.1995, 6 ♀ ; Station 15, 21.09.1995, 8 ♀ ; Station 18, 21.09.1995, 8 ♀ ; Station 19, 26.09.1995, 3 ♀ ; Station 20, 26.09.1995, 1 ♀ ; Station 26, 27.07.1995, 2 ♀ ; Station 33, 15.10.1995,

20 ♀♀; Station 35, 15.10.1995, 20 ♀♀; Station 37, 15.10.1995, 15 ♀♀; Station 38, 22.10.1995, 7 ♀♀; Station 42, 16.10.1995, 30 ♀♀;

Previous records from Turkey: South-eastern Anatolia (Hartmann, 1964); Eskişehir (Gülen, 1977); Bolu, Isparta and Eskişehir (Gülen, 1985a); Afyon (Gülen, 1985b); Sapanca Lake and İznik Lake (Altınsaçlı, 1993); Tokat (Gülen et al., 1994); and Şamlar Lake (Külköylüoğlu, 1998):

General Distribution: North and Central Europe

Subfamily : Cyprinotinae
Bronstein, 1947

Genus : *Heterocypris* Claus, 1892

Heterocypris incongruens (Ramdohr, 1808) Claus, 1892

Material: Station 17, 21.09.1995, 1 ♀.; Station 28, 27.09.1995, 2 ♀♀; Station 29, 27.09.1995, 2 ♀♀.

Previous records from Turkey: Eskişehir and İzmir (Gülen, 1977); Antalya, Denizli, Aydın, Muğla, Afyon, Isparta, Bolu and Zonguldak (Gülen, 1985a); Mersin and Adana (Gülen, 1988); İzmir (Altınsaçlı, 1988); Balıkesir (Altınsaçlı & Kubanç, 1990); İstanbul (Külköylüoğlu et al., 1993); Sinop (Kılıç, 1997), Terkos Lake (Altınsaçlı & Yılmam, 1995) and Şamlar Lake (Külköylüoğlu, 1998).

General Distribution: Cosmopolitan.

Genus : *Cyprinotus* Brady, 1886
Cyprinotus inaequalis Bronstein, 1928

Material: Station 7, 13.09.1995, 10 ♀♀;

Station 11, 20.09.1995, 4 ♀♀; Station 12, 20.09.1995, 3 ♀♀; Station 20, 26.09.1995, 1 ♀; Station 21, 26.09.1995, 4 ♀♀; Station 29, 27.09.1995, numerous ♀♀; Station 33, 15.10.1995, 3 ♀♀; Station 41, 28.10.1995, 1 ♀.

Previous records from Turkey: Gaziantep (Hartmann, 1964); Kütahya (Gülen, 1977); Eskişehir, Bilecik, Bursa, Antalya, Bolu and Zonguldak (Gülen, 1985a); İzmir (Altınsaçlı, 1988); Balıkesir (Altınsaçlı & Kubanç, 1990); Sinop and Samsun (Kaleli, 1993); Amasya, Çankırı, Kayseri; Nevşehir and Sivas (Gülen et al., 1994).

General Distribution: Europe and South-eastern Asia

Subfamily : Herpetocypridinae
Kaufmann, 1900

Genus : *Herpetocypris* Brady & Norman, 1889

Herpetocypris chevreuxi (Sars, 1896)
G. W. Müller, 1912

Material: Station 24, 26.09.1995, 10

Previous records from Turkey: Antakya (Hartmann, 1964; Gülen, 1977); İzmir, Kütahya, Bilecik, Muğla, Bursa and Bolu (Gülen, 1985a); İzmir (Altınsaçlı, 1988); İstanbul (Külköylüoğlu et al., 1993); İznik Lake and Sapanca Lake (Altınsaçlı, 1993) and Amasya (Gülen et al., 1994).

General Distribution: Cosmopolitan

Genus : *Psychrodromus*
Danielopol & Mc Kenzie, 1977

Psychrodromus olivaceus (Brady & Norman, 1889) Danielopol & Mc Kenzie, 1977

Material: Station 1, 26.09.1995, 1 ♀; Station 39, 27.10.1995, 10 ♀♀; Station 40,

16.10.1995, 10 ♀♀

Previous Records from Turkey: Antakya (Hartmann, 1964; Gülen, 1977); İzmir, Kütahya, Bilecik, Muğla, Bursa and Bolu (Gülen, 1985a); İzmir (Altınsaçlı, 1988); İstanbul (Külköylüoğlu et al., 1993); İznik Lake, Sapanca Lake (Altınsaçlı, 1993) and Konya (Gülen et al., 1994).

General Distribution: Europe

Subfamily : Cypridopsinae
Bronstein, 1947

Genus : *Cypridopsis* Brady, 1867

Cypridopsis vidua (O. F. Müller, 1776)
Brady, 1867

Material: Station 8, 13.09.1995, 25 ♀♀; Station 9, 13.09.1995, 10 ♀♀; Station 12, 20.09.1995, 2 ♀♀; Station 14, 26.09.1995, 1 ♀; Station 15, 21.09.1995, 2 ♀♀; Station 20, 26.09.1995, 10 ♀♀; Station 30, 27.09.1995, 1 ♀; Station 31, 29.09.1995, 5 ♀♀; Station 42, 16.10.1995, 7 ♀♀

Previous records from Turkey: Eskişehir (Gülen, 1977); Gökçeada Island, İstanbul, Bolu, Zonguldak and Kırklareli (Gülen, 1985a); Çanakkale and Balykesir (Altınsaçlı, 1990); İznik Lake and Sapanca Lake (Altınsaçlı, 1993); Terkos Lake (Altınsaçlı & Yılmam, 1995); Ordu (Kılıç, 1997) and Şamlar Lake (Külköylüoğlu, 1998).

General Distribution: Cosmopolitan

Genus : *Potamocypris* Brady, 1870

Potamocypris villosa (Jurine, 1820)
Sars, 1890

Material: Station 11, 20.09.1995, 15

♀♀; Station 12, 20.09.1995, 2 ♀♀; Station 14, 26.09.1995, 1 ♀; Station 20, 26.09.1995, 2 ♀♀; Station 22, 26.09.1995, 70 ♀♀; Station 25, 27.09.1995, 15 ♀♀.

Previous records from Turkey: İzmir (Altınsaçlı, 1988) and İstanbul (Külköylüoğlu et al., 1993).

General Distribution: North Africa, Central and South-eastern Asia and Europe.

Potamocypris zschokkei (Kaufmann, 1900) G. W. Müller, 1912

Material: Station 1, 26.09.1995, 4 ♀♀; Station 39, 27.10.1995, 2 ♀♀.

Previous Records from Turkey: Adana (Hartmann, 1964); İzmir (Altınsaçlı, 1988); Bursa (Altınsaçlı, 1993). and İstanbul (Külköylüoğlu et al., 1995).

General Distribution: Europe.

Family : Hemicytheridae Puri, 1953

Subfamily : Hemicytherinae Puri, 1953

Genus : *Tyrrhenocythere*
Ruggieri, 1955

Tyrrhenocythere amnicola (Sars, 1887)
Krstic, 1977

Material: Station 10, 20.09.1995, 6 ♀♀; Station 13, 20.09.1995, 7 ♀♀;

Previous Records from Turkey: Sapanca Lake and İznik Lake (Altınsaçlı, 1993) and Terkos Lake (Altınsaçlı, 1995)

General Distribution: Caspian Sea, Azov Sea, Aral Lake, Black Sea and Kerch Strait.

5. DISCUSSION AND CONCLUSION

In this study, four species (*Ilyocypris biplicata*, *Ilyocypris gibba*, *Ilyocypris*

bradyi, *Ilyocypris decipiens*) of the genus *Ilyocypris* were determined. Species of the genus *Ilyocypris* are found in a wide range of freshwater-bodies, stagnant as well as flowing, from the largest lakes and rivers to the smallest seasonal ditches, pools and canals. They either crawl along the bottom or swim mainly in the bottom water layer of freshwater. Members of the genus are apparently found in weakly saline waters. The family members of Ilyocyprididae are known from recent and fossil populations distributed in the Palaearctic and other populations are recorded from Iran, Ceylon, North America and Australia (Bronstein, 1947). Many studies have been carried out, by Gülen (1975, 1977, 1985a and 1985b), Altınsaçlı (1988), Altınsaçlı & Kubanç (1990) and Külköylüoğlu et al., (1993) in different localities in western Anatolia. These species have been widely distributed in Anatolia: Adana (Hartmann, 1964); Bursa, Bilecik (Gülen, 1985a; Bursa (Altınsaçlı, 1993); İzmir (Gülen, 1975 and 1977; Altınsaçlı, 1988); İstanbul (Külköylüoğlu et al., 1993; Altınsaçlı, 1995); İzmit; Adapazarı (Altınsaçlı, 1993); Zonguldak, Kocaeli (Hartmann, 1964); Kütahya (Gülen, 1977) and Balıkesir (Gülen, 1985a; Altınsaçlı and Kubanç, 1990); They originated from Sarmatic Inland Sea. Also these species came into Lake Akşehir from Sarmatic Inland Sea. Distribution areas of these species are known in Central Asia, North Africa, South Europe and East Europe.

In this study, one species of the genus

Candona (*C. neglecta*) was found in the Sakarya River and its branches. *C. neglecta* is widely distributed in Anatolia and throughout the world.. Satisfactory collections of *Candona neglecta* were possible only from places where the water flow was very slow and a sufficient accumulation of slime and detritus was present at the bottom. This ostracod has been known from saline waters ranging up to 8.13 ‰. Adult females and males are found throughout the year. Males of *C. neglecta* are always fewer in number than females. According to Bronstein (1947), Males of *C. neglecta* mature faster than females and have a shorter individual life span. *C. neglecta* has an exceptionally high resistance to such environmental event as desiccation of the water body. It can stand temporary rises of water temperature above 20 ° C, even though it is known a stenothermic cold water form (Bronstein, 1947). It is a typical cosmopolitan.

One species belonging to the genus *Cypria* was found in the Sakarya River and its branches. *Cypria ophthalmica* was found in Europe, North Africa and North America (Bronstein, 1947). Rich parthenogenetic and bisexual populations of this species have been reported from Anatolia by Gülen (1985a), Altınsaçlı (1993), Altınsaçlı and Yılmam (1995) and Külköylüoğlu (1998). This species is a typical cosmopolitan species.

During this study, one species of the genus *Eucypris* (*Eucypris virens*) was found in the Sakarya River and its branches. This species has already been.

known from Western Anatolia (Gülen, 1975, 1977, 1985 a, 1988; Külköylüoğlu et al., 1993; Kaleli, 1993; Altınsaçlı 1993 and Külköylüoğlu, 1998). Some researchers (G.W. Müller, 1912; Sars, 1928; Bronstein, 1947; Hartmann, 1964) reported that this species had a wide geographical distribution. *E. virens* is also a species originated from South and Central Europe and is placed among the ones succeeded in entering Anatolia. According to Demirsoy (1979), this species of *Eucypris* is a Gondwana and Laurasia relict. However, considering the general distribution of some species belonging to the genus *Eucypris*, the origin of those passed into Anatolia are found to be either same or different.

One species belonging to genus *Prionocypris* was found in Sakarya River and its branches. *Prionocypris zenkeri* was probably originated from South and Central Europe and reached to the Aegean vicinity via water-flow from this region during geological eras when Aegean Sea was territory. Also some rivers flowing into the lake were present in the region during that era, when *Prionocypris zenkeri* passed through Anatolia. The explanation of the existence of such species in Marmara region might be as follows. This species, coming from Danube basin to the Pontic Inland Sea and having very low salinity water, passed through Marmara where it later proceeded towards the ancient internal lake of Anatolia.

One *Heterocypris* species was encountered in Sakarya River and its

branches. The parthenogenetic populations of *Heterocypris incongruens* show a wide geographical distribution, while the bisexual populations are known from Hungary (Daday, 1903) Germany (Wohlgemut, 1914) and North Africa (Gauthier, 1928). In Turkey, first bisexual populations were reported from water-canal in Pamukkale - Denizli (Gülen, 1985a). *Heterocypris incongruens* mainly inhabits small water bodies including ponds, rock pools, tire tracks and man-made containers such as cement tanks, and it is often found in ponds with muddy bottom. According to Bronstein (1947), it is considered a true ubiquist ostracod with no strict ecological requirements living in fresh or saline waters up to 20 g l⁻¹. In this study, parthenogenetic populations of this species were only determined. It is a typical cosmopolitan.

One species belonging to genus *Cyprinotus* is encountered in the Sakarya River and its branches. *C. inaequalis* was reported from western Anatolia by Gülen (1977, 1985a, b and 1988) and Altınsaçlı (1988).

One species belonging to the genus *Herpetocypris* was determined in Sakarya River and its branches. *H. chevreauxi* has been known in Europe, Northern Africa and Asia by various researchers. It has been reported by Gülen (1977, 1985a); Altınsaçlı (1988, 1993); Altınsaçlı & Kubanç (1993) and Külköylüoğlu et al., (1993).

One species belonging to the genus *Psychrodromus* was found in the Sakarya

River and its branches. The parthenogenetic populations of the *Psychrodromus olivaceus* have been recorded from Europe (G. W. Müller, 1912), Caucasus (Bronstein, 1947) and Turkey (Hartmann, 1964; Gülen, 1977; Altınsaçlı, 1988, 1993; Külköylüoğlu et al., 1993). However, in the literature, its bisexual populations were first found from Yugoslavia (Petkovski, 1958, 1959) and later reported from the Lake Karamık, Afyon, Turkey (Gülen, 1985b). *P. olivaceus* is a typical crenobiont found within spring water fauna. According to Bronstein (1947), it prefers freshwater springs and is found throughout the year, producing one to two generations per annum.

Only one species belonging to *Cypridopsis* has been determined in the Sakarya River and its branches. *Cypridopsis vidua* has been reported from Eskişehir (Gülen, 1977); Gökçeada, İstanbul, Bolu, Zonguldak and Kırklareli (Gülen, 1985a). This species was reported from Russia by Bronstein (1947). The parthenogenetic populations of *C. vidua* are known to be distributed all over the Europe. This species is considered a ubiquist and opportunist, although it mostly occurs periphytically on submerged macrophytes. There are no indications that it can be used as an indicator of saline conditions. The species is cosmopolitan. According to Bronstein (1947), this species is a very common species found in a wide variety of aquatic habitats: pools canals, coastal lagoons, marshes, lakes, rivers and rice-

fields. This species has been found from different wetlands, lakes and springs in Anatolia.

Two species belonging to genus *Potamocypris* are encountered in the Sakarya River and its branches. *P. zschokkei* is known from Adana (Hartmann, 1964); İzmir (Altınsaçlı, 1988); Bursa (Altınsaçlı, 1993) and İstanbul (Külköylüoğlu et al., 1995). Also, it has been reported from Alps (Zschokke, 1900), Spain (Margalef, 1946, 1953; Baltanas, 1992) and Luxembourg (Meisch, 1984). According to Meisch (1984), *P. zschokkei* is crenobiont, a stenotherm species occurring in cold waters with preference for shallow, slowly running waters. Bisexual populations are only known from the Spanish Pyrenees at altitude above 1400 m (Margalef, 1946, 1953). *P. zschokkei* is widely spread throughout Europe.

One species belonging to the genus *Tyrrhenocythere* has been encountered in the Sakarya River and its branches. *T. amnicola* is known as marine and brackish species, and it has been recorded from freshwaters of Lake Sapanca, Lake İznik (Altınsaçlı, 1993) and Lake Terkos (Altınsaçlı, 1995) in Turkey. Besides, it has been found in the Black Sea, Azov Sea, along the shore of Bulgaria, Lake Aral, Caspian Sea and Kerch Strait by Schornikov (1967). *T. amnicola* has been recorded from shoreline of the Rumania by Caraion (1967). It is known that this species entered to the Sapanca; İznik and Terkos lakes during the new and old

Eucsin eras of the Black Sea. This species existed in Marmara Sea during these eras. During these eras, the Marmara Sea was a freshwater lake. This species could not live in the Marmara Sea during the I. and II. phases of Tyrrhenien and thus entered into less saline waters of the region. Because, Marmara Sea was a saline lake during the I. and II. phases of Tyrrhenien. The species is brackish form. *T. amnicola* was found in Sakarya River and Babayakup Stream which is a branch of Ankara Stream. The appearance of this species in northern parts Anatolia suggests three possibilities. First is that the species might have come here the past period, when the water level of Paratethys (Sarmatic Inner Sea) arisen had penetrated this region of Anatolia. The second possibility is that this species might have brought here by means of migration (e.g., birds, fish), (passive dispersion). The third one is that this species might have gone from this region to Paratethys (Sarmatic Inner Sea). These possibilities can be supported by both geological and paleontological studies which will be done and this region in future.

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SEASONAL DISTRIBUTION OF FRESHWATER OSTRACODA
(CRUSTACEA) IN SPRINGS OF NEVADA

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ABSTRACT: *In many ecological systems, community structure changes radically with the seasons. Seasonal changes are important because of their effects on both biotic and abiotic factors. In an attempt to address the question of whether ostracods exhibit variation in their seasonal occurrence (i.e., seasonality), twenty freshwater ostracod species collected monthly from seven springs in Nevada-U.S.A. was studied over a year. The seasonal distribution of some species in different genera (**Prionocypris longiforma** and **Cavernocypris wardi**, **Darwinula stevensoni** and **Ilyocypris bradyi**) showed similar occurrence all year around in rheocene springs. Finding some species (e.g., **Darwinula stevensoni** and **Ilyocypris bradyi**) from the same locality suggests differences in their food requirement and life histories. This is maybe because species of different genera can avoid competition by preferring different types of food and habitats in different seasons. These results suggest that the diversity, abundance, and occurrence of the spring ostracods are seasonal, and sampling from an area at one time only may not illustrate the complete faunal richness of that area.*

1. INTRODUCTION

There are few studies on the seasonal distribution (seasonality) of marine and brackish water ostracods (Tressler and Smith 1948, Theisen 1966), and of freshwater ostracods (Hoff 1943, Ferguson 1944, Kulköylüoğlu et al. 1993 and 1995, Kulköylüoğlu 1998) in large water bodies (e.g., lakes), but almost nothing is known about the seasonality in spring-dwelling ostracods. Springs are known as natural laboratories with relatively constant mean annual temperature, chemical composition, and water velocity (Nielson 1950, Odum 1957, Hubbs 1961, Hynes 1970, Roca and Baltan-s 1993, Fetter 1994, van der Kemp 1995). Thus, the occurrence of a species in a constant environment should not be random that any difference in its occurrence may be explicated with some other (e.g., antropogenic) factors.

The occurrence of a species in particular habitats can be important for both ecological and biological studies to estimate the effects of disturbance and changes in that particular environment. For example, previous studies in large water bodies have shown the importance of seasonal distribution of freshwater ostracods in relation to biotic (e.g., competition, predation) and/or abiotic (e.g., temperature, salinity) factors, or both. Understanding of which factor(s) are most important for the seasonal distribution of ostracods can provide invaluable knowledge of how ecosystems function. In terms of conservation perspective, such knowledge can improve

our understanding of how to protect and conserve the natural habitats (e.g., springs).

Most recently, Kulköylüoğlu (1998) proposed a graphical model (Ostracod Watch Model or OWM) to show the seasonal distribution of freshwater ostracods in a water storage reservoir in Turkey. His study suggested possible shifting mechanisms among species in different genera. However, his study, lacking physical and biological data, was based on quarterly occurrence of ostracods and was limited to four (spring, summer, fall, and winter) seasons.

The present study aims to test the graphical models of OWM, and to show seasonal distribution of spring-dwelling ostracods, providing both physical and environmental data.

2. MATERIALS AND METHODS

Monthly samples were collected from seven springs (Figure 1) (one in California and six in Nevada) (Table 1) with a hand dipnet between March 1997 and March 1998. All samples were fixed in 70% ethanol in glass jars, and some of the major physical parameters (pH, conductivity (EC), temperature ($t^{\circ}\text{C}$), dissolved oxygen (DO)) were also measured at each study site (Table 2).

In the laboratory, all material was filtered with standard-sized sieves (0.25: 0.5: 1.0: 2.0 mm mesh sizes, respectively) under tap water. After the ostracods were sorted from detritus and other materials, they were preserved in 70% ethanol. Each species was

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Table 1. Name and the coordinates of the springs. Latitude (lat.) and Longitude (long.) values are in decimal.

ID	Spring Name	elevation (m)	Lat.	Long.
1	W. Pyramid Spr. (Washoe Co., NV)	1750	39.87445	-120.201
2	Siphon Spr.#1 (Carson City, NV)	1750	39.24056	-119.733
3	Siphon Spr.#2 (Carson City, NV)	1750	39.24028	-119.734
4	Sevenmile Spr.#1 (Washoe Co., NV)	1440	40.05251	-119.392
5	Sevenmile Spr.#2 (Washoe Co., NV)	1430	40.05220	-119.392
6	Boca Spr. (Nevada Co., CA)	1800	38.57083	-120.075
7	Verdi Spr. (Washoe, NV)	1500	39.52222	-119.992

Table 2. Average values of the major physical parameters in seven springs. Major parameters include Temperature (Temp) (t°C), Conductivity (EC) (µs /cm), and dissolved oxygen (DO) (mg/L)

ID	pH	DO	EC	Temp(water)	Temp.(air)
1	7.85	8.0	170.28	13.56	18.44
2	6.62	4.72	138.16	13.30	17.27
3	6.72	4.28	159.92	13.84	15.51
4	7.27	7.12	406.40	17.38	22.10
5	7.36	6.72	437.30	17.82	22.00
6	7.65	7.94	188.00	10.81	11.23
7	7.30	5.97	349.43	11.82	14.50

identified based on valve morphology and soft body parts. Permanent slides were also made for each species.

Seven springs were selected as study sites. The Verdi spring is a helocrene spring, and the other six are all rheocrene type of springs. All materials are housed at the hydrobiology laboratory of the Abant Izzet Baysal University, Bolu and are available upon request.

3. RESULTS

Twenty ostracod species (Table 3) collected from seven springs were studied. According to the ostracod watch model, six species (PL, CW, SP, DS, IB, FB) displayed seasonal patterns (Figure 2). Four species (PL, CW, DS, FB) showed a long life cycle. Species of different genera (*D. stevensoni* and *I. bradyi*, and *P. longiforma* and *C. wardi*) were found together in samples from the

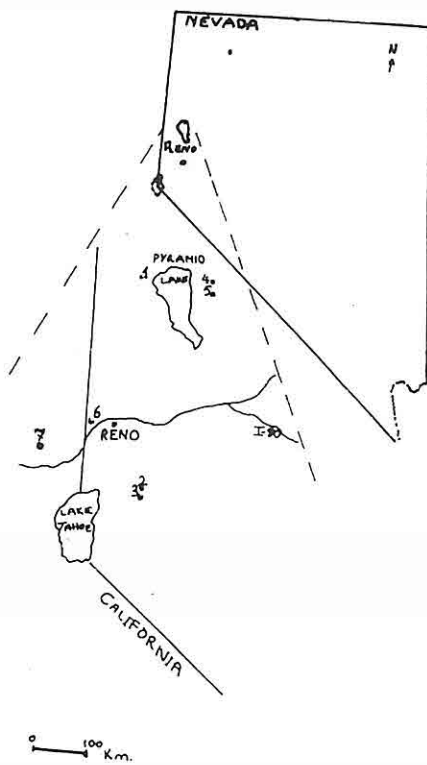


Figure 1. The sampling area in Nevada and California.

same locality over a year. The occurrence of these species together may be related to the availability of different food sources in different seasons which can change both physical and ecological conditions in spring waters where some of the major water parameters were found to have relatively constant values during this study. This may imply that species inhabiting such constant environments (i.e., springs) are not subjected to large ranges of ecological changes. Therefore, the presence or absence of a species from its expected

Table 3. List of twenty species and their codes. First six species are selected for the graphical ostracod watch models

Scientific name	Codes
<i>Prionocypris longiforma</i>	PL
<i>Cavernocypris wardi</i>	CW
<i>Scottia pseudobrowniana</i>	SP
<i>Ilyocypris bradyi</i>	IB
<i>Darwinula stvensoni</i>	DS
<i>Fabaeformiscandona acuminata</i>	FB
<i>Pseudocandona albicans</i>	PC
<i>Candona</i> sp.1	X3
<i>Candona</i> sp.2	X4
<i>Pseudocandona</i> sp.?	X5
<i>Heterocypris incongruens</i>	HI
<i>Heterocypris salina</i>	CS
<i>Ilyocypris gibba</i>	IG
<i>Eucypris virens</i>	EV
<i>Eucypris</i> n. sp.1	ER
<i>Eucypris</i> n. sp.2	EB
<i>Eucypris</i> sp.	EU
<i>Herpetocypris chevreuxi</i>	HC
<i>Cypridopsis vidua</i>	CV
<i>Cypricercus fuscatus</i>	CF

environment should not be related to such changes, but may be correlated to the levels of disturbance caused by antropogenic factors. In terms of a conservation perspective, this knowledge is important to understand the effects of such factors on the food sources of ostracods.

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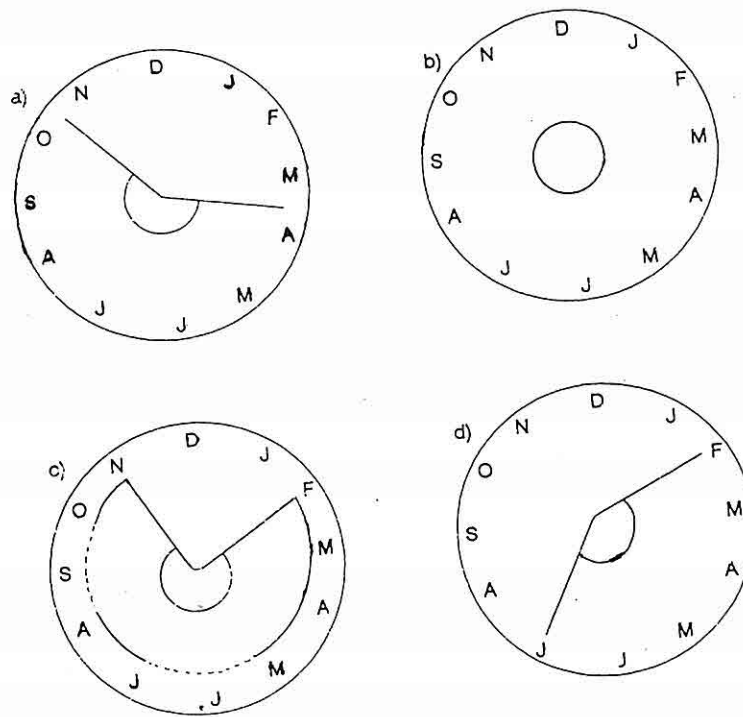


Figure 2. Graphical ostracod watch models (OWM) for the selected species: a) *Prionocypris longiforma* and *Cavernocypris wardi* from W.Pyramid spring, b) *Fabaeformiscandona acuminata* in Verdi spring, c) *Darwinula stevensoni* in Sevenmile spring #1, c) *Ilyocypris bradyi* in Sevenmile spring #2.

4. DISCUSSION

It seems that the ostracod watch model (OWM) proposed to illustrate the seasonal distribution of freshwater ostracods in large water bodies (Külköylüoğlu 1998) can also be used for spring-dwelling ostracods. However, such models should provide both ecological and physical data to estimate the most suitable conditions for the ostracods in these unique habitats (e.i. springs).

In order to show the seasonality in freshwater ostracods, monthly samples should be collected because some species can occur in different seasons. This is particularly because a species can have a long or short life cycle and may occur in different months during which different food source(s) is/are available.

The presence or absence of a species can be related to both biotic and abiotic conditions which can change with the seasons. An accurate estimation of

temporal and spatial requirements of a species (that is, when and where the species will occur) can provide important information to understand the impact of ecological and biological changes related to the species occurrence. If ecological conditions are generally constant, any changes in that particular environment can be considered to be related to antropogenic factors, which are the subject of conservation studies.

Even though the present study provides these information, at this moment data analysis is not available to show which factors influence these natural habitats in long term.

5. CONCLUSION

OWM can be used to show the seasonality in spring-dwelling ostracods. Some species belonging to different genera, were found in different seasons. This may be related to different food requirements of these species. Also, samples should be collected monthly (or weekly or daily) in long term. Species' presence or absence can be related to antropogenic factors. This information can be useful for the conservation studies. Besides, ostracods can also be used as good indicator species to estimate the impacts of such factors on the natural communities.

6. ACKNOWLEDGMENTS

I would like to thank Dean Kinerson and Robert Schroeter (University of Nevada, Reno) for their assistance during some parts of the field work.

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THE EFFECT OF TEMPERATURE ON THE GEOCHEMICAL
COMPOSITION OF THE VALVES OF THE OSTRACOD SPECIES
KRITHE PRAETEXTA PRAETEXTA

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ABSTRACT : The present study aims at deciphering any possible relationship that may exist between temperature and the following geochemical signals: Mg/Ca-, Sr/Ca-, Na/Ca ratios, $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ in the valves of living representatives of the marine, infaunal ostracod species *Krithe praetexta praetexta* (Sars, 1866) grown under constant temperatures of 5, 10 and 14°C. Calibration curves for temperature versus Mg/Ca ratios estimated for each thermoculture differ from the previously established calibration curves of these two parameters on deep-sea representatives of the genus *Krithe*. Nevertheless, the Mg/Ca ratios of the adults of *K. praetexta praetexta* from the three cultures overlap somewhat with the scatter of earlier estimations of Mg/Ca ratios of deep sea representatives of the genus *Krithe* within the range of 5 and 14°C. The wide scatter of the Mg/Ca ratio of individual specimens within the various cultures query the previously obtained strong correlation between temperature and the Mg/Ca ratio of ostracods and suggest that factors other than temperature may play a role in the uptake of Mg by ostracod valves.

There is less scatter for the Sr/Ca ratio of individual ostracods within each thermoculture. The calibration curve established between temperature and the Sr/Ca ratio of individual ostracod valves from the various thermocultures is highly significant for both adults and A-1 juveniles of *K. praetexta praetexta*. However, we cannot rule out any effect from eventual variation in the Sr/Ca ratio (or the Sr content) of the host water in the various thermocultures. A positive correlation is discernible between the Mg/Ca and Sr/Ca ratios of *K. praetexta praetexta* in the present experiment. Thus, if there is a positive correlation between temperature and the Mg/Ca ratio in *K. praetexta praetexta*, then the Sr/Ca variation in *K. praetexta praetexta* could be indirectly related

to temperature just as previously noted for the freshwater ostracod *Candona rawsoni*. There is no correlation between temperature and the Na/Ca ratio of the A-1 juveniles; possibly the variation in the Na/Ca ratio of the valves in the various thermocultures (and aquaria) is a consequence of variation in salinity of the sea water during the course of the experiment.

The oxygen isotope fractionation was determined for ostracod valves of the various thermocultures and show that the adults grown in the cultures show an enrichment in $\delta^{18}\text{O}$ within the ranges of 0.57-1.14 (5°C), 0.73-1.30 (10°C) and 0.76-1.96‰ (14°C). The A-1 juveniles of the 5°C culture calcified close to isotopic equilibrium, whereas the A-1 juveniles of the 14°C culture displayed a 0.5-1.5‰ enrichment in $\delta^{18}\text{O}$. The $\delta^{13}\text{C}$ of *K. praetexta praetexta* shows a positive correlation with temperature for both adults and the A-1 juveniles. We speculate that this results from the life habit of this infaunal species or is due to a positive relationship between temperature and the $\delta^{13}\text{C}$ of the porewater of the sediment. Alternatively, seasonal variation in salinity might explain differences in $\delta^{13}\text{C}$ of calcite shells.

1. INTRODUCTION

Ostracods are small bivalved crustaceans found in almost every aquatic environment. The soft parts of the animal are enclosed by two calcareous valves which consist of low-Mg calcite. During the ontogenetic development ostracods shed their valves up to nine times before reaching adulthood. The valves are readily preserved as fossils. It is known that most, if not all, of the calcium carbonate and trace elements found in the valves derive from the ambient water medium during the time of shell formation (Turpen & Angell, 1971; Rosenfeld, 1982).

Chivas et al. (1983, 1985, 1986ab) established a relationship between Mg and Sr uptake in the calcareous valves of non-marine ostracods and conditions in the aquatic environment during the time of valve formation. They concluded that the Mg/Ca of the valves is controlled by

both water temperature and the Mg/Ca of the water, whereas the Sr/Ca is unaffected by temperature but directly related to the Sr/Ca of the water. However, Xia et al. (1997b) showed that there is a strong covariance between the Sr/Ca- and the Mg/Ca ratios of the ostracod valve of the freshwater species *Candona rawsoni*. Their results imply that the ratio between $\text{Sr/Ca}_{\text{valve}}$ and the $\text{Sr/Ca}_{\text{water}}$ is directly proportional to the Mg concentration in the ostracod calcite and thus indirectly related to temperature.

Chivas et al., (1986b) also discussed that by studying trace elements in conjunction with stable isotopes ($\delta^{18}\text{O}$) data of ostracod shells, a more qualified understanding of the environmental conditions can be achieved. For example, by knowing that there is often a positive correlation between $\delta^{18}\text{O}$ and salinity and a negative correlation between $\delta^{18}\text{O}$ and temperature, it may be

possible to determine whether a Mg/Ca change in ostracods is caused by a change in temperature or a change in the composition of the Mg/Ca of the water. The $\delta^{13}\text{C}$ variation is more difficult to interpret. An increase in $\delta^{13}\text{C}$ can be related to a variety of conditions such as fermentation, changes in primary production and carbonate precipitation as a result of algal bloom (De Deckker & Forester, 1988).

Previous work based on trace elements and stable isotopes of ostracods from marine environments are few. De Deckker et al., (1988) studied Mg/Ca and Sr/Ca ratios in valves of the euryhaline ostracod *Cyprideis* from two cores (spanning the time interval from approximately 40.000 to 9.000 BP) from the Gulf of Carpentaria, Australia, and described chemical changes occurring in different phases of lacustrine and near marine conditions in the Gulf. Cadot & Kaesler (1977) and Bodergat (1983) previously tried to establish a relationship between Mg content of the shells of marine ostracods and temperature. Later, Corrège (1993), Dwyer et al. (1995) and Cronin et al. (1996) developed calibration curves between the Mg/Ca molar ratios of individual ostracod valves of the genus *Krithe* and temperature in marine environments. Subsequently, Corrège & De Deckker (1997) refined the calibration curve of Corrège (1993) and used it for estimating changes in intermediate water temperature in the western Coral Sea, northeast of Australia, for the Late Quaternary.

The purpose of the present study is to further elucidate any possible relationship that may exist between temperature and the following geochemical signals: Mg/Ca ratio, Sr/Ca ratio, Na/Ca ratio, $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ in the valves of the marine, infaunal ostracod species *Krithe praetexta praetexta* (Sars, 1866) (see Majoran & Agrenius, 1995) grown in cultures of constant temperatures.

2. MATERIAL AND METHODS

2.1 Procedures and techniques

Cultures of ostracods were kept in aquaria at constant temperatures of 5, 10 and 14° C between July 1995 and June 1996, according to the procedures and techniques described in detail by Majoran et al., (submitt.). Each thermoconstant culture included two 45 l aquaria housed at the Kristineberg Marine Research Station, on the Gullmarn fjord, Sweden. The aquaria were kept in a continuously flowing open system pumping water from the intermediate watermass of the Gullmarn fjord. From July 1995 to July 1996, the intermediate watermass at a depth of 40 m (58°15.5'N; 11°26.0'E) varied in salinity between 32.7 and 34.8 ‰, in temperature between 5.4 and 12.5 °C and in oxygen content between 3.6 and 6.4 ml/l (Data from Pelagic Monitoring Kristineberg). Constant temperatures of 5, 10 and 14°C were maintained in the aquaria by thermoregulating the incoming water and by keeping constant temperatures in the storage rooms. The temperature was

automatically monitored every hour in the three cultures from which the following means (m) and standard deviations (s) were calculated: $m = 5.01$ °C with $s = 0.24$ (for the 5° C culture), $m = 10.16$ °C with $s = 0.98$ (for the 10° C culture) and $m = 14.10$ with $s = 0.48$ (for the 14° C culture). The experiment was terminated in June 1996, prior to which no sampling was performed. Then, the top 3 cm of the sediment in the aquaria were removed using a siphon passed over the bottom surface. *K. praetexta praetexta* is an infaunal species that lives in the upper 2 cm in the aquarium sediment (see Majoran & Agrenius, 1995). All living ostracods, including adults and the A-6 stage of *K. praetexta praetexta*, recovered from a 125 μ m sieve were sorted and stored.

Ca, Mg, Sr, and Na were measured on *K. praetexta praetexta* either on single valves of adults and the A-1 stage or on bulk samples (comprising several carapaces) from the A-2 and smaller ontogenetic stages due to their small size. The measurements were performed using a SpectraSpan 7 direct current plasma (DCP) atomic emission spectrometer at Duke University, Division of Earth and Ocean Sciences following the cleaning and preparation methods described in Dwyer et al. (1995) and Cronin et al. (1996). Table 1 shows the Mg/Ca-, Sr/Ca- and Na/Ca molar ratios obtained from the DCP analysis.

Carbon and oxygen isotopic analyses were completed on a Kiel Autocarbonate device attached to a MAT 251 dual inlet

RMS. Replicate analyses of NIST and internal laboratory standards were ± 0.04 per mil ^{13}C and 0.06 per mil ^{18}O for samples greater than 15 μ g in weight. For samples between 8 to 15 μ g, the precision was 0.07 per mil ^{13}C and 0.09 per mil ^{18}O . For samples between 2 to 8 μ g, the precision for ^{13}C and ^{18}O was 0.2 per mil, and there was a linear correction for source mixing of up to 0.4 per mil for ^{13}C and 0.9 per mil for ^{18}O .

2.2 Limitations

We did not monitor the variation for each of the various trace elements Mg, Sr and Na neither in the water nor in the porewater of the aquaria in the various thermocultures during this period. It is important to point out that the content and the variation of these trace elements were the same in all thermocultures during the course of the experiment, at least above the sediment/water interface, since there is no effect of temperature on the concentration of these trace elements in sea water. However, Majoran et al. (submitt.) showed that there is a positive correlation between the growth rate of *K. praetexta praetexta* and temperature. This means that the ostracods did not grow at the same rate in the different thermocultures and that they shedded their valves during different times during which variation in the concentration of trace elements may have occurred.

Another concern with this study is that the generation length of *K. praetexta praetexta* including the duration of adult and juvenile specimens of this species is

not known. We do not know for certain if any of the living specimens recorded at the end of the experiment also once were added to the aquaria at the same stage of development at the beginning of the experiment. This seems, however, impossible for juveniles. Of other species investigated for their life cycles by Elofson (1941; 396-397), the duration of each of the juvenile stages are generally considerably shorter than a year. Moreover, considering the similarities in the geochemical results between the adults and juveniles of *K. praetexta praetexta*, particularly with respect to the Sr/Ca ratios, it is also highly improbable that any of the living adults recorded at the end of the experiment also once were present in the aquaria at the beginning of the experiment as adults (Table 1).

An important observation of the geochemical results shown in Table 1 concerns the statistically significant average differences in Na/Ca ratios and $\delta^{13}\text{C}$ of adults of *K. praetexta praetexta* between the two aquaria of the 14° C culture. The differences in Na/Ca ratios of the A-1 juveniles of *K. praetexta praetexta* between the two aquaria of the 14° C culture, are, however, not statistically significant. A possible explanation to the observed differences in Na/Ca ratios and $\delta^{13}\text{C}$ of the adults between the two aquaria, may be related to the circumstance that the adults of aquarium 1 (for unknown reasons) became adults at a different time and salinity than the adults of aquarium 2. This explanation implies that there were

variation in the Na/Ca ratio and $\delta^{13}\text{C}$ of the intermediate watermass or that salinity may play some role in trace element uptake.

3. RESULTS

3.1 Mg/Ca ratio

Figs. 1a-b show the plots of temperature versus the Mg/Ca ratio (in mmol/mol) with least squares fit of samples of cultures of adults and A-1 juveniles of *K. praetexta praetexta*. Each point is provided with standard deviation bars and represents the mean value of all the valves analysed in a thermoconstant culture (includes two aquaria). The following equation was obtained for the adults (Fig. 1a) (T = temperature):

$$(1) T = -37.17 + 2.89(\text{Mg/Ca})_{\text{valve}}, R = 0.98 (N = 3)$$

and the following equation for the A-1 juveniles (Fig. 1b):

$$(2) T = -72.22 + 5.03(\text{Mg/Ca})_{\text{valve}}, R = 0.89 (N = 3)$$

Figs. 2a-b show the plots of temperature versus the Mg/Ca ratio for each individual valve of adults and the A-1 juveniles investigated in the three thermoconstant cultures. There is a conspicuously wide scatter of the points within the 14 and the 10° C cultures. Due to this wide scatter, it was not possible to fit a linear regression to these points that also passed near the 5 °C points.

It is possible to quantify the uptake of Mg by the ostracod shell from the relationship existing between the composition of the ostracod shell and the ambient water medium with respect to

N/A = Not Applicable

Lab #	tank#	spec#	temp (°C)	genus	sp.	v/v	mol	notes	Atomic Ratios (mmol/mol)		Tank Means and Standard Deviations										std.dev. 13C	std.dev. 18O	Pressure
									wt. µg	Si/Ca	Na/Ca	Mg/Ca	sd	Si/Ca	sd	Na/Ca	sd	13-C PDB	18-O PDB				
5	1	1	14	K.	praeflexa	L	A		12	20.43	3.68	8.43	18.50	1.44	3.82	0.10	8.48	0.12	0.36	2.32	0.068	0.109	246
6	1	3	14	K.	praeflexa	L	A		13	18.23	3.91	8.65						-0.107	1.679	0.094	0.216	255	
7	1	4	14	K.	praeflexa	L	A		13	18.39	3.87	8.37						0.678	2.203	0.096	0.238	262	
8	1	5	14	K.	praeflexa	L	A		11	16.95	3.83	8.48						0.351	2.108	0.028	0.088	278	
9	2	1	14	K.	praeflexa	L	A		14	17.13	3.85	9.20	16.85	0.77	3.79	0.09	9.21	0.03	-0.481	1.757	0.008	0.071	286
10	2	2	14	K.	praeflexa	L	A		13	17.18	3.88	9.18						-0.228	1.773	0.014	0.038	282	
11	2	3	14	K.	praeflexa	L	A		15	15.72	3.75	9.24						-0.865	2.023	0.019	0.005	287	
12	2	4	14	K.	praeflexa	L	A		12	17.39	3.69	9.23						-0.864	2.02	0.03	0.057	251	
13	1	1	10	K.	praeflexa	L	A		12	14.72	3.52	8.82	16.92	2.2	3.47	0.05	8.64	0.18	0.079	2.619	0.068	0.048	187
14	1	2	10	K.	praeflexa	L	A		8	19.12	3.42	8.46						-0.175	2.044	0.026	0.069	268	
15	NV	1	NV	K.	praeflexa	L	A	no signal	16	14.74	3.19	8.32	14.74		3.19		8.32		-1.674	3.752	0.031	0.029	277
16	1	1	5	K.	praeflexa	L	A		4	14.36	3.40	6.98	15.96	1.78	3.57	0.12	7.80	1.35	-0.364	2.385	0.082	0.176	268
17	1	1	10	K.	praeflexa	L	A		5	15.12	3.57	8.66											
18	1	2	10	K.	praeflexa	L	A		4	15.90	3.61	6.37											
19	1	3	10	K.	praeflexa	L	A		4	18.45	3.70	9.21											
20	1	4	10	K.	praeflexa	L	A		3	15.72	3.62	2.62											
21	2	1	10	K.	praeflexa	L	A	no signal	3	15.72	3.62	2.62							-2.32	-0.54	0.091	0.050	115
22	2	2	10	K.	praeflexa	L	A		3	16.97	3.50	8.09	17.95	1.38	3.37	0.19	7.49	0.86	-2.27	-3.41	0.094	0.069	89
23	24	24	NV	K.	praeflexa	L	A		3	18.92	3.24	6.88							-9.15	-22.68	0.893	0.833	35
24	25	1	14	K.	praeflexa	L	A		4	16.93	3.77	6.76	16.72	0.52	3.76	0.01	7.70	0.90	-2.03	0.00	0.114	0.151	113
25	26	1	2	14	K.	praeflexa	L		5	16.13	3.75	7.77							-0.437	1.399	N/A	N/A	N/A
26	27	1	3	14	K.	praeflexa	L		4	17.11	3.77	8.57											
27	28	2	1	14	K.	praeflexa	L		5	16.47	3.75	7.55	17.67	1.57	3.69	0.13	6.47	1.08					
31	31	3	14	K.	praeflexa	L	A		3	19.45	3.53	5.38											
32	2	4	14	K.	praeflexa	L	A		5	17.10	3.77	6.49											
35	1	1	5	K.	praeflexa	L	A	no signal	5	15.12	3.36	7.52	15.72	0.85	3.26	0.13	7.78	0.36	-1.01	1.64	0.143	0.113	150
36	2	1	5	K.	praeflexa	L	A		5	15.12	3.36	7.52	15.72	0.85	3.26	0.13	7.78	0.36	-3.24	3.03	0.130	0.054	116
37	2	2	5	K.	praeflexa	L	A		4	16.32	3.17	8.03							-3.59	3.26	0.133	0.130	144
38	NV	5	NV	K.	praeflexa	L	A		3	14.54	3.66	6.99	15.08	0.53	3.49	0.12	7.58	1.74	-1.75	-0.16	0.220	0.114	104
39	NV	5	NV	K.	praeflexa	L	A		3	15.36	3.44	10.01							0.31	1.41	0.190	0.456	258
40	NV	7	NV	K.	praeflexa	L	A		4	15.67	3.41	7.43							-1.31	0.69	0.064	0.209	116
41	NV	12	NV	K.	praeflexa	L	A		3	14.73	3.46	5.91											
44	T1	N/A	5	K.	praeflexa	A-5		5 carapaces*	0.5	24.62	2.60	15.24											
90	N/A	N/A	5	K.	praeflexa	A-6		15 carapaces*	1.4	23.86	2.99	10.13											
91	N/A	N/A	14	K.	praeflexa	A-6		8 carapaces*	3.7	27.99	3.36	14.78											
92	T1	N/A	10	K.	praeflexa	A-2		3 carapaces*	16.2	19.78	3.49	9.79											
93	NV	N/A	NV	K.	praeflexa	A-2		8 carapaces*	13.9	17.95	3.29	9.66											
94	NV	N/A	NV	K.	praeflexa	A-3		8 carapaces*	3.3	21.44	3.35	12.90											
95	NV	N/A	NV	K.	praeflexa	A-4		15 carapaces*	2.6	26.22	3.13	11.64											
96	NV	N/A	NV	K.	praeflexa	A-5		10 carapaces*	0.7	31.89	3.27	24.73											

* = Maximum number of carapaces dissolved in bulk samples. Many of the smaller sized specimens were lost during cleaning.

THE EFFECT OF TEMPERATURE ON THE GEOCHEMICAL COMPOSITION THE
VALVES OF THE OSTRACOD SPECIES KRITHE PRAETEXTA PRAETEXTA

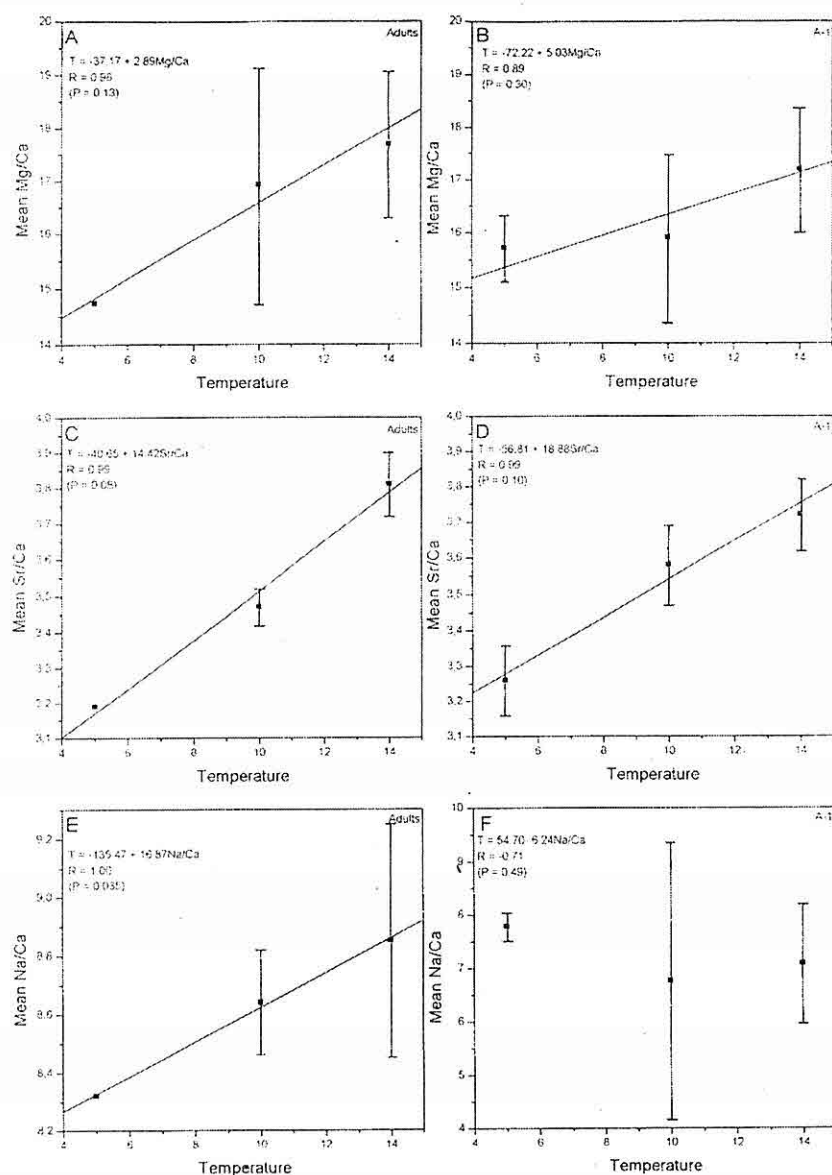


Figure 1. Plots of temperature versus the (A-B) Mg/Ca-, (C-D) Sr/Ca- and (E-F) Na/Ca-ratios (in mmol/mol) for adults and juveniles of the A-1 stage of *K. praetexta praetexta*. Each point is a mean of the trace element composition of the ostracod valves in a thermoconstant culture (specimens from two aquaria) and is provided with standard deviation bars. Least square fits in (A-E).

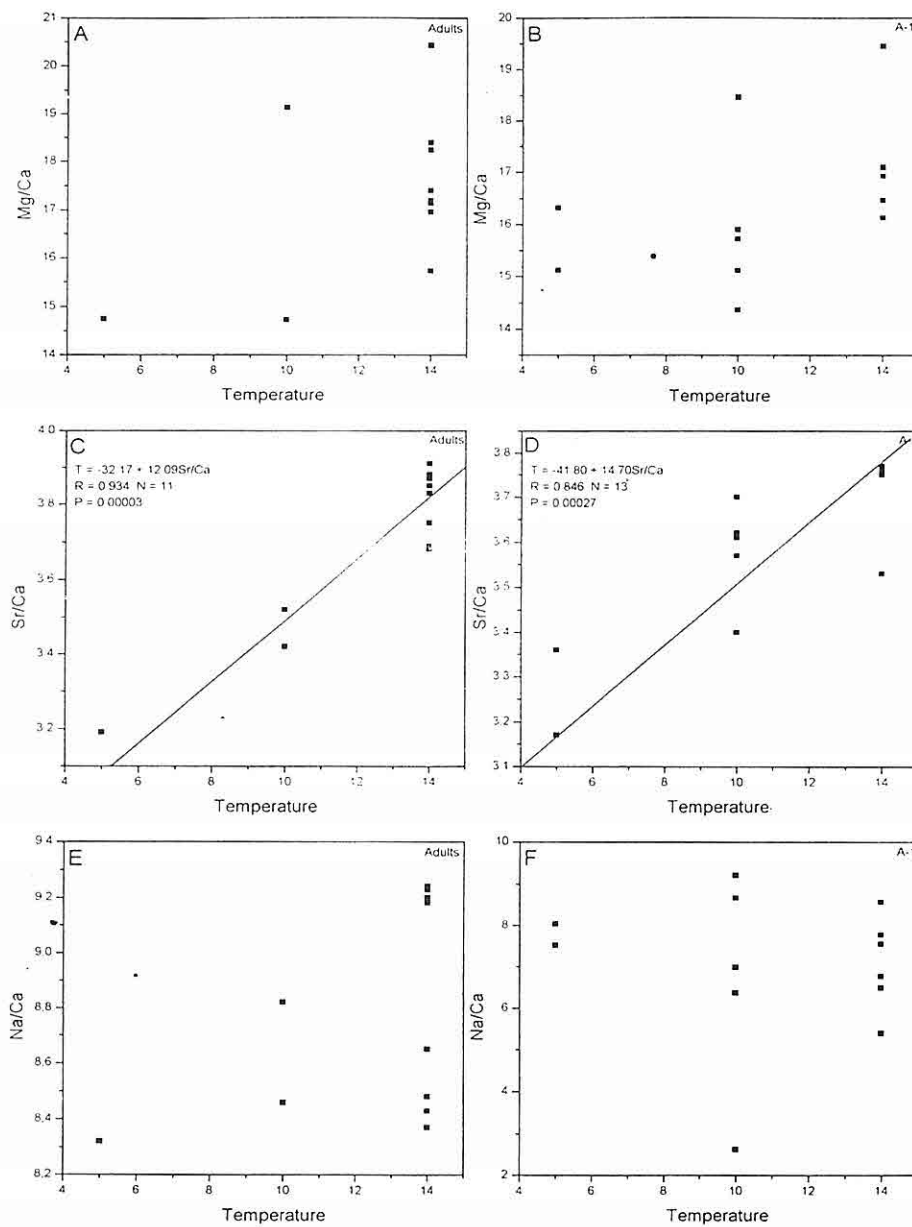


Figure 2. Plots of temperature versus the (A-B) Mg/Ca-, (C-D) Sr/Ca- and (E-F) Na/ Ca-ratios (in mmol/mol) for adults and juveniles of the A-1 stage of *K. praetexta praetexta*. Each point represents an individual measurement of an ostracod valve. The Sr/Ca-ratios (C-D) are provided with least square fits.

Mg. The molar distribution coefficient $K_D[\text{Mg}]$ is defined as follows: $K_D[\text{Mg}] = \text{Mg}/\text{Ca}_{\text{valve}} / \text{Mg}/\text{Ca}_{\text{water}}$ (see Chivas et al., 1986a). If we assume that the Mg/Ca molar ratio of the intermediate watermass is approximately 5.2, i.e. in agreement with standard values for sea water (see Brewer, 1975), the distribution coefficient of Mg in the valves of adults and A-1 juveniles of *K. praetexta praetexta* can be calculated from equations (1) and (2), respectively:

For adults

$$(3) K_D[\text{Mg}] = 2.5 \times 10^{-3} + 6.65 \times 10^{-5} \times T$$

For A-1 juveniles

$$(4) K_D[\text{Mg}] = 2.8 \times 10^{-3} + 3.8 \times 10^{-5} \times T$$

Thus, the molar distribution coefficients $K_D[\text{Mg}]$ for adults and the A-1 juveniles are very similar.

Fig. 3a shows the plot of temperature versus the Mg/Ca ratio (in mmol/mol) for bulk samples of small juveniles of the A-5 and A-6 stages. The results seem to demonstrate a positive relationship between temperature and the Mg/Ca ratio of the juvenile shells (Fig. 3a). It is also evident that the Mg/Ca ratios of these smaller juveniles are considerably higher than for adults and the A-1 stage (Figs. 4a-c). This is in agreement with Chivas et al. (1983, 1986b) who discovered that juveniles and partly calcified specimens always have higher Mg/Ca ratios than adults of the same taxon.

Chivas et al. (1986b) also discovered that small-sized ostracod species calcify their shells at a higher rate than larger

species and have higher Mg/Ca ratios. Corrège & De Deckker (1997) therefore concluded that the effect of temperature on the Mg/Ca ratio of the ostracod shell may be indirect: Temperature effects the growth rate at which ostracods calcify their shells which in turn governs the Mg/Ca ratio. However, inorganic ppt rate studies concluded that no rate effect of Mg uptake in calcite exists over hours to months (Morse & MacKenzie, 1990).

3.2 Sr/Ca ratio

Figs. 1c-d and 2c-d show the plots of temperature versus the Sr/Ca ratio (in mmol/mol) with least squares fit of samples of thermoconstant cultures of adults and A-1 juveniles of *K. praetexta praetexta*. In Figs. 1c-d, each point is provided with standard deviation bars and represents the mean value of all the valves analysed in a thermoconstant culture. In Figs. 2c-d, each point represents the analysis of a single valve. From the calibration curves in Figs. 1c-d, we obtained the following equation for the adults (Fig. 1c):

$$(5) T = -40.65 + 14.42(\text{Sr}/\text{Ca})_{\text{valve}}, \\ R = 0.99 (N = 3)$$

and the following equation for the A-1 juveniles (Fig. 1d):

$$(6) T = -56.81 + 18.88(\text{Sr}/\text{Ca})_{\text{valve}}, \\ R = 0.99 (N = 3)$$

From the calibration curves in Figs. 2c-d, we obtained the following equation for the adults (Fig. 2c):

$$(7) T = -32.17 + 12.09(\text{Sr}/\text{Ca})_{\text{valve}}, \\ R = 0.934 (N = 11) \text{ which is highly significant } (P = 0.00003)$$

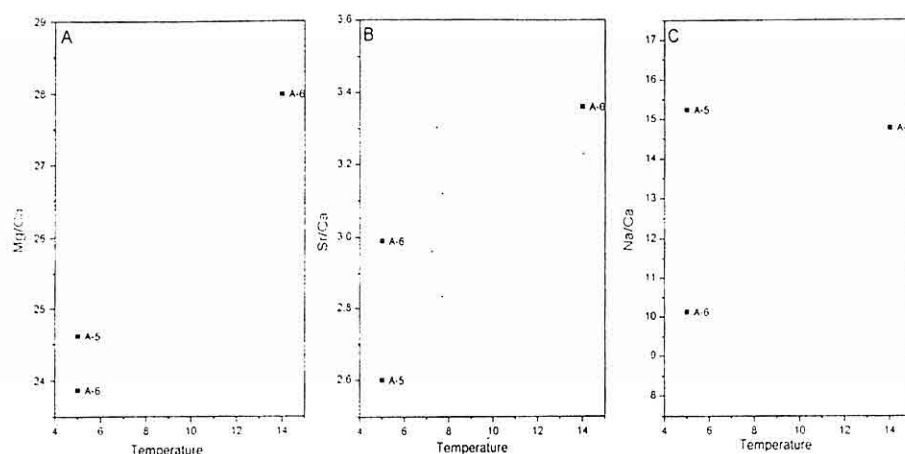


Figure 3. Plots of temperature versus the (A) Mg/Ca-, (B) Sr/Ca- and (C) Na/Ca-ratios (in mmol/mol) of bulk samples of small juveniles (A-6 and A-5 stage) of *K. praetexta praetexta*.

and the following equation for the A-1 juveniles (Fig. 2d):

(8) $T = -41.80 + 14.70(\text{Sr/Ca})_{\text{valve}}$, $R = 0.846$ ($N = 13$) which is highly significant ($P = 0.00027$)

The results indicate a strong correlation between temperature and the Sr/Ca ratio of the valves of *K. praetexta praetexta* in contrast to results from previous studies on freshwater ostracods (Chivas et al., 1985, 1986a).

Similar to the calculations of $K_D[\text{Mg}]$, it is possible to quantify the uptake of Sr by the ostracod shell by the molar distribution coefficient $K_D[\text{Sr}] = \text{Sr}/\text{Ca}_{\text{valve}}/\text{Sr}/\text{Ca}_{\text{water}}$. If we assume that the Sr/Ca molar ratio of the intermediate watermass is approximately 0.0089, i.e. in agreement with standard values for sea water (see Brewer, 1975), it is possible to calculate $K_D[\text{Sr}]$ in the valves of adults and A-1 juveniles of *K. praetexta*

praetexta using equations either equations (5) and (6), respectively, or (7) and (8), respectively. In this case, equations (5) and (6) were used:

For adults

$$(9) \quad K_D[\text{Sr}] = 0.317 + 0.0078T$$

For A-1 juveniles

$$(10) \quad K_D[\text{Sr}] = 0.338 + 0.0060T$$

Thus, the molar distribution coefficients $K_D[\text{Sr}]$ for adults and the A-1 juveniles are very similar.

Fig 3b shows the plot of temperature versus the Sr/Ca ratio (in mmol/mol) in bulk samples of small juveniles of the A-5 and A-6 stages. The results seem to reveal a positive relationship between temperature and the Sr/Ca ratio of the small juvenile shells of the A-5 and A-6 stages. However, in contrast to the Mg/Ca ratios, there is no inverse relationship between ontogenetic stage and Sr/Ca ratio of the shells. The Sr/Ca ratio is in

average higher in adults and the A-1 stage compared to the small juveniles of the A-5 and the A-6 stages (Figs. 4d-f).

3.3 Na/Ca ratio

Figs. 1e-f and 2e-f show the plots of temperature versus Na/Ca ratio of the thermoconstant cultures of adults and A-1 juveniles of *K. praetexta praetexta*. In Figs. 1e-f, each point is provided with standard deviation bars and represents the mean value of all the valves analysed in a thermoconstant culture. In Figs. 2e-f, each point represents the analysis of a single valve. Figs. 1e seems to demonstrate a strong correlation between temperature and the Na/Ca ratio ($R = 1.0$) for adult ostracod valves. However, an inspection of the scatter of points in the 14°C culture may raise some doubts against this strong correlation (Fig. 2e). Moreover, there is no such strong correlation between temperature and the Na/Ca ratio for the A-1 juveniles for which the Na/Ca ratio is widely scattered within the 10 and 14°C cultures (Figs. 1f, 2f). It may possibly be suggested that the variation in the Na/Ca ratio of the valves in the various thermocultures (and aquaria) is a consequence of variation in salinity of the sea water during the course of the experiment. Na is thought not to be lattice bound, instead it is believed to reside in crystal defect sites or maybe in fluid inclusions.

3.4 Oxygen isotope fractionation

The first step taken to calculate the oxygen isotope fractionation of *K.*

praetexta praetexta was to estimate the $\delta^{18}\text{O}$ of the intermediate watermass in the Gullmarn fjord. This was done through the well defined relationship that exists between salinity and $\delta^{18}\text{O}$ for the region, according to Frölich et al. (1988):
 $\delta^{18}\text{O}_{\text{water}} = 0.271 (S) - 8.9\text{‰}$

This equation is primarily based on data from the Baltic Sea and the southern Kattegat. Although the intermediate watermass of the Gullmarn fjord originates from the North Sea and the Skagerrak by the Jutland Current, the equation represents the only available defined relationship that exists between salinity and $\delta^{18}\text{O}$ of the water for this geographical region. The salinity of the intermediate watermass of the Gullmarn fjord varied between 32.7 and 34.8‰ during the time between July 1995 and July 1996. According to the equation of Frölich et al. (1988), a salinity of 32.7 and 34.8‰ corresponds to a $\delta^{18}\text{O}_{\text{water}}$ ($\delta^{18}\text{O}$ of the water) of -0.0383 and 0.5308‰, respectively.

$\delta^{18}\text{O}_{\text{calcite}}$ ($\delta^{18}\text{O}$ of calcite in equilibrium with sea water) was calculated from the palaeotemperature equation of O'Neil et al. (1969) that was modified by Hays & Grossman (1991):
 $0.12(\delta^{18}\text{O}_{\text{calcite}} - \delta^{18}\text{O}_{\text{water}})^2 - 4.36(\delta^{18}\text{O}_{\text{calcite}} - \delta^{18}\text{O}_{\text{water}}) + 15.7 = T(^{\circ}\text{C})$
where $\delta^{18}\text{O}_{\text{calcite}}$ is relative to V-PDB and $\delta^{18}\text{O}_{\text{water}}$ relative to V-SMOW. $\delta^{18}\text{O}_{\text{calcite}}$ was calculated for each temperature (5, 10 and 14°C) and extreme $\delta^{18}\text{O}_{\text{water}}$ (-0.0383 and 0.5308‰). Figs. 6a-b show the calculated range of variation of $\delta^{18}\text{O}_{\text{calcite}}$ for the three

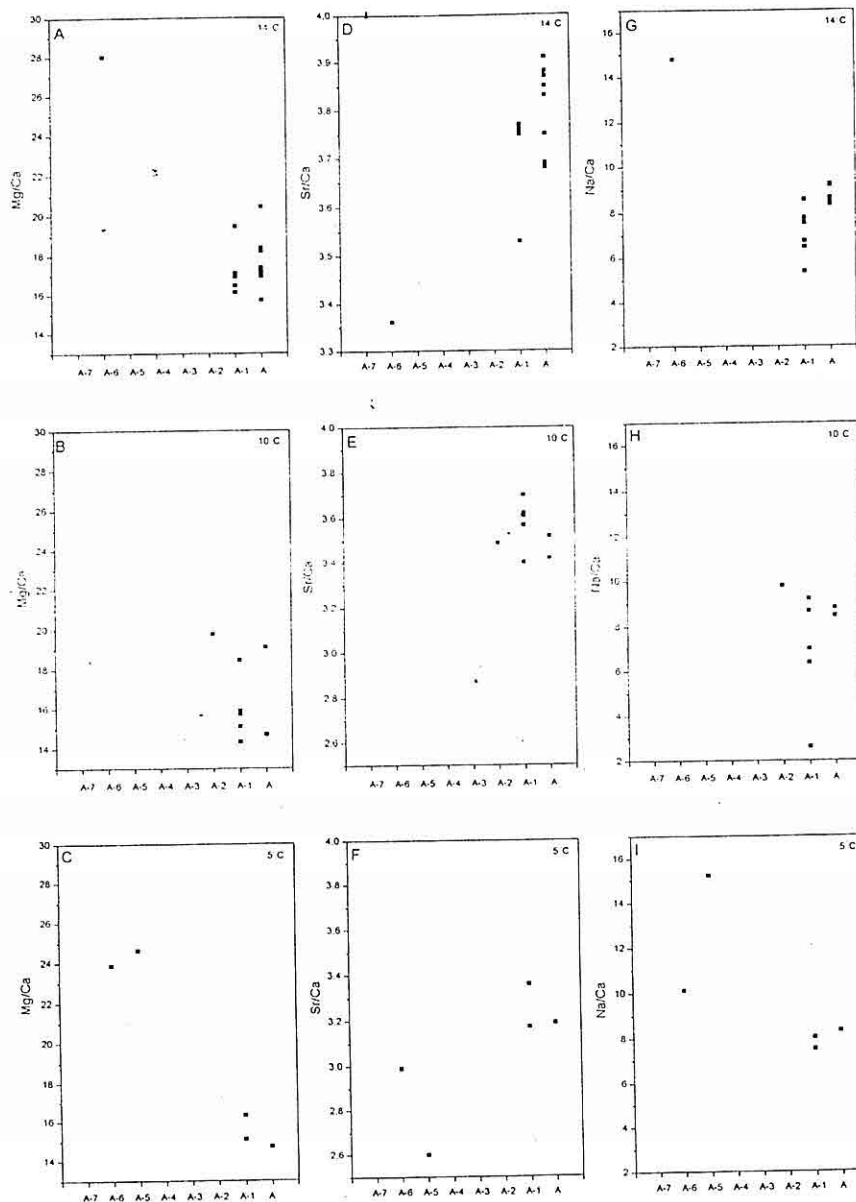


Figure 4. Plots of the (A-C) Mg/Ca-, (D-F) Sr/Ca- and (G-I) Na/Ca- ratios (in mmol/ mol) for different ontogenetic stages of *K. praetexta praetexta* in each of the three thermoconstant cultures of 14, 10 and 5 °C.

temperatures of adults and the A-1 juveniles of *K. praetexta praetexta*, respectively, and also the scatter of individual measures of $\delta^{18}\text{O}$ of *K. praetexta praetexta* valves around each interval of $\delta^{18}\text{O}_{\text{calcite}}$. The adults of the 5, 10 and 14°C cultures show an enrichment in $\delta^{18}\text{O}$ of 0.57-1.14, 0.73-1.30 and 0.76-1.96‰, respectively (Fig. 6a). The A-1 juveniles of the 5°C culture show close to isotopic equilibrium, whereas the A-1 juveniles of the 14°C culture display a 0.5-1.5‰ enrichment in $\delta^{18}\text{O}$ (Fig. 6b). It is more difficult to assess the wide scatter of measured $\delta^{18}\text{O}$ for the A-1 juveniles of the 10°C culture (Fig. 6b). Many of the $\delta^{18}\text{O}$ data show large standard deviations and may be less reliable, although almost all are plotted in Figs. 6a-b (see also Table 1).

3.5 Carbon isotopic composition

The most obvious result of the analysis of carbon isotopes of *K. praetexta praetexta* is that there is a positive correlation between $\delta^{13}\text{C}$ and temperature for both adults and the A-1 juveniles (Figs. 7a-b).

4. DISCUSSION

The slope of the present calibration curves for temperature as a function of the Mg/Ca ratio of adult *K. praetexta praetexta* is based on three points only and differs from earlier calibration curves established by Dwyer et al. (1995) and Corrège & De Deckker (1997) based on the genus *Krithe* of the North Atlantic and the Coral Sea, respectively.

However, Fig. 8 shows that the Mg/Ca ratios of the adults of the three present thermoconstant cultures are overlapped by the scatter of Mg/Ca ratios of adult *Krithe* from coretops of the North Atlantic used to establish the calibration curve of Dwyer et al. (1995, unpublished).

It is possible that part of the differences with respect to the slope among the various calibration curves estimated are due to the fact that they are based on different temperature ranges. Other explanations to the differences may be linked to different physicochemical conditions (which may also affect the growth rate of the ostracods) in the various environments studied (i.e. the North Atlantic, the Coral Sea and the aquaria of the present investigation). However, in contrast with previous calibrations, the strength of the present calibration is related to the fact that we know for certain that the investigation is based on living specimens grown in thermoconstant cultures where the accuracy of the temperature was maintained and monitored every hour during the course of the experiment. Further research is also needed to test if the calibration curve really is linear in longer temperature intervals.

However, in view of the constant temperatures and the wide scatter of the data within the 10 and 14°C cultures (Figs. 2a-b), the results of the present investigation indicate that factors other than temperature may influence the Mg/Ca ratio of ostracod shells. We cannot

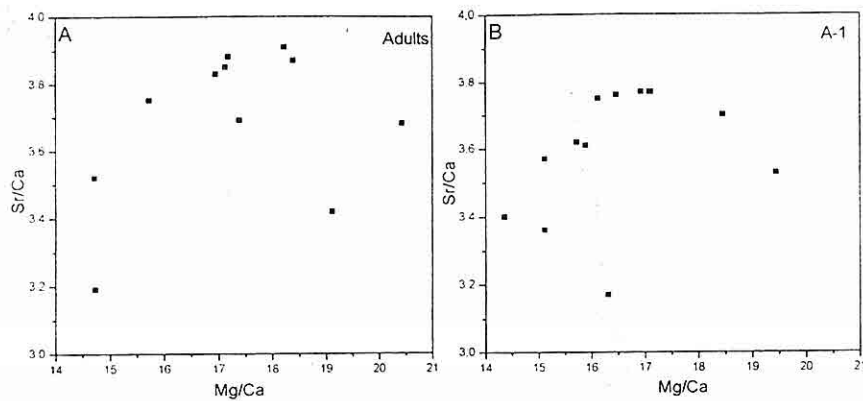


Figure 5. Plots of the Sr/Ca- versus the Mg/Ca-ratios (in mmol/mol) for (A) adults and (B) the A-1 ontogenetic stage of *K. praetexta praetexta* from the three thermoconstant cultures of 14, 10 and 5°C.

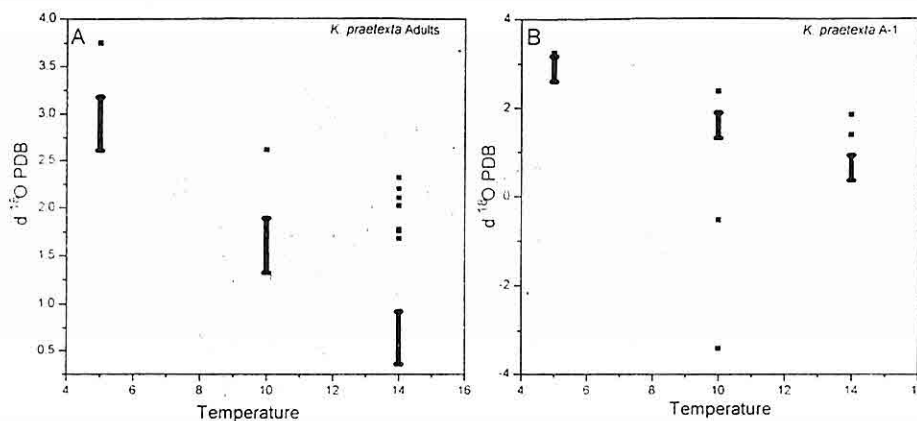


Figure 6. Plots of $\delta^{18}\text{O}$ in the valves of (A) adults and (B) the A-1 ontogenetic stage of *K. praetexta praetexta* from the three thermoconstant cultures of 14, 10 and 5°C. Error bars represent the range of variation for $\delta^{18}\text{O}$ of calcite precipitated in equilibrium with sea water (calculated from O'Neil et al., 1969; Hays & Grossman, 1991; Frölich et al., 1988). Each dot represents the measured $\delta^{18}\text{O}$ of a single ostracod valve of *K. praetexta praetexta*.

rule out that the cleaning method during preparation of the shells for trace element analysis was insufficient and that organic material still remained attached to the shells that could influence the variability

of the Mg/Ca data (see Corrège & De Deckker, 1997, p. 199). Possibly, variation in Mg content and/or the Mg/Ca ratio of the sea water (or porewater) may be responsible for the scatter (see Chivas

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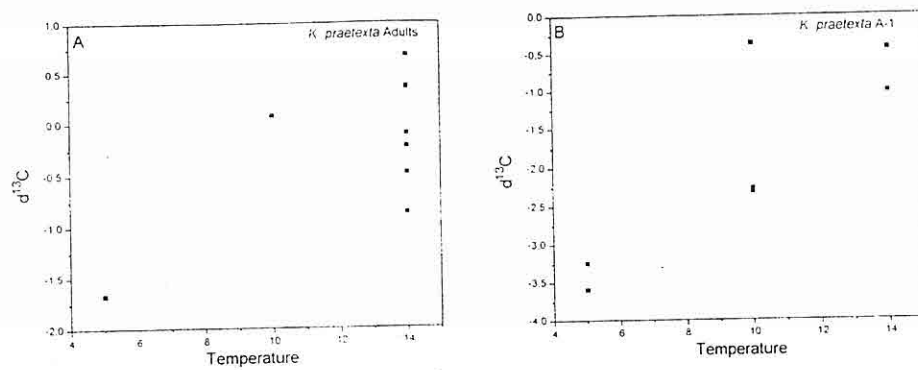


Figure 7. Plots of $\delta^{13}\text{C}$ in the valves of (A) adults and (B) the A-1 ontogenetic stage of *K. praetexta praetexta* from the three thermoconstant cultures of 14, 10 and 5°C.

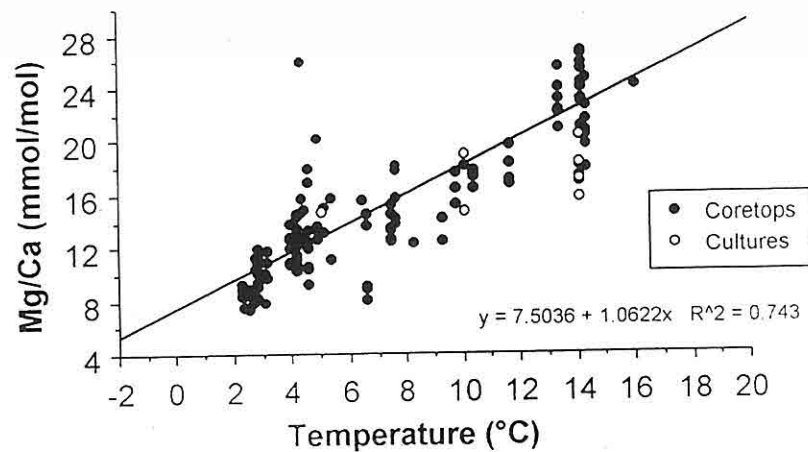


Figure 8. Plot of Mg/Ca ratios of adult *K. praetexta praetexta* of the present thermoconstant cultures of 14, 10 and 5°C (open circles) with North Atlantic Mg/Ca data on *Krithe* from Dwyer et al. (1995, unpublished) (filled circles).

et al., 1986b). Probably, the variation in chemical conditions of the porewater environment is higher than above sediment/water interface in time and space. Chivas et al. (1986b) showed that there is particularly a strong correlation between the Mg content of the water and

the Mg/Ca ratio of the ostracod valves of some non-marine ostracod species. Considering the variation in salinity of the intermediate watermass of the Gullmarn fjord, it is therefore possible that temporal variation in Mg content of the water is a possible explanation to the

wide scatter of the Mg/Ca ratios within the 10 and 14°C cultures. The timing of the moulting procedure for all the individuals in a *Krithe* population is hardly synchronous within a thermoculture or between thermocultures. In connection herewith, we may speculate about the effects of patchiness (spatial) in Mg content and/or the Mg/Ca ratio of the porewater in the sediment. In relation to such patchiness there may be individual differences depending on the position in the sediment during the moulting of *K. praetexta praetexta*.

The scatter of the Sr/Ca data in the 10 and 14°C cultures of *K. praetexta praetexta* is less compared to the Mg/Ca ratios (Figs. 2a-d). Noteworthy is also the significant correlations between temperature and the Sr/Ca ratios in Figs. 2c-d which indicate a stronger correlation between temperature and Sr/Ca ratio than between temperature and Mg/Ca ratio (Figs. 2a-b). This strong correlation between temperature and the Sr/Ca ratio of the valves of *K. praetexta praetexta* is in contrast to results obtained from non-marine ostracods by Chivas et al. (1983, 1985, 1986ab). Their results seem to demonstrate that Sr uptake by ostracod shells depends on the Sr/Ca ratio of the ambient water and not temperature. In connection herewith, it is interesting to note that certain benthic foraminiferal species display a good correlation between Sr/Ca ratios and temperature, at least within the temperature range between -2 and 6°C (see Rathburn & De

Deckker, 1997). In the present analysis we cannot, however, rule out any hidden effect from the variation in Sr/Ca ratio (or the Sr content) of the host water in the various thermocultures. Thus, an alternative but unlikely explanation to the differences in the Sr/Ca ratios among the various thermocultures would be that the Sr/Ca ratio coincidentally was highest in the aquaria when most of the 14°C individuals moulted to the A-1 and adult stages and lowest when the 5°C individuals moulted to the A-1 and adult stages.

Xia et al. (1997b) observed a positive covariance between the Mg/Ca- and Sr/Ca ratios of the valves of the freshwater species *Candona rawsoni* from Coldwater Lake, North Dakota, USA. This occurred during conditions of an inverse correlation between the lake-water ratios of Mg/Ca and Sr/Ca. Xia et al. (1997b) concluded that the $K_D[\text{Sr}]$ varied directly with the Mg concentration in ostracod calcite. They suggested that it is "likely that the $K_D[\text{Sr}]$ increases with Mg concentration because of the large energy required to exclude Mg (and Sr) during shell calcification when ostracods are growing in lake waters of high Mg/Ca".

A positive covariance is discernible between the Mg/Ca and Sr/Ca ratios of *K. praetexta praetexta* in the present experiment (Figs. 5a-b). Thus, if there is a positive correlation between the Mg/Ca ratio and temperature in *K. praetexta praetexta*, then the Sr/Ca variation in *K. praetexta praetexta* could be indirectly

related to temperature, as was proposed for *C. rawsoni* by Xia et al. (1997b). Also, experiments with inorganic calcite have shown that co-precipitation of Sr into calcite is strongly controlled by the precipitation rate (see Morse & MacKenzie, 1990).

Xia et al. (1997a) investigated the oxygen isotope fractionation in the shells of two laboratory controlled freshwater cultures of *C. rawsoni* living under constant temperatures of 15 and 25°C. The results showed that the individuals at 15°C grew more slowly than the individuals of the 25°C, and that the slower growth rate and lower temperature also were associated with a closer approach to equilibrium (inorganic) fractionation. Xia et al. (1997a) expressed this as a stronger discrimination against ^{16}O (i.e. higher ^{18}O) in the 25 °C culture than in the 15° C culture. The results of Xia et al. (1997a) appear consistent with the present A-1 juveniles of *K. praetexta praetexta* where there is a stronger departure from isotopic (inorganic) equilibrium in the 14°C culture than in the 5°C culture. The adults of *K. praetexta praetexta* appear approximately equally enriched in ^{18}O in the three thermoconstant cultures (Fig. 6a). However, it is important to point out that some of the present $\delta^{18}\text{O}$ values plotted in Figs. 6a-b are bedevilled by high standard deviations and therefore less reliable (see also Table 1). Nevertheless, in contrast to the results of the present A-1 juveniles of *K. praetexta praetexta*,

there are other organisms, such as the coralline aragonite *Pavona clavus*, which are characterised by a closer approach to equilibrium fractionation at higher temperatures (faster growth rates) than at lower temperatures (slower growth rates) (see De Villiers et al., 1995).

Klein et al. (1996) showed that the Sr/Ca ratios and the ^{13}C in the calcite bivalve *Mytilus trossulus* primarily is related to variations in mantle metabolic activity and secondarily to variation in seawater salinity. Klein et al. (1996) presented a model (assuming constant salinity and normal seawater chemistry) in which high metabolic activity (involving slow growth rate for *M. trossulus*) gives rise to near-equilibrium skeletal Sr/Ca ratios but depleted ^{13}C with respect to seawater, whereas low metabolic activity (involving fast growth rate for *M. trossulus*) gives rise to elevated skeletal Sr/Ca ratios and $\delta^{13}\text{C}$ values similar to that of seawater. Thus, possible candidates for use as indicators of ancient seawater $\delta^{13}\text{C}$ include those specimens of *M. trossulus* with elevated Sr/Ca ratios with respect to equilibrium values (Klein et al., 1996).

In this study, we have not estimated and compared the metabolic activity of *K. praetexta praetexta* from the different thermocultures. Thus, we do not know how the correlation between temperature and metabolic activity is in this species. Contrary to the continuous growth of bivalves, ostracods grow discontinuously and pass through eight or nine moult stages before adulthood is reached. At

least, Majoran et al. (submitt.) showed that the growth rate (i.e. the time interval between successive moult stages) in *K. praetexta praetexta* is correlated with temperature. The time interval between successive moult stages decrease with an increase in temperature. However, we are unable to tell if there is any inverse relationship between growth rate and metabolic activity in *K. praetexta praetexta* as is observed in the bivalve *M. trossulus*. Therefore, it is presently not possible to discuss the relevance of the model of Klein et al. (1996) to our thermocultures of *K. praetexta praetexta*. Nevertheless, we may offer an explanation to the observed positive correlation between temperature and $\delta^{13}\text{C}$ in *K. praetexta praetexta* as well as to differences in ^{13}C between adults and the A-I stage within a thermoculture. This explanation is related to the fact that this species is infaunal (Majoran & Agrenius, 1995), and to the circumstance that there are concentration depth gradients of $\delta^{13}\text{C}$ in the porewater of marine sediments (McCorkle et al., 1990; Bauer et al., 1995). The bioturbation in the sediment of the aquaria are reduced due to the removal of macrofauna in the beginning of the experiment. McCorkle et al. (1990) concluded that infaunal species are generally depleted in ^{13}C compared to epifaunal species; and deep-dwelling infaunal species are generally more depleted in ^{13}C than species living close to the sediment-water interface. If we assume that the shells of *K. praetexta praetexta* are precipitated in ^{13}C

equilibrium with the ambient porewater, then the positive correlation observed between temperature and $\delta^{13}\text{C}$ (Figs. 7a-b) may be explained by an effect of temperature on the relative position of this species in the sediment. Thus, *K. praetexta praetexta* might live considerably deeper down in the sediment at 5°C than at 14°C for example. It is, however, difficult to explain the differences in $\delta^{13}\text{C}$ of the adult *K. praetexta praetexta* between the two aquaria of the 14°C culture (see Table 1), according to this model. An alternative explanation might be due to a positive relationship between temperature and the $\delta^{13}\text{C}$ in the porewater of the sediment as a consequence of raised chemoautotroph primary production with temperature. This could explain the positive relationship between temperature and shell $\delta^{13}\text{C}$ of *K. praetexta praetexta* in the three thermocultures.

Furthermore, variation in salinity might explain differences in $\delta^{13}\text{C}$ of calcite shells also, according to Klein et al. (1996). There is also a marked annual variation in the productivity of the Gullmarn fjord which affects the $\delta^{13}\text{C}/\delta^{12}\text{C}$ of the dissolved inorganic carbon of the water (Andreasson et al., in press). However, this variation is mainly confined to the upper watermass of the fjord, and the significance of this variation below the pycnocline, i.e. below a depth of 15 m in the fjord, is not known to us.

5. ACKNOWLEDGEMENTS

We are grateful to Kristineberg Marine Research Station for providing facilities to perform this study which was financed by grants (G-AA/GU 06656-308 and 310) to Stefan Majoran from the Swedish Natural Science Research Council. We are also grateful to Fredrik Andreasson for helpful discussions.

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VERTICAL DISTRIBUTION OF HOLOCENE OSTRACODA AT ANADOLU HİSARI (BOSPHORUS-İSTANBUL)

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ABSTRACT: *The vertical distribution of the Holocene ostracods of Anadolu Hisarı has been studied for 36 sediment samples from four boreholes. Forty-four Ostracoda species were determined. Four ostracod assemblages were identified from these species. These assemblages are dominated respectively by; **Aurila convexa** (Baird); **Xestoleberis aurantia** (Baird); **X. depressa** Sars; and **Tyrrenocythere amnicola** (Sars). In general, the fauna exhibits low diversity and richness. Finally, Q-mode cluster analysis was applied to the Bray-Curtis measure of similarity.*

1. INTRODUCTION

The study area fronts Küçükusu Palace which is located on the shore of the Bosphorus (İstanbul) in the northwestern part of Turkey. The samples studied were taken from the Küçükusu Palace foundations (Figure 1). No details are available yet concerning the Holocene ostracods of Anadolu Hisarı and its surroundings, but, previously reported data for the general region are as follows: Meriç et al. (1995a), Meriç et al. (1995b), Erol and Çetin (1995), Meriç and Avşar (1996), Meriç et al. (1996a), Meriç et al. (1996b), Nazik et al. (1996), Meriç and Avşar (1997), Ergin (1997), Nazik

(1998), Nazik et al, (1998). The main purpose of this paper is to give the vertical distribution of Ostracoda at Anadolu Hisarı.

2. MATERIAL AND METHODS

Some 36 sediment samples were obtained from 4 boreholes. An aliquot of 50 gr from each samples was washed and separated for determination of the Ostracoda and benthic foraminifera under the microscope in the laboratory. Forty-four ostracod species in 23 genera and 56 benthic foraminiferal species in 30 genera (Table 1) have been determined. Forty specimens of Ostracoda, were

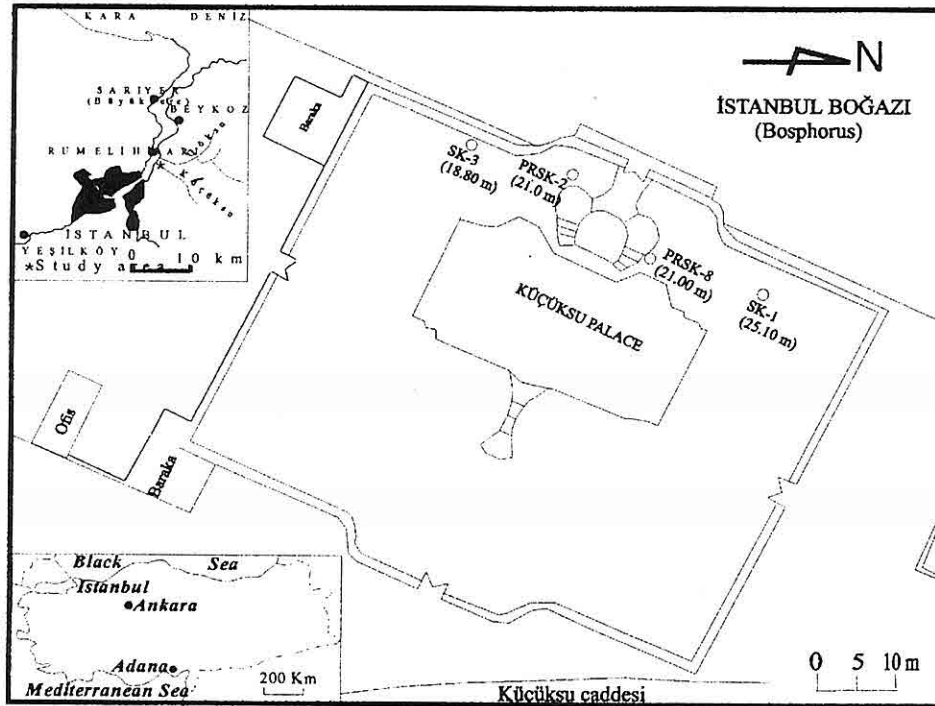


Figure 1. Location map for the boreholes at Küçükusu Palace (Modified from Nazik et al, 1998).

Table 1. Described Ostracods And Benthic Foraminiferal Species From The Study Area

BOREHOLES	SK-3	PRSK-2	PRSK-8	SK-1
FORAMINIFERIDA				
<i>Spiroplectinella sagittula</i> (d'Orbigny)				
<i>Textularia bocki</i> Höglund				
<i>Textularia cf. pala</i> Czek				
<i>Textularia truncata</i> Höglund				
<i>Spirillina vivipara</i> Ehrenberg				
<i>Lachlanella undulata</i> (d'Orbigny)				
<i>Massilina secans</i> (d'Orbigny)				
<i>Quinqueloculina laevigata</i> d'Orbigny				
<i>Quinqueloculina lamarckiana</i> d'Orbigny				
<i>Quinqueloculina seminula</i> (Linné)				
<i>Miliolinella elongata</i> Kruit				
<i>Miliolinella labiosa</i> (d'Orbigny)				
<i>Miliolinella subrotunda</i> (Montagu)				
<i>Miliolinella</i> sp.				
<i>Triloculina marioni</i> Schlumberger				
<i>Triloculina plicata</i> Terquem				
<i>Dentalina inornata</i> d'Orbigny				
<i>Polymorphina</i> sp.				
<i>Globigerina bulloides bulloides</i> d'Orbigny				
<i>Globigerinoides ruber</i> (d'Orbigny)				
<i>Globigerinoides seigliei</i> Bermudez and Bolli				
<i>Cassidulina carinata</i> Silvestri				
<i>Bulimina elongata</i> d'Orbigny				
<i>Bulimina marginata</i> d'Orbigny				
<i>Stomatobina concentrica</i> Parker and Jones				
<i>Rosalina bradyi</i> Cushman				
<i>Rosalina floridensis</i> (Cushman)				
<i>Rosalina globularis</i> d'Orbigny				
<i>Cibicides advenum</i> d'Orbigny				
<i>Cibicides floridanus</i> (Cushman)				
<i>Cibicidina walli</i> Bandy				
<i>Lobatula lobatula</i> (Walker and Jacob)				
<i>Planorbulina mediterraneensis</i> d'Orbigny				
<i>Acervulina cf. inhaerens</i> Schultz				
<i>Sephaerogypsina globula</i> (Reuss)				
<i>Asterigerinata mamilla</i> (Williamson)				
<i>Nonionella</i> sp.				
<i>Aubignyna perlucida</i> (Heron-Allen and Earland)				
<i>Ammonia ammoniformis</i> Colom				
<i>Ammonia compacta</i> (Hofker)				
<i>Ammonia parkinsoniana</i> (d'Orbigny)				
<i>Ammonia tepida</i> Cushman				
<i>Criboelphidium poeyanum</i> (d'Orbigny)				
<i>Porosonion subgranosum</i> (Egger)				
<i>Porosonion</i> sp.				
<i>Haynesina anglica</i> (Murray)				
<i>Haynesina depressula</i> (Walker and Jacob)				
<i>Haynesina</i> sp.				
<i>Elphidium aculeatum</i> (d'Orbigny)				
<i>Elphidium advenum</i> (Cushman)				
<i>Elphidium complanatum</i> (d'Orbigny)				
<i>Elphidium crispum</i> (Linné)				
<i>Elphidium jenseni</i> (Cushman)				
<i>Elphidium cf. limbatum</i> (Chapman)				
<i>Elphidium macellum</i> (Fichtel and Moll)				
<i>Elphidium</i> sp.				

BOREHOLE	SK-3	PRSK-2	PRSK-8	SK-1
OSTRACODA				
<i>Bairdia corpulenta</i> G.W.Müller				
<i>Bairdia longevaginata</i> G.W.Müller				
<i>Leptocythere bisulcata</i> Stancheva				
<i>Leptocythere castanae</i> Sars				
<i>Leptocythere levis</i> G.W.Müller				
<i>Leptocythere pellucida</i> (Baird)				
<i>Leptocythere rara</i> G.W.Müller				
<i>Leptocythere rastrifera</i> Ruggieri				
<i>Callistocythere mediterranea</i> G.W.Müller				
<i>Callistocythere montana</i> Doruk				
<i>Callistocythere pallida</i> G.W.Müller				
<i>Cyprideis sohi</i> Bassiouni				
<i>Cyprideis torosa</i> (Jones)				
<i>Cushmanidea elongata</i> (Brady)				
<i>Costa edwardsii</i> (Roemer)				
<i>Carinocythereis antiquata</i> (Baird)				
<i>Carinocythereis carinata</i> Roemer				
<i>Falunia quadridentata</i> (Baird)				
<i>Falunia rugosa</i> (Costa)				
<i>Falunia</i> sp.				
<i>Aurila convexa</i> (Baird)				
<i>Urocythereis favosa</i> Roemer				
<i>Urocythereis margaritifera</i> G.W.Müller				
<i>Tyrrenocythere amnicola</i> (Sars)				
<i>Loxoconcha ancilla</i> Stancheva				
<i>Loxoconcha mediterranea</i> G.W.Müller				
<i>Loxoconcha rhomboidea</i> Fischer				
<i>Loxoconcha tumida</i> Brady				
<i>Hirschmannia</i> sp.				
<i>Paracytheridea depressa</i> (G.W.Müller)				
<i>Semicytherura acuticostata</i> (Sars)				
<i>Semicytherura ruggieri</i> Pucci				
<i>Semicytherura sulcata</i> G.W.Müller				
<i>Eucytherura</i> sp.				
<i>Xestoleberis aurantia</i> (Baird)				
<i>Xestoleberis communis</i> G.W.Müller				
<i>Xestoleberis depressa</i> Sars				
<i>Paradoxostoma triste</i> G.W.Müller				
<i>Sclerochilus contortus</i> (Norman)				
<i>Argilloecia conoidea</i> Sars				
<i>Propontocypris prifera</i> G.W.Müller				
<i>Candona parallela pannonica</i> Zalanyi				
<i>Candona (Pseudocandona)</i> sp.				
<i>Cyclocypris</i> sp.				

Table 2. Selected parameters of samples from boreholes at Küçüksu Palac(Bosphorus)

Boreholes	Sample	Total Ostracoda (N)	Species Number (S)	Richness (d')	Diversity (H')	Evenness (J')
SK-1	1	210	7	1.95	1.15	0.71
	2	360	6	1.79	0.73	0.42
	3	215	4	1.39	0.50	0.44
	4	52	10	2.30	1.72	0.78
	5	55	6	1.79	1.21	0.85
	6	43	8	2.08	1.44	0.77
	7	40	11	2.40	1.96	0.85
	8	181	12	2.48	1.71	0.65
	9	40	8	2.08	1.63	0.79
SK-3	1	344	10	2.30	1.78	0.78
	2	420	7	1.95	1.53	0.84
	3	777	10	2.30	1.36	0.58
	4	165	6	1.79	1.46	0.85
	5	41	8	2.08	1.57	0.76
	6	110	10	2.30	1.78	0.79
	7	111	12	2.48	2.21	0.90
	8	95	16	2.77	2.35	0.80
PRSK-2	1	47	6	1.79	1.13	0.69
	2	209	7	1.95	1.21	0.67
	3	72	8	2.08	1.42	0.71
	4	83	3	1.10	0.44	0.50
	5	167	6	1.79	1.21	0.69
	6	48	4	1.39	0.64	0.50
	7	42	5	1.61	1.25	0.83
	8	57	5	1.61	1.47	0.91
	9	89	10	2.30	2.15	0.93
	10	88	12	2.48	2.20	0.88
	11	53	10	2.30	2.02	0.89
PRSK-8	1	40	5	1.61	1.38	0.86
	2	253	7	1.95	1.27	0.72
	3	87	7	1.95	1.21	0.76
	4	40	6	1.79	1.41	0.79
	5	40	6	1.79	1.68	0.94
	6	40	9	2.20	1.97	0.90
	7	40	13	2.50	2.41	0.93
	8	190	9	2.20	1.93	0.88
	9	54	8	2.08	1.78	0.89

picked out for all sample, microscopically analyzed, and subjected to statistical analysis. The main parameters used were the number of species per a sample (S), the number of specimens per sample (N); species richness was calculated as $d' = (S-1)/\log(S)$ (Pi), Shannon-Wiener diversity defined as $H' = -\sum (P_i \cdot \log(P_i))$, and Evenness (J'). All these parameters were normalized against 50 gr of dry sediment (Table 2).

3. LITHOLOGY

Quaternary sediments occur transgressively over Paleozoic rocks in the region. The main sediments infilling the area mostly comprise mud, silt, fine and coarse grained, unconsolidated gravelly sand bearing shell fragments, and are abundantly fossiliferous (Figure 2). The thickness of the Quaternary varies between 1-25 m. The age of the sequence has been estimated as Late Pleistocene-Holocene at the type locality

VERTICAL DISTRIBUTION OF HOLOCENE OSTRACODA AT ANADOLU HISARI

SYSTEM	SERIES	FORMATION	LITHOLOGY	EXPLANATIONS	OSTRACODA
QUATERNARY	HOLOCENE	KULUŞLIDİ		Gravelly sand	
				Shelly, organic materials bearing, mud	Aurila convexa (Baird) Callistocythere pallida G.W.Müller Xestoleberis aurantia (Baird) Callistocythere pallida G.W.Müller
				Ostrea and Mytilus bearing mud	Aurila convexa (Baird) Callistocythere mediterranea G.W.Müller
				Ostrea bearing, gravelly sand	Aurila convexa (Baird) Xestoleberis aurantia (Baird)
				Shell fragments, gravelly sand	Xestoleberis depressa Sars Cyprideis sohnii Bassiouni
					Tyrrenocythere amnicola (Sars) Xestoleberis aurantia (Baird) Xestoleberis depressa Sars
				Ostrea fragments and organic materials bearing, coarse-grained sand	Tyrrenocythere amnicola (Sars) Cyprideis sohnii Bassiouni Xestoleberis aurantia (Baird) Xestoleberis depressa Sars
PALEOZOIC				Basement	Tyrrenocythere amnicola (Sars) Callistocythere pallida G.W.Müller Xestoleberis aurantia (Baird) Xestoleberis depressa Sars

Figure 2. The generalized columnar section in the study area.

(Meriç et al., 1991). Samples obtained from various levels in this sequence were investigated and the ostracods *Aurila convexa* (Baird), *Callistocythere mediterranea* G.W.Müller, *C. montana* Doruk, *C. pallida* G.W.Müller, *Leptocythere rara* G.W.Müller, *L. levis* G.W.Müller, *L. rastrifera* Ruggieri, *Cushmanidea elongata* (Brady), *Loxoconcha rhomboidea* Fischer, *Urocythereis margaritifera* G.W.Müller, *Paracytheridea depressa* (G.W.Müller), *Cyprideis sohnii* Bassiouni, *Xestoleberis aurantia* (Baird), *X. communis* G.W.Müller, *X. depressa* Sars, *Tyrrenocythere amnicola* (Sars) were identified, also the benthic foraminifera *Ammonia tepida* Cushman, *Lobatula lobatula* (Walker and Jacob), *Quinqueloculina seminula* (Linné), *Miliolinella subrotunda* Montagu, *Elphidium macellum* (Fichtell and Moll), *Criboelphidium poeyanum* (d'Orbigny); among other less common species. These taxa indicate the occurrence of both marine and brackish-water facies. A Holocene age 9.700 ± 1.000 years was obtained by ESR at the type locality (Meriç et al. 1996a).

4. DISCUSSION AND RESULTS

Ostracod and Foraminiferal Content
The Ostracoda are represented by 23 genera and 44 species. Taxonomic identification was carried out using following authors: Sissingh (1972); Gökçen (1976); Yassini (1979); Bassiouni (1979); Oertli (1985); Gülen et al. (1995). The following references were

used for foraminifera: Hottinger et al. (1993); Cimerman and Langer (1991); Sgarrella and Moncharmont Zei (1993); Hatta and Ujiie (1992); Parisi (1981); Meriç et al. (1995a); Avşar and Meriç (1996). The collection of ostracods and foraminifera is stored at the Department of Geological Engineering, Çukurova University. The more important species of this study were photographed using SEM.

Based on described species, four ostracod assemblages were identified at the locality. These are dominated respectively by *Aurila convexa* (Baird); *Xestoleberis depressa* Sars; *X. aurantia* Baird and *Tyrrenocythere amnicola* (Sars).

Assemblage 1: *Aurila convexa* (Baird) is the dominant species. This assemblage occurs in 16 samples and consists lithologically of fossiliferous mud and greenish-gray gravelly sand. *Aurila convexa* (Baird) is found with the following species: *Callistocythere mediterranea* G.W.Müller, *C. montana* Doruk, *C. pallida* G.W.Müller, *Leptocythere rara* G.W.Müller, *L. levis* G.W.Müller, *L. rastrifera* Ruggieri, *Cushmanidea elongata* (Brady), *Loxoconcha rhomboidea* Fischer, *Urocythereis margaritifera* G.W.Müller, *Paracytheridea depressa* (G.W.Müller), *Cyprideis sohnii* Bassiouni, *Xestoleberis aurantia* (Baird), *X. communis* G.W.Müller, *X. depressa* Sars. In addition, there is an abundance of *Ammonia tepida* Cushman and *Lobatula lobatula* (Walker and Jacob) among the

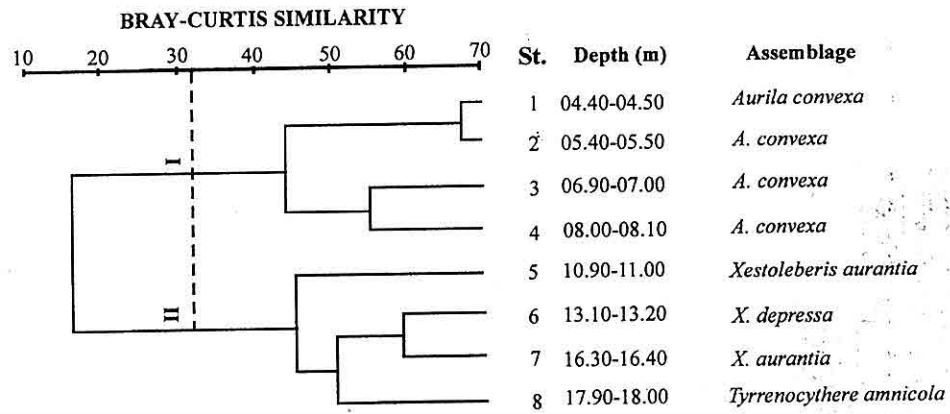


Figure 3. Dendrogram Based on Q-mode Cluster Analysis of 8 Samples From Borehole SK-3.

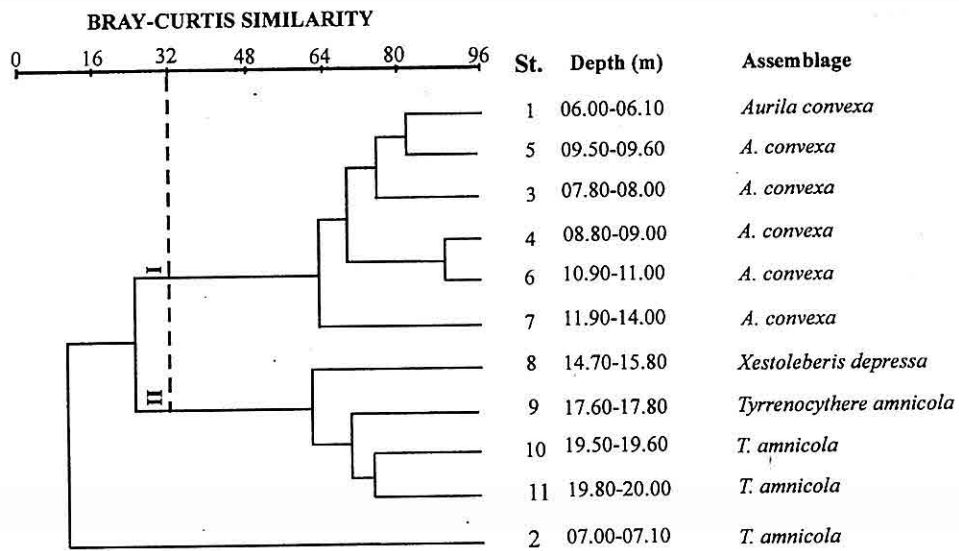


Figure 4. Dendrogram based on Q-mode cluster analysis of 11 samples from borehole PRSK-2.

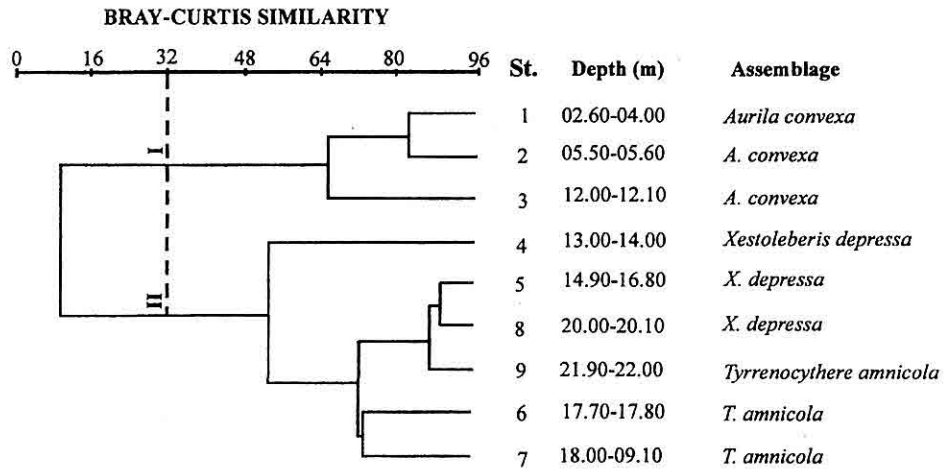


Figure 5. Denrogram Based on Q-mode Cluster Analysis of 9 Samples From Borehole PRSK-8.

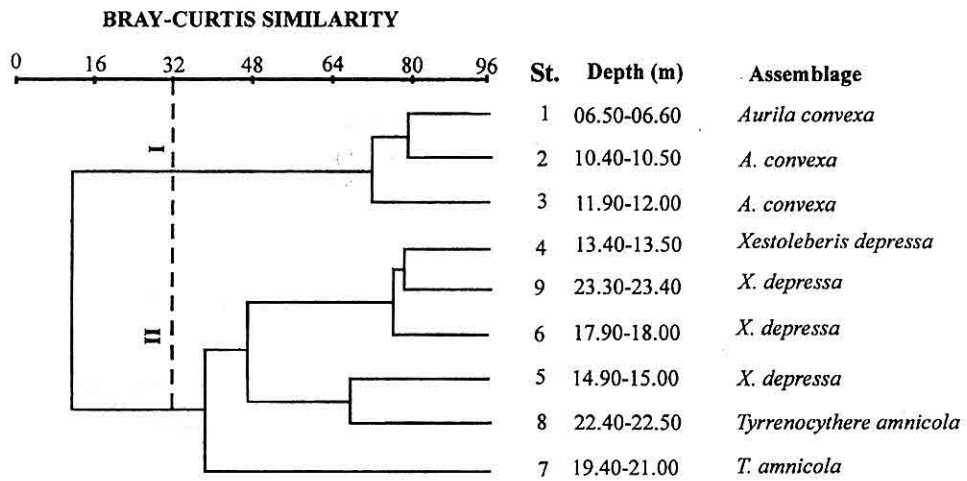


Figure 6. Dendrogram based on Q-mode cluster analysis of 9 samples from borehole SK-1.

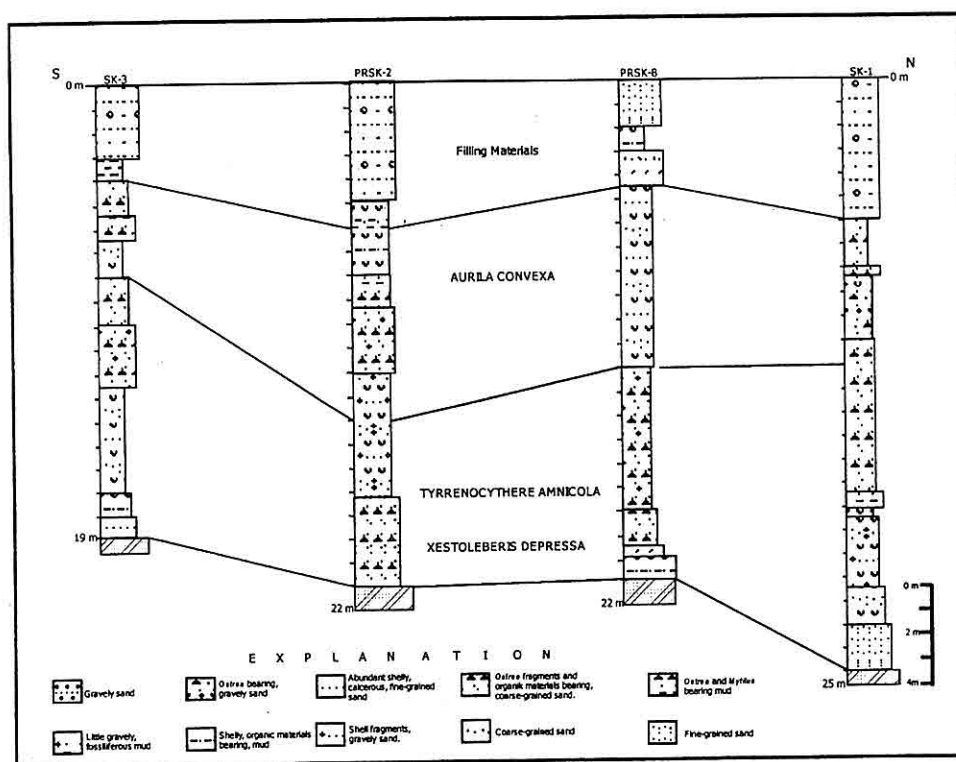


Figure 7. The correlation of the Ostracoda assemblages depending on Q- mode cluster results.

foraminifera in the assemblage.

Assemblage 2: This assemblage is characterized by the abundance of *Xestoleberis depressa* Sars. It is composed lithologically of coarse grained sand, shelly gray mud and coarse grained mud and is found in 11 borehole samples. Other species include *Cyclopyris* sp., *Leptocythere bisulcata* Stancheva, *L. castanae* Sars, *Loxoconcha ancilla* Stancheva, *L. rhomboidea* Fischer, *Cyprideis sohi* Bassiouni, *Tyrrenocythere amnicola* (Sars), *Xestoleberis aurantia* (Baird); and as typical foraminiferal species is *Lobatula*

lobatula (Walker and Jacob).

Assemblage 3: *Xestoleberis aurantia* Baird is a prevalent species in two samples which have similar lithological features to assemblage 2. Other ostracod species of this assemblage are *Aurila convexa* (Baird), *Leptocythere castanae* Sars, *Loxoconcha rhomboidea* Fischer, *Hirschmannia* sp., *Semicytherura sulcata* G.W.Müller, *Paradoxostoma trieste* G.W.Müller, *Cyprideis torosa* (Jones), *C. sohi* Bassiouni, *Tyrrenocythere amnicola* (Sars), *Xestoleberis depressa* Sars, and the common foraminiferal species is *Lobatula lobatula* (Walker and

Jacob).

Assemblage 4: *Tyrrenocythere amnicola* (Sars) is dominant at seven samples in four boreholes. This assemblage also is similar lithologically to assemblage 2. Other species are *Callistocythere montana* Doruk, *C. pallida* G.W.Müller, *Leptocythere bisulcata* Stancheva, *L. castanae* Sars, *Hirschmannia* sp., *Cushmanidea elongata* (Brady), *Loxoconcha rhomboidea* Fischer, *L. ancilla* Stancheva, *L. tumida* Brady, *Propontocypris prifera* G.W.Müller, *Cyprideis sohni* Bassiouni, *Xestoleberis aurantia* (Baird), *X. depressa* Sars, and *Lobatula lobatula* (Walker and Jacob) is the common foraminiferan.

In general, the ostracod fauna exhibits low diversity and richness (Table 2). Under these circumstances, 40 specimens per sample are adequate for preliminary statistical testing.

Q-mode cluster analysis was applied to the Bray-Curtis measure of similarity using the weighted pair-group method with simple arithmetic averaging (Davis, 1973).

A dendrogram based on Q-mode cluster analysis of eight samples from borehole SK-3 distinguished two clusters at the arbitrary similarity level of 32 % of Bray-Curtis similarity. Cluster I combines samples 04.40-04.50 m, 05.40-05.50 m, 06.90-07.00 m and 08.00-08.10 m. Cluster II includes 10.90-11.00 m, 13.10-13.20 m, 16.30-16.40 m and 17.90-18.00 m (Figure 3).

Another dendrogram based on Q-mode

cluster analysis of eleven samples from borehole PRSK-2 was set a part two clusters at the arbitrary similarity level of 32 % of the Bray-Curtis similarity. Cluster I combines samples 06.00-06.10 m, 09.50-09.60 m, 07.80-08.00 m, 08.80-09.00 m, 10.90-11.00 m, 11.90-14.00 m. Cluster II consists of 14.70-15.80 m, 17.60-17.80 m, 19.50-19.60 m, 19.80-20.00 m and 17.00-17.10 m (Figure 4).

A third dendrogram based on Q-mode cluster analysis of nine samples from borehole PRSK-8 provided two clusters at the arbitrary similarity level of 32 % of Bray-Curtis similarity. Cluster I contains samples 02.60-04.00 m, 05.50-05.60 m and 12.00-12.10 m. Cluster II includes 13.00-14.00 m, 14.90-16.80 m, 20.00-20.10 m, 21.90-22.00 m, 17.70-17.80 m and 18.00-19.10 m (Figure 5).

Finally, a dendrogram based on Q-mode cluster analysis of nine samples from borehole SK-I recognized two clusters at the arbitrary similarity level of 32 % of Bray-Curtis similarity. Cluster I consists of samples 06.50-06.60 m, 10.40-10.50 m and 11.90-12.00 m. Cluster II is composed of 13.40-13.50 m, 14.90-15.00 m, 17.90-18.00 m, 19.40-21.00 m, 22.40-22.50 m and 23.30-23.40 m (Figure 6).

Summing up, results of the Q-mode cluster analysis are shown in Figure 7. Cluster I of the four boreholes located between 02.60-12.10 m depth is characterized by the abundance of the *Aurila convexa* (Baird) assemblage. This assemblage is strictly characteristic of a marine environment under the influence

of the Mediterranean Sea water.

Cluster II lies below this and contains most of the samples in which *Xestoleberis depressa* Sars, *X. aurantia* (Baird), *Tyrrenocythere amnicola* (Sars), dominate at depths between 13.00-21.00 m. These assemblages indicate brackish environment, with a mixed fauna of both Black Sea and Mediterranean elements.

Thus, the Quaternary sequence during the early Holocene at Anadolu Hisari commenced with brackish facies and mixed Black Sea/Mediterranean microfaunas; subsequently, a fully Mediterranean marine environment became established.

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SEDIMENTOLOGY AND PALEONTOLOGY WITH SPECIAL REFERENCE
TO THE OSTRACODA FAUNA OF AKYATAN LAGOON
(ADANA-SE TURKEY)

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ABSTRACT : Akyatan, a lagoon on the Seyhan-Ceyhan-Tarsus deltaic plain lies between Karataş and Tuzla approximately 42 km south of Adana. It is elongate, parallel to the shoreline with an inlet providing access to the sea in the south east. It is separated from the adjacent Mediterranean by a beach dune ridge fringed with reed beds. The mainland shore is formed of algal flats with thick reed beds where fresh water canals enter the lagoon. Water depths vary 80-100 cm and increase towards the inlet; they vary with the season. The lagoon is floored with silty clays and clayey silts. The uppermost sediments are at least 2620 ± 70 yrs BP (as determined by radiocarbon dating of thin buried peat layer). Water temperatures vary from 11-12 ° C in winter, 18-23 ° C spring to 30 ° C in summer. Salinities vary from 30-45 ‰ in winter to 9-12 ‰ in spring (due to the heavy rain and influx of fresh water through canals) to 25-50 ‰ in summer. pH of the lagoon water varies from 7.5-9. The most extreme conditions are found in the north westerly inner lagoon away from the inlet and fresh water canal influx.

A study has been completed of 4 cores (79 samples) along the axis of the lagoon which were collected by G.Evans and N.Görür of Imperial College with help from staff METU and MTA in 1975. 15 Ostracoda species were determined. These species are *Cyprideis torosa* (Jones), *Neocyprideis subulata* (Brady), *Heterocypris salina* (Brady), *Eucypris dulcifons* (Diebel and Pietrzenuik), *Eucypris* nsp., *Loxoconcha elliptica* Brady, *Leptocythere lacertosa* (Hirschmann), *Candona neglecta* Sars, *Candona angulata* G.W.Mueller, *Candona* (C.) *parallela pannonica* (Zalanyi), *Darwinula stevensoni* (Brady and Robertson), *Ilyocypris gibba* (Ramdhor), *I. biplicata* (Koch), *Lymnocythere inopinata* (Baird), *Aurila convexa* (Baird), *Candona* sp. 1, *Candona* sp.2 Generally, the assemblage was of great abundance and low diversity. In addition, Pelecypoda, Gastropoda, benthic Foraminiferida, and Charophyta also accompany the Ostracoda association. The lagoon supports a rich fish population which is actively exploited and is a valuable site for resident flocks of flamingoes and migrant birds..

1. INTRODUCTION

Akyatan Lagoon is located between Tuzla and Karataş (Erinç, 1953; Evans, 1971, 1972; Göney, 1976; Gedik, 1977; Erol, 1983; Gürbüz, 1997, 1999) in the southern part of the Çukurova plain which is generated by the three large rivers Seyhan, Ceyhan and Berdan (Tarsus). The Çukurova plain sediments are the upper part of the Tertiary sequences of the Adana Basin (Schmidt, 1961; Görür, 1979; Gürbüz, 1993). This basin is bordered by the Ecemiş Fault Zone in the west, the Taurus mountains in the north and the Amanos mountains in the east (Figure 1). The three rivers (Seyhan, Ceyhan and Berdan) are the main suppliers of sediment to the plain (Bal, 1984; Çetin, et al., 1999). These rivers and their deltas have generated a textbook examples meandering river complexes of beach-dune sand ridges, lagoons which can be traced using topographical maps, satellite imagery and air-photos (Figure 2, 3, Plate 1). The large elongate Akyatan lagoon is one of these elements located on the southern part of the delta plain.

Micropaleontological study has been completed on 4 cores (79 samples) along the axis of the lagoon which were collected by G. Evans and N. Görür of Imperial College with help from staff METU and MTA in 1975 and hydrographic data by G. Evans, V. Ediger and M. N. Bodur of METU Erdemli, and were analyzed by O. Baştürk of that institute. These cores were kept at Southampton University,

Geology Department. These cores were separated into 3-5 cm section for micro-paleontological analysis. The samples were disaggregated in 20 % H₂O₂ water solution and washed on a 125 mm sieve and then dried. Ostracods and foraminiferids were picked and identified using binocular microscope. 14 Ostracoda species have been determined from these locations (Plates II-IV). SEM photographs were taken by Will Smith at Southampton Oceanography Centre.

2. GEOLOGICAL AND GEOMORPHOLOGICAL PROPERTIES OF THE LAGOON

2.1. Bathymetry and Oceanography

The lagoon normally varies in depth from 80-100 cm depending on the season. It has been reported that on rare occasions, it becomes almost completely dry. The greatest depths are in spring and winter due to rain and freshwater flows from drainage/irrigation canals and possibly from the Seyhan and abandoned channels of the Ceyhan during floods.

The area is one of low tidal range (20-30 cm) and most of the local movement within the lagoon is due to low wind induced seiches and wind generated waves which are usually less than 30 cm in height. There are strong winds in summer -lagoon gets rough- waters which are clear in mornings become high in suspended matter in afternoons (personal observation of Graham Evans).

The waters have variable salinity varying from 30-45 ‰ in winter to 9-12‰ in spring (due to rainfall and water from

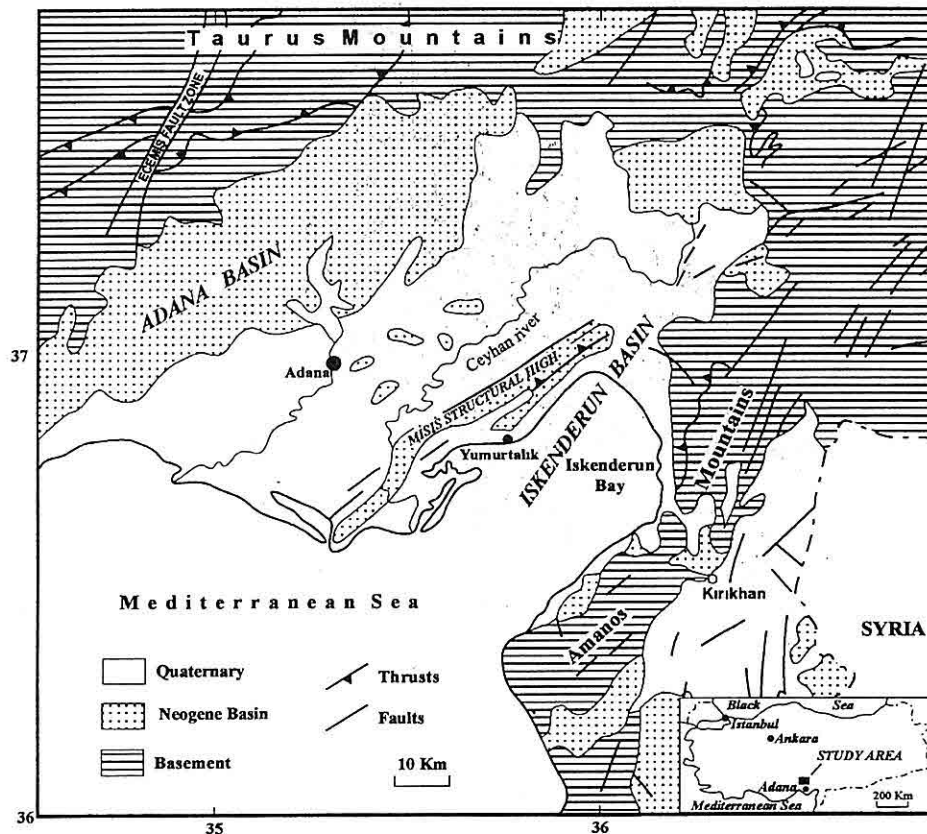


Figure 1. Location map of Adana and Iskenderun Basins

drainage/irrigation canals) and 25-50% in summer. Very rare floods produce occasional very low salinities.

Water temperatures vary from 11-12° C in winter, 18-23° C in spring and up to 30° C in summer. The pH of the water varies from 7.5-9. Lagoon sometimes freezes on the edges during winter (rpt to have done in 1949).

2.2 Fauna

There is a patchy but in places abundant but low diversity macrofauna (*Cardium* sp, *Macoma* sp, *Hydrobio* sp

and *Cerithium* sp. The sediments are burrowed by worms and there is an abundance of fish, medusa and small crabs present. There is an abundant but low diversity population of microfauna (foraminiferids, ostracods and also some charophytes). The lagoon is a valuable nursery ground for fish and supports a valuable commercial fishery. Fish in lagoon are mainly Kefal, Levrek and Chupra. The inlets closed by fish traps for much of the year is only open for several months to allow fish into the lagoon for breeding. Fish traps are open

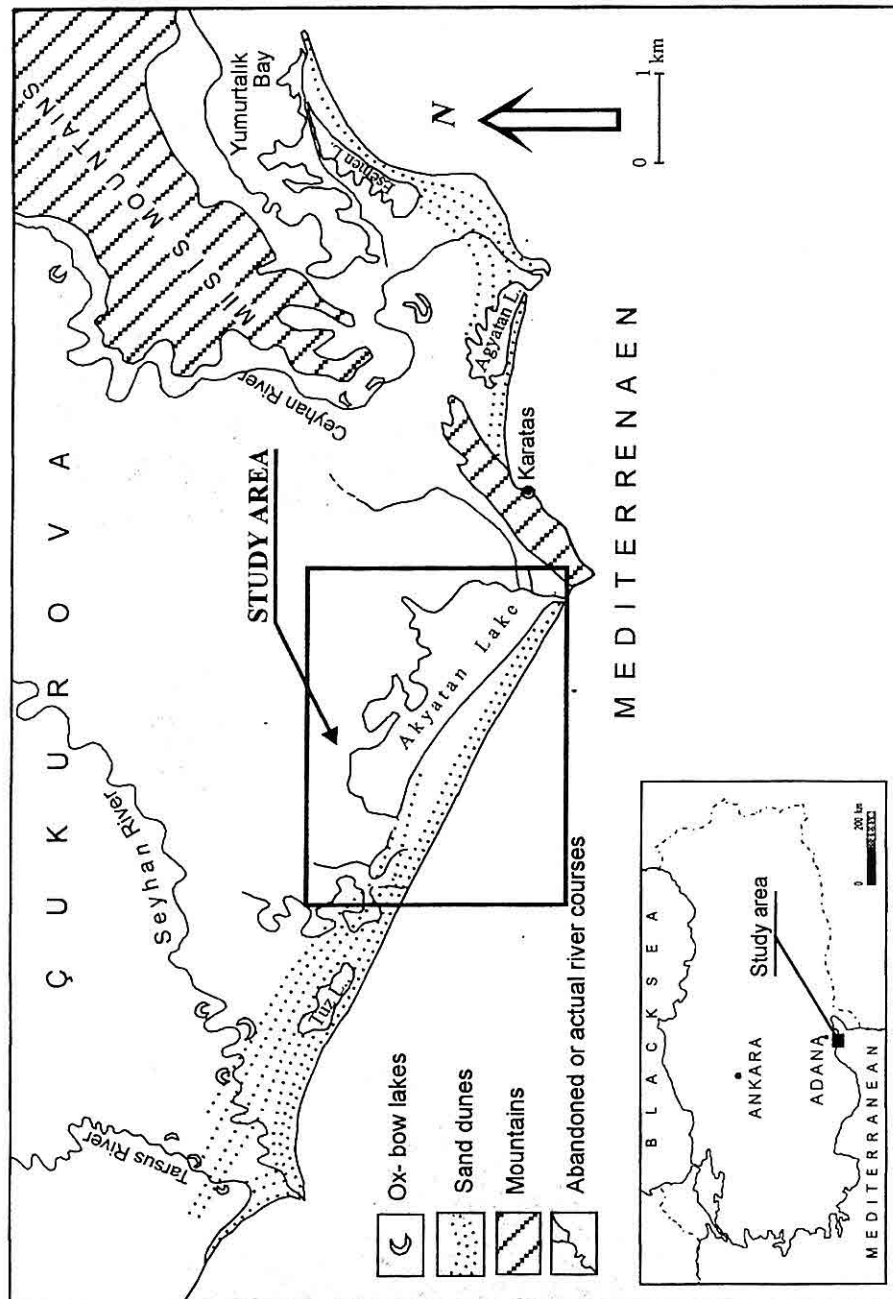


Figure 2. Location map of the study area

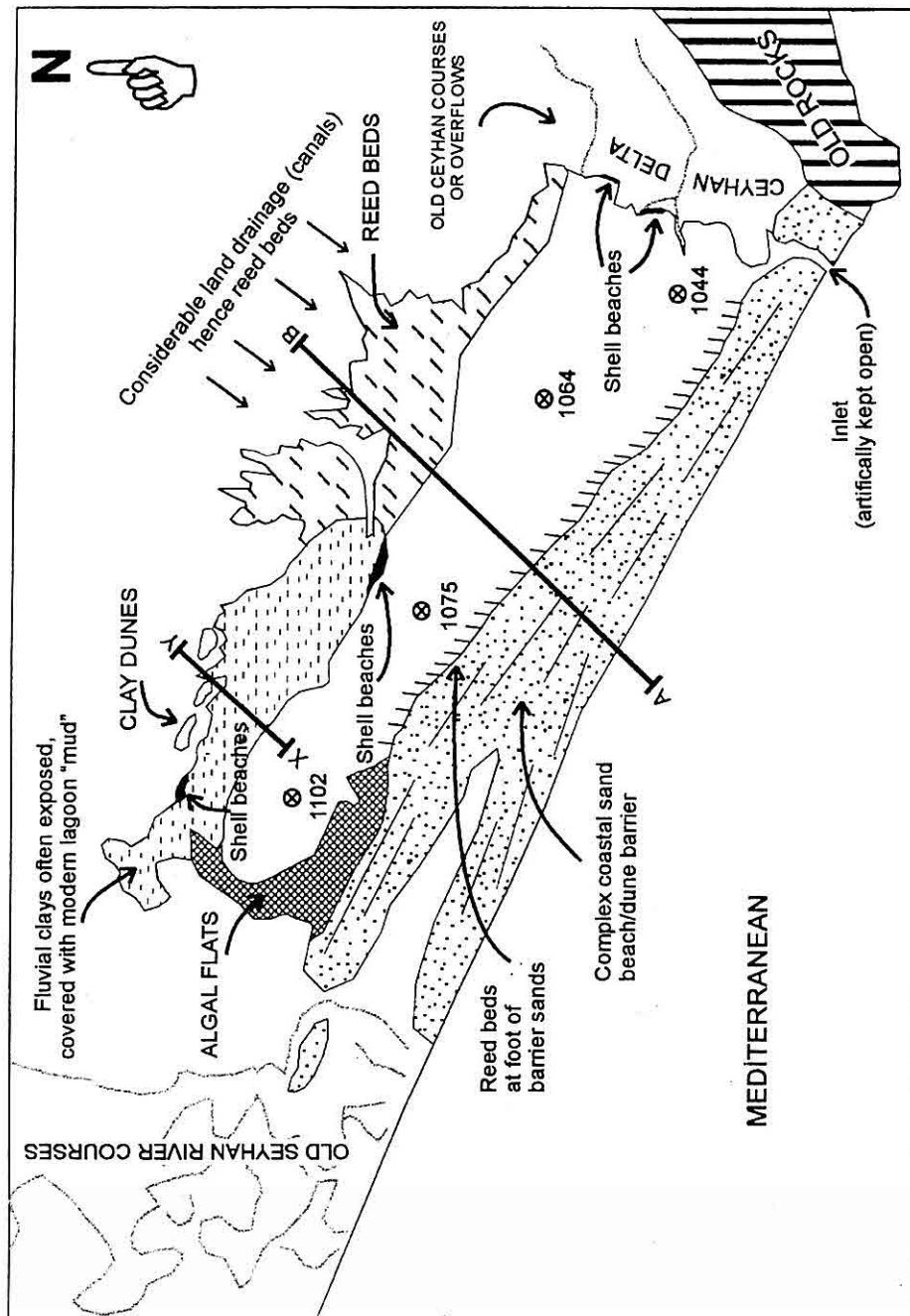


Figure 3. Geological and geomorphological elements of the study area.

February-middle June when fish come into lagoon and lay eggs.

2.3. Physiography

Akyatan lagoon is separated from the adjacent Mediterranean by a beach-dune barrier. This is comprised of an inner ridge, produced at the end of the main Flaudrian transgression and an outer ridge which is progradational regressive feature associated with the now-abandoned course of Seyhan (Evans, 1971). The two features diverge from one another in the NW as the old abandoned river mouth is approached and are separated by a low vegetation covered sandflat.

The coast-parallel dune ridge are today being fashioned into parabolic dunes under present-day winds as the alongshore sand supply is lower than previously due to the displacement of the mouth of the Ceyhan to the NW.

The barrier is breached by a small inlet in the SE, which connects the lagoon to the Mediterranean Sea.

This is often closed in summer due to alongshore sand movement and has to be dredged to maintain contact between the lagoon and sea.

The landward shoreline of the lagoon is irregular and formed of low cliffs cut in the fluvial clays of the deltaic plain (Figure 4). Small discontinuous beaches of shell sand border the cliffs, and in places clay-dunes have formed. Small beaches composed mainly of shell debris and except around old Ceyhan contain little quartz sand, but mud-flake, lithic grains of silt+clay. Depending upon the lagoon water level a broad terrace extend from the beaches into lagoons and also border the NW shoreline. These are often coated with thin cyano-bacteria mats and in places small oncolitically coated mud flakes are present. During summer, when lagoon levels are low, a dense network of dessication cracks develop. Mud flats also show mud-flakes and mud-flake-sands-which show odd gypsum crystals and "birds-eye" structures. Mud flats have many birds' tracts and also

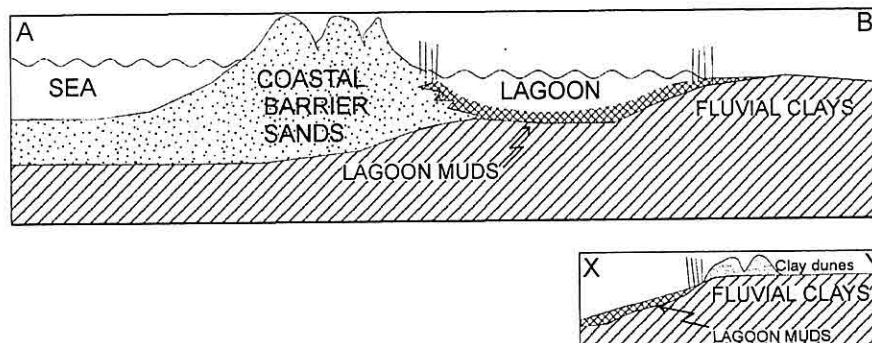


Figure 4. Cross sections showing relationships between lagoon and surroundings.

flamingo feeding pits.

Towards the SE the mainland shoerline is fringed by a wide belt of reeds (*Typha* sp) where irrigation/drainage canals supply fresh water to the lagoon. In the extreme SE low cliffs cut in sandy deposits of old Ceyhan delta occur with narrow shelly sand beaches. Narrow sand-flats occur along the landward side of the beach-dune barrier (Figure 3&5), which are covered by cyanobacteria mats and colonized by a narrow fringe of reeds (*Typha* sp, *Dhragmiles* sp) fed by fresh water from the dunes and spreads of *Juncas* sp and *Salicornia* sp.

A few small islands occur in the NW part of the lagoon flanking the main barrier island and represent drowned beach-dune ridges which mark the most landward extension of the barrier sands during the Flandrian transgression. Other small islands near the mainland shore are erosional remnants of fluvial clay.

2.4. Sediments and Sediment Sources

The beach-dune barrier is composed of sub-angular medium-fine quartzose-lithic sands. The lithic fragments are dominated by limestone grains, with occasional marble together with chert, volcanic fragments, pumice, basic and ultrabasic rocks. Feldspar is rare and sparse, skeletal fragments of contemporary organisms occur.

The heavy mineral fraction is dominated by amphiboles (hornblende and fibrous amphibole) and pyroxenes (diopside, diallage, augite, orthopyroxene) associated with olivine,

garnet, epidote and other rarer constituents (Mange, 1983).

The lagoon is floored with grey mud with shells which contains an increasing admixture of sand towards the inlet in the SE and near the barrier where it interfingers with the sand. It is colonized by a growth of weed which is denser near the inlet and is patchy elsewhere. Generally, the carbonate content of the sediment decreases away from the inlet (50-60% near the inlet, 20-44% mid lagoon and 15-30% inner lagoon).

Originally, the lagoon probably received sediment from the crevasse splays and floods of the Seyhan in the NW and from the former Ceyhan in the SE. However, today the sediment produced by erosion and redistribution of fluvial silty-clay eroded from its landward margin; erosion of dunes of the barrier, during high water stages, and some sand carried landward from the barrier by aeolian transport and through the inlet during storms. To this; is added skeletal carbonate and organic matter produced by indigenous organisms and occasional silt and clay provided by irrigation/drainage canals during floods or heavy rain.

3. LITHOLOGICAL FEATURES AND OSTRACODS OF CORES

Lithological features and ostracod content of boreholes are given below.

Core: TK-1102

(Figure 5) is 62 cm thick in total and was collected where the lagoon water depth was 60 cm, in the western part of Akyatan lagoon. The core begins with a

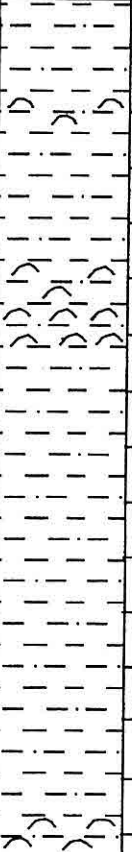
H O L O C E N E				AGE	LITHOLOGY (Tk - 1102)	SAMPLE NUMBER	EXPLANATION	OSTRACODA															
				1	Silty clay, (light olive grey)	1	Silty clay, (light olive grey)	Cyprideis torosa (Jones)	*														
				2		2		*															
				3	Shelly layer	3		*															
				4		4		*															
				5	Shelly layer	5		*	*		*												
				6		6		*	*	*		*											
				7		7		*	*		*												
				8		8		*															
				9	Silty clay, dark grenish grey, vertical streaks (along burrows)	9		*			*												
				10		10		*	*		*												
				11		11		*		*		*											
				12		12		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
				13	Shelly layer	13		*	*		*		*		*		*		*		*		*
				14		14		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
				15		15		*		*		*		*		*		*		*		*	
				16		16		*															

Figure 5. Distribution of Ostracoda and lithological feature in the Core TK-1102

shelly layer in the lower part. This zone is overlain by dark greenish grey silty-clay with vertical streaks (along burrows) and passes upward into a second shelly layer and silty-clay levels. *Cyprideis torosa* Jones is a common ostracod in all samples separated from this core. *Cyprideis torosa* Jones, *Eucypris dulcifons* (Diebel and Pietrzenuik, *Candona* sp1, *Candona* sp2, *Lymnocythere inopinata* (Baird), *Ilyocypris biplicata* (Koch), *Leptocythere lacertosa* (Hirsmann) are observed first 35 cm from the bottom of core. *Cyprideis torosa* Jones and *Lymnocythere inopinata* (Baird) are common between 35-25 cm. The number of Ostracods decreases *Cyprideis torosa*, *Heterocypris salina*, *Eucypris dulcifons*, *Ilyocypris gibba*, *I. biblicata*, *Lymnocythere inopinata* are common at the second shelly layer. But, *Cyprideis torosa* is only observed at the last 15 cm of the core.

Core no: TK-1075

The thickness of this core is 48 cm (Figure 6). This core generally consist of silty clay. *Cypridies torosa* Jones and *Candona* (C.) *parallela pannonica* (Zalanyi) are common ostracods between 48-30 cm. *Cyprideis torosa*, *Eucypris dulcifons*, *Candona neglecta*, *Candona* (C.) *parallela pannonica*, *Ilyocypris gibba*, *Lymnocythere inopinata*, *Leptocythere lacertosa* are observed through upwards. *Cardium* fragments are observed in the lower 15 cm of this core.

Core no: TK-1064

The total thickness of this core is 115

cm (Figure 7). The lower part includes light olive grey coloured silty clay with shells. This part passes upward into a detritus peat, silty-clay and a yellowish brown coloured organic material rich level. These two zones are overlain by silty clay, silty sand and a shelly layer. *Cyprideis torosa*, *Heterocypris salina*, *Eucypris dulcifons*, *Candona neglecta*, *Candona angulata*, *Ilyocypris gibba*, *Darwinula stevensoni*, *Leptocythere lacertosa*, *Lymnocythere inopinata* are distinguished at the silty-clay level (between 115-80 cm). A few ostracods (*Cyprideis torosa* and *Candona* (C.) *parallela pannonica* identified at the level of detritus peat and organic rich, silty-clay. But, Ostracods are rich above the lower parts. Generally *Cyprideis torosa*, *Heterocypris salina*, *Eucypris dulcifons*, *Candona neglecta*, *Candona angulata*, *Ilyocypris gibba*, *Ilyocypris biplicata*, *Darwinula stevensoni*, *Leptocythere lacertosa*, *Lymnocythere inopinata*, are common between 75-20 cm of this core.

Core No: TK-1044

The core (Figure 8) is 95 cm in thickness. Generally, this core consists of dark greenish grey coloured silty clay. A silty-clayey-peaty organic layer with small gastropods occurs between 75-55 cm. A muddy skeletal sand with gastropods and *Cardium* sp are observed at the uppermost levels of this core. *Cyprideis torosa*, *Loxoconcha elliptica*, *Candona* sp.1, *Candona angulata*, *Darwinula stevensoni*, *Leptocythere*

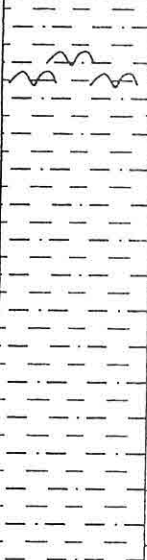
H O L O C E N E			AGE	LITHOLOGY (Tk - 1075)	SAMPLE NUMBER	EXPLANATION	OSTRACODA																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																		
			1	Light olive grey silty clay with <i>Cardium</i> fragments at the base, (this horizon noticeably softer than underlying material)			Cyprideis torosa (Jones)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																		

Figure 6. Distribution of Ostracoda and lithological feature in the Core TK-1075

lacertosa, *Aurila convexa* are identified between 95-75 cm. *Cyprideis torosa* is only observed at the organic layer. *Cyprideis torosa*, *Loxoconcha elliptica*, *Loxoconcha rhomboidea*, *Candona (C.) parallela pannonica*, *Candona angulata*, *Darwinula stevensoni*, *Leptocythere lacertosa* are distinguished in samples of upper 55 cm of the core.

A panel diagram (Figure 19 has been generated, using the total microfossil association and other data (sedimentological, geomorphological investigations and lithology) to show the differences and changes between the lagoon sediments from west to east and bottom to top.

This diagram clearly shows that the

SEDIMENTOLOGY AND PALEONTOLOGY WITH SPECIAL REFERENCE TO THE
OSTRACODA FAUNA OF AKYATAN LAGOON

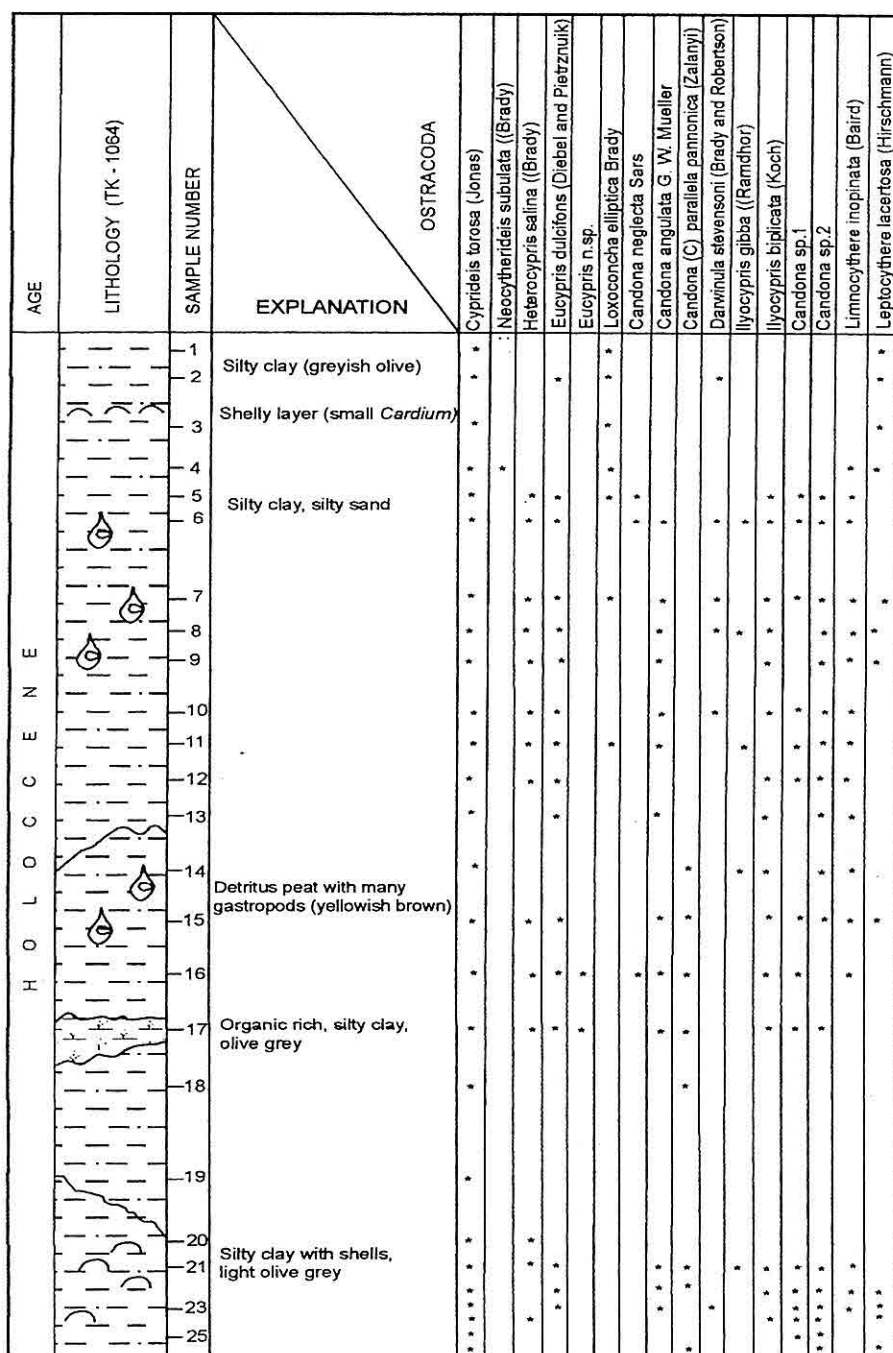


Figure 7. Distribution of Ostracoda and lithological feature in the Core TK-1064

AGE	LITHOLOGY (TK1044)	SAMPLE NUMBER	EXPLANATION	OSTRACODA																
H O L O C E N E		1	Muddy skeletal sand, shelly layer, gastropod and <i>Cardium</i>	*	*	*	*													
		2		*	*	*	*													
		3	Silty clay, greenish grey, scattered shell mainly <i>Cardium</i> , plant a weed, skeletal sand packet and layers dun	*	*	*	*							*	*	*	*	*	*	*
		4		*	*	*	*							*	*	*	*	*	*	*
		5		*	*	*	*							*	*	*	*	*	*	*
		6		*	*	*	*							*	*	*	*	*	*	*
		7		*	*	*	*							*	*	*	*	*	*	*
		8		*	*	*	*							*	*	*	*	*	*	*
		9		*	*	*	*							*	*	*	*	*	*	*
		10	Silty clay	*	*	*	*							*	*	*	*	*	*	*
		11		*	*	*	*							*	*	*	*	*	*	*
		12		*	*	*	*							*	*	*	*	*	*	*
		13		*	*	*	*							*	*	*	*	*	*	*
		14		*	*	*	*							*	*	*	*	*	*	*
		15	Silty clayey peaty organic layer, olive black, with small gastropod.	*	*	*	*		*		*	*			*	*	*	*	*	*
		16		*	*	*	*		*		*	*			*	*	*	*	*	*
		17		*	*	*	*		*		*	*			*	*	*	*	*	*
		18		*	*	*	*		*		*	*			*	*	*	*	*	*
		19		*	*	*	*		*		*	*			*	*	*	*	*	*
		20	Silty clay, dark greenish grey, with streaks and plant roots and shell layer.	*	*	*	*		*	*	*	*		*	*	*	*	*	*	*
		21		*	*	*	*		*		*	*			*	*	*	*	*	*
		22		*	*	*	*		*		*	*			*	*	*	*	*	*
		23		*	*	*	*		*		*	*			*	*	*	*	*	*
		24		*	*	*	*		*		*	*			*	*	*	*	*	*
		25		*	*	*	*		*		*	*			*	*	*	*	*	*
				<i>Cyprideis torosa</i> (Jones)	<i>Heterocypris salina</i> (Brady)	<i>Eucypris dulzions</i> (Diebel and Pleizenuik)	<i>Loxconcha elliptica</i> Brady	<i>Candona neglecta</i> Sars	<i>Candona angulata</i> G. W. Mueller	<i>Candona</i> (C) <i>parallela pannonica</i> (Zalanyi)	<i>Candona</i> sp.1	<i>Danubula sleversoni</i> (Brady and Robertson)	<i>Ilyocypris gibba</i> (Ramdhor)	<i>Ilyocypris bicipitata</i> (Koch)	<i>Limnocythere inopinata</i> (Baird)	<i>Leptocythere laceratosa</i> (Hirschmann)	<i>Loxconcha rhomboidea</i> Fisher	<i>Aurila convexa</i> (Sars)	<i>Carinocythereis antiquata</i> (Baird)	

Figure 8. Distribution of Ostracoda and lithological feature in the Core TK-1044

lagoon was less restricted formerly or had a larger inlet, in the southeastern extremity, and then became more enclosed and restricted. Samples from the marginal parts contain brackish indicators.

4. CONCLUSIONS

Rising sea level during the Flandrian transgression caused the landward displacement of a coastal beach-dune barrier, fed by littoral drift from the local river mouths. The barrier enclosed a

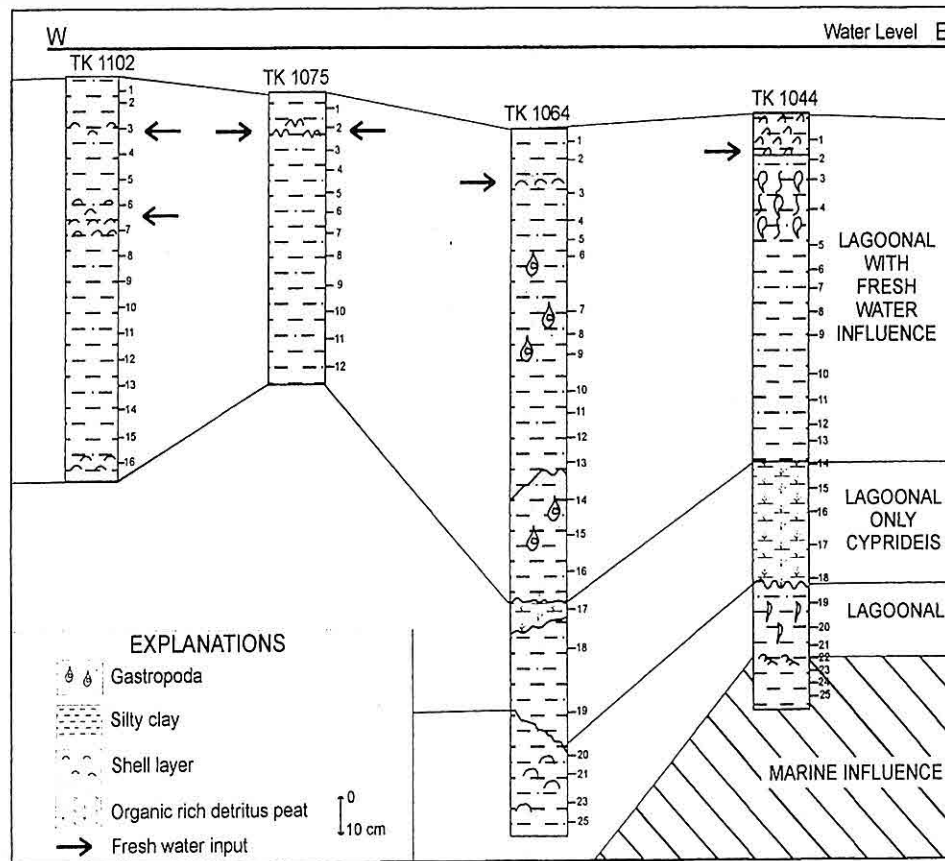


Figure 9. Correlation of cores from west to east of the study area.

protected lagoonal environment where fine-grained sediment accumulated to lie transgressively over older fluvial clays. As the rise of sea level slowed and the shoreline position became more stable, continued supply of sand caused the progradation of the coastal beach-dune barrier by littoral transport from the adjacent Seyhan and infilling of the lagoon by crevassing of the Seyhan and flow through the old course of Ceyhan.

The study of the cores illustrates this gradual filling and with restriction and

isolation of the environment as the inlet which connected it to the open Mediterranean became smaller and less important.

15 Ostracoda species were determined from four cores. This was a great abundance and low diversity assemblage. Generally *Cyprideis torosa* (Jones) is common at all levels. *Ilyocypris biplicata* (Koch), *Lymnocythere inopinata* (Baird) and *Candona* sps are abundant in the shell layer is indicating the influx of fresh water.

Today, the lagoon is kept open artificially and only receives water and sediment from natural sources very rarely due to river avulsion, which may have been caused by man and other manmade changes. Instead, the sediment is mainly produced by erosion of the lagoon shoreline and local production of skeletal and organic matter together with supply during floods from drainage/irrigation canals.

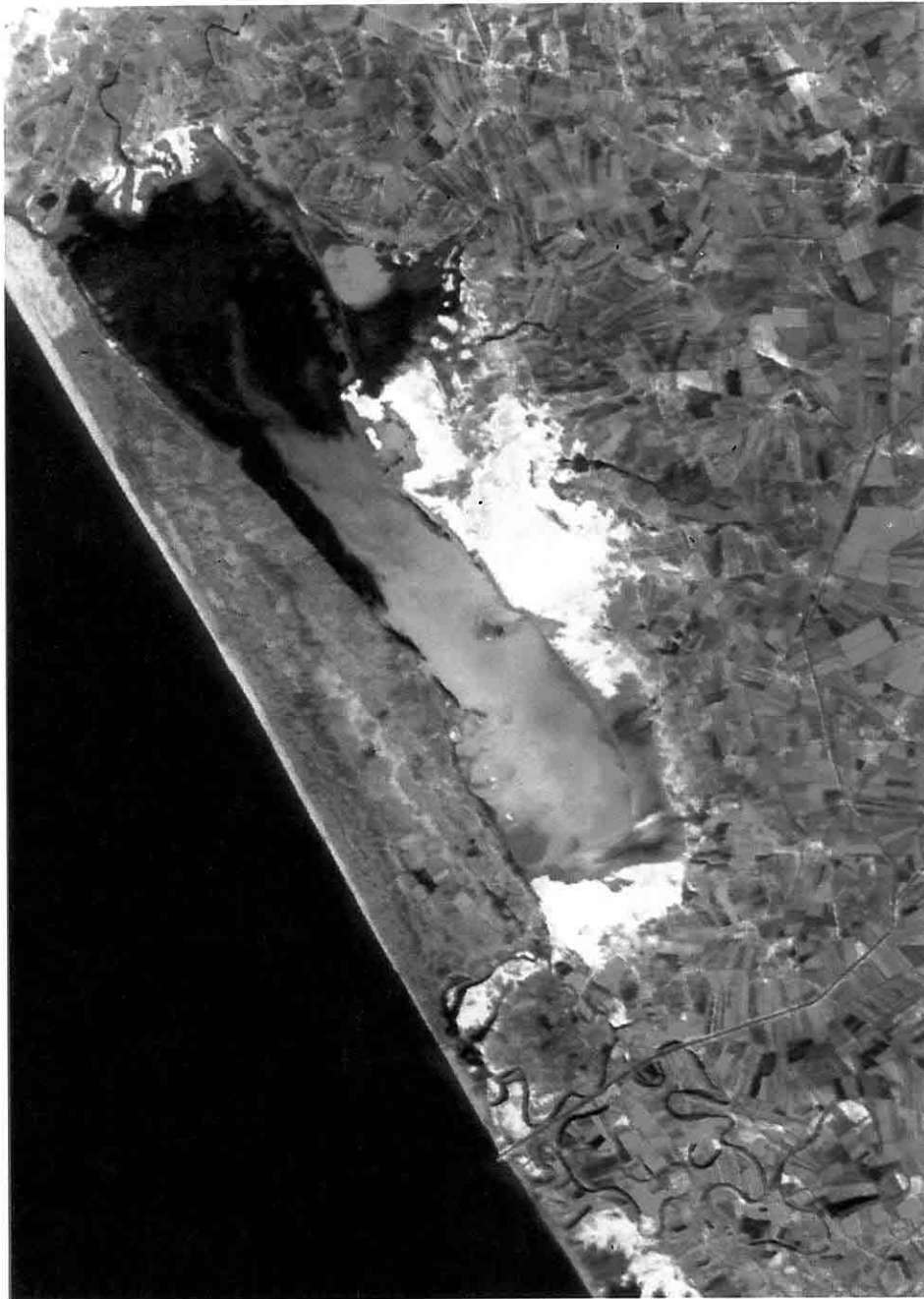
5. ACKNOWLEDGEMENTS

Authors would like to thank members of Southampton Oceanography Centre and Geology Department for their kindness and help. A special thanks to Dr. Süha BERBEROĞLU (Ç.U. Peyzaj Mimarlığı) supplying the satellite imagery of the area.

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PLATE I



Satellite imagery of the study area.

PLATE II

Figure 1. *Ilyocypris gibba* Ramdhor. Right valve, outer view

Figure 2. *Ilyocypris biplicata* (Koch). Right valve, outer view

Figure 3-4. *Lymnocythere inopinata* (Baird). Left valve, outer view

Figure 5-8. *Cyprideis torosa* Jones. **5.**Left valve, **6.** Right valve, **7.** Left valve-
inner view, **8.** Right valve,

PLATE II

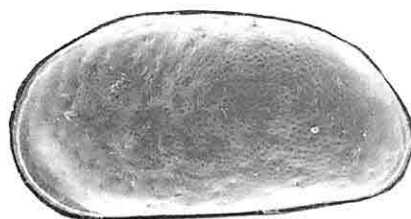
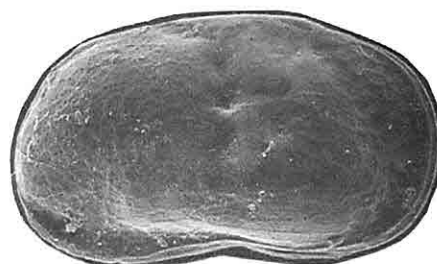
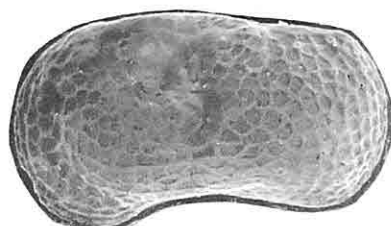
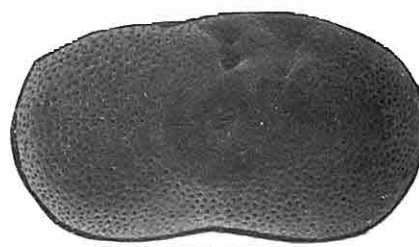
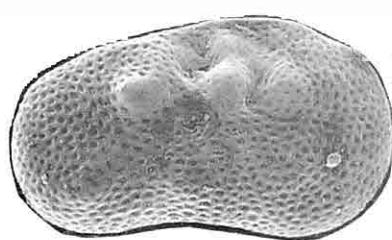


PLATE III

Figure 1. *Heterocypris salina* (Brady). Right valve, outer view

Figure 2. *Eucypris dulcifons* (Diebel&Pietrzenuik). Left valve, outer view

Figure 3. *Eucypris* n.sp. Right valve, outer view

Figure 4-5. *Candona angulata* G.W.Mueller. **4.** Left valve, inner view,

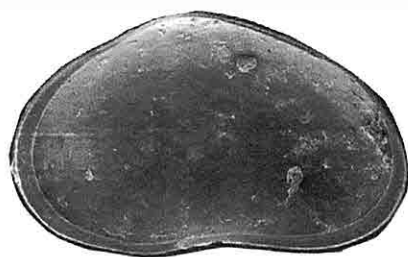
5. Left valve, outer view

Figure 6-7. *Candona (Candona) parallela pannonica* (Zalanyi)

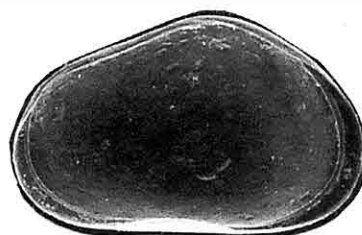
8. Right valve, outer view,

7. Left valve, inner view

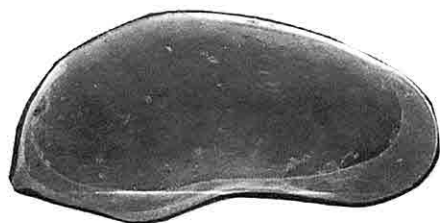
PLATE III



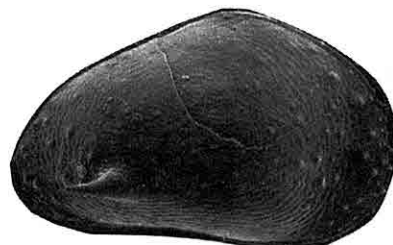
— 100µm 1



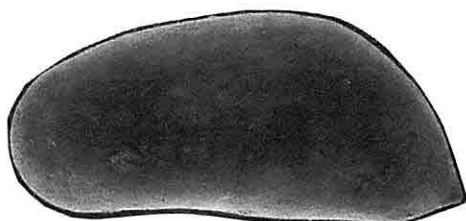
— 100µm 2



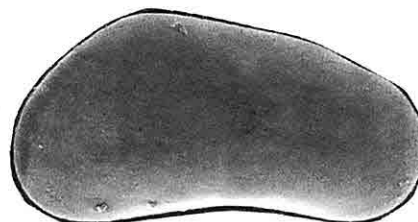
— 100µm 4



— 100µm 3



— 100µm 5



— 100µm 6



— 100µm 7



— 100µm 8

Plate IV

Figure 1. *Candona* sp.1. Right valve, outer view

Figure 2. *Candona* sp.2. Left valve, outer view

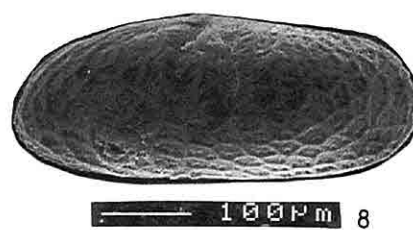
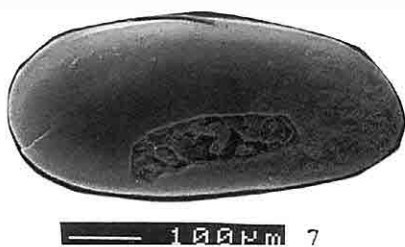
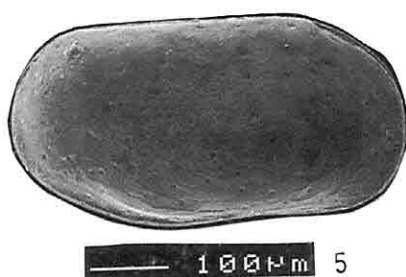
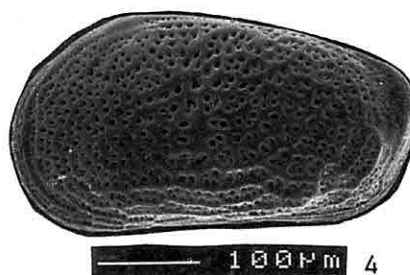
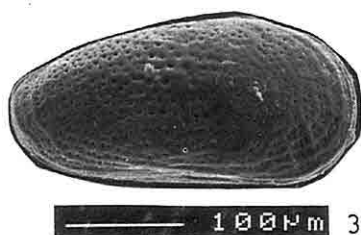
Figure 3-4. *Leptocythere lacertosa* (Hirschmann). **3.** Right valve, outer view,
4. Left valve, outer view

Figure 5-6. *Loxoconcha elliptica* Brady. **5.** Right valve, outer view, **6.** Right valve,
inner view

Figure 7. *Darwinula stevensoni* (Brady and Robertson). Right valve, outer view.

Figure 8. *Neocytherideis subulata* (Brady). Left valve, outer view.

PLATE IV



RECENT OSTRACODA ASSEMBLAGE OF THE GÖKÇEADA-BOZCAADA- ÇANAKKALE REGION

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ABSTRACT: In this study, 15 samples, recovered from depth were examined and evaluated for the ostracoda assemblage in the region of Gökçeada, Bozcaada and Çanakkale (Northeastern Aegean Sea). Ostracodes of Holocene (Late Quaternary) belong to 15 family, which consist of 37 genera and 61 species .

Observed fauna was compared to the previous investigations, carried out within the various parts of Aegean Sea, Marmara Sea, Mediterranean and Atlantic Ocean. Described fauna in this study area, such as *Cytherella vandenboldi* Sissingh, *C. vulgata* Ruggieri, *Callistocythere littoralis* (Müller), *C. intricatoides* (Ruggieri); *C. pallida* (Müller), *C. montana* Doruk, *Cyprideis torosa* (Jones), *Pterygocythereis ceratoptera* (Bosquet), *P. jonesii* (Baird), *Buntonia sublatissima sublatissima* (Neviani), *Urocythereis margaritifera* (Mueller), *U. sororcula* (Sequenza), *Caudites calceolatus* (Costa), *Bosquetina carinella* (Reuss), *B. dentata* (Müller), *Semicytherura acuminata* (Mueller), *S. acuticostata* (Sars), *S. dispar* (Mueller), *S. inversa* (Sequenza), indicates that close relation to the fauna observed in the region of Aegean Sea and Marmara Sea.

Another ostracod species, such as *Cushmanidea elongata* (Brady), *Neocythereideis cylindrica* (Brady), *Olimfalunia quadridentata* (Baird), *Loxoconcha turbida* Müller, *L. granulata* Sars, *Paracytheridea depressa* (Mueller), *Eucytherura gibbera* Mueller, *Xestoleberis aurantia* (Baird), *Aglaocypris complanata* Brady & Robertson were similar with the fauna described in the region of Mediterranean and Atlantic Ocean.

Ostracod species of *Cytheridea acuminata neapolitana* Kollmann, *C. acuminata acuminata* Bosquet, *Acanthocythereis hystrix* (Reuss), *Carinocythereis carinata* (Roemer), *C. antiquata* (Baird), *Urocythereis margaritifera* (Mueller), *Cyclopyris globosa* (Sars) were widely observed in the region of Mediterranean, Aegean Sea and Marmara Sea.

The fauna of the study was generally observed in muddy and sandy samples between Gökçeada and Bozcaada, and at the beginning and final locations of the Bosphorus Dardanelles. In general, ostracodes have epineritic-infraneritic and bathyal zone features. Otherwise, some samples, including marine ostracodes as well as brackish and littoral specimens, represent fresh water derived from continents and deep sea flour fresh water springs in the near field.

1. INTRODUCTION

The purpose of this research is to examine Late Quaternary ostracoda fauna of the Gökçeada-Bozcaada-Çanakkale-Region, and to describe their environments.

The study area is located between Gökçeada-Bozcaada-Çanakkale (Figure 1). The research has been carried out as a part of the Research Project of the Tübitak National Marine Geology and Geophysics. The project was partly submitted for the dissertation of Master of science by Işık (1998), and a research related to the project was completed in the Faculty of Science of the University of Ankara by Işık and Taner (1997). Fine detrital samples were given myself after the dissertation and the research have been completed. Ostracodes were separated and described from the present samples, and their photographs were taken.

Detailed geological and paleontological researches were carried out in the region of Gökçeada-Bozcaada-Çanakkale by Erol and Nuttall (1973), Gökçen (1976), Taner (1977, 1981, 1997), Erol (1987), Şentürk et al. (1987), Ergin et al. (1990).

2. GEOGRAPHIC AND ENVIRONMENTAL DISTRIBUTION OF OSTRACOD SPECIES

In this research, 15 samples recovered from depth were examined and belong to Cytherellidae, Bairdiidae, Leptocytheridae, Cytherideidae, Cushmanideidae, Neocytherideidae,

Trachyleberididae, Loxoconchidae, Paracytherideidae, Cytheruridae, Xestoleberididae, Darwinulidae, Macrocyprididae, Pontocyprididae, Candonidae families 61 ostracoda specimens were described (Plate I-VII).

Sample depths are given as follow:

-Samples with the number of 4, 7, 8, 9, 14 were collected from the muddy lithology having 58, 63, 63, 79, 64 m water depth in the Dardanelles Strait.

-Sample no. 35 was collected from the muddy sand lithology of the 29 m water depth within the exit of the Dardanelles Strait.

-Sample no. 76 collected from the muddy sand lithology, having 45 m water depth, between Gökçeada and Bozcaada.

-Sample no. 83, collected from the very few clayey sand lithology of the 45 m water depth to the north of Bozcaada.

-Sample no. 87, collected from the sand unit, at water depth of 72 m to the south-southern part of Gökçeada.

-Sample no. 95, collected from the sand and gravely sand lithology of the 74 m water depth between Gökçeada and Bozcaada.

-Sample no. 99, collected from very few clayey sand lithology of the 50 m water depth to the north of Bozcaada.

-Sample no. 108 and 110, collected from the sandy unit of the 76 and 46 m water depth to the south of Gökçeada.

-Sample no. 120 and 131, collected from the sandy mud lithology of the 39 and 82 m water depth to the west of Bozcaada.

Geographical distribution of ostracod

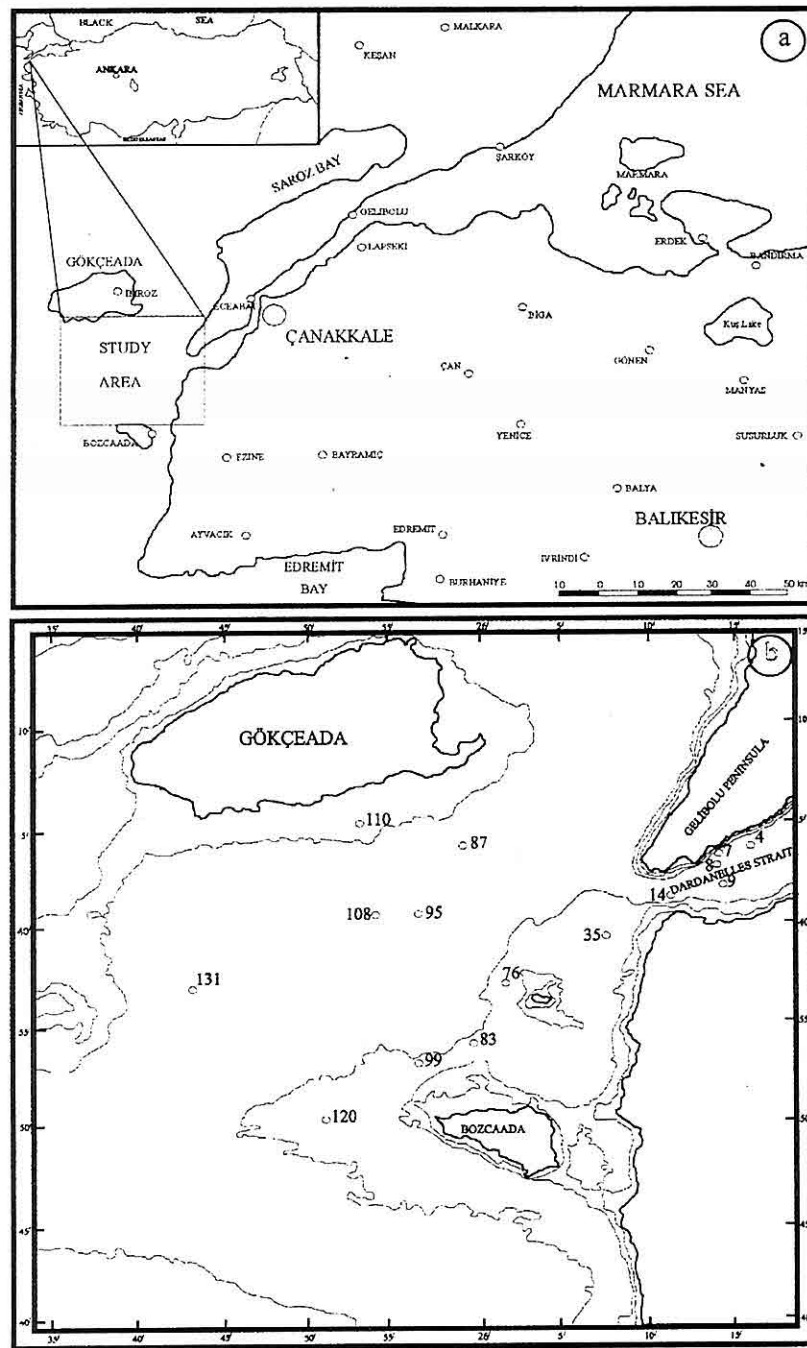


Figure 1. (a) Location map of the study area. (b) Location map of samples.

PLATE I

- Figure 1-2:** *Cytherella vandenboldi* Sissingh. **1.** Left valve, outside view, X40, Sample number 4. **2.** Right valve, outside view, X40, Sample number 131.
- Figure 3-5:** *Cytherella vulgata* Ruggieri. **3.** Right valve, outside view, X100, Sample number 7. **4.** Right valve, outside view, X60, Sample number 131. **5.** Right valve, outside view, X100, Sample number 8.
- Figure 6:** *Bairdia formosa* Brady. Left valve, outside view, X40, Sample number 76.
- Figure 7:** *Bairdia mediterranea* Müller. Right valve, outside view, X57, Sample number 131.
- Figure 8:** *Bairdoppilata supradentata* (Terquem). Carapace, right side view, X55, Sample number 108.
- Figure 9:** *Leptocythere* cf. *rastrifera* Ruggieri. Left valve, outside view, X70, Sample number 99.

PLATE I

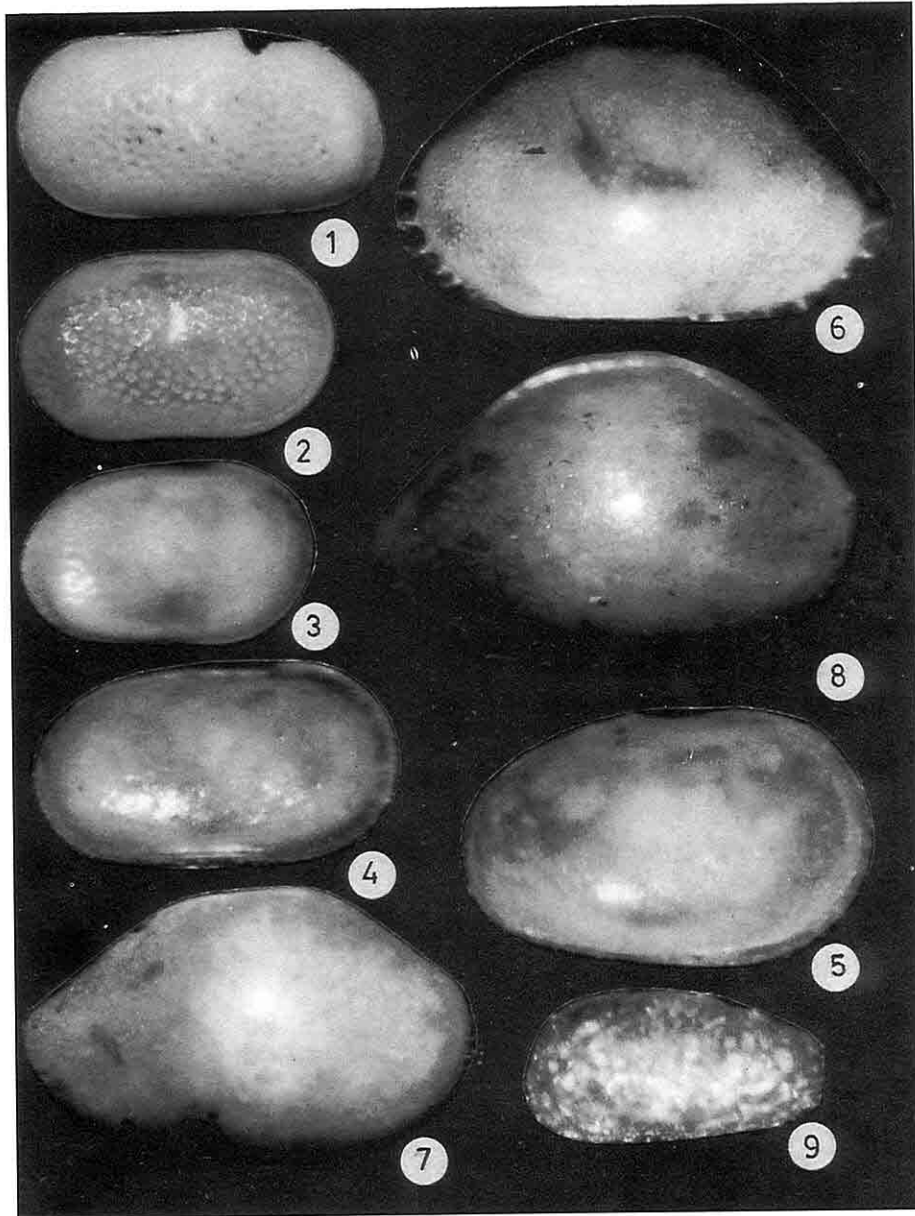


PLATE II

- Figure 1:** *Leptocythere* cf. *psammophila* Guillaume. Carapace, left side view, X75, Sample number 7.
- Figure 2:** *Callistocythere montana* Doruk. Right valve, outside view, X75, Sample number 131.
- Figure 3:** *Callistocythere intricatoides* (Ruggieri). Left valve, outside view, X80, Sample number 76.
- Figure 4:** *Callistocythere pallida* (Müller). Right valve, outside view, X60, Sample number 4.
- Figure 5:** *Cyprideis torosa* (Jones). Right valve, outside view, X65, Sample number 131.
- Figure 6:** *Cytheridea acuminata neapolitana* Kollmann. Left valve, outside view, X50, Sample number 4.
- Figure 7:** *Cytheridea acuminata acuminata* Bosquet. Left valve, outside view, X45, Sample number 4.
- Figure 8:** *Cushmanidea elongata* (Brady). Right valve, outside view, X40, Sample number 99.
- Figure 9:** *Carinocythereis carinata* (Roemer). Left valve, outside view, X50, Sample number 99.
- Figure 10:** *Carinocythereis antiquata* (Baird). Right valve, outside view, X70, Sample number 131.
- Figure 11:** *Costa edwardsii* (Roemer). Carapace, right side view, X50, Sample number 4.

PLATE II

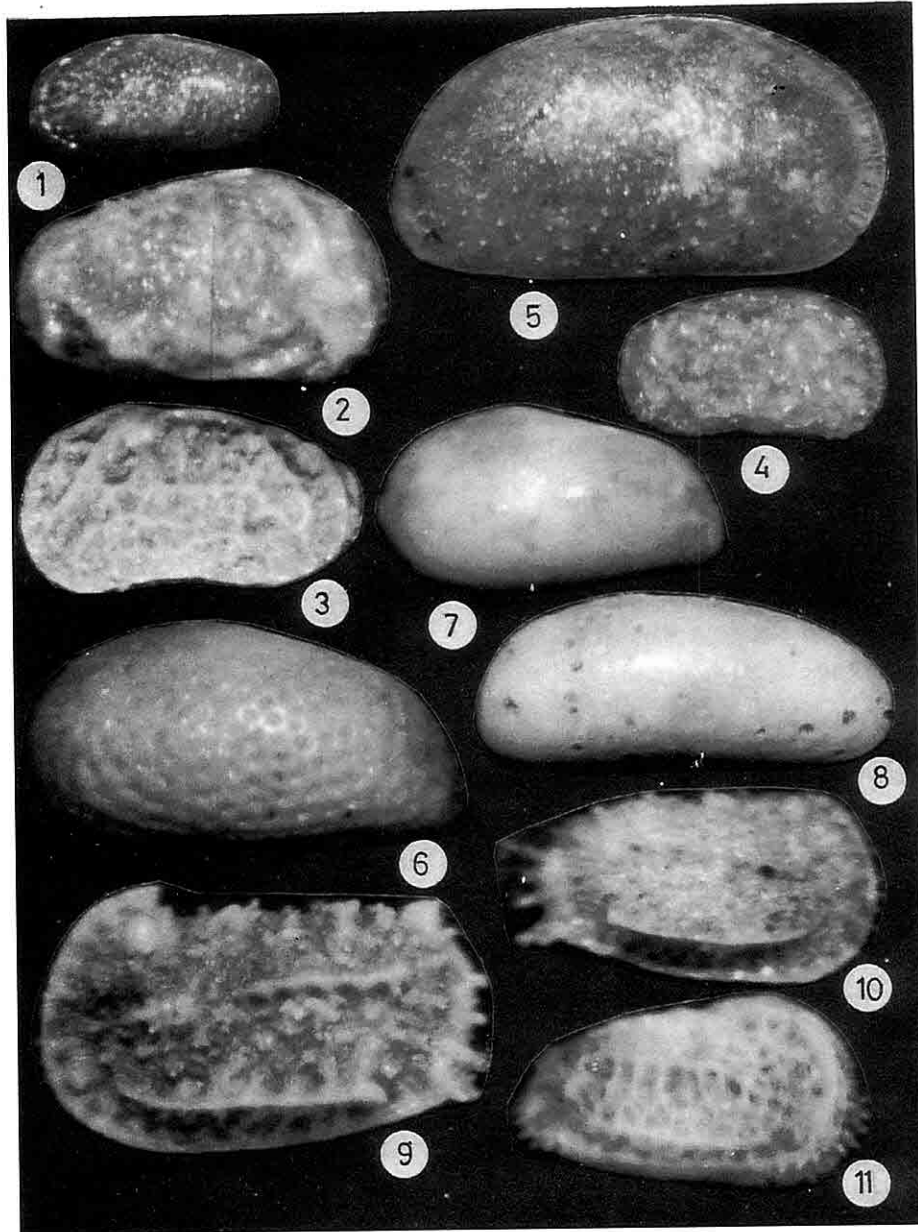


PLATE III

- Figure 1:** *Olimfalunia quadridentata* (Baird). Left valve, outside view, X80, Sample number 99.
- Figure 2:** *Olimfalunia (Hiltermanicythere) rugosa* (Costa). Left valve, outside view, X70, Sample number 131.
- Figure 3:** *Pterygocythereis ceratoptera* (Bosquet). Left valve, outside view, X80, Sample number 76.
- Figure 4:** *Pterygocythereis jonesii* (Baird). Right valve, outside view, X60, Sample number 95.
- Figure 5:** *Echinocythereis laticarina* (Brady). Left valve, outside view, X60, Sample number 87.
- Figure 6:** *Henryhowella sarsii* (Müller). Right valve, outside view, X80, Sample number 131.
- Figure 7:** *Buntonia subulata subulata* Ruggieri. Left valve, outside view, X70, Sample number 4.
- Figure 8:** *Buntonia sublatissima sublatissima* (Neviani). Carapace, left side view, X70, Sample number 4.
- Figure 9:** *Aurila speyeri* (Brady). Carapace, right side view, X50, Sample number 108.
- Figure 10:** *Aurila convexa* (Baird). Right valve, outside view, X70, Sample number 7.

PLATE III

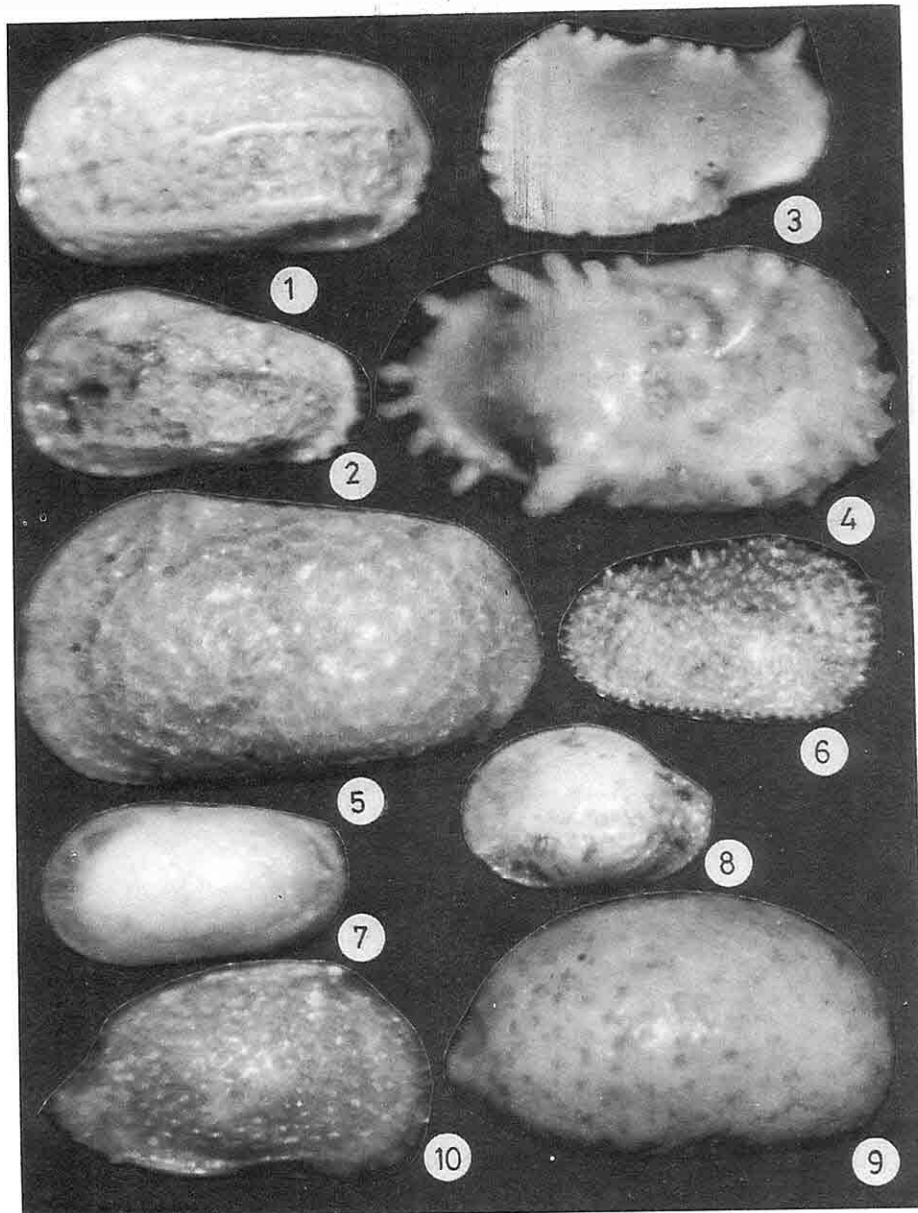


PLATE IV

- Figure 1-3:** *Aurila convexa* (Baird). **1.** Right valve, outside view, X70, Sample number 95. **2.** Left valve, outside view, X75, Sample number 95. **3.** Right valve, outside view, X65, Sample number 99.
- Figure 4:** *Quadracythere (Tenedocythere) prava* (Baird). Carapace, right side view, X50, Sample number 120.
- Figure 5:** *Urocythereis oblonga* (Brady). Carapace, left side view, X50, Sample number 87.
- Figure 6:** *Urocythereis sororcula* (Sequenza). Left valve, outside view, X80, Sample number 95.
- Figure 7:** *Urocythereis margaritifera* (Mueller). Right valve, outside view, X60, Sample number 95.

PLATE IV

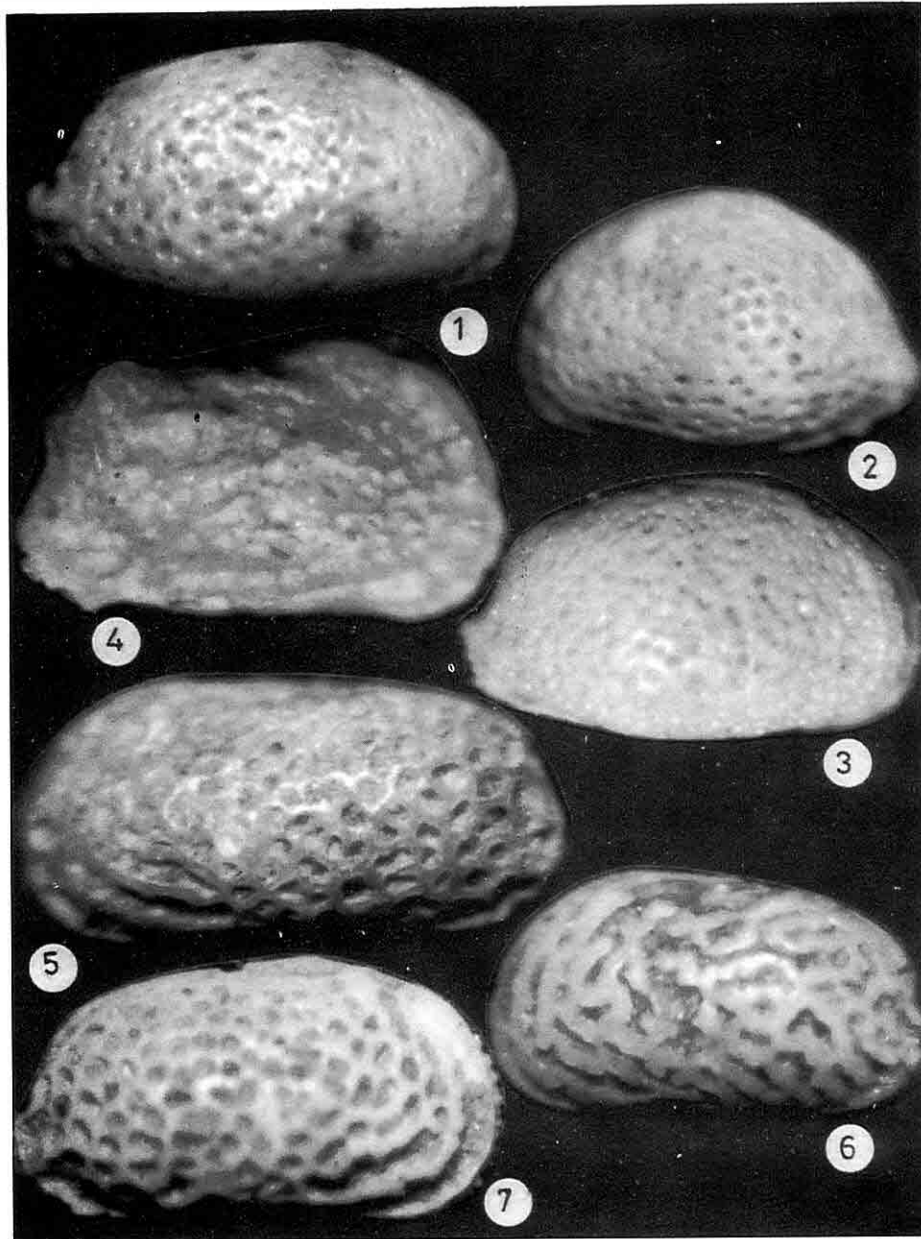


PLATE V

Figure 1: *Caudites calceolatus* (Costa). Left valve, outside view, X80, Sample number 99.

Figure 2-3: *Bosquetina carinella* (Reuss). **2.** Right valve, outside view, X50, Sample number 110. **3.** Right valve, inside view, X50, Sample number 110.

Figure 4: *Bosquetina dentata* (Müller). Right valve, outside view, X60, Sample number 95.

Figure 5: *Loxoconcha tumida* Brady. Left valve, outside view, X100, Sample number 99.

Figure 6: *Loxoconcha mediterranea* Müller. Right valve, outside view, male, X70, Sample number 76.

Figure 7: *Loxoconcha rhomboidea* (Fischer). Carapace, right side view, male, X100, Sample number 35.

PLATE V

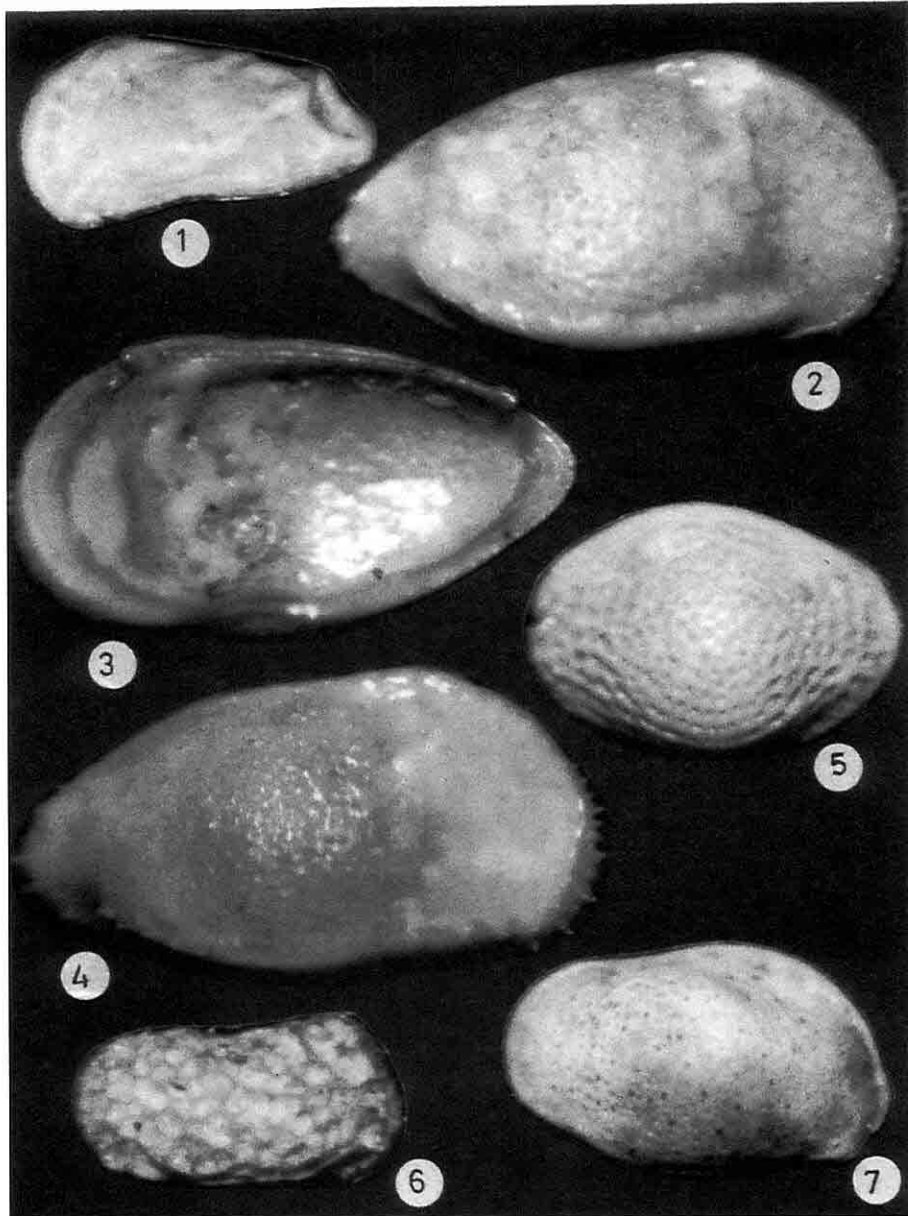


PLATE VI

- Figure 1:** *Loxoconcha granulata* Sars. Right valve, outside view, X100, Sample number 131.
- Figure 2:** *Semicytherura acuminata* (Mueller). Left valve, outside view, X100, Sample number 35.
- Figure 3:** *Semicytherura sulcata* (Mueller). Right valve, outside view, X100, Sample number 76.
- Figure 4:** *Semicytherura inversa* (Sequenza). Right valve, outside view, X100, Sample number 99.
- Figure 5:** *Semicytherura acuticostata* (Sars). Left valve, outside view, X100, Sample number 76.
- Figure 6-7:** *Cytheropteron latissimum* (Norman). **6.** Left valve, outside view, X100, Sample number 76. **7.** Left valve, side view, X100, Sample number 76.
- Figure 8-9:** *Xestoleberis depressa* Sars. **8.** Left valve, outside view, X100, Sample number 99. **9.** Carapace, left side view, X100, Sample number 95.
- Figure 10-11:** *Xestoleberis aurantia* (Baird). **10.** Left valve, inside view, X100, Sample number 76. **11.** Left valve, outside view, X100, Sample number 76.

PLATE VI

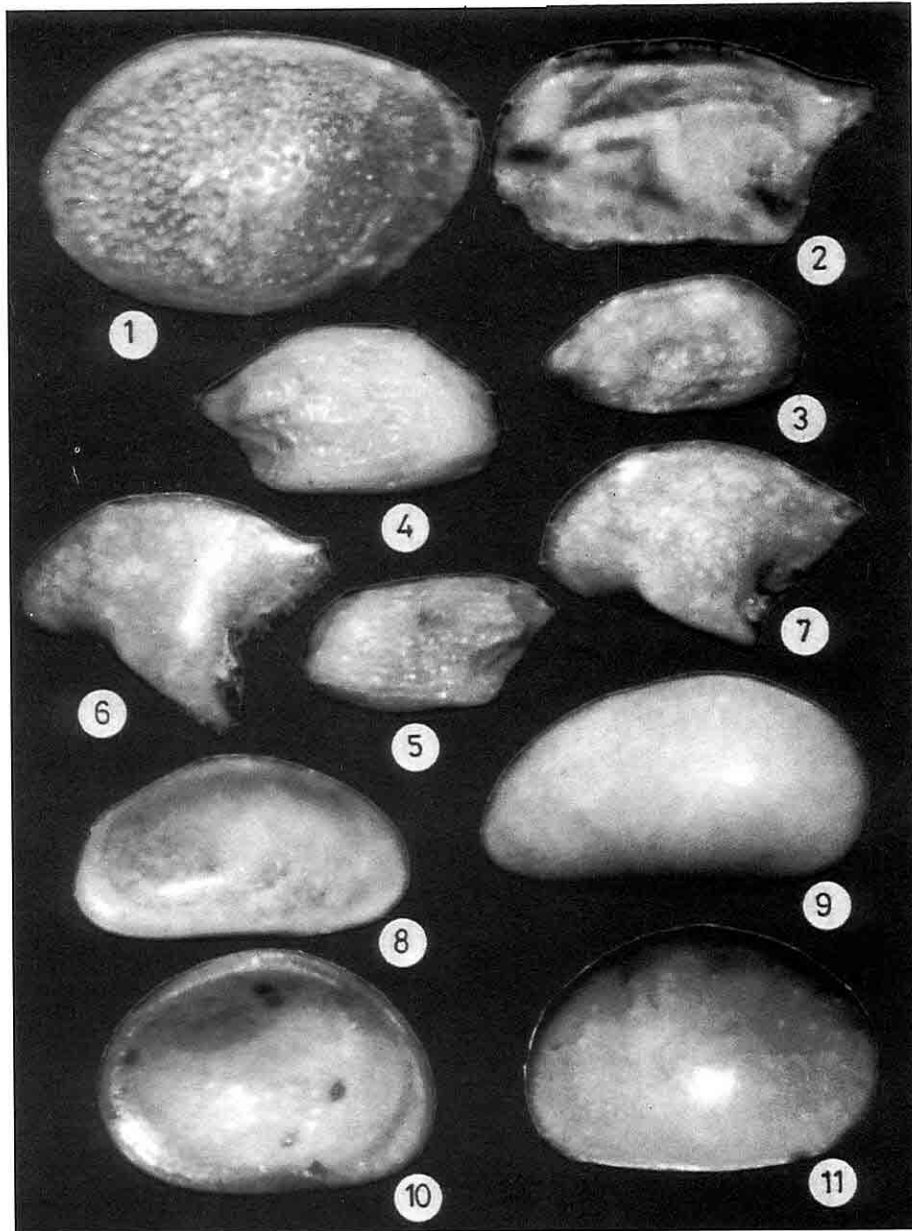


PLATE VII

Figure 1-3: *Xestoleberis* sp. **1.** Left valve, outside view, X90, Sample number 95. **2.** Carapace, right side view, X90, Sample number 35. **3.** Left valve, inside view, X100, Sample number 7.

Figure 4: *Darwinula cylindrica* Straub. Left valve, outside view, X70, Sample number 76.

Figure 5: *Macrocypris* sp. Left valve, outside view, X100, Sample number 131.

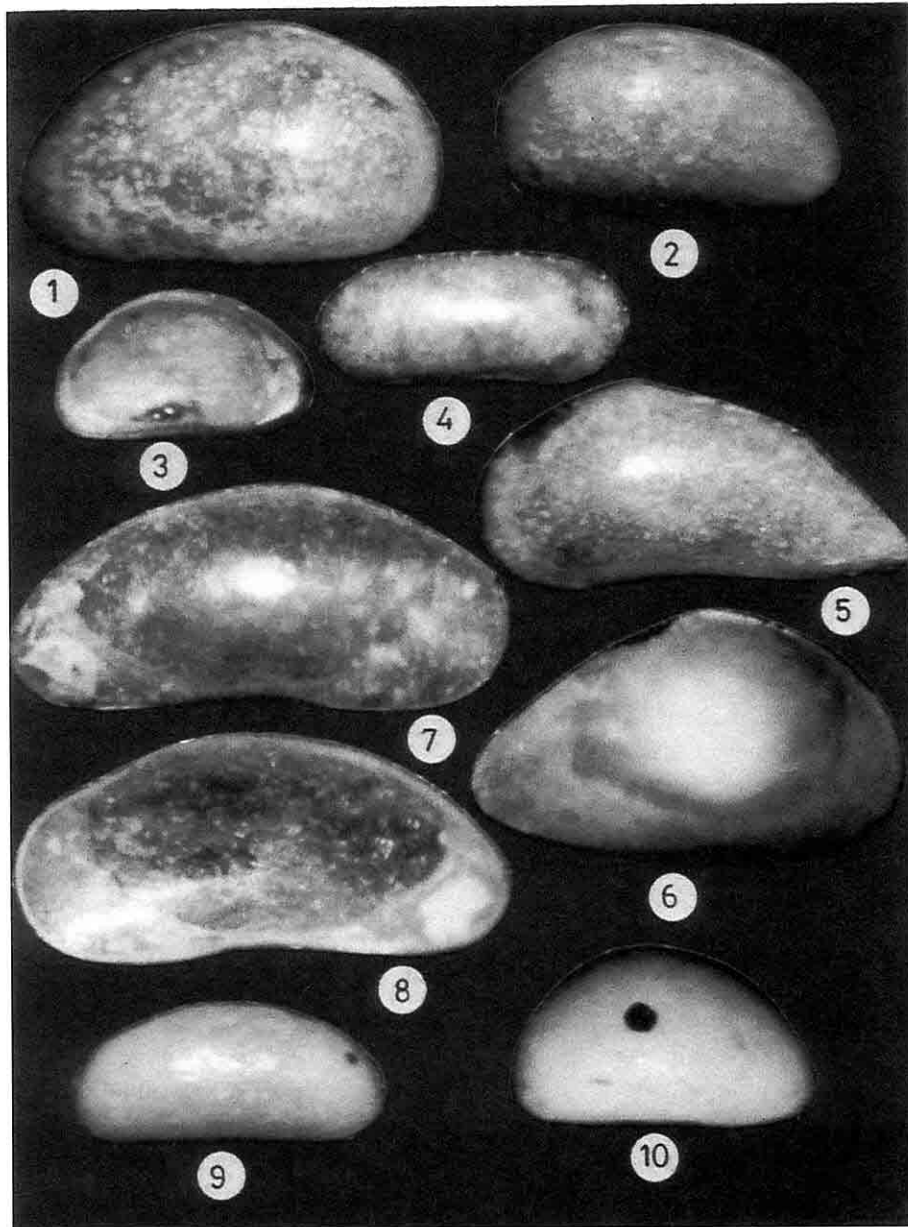
Figure 6: *Pontocypris rara* (Müller). Left valve, outside view, X65, Sample number 131.

Figure 7-8: *Argilloecia conoidea* (Sars). **7.** Right valve, outside view, X65, Sample number 35. **8.** Right valve, inside view, X65, Sample number 35.

Figure 9: *Aglaiocypris complanata* Brady ve Robertson. Right valve, outside view, X100, Sample number 131.

Figure 10: *Cyclocypris* sp. Right valve, outside view, X110, Sample number 131.

PLATE VII



species were prepared from the previously published works which carried out at coastal zone of the Aegean Sea, the Mediterranean and the Atlantic Ocean (Sissingh, 1972; Uffenorde, 1972; Ruggieri, 1976; Gökçen, 1976; Yassini, 1979; Guillaume et al., 1985; Nazik, 1994; Gülen et al., 1995; Tunoğlu, 1996, 1998; Nazik, 1998) (Table 1).

The geographical distribution of ostracod species, observed in the study as follows; *Cytherella vandenboldi* Sissingh, *C. vulgata* Ruggieri, *Bairdia formosa* Brady in the Aegean Sea; *Cyprideis torosa* (Jones), *Cytheridea acuminata neapolitana* Kollmann, *Acanthocytheris hystrix* (Reuss), *Carinocytheris carinata* (Roemer), *C. antiquata* (Baird), *Aurila speyeri* (Brady), *A. convexa* (Baird), *Quadracythere (Tenedocythere) prava* (Baird), *Urocythereis sororcula* (Sequenza), *U. oblonga* (Brady), *Loxoconcha rhomboidea* (Fischer) in the Atlantic, Mediterranean and Aegean Sea; *Callistocythere littoralis* (Müller), *Pterygocythereis ceratoptera* (Bosquet), *P. jonesii* (Baird), *Bosquetina dentata* (Müller), *Semicytherura acuticostata* (Sars) in the Quaternary sediments of the Marmara Sea, Mediterranean and Atlantic Ocean (Gökçen, 1976; Nazik, 1994; Tunoğlu, 1996, 1998; Gülen et al., 1990, 1995; Sissingh, 1972; Uffenorde, 1972; Ruggieri, 1976; Guillaume et al., 1985; Stambolidis, 1985; Kubanç, 1989; Kubanç, 1995; Meriç et al., 1995).

Otherwise, identified specimens in the study, such as *Callistocythere montana* Doruk, *Cyprideis torosa* (Jones), *Carinocytheris carinata* (Roemer), *C.*

antiquata (Baird), were found in the Antakya Basin of Late Miocene by Doruk (1979) and also found in various zones of Miocene in the different parts of Turkey by Bassiouni (1979). Morkhoven (1962) determined *Cushmanidea elongata* (Brady), *Quadracythere (Tenedocythere) prava* (Baird), *Xestoleberis aurantia* (Baird), *X. depressa* Sars, *Darwinula cylindrica* Straub in Quaternary deposits.

The life environment of the examined ostracods was identified according to Morkhoven (1962) (Table 2). These ostracod genera represent various environments, as follows; lacustrine environment represented by *Darwinula*, *Cyclocypris*; brackish represented by *Cyprideis*; brackish-littoral environment represented by *Leptocythere*, *Loxoconcha*; brackish - epineritic environment represented by *Cytheridea*, littoral - epineritic environment represented by *Bairdia*, *Bairdoppilata*; epineritic environment represented by *Cushmanidea*, *Neocytherideis*, *Carinocythereis*, *Aurila*, *Quadracythere*, *Urocythereis*, *Caudites*, *Paracytheridea*, *Semicytherura*, *Cytherois*; epineritic-infraneritic environment represented by *Cytherella*, *Acanthocythereis*, *Costa*, *Olimfalunia*, *Pterygocythereis*, *Pontocypris*; *Buntonia* represents the environment from littoral upto bathyal, infraneritic environment represented by *Bosquetina* and *Pseudocytherura*; infraneritic - bathyal environment represented by *Echinocythereis*, *Henryhowella*, *Eucytherura*, *Macrocypris*, *Argilloecia*, *Paracypris*.

Table 1 (continued).

[illegible]

Table 2. Ecological distributions of ostracode genera in Gökçeada-Bozcaada-Çanakkale Region

	Ecology of genera					
	L a c u s t r i n e	B r a c k i s h	L i t t o r a l	E p i n e r i t i c	I n f r a n e r i t i c	B a t h y a l
OSTRACODA						
<i>Cytherella</i>						
<i>Bairdia</i>						
<i>Bairdoppilata</i>						
<i>Leptocythere</i>						
<i>Callistocythere</i>						
<i>Cyprideis</i>						
<i>Cytheridea</i>						
<i>Cushmanidea</i>						
<i>Neocytherideis</i>						
<i>Acanthocythereis</i>						
<i>Carinocythereis</i>						
<i>Costa</i>						
<i>Olimfalunia</i>						
<i>Pterygocythereis</i>						
<i>Echinocythereis</i>						
<i>Henryhowella</i>						
<i>Buntonia</i>						
<i>Aurila</i>						
<i>Quadracythere</i>						
<i>Urocythereis</i>						
<i>Caudites</i>						
<i>Bosquetina</i>						
<i>Loxoconcha</i>						
<i>Paracytheridea</i>						
<i>Eucytherura</i>						
<i>Pseudocytherura</i>						
<i>Semicytherura</i>						
<i>Cytheropteron</i>						
<i>Xestoleberis</i>						
<i>Cytherois</i>						
<i>Darwinula</i>						
<i>Macrocypis</i>						
<i>Pontocypis</i>						
<i>Argilloecia</i>						
<i>Paracypis</i>						
<i>Cyclocypis</i>						

3. DISCUSSION AND CONCLUSIONS

41 genera and 61 species of ostracoda were determined from the 15 samples obtained from the Gökçeada-Bozcaada-Çanakkale region. The depth relation environmental characteristics of these species were pointed out during the study in the Aegean and the Marmara Seas. In Crete and Rhodos, Sissing (1972) indicated that genera *Cytheropteron*, *Henryhowella* are at a depth of ± 100 metres and deeper, genus *Cyprideis*, *Cytheridea* and *Xestoleberis* are no more than 50 metres in the shallows. Gökçen (1976), who studied in the northeastern coast of the Aegean Sea, showed depth of 16 metres and circalittoral zone for *Carinocythereis antiquata* (Baird) species, *Bosquetina dentata* (Müller) species forms the bathyal fauna in the Mediterranean, *Acanthocythereis hystrix* (Reuss) species is at epibathyal depth, genera of ostracods like *Bairdia*, *Callistocythere*, *Bosquetina*, *Paracytheridea* are found at a temperature between 10-22°C, *Xestoleberis* and *Loxoconcha* are adapted to mesohaline salinity. Tunoğlu (1996), in his study which was in the Marmara Sea, explained *Pterygocythereis ceratoptera* (Bosquet) and *P. jonesii* (Baird) are at a depth of 20-60 metres and *Bosquetina dentata* (Müller) species is observed in deep sea. In Saros Bay, Tunoğlu (1998) pointed out genera *Paracytheridea*, *Callistocythere*, *Urocythereis*, *Olimfalunia* (*Hiltermanicythere*), *Loxoconcha*, *Xestoleberis* in infralittoral zone. Even if

similar conditions have been observed in this study, *Bosquetina dentata* (Müller) represents the more shallow depth.

According to this study and Table 1 and 2, there are mostly ostracoda of neritic and bathyal in the study area, in addition that brackish and littoral ostracods with marine ones are at the place where the rivers join the sea. This case has been determined at samples of 4, 7, 14, 35, 76, 87, 95, 99. Moreover, the ostracoda of fresh water, like *Cyclocypris globosa* (Sars) which was taken from the final locations of the Dardanelles Strait and *Darwinula cylindrica* Straub, *Cyclocypris globosa* (Sars) in samples of 76, 95, 99 which were taken from between Gökçeada and Bozcaada, explained that there are fresh water flows from the land into sea or fresh water springs at the bottom of sea.

4. ACKNOWLEDGEMENTS

The author wishes to thank Prof. Güler TANER (Ankara University, Science Faculty) and Uğraş Işık (M.Sc. TPAO) who helped to supply materials.

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OSTRACODA AND BENTHIC FORAMINIFERA OF TERTIARY SEQUENCE OF WESTERN PART OF ISTANBUL

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ABSTRACT: *The samples, derived from the various drillings located at the western part of the İstanbul, were examined systematically and ostracod assemblages were evaluated. Pliocene-Late Miocene and Oligocene-Late Eocene aged sediments have been observed from the top the bottom at the 5 drilling holes. The first drilling hole (Jawa tank), is situated in the north of Merter in Bakırköy basin, has 163.00 m thickness. The determined ostracod and benthic fauna of this drilling are found between Late Miocene and Oligocene-Late Eocene. Secondly, the samples belonging to the two drilling holes located at the western part of Bakırköy basin (surroundings of Ataköy) were carefully analyzed. The sequence is in Pliocene, Late Miocene and Late Eocene age, and has 292.00 m thickness at this drilling; in addition; the other drilling, representing only Late Eocene according to the ostracod and benthic foraminifera, is 210.00 m thickness in this region. Finally, there are two drilling holes 400 m eastern part of the Jawa tank. Both of the drilling holes are 175.00 m thickness; and the number one has Pliocene age, in accordance with ostracod and benthic foraminifera content, also, the number two is found Late Miocene and Late Eocene age interval. In this study, age and environmental changes of Tertiary sequence located in the western part of İstanbul were investigated depending on the ostracod and benthic foraminifera.*

1. INTRODUCTION

Some detailed geological and paleontological studies have been carried out by Akartuna (1953), Erentöz (1953), Pamir (1954), Ozansoy (1962), Sönmez (1963), Sönmez-Gökçen (1964, 1973), Şafak (1997), Nazik (1998), Şafak et al. (1999) in the study area and surroundings (Fig.1). Tertiary sequence locating in the

western part of the Istanbul (Jawa drilling-northern Merter; Borehole I-II, Merter; Ataköy W₁-W₂ drillings vicinity of Bakırköy) has micropaleontologically been investigated. Depending on the rich ostracods and benthic foraminifer fauna, stratigraphic properties and environmental interpretation of studied area was done. In addition, this area was

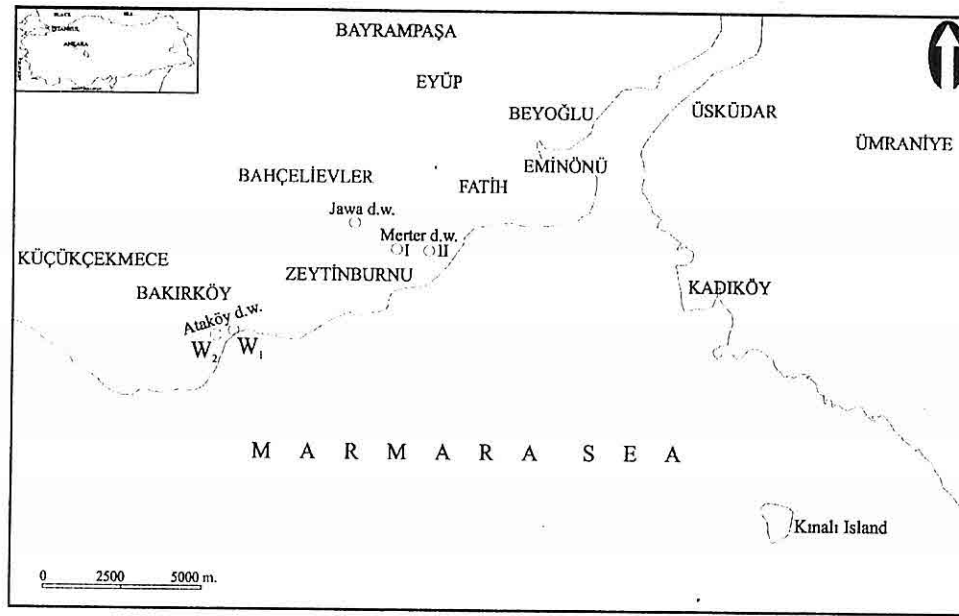


Figure 1. Location map and drilling places.

compared with the others. Borehole I and II of Merter drilling have been evaluated first time in this study. Ostracod species of Jawa drilling-northern Merter (Şafak, 1997), and ostracod and benthic foraminifera of W₁-W₂ drillings of Ataköy (Şafak et al., 1999) were previously researched. The results of these studies are used in this article for

the purpose of the comparison. The evaluation of environmental conditions and chronostratigraphy of the region were carried out by the articles of the following authors; Morkhoven (1962), Sönmez-Gökçen (1964), Sissingh (1972), Krstic (1975), Bassiouni (1979), Yassini (1979), Freels (1980), Taner (1982, 1997).

2. STRATIGRAPHY

The lithological characteristics of the drillings located at the study area is as follows:

The first drilling (Jawa) at the northern part of Merter in the Bakırköy Basin is beige colored, poorly sorted, clayey and fossiliferous coarse sand between 1.00-7.00 m; gravelly, sandy claystone 7.00-36.00 m; claystone banded sandstone 36.00-47.00 m; sandstone 47.00-58.00 m; and siltstone banded claystone 58.00-70.00 m; claystone 70.00-82.00 m; intercalation of sandstone, siltstone and claystone 82.00-94.00 m; siltstone and sandstone including yellow colored, poorly sorted gravel bands 94.00-106.00 m, claystone comprising sand and gravel 106.00-114.00 m; claystone banded sandstone 114.00-126.00 m; conglomerate levels consisting of gray colored, poorly sorted, graywacke and quartz 140.00-151.00 m; gravelly sandstone interbedded with claystone 151.00-161.00 m; and also coarse-sandy claystone containing gray colored, quartz, graywacke and limestone grains.

There are two boreholes at the western part of the Bakırköy Basin (surroundings of Ataköy). The first borehole (W₁ borehole) consists of siltstone and claystone banded limestone between 1.00-123.00 m; marl, siltstone-claystone banded limestone 124.00-250.00 m; and limestone and marl banded limestone 251.00-292.00 m. In addition, the second borehole (W₂ borehole) is composed of limestone, claystone banded marl and siltstone levels between 25.00-210.00 m.

The third area (Merter drilling) located at 400 m. eastern part of Jawa drilling has also two boreholes. Adana Tank borehole contains clayey limestone levels between 1.00-170.00 m; and Old Mamul borehole includes detritic materials between 1.00-170.00 m (Fig.2).

The following chronostratigraphic levels were described from the investigated drillings according to the ostracod and benthic foraminifera. Characteristic ostracod and benthic foraminiferal species determined from this system and stage were compared with species and stratigraphic level of Turkey and Northwestern Europe. In addition, paleoecological conditions at drillings characterized by ostracod assemblages have been indicated.

Upper Eocene (Priabonian)

Priabonian is located between 140.00-163.00 m at the Jawa drilling. Ostracods are very common *Bairdoppilata gliberti* Keij, *Schizocythere tessellata tessellata* (Bosquet), *Eucythere* sp., *Nucleolina multicostata* (Deltel), *Pokornyella osnabrugensis* (Lienenklaus), *P. ventricosa* (Bosquet), *Hermanites pajenborchiana* Keij, *H. alata* Ducasse, *Quadracythere hulusii* Sönmez-Gökçen, *Xestoleberis subglobosa* (Bosquet), *X. convexa* Deltel, *Paracypris contracta* (Jones) (Plate I-II-II-IV). Benthic foraminifers are not numerous and are represented by *Halkyardia minima* (Liebus), *Europertia magna* (le Calvez), *Asterigerina rotula* (Kaufmann), *Chapmanina gassinensis* (Silvestri),

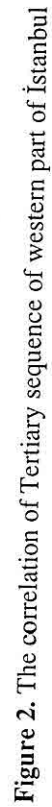


Figure 2. The correlation of Tertiary sequence of western part of Istanbul

OSTRACODA AND BENTHIC FORAMINIFERA OF TERTIARY SEQUENCE
OF WESTERN PART OF ISTANBUL

Nummulites fabianii (Prever) (Table 1). The same level is observed in both W₁

Table 1. The distribution of benthic foraminifers in the Eocene sequence at the Jawa drilling well.

E O C E N E									SERIES
Priabonian									STAGE
161.00 - 145.00 m.									THICKNESS
161	160	158	157	154	152	148	146	145	Sample number / Benthic foraminifers
X				X					<i>Pyrgo</i> sp.
X						X			<i>Triloculina</i> sp.
X		X	X	X	X	X			<i>Quinqueloculina</i> sp.
X		X	X	X	X	X			<i>Halkyardia minima</i> (Liebus)
						X	X		<i>Europertina magna</i> (le Calvez)
X			X	X	X	X		X	<i>Asterigerina rotula</i> (Kaufmann)
					X				<i>Ammonia</i> sp.
		X							<i>Nonionella</i> sp.
X		X	X		X				<i>Melonis</i> sp.
X		X	X	X	X			X	<i>Chapmanina gassinensis</i> (Silvestri)
X	X		X			X			<i>Porosonion</i> sp.
X		X	X	X	X				<i>Elphidium</i> sp.
X									<i>Nummulites fabianii</i> (Prever)

and W₂ boreholes of Ataköy drillings. It is found between 251.00-292.00 m of W₁ borehole with the ostracod assemblages of the *Cytherella triestina* Kollmann, *Thracella apostolescui* Sönmez, *Leguminocythereis genappensis* Keij, *Nucleolina multicostata* (Deltel), *Pokornyella osnabrugensis* (Lienenklaus), *P. ventricosa* (Bosquet), *Cytheretta tenuistriata* (Reuss), *Xestoleberis subglobosa* (Bosquet); also the assemblages of benthic foraminifers contain; *Halkyardia minima* (Liebus), *Sphaerogypsina globula* (Reuss), *Asterigerina rotula* (Kaufmann), *Chapmanina gassinensis* (Silvestri), *Nummulites striatus* (Brugière), *N. fabianii* (Prever). In addition, W₂ borehole, is between 25.00-210.00 m, and consists of abundant ostracods; *Cytherella triestina* Kollmann, *Bairdia elongata* Lienenklaus, *B. cymbula* Deltel,

B. crebra Deltel, *Schizocythere tessellata tessellata* (Bosquet), *S. appendiculata appendiculata* Triebel, *Eucythere* sp., *Krithe rutoti* Keij, *K. obesa* Sönmez-Gökçen, *Echinocythereis isabenana* Oertli, *Leguminocythereis genappensis* Keij, *Nucleolina multicostata* (Deltel), *Pokornyella osnabrugensis* (Lienenklaus), *P. ventricosa* (Bosquet), *Hermanites paijenborchiana* Keij, *H. triebeli* Stchepinsky, *Quadracythere vermiculata* (Bosquet), *Q. hulusii* Sönmez-Gökçen, *Cytheretta concinna* Triebel, *Xestoleberis subglobosa* (Bosquet), *X. muelleriana* Lienenklaus, *Uroleberis* sp., *Paracypris conrcta* (Jones) (Plate I-II-II-IV) and has been recognized by means of the benthic foraminifera assemblage of the *Halkyardia minima* (Liebus), *Sphaerogypsina globula* (Reuss), *Asterigerina rotula* (Kaufmann),

PLATE I

X100

- Figure 1:** *Bairdia cymbula* Deltel. Merter drilling, borehole II, sample number 142, Upper Eocene. Carapace, right side view.
- Figure 2:** *Bairdoppilata gliberti* Keij. Jawa drilling, sample number 152, Upper Eocene. Left valve, outside view.
- Figure 3:** *Schizocythere tessellata tessellata* (Bosquet). Jawa drilling, sample number 158, Upper Eocene. Carapace, left side view.
- Figure 4:** *Leptocythere sanmarinensis* Ruggieri. Jawa drilling, sample number 24, Upper Miocene. Carapace, right side view.
- Figure 5:** *Callistocythere* sp. Jawa drilling, sample number 4, Upper Miocene. Carapace, right side view.
- Figure 6:** *Limnocythere* sp. Ataköy drilling, W₁ borehole, sample number 12, Pliocene. Left valve, outside view.
- Figure 7:** *Limnocythere* sp. 2 Ünal. Jawa drilling, sample number 26, Upper Miocene. Left valve, outside view.
- Figure 8:** *Paralimnocythere* sp. Jawa drilling, sample number 8, Upper Miocene. Right valve, outside view.
- Figure 9:** *Eucythere* sp. 1. Jawa drilling, sample number 157, Upper Eocene. Left valve, outside view.
- Figure 10:** *Eucythere* sp. 2. Jawa drilling, sample number 158, Upper Eocene. Carapace, right side view.
- Figure 11:** *Cyprideis torosa* (Jones). Jawa drilling, sample number 4, Upper Miocene. Right valve, outside view.
- Figure 12-13:** *Cyprideis sarmatica* Krstic. Jawa drilling, sample number 88, Upper Miocene. **12.** Carapace, dorsal view. **13.** Carapace, right side view.

PLATE I

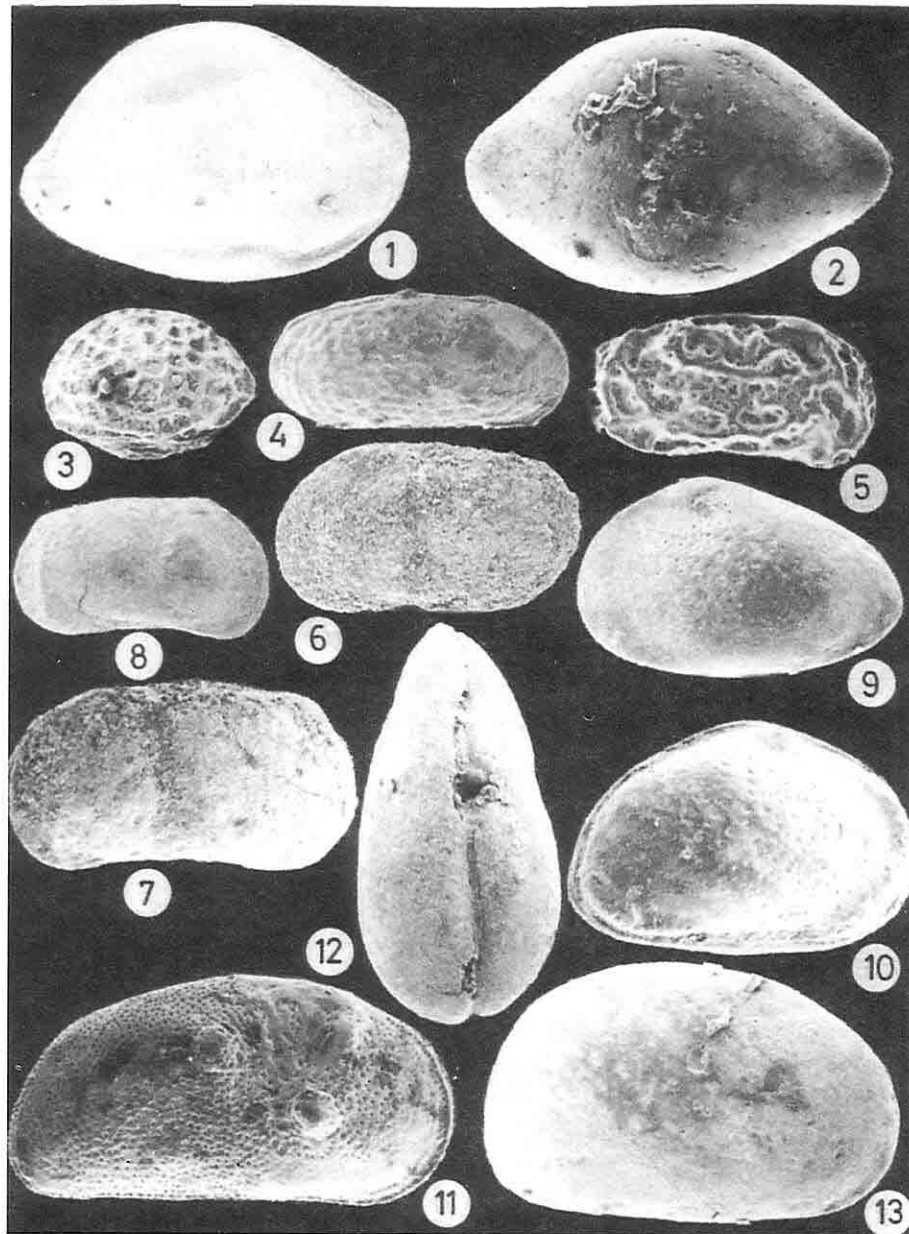


PLATE II

X100

- Figure 1:** *Cyprideis sarmatica* Krstic. Jawa drilling, sample number 81, Upper Miocene. Carapace, dorsal view.
- Figure 2:** *Cyprideis anatolica* Bassiouni. Merter drilling, borehole II, sample number 80, Upper Miocene. Left valve, outside view.
- Figure 3:** *Cyprideis panonica* (Mehes). Merter drilling, borehole I, sample number 8, Pliocene. Left valve, outside view.
- Figure 4-5:** *Cyprideis seminulum* (Reuss). **4.** Jawa drilling, sample number 60, Upper Miocene. Right valve, outside view. **5.** Jawa drilling, sample number 21, Upper Miocene. Right valve, outside view.
- Figure 6:** *Cyprideis trituberculata* Krstic. Jawa drilling, sample number 21, Upper Miocene. Carapace, left side view.
- Figure 7:** *Echinocythereis lütfullahi* Sönmez-Gökçen. Jawa drilling, sample number 154, Upper Eocene. Carapace, left side view.
- Figure 8-9:** *Echinocythereis isabenana* Oertli. Jawa drilling, sample number 162, Upper Eocene. **8.** Carapace, right side view. **9.** Carapace, left side view.
- Figure 10.** *Nucleolina multicostata* (Deltel). Jawa drilling, sample number 162, Upper Eocene. Carapace, left side view.

PLATE II

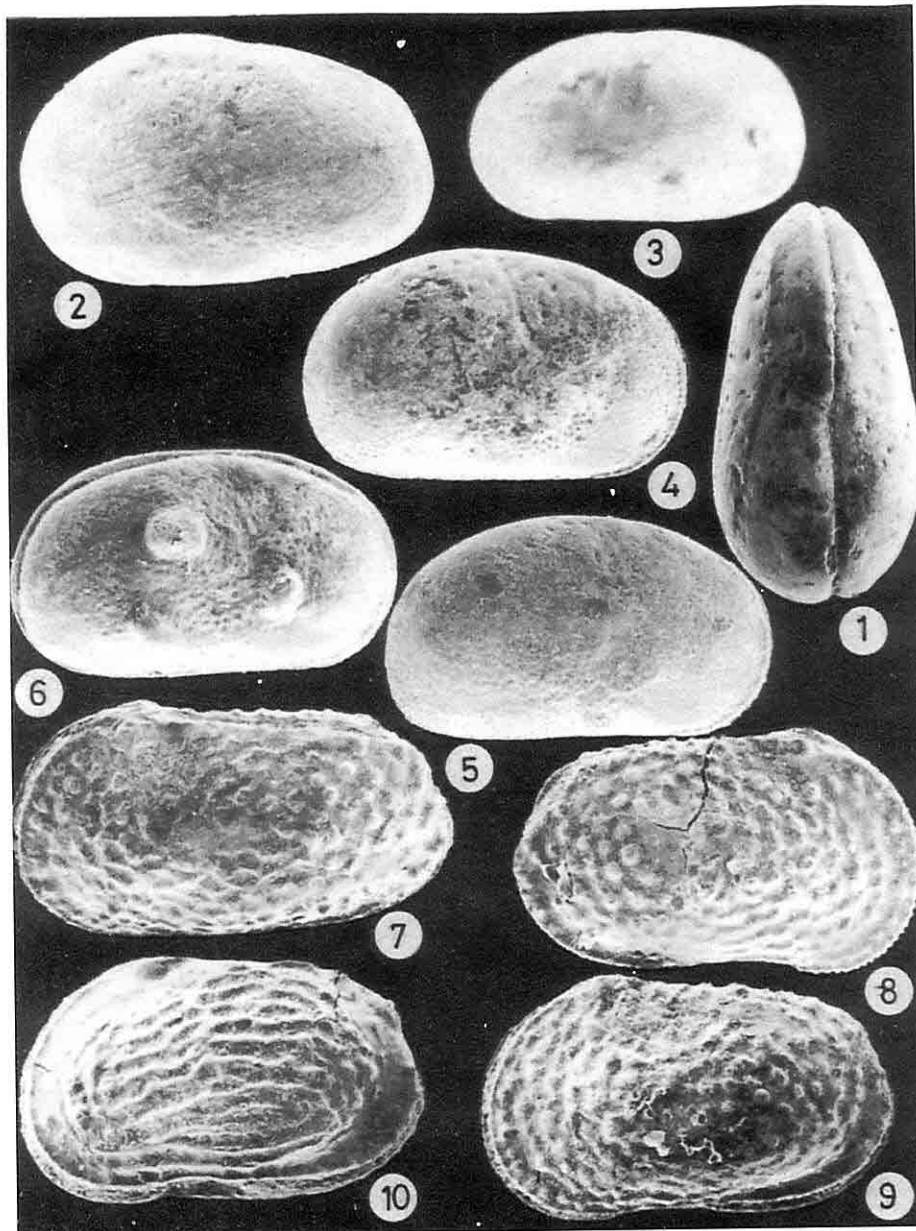


PLATE III

X100

- Figure 1-2:** *Nucleolina multicostata* (Deltel). **1.** Jawa drilling, sample number 162, Upper Eocene. Carapace, right side view. **2.** Merter drilling, borehole II, sample number 162, Upper Eocene. Right valve, inside view.
- Figure 3:** *Pokornyella ventricosa* (Bosquet). Jawa drilling, sample number 157, Upper Eocene. Carapace, left side view.
- Figure 4-5:** *Pokornyella osnabrugensis* (Lienenklaus). **4.** Merter drilling, borehole II, sample number 151, Upper Eocene. Carapace, right side view. **5.** Jawa drilling, sample number 157, Upper Eocene. Carapace, right side view.
- Figure 6:** *Hermanites paijenborchiana* Keij. Jawa drilling, sample number 154, Upper Eocene.
- Figure 7:** *Bradleya* sp. Jawa drilling, sample number 152, Upper Eocene. Carapace, left side view.
- Figure 8-10:** *Quadracythere hulusii* Sönmez-Gökçen. Jawa drilling, sample number 154, Upper Eocene. **8.** Left valve, outside view. **9.** Right valve, inside view. Merter drilling, borehole II, sample number 151, Upper Eocene. **10.** Carapace, left side view.
- Figure 11:** *Urocythereis seminulum* (Sequenza). Jawa drilling, sample number 4, Upper Miocene. Carapace, left side view.
- Figure 12:** *Urocythereis margaritifera* (Müller). Merter drilling, borehole I, sample number 13, Pliocene. Right valve, outside view.

PLATE III

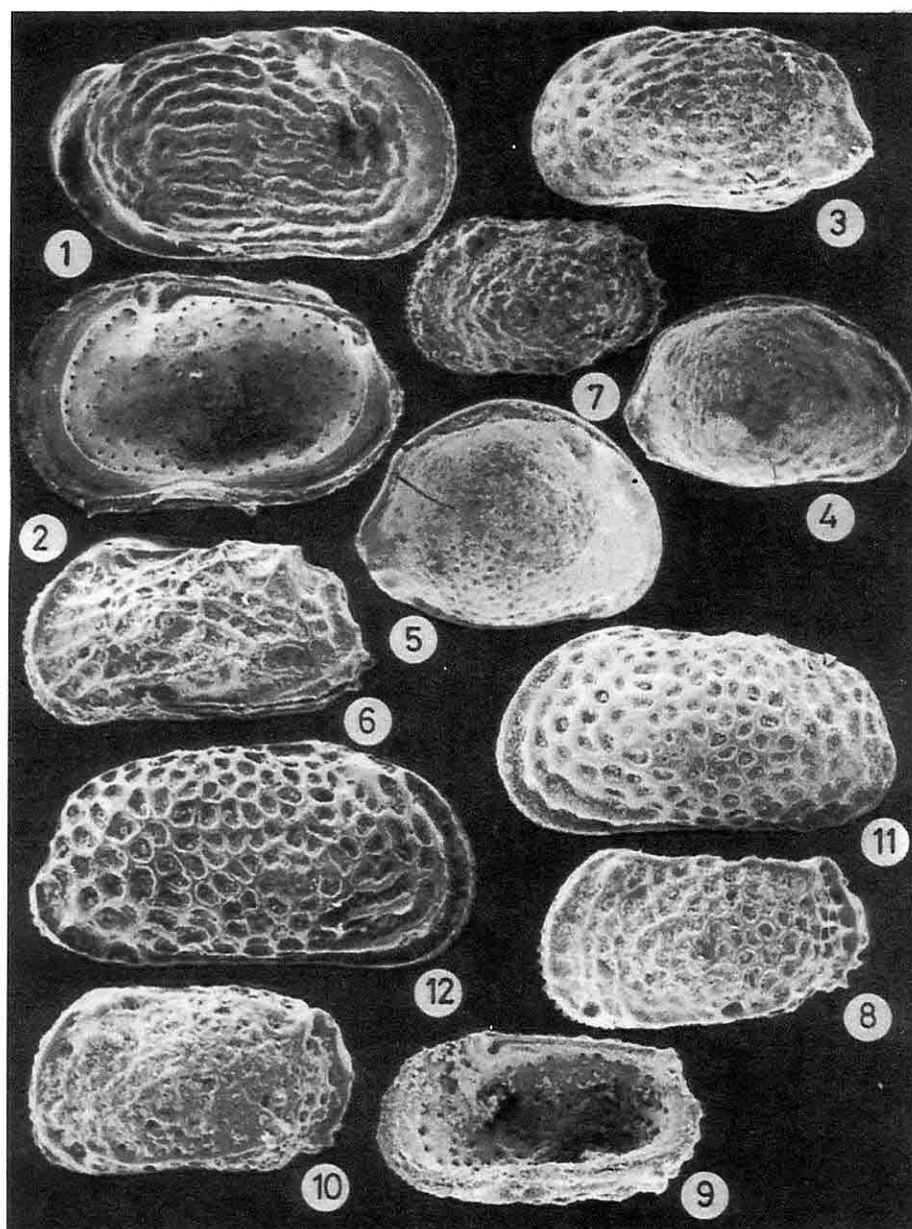
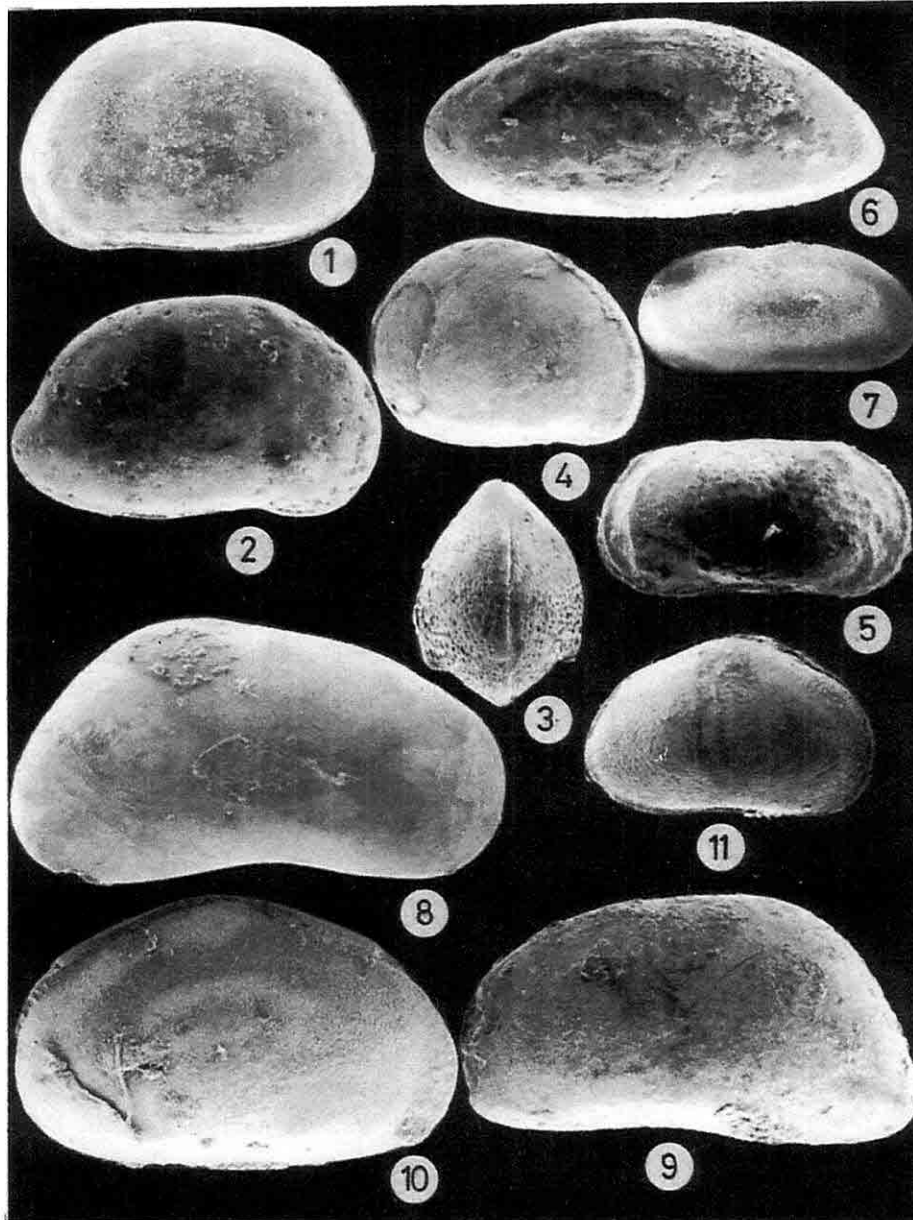


PLATE IV

X100

- Figure 1-2:** *Tyrrhenocythere triebeli* Krstic. **1.** Merter drilling, borehole II, sample number 80, Upper Miocene. Left valve, outside view. **2.** Jawa drilling, sample number 4, Upper Miocene. Right valve, outside view.
- Figure 3:** *Cytheropteron kuruensis* Sönmez-Gökçen. Jawa drilling, sample number 156, Upper Eocene. Carapace, dorsal view.
- Figure 4:** *Xestoleberis subglobosa* (Bosquet). Jawa drilling, sample number 150, Upper Eocene. Carapace, right side view.
- Figure 5:** *Ilyocypris* cf. *bradyi* (Norman). Ataköy drilling, W₁ borehole, sample number 33, Pliocene. Right valve, outside view.
- Figure 6:** *Paracypris contracta* (Jones). Ataköy drilling, W₂ borehole, sample number 120-125, Upper Eocene. Carapace, left side view.
- Figure 7:** *Candona (Candona) parallela pannonica* Zalanyi. Merter drilling, borehole I, sample number 26, Pliocene. Carapace, outside view.
- Figure 8:** *Candona (Candona) decimai* Freels. Jawa drilling, sample number 76, Upper Miocene. Right valve, outside view.
- Figure 9:** *Candona (Candona) devexa* Kaufmann. Jawa drilling, sample number 13, Upper Miocene. Carapace, left side view.
- Figure 10:** *Eucypris* sp. Ataköy drilling, W₁ borehole, sample number 35, Pliocene. Carapace, left side view.
- Figure 11:** *Eucypris dulcifons* Diebel & Pietrzenuik. Ataköy drilling, W₁ borehole, sample number 33, Pliocene. Carapace, right side view, X75.

PLATE IV



Chapmanina gassinensis (Silvestri), *Nummulites striatus* (Brugière), *N. fabianii* (Prever).

The ostracod assemblages of the *Bairdia elongata* Lienenklaus, *B. cymbula* Deltel, *Triebelina punctata* Deltel, *Schizocythere tessellata tessellata* (Bosquet), *Schuleridea* cf. *perforata* (Roemer), *Thracella apostolescui* Sönmez, *Leguminocythereis genappensis* Keij, *Nucleolina multicostata* (Deltel), *Pokorniyella osnabrugensis* (Lienenklaus), *P. ventricosa* (Bosquet), *Hermanites triebeli* Stchepinsky, *Quadracythere hulusii* Sönmez-Gökçen, *Xestoleberis* cf. *subglobosa* (Bosquet), *Paracypris contracta* (Jones) (Table 2) (Plate III); and benthic foraminiferal fauna of *Miliolinella subrotunda* (Montagu), *Halkyardia minima* (Liebus), *Asterigerina rotula* (Kaufmann), *Chapmanina gassinensis* (Silvestri), *Nummulites fabianii* (Prever) (Table 3) characterizing Priabonian were described from the borehole II (Old Mamul Tank) of the Merter drilling, between 92.00-173.00 m, at the 400 m western part of the Jawa drilling.

Cytherella triestina Kollmann, at the Upper Eocene of Yugoslavia (Kollmann, 1962), Trace-western Bakırköy (İstanbul) region (Sönmez-Gökçen, 1973, Şafak et al., 1999) and Middle Eocene of Malatya (E. Turkey) (Nazik, 1993); *Bairdia cymbula* Deltel, at the Middle Eocene of Aquitaine Basin (France) (Deltel, 1963; Oertli, 1985), and Upper Eocene of western Bakırköy (İstanbul-Turkey) (Sönmez-Gökçen, 1973, Şafak et al.,

1999); *Bairdoppilata gliberti* Keij, at the Upper Paleocene-Eocene of Belgium (Apostolescu, 1964; Keij, 1957; Marliere, 1958), Eocene of Paris Basin (France) (Apostolescu, 1964; Keij, 1957), Middle and Upper Eocene of Aquitaine Basin (Ducasse, 1959), Upper Eocene of Trace-western Bakırköy (İstanbul-Turkey) (Sönmez-Gökçen, 1973, Şafak, 1997), *Schizocythere tessellata tessellata* (Bosquet) at the Lower-Upper Eocene of Belgium (Apostolescu, 1964; Keij, 1957), Upper Paleocene-Upper Eocene of Paris Basin (France) (Apostolescu, 1964; Keij, 1957, Triebel, 1950), Eocene of Aquitaine Basin (Ducasse, 1959), Upper Eocene of Trace-western Bakırköy (İstanbul-Turkey) (Sönmez-Gökçen, 1973, Şafak, 1997, Şafak et al., 1999), Middle Eocene of Malatya region (Nazik, 1993); *Nucleolina multicostata* (Deltel), at the Middle-Upper Eocene of Aquitaine Basin (France) (Deltel, 1963), Upper Eocene of Trace-western Bakırköy (İstanbul-Turkey) (Sönmez-Gökçen, 1973, Şafak, 1997, Şafak et al., 1999), Middle Eocene of Malatya region (Nazik, 1993); *Pokorniyella osnabrugensis* (Lienenklaus), at the Lower Oligocene of Germany (Lienenklaus, 1894), Lower Eocene-Upper Eocene of Aquitaine Basin (France) (Ducasse, 1959), Upper Eocene of Trace-western Bakırköy (İstanbul-Turkey) (Sönmez-Gökçen, 1973, Şafak, 1997, Şafak et al., 1999), Middle Eocene of Malatya region (Nazik, 1993); *Pokorniyella ventricosa* (Bosquet), at the Lower-Middle Eocene of Belgium (Keij, 1957), Middle Eocene of Paris Basin

Table 2. The distribution of ostracodes in the Tertiary sequence at Borehole II of Merter drilling.

TERTIARY																								SYSTEM	
PALEOGENE																								NEOGENE	
Eocene																								MIOCENE	
PRIABONIAN																								MESSINIAN	
173.00 - 80.00 m.																								THICKNESS	
173	172	170	169	167	166	165	164	163	162	156	152	151	149	148	147	146	145	144	143	142	92	88	85	80	Sample number / Ostracodes
			Δ		▲		Δ		Δ			Δ	▲	▲	Δ	Δ		▲							<i>Bairdia elongata</i> Lienenklaus
					Δ		Δ						Δ												<i>Bairdia incegiensis</i> Sonmez-Gökçen
	Δ	Δ	Δ	Δ		▲	○	▲	Δ					Δ	▲	○			▲						<i>Bairdia cymbula</i> Dettel
					Δ							Δ													<i>Bairdoppliata cf. gibberti</i> Keijl
										Δ															<i>Triebelina punctata</i> Dettel
Δ						Δ						Δ	▲					Δ							<i>Schizocythere tessellata tessellata</i> (Bosquet)
																						Δ			<i>Limnocythere</i> sp.
	Δ			▲	Δ			Δ	▲		▲		Δ				Δ								<i>Eucythere</i> sp.
																				▲		Δ	Δ		<i>Cyprideis anatica</i> Bassiouni
																							Δ		<i>Cyprideis pannonica</i> (Mehes)
																				▲		Δ			<i>Cyprideis seminulum</i> (Reuss)
																							Δ		<i>Tyrhenocythere triebeli</i> Krstic
Δ				Δ														Δ							<i>Schuleridea cf. perforata</i> (Roemer)
				Δ																					<i>Thracella opostolescui</i> Sonmez
				Δ									▲												<i>Leguminocythereis genappensis</i> Keijl
														Δ											<i>Leguminocythereis</i> sp.
	Δ					Δ	▲	Δ	Δ				○												<i>Nucleolina multicosiata</i> (Dettel)
▲		▲	▲	○	○	○	Δ	Δ	Δ		○	▲	Δ					▲							<i>Pokorniyella osnabrugensis</i> (Lienenklaus)
				Δ	Δ	Δ	Δ					Δ	Δ												<i>Pokorniyella vanfricosa</i> (Bosquet)
						▲																			<i>Hermanites triebeli</i> Stchepinsky
			Δ									Δ													<i>Quadracythere hulusii</i> Sonmez-Gökçen
Δ									Δ			Δ	Δ					▲							<i>Xestoleberis cf. subglobosa</i> (Bosquet)
									Δ																<i>Xestoleberis</i> sp.
																									<i>Uroleberis</i> sp.
						Δ	Δ																		<i>Paracypris contracta</i> (Jones)
								Δ																	<i>Paracypris</i> sp.

Δ	1-2 valve very rare
▲	3-5 valve rare
○	6-15 valve common

Table 3. The distribution of benthic foraminifera in the Tertiary sequence at Borehole II of Merter drilling.

PALEOGENE		NEOGENE				SYSTEM
EOCENE		MIOCENE				SERIES
Priabonian		Messinian				STAGE
175.00 - 80.00 m.						THICKNESS
143	142	92	88	86	80	Sample number / Benthic foraminifers
	X					<i>Miliolinella subrotunda</i> (Montagu)
		X				<i>Quinqueloculina seminula</i> (Linné)
		X		X	X	<i>Porosonion subgranosum</i> (Egger)
X						<i>Halkyardia minima</i> (Liebus)
X						<i>Asterigerina rotula</i> (Kaufmann)
X						<i>Chapmanina gassinensis</i> (Silvestri)
X						<i>Nummulites fabianii</i> (Prever)

(France) (Apostolescu, 1964), Eocene of Aquitaine Basin (Ducasse, 1959), in addition, Middle Eocene of southern part of Aquitaine Basin (Deltel, 1961), Upper Eocene of Trace-western Bakırköy (İstanbul - Turkey) (Sönmez - Gökçen, 1973, Şafak, 1997, Şafak et al., 1999), Upper Eocene of Malatya region (Nazik, 1993); *Hermanites pajenborchiana* Keij, at the Lower-Middle Eocene of Belgium (Keij, 1957), Lower Eocene-Upper Eocene of Paris Basin (France) (Apostolescu, 1955; Bosquet, 1852), Middle-Upper Eocene of northern part of Aquitaine Basin (France) (Ducasse, 1959), and Middle Eocene - Lower Oligocene of southern part of Aquitaine Basin (France) (Deltel, 1961), Upper Eocene of Trace-western Bakırköy (İstanbul-Turkey) (Sönmez - Gökçen, 1973, Şafak, 1997, Şafak et al., 1999); *Hermanites alata* Ducasse, at the Upper Eocene of Aquitaine Basin (France) (Ducasse, 1963), Upper Eocene of Trace-western Bakırköy (İstanbul - Turkey) (Sönmez - Gökçen, 1973, Şafak, 1997, Şafak et al., 1999), Middle Eocene of

Malatya region (Şafak, 1990, Nazik, 1993); *Hermanites triebeli* Stchepinsky, at the Lower Eocene of Germany (Moos, 1963), Lower Oligocene of France (Stchepinsky, 1960), Upper Eocene of Trace-western Bakırköy (İstanbul-Turkey) (Sönmez-Gökçen, 1973, Şafak et al. 1998), Middle Eocene of Malatya region (Nazik, 1993); *Quadracythere vermiculata* (Bosquet), Middle Eocene of Belgium (Keij, 1957), Middle Eocene of Paris Basin (France) (Apostolescu, 1964; Bosquet, 1852; Keij, 1957), Middle-Upper Eocene of northern part of Aquitaine Basin (Ducasse, 1959), Upper Eocene of Trace - western Bakırköy (İstanbul-Turkey) (Sönmez-Gökçen, 1973, Şafak et al., 1999); *Paracypris contracta* (Jones), Middle-Upper Eocene of Belgium (Keij, 1957), Upper Eocene of England (Haskins, 1968), Upper Eocene of Trace - western Bakırköy (İstanbul-Turkey) (Şafak, 1997, Şafak et al., 1999) were described at this stage.

Nummulites fabianii (Prever), at the Upper Eocene of Oman-Zagros (Henson,

1950), Gulf of Oman (Blondeau et al., 1977), Transylvania (Bombita and Popescu, 1977), Antakya-Turkey (Sirel and Gündüz, 1981); in addition, *Halkyardia minima* (Liebus), *Nummulites fabianii* (Prever), at the Upper Eocene of Hungary (Hantken, 1875), Trace-Turkey (Dizer, 1982); *Eorupertia magna* (le Calvez), *Sphaerogypsina globula* (Reuss), *Chapmanina gassinensis* (Silvestri), *Nummulites fabianii* (Prever), at the Upper Eocene of Yugoslavia (Drobne et al., 1979), *Halkyardia minima* (Liebus), *Asterigerina rotula* (Kaufmann), *Chapmanina gassinensis* (Silvestri), *Nummulites fabianii* (Prever), at the Upper Eocene of Malatya (Sirel, 1976), Elazığ (Avşar, 1983), *Chapmanina gassinensis* (Silvestri), *Nummulites fabianii* (Prever), Afyon (Sirel and Acar, 1982) and Adıyaman (Meriç, 1987) were determined.

Jawa drilling, in the northern part of Merter; W₁-W₂ boreholes of Ataköy drilling in the western part of Bakırköy Basin and Borehole II of Merter drilling locating at the 400 m east of Jawa drilling have shallow marine characteristics at Upper Eocene (Table 7)

Oligocene (Stampian)

The existence of *Cytheromorpha zinndorfi* (Lienenklaus), *Eucythere* sp., *Pokornyella osnabrugensis* (Lienenklaus) assemblage indicates that there is the Stampian stage between 141.00-148.00 m in Jawa drilling (Plate III).

Cytheromorpha zinndorfi (Lienenklaus), at the Lower Oligocene-

Lower Miocene of Germany (Keij, 1957; Lienenklaus, 1905), Upper Eocene of Belgium (Keij, 1957), Lower Oligocene of Paris Basin (France) (Apostolescu, 1964), Lower-Upper Oligocene of Switzerland (Oertli, 1956), Lower Oligocene of Trace-Bakırköy Region (Turkey) (Sönmez-Gökçen, 1963; 1964; 1973; Şafak, 1997); *Pokornyella osnabrugensis* (Lienenklaus) at the Lower Oligocene of Germany (Lienenklaus, 1894) were described.

Oligocene is shallow marine characteristics at Jawa drilling in the northern part of Merter-Bakırköy Basin (Table 7).

Upper Miocene

Tortonian

Tortonian deposits at the Jawa drilling, whose thickness varies from 36.00-126.00 m, were characterized by the following ostracods:

Neonesidea corpulenta (Mueller), *Cyprideis anatolica* Bassiouni, *C. pannonica* (Mehes), *C. seminulum* (Reuss), *C. torosa* (Jones), *C. trituberculata* Krstic, *C. sarmatica* Krstic, *C. quadrituberculata* Krstic, *C. tuberculata* (Mehes), *Cytheridea acuminata acuminata* Bosquet, *Aurila speyeri* (Brady), *A. convexa* (Baird), *Xestoleberis ventricosa* Mueller, *X. reymonti* Ruggieri, *Ilyocypris bradyi* (Norman), *Candona (Candona) parallela pannonica* Zalanyi, *C. (Candona) neglecta* Sars, *C. (Candona) devexa* Kaufmann, *Heterocypris salina salina* (Brady), *Eucypris dulcifons* Diebel &

Pietrzenuik (Plate I-II). The benthic fauna yields: *Siphonaperta aspera* (d'Orbigny), *Quinqueloculina seminula* (Linné), *Q. laevigata* d'Orbigny, *Triloculina marioni* Schlumberger, *Lobatula lobatula* (Walker & Jacob), *Porosononion subgranosum* (Egger), *Elphidium crispum* (Linné) (Table 4).

At the W₁ borehole of Ataköy drilling, thickness varies from 130.00 to 248.00 m. This level contains *Cyprideis seminulum* (Reuss), *C. pannonica* (Mehes), *C. anatolica* Bassiouni, *C. torosa* (Jones), *Xestoleberis ventricosa* Mueller, *X. reymonti* Ruggieri, *Ilyocypris bradyi* (Norman), *I. cf. gibba* (Ramdohr), *Heterocypris salina salina* (Brady) from the ostracods (Plate I-II-IV) and *Quinqueloculina* cf. *lamarckiana* d'Orbigny, *Triloculina* cf. *schreiberiana* d'Orbigny, *Eponides concameratus* (Williamson), *Lobatula lobatula* (Walker & Jacob), *Ammonia compacta* Hofker, *A. parkinsoniana* (d'Orbigny), *Porosononion subgranosum* (Egger) and *Elphidium crispum* (Linné) from the benthic foraminifera.

Cyprideis pannonica (Mehes), characteristics of this stage, is found at Lower Pannonian (Upper Miocene) of Hungary, Yugoslavia, Italy, Romania and Turkey (Mehes, 1908; Pokorny, 1942; Krstic, 1968 a,b; Decima, 1964; Hanganu, 1966; Bassiouni, 1979), *Cyprideis seminulum* (Reuss), at the Upper Pannonian (Upper Miocene) of Austria and Turkey (Kollmann, 1960; Bassiouni, 1979; Şafak and Nazik, 1994; Nazik and Gökçen, 1995; Şafak and

Meriç, 1996), *Cyprideis trituberculata* Krstic, *C. tuberculata* (Mehes) and *C. quadrituberculata* Krstic, at the Pannonian-Pontian (Upper Miocene) of Pannonian Basin, SW Anatolia, Gelibolu Peninsula and Bakırköy Region (İstanbul) (Krstic, 1968 a,b; 1971; Bassiouni, 1979, Ünal and Tunçoğlu, 1996, Şafak, 1997), and *Candona* (*Candona*) *neglecta* Sars, at the Upper Miocene-Pliocene of Rhone Basin (France) (Carbonnel, 1969) were determined.

Upper Miocene (Tortonian) has littoral and shallow marine characters, in addition, it is possible to see the characteristics of lagoonal (brackish) and lacustrine environment at Jawa drilling in the northern of Merter (Bakırköy Basin).

Tortonian of Ataköy drilling, locating in the western part of Bakırköy Basin, has also littoral and lagoonal characteristics (Table 7).

Messinian

This stage is located between 1.00-36.00 m at the Jawa drilling with the ostracods of *Neonesidea corpulenta* (Mueller), *Leptocythere sanmarinensis* Ruggieri, *Cyprideis anatolica* Bassiouni, *C. pannonica* (Mehes), *C. seminulum* (Reuss), *C. torosa* (Jones), *C. trituberculata* Krstic, *C. sohni* Bassiouni, *C. quadrituberculata* Krstic, *C. tuberculata* (Mehes), *C. compacta turgida* Bassiouni, *Aurila speyeri* (Brady), *A. convexa* (Baird), *Urocythereis seminulum* (Sequenza), *Tyrrhenocythere triebeli* Krstic, *Xestoleberis ventricosa* Mueller, *X.*

reymenti Ruggieri, *X. communis* Mueller, *Ilyocypris bradyi* (Norman), *Candona* (*Candona*) *decimai* Freels, *C. (Candona)* *parallela pannonica* Zalanyi, *C. (Candona)* *neglecta* Sars, *C. (Candona)* *deveza* Kaufmann, *Heterocypris salina salina* (Brady) and *Eucypris dulcifons* Diebel & Pietrzenuik; and with the benthic foraminifera of *Adelosina partschi* (d'Orbigny), *Siphonaperta aspera* (d'Orbigny), *Quinqueloculina seminula* (Linné), *Q. viennensis* Le Calvez, *Quinqueloculina* sp., *Pyrgo* sp., *Eponides concameratus* (Williamson), *Ammonia parkinsoniana* (d'Orbigny), *A. compacta* Hofker, *Porosononion subgranosum* (Egger), *Elphidium crispum* (Linné), *Elphidium* sp. (Table 4) (Plate I-II-III-IV).

Messinian, strictly noticed between 124.00-128.00 m of W₁ borehole at the Ataköy drilling, includes the ostracods; *Cyprideis seminulum* (Reuss), *C. pannonica* (Mehes), *C. anatolica* Bassiouni, *C. pontica* Krstic, *Tyrrhenocythere triebeli* Krstic, *Heterocypris salina salina* (Brady); and also is represented by the benthic foraminifera of *Quinqueloculina seminula* (Linné), *Asterigerina* sp., *Ammonia compacta* Hofker and *Elphidium crispum* (Linné).

In addition, it is possible to observe the same level at the borehole II (Old Mamul Tank) between 80.00-92.00 m, located in the Merter at the 400 m eastern part of Jawa drilling, with ostracods the *Cyprideis anatolica* Bassiouni, *C. pannonica* (Mehes), *C. seminulum*

(Reuss), *Tyrrhenocythere triebeli* Krstic (Table 2) and benthic foraminifera of the *Quinqueloculina seminula* (Linné), *Porosononion subgranosum* (Egger) (Table 3) (Plate II).

Tyrrhenocythere triebeli Krstic, characteristics of the Messinian stage, at the Upper Pontian / Messinian of eastern part of Yugoslavia and in the east of Macedonia (Krstic, 1976); at the Messinian of West Bakırköy region-İstanbul (Turkey) (Şafak, 1997; Şafak et al., 1999), *Cyprideis trituberculata* Krstic, *C. tuberculata* (Mehes), *C. quadrituberculata* Krstic, at the Pannonian-Pontian (Upper Miocene) of Pannonian Basin, SW Anatolia, Gelibolu Peninsula and Bakırköy region (İstanbul) (Krstic, 1968 a,b; 1971; Bassiouni, 1979, Ünal and Tunçoğlu, 1996, Şafak, 1997) were described and observed as the characteristics of the same stage in this study.

Upper Miocene (Messinian) has various characteristics changing from littoral and shallow marine to lagoonal and lacustrine.

Messinian of W₁ borehole (Ataköy drilling) in the western part of the Bakırköy Basin is littoral and lagoonal characteristics.

Also Upper Miocene (Messinian) of borehole II at Merter drilling locating at the 400 m eastern part of Jawa drilling was lagoonal environment characteristics (Table 7).

Pliocene

This sequence ranges from 1.00-123.00

Table 4. The distribution of benthic foraminifers in the Upper Miocene sequence of Jawa drilling well.

MIOCENE																					SERIES
Tortonian										Messinian										STAGE	
126.00 - 1.00 m.																					THICKNESS
126	95	94	50	38	33	32	31	28	24	23	21	17	16	10	8	7	6	5	4	2	Sample number / Benthic foraminifers
						X															<i>Adelosina partschi</i> (d'Orbigny)
			X		X									X							<i>Siphonaperta aspera</i> (d'Orbigny)
							X														<i>Quinqueloculina viennensis</i> le Calvez
			X																		<i>Quinqueloculina laevigata</i> d'Orbigny
			X		X	X		X	X					X	X						<i>Quinqueloculina seminula</i> (Linné)
											X								X	X	<i>Quinqueloculina</i> sp.
																			X	X	<i>Pyrgo</i> sp.
			X																		<i>Triloculina marioni</i> Schlumberger
								X	X						X			X			<i>Eponides concameratus</i> (Williamson)
			X																		<i>Lobatula lobatula</i> (Walker & Jacob)
												X	X								<i>Ammonia parkinsoniana</i> (d'Orbigny)
																				X	<i>Ammonia compacta</i> Hofker
X	X	X		X	X	X	X	X	X	X	X	X	X	X	X						<i>Porosonion subgranosum</i> (Egger)
				X		X		X	X			X	X	X	X						<i>Elphidium crispum</i> (Linné)
					X		X	X								X					<i>Elphidium</i> sp.

m at the W₁ borehole of the Ataköy drilling with the existence of the abundant ostracods; *Cyprideis seminulum* (Reuss), *C. pannonica* (Mehes), *C. anatolica* Bassiouni, *C. torosa* (Jones), *C. sublittoralis sublittoralis* Pokorny, *Cyamocytheridea dertonensis* Ruggieri, *Urocythereis favosa exedata* Uliczny, *Loxoconcha tumida* Brady, *Xestoleberis ventricosa* Mueller, *X. reymonti* Ruggieri, *X. communis* Mueller, *Darwinula stevensoni* (Brady & Robertson), *D. cylindrica* Straub, *Ilyocypris* cf. *bradyi* (Norman), *Candona* (*Candona*) *altoides* Petkovski, *C. (Candona) parallela pannonica* Zalanyi, *C. (Candona) decimai* Freels, *C. (Candona) candida* (Müller), *C. (Candona) neglecta* Sars, *Heterocypris salina salina* (Brady) and *Eucypris dulcifons* Diebel & Pietrzenuik (Plate I-II-IV) and includes benthic foraminifera of *Siphonaperta aspera* (d'Orbigny), *Quinqueloculina seminula* (Linné), *Eponides concameratus* (Williamson), *Cibicides advenum* (d'Orbigny), *Ammonia compacta* Hofker, *A. parkinsoniana* (d'Orbigny), *Challengerella bradyi* Billman, Hottinger & Oesterle, *Elphidium crispum* (Linné).

Pliocene, consisting of *Callistocythere* sp., *Limnocythere* sp., *Cyprideis pannonica* (Mehes), *Aurila convexa* (Baird), *Urocythereis margaritifera* (Müller), *Xestoleberis* cf. *ventricosa* Müller, *X. reymonti* Ruggieri, *Candona* (*Candona*) *parallela pannonica* Zalanyi, *C. (Candona) neglecta* Sars, *Heterocypris* cf. *salina salina* (Brady) from the ostracods (Table 5) (Plate III);

and *Siphonaperta aspera* (d'Orbigny), *Quinqueloculina seminula* (Linné), *Q. laevigata* d'Orbigny, *Ammonia tepida* Cushman, *Porosonion subgranosum* (Egger), *Elphidium crispum* (Linné) from the benthic foraminifera (Table 6), is situated at the borehole I (Adana Tank Borehole) of the Merter drilling at the 400 m eastern part of Jawa.

Some of the ostracod species characterizing the Pliocene series; *Cyprideis torosa* (Jones), at the Plio-Pleistocene sediments of Mediterranean (Decima, 1964; Carbonnel, 1969; Sissingh, 1972), Paratethys (Pokorny, 1952) and Europe (Vesper, 1972), and Pliocene of Central Anatolia, Eastern Mediterranean, Marmara Region (İstanbul) (Bassiouni, 1979; Nazik, 1996; Şafak et al., 1999), *Urocythereis favosa exedata* Uliczny, at the Pliocene of Aegean Islands, (Sissingh, 1972), Antakya, Adana, İstanbul (Doruk, 1975; Bassiouni, 1979; Şafak, 1993; Nazik, 1996; Şafak et al., 1999), *Urocythereis margaritifera* (Müller), at the Pliocene of Algeria (Yassini, 1979), Aegean Islands (Sissingh, 1972), Mediterranean and Marmara-İstanbul in Turkey (Şafak, 1993; Şafak and Nazik, 1994; Nazik, 1996; Şafak et al., 1999), *Candona* (*Candona*) *neglecta* Sars, at Plio-Quaternary of Yugoslavia (Sokac, 1975 a,b) and Upper Miocene-Pliocene of Rhone Basin (France) (Carbonnel, 1969) were described.

Pliocene, characterized by littoral-lagoonal facies at W₁ borehole of Ataköy

Table 5. The distribution of ostracodes in the Pliocene sequence at Borehole I of Merter drilling.

PLIOCENE													SERIES
26.00-1.00 m													THICKNESS
26	24	18	17	16	14	13	12	11	8	6	5	2	1
					Δ								Sample numbers / Ostracodes
							Δ						<i>Callistocythere</i> sp.
								Δ					<i>Limnocythere</i> sp.
						Δ	Δ		Δ		▲	Δ	<i>Cyprideis pannonica</i> (Mehes)
		Δ											<i>Aurila convexa</i> (Baird)
			Δ			Δ							<i>Urocythereis margaritifera</i> (Müller)
											Δ		<i>Loxoconcha</i> sp.
												Δ	<i>Xestoleberis</i> cf. <i>ventricosa</i> Müller
													<i>Xestoleberis roymonti</i> Ruggieri
Δ				Δ									<i>Candona</i> (C) <i>parallela pannonica</i> Zalanyi
												Δ	<i>Candona</i> (C) <i>neglecta</i> Sars
	Δ				Δ			Δ		Δ			<i>Heterocypris</i> cf. <i>salina</i> (Brady)
											Δ		<i>Heterocypris</i> sp.

Table 6. The distribution of benthic foraminifers in the Pliocene sequence at Borehole I of the Merter drilling.

PLIOCENE															SERIES
26.00-1.00 m															THICKNESS
26	24	23	20	19	17	16	15	14	13	12	11	6	5	2	1
								X			X				Sample number / Benthic foraminifers
									X						<i>Siphanoperta aspera</i> (d'Orbigny)
					X				X						<i>Quinqueloculina seminula</i> (Linné)
				X											<i>Quinqueloculina laevigata</i> d'Orbigny
														X	<i>Ammonia tepida</i> Cushman
X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
			X							X					<i>Porosonion subgranosum</i> (Egger)
				X						X					<i>Elphidium crispum</i> (Linné)

drilling and borehole I at Merter drilling (Old Mamul Deposit), has lacustrine and lagoonal characteristics together with shallow marine environment (Table 7).

3. RESULTS

Tertiary stratigraphy of the Bakırköy and Merter regions located at the western part of Istanbul was carried out within the study. Totally five boreholes were micropaleontologically evaluated. It is indicated that there was Upper Eocene-Oligocene at the bottom, and later Upper Miocene (Tortonian-Messinian) with the

time interval; and finally Pliocene sequence according to these ostracod and benthic foraminifera.

The Upper Eocene (Priabonian) is typical of ostracod assemblages with *Cytherella triestina* Kollmann, *Thracella apostolescui* Sönmez, *Bairdia elongata* Lienenklaus, *B. cymbula* Deltel, *B. crebra* Deltel, *Bairdoppilata gliberti* Keij, *Triebelina punctata* Deltel, *Schizocythere tessellata* tessellata (Bosquet), *Eucythere* sp., *Krithe rutoti* Keij, *K. obesa* Sönmez-Gökçen, *Echinocythereis isabonana* Oertli, *Leguminocythereis*

OSTRACODA AND BENTHIC FORAMINIFERA OF TERTIARY SEQUENCE
OF WESTERN PART OF ISTANBUL

Table 7. The environmental distribution of the ostracod genera in the Tertiary sequence of western part of İstanbul

SYSTEM	SERIES	STAGES	Ostracod genera	Lacustrine	Brackish	Littoral	Epimeritic	Infralittoral	Bathyal
TERTIARY	NEOGENE	PLIOCENE	<i>Callistocythere</i>						
			<i>Limnocythere</i>						
			<i>Cyprideis</i>						
			<i>Cyamocythereidea</i>						
			<i>Aunla</i>						
			<i>Urocythereis</i>						
			<i>Loxoconcha</i>						
			<i>Semicytherura</i>						
			<i>Xestoleberis</i>						
			<i>Darwinula</i>						
TERTIARY	NEOGENE	MESSINIAN	<i>Ilyocypris</i>						
			<i>Candona</i>						
			<i>Heterocypris</i>						
			<i>Eucypris</i>						
			<i>Cypns</i>						
			<i>Limnocythere</i>						
			<i>Cyprideis</i>						
			<i>Aunla</i>						
			<i>Urocythereis</i>						
			<i>Tyrrenocythere</i>						
TERTIARY	NEOGENE	TORTONIAN	<i>Loxoconcha</i>						
			<i>Xestoleberis</i>						
			<i>Ilyocypris</i>						
			<i>Candona</i>						
			<i>Heterocypris</i>						
			<i>Eucypris</i>						
			<i>Bairdia</i>						
			<i>Neonesidea</i>						
			<i>Callistocythere</i>						
			<i>Limnocythere</i>						
TERTIARY	PALEOGENE	OLOCENE	<i>Cyprideis</i>						
			<i>Aunla</i>						
			<i>Loxoconcha</i>						
			<i>Xestoleberis</i>						
			<i>Ilyocypris</i>						
			<i>Candona</i>						
			<i>Heterocypris</i>						
			<i>Eucypris</i>						
			<i>Bairdia</i>						
			<i>Cytheromorpha</i>						
TERTIARY	PALEOGENE	STAMPAN	<i>Eucythere</i>						
			<i>Pokornyiella</i>						
TERTIARY	PALEOGENE	PRIABONIAN	<i>Cytherella</i>						
			<i>Cytherelloidea</i>						
			<i>Bairdia</i>						
			<i>Triebelina</i>						
			<i>Bairdopplata</i>						
			<i>Hemicypnideis</i>						
			<i>Schizocythere</i>						
			<i>Eucythere</i>						
			<i>Thracella</i>						
			<i>Krithe</i>						
TERTIARY	PALEOGENE	PRIABONIAN	<i>Echinocythereis</i>						
			<i>Leguminocythereis</i>						
			<i>Nucleolina</i>						
			<i>Pokornyiella</i>						
			<i>Hermanites</i>						
			<i>Bradleya</i>						
			<i>Quadracythere</i>						
			<i>Cytheretta</i>						
			<i>Loxoconcha</i>						
			<i>Cytherura</i>						
TERTIARY	PALEOGENE	PRIABONIAN	<i>Cytheropteron</i>						
			<i>Xestoleberis</i>						
			<i>Uroleberis</i>						
			<i>Paracypris</i>						

genappensis Keij, *Nucleolina multicostata* (Deltel), *Pokornyyella osnabrugensis* (Lienenklaus), *P. ventricosa* (Bosquet), *Hermanites paijenborchiana* Keij, *H. alata* Ducasse, *Quadracythere hulusii* Sönmez-Gökçen, *Quadracythere vermiculata* (Bosquet), *Cytheretta concinna* Triebel, *Xestoleberis subglobosa* (Bosquet), *X. convexa* Deltel, *Uroleberis* sp., *Paracypris contracta* (Jones); and benthic foraminiferal fauna of *Halkyardia minima* (Liebus), *Europertia magna* (le Calvez), *Asterigerina rotula* (Kaufmann), *Chapmanina gassinensis* (Silvestri), *Nummulites fabianii* (Prever), *N. striatus* (Brugière).

The Oligocene (Stampian) is represented mostly by *Cytheromorpha zinndorfi* (Lienenklaus), *Eucythere* sp., *Pokornyyella osnabrugensis* (Lienenklaus).

The Upper Miocene (Tortonian) is characterized by the ostracods of *Neonesidea corpulenta* (Mueller), *Cyprideis anatolica* Bassiouni, *C. pannonica* (Mehes), *C. seminulum* (Reuss), *C. torosa* (Jones), *C. trituberculata* Krstic, *C. sarmatica* Krstic, *C. quadrituberculata* Krstic, *C. tuberculata* (Mehes), *Cytheridea acuminata acuminata* Bosquet, *Aurila speyeri* (Brady), *A. convexa* (Baird), *Xestoleberis ventricosa* Mueller, *X. reymonti* Ruggieri, *Ilyocypris bradyi* (Norman), *I. cf. gibba* (Ramdohr), *Heterocypris salina salina* (Brady), *Candona* (*Candona*) *parallela pannonica* Zalanyi, *C. (Candona) neglecta* Sars, *C.*

(*Candona*) *devexa* Kaufmann, *Heterocypris salina salina* (Brady), *Eucypris dulcifons* Diebel & Pietrzenuik and benthic foraminiferal assemblage with *Siphonaperta aspera* (d'Orbigny), *Quinqueloculina seminula* (Linné), *Q. cf. lamarckiana* d'Orbigny, *Q. laevigata* d'Orbigny, *Triloculina marioni* Schlumberger, *T. cf. schreiberiana* d'Orbigny, *Eponides concameratus* (Williamson), *Lobatula lobatula* (Walker & Jacob), *Ammonia compacta* Hofker, *A. parkinsoniana* (d'Orbigny), *Porosononion subgranosum* (Egger), *Elphidium crispum* (Linné).

The microfauna shows a typical Messinian characteristics with *Neonesidea corpulenta* (Mueller), *Leptocythere sanmarinensis* Ruggieri, *Cyprideis anatolica* Bassiouni, *C. pannonica* (Mehes), *C. seminulum* (Reuss), *C. torosa* (Jones), *C. trituberculata* Krstic, *C. sohni* Bassiouni, *C. quadrituberculata* Krstic, *C. tuberculata* (Mehes), *C. pontica* Krstic, *C. compacta turgida* Bassiouni, *Aurila speyeri* (Brady), *A. convexa* (Baird), *Urocythereis seminulum* (Sequenza), *Tyrrhenocythere triebeli* Krstic, *Xestoleberis ventricosa* Mueller, *X. reymonti* Ruggieri, *X. communis* Mueller, *Ilyocypris bradyi* (Norman), *Candona* (*Candona*) *decimai* Freels, *C. (Candona) parallela pannonica* Zalanyi, *C. (Candona) neglecta* Sars, *C. (Candona) devexa* Kauffmann, *Heterocypris salina salina* (Brady), *Eucypris dulcifons* Diebel & Pietrzenuik of ostracod assemblages and *Adelosina partschi* (d'Orbigny),

Siphonaperta aspera (d'Orbigny), *Quinqueloculina seminula* (Linné), *Q. viennensis* Le Calvez, *Quinqueloculina* sp., *Pyrgo* sp., *Eponides concameratus* (Williamson), *Ammonia parkinsoniana* (d'Orbigny), *A. compacta* Hofker, *Porosonion subgranosum* (Egger), *Elphidium crispum* (Linné), *Elphidium* sp. of foraminiferal assemblages.

The following ostracods, *Callistocythere* sp., *Limnocythere* sp., *Cyprideis seminulum* (Reuss), *C. pannonica* (Mehes), *C. anatolica* Bassiouni, *C. torosa* (Jones), *C. sublittoralis sublittoralis* Pokorný, *Cyamocytheridea dertonensis* Ruggieri, *Aurila convexa* (Baird), *Urocythereis favosa exedata* Uliczny, *U. margaritifera* (Müller), *Loxoconcha tumida* Brady, *Xestoleberis ventricosa* Mueller, *X. reymonti* Ruggieri, *X. communis* Mueller, *Darwinula stevensoni* (Brady & Robertson), *D. cylindrica* Straub, *Ilyocypris* cf. *bradyi* (Norman), *Candona* (*Candona*) *altoides* Petkovski, *C. (Candona) parallela pannonica* Zalanyi, *C. (Candona) decimai* Freels, *C. (Candona) candida* (Müller), *C. (Candona) neglecta* Sars, *Heterocypris salina salina* (Brady), *Eucypris dulcifons* Diebel & Pietrzenuik, and benthic foraminifera of *Siphonaperta aspera* (d'Orbigny), *Quinqueloculina seminula* (Linné), *Q. laevigata* d'Orbigny, *Eponides concameratus* (Williamson), *Cibicides advenum* (d'Orbigny), *Ammonia tepida* Cushman, *A. compacta* Hofker, *A. parkinsoniana* (d'Orbigny), *Challengerella bradyi* Billman, Hottinger

& Oesterle, *Porosonion subgranosum* (Egger), *Elphidium crispum* (Linné) have been recognized from the Pliocene.

Upper Eocene-Oligocene is represented by a shallow marine facies; in general Upper Miocene (Tortonian and Messinian) consists of littoral-lagoonal and sometimes lacustrine characteristics, and Pliocene is characterized by very shallow marine to littoral-lagoonal environment.

4. ACKNOWLEDGEMENT

The authors would like to thank, to Prof. Dr. Okay Eroskay (Kültür University) for providing drilling samples, to Refik Üreyen and Turgay Gönül (Arçelik Ar-Ge Center) for taking SEM photoes (Geol JSM-6400 Scanning Electron Microscopy), and to Yasemin Leventeli (University of Çukurova) for drawing the tables.

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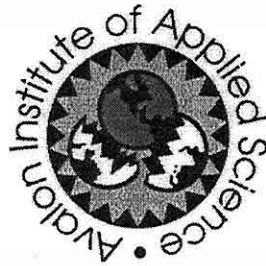
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