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**HOLOCENE ENVIRONMENTAL RECONSTRUCTION
OF LAKE BAFA (SW, ANATOLIA) BY STATISTICAL
ANALYSES OF OSTRACOD AND BENTHIC
FORAMINIFER ASSEMBLAGES**

MASTER OF SCIENCE

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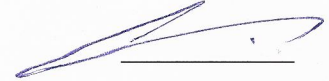
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ÖZET

BAFA GÖLÜ (GB ANADOLU) HOLOSEN ÇEVRESEL DEĞİŞİMLERİNİN, OSTRACOD VE BENTİK FORAMİNİFER TOPLULUKLARININ İSTATİSTİKSEL ANALİZLER İLE YENİDEN YAPILANDIRILMASI

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Sediman arşivleri, geçmiş ortam koşulları hakkında önemli bilgi sağlar ve bu koşulların araştırılmasında çeşitli belirteçler (ör. sediman özellikleri, jeokimya ve fosil toplulukları) yaygın olarak kullanılmaktadır. Dinamik kıyı ortamlarında, değişen süreçler belirteç yorumlarının karmaşık çevresel ortamların yeniden yapılandırmasında kullanımını zorlaştırır. Burada, GB Anadolu'da bulunan hafif tuzlu su ekosistemine sahip Bafa Gölü'nden alınan sediman karotuna ait belirteç analizlerini sunuyorum. Karot alınan sulak alanın başlangıçta Latmian Körfezi ile Ege Denizi'ne bağlantısı vardı. Fakat, Büyük Menderes nehrinin delta ilerlemesi nedeniyle bölge açık denizden izole edilmiş ve kapalı bir göl sistemi haline gelmiştir. Geçmiş kıyı çizgileri öncel çalışmalarda nehrin alüviyal yelpaze ve delta kısımlarından alınan sediman karotları üzerinde farklı yöntemler (ör. sedimantolojik, mikro-faunistik, palinolojik yöntemler) uygulanarak çalışılmıştır.

Bu çalışmada, çoğunlukla hafif tuzlu su ortam çalışmalarında güvenilir ve kullanışlı belirteçler olan ostrakod ve bentik foraminifer mikrofosil topluluklarını kullandım. Bafa Gölü'nde 57 ostracoda ve 69 bentik foraminifer türü tespit ettim ve bunların sediman karotu boyunca oluşumlarını istatistiksel olarak değerlendirdim. İndikatör türlerin sınırlandırılmış hiyerarşik kümeleme analizi ve ekolojik özelliklerine dayanarak, Holosen'de Bafa Gölü'nde beş ayrı geçmiş ortam belirledim: (1) $(8500 \pm 160 - 6700 \pm 250 \text{ GÖY})$ - Günümüzden Önce Yıl) bazı sığ sularda yaşayan ostrakod türlerinin bulunuşu (ör. *Loxoconcha rhombodei*, *Aurila convexa*, *Semicytherura sulcata*) ek olarak marjinal deniz ortamlarında bulunan bentik foraminiferler (ör. *Miliolinella labiosa*, *Rosalina obtusa*, *Parrina bradyi*) (2) $(6400 \pm 175 - 3330 \pm 430 \text{ GÖY})$ denizel ostrakod (ör. *Xestoleberis prognata*, *Loxoconcha tumida*, *Paradoxostoma simile*) ve bentik foraminifer (ör. *Ammodiscus planorbis*, *Adelosina cliarensis*, *Adelosina laevigata*) türlerinin varlığına sahip Akdenizel ortam (3) $(2800 \pm 340 - 2260 \pm 50 \text{ GÖY})$ Akdeniz kıyısında yaşayan ostrakod türleri (ör.

Bythocythere turgida, *Cytheretta judaea*, *Costa punctatissima*) ve bentik foraminiferler (ör. *Brizalina spatulhata*, *Brizalina striatula*, *Bulimina elongata*) ile ortaya çıkan kıyı denizel ortam. (4) (2200 ± 70 - 710 ± 95 GÖY) düşük oksijenli (ör. *Cyprideis torosa*, *Limnocythere inopinata*, *Fabaeformiscandona pokoryni*) ve denizel ostrakodların (ör. *Aurila woodwardi*, *Sarsicytheridea bradii*, *Sarsicytheridea punctillata*) ve *Ammonia tepida*, *Quinqueloculina laevigata*, *Sigmoilinita edwardsi* gibi bentik foraminifer türlerinin gözlemlendiği izole lagün ortamı. (5) (600 ± 80 – 55 ± 10 GÖY) hafif tuzlu su ortamı; düşük oksijenli hafif tuzlu su ortamlarında yaşayan *Fabaeformiscandona wegelini* and *Darwinula stewensoni*, gibi ostrakod türlerini ve düşük oksijenli hafif tuzlu su ortamlarını tercih eden *Ammonia parkinsonia* gibi bentik foraminifer türünün bulunması nedeniyle belirlenen yaş aralığı hafif tuzlu su ortamı olarak adlandırılmıştır.

Ayrıca, türlere göre belirlenen geçmiş ortamları sediman karotuna ait μ XRF analizlerinden elde edilen jeokimyasal değişkenlerle karşılaştırdım. Sayılan türlerin ve μ XRF verilerinin kanonik uygunluk analizleri (CCA), Fe, K, Mn, Sr ve Ca / Ti içeriğinin, ostrakod ve bentik foraminifer türlerinin dağılımında istatistiksel olarak önemli bir rol oynadığını ortaya koydu. hafif tuzlu su ortamında yaşayan türler buharlaşma oranının ve/veya karbonat çökeliminin artması ile değişen Ca/Ti anomalileri ile pozitif korelasyon gösterirken, izole lagün ortamında yaşayan türler gölsel ortamlardaki oksijen değişiminin belirtisi olan yüksek Fe içeriği ile ilişkilendirilmiştir. Mn ve K anomalileri, Mn-içeren sediman girdisi ve/veya göldeki oksijen değişimi ve tuzluluktaki artış ile ilişkili, genellikle kıyı denizel ortamlarda yaşayan türler ile ilişkili olduğu görülmüştür. Sıgsu seviyesi veya tuzluluktaki artış ile ilişkilendirilen Sr veya Sr/Ca içerikleri genellikle denizel türlerle ilintilendirilmiştir. Bu nedenle, CCA sonuçlarının türlerin kümelenme analizleri ile oldukça uygun olduğu sonucuna varılabilmektedir.

Sonuç olarak, ostrakod ve bentik foraminifer türlerinin detaylı tanımlanması ile türlere ait ekolojik özellikler ve çoklu-değişken istatistiksel analizleri Bafa Gölü'nün son 8500 yılının paleo-çevre rekonstrüksiyonunun daha iyi anlaşılmasına katkı koyacaktır.

Anahtar Kelimeler: Ostracoda, Bentik Foraminifera, Hiyerarşik Kümeleme Analizi, Kanonik Uygunluk Analizi, GB Anadolu

ABSTRACT

HOLOCENE ENVIRONMENTAL RECONSTRUCTION OF LAKE BAFA (SW, ANATOLIA) BY STATISTICAL ANALYSES OF OSTRACOD AND BENTHIC FORAMINIFER ASSEMBLAGES

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Sediment archives provide crucial information of paleoenvironmental conditions, and then various proxies (e.g. sediment properties, geochemistry, and fossil assemblages) have been commonly used for their investigations. In dynamic coastal environments, changing processes make the proxy interpretation difficult to reconstruct complex environmental settings. Here, I present proxy analyses of sediment core from Lake Bafa a brackish-water ecosystem situated in SW Anatolia. The coring site was initially connected to the Aegean Sea from so-called Latmian Gulf. However, due to the delta progradation of Büyük Menderes river, the site was isolated from the open sea and a closed lake system established. Paleoshorelines have been previously studied by applying different proxies (e.g. sedimentological, micro-faunistical, palynological methods) on sediment cores taken from alluvial fan and delta parts of the river.

In this study, I mainly used the abundant microfossil assemblages of ostracoda and benthic foraminifera, which are reliable and useful proxies in brackish study sites. I identified 57 ostracoda and 69 benthic foraminifera species in Lake Bafa, and statistically evaluated their occurrence throughout the core. Based on constrained hierarchical clustering analysis and ecological properties of indicator species, I characterized five distinct paleoenvironments in Lake Bafa during the Holocene: (1) (8500 $\pm$ 160 – 6700 $\pm$ 250 BP) presence of some ostracod species living in shallow waters (e.g. *Loxoconcha rhombodei*, *Aurila convexa*, *Semicytherura sulcata*) plus benthic foraminifera species (e.g. *Miliolinella labiosa*, *Rosalina obtusa*, *Parrina bradyi*) living in marginal marine conditions, (2) (6400 $\pm$ 175 – 3330 $\pm$ 430 BP) full marine environment with the presence of marine ostracoda (e.g. *Xestoleberis prognata*, *Loxoconcha tumida*, *Paradoxostoma simile*) and benthic foraminifera species (e.g. *Ammodiscus planorbis*, *Adelosina cliarensis*, *Adelosina laevigata*) (3) (2800 $\pm$ 340 – 2260 $\pm$ 50 BP) coastal marine environment revealed by ostracoda species living in Mediterranean coast (e.g. *Bythocythere turgida*, *Cytheretta judaea*, *Costa punctatissima*) and benthic foraminifera (e.g. *Brizalina spatulhata*, *Brizalina striatula*, *Bulimina elongata*) (4) (2200 $\pm$ 70 – 710 $\pm$ 95 BP) isolated lagoon environment in which low-oxygen ostracoda (e.g. *Cyprideis torosa*, *Limnocythere inopinata*, *Fabaeformiscandona pokoryni*), marine ostracoda (e.g. *Aurila woodwardi*,

Sarsicytheridea bradii, *Sarsicytheridea punctillata*) and benthic foraminifera (e.g. *Ammonia tepida*, *Quinqueloculina laevigata*, *Sigmoilinita edwardsi*) are found, (5) ($600 \pm 80 - 55 \pm 10$ BP) brackish water environment including some low-oxygen brackish ostracoda species such as *Farbaeformiscandona wegelini* and *Darwinula stewensoni*, and benthic foraminifera species of *Ammonia parkinsonia* who prefer low oxygen brackish water environments.

In addition, I correlated the species-based paleoenvironments with geochemical variables obtained by μ XRF analyses of sediment core. Canonical correspondence analyses (CCA) of counted species and μ XRF data revealed that Fe, K, Mn, Sr, Ca/Ti and Sr/Ca contents have statistically significant role in the distribution of ostracoda and benthic foraminifera species. The species living in brackish environment have positive correlation with Ca/Ti anomalies changing with the increase in evaporation rate and/or carbonate precipitation, whereas the species in isolated lagoon environments are correlated with higher Fe content that is a possible indication for oxygen variation in the lake environments. Mn and K anomalies, indicators for Mn-bearing sediment input and/or oxygen variation in the lake and the increase in the salinity, are mainly correlated with the species in coastal marine environment. Sr or Sr/Ca contents as an indication for shallow-water level or increase in salinity are generally correlated with the species in marine environments. Hence, it can be concluded that CCA results are well-correlated with the clustering analysis of species.

As a conclusion, the detailed identification of ostracoda and benthic foraminifera species with their ecological properties and multi-variate statistical analyses will certainly contribute the better understanding of the paleoenvironmental reconstruction of Lake Bafa for the last 8500 BP.

Keywords: Ostracoda, Benthic Foraminifera, Hierarchical Clustering Analysis, Canonical Correspondence Analysis, SW Anatolia



To my cat

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SYMBOLS AND ABBREVIATIONS

BP	Before Present
CCA	Canonical Correspondence Analysis
CHC	Constrained Hierarchical Cluster
D.O.	Dissolved Oxygen
Temp.	Temperature
VIF	Variance Inflation Factor
MS	Magnetic Susceptibility
TOC	Total Organic Carbon
K	Potassium
Ca	Calcium
Mn	Manganese
Fe	Iron
Sr	Strontium
Ti	Titanium

1. INTRODUCTION

The fossil assemblage in lakes and lagoons (especially ostracoda and benthic foraminifera) is the most common proxy used in paleoenvironmental reconstruction studies (e.g. Holmes, 1992; Edwards et al., 2006; Abu-Zied et al., 2007; Keatings et al., 2010). Not only isotope analyses, ^{14}C -dating, and shell chemistry of species are used for both paleoclimatological and paleoenvironmental reconstruction studies (e.g. Holmes and Chivas, 2002; Toth et al., 2010; Koukousioura et al., 2012), but also distribution of species revealed by their sensitivity to various ecological factors (e.g. salinity, pH, dissolved oxygen) (Frenzel and Boomer, 2005) and some statistical analyses (e.g. hierarchical clustering analysis) are rather important proxies (e.g. Viehberg, 2006; Ligios et al., 2008).

Ostracoda and benthic foraminifera are widely used as paleoenvironmental proxies especially for stratigraphic and paleoecological purposes (e.g. Kouwenhoven and Van der Zwaan, 2006; Bertrand et al., 2011; Nazik et al., 2011; Faranda et al., 2013; Fajemila et al., 2015). The main characteristics of these species are; covering wide distribution from continental water bodies to the deep ocean; the sensitivity to various environmental changes due to their short reproductive cycles; and long-term preservation in sediments because of their hard shells (e.g. Murray, 2006; Rodriguez-Lazaro and Ruiz-Munoz, 2012; Barbieri and Vaiani, 2018). Therefore, ostracoda and benthic foraminifera species are very useful for ecological studies in modern environments such as the paralic realm (e.g. estuaries, lagoons) in which there is an abundance of these species (e.g. Geslin et al., 2002; Coccioni et al., 2009; du Châtelet and Debenay, 2010; Barbieri and Vaiani, 2018).

The various type of lakes (e.g. coastal, volcanic, tectonic, and glacial) are common throughout the Anatolia. Delta progradation especially in the southwestern part (e.g. Büyük Menderes, Dalyan) is one of the key parameter that hampers the connection of the lakes (e.g. Lake Bafa) with the marginal sea (Brückner, 1997). The formation of delta progradation and geomorphological features closed to the Anatolian lakes is divided in three distinct stages; early, middle, and late Holocene (Kayan, 1999). In the early Holocene, transgression and consequent sedimentation was formed after

glacial period. The middle Holocene was the time when the sea level reached the recent level and the rising stopped. During the transition time from marine to terrestrial environment, the formation of alluvial and delta was abundant. In the late Holocene, delta progradation was retarded and covered by sediments.

The lakes throughout the Anatolia have been investigated by using different proxies for the reconstruction of paleoclimatology and paleoenvironment (e.g. Klkylođlu, 2005; Altnsađlı and Mezquita, 2008; Viehberg et al., 2012; lgen et al., 2012; Kaiser et al., 2016; n et al., 2017; Danladi and Akçer-n, 2018). Lake Bafa is a good example of coastal lake located in the southwest Anatolia, and had previously connected to Aegean Sea (Eisma, 1978; Erinç, 1978). It is a type of coastal lake but the influence of extensional tectonism (i.e. horst and graben system) in the southern part of the Menderes Massif (Bozkurt, 2001) is also obvious on its formation. Since it behaves as a sediment trap after the closure of its connection from the Aegean Sea (so-called Latimian Gulf) due to the progressive delta progradation of Byk Menderes (Meander) river (e.g. Mllenhoff et al., 2004), there are some studies about paleogeographic reconstruction of the lake by using sediment cores taken from alluvial and delta plain (e.g. Mllenhoff et al., 2004; Brckner et al., 2006). It is also suggested that the humans living in and around the ancient city of Miletus have impacted on the ecosystem and consequent artificial (man-made) changes (Brckner et al., 2006; Knipping et al., 2008).

Paleogeographical and paleoenvironmental reconstruction of the Lake Bafa has been mainly based on geomorphological (Erol, 1996), sedimentological, palynological (Mllenhoff et al., 2004; Brckner et al., 2006; Knipping et al., 2008), and multi-proxy study with robust age model studies (Akçer et al., under review).

In this study, we aim to reveal the first detailed taxonomy determination of Holocene ostracod and foraminifera fauna and paleoenvironmental reconstruction by state of the art statistical methods. The identified and counted species based on the level in the sediment cores were statistically analyzed (Constrained Hierarchical Cluster) in R program to cluster them based on their environments. Clustering analysis of these species will provide new insight into the paleoenvironmental reconstruction of the lake. In addition, canonical correspondence analyses were performed on counted species of Lake Bafa with the correlation of multi-proxy data presented by Akçer et

al. (under review). Hereby, we characterize the paleoenvironmental changes based on ostracod and benthic foraminifera fauna assemblage during the evolution of Lake Bafa.

1.1. Study Area

Lake Bafa is located along the NW direction in the western edge of Büyük Menderes Graben (Figure 1.1.). The average width of the lake is 4.5 km with 15.3 km long and the water depth of 21m (e.g. Kazancı et al., 2008). It is mainly fed by Büyük Menderes River and small-volume saline springwaters (Koç, 2008). Physicochemical properties of the lake vary based on the different studies, therefore the minimum and maximum values for each parameter are given as follows: salinity (4‰; Koçak et al., 2017 and 30‰; Kazancı et al., 2008); annual temperature (8°C; Demir, 2007 and 32°C; Koçak et al., 2017); dissolved oxygen (3.1-14.1 mg/l; Koçak et al., 2017); and pH values (7.4; Koç, 2008; 9.2; Koçak et al., 2017).

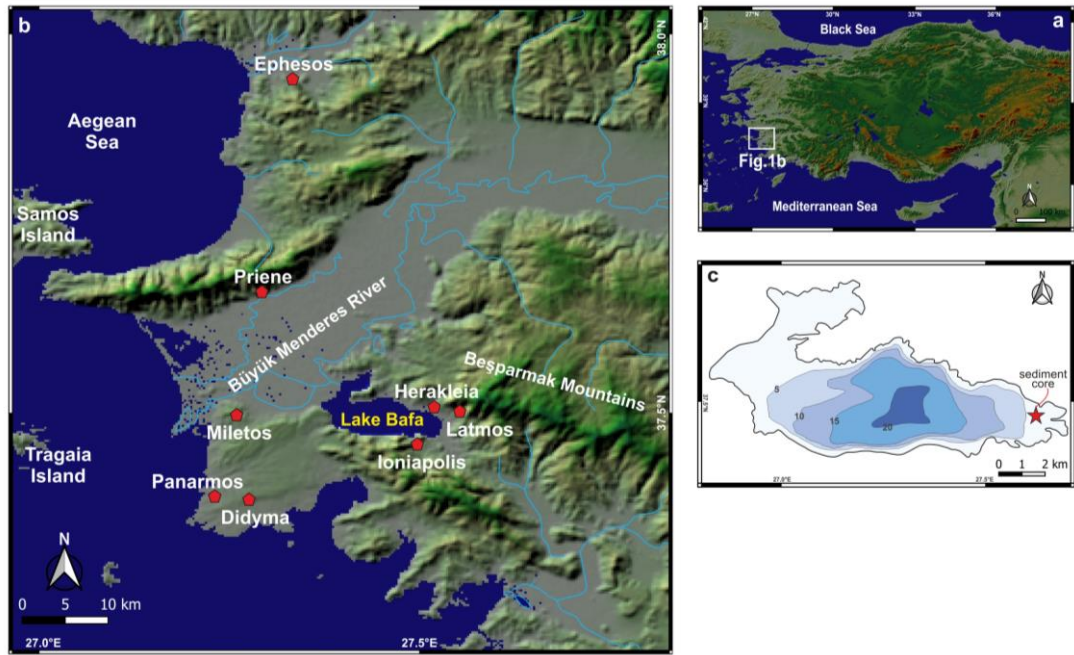


Figure 1. 1. a) Location of the study area; b) Digital Elevation Map (ASTER GDEM 30m x 30m resolution) showing Büyük Menderes Valley and ancient cities around Lake Bafa; c) Map of Lake Bafa displaying bathymetry of the lake and our core location (Demir, 2007).

Lake Bafa is also situated at the southwestern part of the Menderes Massif consisting of core and cover units (Figure 1.2.). The core of massif includes Upper Proterozoic metasediments, mica schist, orthogneiss, metagabbros, and metanorite intrusions (e.g. Candan et al., 2001; Erdoğan and Güngör, 2004; Gürsu, 2016). The orthogneiss and mica schist are mainly emplaced in the northern and eastern parts of the lake (Figure 1.2.). On the other hand, the cover units comprise of Paleozoic-Lower Tertiary platform carbonates, marl, clayey limestone, and marble (e.g. Okay, 1989; Özer et al., 2001) (Figure 1.2.). Of those, massive marbles with emery deposits and poorly-preserved rudist fossils are exposed in the southern part of the lake (e.g. Özer et al., 2001).

The surrounding of Lake Bafa, namely the Latmian Gulf and Büyük Menderes river valley, has been continuously convenient routes and regions for human settlement (i.e. the iconic classical Graceo-Roman cities of Miletos, Priene, Myous, and Herakleia-ad-Latmos; Figure 1.1.) because of the climatic and strategic advantages (e.g. Müllenhof et al., 2004; Knipping et al., 2008). Therefore, there has been strong cultural imprints in the region (e.g. Archaic period, 7th-6th cent. BC; Early Bronze Age, 3rd millennium BC) especially during the Greek and Roman times (Knipping et al., 2008; Akçer et al., under review)

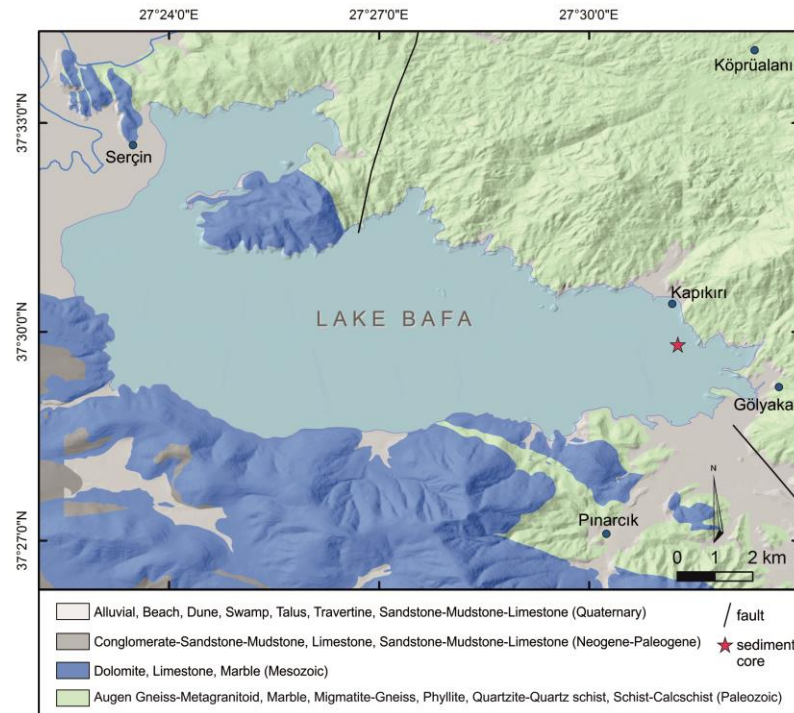


Figure 1. 2. Simplified geological map of the Lake Bafa (modified from MTA, 2002).

1.2. Materials and Methods

1.2.1. Sampling and species identification

Sediment core (BAFA09P02) with a length of 298 cm that was recovered at water depth of 4.9 m in Lake Bafa (Figure 1.1.; Akçer, 2011) was used for sampling of ostracoda and benthic foraminifera species. Lithological and paleontological features such as color, clast size, and fossil assemblages were noted throughout the sediment core (Figure 2.1.). Core is sampled at 5 cm intervals. A solution prepared by using Calgon was added to a total of 44 samples to differentiate the fossils from sediments easily. Samples were then sieved to 63 and 150 microns, and dried in Freeze Dryer. Samples with 30 gr dry weight were examined under the binocular stereo microscope to identify ostracoda and benthic foraminifera species and their taxonomies. We follow Bonaduce et al. (1975), Griffiths and Holmes, (2000) and Meisch (2000) for the identification of ostracoda, and Loeblich and Tappan (1988), Cimerman and Langer (1991), Sgarrella (1993), Sakıncı (2008), Milker and Schmiedl (2012) for the benthic foraminifera species. Scanning electron microscope (SEM) images of Ostracoda species were taken in Universitat Köln (Institute für Mineralogie und Geologie, Köln, Germany), and those from benthic foraminifera were taken in Universitat Bonn (Institute für Geologie, Mineralogie, Bonn, Germany) and Hitit University (Çorum, Turkey).

1.2.2. Statistical analyses

1.2.2.1. Constrained hierarchical clustering analysis of species

Ostracoda and benthic foraminifera species identified in a total of 44 samples were counted using Morpheus program. The sampling and counting processes were performed until nothing remains from the sediment samples (each has 30 gr dry weight). The square root transformation was applied on the counted species data using R-package of “plyr” for a better visualization of the data. The transformed data of both ostracoda and benthic foraminifera were illustrated as heatmaps (Figures 2.1. and 2.6.) using R-packages of “scales” and “ggplot2”. Thus, the distribution and

abundance of the species can easily be followed from the heatmaps (Figures 2.1. and 2.6.).

Prior to Constrained Hierarchical Clustering analysis of counted species data, the *broken-stick model* (MacArthur, 1957) was applied using “bstick” function in “Rioja” (Juggins, 2009) and “Vegan” (Dixon, 2003; Oksanen et al., 2011) R-packages for a precise determination of the number of zones (i.e. clusters) in the species assemblages. The comparison between resulting division of total variance (i.e. a stick of unit length) and that expected from the broken-stick model proposes a more precise number of zones (Bennett, 1996). In this model, the number zones or groups (n) are plotted against the residual variation after n zones as a proportion of the total variance (Bennett, 1996) (Figures 2.2. and 2.7.). In other words, the nth zone or group as a proportion of the total variance (fluctuating black curve) is compared with the values obtained by broken-stick model (smooth red curve) (Figures 2.2. and 2.7.). The value of n where two curves are intersected in Figures 2.2. and 2.7. indicates the maximum number of reliable groups. The mathematical details of broken-stick model can be found in Bennett (1996).

After determining the value of n for both counted ostracoda and benthic foraminifera species data, *Constrained Hierarchical Clustering* analyses were performed (Figures 2.3. and 2.8.) using “chclust” function in “Rioja” R-package (Juggins, 2009). The “CONISS” method including agglomerative procedures (Grimm, 1987) was used for clustering analyses. The underlying method in CONISS is the incremental sum of squares method (Ward, 1963) that has been successfully performed especially for clustering analysis of species frequency and/or stratigraphy data (e.g. Behling and Costa, 2000 for pollen species; Gehrels et al., 2001 for foraminifera). The aim of this method is to minimize the total within-cluster dispersion (i.e. a measure of variance) for x groups around x centroid (Grimm, 1987). The overall optimal x groups can be determined by an incremental sum of square method, and this agglomerative algorithm can also place the clusters in a hierarchy (Grimm, 1987). The analysis provides a total dispersion and values related to each stage by increasing the dispersion in the combination of all clusters, and therefore suitable with the broken-stick model (Bennett, 1996).

The indicator ostracoda and benthic foraminifera species for each clusters were also determined by using the “multipatt” function in “indicspec” R-package (De Cáceres and Legendre, 2009) (Tables 2.2. and 2.6.). This package evaluates the strength and statistical significance of the relationship between species abundance and the clusters of depths. On the other hand, the “multipatt” (multi-level pattern analysis) function examines the relationship between species and combinations of depth-based clusters (De Cáceres and Legendre, 2009). The “Indicator Value (IndVal)” index (Dufrêne and Legendre, 1997) is the default index used to measure this association in “multipatt” function. Therefore, index values in Tables 2.2. and 2.6. (1 to 5) represents the clusters of which the indicator species are pertained. The statistical significance of this relationship was also tested using a permutation test, and the results with p-values less than or equal to 0.05 (Tables 2.2. and 2.6.) are especially significant.

1.2.2.2. Canonical correspondence analysis of μ XRF and species data

The raw data of counted species were transformed by chi-square method using “decostand” function in “Vegan” R-package. The chi-square method that divides by row sums and square root of columns sums and adjusts for square root of matrix total has been applied for counted species data (Legendre and Gallagher, 2001). This also helps the transformation of skewed distribution to normal. In addition, this method reduces the value of abundant species more than that of rare species. Therefore, it is especially used for giving more weight to rare species.

The outliers in the μ XRF data of a sediment core from Lake Bafa (Akçer et al., under review) were detected using “moutlier1” function in MATLAB (Rencher, 2002; Trujillo-Ortiz et al., 2006). This test is mainly based on the Wilk’s method (1963) to detect the single outliers from normal multivariate sample. A total of 290 outliers were detected in μ XRF data using the significance level of 0.05 and extracted from the dataset. Although the sampling interval was 0.2 mm for μ XRF data, there were still missing levels in the sediment core. The “NA” values were replaced using “na.ma” function in “imputeTS” R-package (Moritz and Bartz-Beielstein, 2017). In this function, the missing values are replaced by moving average values, meaning an equal number of observation on either side of a central value. To expand both sides

of the center element, the integer width of the moving average window “k” was taken as 20 means 41 observations (20 left, 20 right). The interpolated μ XRF data were then transformed to percentage using one of the standardization method in “decostand” function called “total” that divides the data by margin total. The percentage transformed data were then filtered using “sgolayfilt” function in MATLAB. This function is based on Savitzky-Golay’s filtering method (Savitzky and Golay, 1964) that smooths the data depending on local least-squares polynomial approximation.

Collinearity test was also performed on transformed and filtered μ XRF data using “vifstep” function in “usdm” R-package (Naimi et al., 2014) to detect the collinear chemical variables based on the calculating variance inflation factor (VIF). The VIF depends on the square of the multiple correlation coefficient that results from regression of a predictor variable against all others. The correlation coefficient should be close to 1 if the variable has a strong linear relationship with at least one other variables. In that case, VIF would be large for that variable, and therefore VIF greater than 10 means a collinearity problem. Accordingly, some of the μ XRF variables (Br and Ti) that have elevated VIF (>10) were excluded from the dataset for further analysis. The Canonical Correspondence Analysis (CCA; ter Braak, 1986; ter Braak and Verdonschot, 1995) on transformed μ XRF and counted species data was performed using “Vegan” R-package to reveal the role of chemical variables (μ XRF analyses; Akçer et al., under review) on the distribution of species assemblages in Lake Bafa. ANOVA-like permutation test was also performed on CCA results to detect significant relationships (p -value < 0.05) between species and chemical variables.

2. RESULTS

2.1. Lithological Descriptions

The five distinct paleoenvironments along the sediment core of Lake Bafa (Akçer et al., under review) were determined mainly based on the micropaleontological properties (Figure 2.1.). During the whole marine period, a total of 63 benthic foraminifera and 42 marine ostracoda species were identified. Marine conditions can also be divided into three considering the ecological conditions of the ostracoda species. Foraminifera species do not provide such indication as they have high tolerance to marine conditions. Number of the ostracoda species is 7, 12 and 23 for the marginal, full-marine and coastal marine conditions, respectively. Units are generally enriched by green-colored bivalve-bearing sandy mud (Figure 2.1.). The core is dominant by dark green-colored mud in 298-250 cm interval. Between 298-182 cm, there is a relatively high abundance of macrofossils such as bivalvia, gastropoda, and vermetid particles (Figure 2.1.). The planktonic foraminifera genus of *Globegerinella* were only observed at the depth 189 cm, 196 cm, 238 cm, and 245 cm indicating the relatively high salinity during the coastal and full-marine environments (Figure 2.1.). In the isolated lagoon part where the lake was separated from the open sea, there is a decrease in the variety of benthic foraminifera compared to marine environments. This part is also partly dominant by bivalve and gastropod shells (Figure 2.1.). The brackish environment is abundant by light-green silty and sandy clay including dominantly low-oxygen ostracoda species and rarely benthic foraminifera (Figure 2.1.).

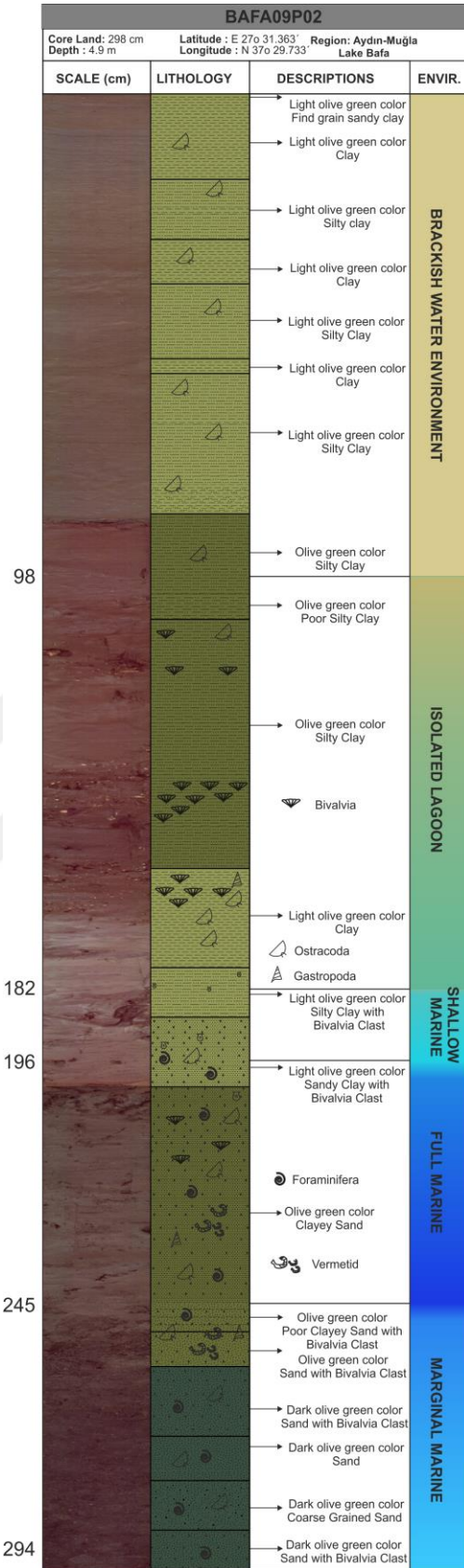


Figure 2. 1. Lithological description of BAFA09P02 sediment core (modified after Akçer et al., under review)

2.2. Ostracoda species in Lake Bafa

We identified 57 ostracoda species pertaining to 18 families and 29 genera from 44 sediment samples taken along the sediment core (Figure 2.2).

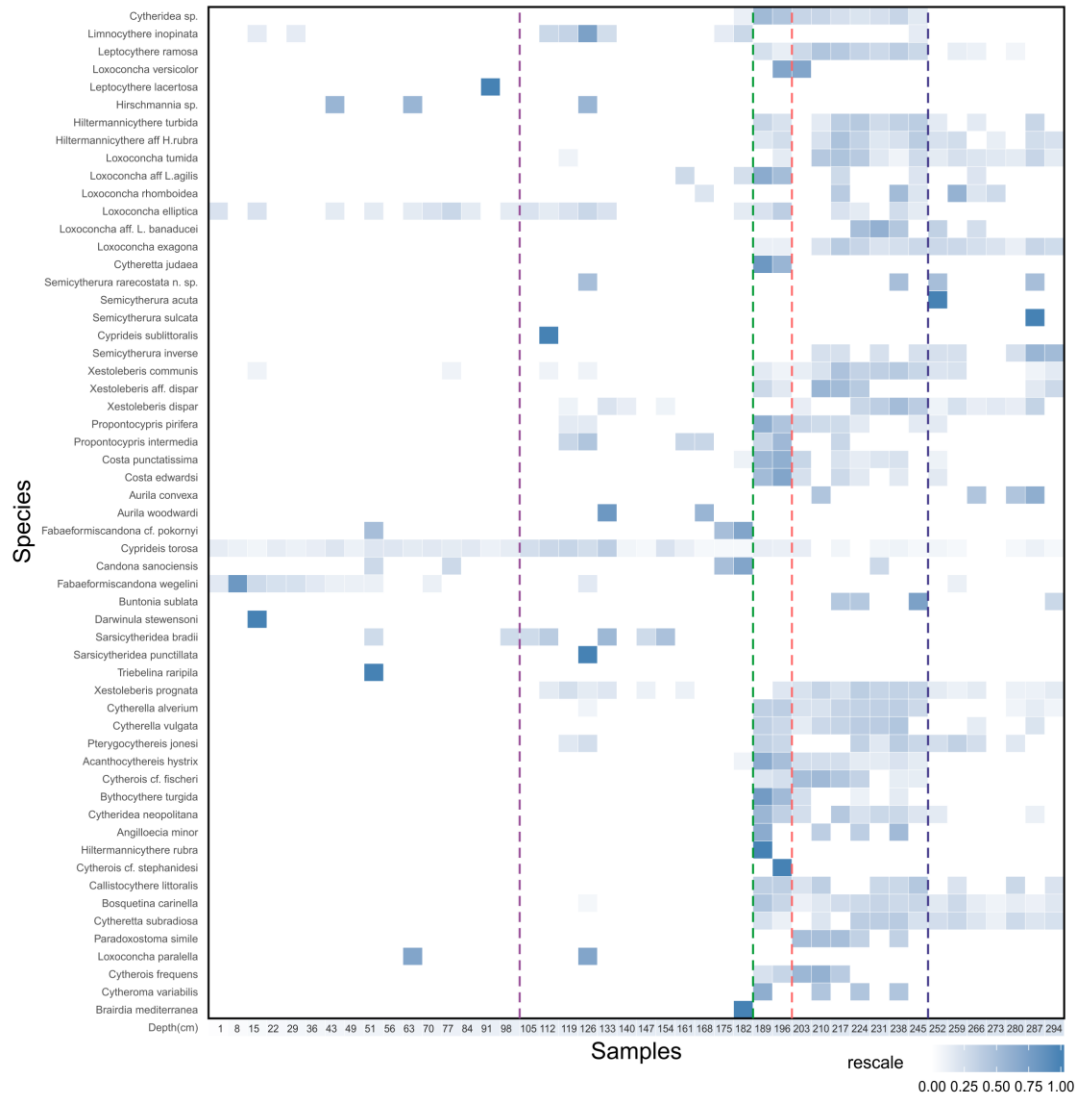


Figure 2. 2. Heatmap of identified ostracoda species in the sediment core of Lake Bafa. Changing from light to dark color in boxes represents the increase in species abundance. Colored dash lines indicate statistically defined paleoenvironments in Lake Bafa (from right to left, marginal marine, full marine, coastal marine, isolated lagoon and brackish).

2.2.1. Taxonomy and ecological properties

The taxonomy of identified ostracoda species are:

Class Ostracoda Latreille, 1802

Subclass Podocopa Müller, 1894

Order Podocopida Sars, 1866

Suborder Platycopa Sars, 1866

Family Cytherellidae Sars, 1866

Genus *Cytherella* Jones, 1849

Cytherella alvearium (Bonaduce, Ciampo and Masoli, 1976)

Cytherella vulgata (Ruggieri, 1962)

Suborder Bairdiocopina Sars, 1865

Superfamily Bairdioidea Sars, 1865

Family Bairdiidae Sars, 1865

Genus *Bairdia* McCoy, 1844

Bairdia mediterranea (G.W.Müller, 1894)

Genus *Triebelina* Bold, 1946

Triebelina raripila (G.W.Müller, 1894)

Suborder Cytherocopina Baird, 1850

Superfamily Cytheroidea Baird, 1850

Family Bythocytheridae Sars, 1866

Genus *Bythocythere* Sars, 1866

Bythocythere turgida (Sars, 1866)

Family Cytherideidae Sars, 1925

Genus *Cyprideis* Jones, 1857

Cyprideis torosa (Jones, 1857)

Cyprideis sublittoralis (Pokorny, 1952)

Genus *Cytheridea* Bosquet, 1852

Cytheridea neapolitana (Kolmann, 1958)

Cytheridea sp.

Genus *Sarsicytheridea* Athersuch, 1982

Sarsicytheridea bradii (Norman, 1865)

Sarsicytheridea punctillata (Brady, 1865)

Family Cytheromatidae Elofson, 1939

Genus *Cytheroma* Mueller, 1894

Cytheroma variabilis (G.W.Müller, 1894)

Family Cytheruridae Müller, 1894

Genus *Semicytherura* Wagner, 1957

Semicytherura inversa (Seguenza, 1880)

Semicytherura acuta (G.W.Müller, 1912)

Semicytherura rarecostata n. sp. (Bonaduce, Ciampo and Masoli, 1976)

Semicytherura sulcata (G.W.Müller, 1894)

Family Hemicytheridae Puri, 1953

Genus *Aurila* Pokorny, 1955

Aurila convexa (Baird, 1850)

Aurila woodwardi (Brady, 1868)

Family Leptocytheridae Hanai, 1957

Genus *Leptocythere* Sars, 1925

Leptocythere lacertosa (Hirschmann, 1912)

Leptocythere ramosa (Rome, 1942)

Genus *Callistocythere* Ruggieri, 1953

Callistocythere littoralis (G.W.Müller, 1894)

Family Cytherettidae Triebel, 1952

Genus *Cytheretta* G.W.Müller, 1894

Cytheretta subradiosa (Roemer, 1838)

Cytheretta judaea (Brady, 1868)

Family Limnocytheridae Klie, 1938

Genus *Limnocythere* Brady, 1867

Limnocythere inopinata (Baird, 1843)

Family Loxoconchidae Sars, 1925

Genus *Loxoconcha* Sars, 1866

Loxoconcha paralella (G.W.Müller, 1894)

Loxoconcha aff. *L. agilis* (Ruggieri, 1967)

Loxoconcha aff. *L. banaducei* (Ciampo, 1971)

Loxoconcha elliptica (Brady, 1868)

Loxoconcha exagona (Bonaduce, Ciampo and Masoli, 1976)

Loxoconcha rhomboidea (Fischer, 1855)

Loxoconcha tumida (Brady, 1869)

Loxoconcha versicolor (G.W.Müller, 1894)

Family Paradoxostomatidae Brady & Norman, 1889

Genus *Paradoxostoma* Fischer, 1855

Paradoxostoma simile (G.W.Müller, 1894)

Genus *Cytherois* G.W.Müller, 1894

Cytherois frequens (G.W.Müller, 1894)

Cytherois cf. *stephanidesi* (Klie 1938)

Cytherois cf. *fischeri* (Sars, 1866)

Family Trachyleberididae Sylvester-Bradley, 1948

Genus *Bosquetina* Keij, 1957

Bosquetina carinella (Reuss, 1850)

Genus *Acanthocythereis* Howe, 1963

Acanthocythereis hystrix (Reuss, 1850)

Genus *Buntonia* Howe, 1953

Buntonia subulata (Ruggieri, 1954)

Genus *Costa* Neviani, 1928

Costa edwardsi (Roemer, 1838)

Costa punctatissima (Ruggieri, 1962)

Genus *Pterygocythereis* Black, 1933

Pterygocythereis jonesi (Baird, 1850)

Genus *Hiltermannicythere*

Hiltermannicythere aff *H.rubra* (G.W.Müller, 1894)

Hiltermannicythere rubra (Müller, 1894)

Hiltermannicythere turbida (G.W.Müller, 1894)

Family Xestoleberididae Sars, 1928

Genus *Xestoleberis* Sars, 1866

Xestoleberis communis (G.W.Müller, 1894)

Xestoleberis dispar (G.W.Müller, 1894)

Xestoleberis aff. *Dispar*

Xestoleberis prognata (Bonaduce and Danielopol, 1988)

Suborder Darwinulocopina Sohn, 1988

Superfamily Darwinuloidea Brady & Norman, 1889

Family Darwinulidae Brady & Norman, 1889

Genus *Darwinula* Brady and Robertson 1885

Darwinula stevensoni (Brady and Robertson, 1870)

Suborder Cypridocopina Jones, 1901

Superfamily Cypridoidea Baird, 1845

Family Candonidae Kaufmann, 1900

Genus *Candona* Baird, 1845

Candona sanociensis (Sywula, 1971)

Genus *Fabaeformiscandona* Krstic, 1972

Fabaeformiscandona wegeli (Petkovski, 1962)

Fabaeformiscandona cf. Pokornyi (Kheil, 1964)

Superfamily Pontocypridoidea Müller, 1894

Family Pontocyprididae Müller, 1894

Genus *Propontocypris* Sylvester-Bradley, 1947

Propontocypris intermedia (G.Brady, 1868)

Propontocypris pirifera (G.Brady, 1868)

Genus *Argilloecia* Sars, 1866

Argilloecia minor (G.W.Müller, 1894)

Table 2. 1. Ecological Properties of Ostracoda Species

Species	Environment	Depth (m)	Salinity (‰)	D.O.(mg/l)	Temp. (°C)	References
<i>Cytherella alvearium</i>	Marine; Bathyal, Sublittoral (Neritic)		34.4	5.41	25.7	Paçal, 2011; Seko et al., 2012; Perçin-Paçal et al., 2015
<i>Cytherella vulgata</i>	Mediterranean Sea	20-30	32.3-36.9	6.62-7.22	9.3-16.4	Bonaduce , 1975; Perçin-Paçal et al., 2015
<i>Bairdia mediterranea</i>	Marine	70	30-40		>10	Kornicker, 1961 ; Bonaduce , 1975; Ruiz et al., 2011
<i>Triebelina raripila</i>	Shallow Marine - Mediterranean					Yassini, 1979; Szczechura, 1998; Keyser and Schöning, 2000
<i>Bythocythere turgida</i>	Black Sea, Shallow Marine; Marine; Sublittoral, Neritic, Littoral	27-70	27.7-36.9	4.56-7.22	9.3-19	Bonaduce , 1975; Athersuch et al., 1983; Opreanu 2005; Perçin-Paçal et al., 2015
<i>Cyprideis torosa</i>	Mediterranean Sea, Aegean Sea, Dardanelles Strait, Sea of Marmara, Bosphorus Strait, Black Sea, Lagoonal, Shallow Marine, Brackish/Freshwater	<40	Oligo-mesohaline 0.4 to 150	*Low oxygen, hypoxia< 4.56-8.42	Polythermophilic eurythermic	Bonaduce , 1975 ; Heip, 1976 ; Athersuch,1979; Neale, 1983; *Jahn et al., 1996; Meisch, 2000; *Anadon et al., 2002; *Anadon et al., 2012 ; Mesquita et al.,2012; Perçin-Paçal et al., 2015
<i>Cyprideis sublittoralis</i>	Brackish; Shallow Water		3-8	Oxygen deficiency <	Eurythermal	Witt, 2010
<i>Cytheridea neapolitana</i>	Marine; Near-Shore Mediterranean, (Aegean Sea, Dardanella Strait, Sea of Marmara)	20-60	34.2-36.4	4.10-5.41	25.5-29	Bonaduce , 1975 ; Carboni et al.,2002; Paçal, 2011 ; Perçin-Paçal et al., 2015
<i>Sarsicytheridea punctillata</i>	deepwater marine ;normal marine to slightly estuarine salinities					Brouwers et al., 2000; Stepanova et al., 2010
<i>Cytheroma variabilis</i>	Marine	172				Bonaduce , 1975
<i>Semicytherura inversa</i>	Marine	46-120	21.5-29.9	7.17-9.67	9.1-26.0	Bonaduce et al.,1975; Perçin-Paçal et al., 2015
<i>Semicytherura acuta</i>	Marine	<119				Bonaduce , 1975

Table 2.1. (continue)

<i>Semicytherura rarecostata</i> n. sp.	Marine	24 -135	36.9	7.22	15.3	Bonaduce , 1975 ; Perçin-Paçal et al., 2015
<i>Semicytherura sulcata</i>	Shallow Marine; Mediterranean Coasts	40 -70	0.1-37.4	3.38-5.41	24.5-31	Bonaduce et al., 1975; Luque et al., 2002 Paçal, 2011
<i>Aurila convexa</i>	Littoral and Shallow Sublittoral,Transported to Shallow Marine, Mediterranean	50 -70	22.0-36.9	4.56-8.53	28.2-33.4	Bonaduce , 1975 ; Athersuch et al., 1989; Seko et al., 2012 ; Paçal, 2011; Perçin-Paçal et al., 2015
<i>Aurila woodwardi</i>	Coastal Marine	<20	Polyhaline euohaline			Bonaduce et al., 1975; Salel et al., 2016
<i>Leptocythere lacertosa</i>	Sublittoral(Neritic), Littoral, Brackish		22.9–47.5		13.6–21.7	Lord, 1980; Nachite and Bekkali, 2010 ; Cabral and Loureiro, 2013; Ejarque et al., 2016
<i>Leptocythere ramosa</i>	Brackish Water/Marine, Mediterranean Coastal Marine	15-42				Bonaduce , 1975 ; Carboni et al.,2002
<i>Callistocythere littoralis</i>	Marine, Littoral	<135	27.7-36.9 Polyhaline euohaline	4.56-8.50	9.1-19.0	Bonaduce , 1975 ; Perçin-Paçal et al., 2015; Salel et al., 2016; Ejarque et al., 2016
<i>Cytheretta subradiosa</i>	Near-Shore Mediterranean Coasts	50-120	34.4-37.4	4.14-5.30	29.8-33.4	Bonaduce , 1975 ; Paçal, 2011
<i>Limnocythere inopinata</i>	Ponds, Swamps, Ditches, Lakes, Slow Brooks, Rivers, and Rice Fields, Lacustrine	<6	0.5-12 Freshwater/ oligohaline	*Low oxygen<	Polythermophilic	De Deckker, 1981; Meisch, 2000; Mischke et al., 2003; Yılmaz and Külköylüoğlu, 2006; *Anadon et al.,2012 ; Salel et al., 2016
<i>Loxoconcha paralella</i>	Marine,Sublittoral(Neritic), Littoral, Brackish					Perçin-Paçal et al., 2015
<i>Loxoconcha aff L.agilis</i>	Marine, Sublittoral(Neritic), Littoral, Brackish	46-170	27.7- 37.6	4.56-8.50	9.1-19.0	Bonaduce , 1975 ; Paçal, 2011; Perçin-Paçal et al., 2015
<i>Loxoconcha aff. L. banaducei</i>	Marine,Sublittoral(Neritic), Littoral, Brackish	121				Bonaduce , 1975

Table 2.1. (continue)

<i>Loxoconcha elliptica</i>	Marine/ Brackish, Littoral, Shallow Coastal, Lagoons, River Mouths, and Salt Marshes. Dardanella Strait, Lagoon of Turkey, Tina Menar Estuary	<20	18 -65; Oligohaline / mesohaline to very euryhaline		10.9–21.7	Bonaduce , 1975 ; Anadon et al., 2002; Cabral and Loureiro, 2013; Martinez-Garcia et al., 2013; Perçin-Paçal et al., 2015; Shennan et al.,2015; Altınsaçlı et al., 2015; Salel et al., 2016
<i>Loxoconcha exagona</i>	Marine euryhaline		Mesohaline; 34.4-37.4	4.14-5.41	25.7-29	Paçal, 2011; Anadon et al., 2002
<i>Loxoconcha rhomboidea</i>	Marine Near Shore, Littoral/Shallow Sublittoral	0.30-70	22-33.8 Polyhaline euhoaline	4.56-10.92	9.1-26.0	Bonaduce , 1975; Athersuch et al., 1989; Luque et al., 2002 ; Cabral and Loureiro, 2013; Perçin-Paçal et al., 2015; Salel et al., 2016; Paçal, 2011
<i>Loxoconcha tumida</i>	Mediterranean Sea	20-70; max 125				Bonaduce et al., 1975
<i>Loxoconcha versicolor</i>	Mediterranean Sea/ Sublittoral(Neritic), Littoral	30-172	32.3-36.9	6.62-7.22	14.5-16.4	Bonaduce , 1975; Perçin-Paçal et al., 2015
<i>Paradoxostoma simile</i>	Sublittoral(Neritic), Littoral - Filamentous Algae and Sea-Grass	30	36.9 Polyhaline euhoaline	7.22	15.3	Bonaduce , 1975; Athersuch, 1979; Perçin-Paçal et al., 2015; Salel et al., 2016
<i>Cytherois frequens</i>	Marine,Sublittoral(Neritic), Littoral, Brackish	~170				Bonaduce , 1975
<i>Cytherois cf. stephanidesi</i>	Mediterranean Associated with Algae and Fine Sediment, Brackish		0-20		12.4-21.4	Cabral and Loureiro, 2013; Ejarque et al., 2016
<i>Cytherois cf. Fischeri</i>	Coastal Marine, Brackish Water		Polyhaline, euryhaline 4 to 35		13.7–19.7	Athersuch et al., 1989; Ruiz et al., 2000 ; Cabral and Loureiro, 2013; Altınsalı et al., 2015; Ejarque et al., 2016 ; Salel et al., 2016
<i>Bosquetina carinella</i>	Marine/Sublittoral(Neritic), Littoral	1 to 30	21.9-36.9	4.56-8.42	9.3-27.0	Seko et al., 2012 ; Perçin-Paçal et al., 2015

Table 2.1. (continue)

<i>Acanthocythereis hystrix</i>	Mediterranean- marine	28-170	34.2-37.2	4.30-5.41	25.5-29.8	Bonaduce et al., 1975; Yassini, 1979; Nazik, 2001; Paçal, 2011; Seko et al., 2012
<i>Buntonia subulata</i>	Sublittoral(Neritic), Littoral, Aegean Sea, Sea of Marmara	20-30	27.7-36.9	4.56-7.34	15.5-19.0	Perçin-Paçal et al., 2015
<i>Costa edwardsi</i>	Marine/Bathyal, Sublittoral (Neritic), Littoral, Mediterranean, Shallow Waters, Aegean Sea, Dardanelle Strait, Marmara, Bosphorus strait, Black Sea	24-125	27.7-36.9; Polyhaline-euhaline	4.56-7.34	9.3-25.5	Bonaduce , 1975; Anadon et al., 2002 ; Paçal, 2011; Perçin-Paçal et al., 2015
<i>Costa punctatissima</i>	Marine/Shallow Water, Lived at Depths	1 to 30; 40-125	21.9-36.9	4.56-8.42	9.1-27.0	Seko et al., 2012; Perçin-Paçal et al., 2015
<i>Pterygocythereis jonesi</i>	Marine/Bathyal, Sublittoral (Neritic), Littoral	1 to 30	21.5-36.9	4.56-8.50	9.3-27.0	Perçin-Paçal et al., 2015
<i>Hiltermannicythere aff H.rubra</i>	Marine/Sublittoral(Neritic), Littoral	36				Bonaduce , 1975; Perçin-Paçal et al., 2015
<i>Hiltermannicythere rubra</i>	Marine/Sublittoral(Neritic), Littoral, Mediterranean Sea, Aegean Sea, Dardanelle Strait, Sea of Marmara, Black Sea	20-30	22.7-36.9	4.56-8.50	9.3-19.0	Paçal, 2011; Perçin-Paçal et al., 2015; Shennan et al., 2015
<i>Hiltermannicythere turbida</i>	Marine/Sublittoral(Neritic), Littoral	27-125	Polyhaline euhaline			Bonaduce , 1975; Salel et al., 2016

Table 2.1. (continue)

<i>Xestoleberis communis</i>	Mediterranean Near Shore/Sublittoral (Neritic), Littoral	0.30-30; 36-125	22.7-36.9 Polyhaline euryhaline	7.02-9.12	9.0-26.0	Bonaduce , 1975 ; Anadon et al., 2002 ; Perçin-Paçal et al., 2015; Salel et al., 2016; Ejarque et al., 2016
<i>Xestoleberis dispar</i>	Marine/Near Shore	50-60 max 125	Euryhaline mesohaline 37.2	5.3	29.8	Bonaduce , 1975; Paçal, 2011
<i>Xestoleberis aff. dispar</i>	Marine/Near Shore					Bonaduce , 1975
<i>Xestoleberis prognata</i>	Deep Marine, Bathyal					Bonaduce and Danielopol, 1988; Abate et al., 1994; Dall' Antonia et al., 2001; Bonaduce and Barra, 2002
<i>Darwinula stevensoni</i>	Dardanelles Strait, Lagonal, Freshwater/ Brackish	Very shallow to shallow	Freshwater to mesohaline oligosaline tolerant high	*Low oxygen	Thermoeuryplastic	*Anadon et al., 2012; Mesquita et al., 2012; Gross et al., 2013; Altınsaçlı et al., 2014; Perçin-Paçal et al., 2015; Altınsaçlı et al., 2015; Salel et al., 2016
<i>Candona sanociensis</i>	Freshwater/Brackish, Springs, Streams, Wells, and the Groundwater				20.0-26.3	Meisch, 2000; Perçin-Paçal et al., 2015; Akdemir et al., 2016
<i>Fabaeformiscandona wegeli</i>	Freshwater/Brackish, Interstitial Groundwater connected to streams, Surface water, Hypogean	1		Poor oxygen		Rogulj et al., 1994; Meisch, 2000; Smith and Palmer, 2012; Perçin-Paçal et al., 2015
<i>Fabaeformiscandona cf. Pokorny</i>	Freshwater, Shallow Pools and the Swampy Shore-Zone of Lakes		Fresh(<5) to oligohaline			Reischenbacher et al., 2007; Gebhardt et al., 2009

Table 2.1. (continue)

<i>Propontocypris intermedia</i>	Shallow Marine/Sublittoral (Neritic), Littoral, Brackish/Freshwater, Well Adapted to the Marine		Polyhaline euhaline			Kurc,1961; Ruiz et al., 2006; Salel et al., 2016
<i>Propontocypris pirifera</i>	Marine/Littoral, Brackish, Mediterranean Sea, Bosphorus Strait		Oligo-meso haline, also polyhaline			Mazzini et al., 1999; Anadon et al., 2002 ; Antonietto et al., 2012; Perçin-Paçal et al., 2015
<i>Argilloecia minor</i>	Marine/Sublittoral(Neritic), Littoral, Deep-Water	71	26.9	9.47	13.1	Bonaduce , 1975; Perçin-Paçal et al., 2015
<i>Sarsicytheridea bradii</i>	Marine, Shallow Marine	10-15	Tolerated reduced salinity		8-12	Brouwers et al., 1991; Majoran, 1999
<i>Cytheretta judaea</i>	Mediterranean Coast					Athersuch, 1979

2.2.2. Multivariate statistical analysis of ostracoda species

2.2.2.1. Constrained hierarchical clustering analysis

The broken-stick model reveals at five groups in the counted ostracoda species data (i.e. first intersection of two curves, Figure 2.3.). Accordingly, constrained hierarchical clustering analysis was performed considering five clusters in the dataset (Figure 2.4.). In addition to clustering analysis, the ecological properties (Table 2.1.) and statistically identified indicator species (Table 2.2.) were also used for defining the five distinct paleoenvironments in Lake Bafa during the Holocene:

(5) (252-294 cm) Marginal marine environment (salinity ‰ 21.5-36.9) in which some indicator species (e.g. *Semicytherura sulcata*, *Semicytherura inversa*, *Semicytherura acuta*, *Semicytherura rarecostata* n.sp., *Aurila convexa*, *Loxoconcha exagona*, *Loxoconcha rhomboidea*) live in shallow (or marginal) marine waters (see also Table 2.1.).

(4) (203-245 cm) Full marine environment (polyhaline-euhaline; salinity ‰ 22.7-37.4) with the presence of polyhaline *Leptocythere ramosa*, and some other distinct marine species (*Buntonia sublata*, *Xestoleberis communis*, *Xestoleberis dispar*, *Xestoleberis prognata*, *Cytheretta subradiosa*, *Loxoconcha tumida*, *Paradoxostoma simile Cytherois* cf. *fisheri*, *Loxoconcha* aff. *L. bonaducei*, *Hiltermannicythere* aff. *H. rubra* and *Hiltermannicythere turbida*) especially abundant in this cluster (see also Table 2.1.).

(3) (189-196 cm) Coastal marine environment (polyhaline-euhaline; salinity ‰ 21.9-37.6) inferred from the Mediterranean-based species of *Cytheridea neapolitana*, *Loxoconcha elliptica*, *Costa edwardsi*, *Costa punctatissima*, *Propontocypris pirifera*, *Cytheromorpha variabilis*, *Hiltermannicythere rubra*, *Bosquetina carinella*, *Acanthocytheris hystrix*, *Cytherois frequens*, *Callistocythere littoralis*, *Cytherois* cf. *stephanidesi*, *Angilloecia minor*, *Bythocythere turgida*, *Pterygocythere jonesi*, *Cytherella vulgata*, *Cytherella alverium*, *Propontocypris intermedia*, *Xestoleberis* aff. *Dispar*, *Cytheretta judaea*, *Loxoconcha* aff. *L. agilis* and *Loxoconcha versicolor* (see also Table 2.1.).

(2) (105-182 cm) Isolated-lagoon environment (oligohaline-polyhaline) in which some species live in low-oxygen brackish environments such as *Cyprideis torosa*, *Cyprideis sublittoralis*, *Limnocythere inopinata*, *Candona sanociensis* and *Fabaeformiscandona cf. pokornyi* are found. In addition, the species such as *Aurila convexa*, *Xestoleberis dispar*, *Aurila woodwardi*, *Bairdia mediterranea*, *Loxoconcha parallela*, *Sarcytheridea puncillata* and *Sarcytheridea bradii* who live in coastal/near shore marine environments are also identified as indicator species for this cluster (see also Table 2.1.). The presence of species living in the low-oxygen brackish environments possibly indicates that the lake was entirely separated from the sea.

(1) (1-98 cm) Brackish water environment low oxygen including some ostracoda species such as *Farbaeformiscandona wegelini*, *Darwinula stewensoni* and *Leptocythere lacertosa* (see also Table 2.1.).

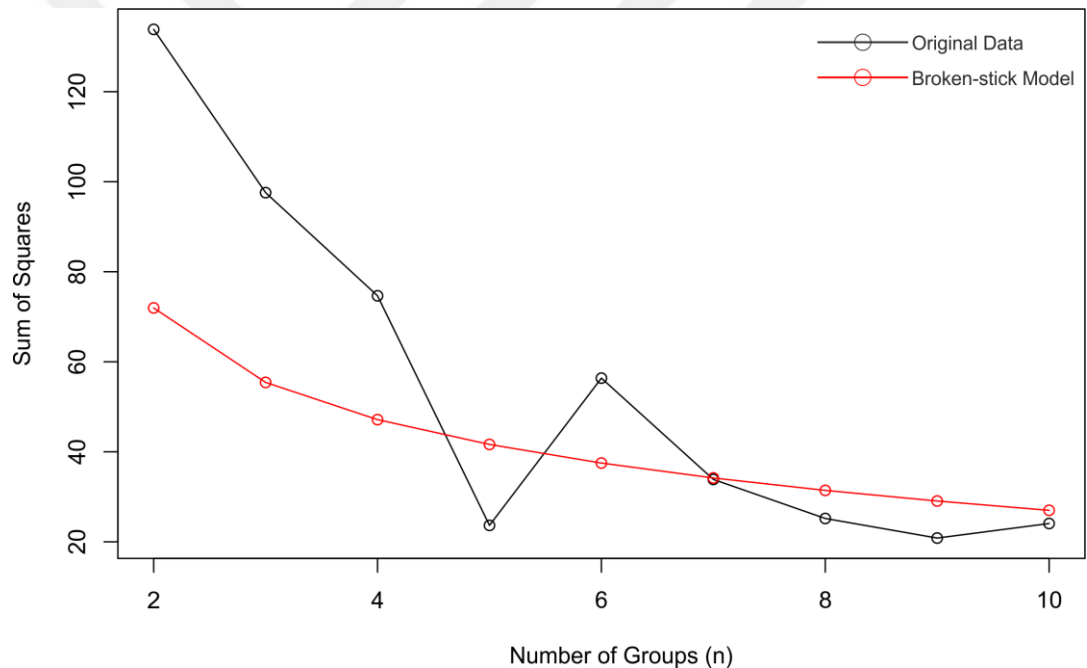


Figure 2. 3. Broken-stick model of ostracoda abundance data

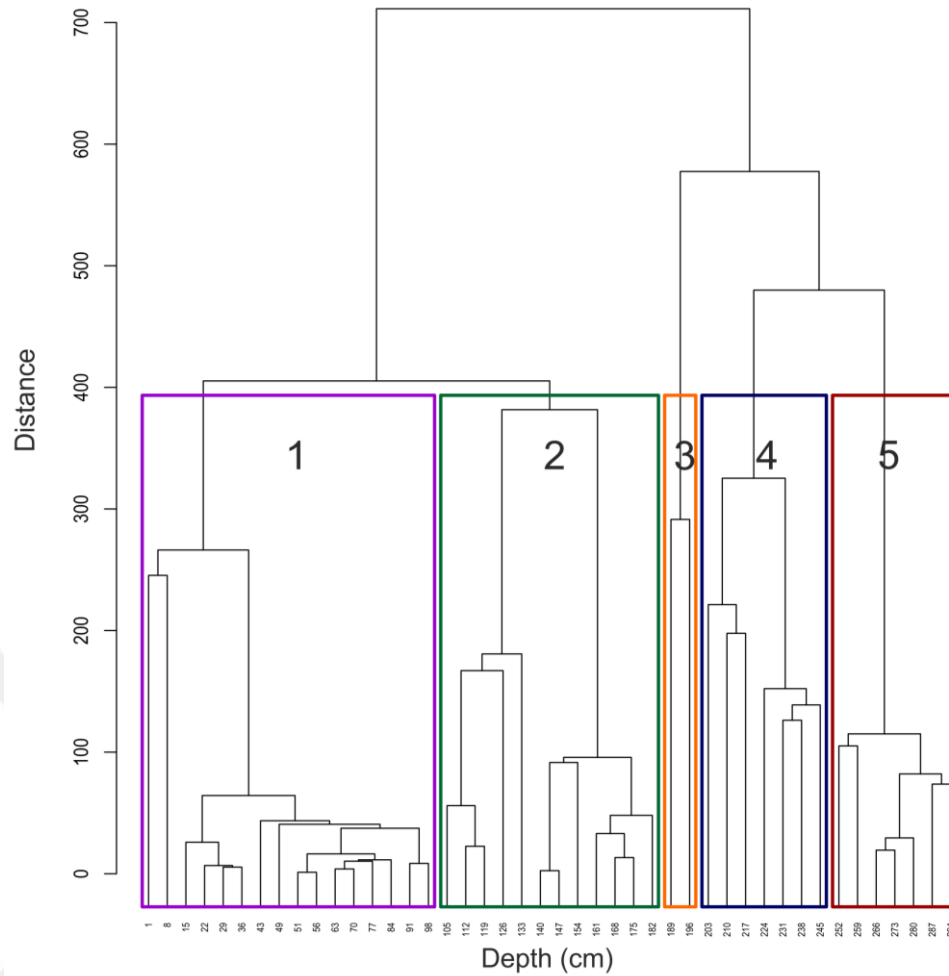


Figure 2. 4. Constrained Hierarchical Analysis of Ostracoda. Paleoenvironments are; 1. Brackish, 2. Isolated lagoon, 3. Coastal Marine, 4. Full Marine, 5. Marginal Marine.

The indicator ostracoda species in Lake Bafa were also statistically determined using the “multipatt” function in “indicspecies” R-package (De Cáceres and Legendre, 2009) (Table 2.2.). The first columns of sign (0 or 1) point out which clusters (i.e. paleoenvironments) were included in the combination favored by the species (Table 2.2). The column “index” means the index to the cluster combination (1: brackish, 2: isolated lagoon, 3: coastal marine, 4: full marine, 5: marginal marine). The p-values were obtained by permutation test to control the statistical significance ($\alpha < 0.05$) in the relationship between indicator species and related clusters (Table 2.2.). Therefore, the species with p-values lower than or equal to 0.05 are statistically significant for their related clusters. The species with higher p-values were yet assigned to true clusters based on their ecological properties, but it is noteworthy to state that this relationship is statistically insignificant.

Table 2. 2. Indicator species and abbreviation for ostracoda in each clusters

Abbr.	Ostracoda Species	s.1	s.2	s.3	s.4	s.5	index	stat	p
BRM	<i>Bairdia mediterranea</i>	0	1	0	0	0	2	0.29	0.64
CVB	<i>Cytheroma variabilis</i>	0	0	1	0	0	3	0.59	0.06
CSF	<i>Cytherois frequens</i>	0	0	1	0	0	3	0.63	0.02
LXP	<i>Loxoconcha paralella</i>	0	1	0	0	0	2	0.22	1.00
PSS	<i>Paradoxostoma simile</i>	0	0	0	1	0	4	0.85	0.01
CTS	<i>Cytheretta subradiosa</i>	0	0	0	1	0	4	0.58	0.11
BEC	<i>Bosquetina carinella</i>	0	0	1	0	0	3	0.77	0.01
CTC	<i>Callistocythere littoralis</i>	0	0	1	0	0	3	0.75	0.02
CCS	<i>Cytherois cf. stephanidesi</i>	0	0	1	0	0	3	0.71	0.04
HCR	<i>Hiltermannicythere rubra</i>	0	0	1	0	0	3	0.71	0.05
AEM	<i>Angilloecia minor</i>	0	0	1	0	0	3	0.60	0.07
CNT	<i>Cytheridea neopolitana</i>	0	0	1	0	0	3	0.86	0.01
BCT	<i>Bythocythere turgida</i>	0	0	1	0	0	3	0.99	0.00
CCF	<i>Cytherois cf. fischeri</i>	0	0	0	1	0	4	0.79	0.02
ACH	<i>Acanthocythereis hystrix</i>	0	0	1	0	0	3	0.94	0.00
PCJ	<i>Pterygocythereis jonesi</i>	0	0	1	0	0	3	0.71	0.04
CTV	<i>Cytherella vulgata</i>	0	0	1	0	0	3	0.70	0.04
CTA	<i>Cytherella alverium</i>	0	0	1	0	0	3	0.75	0.03
XBP	<i>Xestoleberis prognata</i>	0	0	0	1	0	4	0.82	0.00
TBR	<i>Triebelina raripila</i>	1	0	0	0	0	1	0.25	1.00
SCP	<i>Sarsicytheridea punctillata</i>	0	1	0	0	0	2	0.29	0.64
STB	<i>Sarsicytheridea bradii</i>	0	1	0	0	0	2	0.61	0.04
DSW	<i>Darwinula stewensoni</i>	1	0	0	0	0	1	0.25	1.00
BTS	<i>Buntonia sublata</i>	0	0	0	1	0	4	0.62	0.06
FCW	<i>Fabaeformiscandona wegelini</i>	1	0	0	0	0	1	0.76	0.02
CSN	<i>Candona sanociensis</i>	0	1	0	0	0	2	0.35	0.59
CDT	<i>Cyprideis torosa</i>	0	1	0	0	0	2	0.70	0.03
FCP	<i>Fabaeformiscandona cf. Pokrnyi</i>	0	1	0	0	0	2	0.37	0.36
AWW	<i>Aurila woodwardi</i>	0	1	0	0	0	2	0.41	0.20
ACN	<i>Aurila convexa</i>	0	0	0	0	1	5	0.59	0.06
CEW	<i>Costa edwardsi</i>	0	0	1	0	0	3	0.96	0.00
CPT	<i>Costa punctatissima</i>	0	0	1	0	0	3	0.95	0.00
PCI	<i>Propontocypris intermedia</i>	0	0	1	0	0	3	0.88	0.00
PCP	<i>Propontocypris pirifera</i>	0	0	1	0	0	3	0.93	0.00
XBD	<i>Xestoleberis dispar</i>	0	0	0	1	0	4	0.71	0.04
XAD	<i>Xestoleberis aff. dispar</i>	0	0	1	0	0	3	0.55	0.14
XBC	<i>Xestoleberis communis</i>	0	0	0	1	0	4	0.87	0.00
STI	<i>Semicytherura inverse</i>	0	0	0	0	1	5	0.75	0.02
CSL	<i>Cyprideis sublittoralis</i>	0	1	0	0	0	2	0.29	0.64
SCS	<i>Semicytherura sulcata</i>	0	0	0	0	1	5	0.38	0.36
SCA	<i>Semicytherura acuta</i>	0	0	0	0	1	5	0.38	0.36
SCR	<i>Semicytherura rarecostata</i> . sp.	0	0	0	0	1	5	0.40	0.42

Table 2.2. (continue)

CTJ	<i>Cytheretta judaea</i>	0	0	1	0	0	3	1.00	0.00
LEG	<i>Loxoconcha exagona</i>	0	0	0	0	1	5	0.66	0.06
LXB	<i>Loxoconcha aff. L. banaducei</i>	0	0	0	1	0	4	0.59	0.06
LXE	<i>Loxoconcha elliptica</i>	0	0	1	0	0	3	0.76	0.00
LXR	<i>Loxoconcha rhomboidea</i>	0	0	0	0	1	5	0.46	0.29
LXA	<i>Loxoconcha aff. L. agilis</i>	0	0	1	0	0	3	0.95	0.00
LXT	<i>Loxoconcha tumida</i>	0	0	0	1	0	4	0.74	0.04
HHR	<i>Hiltermannicythere aff. H. rbra</i>	0	0	0	1	0	4	0.66	0.05
HCT	<i>Hiltermannicythere turbida</i>	0	0	0	1	0	4	0.66	0.05
HMS	<i>Hirschmannia sp.</i>	1	0	0	0	0	1	0.27	0.69
LCL	<i>Leptocythere lacertosa</i>	1	0	0	0	0	1	0.25	1.00
LXV	<i>Loxoconcha versicolor</i>	0	0	1	0	0	3	0.62	0.09
LCR	<i>Leptocythere ramosa</i>	0	0	0	1	0	4	0.87	0.00
LCI	<i>Limnocythere inopinata</i>	0	1	0	0	0	2	0.68	0.03
CYS	<i>Cytheridea sp.</i>	0	0	1	0	0	3	0.88	0.00

2.2.2.2. Canonical correspondence analysis

To reveal the role of geochemical variables on the distribution of ostracoda species, Canonical Correspondence Analysis (CCA) was applied on counted species and μ XRF data from Lake Bafa (Akçer et al., under review). The main idea of performing CCA on μ XRF and counted species data of Lake Bafa is to determine the most significant geochemical variables that possibly affect the species distribution. In other words, the underlying reason of applying this statistical analysis is to find the possible paleoenvironmental changes in Lake Bafa revealed by anomalies of geochemical variables in the sediment core (i.e. μ XRF analyses).

The scree plot of CCA for ostracoda species reveals that a total of the first two axes exceeds the others, and therefore CCA results can be reliable (Figure 2.5.). Ostracoda species were illustrated in CCA triplot by different colors according to their paleoenvironments (i.e. marginal marine, full marine, coastal marine, isolated lagoon and brackish) determined via constrained hierarchical clustering analysis (Figure 2.6.). The eigenvalues for CCA axis 1 (0.80) and axis 2 (0.52) represent 16% of the total variance (i.e. inertia) and 51% of the cumulative variance in the weighted averages of the ostracoda species (Table 2.3.) (Figure 2.6.). This means that CCA

triplot may not be very realistic for presenting the observed abundances, but more reliable for displaying the weighted averages of species abundance data. This is also evident in scree plot of CCA (Figure 2.5.).

Table 2. 3. CCA results of the counted ostracoda species and chemical variables from Lake Bafa sediment core (μ XRF analyses; Akçer et al., under review)

CCA Parameters	CCA axes				Inertia
	1	2	3	4	
Eigenvalues for constrained axes	0.80	0.52	0.41	0.33	2.62
Eigenvalues for unconstrained axes	0.81	0.62	0.55	0.45	5.74
Species-chemical variable correlations	0.97	0.91	0.88	0.77	
Cumulative percentage variance of					
species data	9.6	6.2	5.0	4.0	
species-environment relation	30.6	20.0	15.8	12.6	

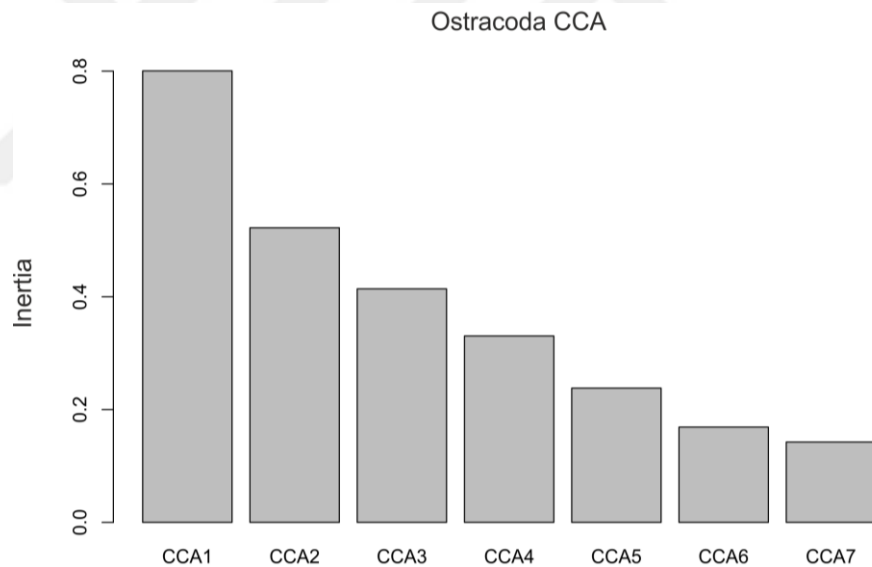


Figure 2. 5. Screeplot of ostracoda CCA

CCA triplot can be interpreted via several ways such as; centroid principle, distance rule, biplot rule, and biplot rule for compositional data (ter Braak and Verdonschot, 1995). In centroid principle, species are thought to be located at the centroid of their niche (i.e. at the centroid of the points for depth of sediment core in our case). For instance, FCW- *Fabaeformiscandona wegelini* is located at the centre of depths (i.e. 1, 22, 36, 49) (Figure 2.6.) defined as brackish environment based on the hierarchical

clustering analysis (Figure 2.4.). Similarly, the position of AWW- *Aurila woodwardi* in Figure 2.6. indicates that its distribution is mainly confined to the depths of 175 and 182 belonging to isolated lagoon environment (Figure 2.4.). As a distance rule, the chi-square distance as a measure of dissimilarity between the abundance profile across sites (depths in our case) of one species and that of another (ter Braak and Verdonschot, 1995) can also be considered to interpret the CCA triplot (Figure 2.5.). The comparison of relative abundances is the most important part in the mathematical formula of the chi-square distance (ter Braak and Verdonschot, 1995). In CCA triplot, the chi-square distance increases when two species are apart from each other, and therefore the close proximity of species means that they have similar distribution across the depth (ter Braak and Verdonschot, 1995). For instance, in Figure 2.5., the distribution of ostracoda species is almost suitable with the results of clustering analysis, except for some species that have high ecological tolerance (e.g. PCI-*Propontocypris intermedia* and LXE-*Loxoconcha elliptica* living both marine and brackish environments, Table 2.1.).

On the other hand, there is a high correlation ($p < 0.001$) between ostracoda species and environmental variables (μ XRF data of Akçer et al., under review) revealed by CCA axis 1 (0.97) and axis 2 (0.91). The further ANOVA permutation test performed on CCA result especially identified 6 geochemical variables (Fe, K, Mn, Sr, Ca/Ti and Sr/Ca) that significantly explained the variation in the ostracoda assemblages (Table 2.4). These variables yield 90.7% of the variance (Fe 12.4%, K 20.3%, Mn 18.5%, Sr 12.8%, Ca/Ti 12.4% and Sr/Ca 14.3%). The remaining 9.3% of the variance is represented by Zr, but its role for the distribution of ostracoda species is statistically insignificant ($p > 0.05$) (Table 2.4.). To interpret the role of geochemical variables on the distribution of ostracoda species, the arrows in CCA plot that indicate the direction of maximum change in the value of geochemical variable can be used (ter Braak and Verdonschot, 1995). For instance, Fe and Ca/Ti are positively correlated with the ostracoda species found in the clusters of brackish and isolated lagoon environments (e.g. LCL- *Leptocythere lacertosa*, HMS- *Hirschmannia* sp., BRM-*Bairdia mediterranea*, CDT-*Cyprideis torosa*, CSL- *Cyprideis sublittoralis*, LXP-*Loxoconcha paralella*), whereas they have negative correlation with marine ostracoda species (Figure 2.6.). In other words, some of the ostracoda species (e.g. LCL, BRM) may occur at higher Fe while others at higher

(e.g. TBR, HMS, LXP) or lower (e.g. LXA, PCP, CEW) Ca/Ti (Figure 2.6.). Similarly, most of the marine ostracoda species (especially those in full and marginal marine clusters) possibly occur at higher Sr/Ca and Sr (Figure 2.4.). These anomalies in geochemical variables will be tackled in the following part considering the paleoenvironmental changes similar to μ XRF data interpretations.

Fe and Ca/Ti are positively correlated with the ostracoda species found in the clusters of brackish and isolated lagoon environments, whereas they have negative correlation with marine ostracoda species (Figure 2.6.). The variations in oxygen conditions of lakes and/or Fe-bearing minerals (e.g. oxides, carbonates), sediment grains or organic matters input to the lake are the main reasons of Fe anomalies in sediment cores (e.g. Schaller et al., 1997; Granina et al., 2004; Akçer et al., under review). Ca/Ti anomalies in the sediment core can be explained by increase in evaporation rate (especially in isolated-lagoon period) (Croudace and Rothwell, 2015) or carbonate precipitation (Kylander et al., 2011; Liu et al., 2013) or high biological productivity (Kylander et al., 2013; Davies et al., 2015). In CCA triplot, Fe is mainly correlated with the ostracoda species found in the cluster of isolated lagoon environment (BRM-*Brairidia mediterranea*, CSN-*Candona sanociensis*, STB-*Sarsicytheridea bradii*, AWW- *Aurila woodwardi*) (Figure 2.6.). However, Ca/Ti ratio is especially correlated with the ostracoda species of brackish-water environment (Figure 2.6.) where there is a high chance of carbonate precipitation and/or high productivity compared to open systems (i.e. marine environments). The paleoenvironmental changes revealed by Fe anomalies are therefore believed to be more effective in the distribution of ostracoda species found in the isolated lagoon environment, whereas those revealed by Ca/Ti anomalies are possibly more significant for the brackish-water ostracoda species.

Mn variations can also be related to sediment input and/or change in the oxygen conditions of the lake similar to Fe. The changes in Mn content due to these environmental factors might result in the diversity of ostracoda species especially during the coastal marine period as there is a positive correlation between Mn and some coastal marine species (e.g. LXA-*Loxoconcha aff. L. agilis*, HCR-*Hiltermannicythere rubra*) in CCA triplot (Figure 2.6.). For instance, HCR occur at higher Mn content while LXA probably occur at lower Mn (Figure 2.6.). In addition,

some of the coastal marine species (e.g. XAD-*Xestoleberis aff. dispar*, BEC-*Bosquetina carinella*, CTC-*Callistocythere littoralis*) may found in relation with the higher K contents (Figure 2.6.) as a possible indication for increase in salinity (i.e. cation K⁺ precipitate in authigenic lacustrine minerals only under high saline conditons, Cohen, 2003). On the other hand, Sr/Ca is positively correlated with marine species in CCA triplot (indicating by arrow). The anomalies of Sr/Ca generally indicate either higher Sr aragonite that requires a shallow-water source (e.g. Thomson et al., 2004; Rothwell et al., 2006) or the increase in salinity (e.g. Francus et al., 2013). For instance, BTS-*Buntonia subblata* clustered in full-marine environment may occur at relatively higher Sr/Ca (Figure 2.6.), possibly indicating increase in salinity. In addition, some of the marginal (SCA-*Semicytherura acuta*) and coastal (CTV-*Cytherella vulgata*) marine ostracoda species have positive relationship with the Sr/Ca (Figure 2.6.) possibly due to shallow-water conditions in these periods. Similary, Sr is positively correlated with especially marginal marine (e.g. LEG-*Loxoconcha exagona*) and some full-marine (e.g. CTS- *Cytheretta subradiosa*) ostracoda species (Figure 2.6.), confirming the interpretations based on Sr/Ca content.

Table 2. 4. Canonical (regression) coefficient for the chemical variables from Lake Bafa sediment core (mXRF analyses; Akçer et al., under review). Some of the chemical variables (i.e. selected) are statistically significant determined by ANOVA test (*p < 0.05), and these were used for further interpolation of CCA of ostracoda species.

Chemical Variables	CCA axis 1	CCA axis 2	CCA axis 3	CCA axis 4	*p-value
<u>Selected variables</u>					
Fe	0.1001	0.4258	0.5859	0.0156	0.008
K	-0.6906	-0.1489	-0.2305	0.4537	0.001
Mn	-0.0268	0.8016	0.2588	-0.5012	0.001
Sr	-0.5795	-0.2790	-0.4633	-0.2059	0.002
Ca/Ti	0.6417	-0.2363	-0.4056	-0.2810	0.004
Sr/Ca	-0.8865	-0.0831	0.0038	-0.2181	0.002
<u>Passive variables</u>					
Zr	-0.5555	-0.5256	-0.2001	0.3118	0.051

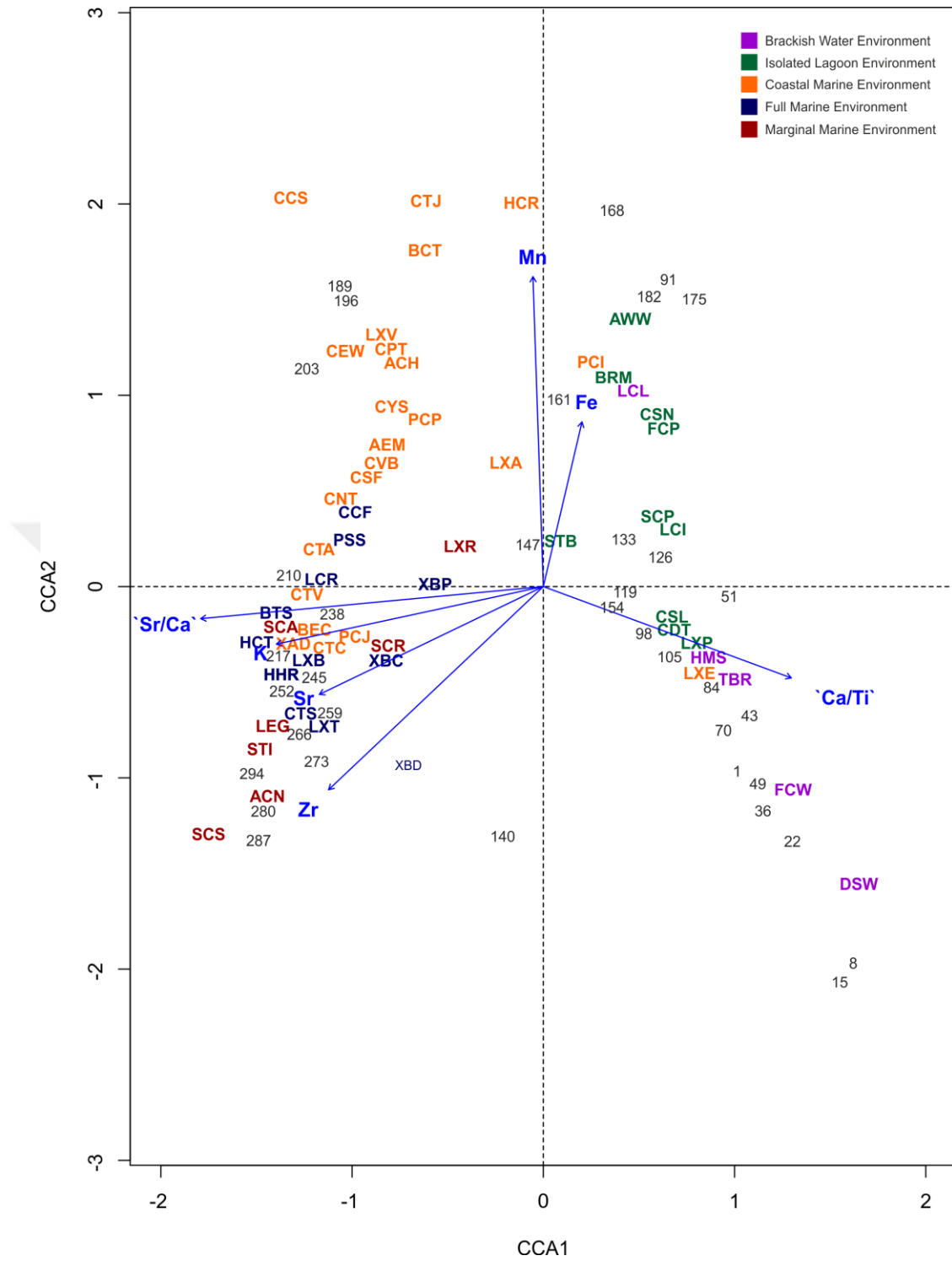


Figure 2. 6. Canonical Correspondence Analysis (CCA) of Ostracoda with respect to μXRF analyses of Lake Bafa sediment core (Akçer et al., under review).

2.3. Foraminifera species in Lake Bafa

We identified 69 foraminifera species of 22 families and 33 genera from 44 sediment samples taken along the sediment core (Figure 2.7.).

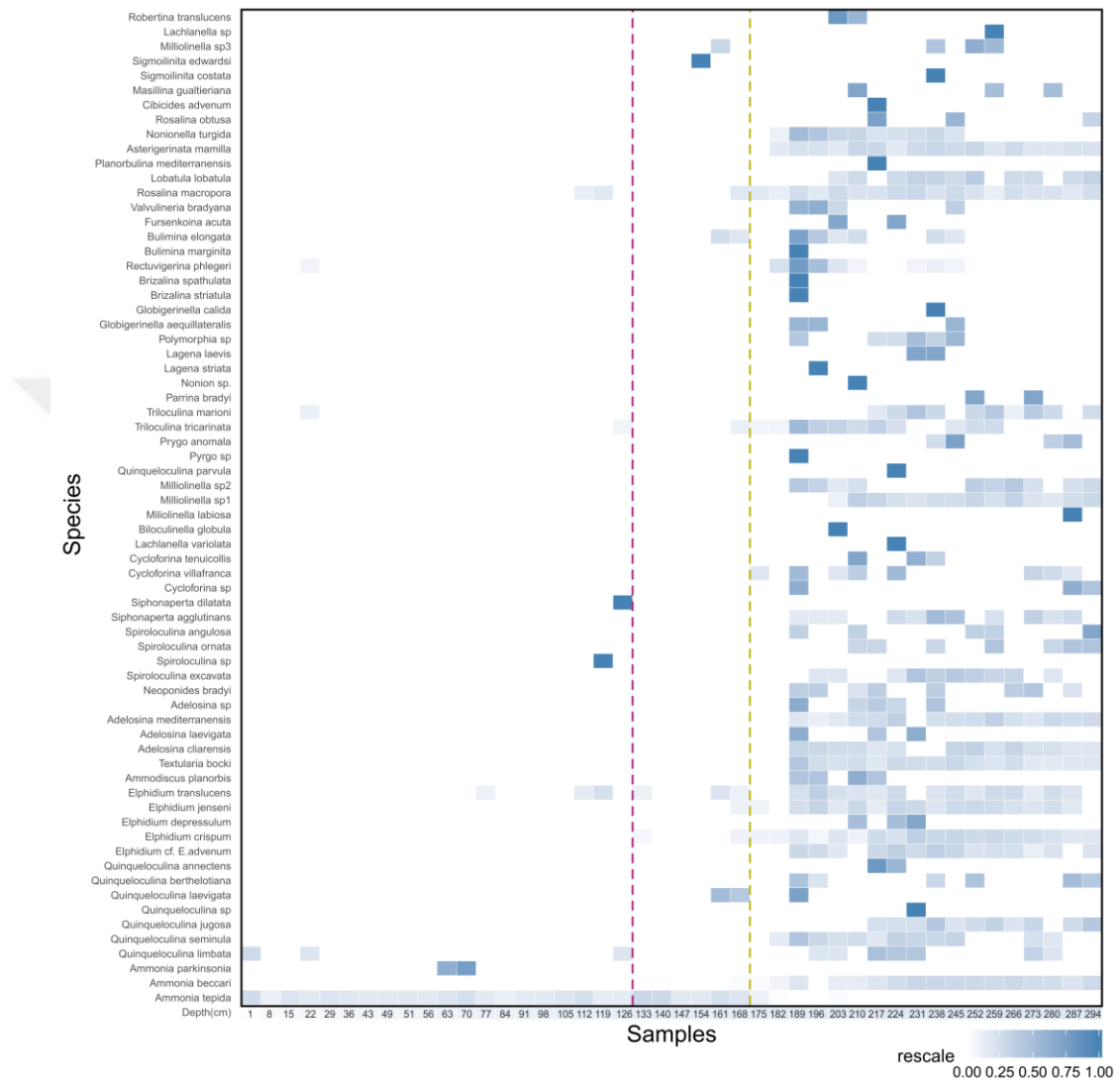


Figure 2. 7. Heatmap of identified benthic foraminifera species in the sediment core of Lake Bafa. Changing from light to dark color in boxes represents the increase in species abundance. Colored dash lines indicate statistically defined paleoenvironments in Lake Bafa (from right to left, full marine, isolated lagoon and brackish).

2.3.1. Taxonomy and ecological properties

The taxonomy of identified benthic foraminifera species are:

Kingdom Chromista

SubKingdom Harosa

InfraKingdom Rhizaria

Phylum Foraminifera

Order Astrorhizida Lankester, 1885

Suborder Ammodiscina Mikhalevich, 1980

Superfamily Ammodiscacea Reuss, 1862

Family Ammodiscidae Reuss, 1862

Subfamily Ammodiscinae Reuss, 1862

Genus *Ammodiscus* Reuss, 1862

Ammodiscus planorbis (Haglund, 1947)

Order Textulariida Delage & Herouard, 1896

Suborder Textulariina Delage & Herouard, 1896

Superfamily Textulariaceae Ehrenberg, 1838

Family Textulariidae Ehrenberg, 1838

Subfamily Textulariinae Ehrenberg, 1838

Genus *Textularia* Defrance, 1824

Textularia bocki (Höglund, 1947)

Order Miliolida Lankester, 1885

Superfamily Miliolacea Ehrenberg, 1839

Family Spiroloculinidae Wiesner, 1920

SubFamily Spiroloculininae Wiesner, 1920

Genus *Adelosina* d'Orbigny, 1826

Adelosina cliarensis (Heron-Allen and Earland)

Adelosina laevigata (d'Orbigny, 1826)

Adelosina mediterraneensis (Le Calvez and Le Calvez, 1958),

Adelosina sp.

Genus *Spiroloculina* d'Orbigny, 1826

Spiroloculina angulosa (Terquem, 1878)

Spiroloculina excavata (d'Orbigny, 1846)

Spiroloculina ornata (d'Orbigny, 1839)

Spiroloculina sp.

Family Hauerinidae Schwager, 1876

Subfamily Hauerininae Schwager, 1876

Genus *Siphonaperta* Vella, 1957

Siphonaperta agglutinans (d'Orbigny, 1839)

Siphonaperta dilatata (Le Calvez and Le Calvez, 1958)

Genus *Cycloforina* Luczowska, 1972

Cycloforina tenuicollis (Wiesner, 1923)

Cycloforina villafranca (Le Calvez and Le Calvez, 1958)

Cycloforina sp.

Genus *Lachlanella* Vella, 1957

Lachlanella variolata (d'Orbigny, 1826)

Lachlanella sp.

Genus *Massilina* Schlumberger, 1893

Massilina gualtieriana (d'Orbigny, 1839)

Genus *Quinqueloculina* d'Orbigny, 1826

Quinqueloculina annectens (Schlumberger, 1893)

Quinqueloculina berthelotiana (d'Orbigny, 1839)

Quinqueloculina jugosa (Cushman, 1944)
Quinqueloculina laevigata (d'Orbigny, 1839)
Quinqueloculina limbata (d'Orbigny, 1826)
Quinqueloculina parvula (Schlumberger, 1894)
Quinqueloculina seminula (Linnaeus, 1758)
Quinqueloculina sp
Quinqueloculina sp2

SubFamily Miliolinellinae Vella, 1957

Genus *Biloculinella* Wiesner, 1931
Biloculinella globula (Bornemann, 1855)
Genus *Miliolinella* Wiesner, 1931
Miliolinella labiosa (d'Orbigny, 1839a)
Miliolinella sp1
Miliolinella sp2
Miliolinella sp3

Genus *Pyrgo* Defrance, 1824
Pyrgo anomala (Schlumberger, 1891)
Pyrgo sp.

Genus *Triloculina* d'Orbigny 1826
Triloculina marioni (Schlumberger, 1893)
Triloculina tricarinata (d'Orbigny, 1826)

SubFamily Sigmoilinitinae Luczkowska, 1974

Genus *Sigmoilinita* Schlumberger, 1887
Sigmoilinita costata (Schlumberger, 1893)
Sigmoilinita edwardsi (Schlumberger, 1887)

Family Tubinellidae Rhumbler, 1906

Genus *Parrina* Cushman, 1931

Parrina bradyi (Millett, 1989)

Order Lagenida Lankester, 1885

Superfamily Nodosariacea Ehrenberg, 1838

Family Lagenidae Reuss, 1861

Genus *Lagena* Walker and Jacob, 1798

Lagena striata (d'Orbigny, 1839)

Lagena laevis (Montagu, 1803)

Superfamily Polymorphinacea d'Orbigny, 1839

Family Polymorphinidae d'Orbigny, 1839

Genus *Polymorphina* d'Orhigny, 1826

Polymorphina sp.

Order Robertinida Mikhalevich, 1980

Superfamily Robertinacea Reuss, 1850

Family Robertinidae Reuss, 1850

Genus *Robertina* d'Orbigny, 1846

Robertina translucens (Cushman and Parker, 1936)

Family Globigerinidae Carpenter, Parker and Jones, 1862

Genus *Globigerina* d'Orbigny, 1826

Globigerina calida (Parker, 1962)

Globigerinella aequilateralis (Brady, 1879)

Order Buliminida Fursenko, 1958

SuperFamily Bolivinaacea Glaesner, 1937

Family Bolivinidae Glaesner, 1937

Genus *Brizalina* O.G.Costa, 1856

Brizalina spathulata (Williamson, 1858)

Brizalina striatula (Cushman, 1922)

SuperFamily Buliminacea Jones, 1875

Family Siphogenerinoididae Saidova, 1981

SubFamily Tubulogenerininae Saidova, 1981

Genus *Rectuvigerina* Mathews, 1945

Rectuvigerina phlegeri (Le Calvez, 1959)

Family Buliminidae Jones, 1875

Genus *Bulimina* d'Orbigny, 1846

Bulimina elongata (d'Orbigny, 1846)

Bulimina marginata (d'Orbigny, 1826)

Superfamily Fursenkoinacea Loeblich & Tappan, 1961

Family Fursenkoinidae Loeblich and Tappan, 1961

Genus *Fursenkoina* Loeblich and Tappan, 1961

Fursenkoina acuta (d'Orbigny, 1846)

Order Rotalida Lankester, 1885

Superfamily Discorbacea Ehrenberg, 1838

Family Bagginidae Cushman, 1927

Genus *Valvulineria* Cushman, 1926

Valvulineria bradyana (Fornasini, 1900)

Family Neoeponididae Loeblich & Tappan, 1994

Genus *Neoeponides* Reiss, 1960

Neoeponides bradyi (Le Calvez, 1974)

Family Rosalinidae Reiss, 1963

Genus *Rosalina* d'Orbigny, 1826

Rosalina macropora (Hofker, 1951)

Rosalina obtusa (d'Orbigny)

Superfamily Planorbulinacea Schwager, 1877

Family Cibicididae Cushman, 1927

Subfamily Cibicidinae Cushman, 1927

Genus *Cibicides* de Montfort, 1808

Cibicides advenum (d'Orbigny, 1839)

Genus *Lobatula* Fleming, 1828

Lobatula lobatula (Walker and Jacob, 1798)

Family Planorbulinidae Schwager, 1877

Subfamily Caribbeanellinae Saidova, 1981

Genus *Planorbulina* d'Orbigny, 1826

Planorbulina mediterraneensis (d'Orbigny, 1826)

Superfamily Asterigerinacea d'Orbigny, 1839

Family Asterigerinatidae Reiss, 1963

Genus *Asterigerinata* Bermudez, 1949

Asterigerinata mamilla (Williamson, 1858)

Superfamily Nonionacea Schultze, 1854

Family Nonionidae Schultze, 1854

Subfamily Nonioninae Schultze, 1854

Genus *Nonion* de Montfort, 1808

Nonion sp.

Genus *Nonionella* Cushman, 1926

Nonionella turgida (Williamson, 1858)

Superfamily Rotaliacea Ehrenberg, 1839

Family Rotaliidae Ehrenberg, 1839

Subfamily Pararotaliinae Reiss, 1963

Genus *Ammonia* Brünnich, 1772

Ammonia beccarii (Linné, 1758)

Ammonia parkinsoniana (d'Orbigny, 1839a)

Ammonia tepida (Cushman, 1926)

Family Elphidiidae Galloway, 1933

Subfamily Elphidiinae Galloway, 1933

Genus *Elphidium* Montfort, 1808

Elphidium cf. E advenum (Cushman, 1922)

Elphidium crispum (Linné, 1758)

Elphidium depressulum (Cushman, 1933)

Elphidium jenseni (Cushman, 1924)

Elphidium translucens (Natland, 1938).

Table 2. 5. Ecological Properties of Benthic Foraminifera Species

Species	Environment	Depth (m)	Salinity (‰)	D.O. (mg/l)	Temp. (°C)	References
<i>Ammodiscus planorbis</i>	Marine- Deeper	145<	Euhaline; >30			Hiltermann and Haman, 1985; Sgarrella, 1993
<i>Textularia bocki</i>	Epifaunal, Shelf-Bathyal, Deeper, Modern Marginal Marine or Paralic	88				Jones, 2013; Murray, 2014; Corbi et al., 2016
<i>Adelosina cliarensis</i>	Marine		29.9- 33.0			Yanko et al., 1998
<i>Adelosina laevigata</i>	Marine		34		25	Lacuna et al., 2013
<i>Adelosina mediterraneensis</i>	Mediterranean/ Marine/Infralittoral	10-100				Sgarrella, 1993
<i>Spiroloculina angulosa</i>	Marine, Lagoon, Inner Shelf, Epifaunal	0-40	Hypersaline		Warm	Murray, 2014
<i>Spiroloculina excavata</i>	Marine/Epifaunal	0-40	Hypersaline		Warm	Murray, 2014
<i>Spiroloculina ornata</i>	Shallow Marine, Marine/Epifaunal	0-40	Hypersaline		Warm	Murray, 2014
<i>Massilina gualtieriana</i>	Epiphytic, Marine, Inner Shelf				Warm	Murray, 2014
<i>Quinqueloculina annectens</i>	Epifaunal, Marine/Hypersaline Lagoon, Marine Shelf, rarely Bathyal		32-65		Cold/Warm	Murray, 2014
<i>Quinqueloculina berthelotiana</i>	Marine/Epifaunal, Hypersaline Lagoon, Marine Shelf, rarely Bathyal/ Infralittoral Bottoms with Vegetation Cover		Hypersaline		Cold/Warm	Sgarrella, 1993; Murray, 2014
<i>Quinqueloculina jugosa</i>	Marine/Epifaunal, Lagoon, Marine Shelf, rarely Bathyal		Hypersaline		Cold/Warm	Murray, 2014
<i>Quinqueloculina laevigata</i>	Marine/Epifaunal, Hypersaline Lagoon, Marine Shelf, rarely Bathyal	Intertidal Marsh	Hypersaline- 2-56		Cold/Warm	Brasier, 1975; Murray, 2014
<i>Quinqueloculina limbata</i>	Marine/Epifaunal		Hypersaline		Cold/Warm	Murray, 2014
<i>Quinqueloculina parvula</i>	Modern Marginal Marine or Paralic Environments		Hypersaline		Cold/Warm	Jones, 2013; Murray, 2014
<i>Quinqueloculina seminula</i>	Marine/Epifaunal, Coastal, Marshes	<60	Hypersaline		>15	Murray, 2014

Table 2.5. (continue)

<i>Cycloforina villafranca</i>	Marine/Epifaunal		Hyposaline		Murray, 2014
<i>Biloculinella globula</i>	Marine/Circalittoral and Bathyal Zones, Deep-Water, Çanakkale Strait, Northern Shelf, Istanbul Strait	120-390			Sgarrella, 1993; Kirci-Elmas and Meriç, 2013
<i>Miliolinella dilatata</i>	Marine, Lagoons and Marshes, Inner Shelf	32-49	33.1 - 33.8	26.4 - 27.48	Panchang and Nigam, 2014; Murray, 2014
<i>Miliolinella labiosa</i>	Modern Marginal Marine or Paralic Environments			24-29	Blackmon and Todd, 1959; Jones, 2013
<i>Pyrgo anomala</i>	Marine/Inner Shelf or Epifaunal, Shelf-Bathyal	>70			Sgarrella, 1993 ; Murray, 2014
<i>Triloculina marioni</i>	Epifaunal-Marine,Hypersaline Lagoon or Marine Inner Shelf, some Bathyal		Hypersaline 32-55	Warm	Scott et al., 2007 ; Murray, 2014
<i>Triloculina tricarinata</i>	Hypersaline Lagoons, Marine/ Circalittoral,Epibathyal	50-100<	Hypersaline		Sgarrella, 1993; Scott et al., 2007
<i>Sigmoilinita costata</i>	Mediterranean,Marine, Infralittoral, Circalittoral	<100-150			Sgarrella, 1993
<i>Sigmoilinita edwardsi</i>	Marine, Mediterranean Coast			27-29	Blackmon and Todd, 1959 ; Meric et al., 2008
<i>Parrina bradyi</i>	Marine, Barbuda Nearshore, Lagoon, Bermuda Mangrove, Ponds			28-29	Blackmon and Todd, 1959 ; Javaux and Scott, 2003
<i>Lagena striata</i>	Mediterranean, Infralittoral to the Bathyal, Deep-water	100-840	32.6-34.6	9 to 11	Sgarrella, 1993
<i>Lagena laevis</i>	Marine Coast, Adriatic Sea, Mediterranean, Infralittoral and Bathyal	30-820			Sgarrella, 1993
<i>Robertina translucens</i>	Marine, Mediterranean, Deeper	25-90<			Sgarrella, 1993

Table 2.5. (continue)

<i>Globigerinella calida</i>	Water column and sink to the Sea floor when the die		Hypersalinity marine salinity			Jones, 2013
<i>Globigerinella aequilateralis</i>	Marine		Hypersalinity marine salinity	26-28		Blackmon and Todd, 1959 ; Jones, 2013
<i>Brizalina spathulata</i>	Normal marine, Mediterranean, Sea of Marmara, Çanakkale strait, Marginal Marine-Bathyal , Infaunal, Deeper	27-82	32-38*	Low oxygen Dysoxic	17 to 25	Chendes et al., 2004; Kirci-Elmas, 2013; Jones, 2013; Murray, 2014*
<i>Brizalina striatula</i>	Marine, Marginal Marine	5 -41	20-38			Debenay et al.,1998; Jones, 2013; Murray, 2014
<i>Rectuvigerina phlegeri</i>	Mediterranean, Marine	20-115		Low DO		Sgarrella, 1993
<i>Bulimina elongata</i>	Modern Marginal Marine or Paralic Environments, Shallow to Deep Marine/ Infralittoral and upper Circalittoral muddy sediment	16-80	Normal marine salinity	Dysoxic-anoxic	Cold	Sgarrella, 1993; Jones, 2013 ; Murray, 2014
<i>Bulimina marginata</i>	Marine, Deep water, Marmara Sea		Hyposalinity hypersalinity	<0.5, Dysoxic-anoxic Oxygen deficient 0.1-0.9		Kirci-Elmas, 2013; Jones, 2013
<i>Fursenkoina acuta</i>	Marine, Mediterranean,Lagoons, Shelf, upper Bathyal, Infralittoral	0-1200				Sgarrella, 1993; Murray, 2014
<i>Valvulineria bradyana</i>	Continental Shelf in the Mediterranean/Circalittoral and Epibathyal, Deeper	50-350 90-120	37-38		25	Sgarrella, 1993
<i>Rosalina macropora</i>	Marine,Epifaunal,Lagoon,Inner Shelf	0-100			Warm	Murray, 2014
<i>Rosalina obtusa</i>	Marine/Nearshore or Intertidal, Mediterranean/Infralittoral Bottoms with egetation cover, Gulf of Naples	20-60				Jorissen, 1987; Sgarrella, 1993; Murray, 2014

Table 2.5. (continue)

<i>Cibicides advenum</i>	Normal Marine, Lagoons, Epifaunal, Shelf Bathyal	0 to > 2000			Cold-Warm	Scott et al., 2007; Murray, 2014
<i>Lobatula lobatula</i>	Brackish-Normal Marine, Transition, Shallow Marine	40		Oxygen-deficient		Di Bella et al., 2012; Kirci-Elmas, 2018
<i>Planorbulina mediterraneensis</i>	Shallow-water, Marine/Infralittoral, Inner Continental Shelf	<360				Sgarrella, 1993; Kirci-Elmas, 2013
<i>Asterigerinata mamilla</i>	Marine/Subtropical-Tropical, Inner Shelf, Seagrass, Epifaunal	0-100			15	Blackmon and Todd, 1959; Jones, 2013; Murray, 2014 ; Scott et al., 2007 ; Corbi et al., 2016
<i>Nonionella turgida</i>	Marine, Shelf–upper Bathyal	10–1000	31–33	Low oxygen	Warm	Jones, 2013
<i>Ammonia beccarii</i>	Shallow/ Subtidal, Transitional and Open Bay Environment, Lower Estuarine – Marginal Marine, Delta’s Shallow Water and Nutrient rich env.		13-40	Dysaerobic (0.1-1)	15- 30	Sgarrella, 1993; Donnici and Serandrei Barbero, 2002; Scott et al., 2007 ; Bella et al., 2012
<i>Ammonia parkinsoniana</i>	Mediterranean/Coastal Marine, Low Marsh, Intertidal/Subtidal, Brackish	10 to 21	1.4 ~ and 6.9	Depressed oxygen level (<0.5)	Warm	Hiltermann and Haman, 1985; Sgarrella, 1993; Debenay and Guillou, 2002 ; Jones, 2013 ; Jones, 2013
<i>Ammonia tepida</i>	Marine, Intertidal–High Subtidal		13-34			Resig, 1974 ; Abu-Zied et al., 2013
<i>Elphidium cf. E advenum</i>	Subtidal, Brackish, Lagoons, Estuaries and Inner Shelf	0-2	High salinity High-salinity <64		32	Jorissen, 1987; Murray, 1970; Scott et al., 2007; Abu-Zied et al., 2013
<i>Elphidium crispum</i>	Shallow Marine, Gulf of Naples, Mediterranean Infralittoral sand, coarse and Circalittoral detritic sand	1 to 40	Normal and Hypersaline		8 to 33	Murray, 1963; Sgarrella, 1993; Mendes et al., 2004; Jones, 2013; Murray, 2014
<i>Elphidium depressulum</i>	Shallow Marine, Brackish Water, Lagoon		Euryhaline			Murray, 1970; Yanko et al., 1998; Donnici et al., 2012; Kirci-Elmas, 2013

Table 2.5. (continue)

<i>Elphidium jenseni</i>	Coral bank, Marine					Murray,1970
<i>Elphidium translucens</i>	Shallow Marine, Brackish, Epifaunal, Epiphytic	33.3	5.2 -6.4	13-17.5		Bandy, 1953; Jones, 2013
<i>Cycloforina villafranca</i>	Infralittoral and Upper Circalittoral	<80				Sgarrella, 1993
<i>Neoeponides bradyi</i>	Marine, Deep Water, Eastern Aegean Sea, Nearshore/Shallow water	>35				Langer and Lipps, 2003; Yümün et al., 2016
<i>Siphonaperta agglutinans</i>	Marine, sandy bottom, Mediterranean, Ionian Sea					Aiello et al.,2006
<i>Lachanella variolata</i>	Marine					Scicchitano et al., 2010

2.3.2 Multivariate statistical analysis of benthic foraminifera species

2.3.2.1. Constrained hierarchical clustering analysis

The broken-stick model reveals three groups in the counted benthic foraminifera species data (Figure 2.8.). Accordingly, constrained hierarchical clustering analysis was performed considering three clusters in the dataset (Figure 2.9.). As benthic foraminifera species are originally marine species, they have high tolerance in almost all marine conditions. Therefore, the sub-divisions of marine environment (i.e. marginal, full-marine, coastal) revealed by clustering analysis of ostracoda species could not be statistically defined for benthic foraminifera assemblages. However, ecological properties of benthic foraminifera species clustered in marine environment reveal these distinct marine phases as given below:

(3) (175-294 cm) Full marine environment with deeper and shallow species because of the presence of

Marginal Marine Species; *Miliolinella labiosa*, *Rosalina obtusa*, *Parrina bradyi*, *Spiroloculina angulosa*, *Quinqueloculina berthelotiana*, *Quinqueloculina jugosa*, *Triloculina marioni*, *Spiroloculina ornata*,

Full Marine Species; *Ammodiscus planorbis*, *Adelosina cliarensis*, *Adelosina mediterraneensis*, *Adelosina laevigata*, *Masillina gualtieriana*, *Cycloforina villafranca*, *Prygo anomala*, *Asterigerinata mamilla*, *Sigmoilinita costata*, *Fursenkoina acuta*, *Rosalina macropora*, *Cibicides advenum*, *Lobatula lobatula*, *Planorbulina mediterraneensis*, *Elphidium crispum*, *Elphidium depressulum*, *Spiroloculina excavata*, *Quinqueloculina limbata*, *Quinqueloculina parvula*, *Quinqueloculina seminula*, *Quinqueloculina annectens*, *Biloculinella globula*, *Lagena laevis*, *Robertina translucens*, *Ammonia beccarii*, *Neoeponides bradyi*, *Siphonaperta agglutinans*, *Lachanella variolata*

Coastal Marine with low oxygen; *Brizalina spatulohata*, *Brizalina striatula*, *Bulimina elongata*, *Noninella turgida*, *Elphidium cf. E. advenum*, *Elphidium translucens*, *Triloculina tricarinata*, *Bulimina marginata*, *Rectuvigerina phlegeri*, *Textularia bocki*, *Lagena striata*, *Valvulineria bradyana* in the sediment core.

(2) (133-168 cm) **Isolated-lagoon**, the presence of *Ammonia tepida*, *Quinqueloculina laevigata* and *Sigmoilinita edwardsi*.

(1) (1-126 cm) **Brackish environment** due to the existence of *Ammonia parkinsonia* who have a tendency of living in warm water.

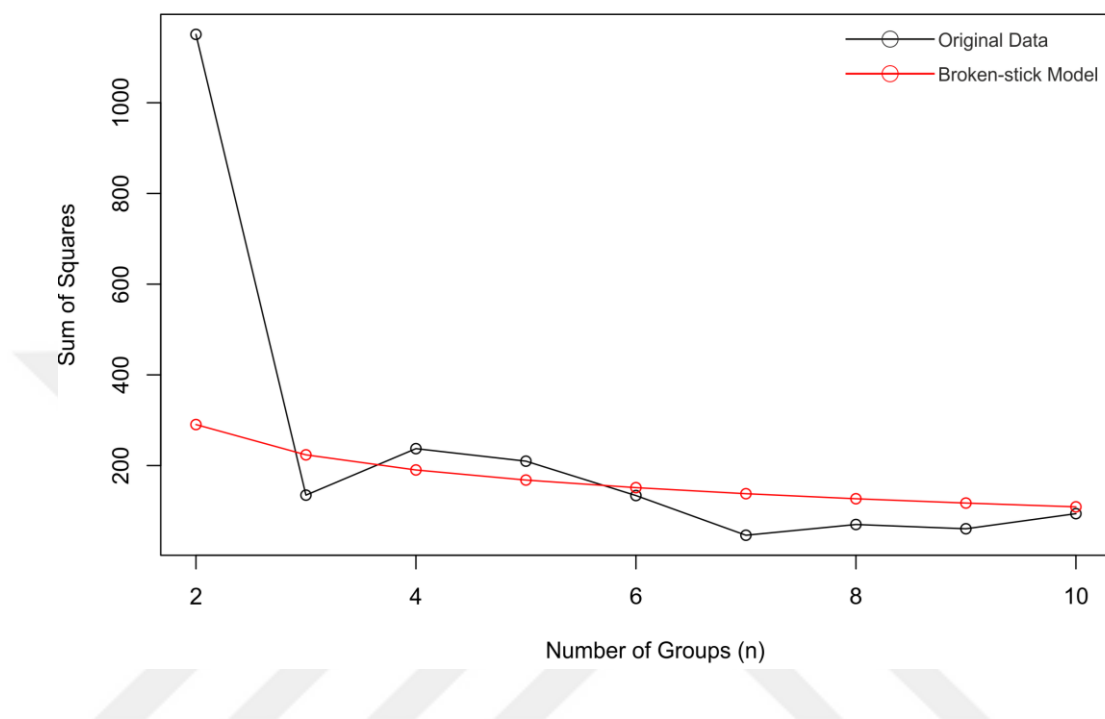


Figure 2. 8. Broken-stick model of benthic foraminifera abundance data

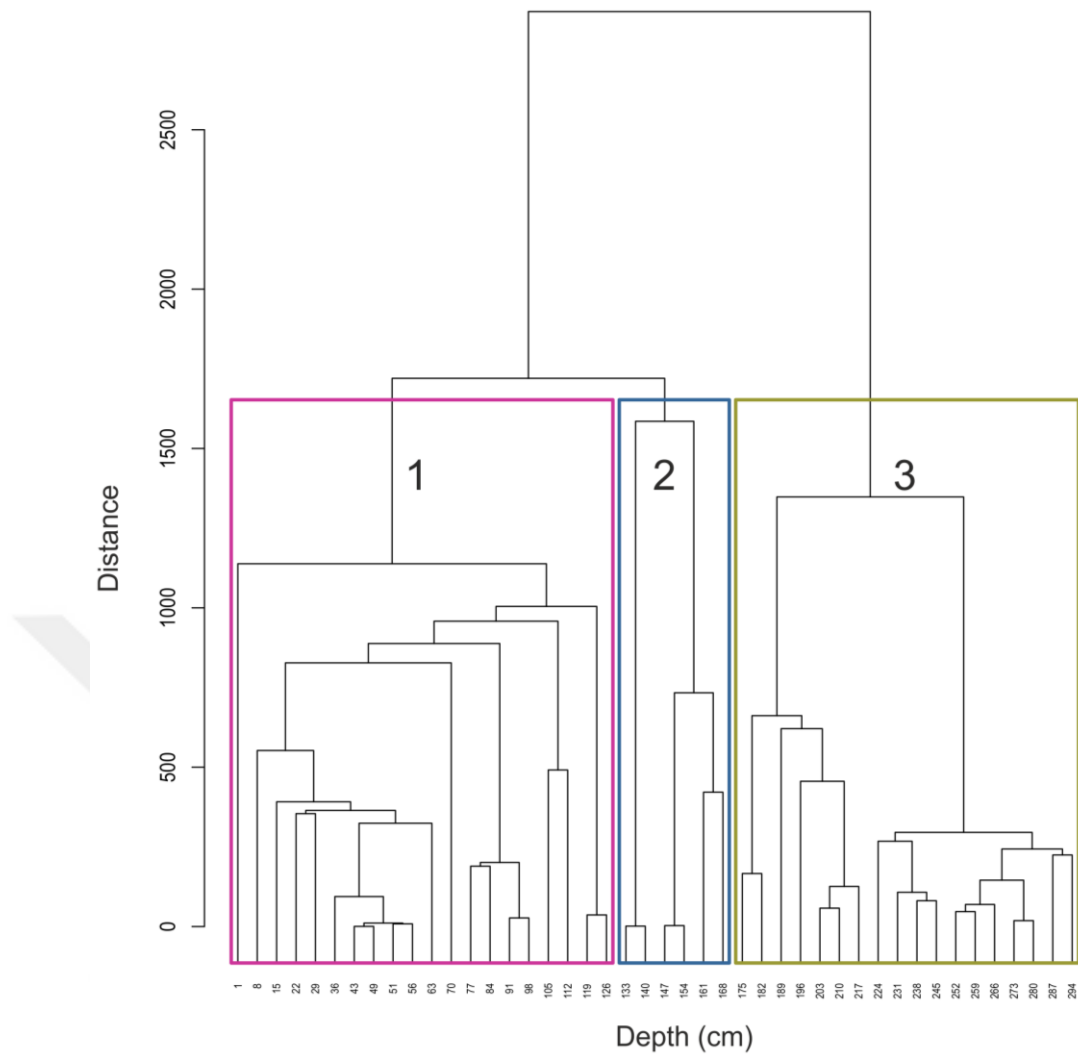


Figure 2. 9. Constrained Hierarchical Analysis of Benthic Foraminifera. Paleoenvironments are; 1. Brackish, 2. Isolated lagoon, 3. Full Marine

The indicator benthic foraminifera species in Lake Bafa were also statistically determined using the “multipatt” function in “indicspecies” R-package (De Cáceres and Legendre, 2009) (Table 2.6.). The first columns of sign (0 or 1) point out which clusters (i.e. paleoenvironments) were included in the combination favored by the species (Table 2.6.). The column “index” means the index to the cluster combination (1: brackish, 2: isolated lagoon, 3: marine). The p-values were obtained by permutation test to control the statistical significance ($\alpha < 0.05$) in the relationship between indicator species and related clusters (Table 2.6.). Therefore, the species with p-values lower than or equal to 0.05 are statistically significant for their related clusters. The species with higher p-values were yet assigned to true

clusters based on their ecological properties, but it is noteworthy to state that this relationship is statistically insignificant.

Table 2. 6. Indicator species and abbreviation for benthic foraminifera for each clusters

Abr.	Benthic Foraminifera Species	s.1	s.2	s.3	index	stat	p.value
AMT	<i>Ammonia tepida</i>	0	1	0	2	0.7870311	0.00079984
AMB	<i>Ammonia beccari</i>	0	0	1	3	0.9706098	0.00019996
AMP	<i>Ammonia parkinsonia</i>	1	0	0	1	0.3162278	0.62727455
QCL	<i>Quinqueloculina limbata</i>	0	0	1	3	0.5781015	0.04539092
QCS	<i>Quinqueloculina seminula</i>	0	0	1	3	0.8164966	0.00019996
QCJ	<i>Quinqueloculina jugosa</i>	0	0	1	3	0.781736	0.00219956
QS1	<i>Quinqueloculina sp</i>	0	0	1	3	0.5773503	0.02279544
QLV	<i>Quinqueloculina laevigata</i>	0	1	0	2	0.48795	0.04459108
QS2	<i>Quinqueloculina sp2</i>	0	0	1	3	0.2357023	0.55028994
QCB	<i>Quinqueloculina berthelotina</i>	0	0	1	3	0.5773503	0.02679464
QCA	<i>Quinqueloculina annectens</i>	0	0	1	3	0.3333333	0.29174165
EAD	<i>Elphidium cf. E.advenum</i>	0	0	1	3	0.8819171	0.00019996
ECR	<i>Elphidium crispum</i>	0	0	1	3	0.9786452	0.00019996
EDP	<i>Elphidium depressulum</i>	0	0	1	3	0.4082483	0.10837832
EJE	<i>Elphidium jenseni</i>	0	0	1	3	0.9287014	0.00019996
ETR	<i>Elphidium translucens</i>	0	0	1	3	0.763	0.00239952
APL	<i>Ammodiscus planorbis</i>	0	0	1	3	0.4714045	0.10357928
TBC	<i>Textularia bocki</i>	0	0	1	3	0.942809	0.00019996
ACL	<i>Adelosina cliarensis</i>	0	0	1	3	0.8819171	0.00039992
ALV	<i>Adelosina laevigata</i>	0	0	1	3	0.4082483	0.09818036
AMR	<i>Adelosina mediterraneensis</i>	0	0	1	3	0.9128709	0.00019996
ASP	<i>Adelosina sp</i>	0	0	1	3	0.5270463	0.0339932
NPB	<i>Neoponides bradyi</i>	0	0	1	3	0.6666667	0.00679864
SCE	<i>Spiroloculina excavata</i>	0	0	1	3	0.745356	0.00039992
SCS	<i>Spiroloculina sp</i>	1	0	0	1	0.2236068	1
SCO	<i>Spiroloculina ornata</i>	0	0	1	3	0.6236096	0.00479904
SCA	<i>Spiroloculina angulosa</i>	0	0	1	3	0.5270463	0.06458708
SPA	<i>Siphonaperta agglutinans</i>	0	0	1	3	0.781736	0.0009998
SPD	<i>Siphonaperta dilatata</i>	1	0	0	1	0.2236068	1
CFS	<i>Cycloforina sp</i>	0	0	1	3	0.4082483	0.11437712
CFV	<i>Cycloforina villafranca</i>	0	0	1	3	0.6666667	0.00839832
CFT	<i>Cycloforina tenuicollis</i>	0	0	1	3	0.4082483	0.10577884
LVR	<i>Lachlanella variolata</i>	0	0	1	3	0.2357023	0.54129174
BCG	<i>Biloculinella globula</i>	0	0	1	3	0.2357023	0.54929014
MOL	<i>Miliolinella labiosa</i>	0	0	1	3	0.2357023	0.54889022
MS1	<i>Milliolinella sp1</i>	0	0	1	3	0.8819171	0.00019996
MS2	<i>Milliolinella sp2</i>	0	0	1	3	0.745356	0.00159968
QCP	<i>Quinqueloculina parvula</i>	0	0	1	3	0.2357023	0.54129174
PYS	<i>Pyrgo sp</i>	0	0	1	3	0.2357023	0.55128974
PAN	<i>Prygo anomala</i>	0	0	1	3	0.4714045	0.07758448

Table 2.6. (continue)

TCT	<i>Triloculina tricarinata</i>	0	0	1	3	0.7645747	0.0009998
TCM	<i>Triloculina marioni</i>	0	0	1	3	0.7408644	0.00339932
PRB	<i>Parrina bradyi</i>	0	0	1	3	0.3333333	0.4215157
NOS	<i>Nonion sp.</i>	0	0	1	3	0.2357023	0.54029194
LGS	<i>Lagena striata</i>	0	0	1	3	0.2357023	0.54429114
LGL	<i>Lagena laevis</i>	0	0	1	3	0.3333333	0.41631674
PMS	<i>Polymorphia sp</i>	0	0	1	3	0.5773503	0.02439512
GGA	<i>Globigerinella aequilaterlis</i>	0	0	1	3	0.4082483	0.1079784
GGC	<i>Globigerinella calida</i>	0	0	1	3	0.2357023	0.54309138
BST	<i>Brizalina striatula</i>	0	0	1	3	0.2357023	0.55128974
BSP	<i>Brizalina spathulata</i>	0	0	1	3	0.2357023	0.55128974
RGP	<i>Rectuvigerina phlegeri</i>	0	0	1	3	0.6647017	0.01419716
BMR	<i>Bulimina marginita</i>	0	0	1	3	0.2357023	0.55128974
BEL	<i>Bulimina elongata</i>	0	0	1	3	0.5	0.16036793
FKA	<i>Fursenkoina acuta</i>	0	0	1	3	0.3333333	0.40571886
VBR	<i>Valvulineria bradyana</i>	0	0	1	3	0.4714045	0.09218156
RMC	<i>Rosalina macropora</i>	0	0	1	3	0.9335373	0.00019996
LBL	<i>Lobatula lobatula</i>	0	0	1	3	0.781736	0.00039992
PBM	<i>Planorbulina mediterranensis</i>	0	0	1	3	0.2357023	0.5394921
AGM	<i>Asterigerinata mamilla</i>	0	0	1	3	0.9718253	0.00019996
NTR	<i>Nonionella turgida</i>	0	0	1	3	0.745356	0.00139972
ROB	<i>Rosalina obtusa</i>	0	0	1	3	0.4082483	0.10377924
CCA	<i>Cibicides advenum</i>	0	0	1	3	0.2357023	0.5394921
MGA	<i>Masillina gualtieriana</i>	0	0	1	3	0.4082483	0.1069786
SCT	<i>Sigmoilinita costata</i>	0	0	1	3	0.2357023	0.54309138
SED	<i>Sigmoilinita edwardsi</i>	0	1	0	2	0.4082483	0.13777245
MS3	<i>Milliolinella sp3</i>	0	0	1	3	0.3535534	0.24895021
LHS	<i>Lachlanella sp</i>	0	0	1	3	0.2357023	0.55368926
RTR	<i>Robertina translucens</i>	0	0	1	3	0.3333333	0.29554089

2.3.2.2. Canonical correspondence analysis

The scree plot of CCA for benthic foraminifera reveals that a total of the first two axes exceeds the others, and hence CCA results can be reliable (Figure 2.10.). Benthic foraminifera species were illustrated in CCA triplot by different colors according to their paleoenvironments (i.e. full-marine, isolated lagoon and brackish) determined by constrained hierarchical clustering analysis (Figure 2.11.). The eigenvalues for CCA axis 1 (0.74) and axis 2 (0.36) represent 23 % of the total variance (i.e. inertia) and 62% of the cumulative variance in the weighted averages of the benthic foraminifera species (Table 2.7.). As explained in the section of ostracoda

species, the chi-square distance in CCA triplot increases when two species are located away from each other, and hence close proximity of species indicates that they have similar distribution along the depth (ter Braak and Verdonschot, 1995). For instance, in Figure 2.11., the distribution of benthic foraminifera species is well-correlated with the results of clustering analysis (i.e. brackish, isolated lagoon and marine environments), except for some species (e.g. LGS-*Lagena striata*, VBR-*Valvulineria bradyana*, BEL-*Bulimina elongata*, BMR-*Bulimina marginita*) that might be clustered as coastal marine species based on their ecological properties.

Table 2. 7. CCA results of the counted benthic foraminifera species and chemical variables from Lake Bafa sediment core (mXRF analyses; Akçer et al., under review)

<u>CCA Parameters</u>	<u>CCA axes</u>				<u>Inertia</u>
	1	2	3	4	
Eigenvalues for constrained axes	0.74	0.36	0.23	0.16	1.77
Eigenvalues for unconstrained axes	0.38	0.35	0.30	0.26	2.93
Species-chemical variable correlations	0.92	0.93	0.94	0.88	
Cumulative percentage variance of					
species data	15.8	7.6	5.0	3.3	
species-environment relation	42.0	20.1	13.2	8.8	

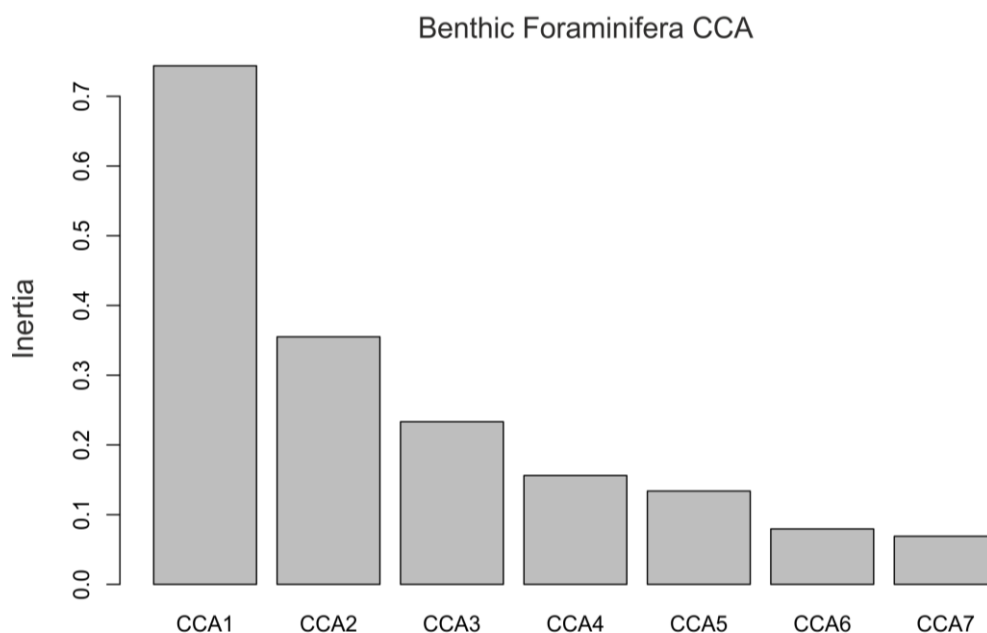


Figure 2. 10. Screeplot of benthic foraminifera CCA

There is a relatively high correlation ($p < 0.001$) between benthic foraminifera species and environmental variables (μ XRF data of Akçer et al., under review) revealed by CCA axis 1 (0.92) and axis 2 (0.93). The further ANOVA permutation test performed on CCA result especially identified 5 chemical variables (Fe, K, Mn, Sr and Ca/Ti) that significantly explained the variation in the benthic foraminifera assemblages (Table 2.8.). These variables yield 88.3% of the variance (Fe 12.1%, K 20.3%, Mn 26.5%, Sr 19.6%, and Ca/Ti 9.8%). The remaining 11.7% of the variance is represented by Zr and Sr/Ca, but their role for the distribution of benthic foraminifera species is statistically not significant ($p > 0.05$) (Table 2.8.). The relationship between chemical variables (μ XRF data; Akçer et al., under review) and the distribution of benthic foraminifera species (Figure 2.11.) is almost identical with that for ostracoda species (Figure 2.6.). For instance, Fe is positively correlated with benthic foraminifera species (i.e. SED-*Sigmoilinita edwardsi*, QLV-*Quinqueloculina laevigata*) (Figure 2.10.) clustered as isolated lagoon environment based on the hierarchical analysis (Figure 2.9.). The role of Fe in the distribution of ostracoda species statistically clustered in the isolated lagoon environment was also revealed in CCA triplot (Figure 2.6.), possibly due to oxygen variation and/or Fe-bearing sediment input to the lake. Similarly, the positive relationship between AMP-*Ammonia parkinsonia* and Ca/Ti (Figure 2.11.) may indicate the possible carbonate precipitation and/or high productivity in brackish environment (i.e. close system) compared to marine environment (i.e. open system). Some of the benthic foraminifera species (BST; *Brizalina striatula*, BMR; *Bulimina marginita*, RGP; *Rectuvigerina phlegeri*, BEL; *Bulimina elongata*) statistically clustered in marine environment may occur at higher Mn according to CCA triplot (Figure 2.11.). However, these species especially live in coastal marine conditions according to their ecological properties. Therefore, as revealed by CCA of ostracoda species, Mn anomalies related to sediment input and/or changes in the oxygen conditions of the lake have a significant role in the distribution of both benthic foraminifera and ostracoda species during the coastal marine conditions. In addition, most of the full-marine and marginal marine species are positively correlated with K and Sr in CCA triplot (Figure 2.11.). This relationship was also revealed by the CCA of ostracoda species, and possibly indicating the increase in salinity especially during the full-

marine period and shallow-marine conditions in marginal marine period (Figure 2.6.).

Table 2. 8. Canonical (regression) coefficient for the chemical variables from Lake Bafa sediment core (mXRF analyses; Akçer et al., under review). Some of the chemical variables (i.e. selected) are statistically significant determined by ANOVA test (*p < 0.05), and these were used for further interpretation of CCA of benthic foraminifera species.

Chemical Variables	CCA axis 1	CCA axis 2	CCA axis 3	CCA axis 4	*p-value
<u>Selected variables</u>					
Fe	-0.1360	0.5384	-0.1944	-0.6865	0.002
K	0.5210	-0.4217	0.5141	-0.3627	0.001
Mn	0.0268	0.9318	-0.3201	-0.0154	0.001
Sr	0.5251	-0.4788	-0.1503	0.6092	0.001
Ca/Ti	-0.5701	-0.1514	0.0403	0.5675	0.006
<u>Passive variables</u>					
Zr	0.3754	-0.6256	0.3720	0.2035	0.245
Sr/Ca	0.7936	-0.1817	-0.3310	-0.2042	0.204

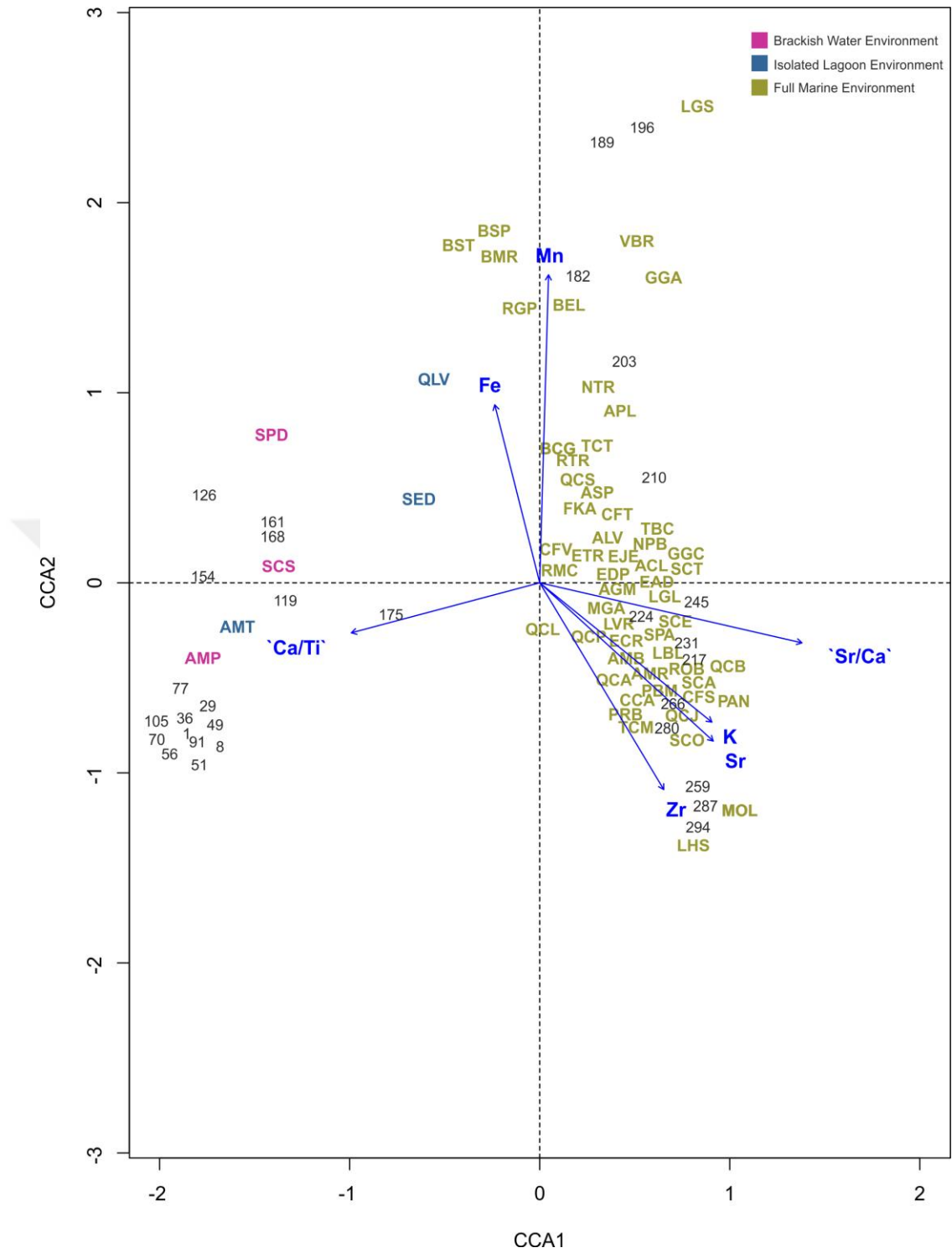


Figure 2. 11. Canonical Correspondence Analysis (CCA) of Benthic Foraminifera with respect to μ XRF analyses of Lake Bafa sediment core (Akçer et al., under review).

3. DISCUSSION

3.1. Ostracoda and Foraminifera Assemblages of Lake Bafa

The fossil assemblages in Lake Bafa have been investigated for several decades (e.g. Brückner, 2006; Kazancı et al., 2008; Altınsaçlı, 2014; Akçer et al., under review). Most of these studies predominantly have focused on the distribution of living organisms (e.g. phytoplankton, ostracoda) sampled from surface water or sediment in shallow levels as a proxy for the understanding of recent climatic changes (e.g. Kazancı et al., 2008; Altınsaçlı, 2014). However, there are limited studies that use fossil (e.g. ostracoda and foraminifera) assemblages for paleoenvironmental reconstructions (Brückner, 2006; Akçer et al., under review).

The detailed identification of ostracoda and benthic foraminifera species in this study provides new insight into paleoenvironmental conditions of Lake Bafa. The presence of some indicator (both statistically and ecologically determined) ostracoda (e.g. *Semicytherura sulcata*, *Semicytherura inversa*, *Semicytherura acuta*, *Semicytherura rarecostata n.sp.*, *Aurila convexa*, *Loxoconcha exagona*, *Loxoconcha rhomboidea*) and benthic foraminifera (e.g. *Miliolinella labiosa*, *Rosalina obtusa*, *Parrina bradyi*, *Spiroloculina angulosa*, *Quinqueloculina berthelotiana*) living in marginal marine conditions indicates **marginal marine paleoenvironment** in Lake Bafa for this time interval (8500 ± 160 – 6700 ± 250 BP; age data from Akçer et al., under review).

The following **full marine paleoenvironment** is especially defined by the presence of marine ostracoda (e.g. *Loxoconcha tumida*, *Paradoxostoma simile*, *Hiltermannicythere aff H. rubra*, *Hiltermannicythere turbida*, *Loxoconcha aff L. bonaducei*, *Leptocythere ramosa*) and benthic foraminifera species (e.g. *Ammodiscus planorbis*, *Adelosina cliarensis*, *Adelosina laevigata*, *Adelosina mediterraneensis*, *Quinqueloculina annectans*, *Quinqueloculina limbata*, *Quinqueloculina seminula*, *Cycloforina villafranca*, *Pyrgo anomala*, *Sigmoilinita costata*, *Asterigerinata mamilla*, *Neoepionides bradyi*, *Lachanella variolata*, *Fursenkoina acuta*, *Cibicides advenum*, *Siphonaperta agglutinans*, *Planorbulina mediterraneensis*). In addition, the identified deep marine ostracoda species such as *Buntonia sublata* and *Xestoleberis prognata* (e.g. Bonaduce and Barra, 2002; Perçin-Paçal et al., 2015; see also Table

2.1.) and benthic foraminifera species such as *Robertina translucens* and *Biloculina globula* (e.g. Sgarrella, 1993; see also Table 2.5.) also support the *full marine environment* for this time interval ($6400 \pm 175 - 3330 \pm 430$ BP; age data from Akçer et al., under review).

The subsequent period of **coastal marine paleoenvironment** in Lake Bafa ($2800 \pm 340 - 2260 \pm 50$ BP; age data from Akçer et al., under review) is revealed by *Bythocythere turgida*, *Cytheridea neapolitana*, *Loxoconcha elliptica*, *Xestoleberis aff. Dispar*, *Costa edwardsi*, *Costa punctatissima*, *Hiltermannicythere rubra*, *Propontocypris intermedia*, *Propontocypris pirifera*, *Cyteretta judaea* and *Bosquetina carinella* of ostracoda species living in Mediterranean coast (e.g. Seko et al., 2012; Faranda et al., 2013; Perçin-Paçal et al., 2015). The presence of benthic foraminifera species such as *Brizalina spatulata*, *Brizalina striatula*, *Bulimina elongata*, *Noninella turgida*, *Elphidium cf. E. advenum*, *Elphidium translucens*, *Triloculina tricarinata*, *Bulimina marginata*, *Rectuvigerina phlegeri*, *Textularia bocki*, *Lagena striata*, *Valvulineria bradyana* in the same interval of raw data including counted species (Figure 2.7.) also indicates the coastal marine environment for this time interval.

The **isolated lagoon paleoenvironment** in Lake Bafa ($2200 \pm 70 - 710 \pm 95$ BP; age data from Akçer et al., under review) is similarly defined by the existence of identified ostracoda and benthic foraminifera species. *Cyprideis torosa* species who live in brackish environment and *Cyprideis sublittoralis*, *Limnocythere inopinata* and *Fabaeformiscandona pokoryni* of low oxygen and shallow water species reveal the presence of brackish environment in Lake Bafa for this time interval. In addition, the marine ostracoda species such as *Aurila woodwardi*, *Bairdia mediterranea*, *Sarsicytheridea punctillata* and *Loxoconcha paralella* and the benthic foraminifera species such as *Ammonia tepida*, *Quinqueloculina laevigata*, *Sigmoilinita edwardsi* show that there was a isolated lagoon environment in Lake Bafa at that time interval.

For the last paleoenvironment in Lake Bafa during time interval of 600 ± 80 BP and 55 ± 10 BP (age data from Akçer et al., under review), low-oxygen **brackish water paleoenvironment** is defined especially due to presence of identified ostracoda species of *Leptocythere lacertosa*, *Darwinula stevensoni*, *Fabaeformiscandona wegelini* and benthic foraminifera species of *Ammonia parkinsonia* (also identified

by Brückner et al., 2006) who live in brackish water and low-oxygen environments. The microfauna assemblages (e.g. *Cyprideis torosa*, ostracoda; *Haynesina* sp., foraminifera) revealed by Müllenhof et al. (2004) for the similar time interval also support the brackish conditions.

3.2. Correlation of Fossil Assemblages with Multi-Proxy Data: Implications for Paleoenvironmental Conditions in Lake Bafa

In this part, paleoenvironmental conditions around Lake Bafa during the last ~8500BP revealed by the statistical analysis and ecological properties of ostracoda and benthic foraminifera species will be compared with the chemical variables (e.g. μ XRF, magnetic susceptibility) measured from the same sediment core (Akçer et al., under review) that we analyzed the species distributions with different sampling intervals. In addition, the role of chemical variables in the variation of species determined by using CCA (e.g. Viehberg, 2006) will be discussed in detail. The time intervals of species-based paleoenvironmental changes obtained from the corresponding intervals of the sediment core (Akçer et al., under review) will be tackled in consideration of previous and recent literature (e.g. Müllenhof, 2004; Brückner, 2006; Akçer et al., under review).

Magnetic Susceptibility (MS) is an import proxy used in paleoenvironmental and paleoclimatological reconstruction studies (e.g. Maher and Thompson, 1999; Cohen, 2003; Xie et al., 2009; Zhang et al., 2012; Radaković et al., 2018). MS values in the sediments are mainly based on the mineral composition (i.e. high MS in ferro-and-paramagnetic iron minerals such as magnetite, hematite and pyrite, whereas low MS in diamagnetic minerals such as quartz, feldspar and calcite). Detrital sediments and tephra layers generally contain high MS minerals while biogenic and siliciclastic sediments mainly include low MS minerals (Stoner et al., 1996). MS contents are sometimes used in dating of sediments (e.g. Ghilardi et al., 2008). In addition, MS values can be significantly low in anoxic sediments due to redox conditions during the early diagenesis (e.g. Çağatay et al., 2014).

In our species-based paleoenvironments, MS values (Akçer et al., under review) are the highest in marginal marine environment but gradually decrease through the full

marine environment (Figure 3.1.). In the beginning of full marine environment, MS values are higher than the lowest values in marginal marine environment. In the subsequent coastal marine environment, MS values gradually decrease and become almost stable in isolated lagoon and brackish environments. The possible reasons of high MS values in marine environments compared to isolated lagoon and brackish environments can be the mineral contents of authigenic materials (e.g. sand-size sediments enriched by magnetic minerals; Akçer et al., under review) and/or differences in oxygen conditions (e.g. Çağatay et al., 2014). The variance of MS values in marine environments (marginal, full and coastal) can also be explained by the changes in sea-level (e.g. Zhang et al., 2000) also noted around the Lake Bafa at that time interval (e.g. Müllenhof, 2004; Brückner, 2006).

The mixing regimes, degradation of organic materials and clastic dilution (i.e. detrital input) are the main factors especially for high/moderate Total Organic Carbon (TOC) contents (e.g. Tyson, 2001; Li et al., 2015). TOC values in the sediment core of Akçer et al. (under review) are the lowest in the core intervals corresponding to marginal marine environment and the highest in the isolated-lagoon environment. The possible reason is the high oxygenation and related low production and/or preservation of organic material in marine conditions (Akçer et al., under review). TOC values are generally low in marine environments and reach their highest at transition from full marine to coastal marine environment. On the contrary, TOC values are the highest in isolated lagoon environment possibly due to increase in organic productivity and decrease in oxygen. This is especially supported by the change in environmental conditions (i.e. transition from marine to brackish) in this environment where TOC values can reach their highest as mentioned above. As also noted by Akçer et al., (under review), TOC values relatively decrease through the top of the core that correspond to the brackish environment in our reconstruction. This is probably related to complete extinction of marine species and low-productivity of other species due to anoxic conditions.

Anomalies in the oxygen ($\delta^{18}\text{O}$) and carbon ($\delta^{13}\text{C}$) isotope compositions (‰ V-PDB) of benthic foraminifera and ostracoda species found in the sediment core of Lake Bafa (Akçer et al., under review) are also well-correlated with our species-based paleoenvironmental reconstruction model. These records are generally good indicator

for the understanding of paleotemperature, water residence time, precipitation/evaporation ratios, and past lake productivity (e.g. Cohen, 2003). In the isotope compositions of Lake Bafa sediment core (Akçer et al., under review), there is a clear tendency in both oxygen and carbon isotope anomalies of ostracoda and benthic foraminifera species to co-vary especially in our species-based isolated lagoon environments. $\delta^{18}\text{O}$ isotope anomalies are clearly increased after a rapid decrease in the beginning of isolated lagoon environment, while $\delta^{13}\text{C}$ anomalies are vice versa. There should be several factors that affected the changes in isotope compositions of species during this time interval. For instance, the evaporation rate in Lake Bafa (high $\delta^{18}\text{O}$) could be higher in isolated lagoon environment than the marine environments as also noted by Akçer et al. (under review). $\delta^{13}\text{C}$ anomalies, on the other hand, were significantly decreased in the beginning of isolated lagoon environment possibly due to diminishing in organic productivity after rapid change in ecological conditions (i.e. marine to brackish). However, these anomalies were increased and remained stable especially in brackish environment again due to advance in species productivity.

K is generally considered to increase during the erosion and terrestrial sediment input into water bodies. The detrital sediments including K-bearing minerals (e.g. biotite, muscovite, K-feldspar) are one of the major inputs causing increase in K content in the lake sediment. Considering the rock units (e.g. meta-granitoids) surrounding the Lake Bafa, there is a high chance of K-bearing sediment inputs to the lake especially during the isolated lagoon environment. Accordingly, there are some High-K anomalies in the sediment core of Akçer et al. (under review) that correspond to our species-based isolated lagoon environment.

Mn and Fe are transported to the lake via minerals (e.g. oxides, carbonates), sediment grains or organic matters. In addition, the mobility of these elements especially increases at redox boundaries, and therefore they are widely used for describing redox history of the lakes (e.g. Schaller et al., 1997; Granina et al., 2004). Accordingly, the anomalies of these elements are good indicator for oxygen conditions in deep waters (Akçer et al., under review; and references therein). In sediment core of Lake Bafa, Mn and Fe contents are especially high in full marine environments due to high oxygenated conditions (Akçer et al., under review). Ca

content, on the other hand, is a good indicator for biogenic production and/or detrital input (e.g. Croudace and Rothwell, 2015). In addition, Ca might precipitate as endogenic and/or biogenic carbonate, and Ca/K is the best indicator for this (e.g. Croudace and Rothwell, 2015). Akçer et al. (under review) especially used the Ca/K ratio to understand endogenic carbonate precipitation in Lake Bafa, and this ratio is especially high in our species-based marginal marine environment. This ratio is also high at some parts of the isolated lagoon environment, but this is probably due to detrital input and/or biogenic productivity. Sr/Ca is especially important for indicating high-Sr aragonite that requires a shallow-water source (e.g. Thomson et al., 2004; Rothwell et al., 2006). In addition, this ratio also indicates the increase in salinity (e.g. Francus et al., 2013). In the sediment core of Lake Bafa (Akçer et al., under review), this ratio reaches its highest in marginal marine and isolated lagoon environments, possibly related to decrease in water levels.

In this study, we determined five distinct paleoenvironments (i.e. marginal marine, full marine, coastal marine, isolated lagoon, and brackish) around Lake Bafa based on the assemblages of ostracoda and benthic foraminifera species. The previous studies on the paleoenvironmental reconstruction of Lake Bafa (e.g. Müllenhof et al., 2004; Brückner et al., 2006, Akçer et al., under review) suggest three paleoenvironments as marine, isolated lagoon and brackish. Detailed examination of ostracoda and benthic foraminifera species around Lake Bafa especially provides new insight into paleoenvironmental changes during the marine time (i.e. marginal, full and coastal marine). In addition, we suggested new time intervals for these paleoenvironmental conditions based on the calibrated ^{14}C ages obtained by Akçer et al. (under review) from the same sediment core that we examined in terms of species distribution with different sampling intervals.

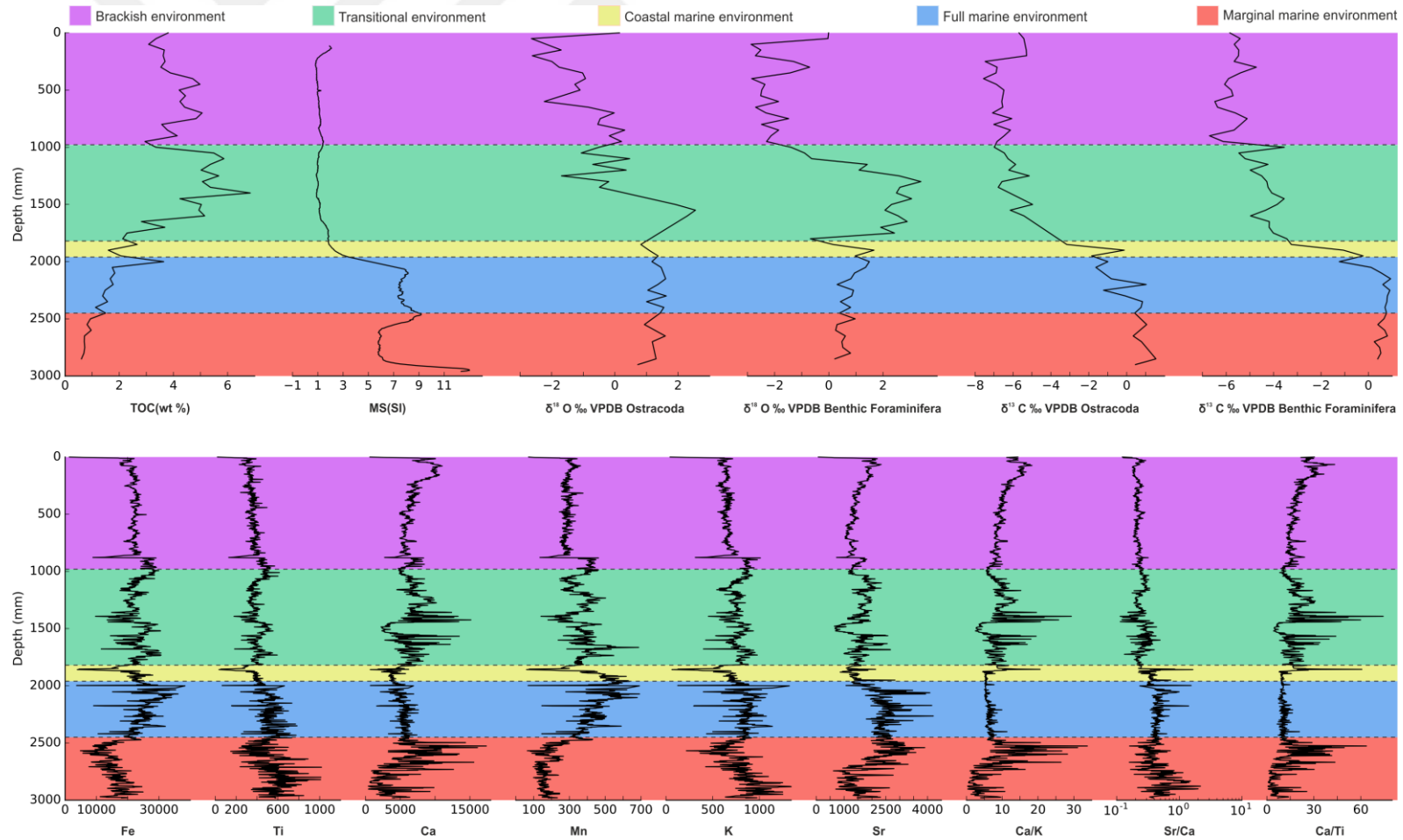


Figure 3. 1. Five distinct paleoenvironments in Lake Bafa in comparison with multi-proxy data (modified after Akçer et al., under review)

Our paleoenvironmental reconstruction model for Lake Bafa starts at ~8500 BP with **the marginal marine environmental** condition especially revealed by the presence of foraminifera species (e.g. *Milionella labiosa*, *Rosalina obtusa*, *Parrina bradyi*) who live in marginal marine environments (e.g. Jones, 2013) and also supported by the presence of Mediterranean coast ostracoda species (e.g. *Semicytherura sulcata*, *Semicytherura inversa*). This finding possibly indicates the lower sea-level conditions at that time (also evident for Aegean coasts; Kayan, 1999) compared to subsequent full-marine environment.

Müllenhof et al (2004) revealed a sea-level change before 5950 BP due to the postglacial transgression based on the clear decreasing in the amount of coarse pebbles and single marine microfossils (*Xestoleberis cf. fuscomaculata*, ostracoda; and *Triloculina sp.*, foraminifera). The sea-level was probably reached its highest level during the Early Bronze Age (~4450-3950 BP, Archipelago-like environment; Brückner et al., 2006) that can be also supported by the presence of deep marine ostracoda (e.g. *Buntonia sublata*) and benthic foraminifera species (e.g. *Robertina translucens*) in **full-marine time** (~6400-3330 BP; Akçer et al., under review) of our paleoenvironmental reconstruction. The sea-level rise in the Aegean Sea during this time interval that reached the present level was also suggested by Kayan (1999). The full marine conditions were considered to continue until ~3190-3076 BP based on the micro and macro fossil assemblages revealed by Müllenhof (2004). Kayan (1999) also stated that there was a little sea-level rise in the Aegean Sea around ~4000-3000 BP that corresponds to the end of full-marine environment in our reconstruction model. This is almost coeval with the catastrophic Minoan eruptions of Santorini volcano (e.g. Druitt et al., 1989) that resulted from tsunami recorded in some parts of the Aegean coasts (Minoura et al., 2000; 2003; Novikova et al., 2011). Although there is no evidence of tsunami in our sediment core of Lake Bafa (Akçer et al., under review), the transition from full-marine to coastal marine environment could be directly or indirectly related to volcano-related tsunami events around the Aegean Sea (e.g. accelerating the closure of the Lake Bafa).

The archipelago-like landscape was transformed to deltaic environment (i.e. integration of islands) due to increase in the siltation/sedimentation rate in Lake Bafa during ~2450 BP (Brückner, 2003; Brückner et al., 2006). The increase in human

impact (e.g. deforestation) possibly accelerated the sedimentation rate in this time interval. These findings are almost suitable with my reconstruction model that proposed a **coastal marine condition** around Lake Bafa during ~2800– 2260 BP (age data from Akçer et al., under review) relatively postdating the previous ages of Müllenhof et al. (2004).

In the beginning of ~2200 BP, there is a sharp decrease in the abundance and diversity of ostracoda and benthic foraminifera species in Lake Bafa (Figures 2.2. and 2.7.) possibly due to the increase in the siltation and delta progradation. Therefore, I believe that Lake Bafa was entirely separated from the open sea at that time, and its surrounding became an **isolated-lagoon environment** (~2200-710 BP). This period was also believed to occur during the late Hellenistic and Roman Imperial time (~2035-1485 BP) due to the progressive degradation of climax vegetation and related increase of soil erosion by intense human impact, and sediment accumulation in coastal zone (e.g. Kayan, 1999; Brückner, 2003; Brückner et al., 2006). After the sharp decrease in species assemblages, the low abundance of benthic foraminifera and ostracoda species were observed over again till the end of isolated-lagoon period. The existence of marine species in this period can be explained by several reasons such as anthropogenic effects (e.g. channelling) that aimed to reconstruct the marine trade substantially destroyed around ~4000-3000BP due to Minoan eruption, or the possible temporary sea-level rises around the lake (e.g. ~1850 BP around Miletus; Eisma, 1978; 1140-820 BP in this study) that might result in the input of the sea water including new marine species to the lake.

Subsequent anoxic condition revealed by sedimentological and paleontological (e.g. presence of foraminifera *Haynesina* sp.) features (e.g. Müllenhof, 2004; Brückner et al., 2006) around ~623 BP indicates entirely **brackish environment** that is also supported by our species assemblages (Figures 2.4. and 2.9.). In addition, our new species-based time interval (~606-54 BP) for brackish condition is almost coeval with the previous thoughts (e.g. Brückner et al., 2006).

4. CONCLUDING REMARKS

The main outcomes of this study can be listed as follows:

- A total of 57 ostracoda and 69 benthic foraminifera species in Lake Bafa were determined under the binocular microscope and by the help of scanning electron images. Ecological properties of all species were also noted from the literature to use them for further statistical interpretations. The identified species were also counted using Morpheus program.

- Constrained Hierarchical Clustering Analyses of the counted ostracoda and benthic foraminifera species reveal the five and three paleoenvironmental conditions for Lake Bafa, respectively. The possible reason of the difference in clustering analysis is that benthic foraminifera species have high tolerance in marine conditions, and therefore there is no statistically distinct clustering in these marine species. However, their ecological properties also indicate three distinct marine conditions (i.e. marginal marine, full-marine and coastal marine) that are statistically defined by clustering analysis of ostracoda species. The isolated-lagoon and brackish environments were defined by both clustering analysis and ecological properties of ostracoda and benthic foraminifera species. In addition, the indicator species for each clusters were determined considering the statistical analysis and ecological properties of the species.

- Based on the ecological properties and clustering analysis of ostracoda and benthic foraminifera species with corresponding age data from sediment core, the mainly five distinct paleoenvironments in Lake Bafa during the Holocene can be defined as: (1) $(8500 \pm 160 - 6700 \pm 250 \text{ BP})$ marginal marine environment due to presence of some ostracoda (e.g. *Semicytherura sulcata*, *Semicytherura inversa*, *Semicytherura acuta*) and benthic foraminifera (e.g. *Miliolinella labiosa*, *Rosalina obtusa*, *Parrina bradyi*) live in shallow-marine waters, (2) $(6400 \pm 175 - 3330 \pm 430 \text{ BP})$ full-marine environment with the presence of marine ostracoda (e.g. *Leptocythere ramosa*, *Loxoconcha tumida*, *Paradoxostoma simile*) and benthic

foraminifera species (e.g. *Ammodiscus planorbis*, *Adelosina cliarensis*, *Adelosina laevigata*) (3) ($2800 \pm 340 - 2260 \pm 50$ BP) coastal marine environment revealed by ostracoda species living in Mediterranean coast (e.g. *Bythocythere turgida*, *Cytheridea neapolitana*, *Loxoconcha elliptica*, *Costa punctatissima*) and benthic foraminifera (e.g. *Brizalina spatulohata*, *Brizalina striatula*, *Bulimina elongata*, *Triloculina tricarinata*) (4) ($2200 \pm 70 - 710 \pm 95$ BP) isolated-lagoon environment in which low-oxygen ostracoda (e.g. *Limnocythere inopinata*, *Fabaeformiscandona pokoryni*), marine ostracoda (e.g. *Aurila woodwardi*, *Bairdia mediterranea*, *Sarsicytheridea punctillata*) and benthic foraminifera (e.g. *Ammonia tepida*, *Quinqueloculina laevigata*, *Sigmoilinita edwardsi*) are found, (5) ($600 \pm 80 - 55 \pm 10$ BP) brackish water environment including some low-oxygen ostracoda species such as *Farbaeformiscandona wegelini*, *Loxoconcha elliptica* and *Darwinula stewensoni*, and benthic foraminifera species of *Ammonia parkinsonia* who live in brackish water and low-oxygen environments.

- In order to reveal a possible role of geochemical variables on the distribution ostracoda and benthic foraminifera species, I applied Canonical Correspondence Analysis (CCA) for the counted species and μ XRF data of Lake Bafa sediment core. CCA results indicate that Fe, K, Mn, Sr, Ca/Ti and Sr/Ca anomalies are statistically significant variables for distribution of both species. Of those, Ca/Ti is especially correlated with the species in brackish environment as an indication for carbonate precipitation and/or high productivity, whereas Fe has positive correlation with the species in isolated lagoon environments possibly due to the oxygen variation in the lake and/or Fe-bearing sediment input. Mn and K are especially correlated with the species in coastal marine environments due to Mn-bearing sediment input and/or oxygen variation in the lake, and the increase in salinity. Sr and Sr/Ca are mainly correlated with the marine species as a possible indication for shallow-water level (e.g. marginal marine) and the increase in salinity. The anomalies of μ XRF data along the sediment core also support the interpretations of CCA results.

- In conclusion, I believe that the detailed identification of ostracoda and benthic foraminifera species with their ecological properties and multi-variate statistical analyses will provide new insight into the paleoenvironmental reconstruction of Lake Bafa for the last 8500 BP.



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APPENDIX A

Ostracoda Plates

APPENDIX A (cont.)

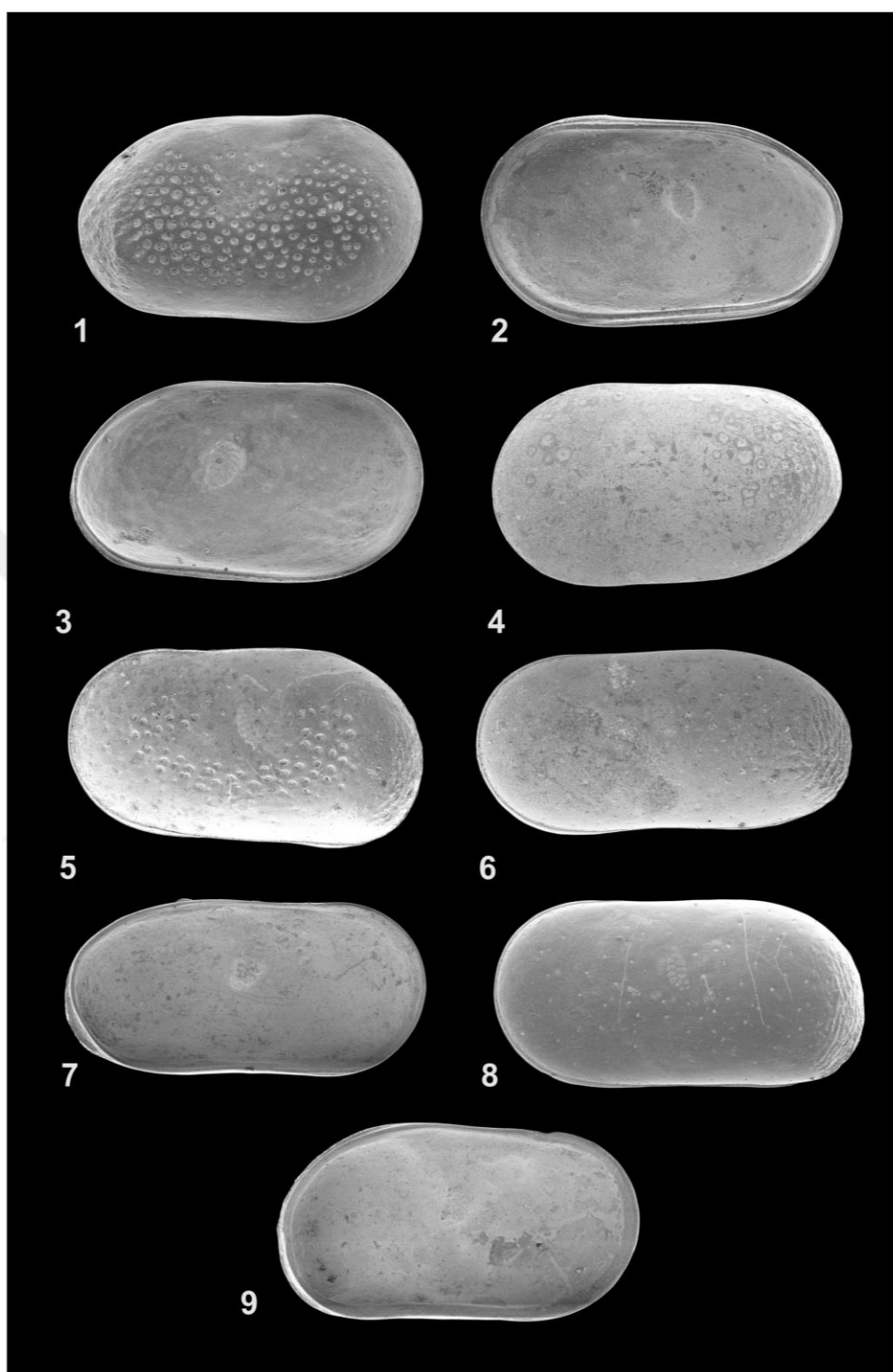


Figure A. 1- *Cytherella alverium*. Lateral exterior view of right valve (x 140); 2- *Cytherella alverium*. Interior view of right valve (x 160); 3- *Cytherella alverium*. Interior view of left valve (x 160); 4- *Cytherella alverium*. Lateral exterior view of left valve (x 140); 5- *Cytherella vulgata*. Lateral exterior view of left valve (x 120); 6- *Cytherella vulgata*. Lateral exterior view of left valve(x 130); 7- *Cytherella vulgata*. Interior view of left valve (x 130); 8- *Cytherella vulgata*. Lateral exterior view of left valve (x 130); 9- *Cytherella vulgata*. Interior view of left valve (x 120)

APPENDIX A (cont.)

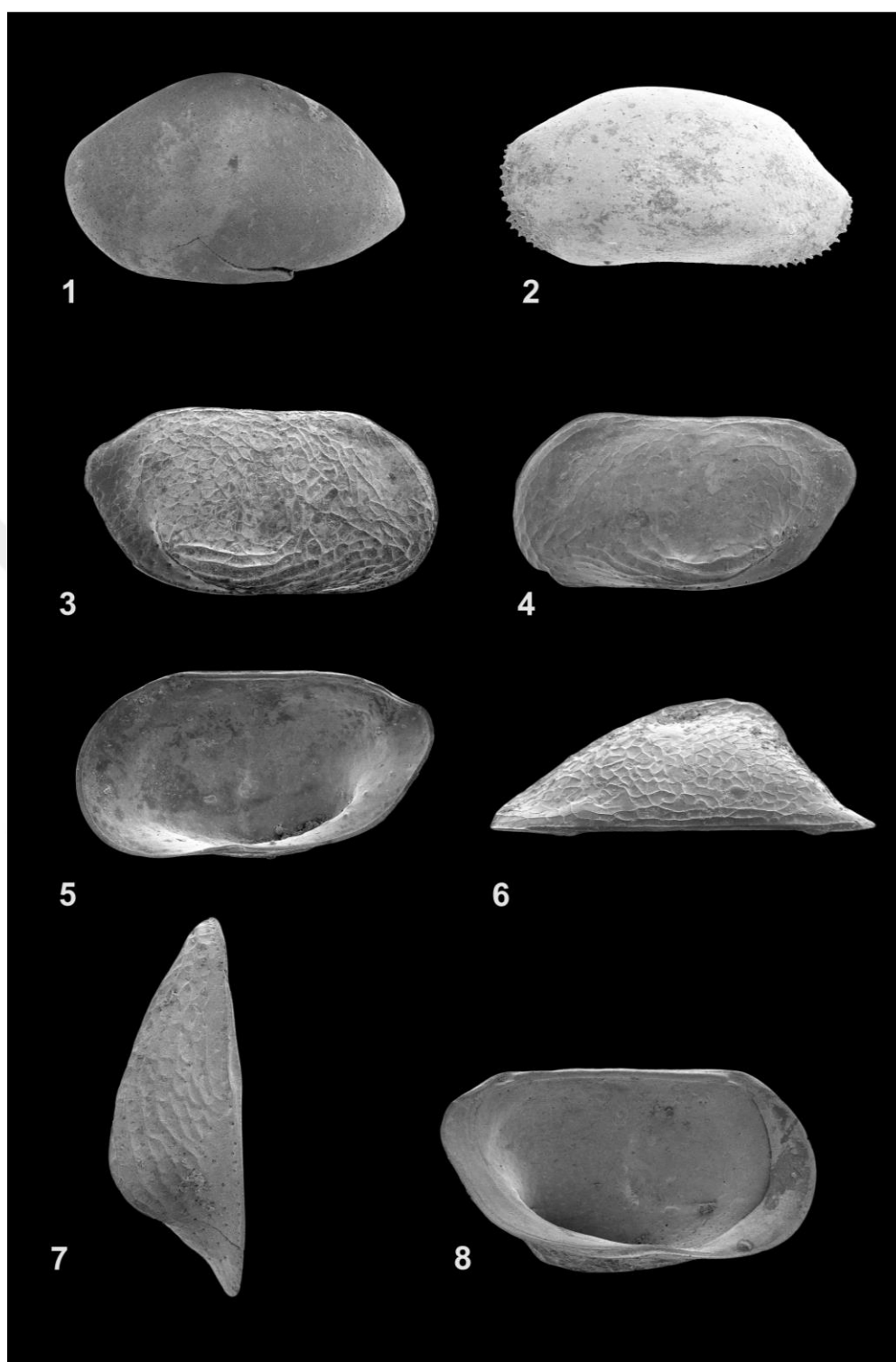


Figure A. 2 1- *Brairdia mediterranea*. Lateral exterior view of left valve (x 110); 2- *Triebelina raripila*. Lateral exterior view of left valve (x 160); 3-*Bythocythere turgida*. Lateral exterior view of right valve (x 120); 4-*Bythocythere turgida*. Lateral exterior view of left valve (x 150); 5-*Bythocythere turgida*. Interior view of right valve (x 150); 6-*Bythocythere turgida*. Dorsal view of right valve (x 110); 7-*Bythocythere turgida*. Dorsal view of left valve (x 80); 8-*Bythocythere turgida*. Interior view of left valve (x 110)

APPENDIX A (cont.)

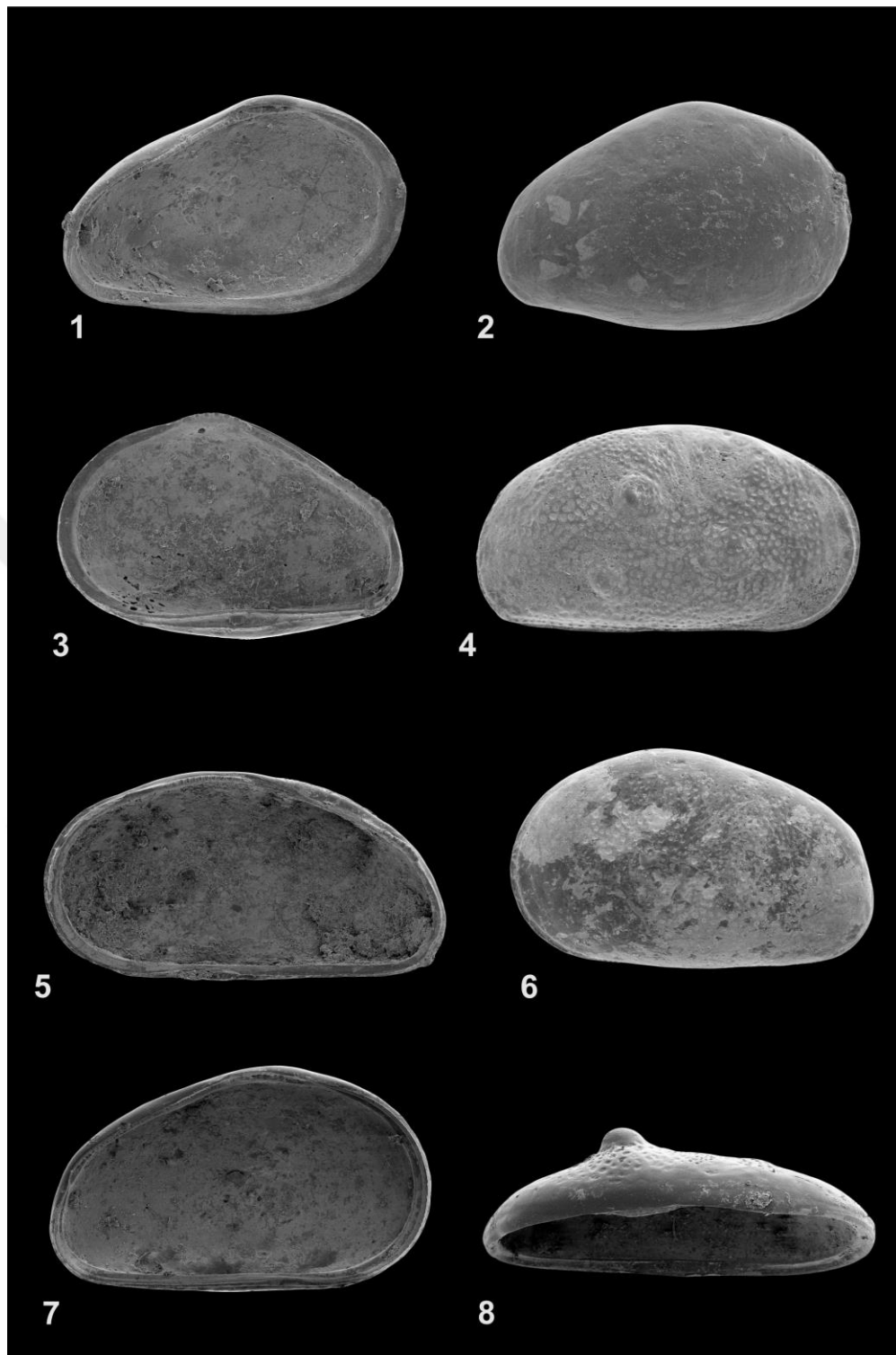


Figure A. 3 1- *Cyprideis torosa*. Interior view of left valve (x 330); 2- *Cyprideis torosa*. Exterior view of right valve (x 260); 3- *Cyprideis torosa*. Interior view of right valve (x 270); 4- *Cyprideis torosa*. Exterior view of right valve (x 90); 5- *Cyprideis torosa*. Interior view of right valve (x 110); 6- *Cyprideis torosa*. Exterior view of left valve (x 110); 7- *Cyprideis torosa*. Interior view of right valve (x 140); 8- *Cyprideis torosa*. Dorsal view of left valve (x 160)

APPENDIX A (cont.)

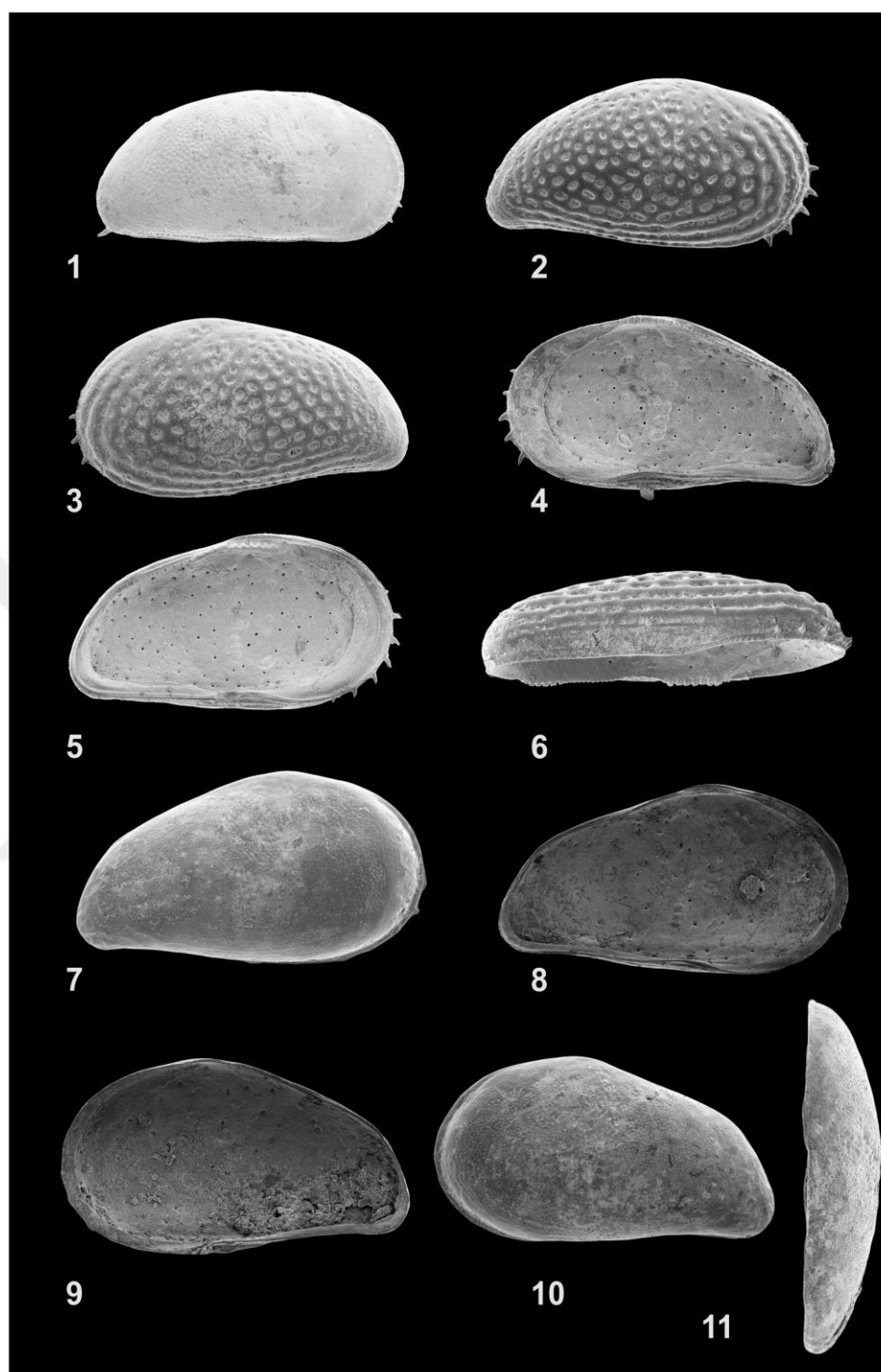


Figure A. 4 1-*Cyprideis sublittoralis*. Exterior view of right valve (x 80); 2-*Cytheridea neapolitana*. Exterior view of right valve (x 110); 3-*Cytheridea neapolitana*. Exterior view of left valve (x110); 4- *Cytheridea neapolitana*. Interior view of right valve (x 110); 5-*Cytheridea neapolitana*. Interior view of left valve (x 110); 6-*Cytheridea neapolitana*. Dorsal view of right valve (x 80); 7-*Cytheridea sp.* Exterior view of right valve (x 170); 8-*Cytheridea sp.* Interior view of left valve (x 130); 9-*Cytheridea sp.* Interior view of right valve (x 180); 10-*Cytheridea sp.* Exterior view of left valve (x 120); 11-*Cytheridea sp.* Ventral view of right valve (x 140)

APPENDIX A (cont.)

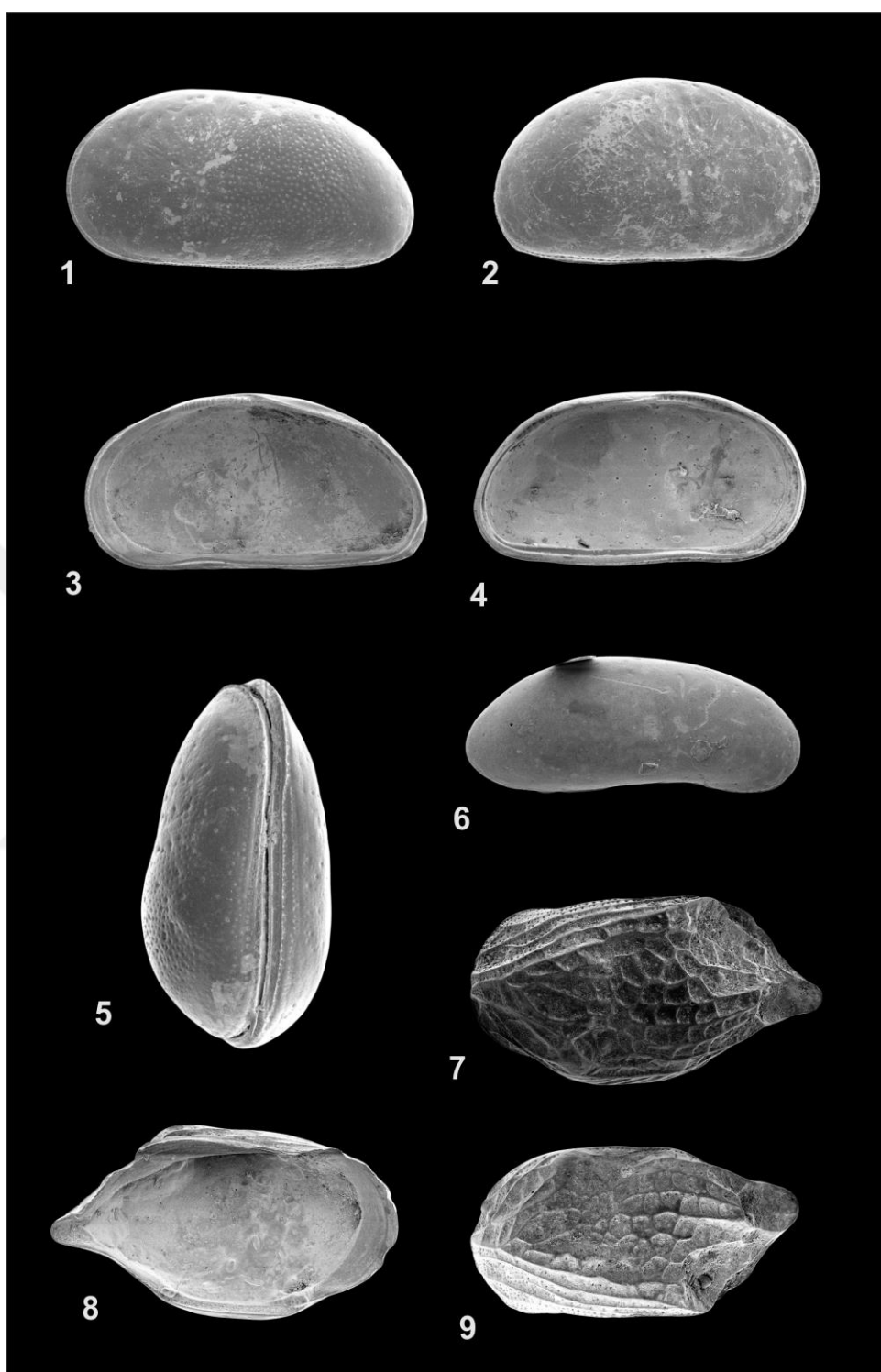


Figure A. 5 1-*Sarsicythere bradii*. Exterior view of left valve (x 90); 2-*Sarsicythere bradii*. Exterior view of right valve (x 90); 3-*Sarsicythere bradii*. Interior view of right valve (x 90); 4- *Sarsicythere bradii*. Interior view of left valve (x 90); 5-*Sarsicythere bradii*. Ventral view of a complete carapace (x 80); 6-*Cytheroma variabilis*. Exterior view of right valve (x 210); 7-*Semicytherura inverse*. Lateral exterior view of left valve (x 170); 8-*Semicytherura inverse*. Interior view of left valve (x 160); 9-*Semicytherura inverse*. Lateral exterior view of left valve (x 160)

APPENDIX A (cont.)

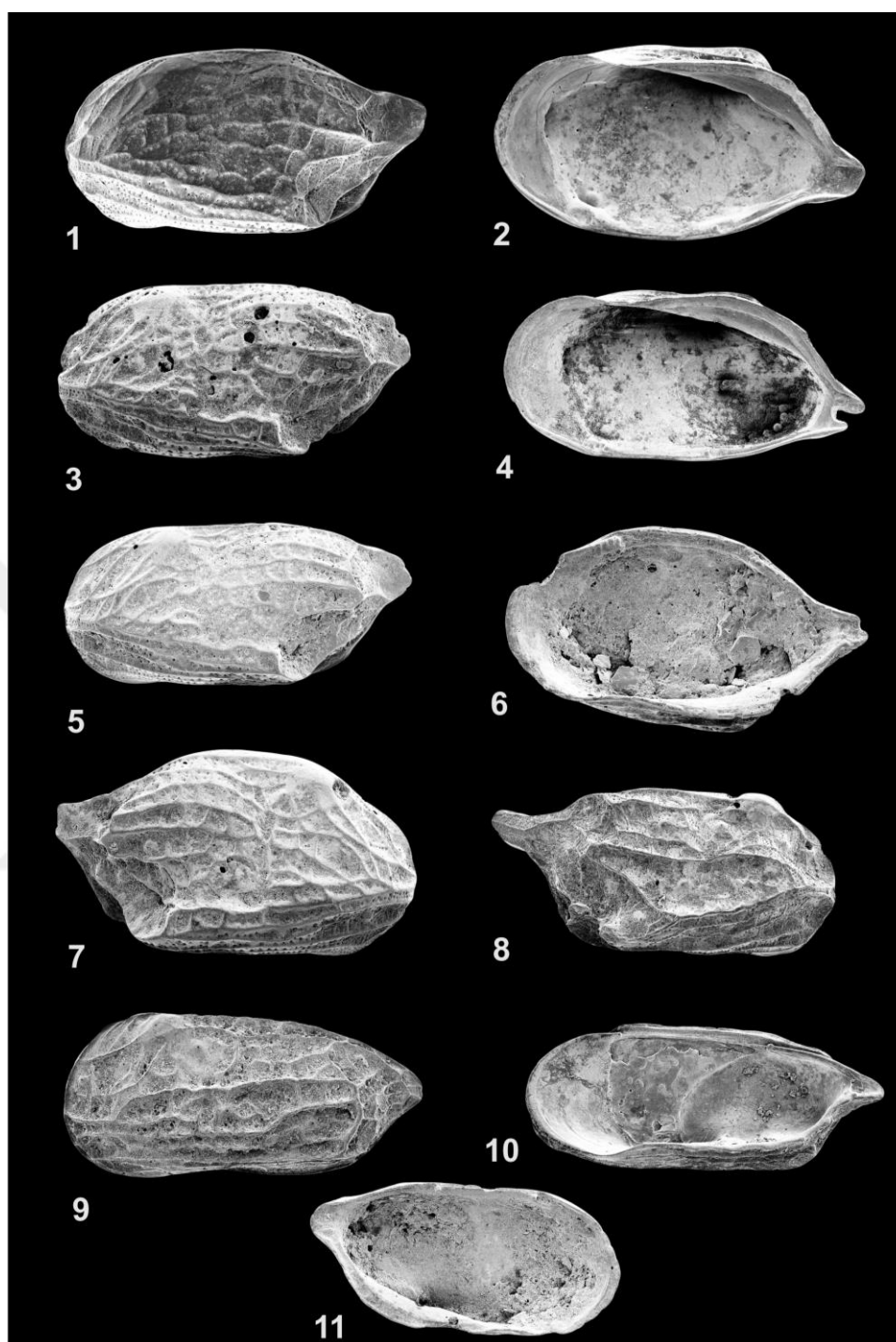


Figure A. 6 1-*Semicytherura inverse*. Lateral exterior view of left valve (x 160); 2- *Semicytherura inverse*. Interior view of left valve (x 180); 3-*Semicytherura inverse*. Lateral exterior view of left valve (x 170); 4-*Semicytherura inverse*. Lateral exterior view of left valve (x 170); 5-*Semicytherura inverse*. Lateral exterior view of left valve (x 160); 6-*Semicytherura inverse*. Interior view of right valve (x 160); 7-*Semicytherura inverse*. Lateral exterior view of right valve (x 180); 8-*Semicytherura acuta*. Lateral exterior view of right valve (x 210); 9- *Semicytherura rarecostata* n.sp. Lateral exterior view of left valve (x 260); 10-*Semicytherura rarecostata* n.sp. Lateral exterior view of right valve (x 260); 11-*Semicytherura rarecostata* n.sp. Lateral exterior view of left valve (x 170)

APPENDIX A (cont.)

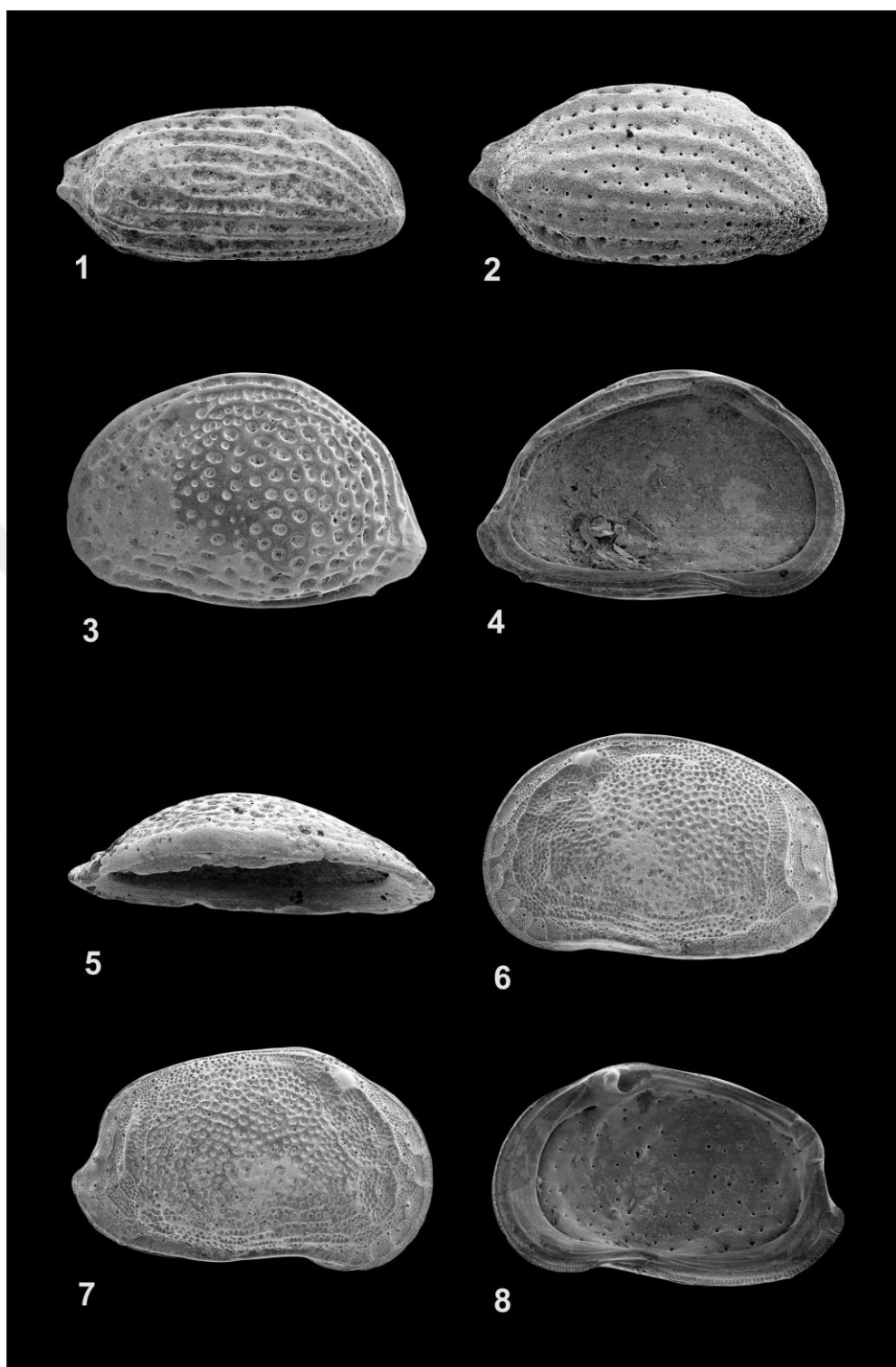


Figure A. 7 1-*Semicytherura sulcata*. Lateral exterior view of right valve (x 170);
 2-*Semicytherura sulcata*. Lateral exterior view of right valve (x 190); 3-*Aurila convexa*. Lateral
 exterior view of left valve (x 120); 4-*Aurila convexa*. Interior view of the left valve (x 130);
 5-*Aurila convexa*. Ventral view of right valve (x 130); 6-*Aurila woodwardii*. Lateral exterior view
 of left valve (x 120); 7-*Aurila woodwardii*. Lateral exterior view of right valve (x 120);
 8-*Aurila woodwardii*. Interior view of right valve (x 110)

APPENDIX A (cont.)

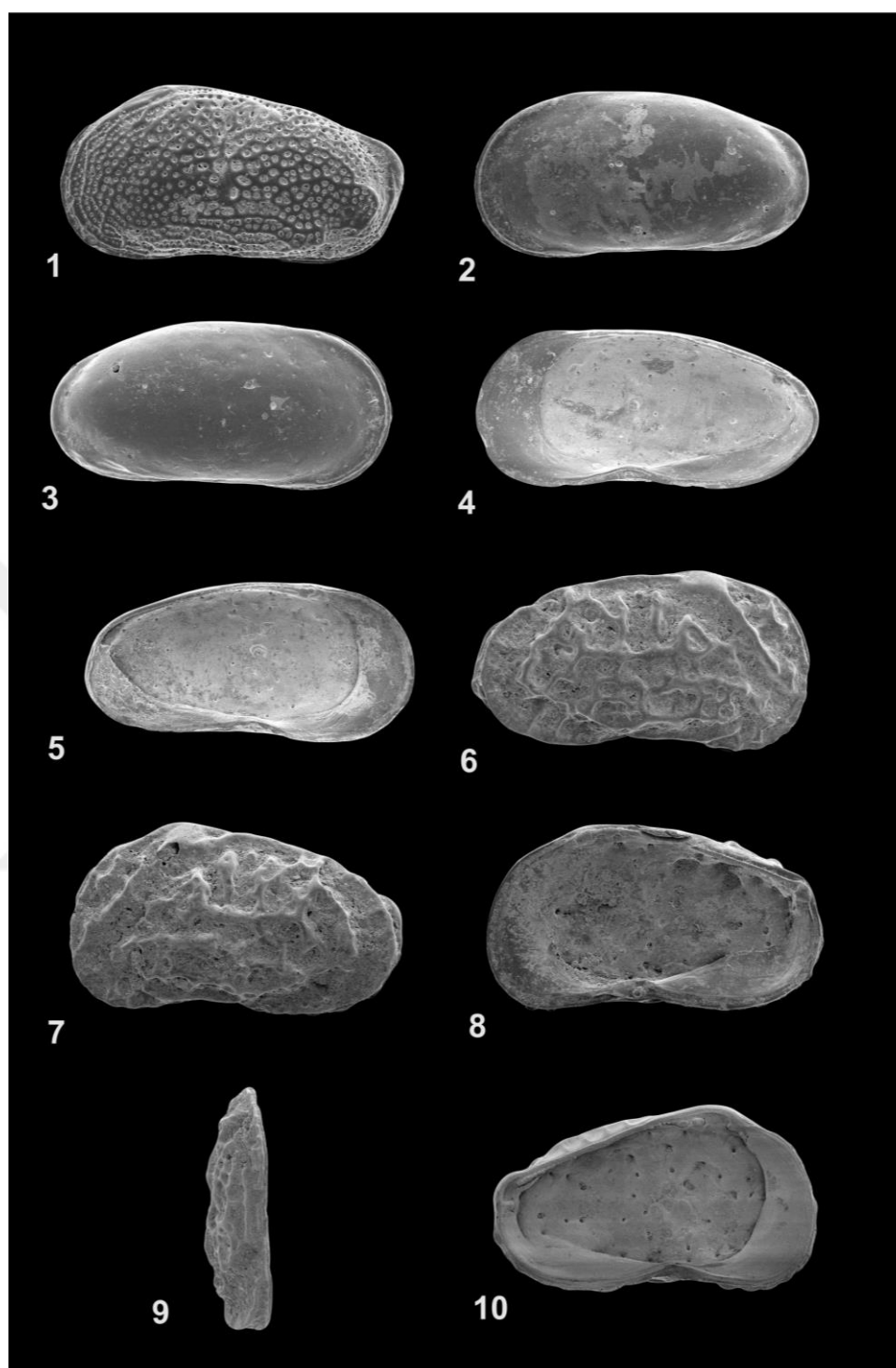


Figure A. 8 1-*Leptocythere lacertosa*. Lateral exterior view of left valve (x 200); 2-*Leptocythere ramosa*. Lateral exterior view of left valve (x 160); 3- *Leptocythere ramosa*. Lateral exterior view of right valve (x 190); 4- *Leptocythere ramosa*. Interior view of right valve (x 190); 5- *Leptocythere ramosa*. Interior view of left valve (x 170); 6- *Callistocythere littoralis*. Lateral exterior view of right valve (x 150); 7- *Callistocythere littoralis*. Lateral exterior view of left valve (x 160); 8- *Callistocythere littoralis*. Interior view of right valve (x 160); 9- *Callistocythere littoralis*. Ventral view of left valve (x 120); 10- *Callistocythere littoralis*. Interior view of left valve (x 150)

APPENDIX A (cont.)

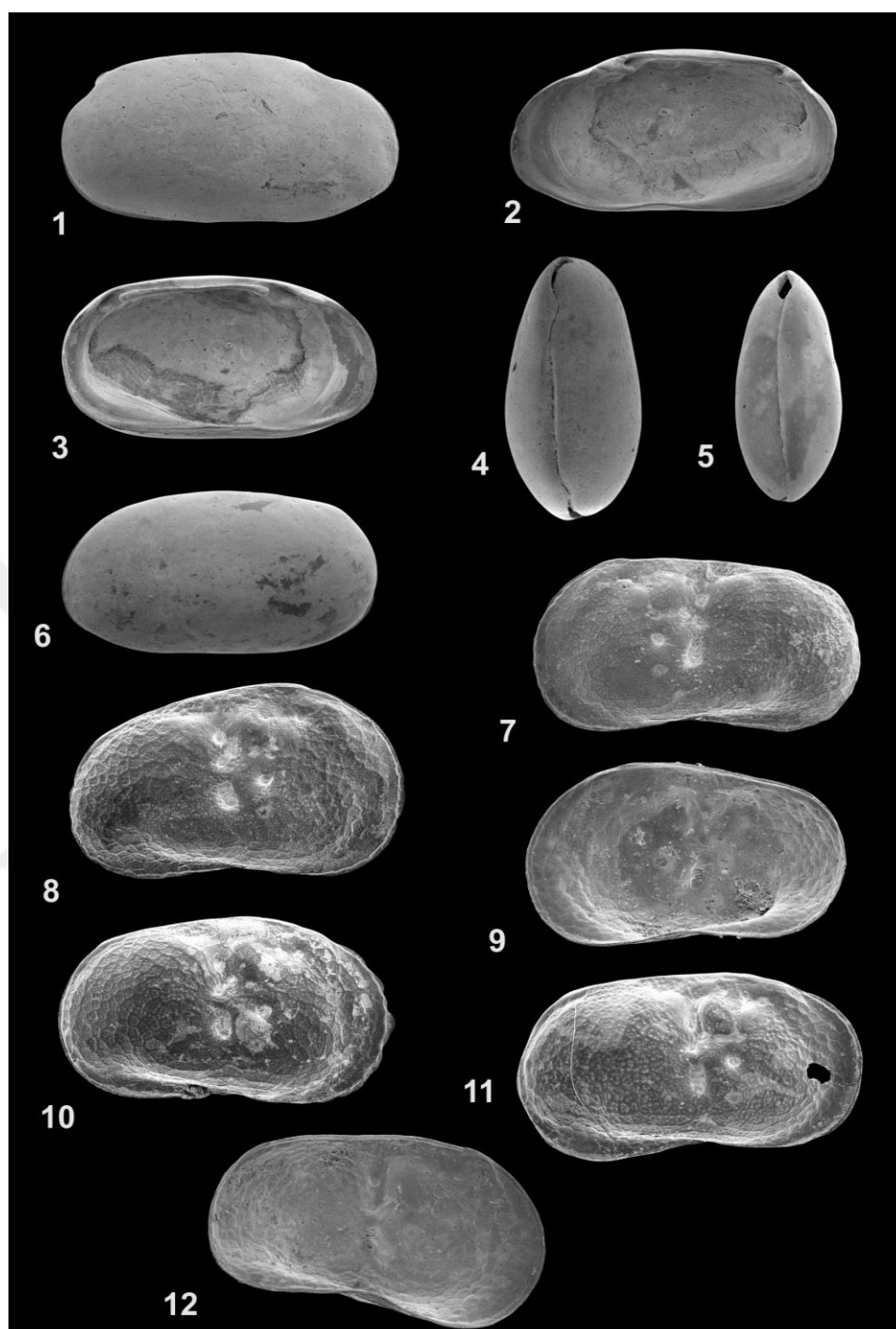


Figure A. 9 1-*Cytheretta subradiosa*. Lateral exterior view of left valve (x 120); 2-*Cytheretta subradiosa*. Interior view of left valve (x 110); 3-*Cytheretta subradiosa*. Lateral exterior view of right valve (x 110); 4-*Cytheretta subradiosa*. Ventral view of a complete caparace (x 90); 5-*Cytheretta subradiosa*. Ventral view of a complete caparace (x 80); 6-*Cytheretta judaea*. Lateral exterior view of right valve (x 110); 7-*Limnocythere inopinata*. Lateral exterior view of left valve (x 170); 8-*Limnocythere inopinata*. Lateral exterior view of right valve (x 220); 9-*Limnocythere inopinata*. Lateral exterior view of left valve (x 210); 10-*Limnocythere inopinata*. Lateral exterior view of right valve (x 180); 11-*Limnocythere inopinata*. Lateral exterior view of right valve (x 150); 12-*Limnocythere inopinata*. Lateral exterior view of right valve (x 190)

APPENDIX A (cont.)

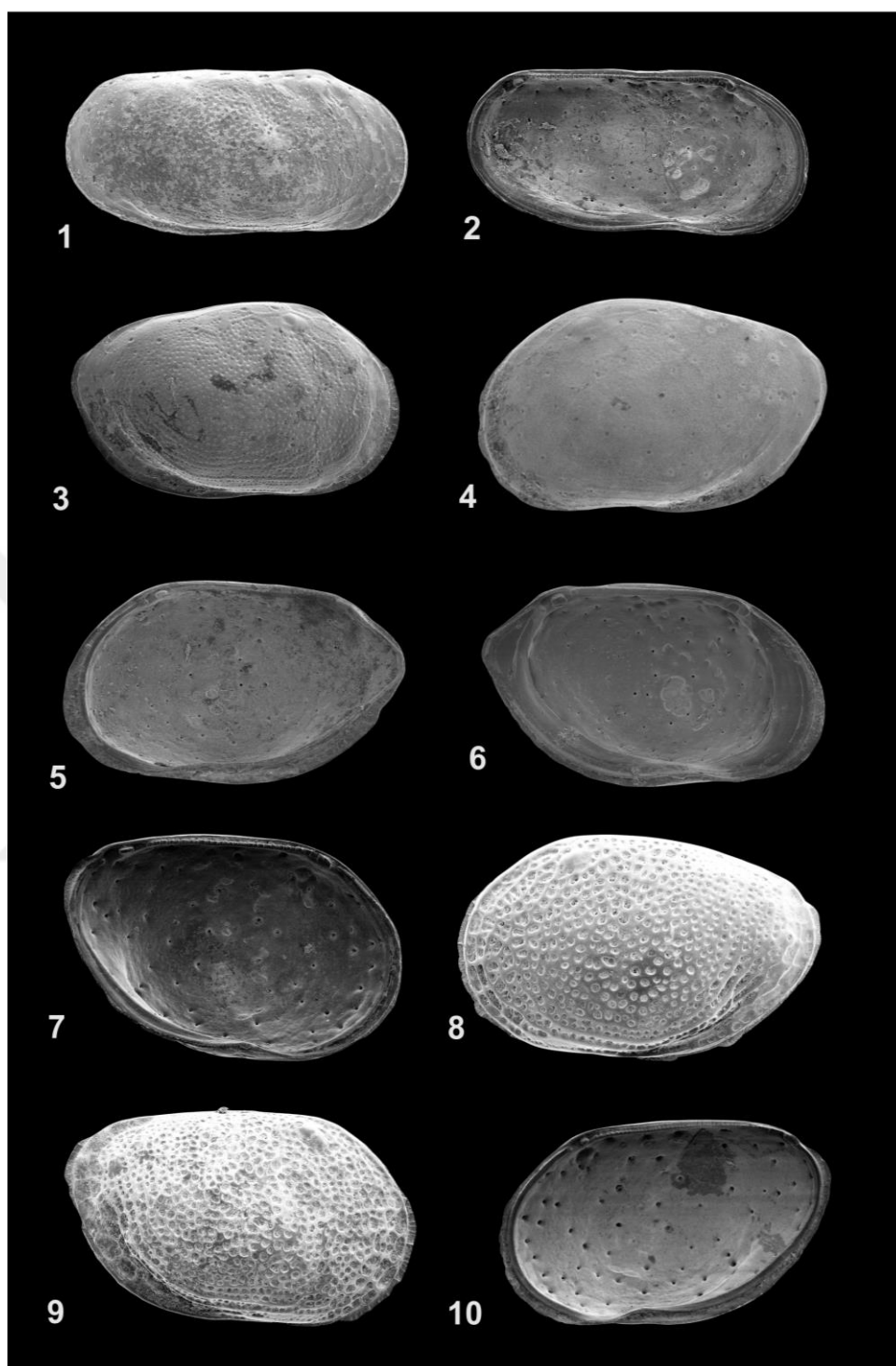


Figure A. 10 1-*Loxoconcha paralella*. Lateral exterior view of right valve (x 170); 2-*Loxoconcha paralella*. Interior view of left valve (x 160); 3-*Loxoconcha* aff. *L. Agilis*. Lateral exterior view of right valve (x 210); 4-*Loxoconcha* aff. *L. Agilis*. Lateral exterior view of left valve (x 150); 5-*Loxoconcha* aff. *L. Agilis*. Interior view of right valve (x 200); 6-*Loxoconcha* aff. *L. Agilis*. Interior view of left valve (x 150); 7-*Loxoconcha bonaducei*. Interior view of left valve (x 160); 8- *Loxoconcha bonaducei*. Lateral exterior view of left valve (x 50); 9-*Loxoconcha bonaducei*. Lateral exterior view of right valve (x 210); 10-*Loxoconcha bonaducei*. Interior view of right valve (x 140)

APPENDIX A (cont.)

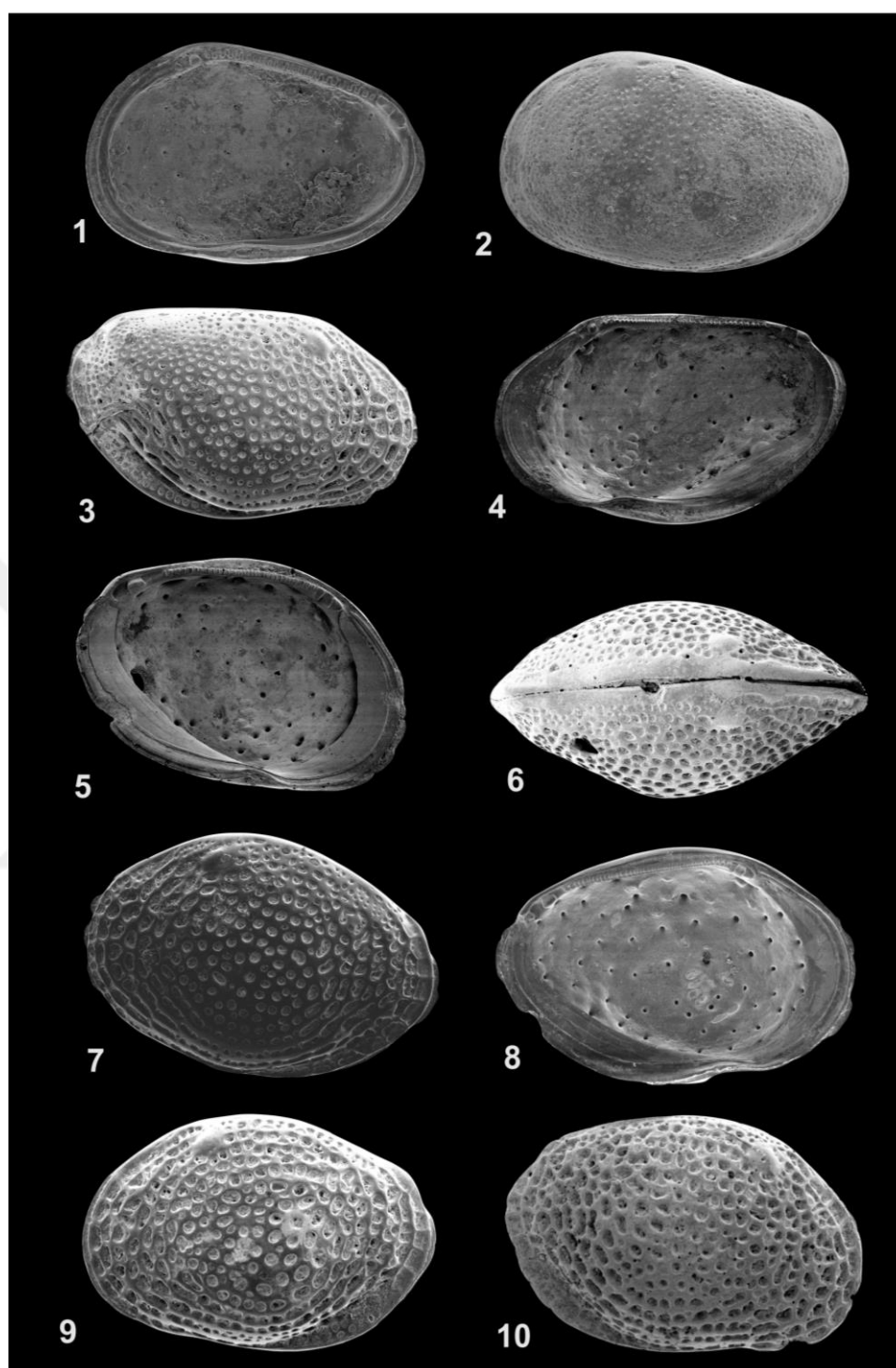


Figure A. 11 1-*Loxoconcha elliptica*. Interior view of right valve (x 300); 2-*Loxoconcha elliptica*. Lateral exterior view of left valve (x 230); 3-*Loxoconcha exagona*. Lateral exterior view of right valve (x 110); 4-*Loxoconcha exagona*. Interior view of right valve (x 110); 5-*Loxoconcha exagona*. Interior view of left valve (x 120); 6-*Loxoconcha exagona*. Dorsal view of a complete caparace (x 100); 7-*Loxoconcha rhombodei*. Lateral exterior view of left valve (x 110); 8-*Loxoconcha rhombodei*. Interior view of left valve (x 110); 9-*Loxoconcha rhombodei*. Lateral exterior view of left valve (x 140); 10-*Loxoconcha rhombodei*. Lateral exterior view of right valve (x 130)

APPENDIX A (cont.)

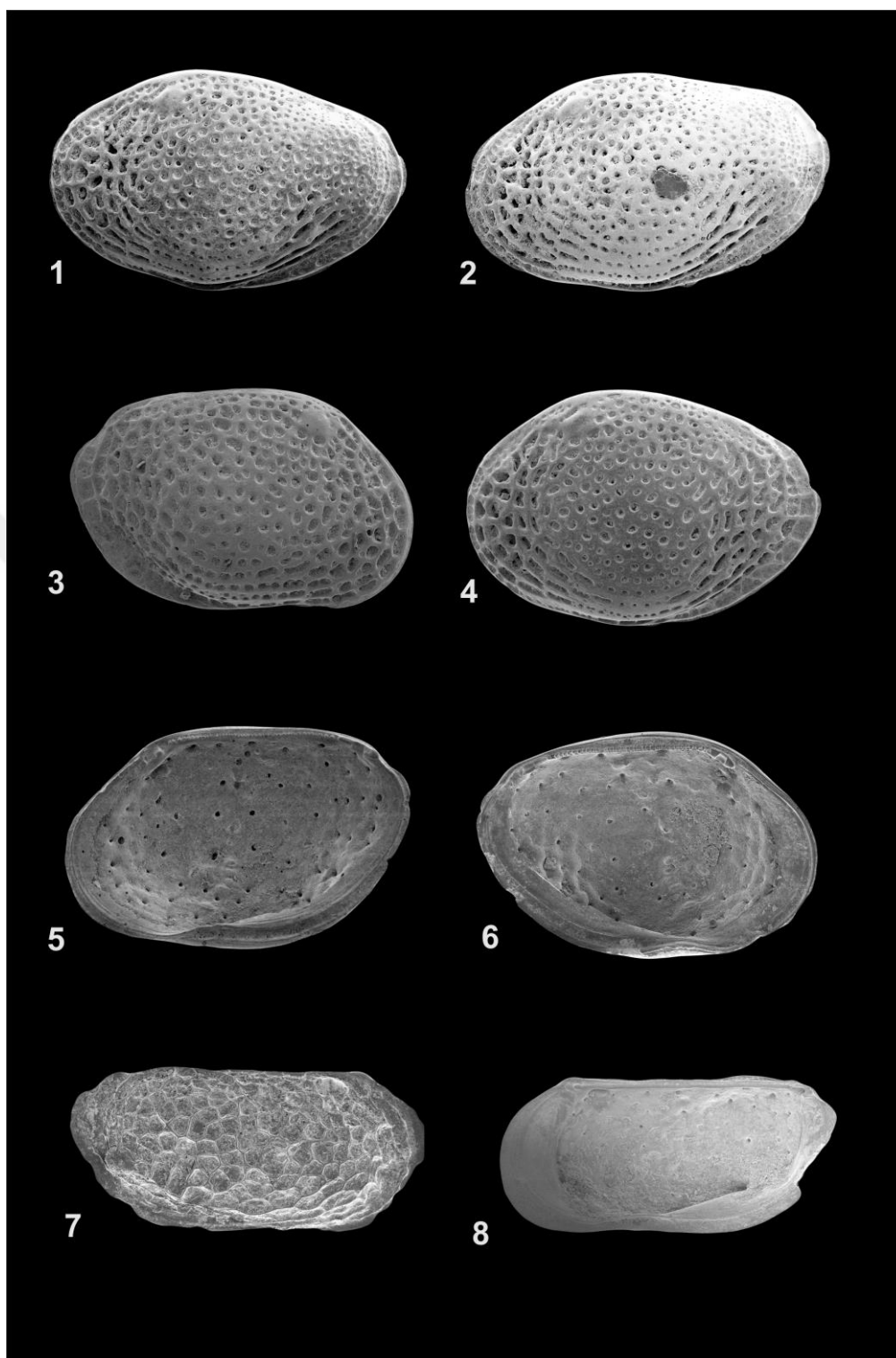


Figure A. 12 1-*Loxoconcha tumida*. Lateral exterior view of left valve (x 110); 2-*Loxoconcha tumida*. Lateral exterior view of left valve (x 110); 3-*Loxoconcha tumida*. Lateral exterior view of right valve (x 130); 4-*Loxoconcha tumida*. Lateral exterior view of left valve (x 120); 5-*Loxoconcha tumida*. Interior view of right valve (x 120); 6-*Loxoconcha tumida*. Interior view of the left valve (x 110); 7-*Loxoconcha versicolor*. Lateral exterior view of right valve (x 190); 8-*Loxoconcha versicolor*. Interior of right valve (x 180)

APPENDIX A (cont.)

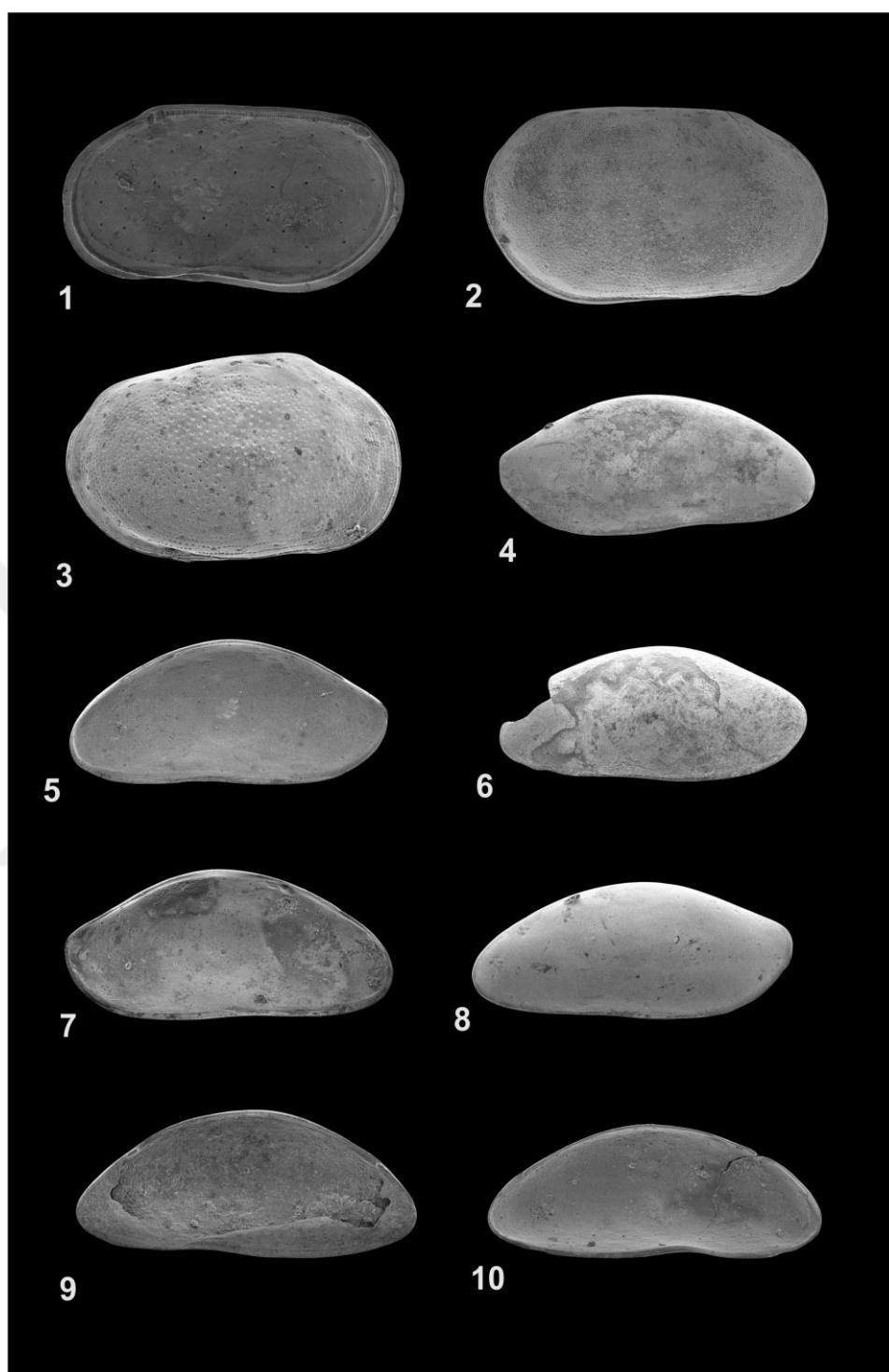


Figure A. 13 1-*Hirschmannia* sp. Interior view of the left valve (x 140); 2-*Hirschmannia* sp. Lateral exterior view of left valve (x 150); 3-*Hirschmannia* sp. Lateral exterior view of right valve (x 180); 4-*Paradoxostoma simile*. Lateral exterior view of left valve (x 130); 5-*Paradoxostoma simile*. Interior view of left valve (x 200); 6-*Paradoxostoma simile*. Lateral exterior view of right valve (x 200); 7-*Paradoxostoma simile*. Interior view of right valve (x 210); 8-*Paradoxostoma simile*. Lateral exterior view of right valve (x 130); 9-*Cytherois frequens*. Interior view of left valve (x 130); 10-*Cytherois frequens*. Lateral exterior view of right valve (x 160)

APPENDIX A (cont.)

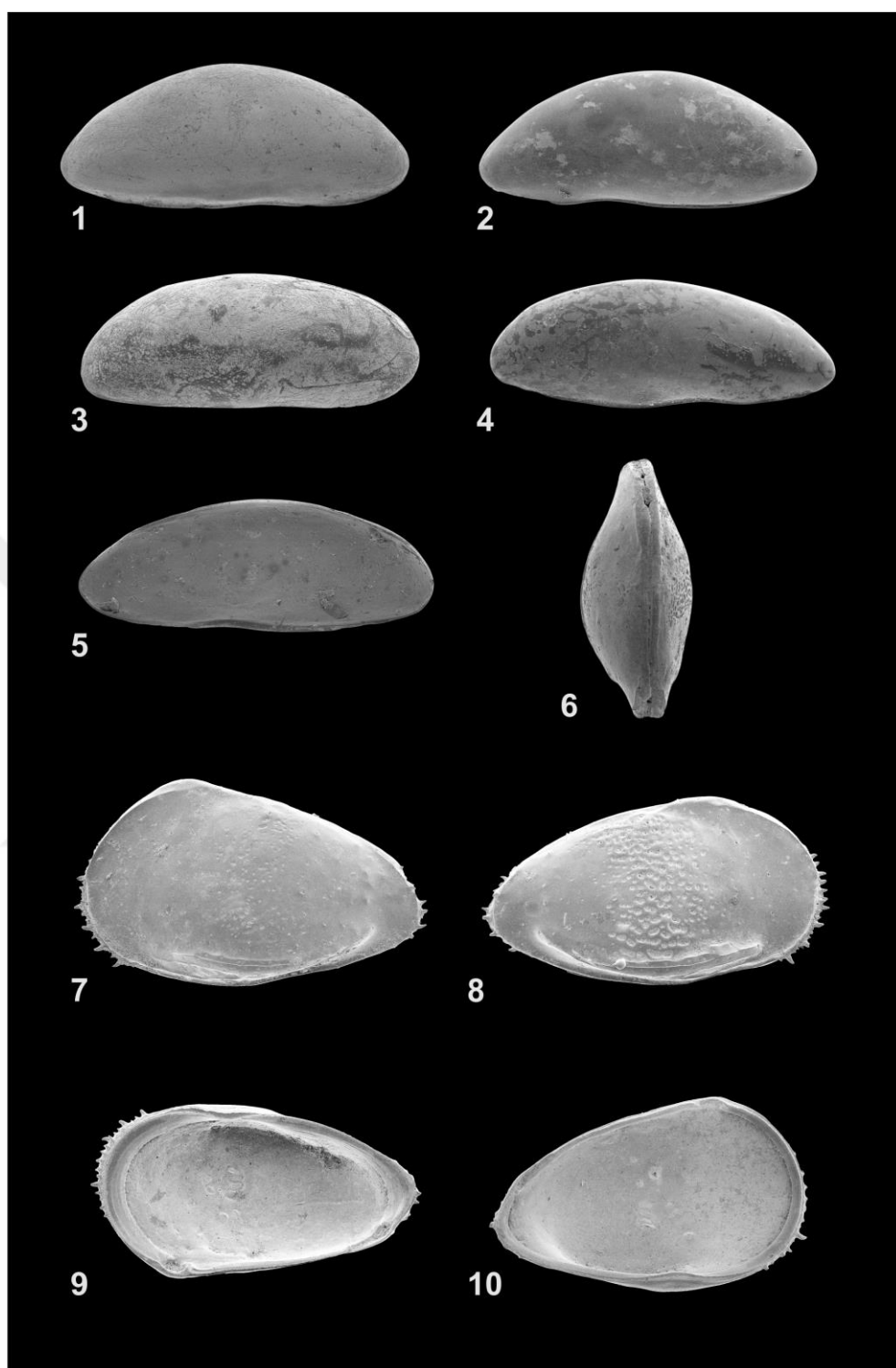


Figure A. 14 1-*Cytheroidea frequens*. Lateral exterior view of right valve (x 170); 2-*Cytheroidea frequens*. Lateral exterior view of left valve (x 130); 3-*Cytheroidea cf. Stephanidesi*. Lateral exterior view of right valve (x 260); 4-*Cytheroidea cf. Fischeri*. Lateral exterior view of left valve (x 190); 5-*Cytheroidea cf. Fischeri*. Interior view of left valve (x 230); 6-*Bosquetina carinella*. Ventral view of a complete carapace (x 50); 7-*Bosquetina carinella*. Lateral exterior view of left valve (x 80); 8-*Bosquetina carinella*. Lateral exterior view of right valve (x 70); 9-*Bosquetina carinella*. Interior view of right valve (x 60); 10-*Bosquetina carinella*. Interior view of left valve (x 90)

APPENDIX A (cont.)

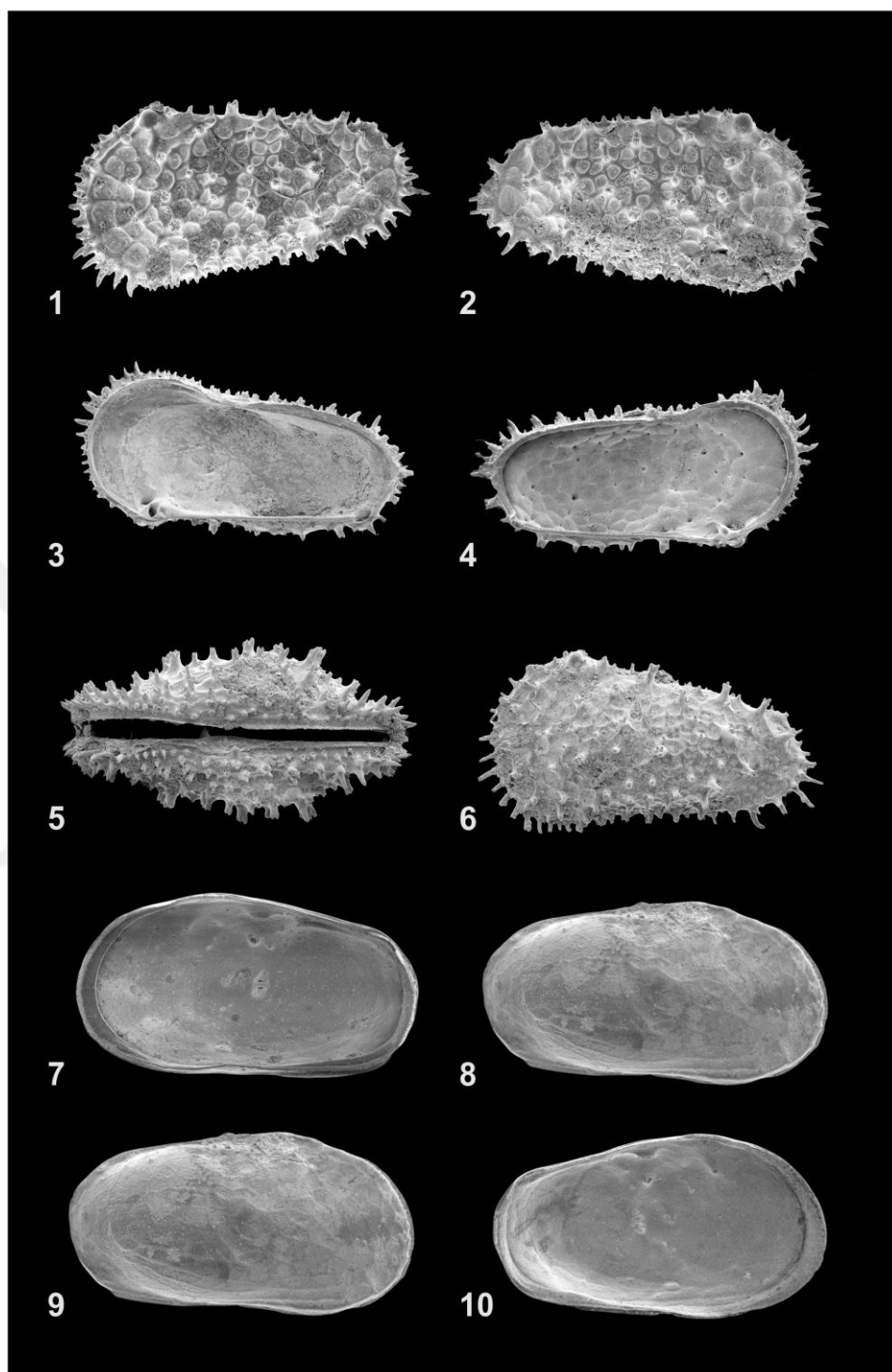


Figure A. 15 1-*Acanthocythereis hystrix*. Lateral exterior view of left valve (x 100); 2-*Acanthocythereis hystrix*. Lateral exterior view of right valve (x 100); 3-*Acanthocythereis hystrix*. Interior view of right valve (x 80); 4-*Acanthocythereis hystrix*. Interior view of left valve (x 90); 5-*Acanthocythereis hystrix*. Ventral view of a complete caparapace (x 100); 6-*Acanthocythereis hystrix*. Lateral exterior view of left valve (x 110); 7-*Buntonia sublata*. Interior view of right valve (x 130); 8-*Buntonia sublata*. Lateral exterior view of right valve (x 140); 9-*Buntonia sublata*. Lateral exterior view of right valve (x 140); 10-*Buntonia sublata*. Interior view of left valve (x 170)

APPENDIX A (cont.)

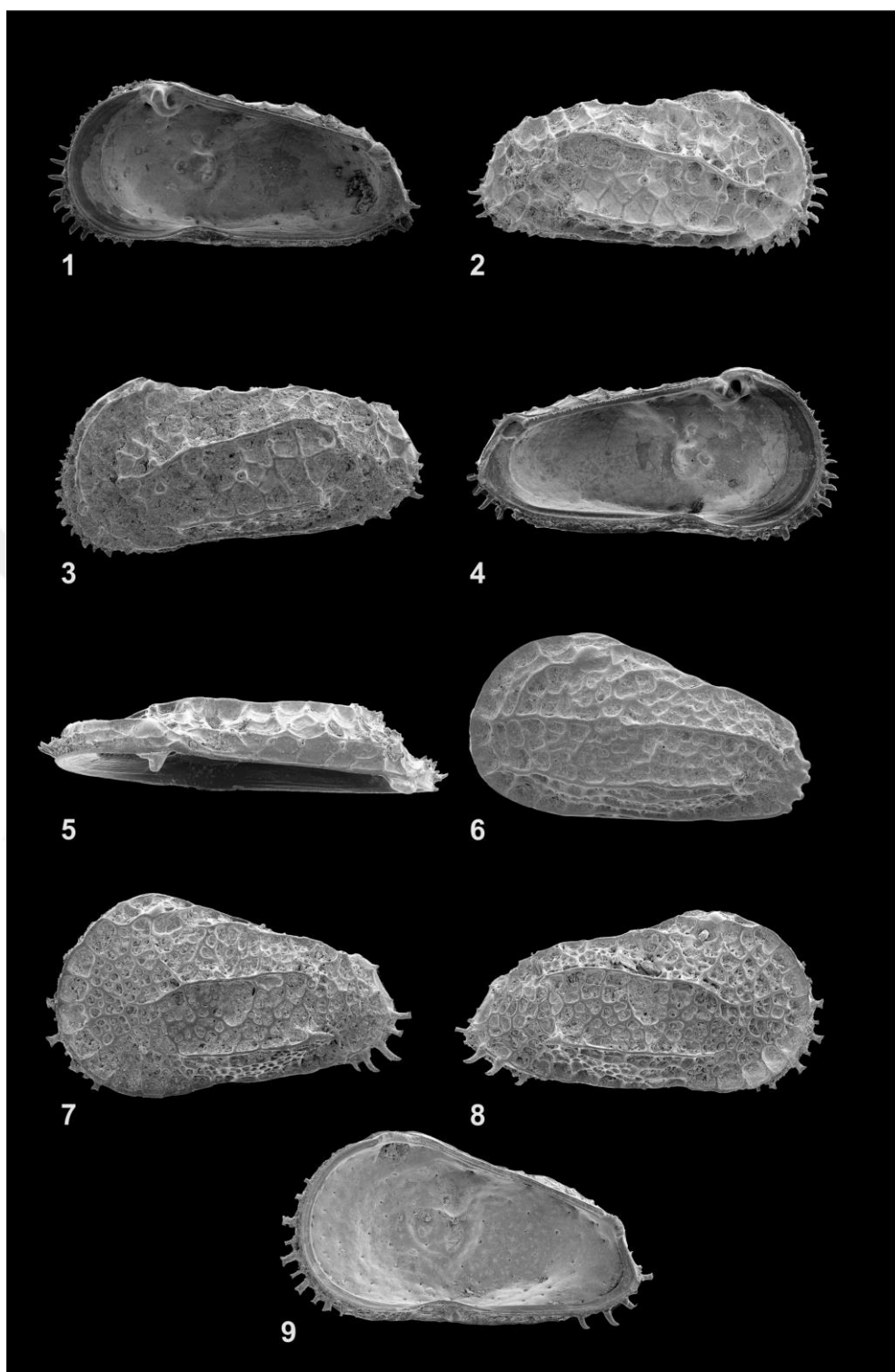


Figure A. 16 1-*Costa edwardsi*. Interior view of right valve (x 100); 2-*Costa edwardsi*. Lateral exterior view of right valve (x 100); 3-*Costa edwardsi*. Lateral exterior view of left valve (x 100); 4-*Costa edwardsi*. Interior view of left valve (x 90); 5-*Costa edwardsi*. Ventral view of right valve (x 110); 6-*Costa punctatissima*. Lateral exterior view of left valve (x 140); 7-*Costa punctatissima*. Lateral exterior view of left valve (x 160); 8-*Costa punctatissima*. Lateral exterior view of right valve (x 130); 9-*Costa punctatissima*. Interior view of right valve (x 140)

APPENDIX A (cont.)

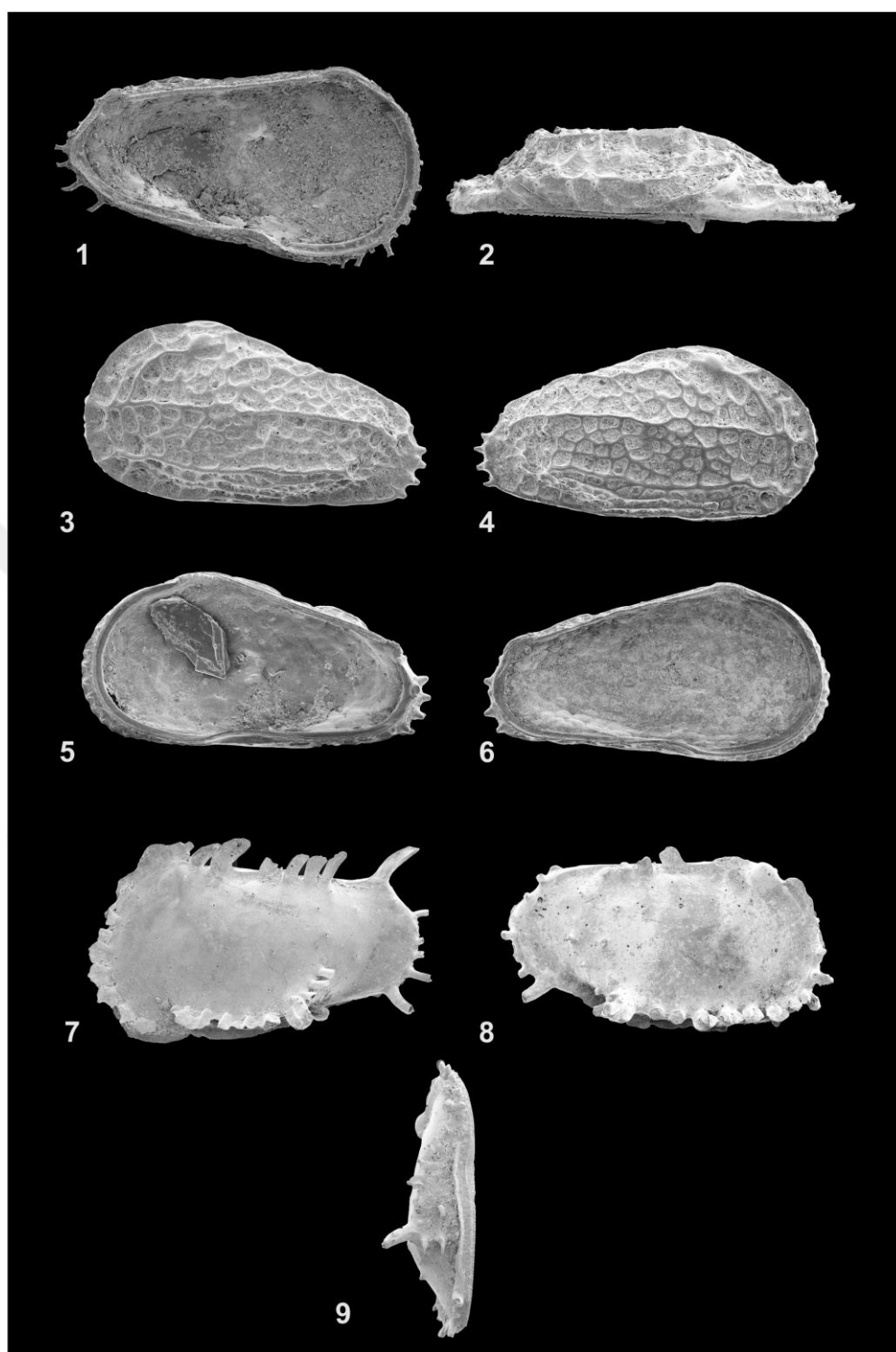


Figure A. 17 1-*Costa punctatissima*. Interior view of left valve (x 130); 2-*Costa punctatissima*. Ventral view of right valve (x 110); 3-*Costa punctatissima*. Lateral exterior view of left valve (x 140); 4-*Costa punctatissima*. Lateral exterior view of right valve (x 140); 5-*Costa punctatissima*. Interior view of right valve (x 140); 6-*Costa punctatissima*. Interior view of left valve (x 140); 7-*Pterygocythereis jonesi*. Lateral exterior view of left valve (x 100); 8-*Pterygocythereis jonesi*. Lateral exterior view of right valve (x 90); 9-*Pterygocythereis jonesi*. Ventral view of right valve (x 60)

APPENDIX A (cont.)

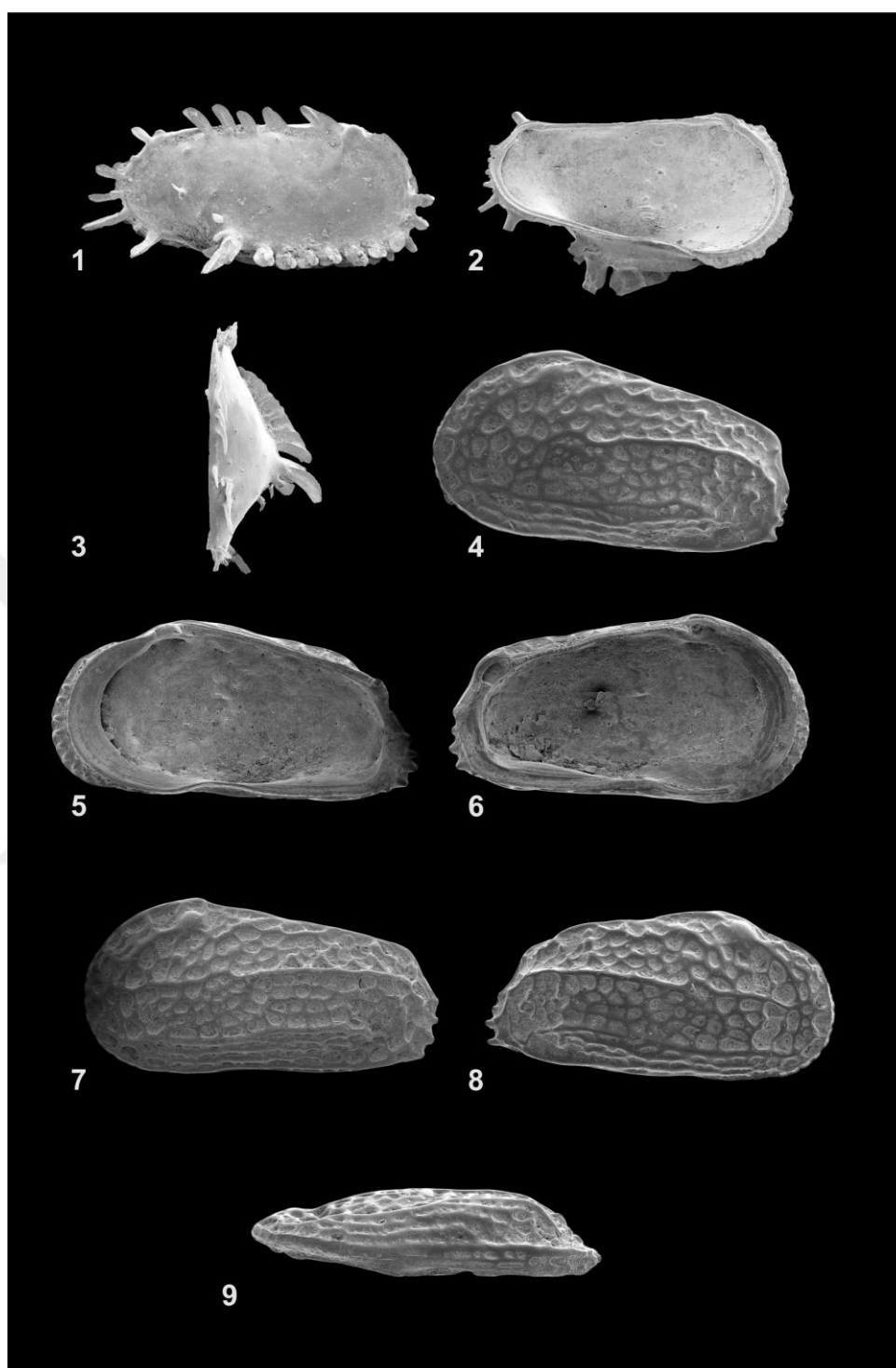


Figure A. 18 1-*Pterygocythereis jonesi*. Lateral exterior view of right valve (x 80); 2-*Pterygocythereis jonesi*. Interior view of left valve (x 100); 3-*Pterygocythereis jonesi*. Dorsal view of left valve (x 90); 4-*Hiltermannicythere* aff. *H. Rubra*. Lateral exterior view of left valve (x 120); 5-*Hiltermannicythere* aff. *H. Rubra*. Interior view of right valve (x 120); 6-*Hiltermannicythere* aff. *H. Rubra*. Interior view of left valve (x 120); 7-*Hiltermannicythere* aff. *H. Rubra*. Lateral exterior view of left valve (x 120); 8-*Hiltermannicythere* aff. *H. Rubra*. Lateral exterior view of right valve (x 140); 9-*Hiltermannicythere* aff. *H. Rubra*. Ventral view of left valve (x 120)

APPENDIX A (cont.)

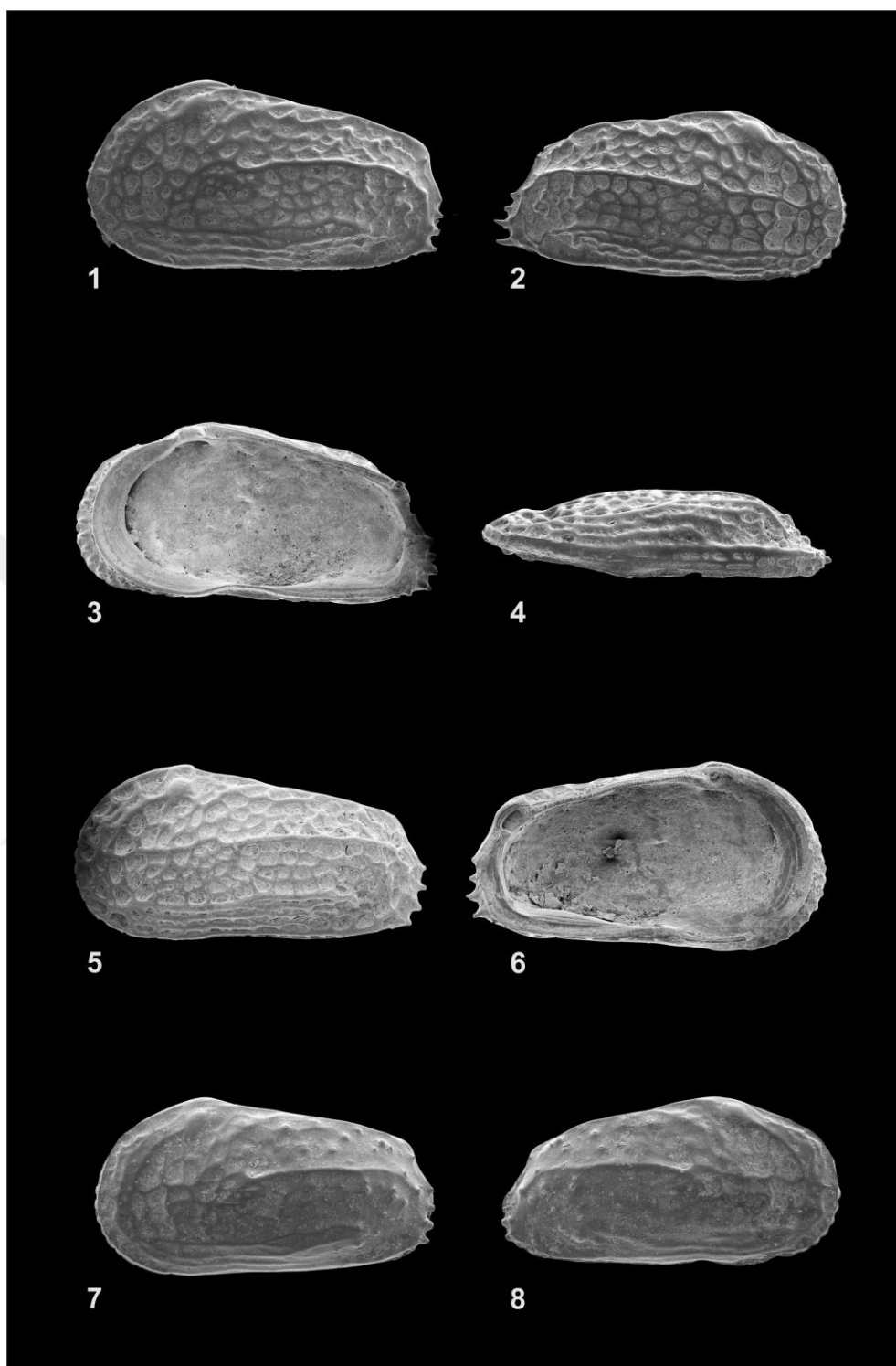


Figure A. 19 1-*Hiltermannicythere* aff. *H. Rubra*. Lateral exterior view of left valve (x 120); 2-*Hiltermannicythere* aff. *H. Rubra*. Lateral exterior view of right valve (x 110); 3-*Hiltermannicythere* aff. *H. Rubra*. Interior view of right valve (x 120); 4-*Hiltermannicythere* aff. *H. Rubra*. Ventral view of left valve (x 120); 5-*Hiltermannicythere* aff. *H. Rubra*. Lateral exterior view of left valve (x 120); 6-*Hiltermannicythere* aff. *H. Rubra*. Interior view of left valve (x 140); 7-*Hiltermannicythere rubra*. Lateral exterior view of left valve (x 120); 8-*Hiltermannicythere rubra*. Lateral exterior view of right valve (x 120)

APPENDIX A (cont.)

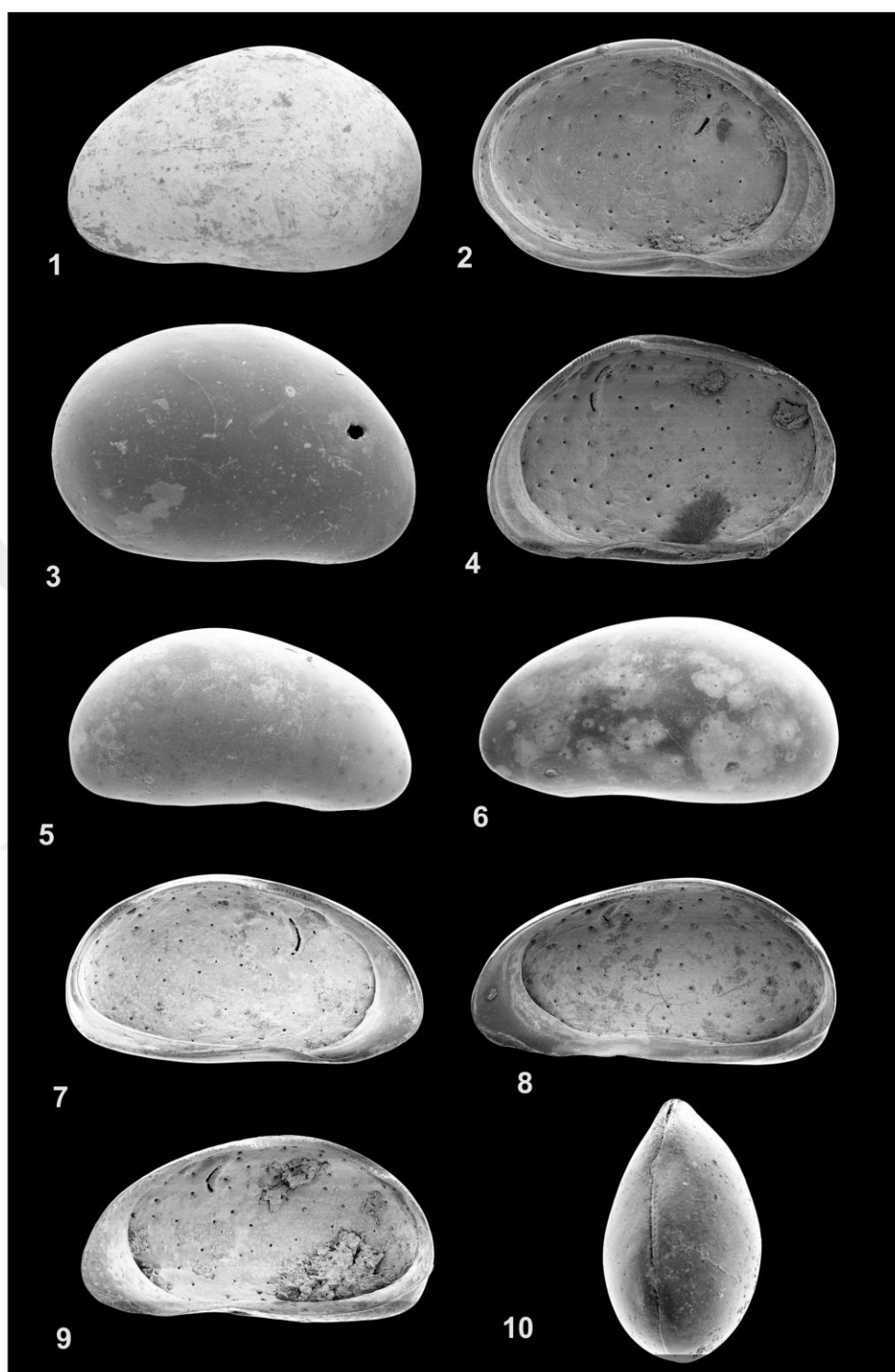


Figure A. 20 1-*Xestoleberis communis*. Lateral exterior view of right valve (x 150); 2-*Xestoleberis communis*. Interior view of right valve (x 150); 3-*Xestoleberis communis*. Lateral exterior view of left valve (x 170); 4-*Xestoleberis communis*. Interior view of left valve (x 160); 5-*Xestoleberis dispar*. Lateral exterior view of left valve (x130); 6-*Xestoleberis dispar*. Lateral exterior view of right valve (x130); 7-*Xestoleberis dispar*. Interior view of right valve (x 120); 8-*Xestoleberis dispar*. Interior view of left valve (x130); 9-*Xestoleberis dispar*. Interior view of left valve (x 130); 10-*Xestoleberis dispar*. Dorsal view of a complete carapace (x 140)

APPENDIX A (cont.)

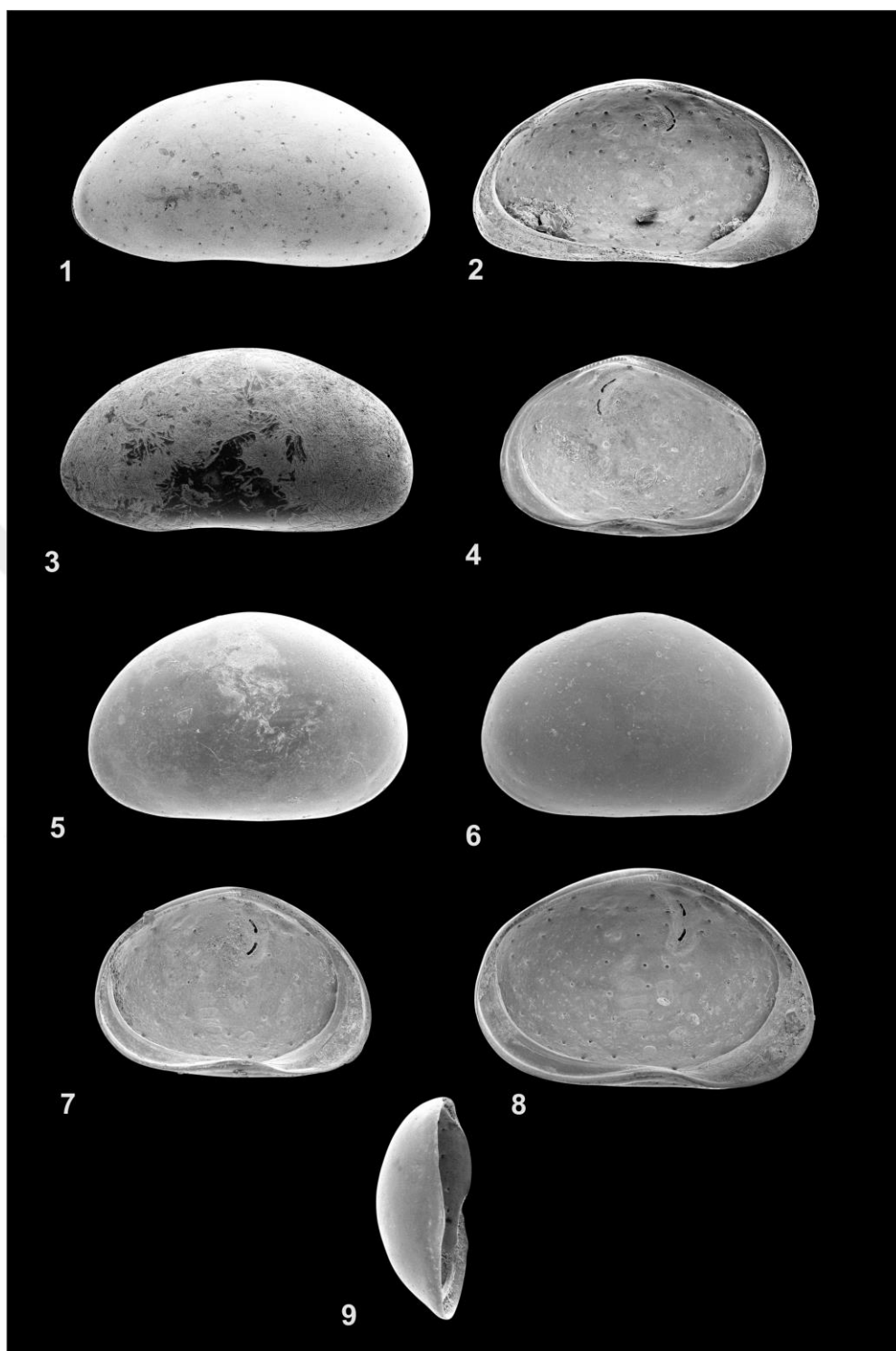


Figure A. 21 1-*Xestoleberis* aff. *Dispar*. Lateral exterior view of right valve (x 170); 2-*Xestoleberis* aff. *Dispar*. Interior view of left valve (x 210); 3-*Xestoleberis* aff. *Dispar*. Lateral exterior view of right valve (x 160); 4-*Xestoleberis prognata*. Interior view of right valve (x 250); 5-*Xestoleberis prognata*. Lateral exterior view of left valve (x 170); 6-*Xestoleberis prognata*. Lateral exterior view of right valve (x 160); 7-*Xestoleberis prognata*. Interior view of left valve (x 190); 8-*Xestoleberis prognata*. Interior view of left valve (x 190); 9-*Xestoleberis prognata*. ventral view of left valve (x 150)

APPENDIX A (cont.)

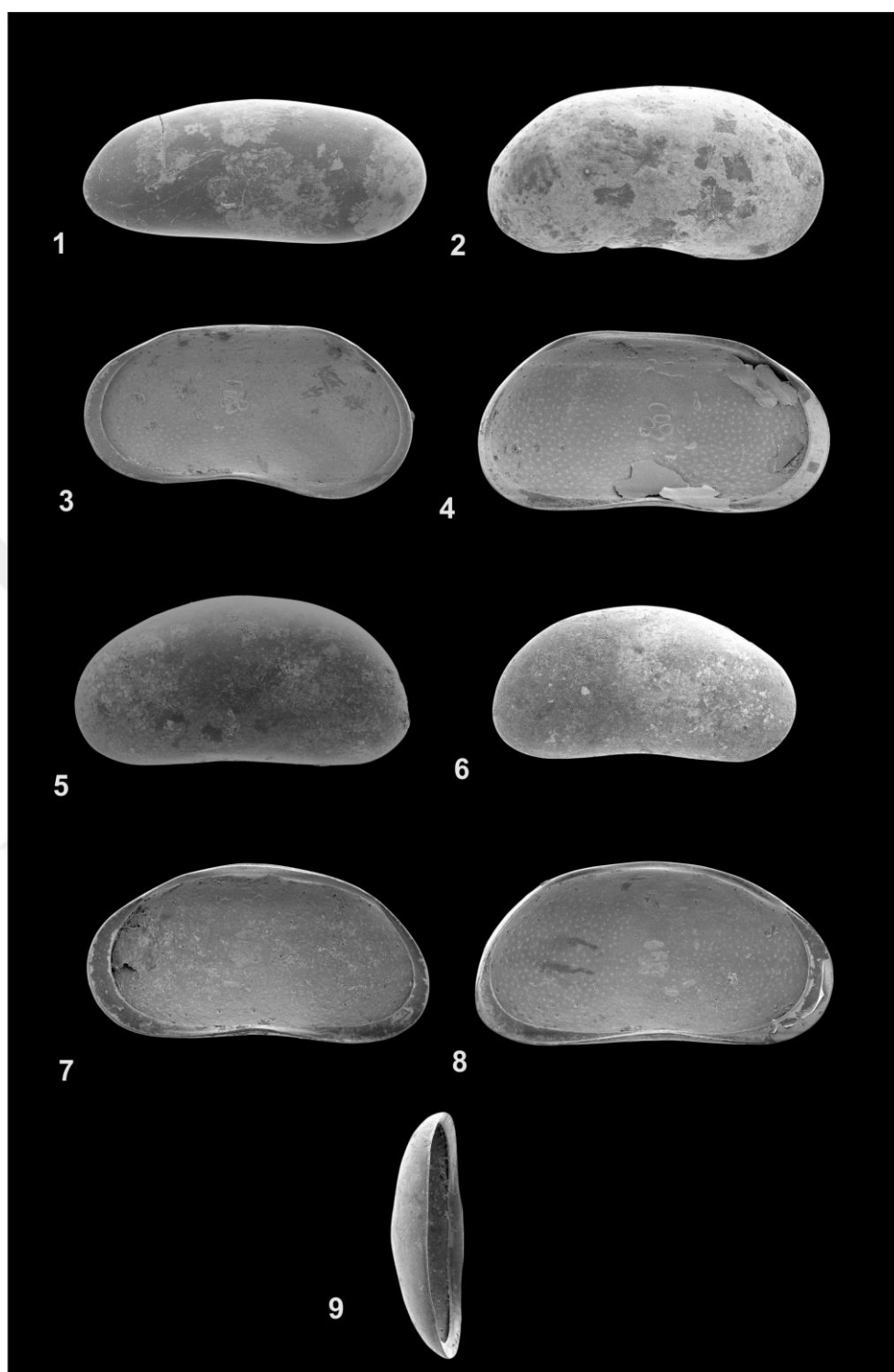


Figure A. 22 1-*Darwinula stevensoni*. Lateral exterior view of right valve (x 160); 2-*Candona sanociensis*. Lateral exterior view of right valve (x 150); 3-*Candona sanociensis*. Interior view of left valve (x 80); 4-*Candona sanociensis*. Interior view of left valve (x 120); 5-*Fabaeformiscandona wegeli*. Lateral exterior view of right valve (x 90); 6-*Fabaeformiscandona wegeli*. Lateral exterior view of left valve (x 70); 7-*Fabaeformiscandona wegeli*. Interior view of left valve (x 130); 8-*Fabaeformiscandona wegeli*. Interior view of right valve (x 90); 9-*Fabaeformiscandona wegeli*. Dorsal view of left valve (x 80)

APPENDIX A (cont.)

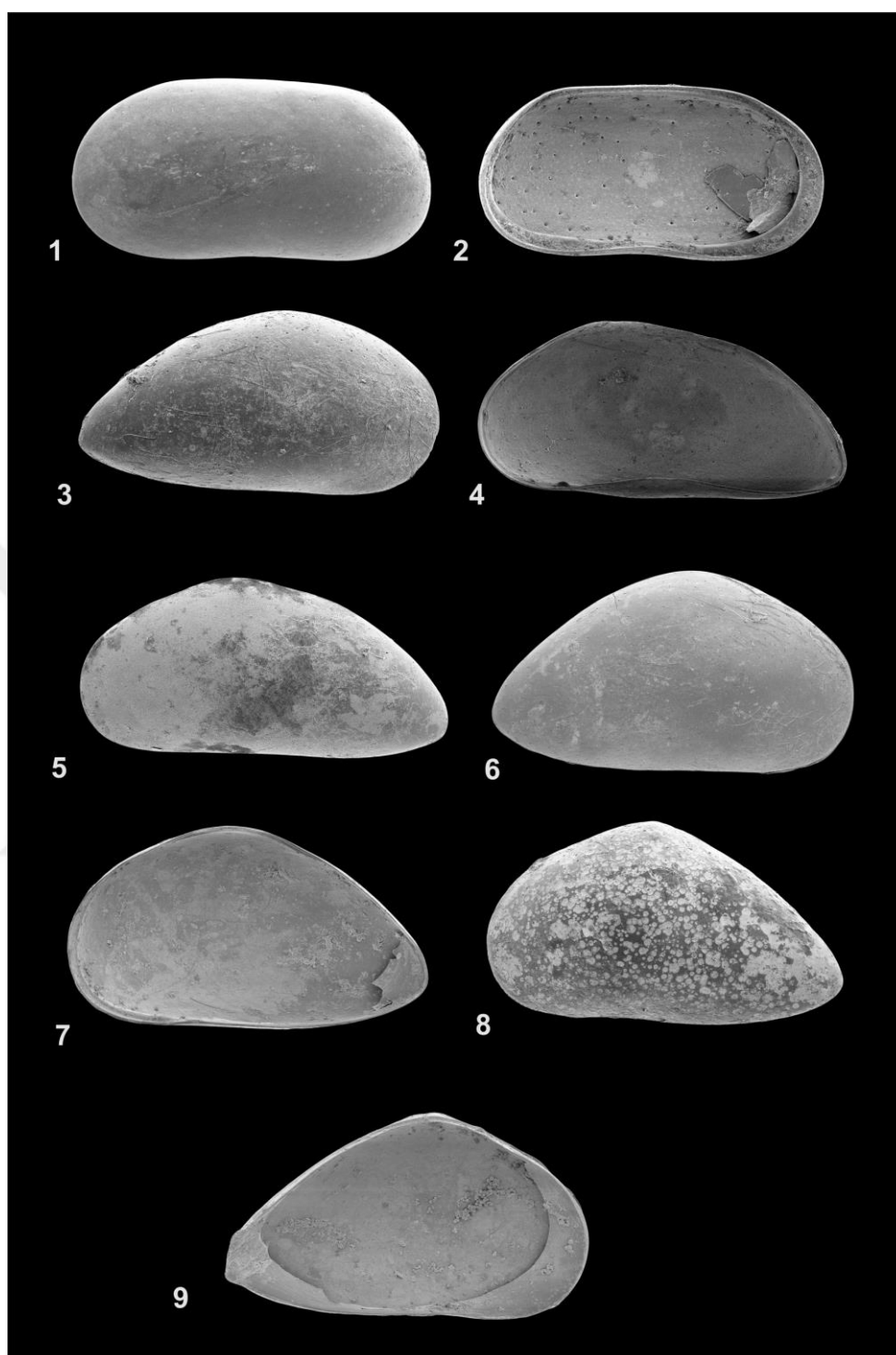


Figure A. 23 1-*Fabaeformiscandona* cf. *Pokornyi*. Lateral exterior view of right valve (x130); 2-*Fabaeformiscandona* cf. *Pokornyi*. Interior view of left valve (x120); 3-*Propontocypris intermedia*. Lateral exterior view of right valve (x130); 4-*Propontocypris intermedia*. Interior view of right valve (x200); 5-*Propontocypris intermedia*. Lateral exterior view of left valve (x170); 6-*Propontocypris intermedia*. Lateral exterior view of right valve (x100); 7-*Propontocypris intermedia*. Interior view of right valve (x110); 8-*Propontocypris pirifera*. Lateral exterior view of left valve (x110); 9-*Propontocypris pirifera*. Interior view of left valve (x100)

APPENDIX A (cont.)

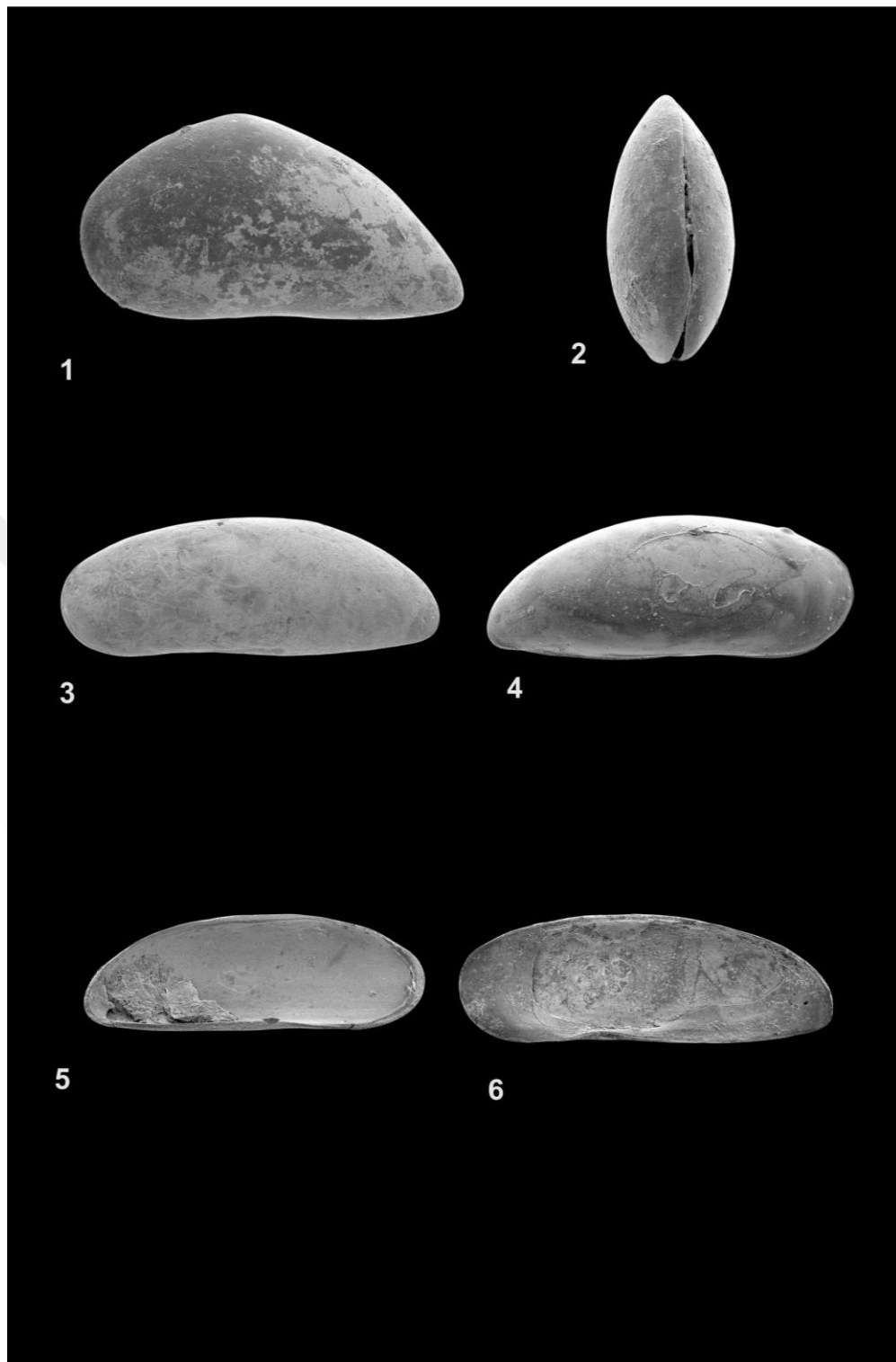


Figure A. 24 1-*Propontocypris pirifera*. Lateral exterior view of left valve (x 220); 2-*Propontocypris pirifera*. Ventral view of a complete carapace (x 200); 3-*Argilloecia minor*. Lateral exterior view of left valve (x 230); 4-*Argilloecia minor*. Lateral exterior view of right valve (x 260); 5-*Argilloecia minor*. Interior view of left valve (x 200); 6-*Argilloecia minor*. Interior view of right valve (x 220)

APPENDIX B

Benthic Foraminifera Plates

APPENDIX B (cont.)

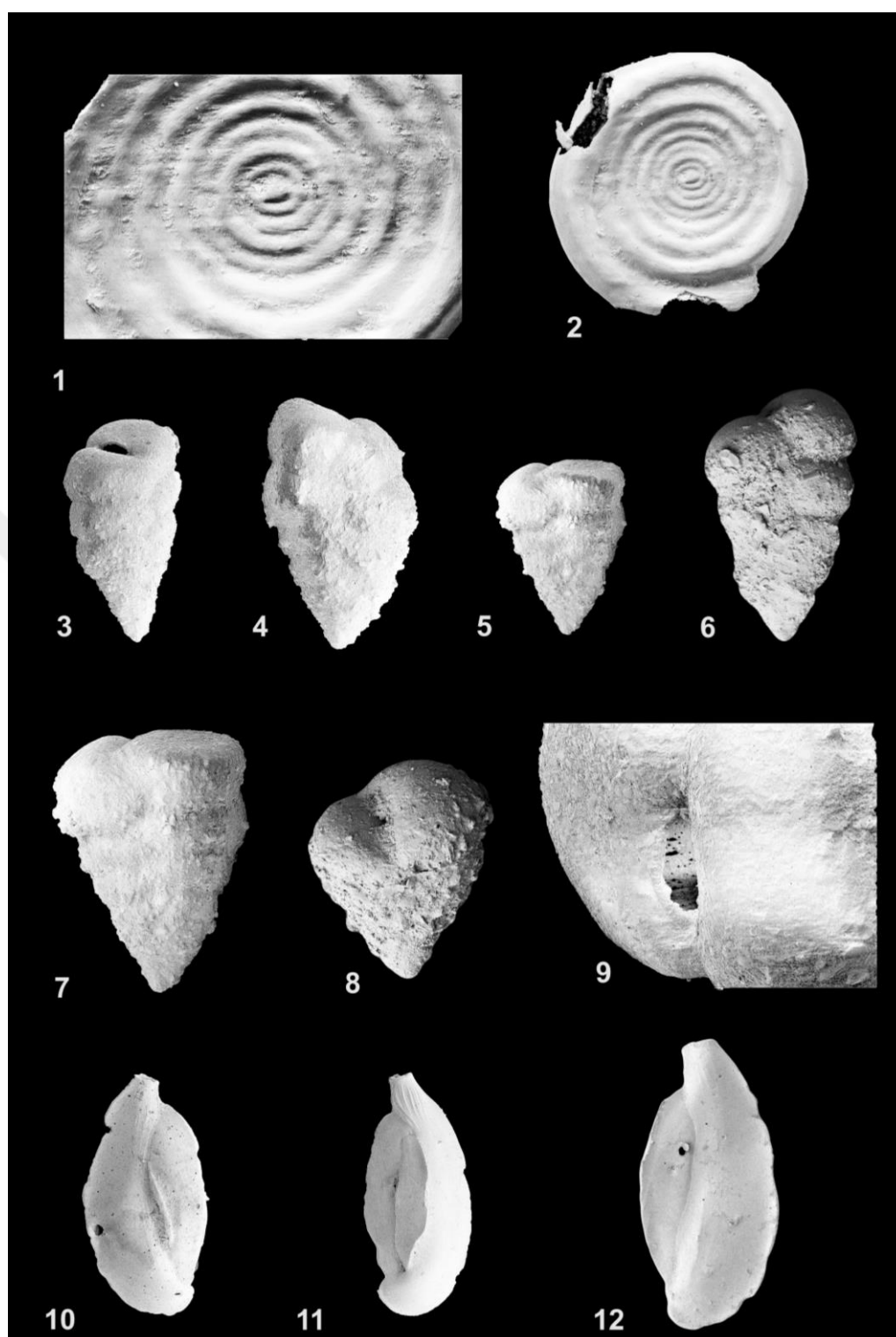


Figure B. 1 1-*Ammodiscus planorbis*. side view (x 2400); 2-*Ammodiscus planorbis*. side view (x 1200); 3-*Textularia bocki*. edge view (x 300); 4-*Textularia bocki*. side view (x 500); 5-*Textularia bocki*. side view (x 300); 6-*Textularia bocki*. side view; 7-*Textularia bocki*. side view (x 500); 8-*Textularia bocki*. side view; 9-*Textularia bocki*. apartural view (x 1200); 10-*Adelosina cliarensis*. apartural view (x300); 11-*Adelosina cliarensis*. side view (x 300); 12-*Adelosina cliarensis*. side view (x 500)

APPENDIX B (cont.)

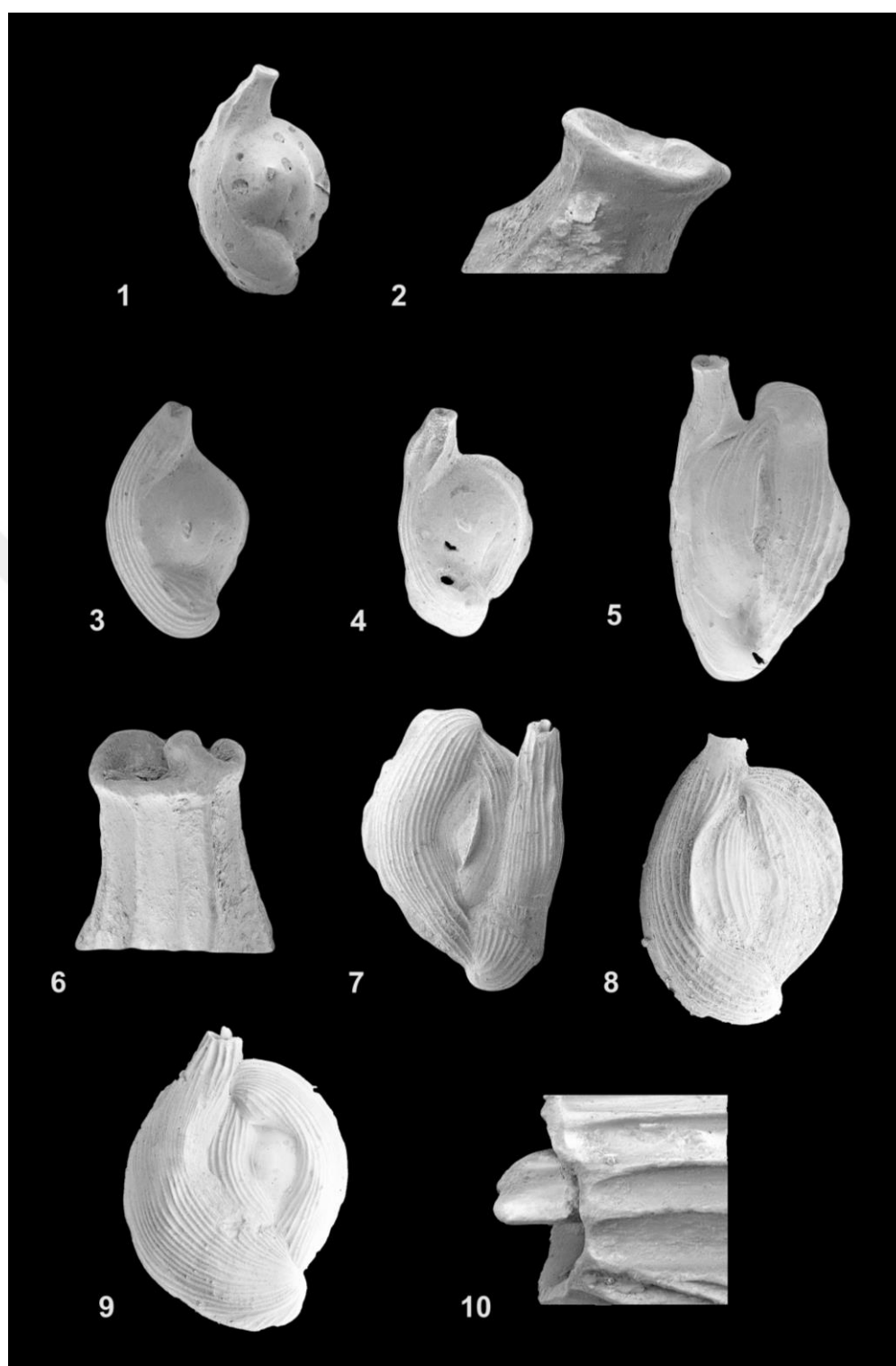


Figure B. 2 1-*Adelosina laevigata*. side view (x 400); 2-*Adelosina laevigata*. apartural view (x 3000); 3-*Adelosina mediterraneis*. side view (x 300); 4-*Adelosina mediterraneis*. side view (x 280); 5-*Adelosina mediterraneis*. side view (x 300); 6-*Adelosina mediterraneis*. apartural view (x 1200); 7-*Adelosina mediterraneis*. side view (x 200); 8-*Adelosina mediterraneis*. side view (x 300); 9-*Adelosina mediterraneis* side view (x 200); 10-*Adelosina mediterraneis*. apartural view (x 1600)

APPENDIX B (cont.)

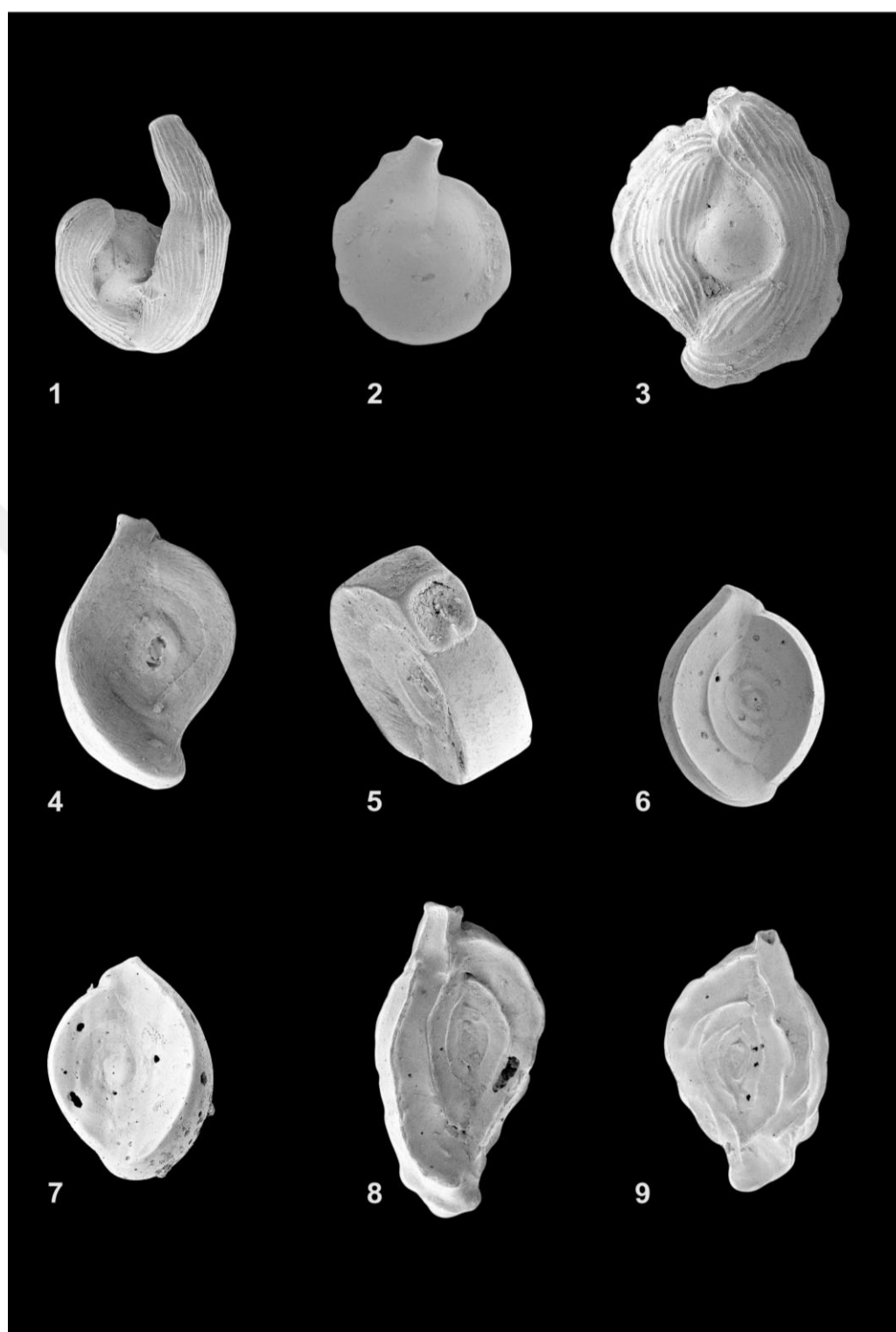


Figure B. 3 1-*Adelosina* sp1. side view (x 200); 2-*Adelosina* sp2. side view (x 500); 3-*Adelosina* sp3. side view (x 250); 4-*Spiroloculina angulosa*. side view (x 600); 5-*Spiroloculina excavata*. apertural view (x 400); 6-*Spiroloculina excavata*. side view(x 400); 7-*Spiroloculina excavata*. side view (x 500); 8-*Spiroloculina ornata*. side view (x 350); 9-*Spiroloculina* sp. side view (x 250)

APPENDIX B (cont.)

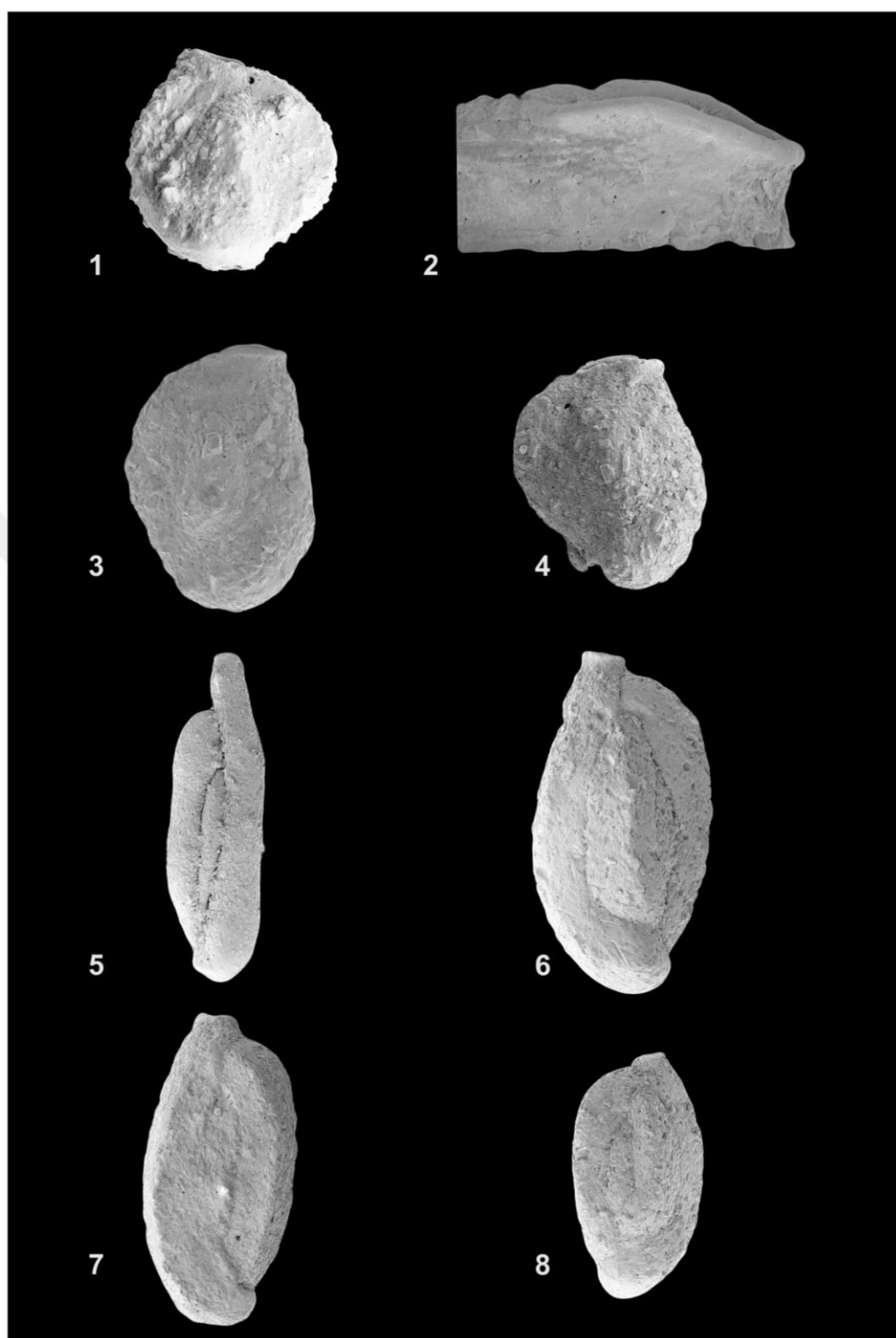


Figure B. 4 1-*Siphonaperta agglutinans*. side view (x 100); 2-*Siphonaperta agglutinans*. apertural view (x 1200); 3-*Siphonaperta agglutinans*. side view (x 300); 4-*Siphonaperta agglutinans*. side view (x 400); 5-*Cycloforina tenuicollis*. side view (x 500); 6-*Cycloforina villafranca*. side view (x 600); 7-*Cycloforina villafranca*. side view (x 400); 8-*Cycloforina villafranca*. side view (x 500)

APPENDIX B (cont.)

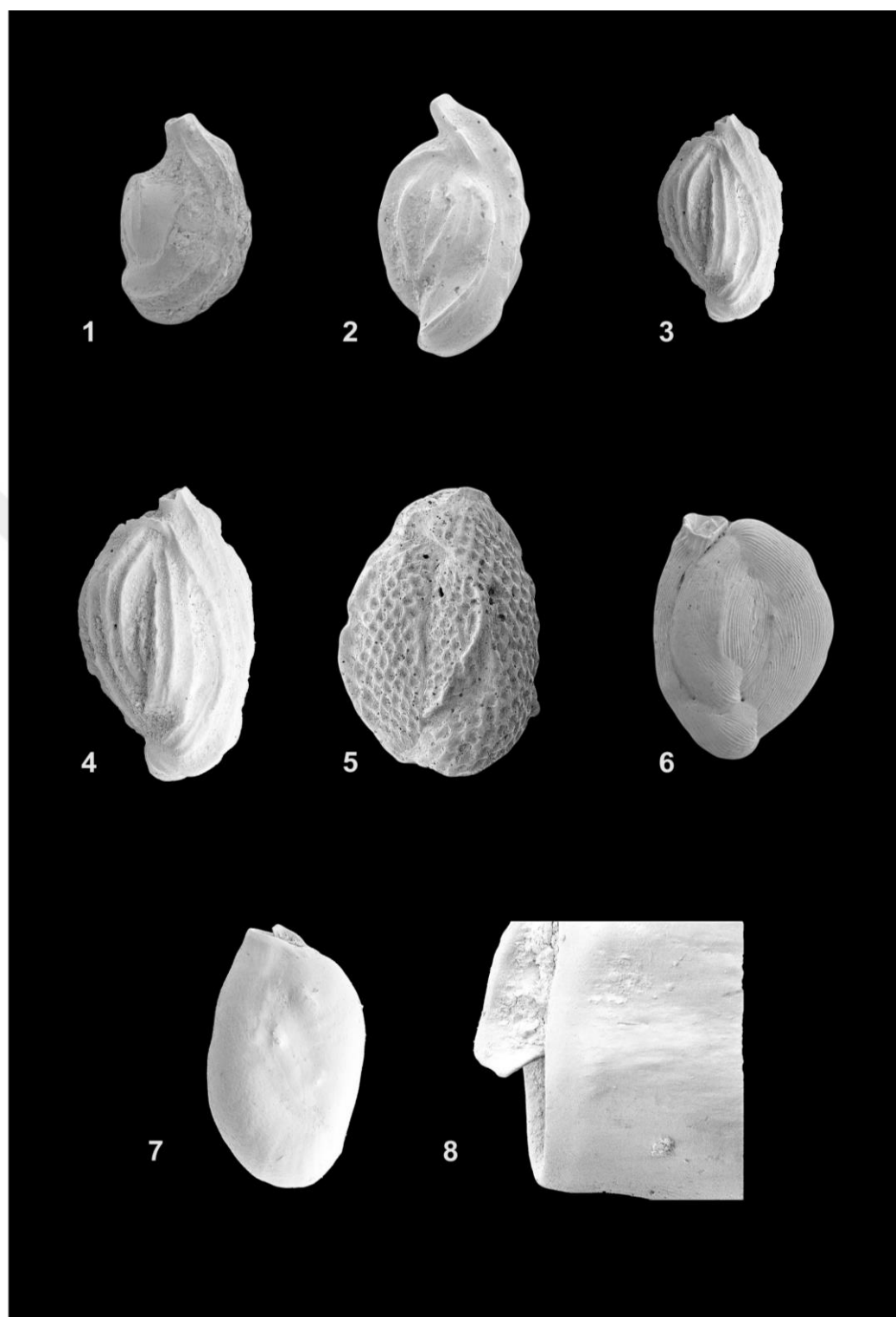


Figure B. 5 1-*Cycloforina* sp. side view (x 500); 2-*Cycloforina* sp. side view (x 300); 3-*Cycloforina* sp. side view (x 400); 4-*Cycloforina* sp. side view (x 500); 5-*Lachlanella variolata*. side view (x 300); 6-*Lachlanella* sp. side view (x 120); 7-*Massilina gualtieriana*. side view (x 300); 8-*Massilina gualtieriana*. apertural view (x 1200)

APPENDIX B (cont.)

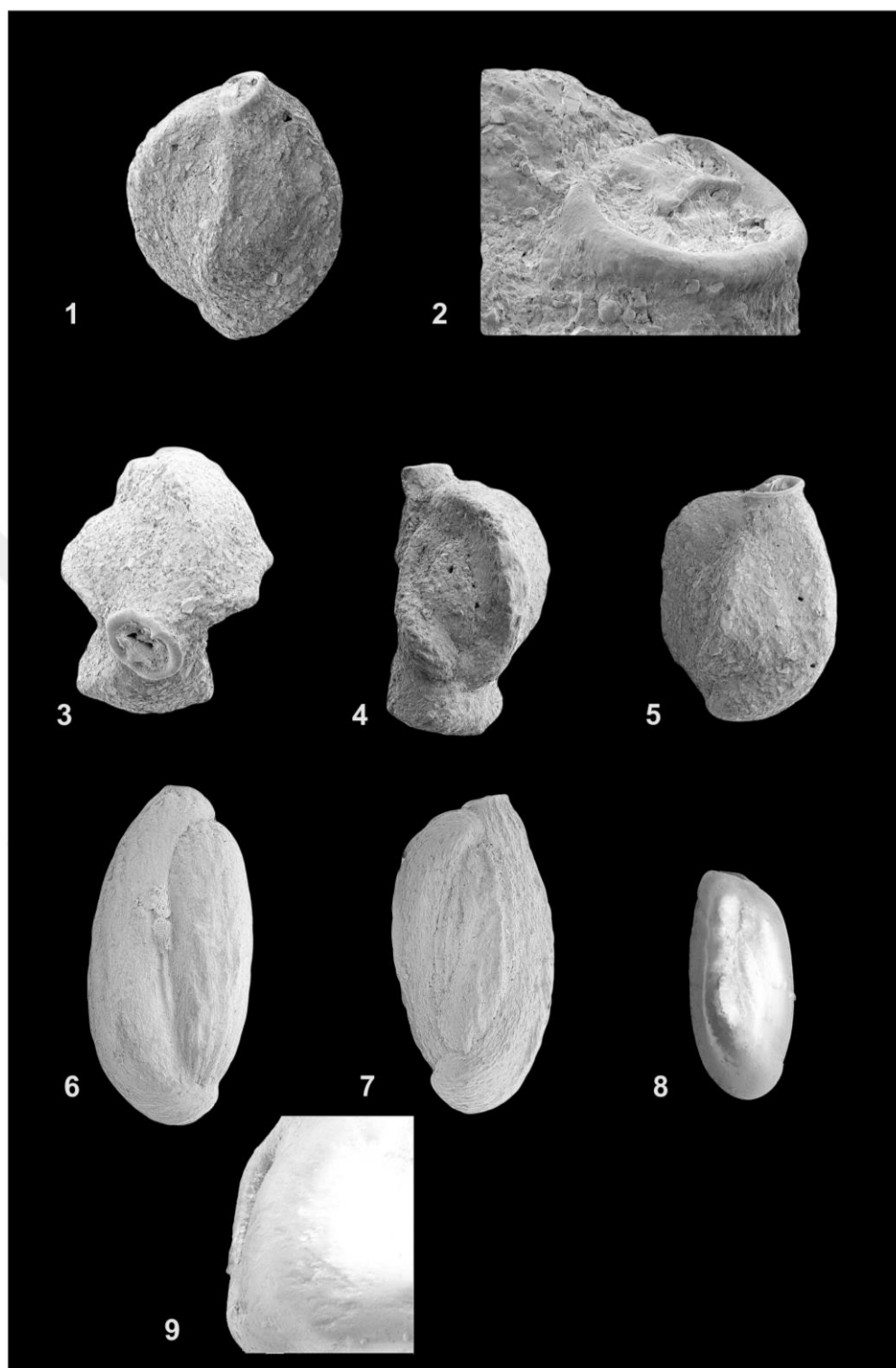


Figure B. 6 1-*Quinqueloculina annectens*. side view (x 600); 2-*Quinqueloculina annectens*. apartural view (x 2500); 3-*Quinqueloculina berthelotiana*. apartural view (x 500); 4-*Quinqueloculina berthelotiana*. side view (x 500); 5-*Quinqueloculina berthelotiana*. side view (x 600); 6-*Quinqueloculina jugosa*. side view (x 400); 7-*Quinqueloculina jugosa*. side view (x 600); 8-*Quinqueloculina laevigata*. side view (x 400); 9-*Quinqueloculina laevigata*. apartural view (x 1600)

APPENDIX B (cont.)

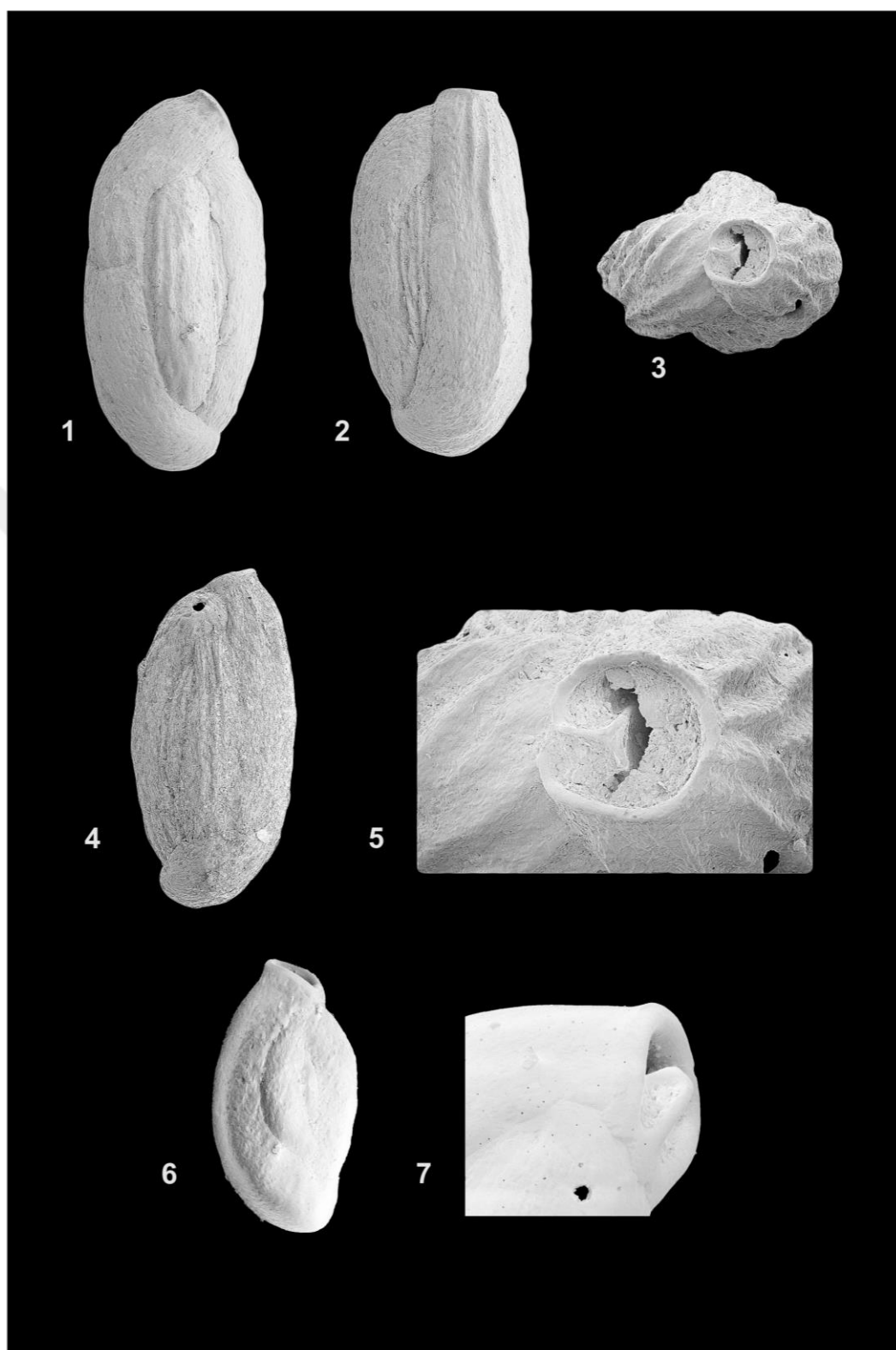


Figure B. 7 1-*Quinqueloculina limbata*. side view (x 400); 2-*Quinqueloculina limbata*. side view (x 400); 3-*Quinqueloculina limbata*. apartural view (x 400); 4-*Quinqueloculina limbata*. side view (x 600); 5-*Quinqueloculina limbata*. apartural view (x 1000); 6-*Quinqueloculina parvula*. side view (x 800); 7-*Quinqueloculina parvula*. apartural view (x 900)

APPENDIX B (cont.)

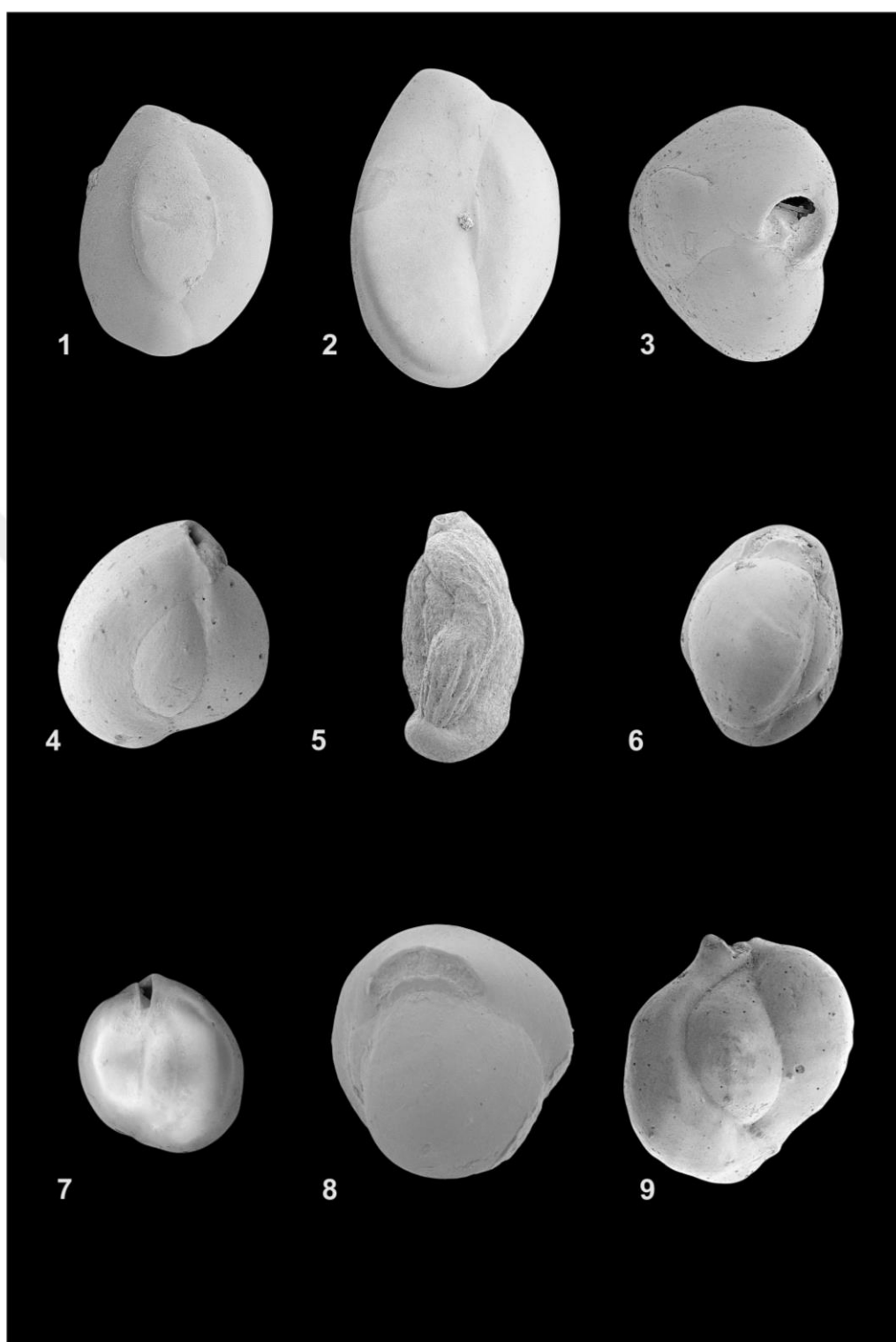


Figure B. 8 1-*Quinqueloculina seminula*. side view (x 400); 2-*Quinqueloculina seminula*. side view (x 400); 3-*Quinqueloculina seminula*. apartural view (x 500); 4-*Quinqueloculina seminula*. side view (x 600); 5-*Quinqueloculina* sp. side view (x 200); 6-*Biloculinella globula*. lateral view (x 500); 7-*Biloculinella globula*. side view (x 1000); 8-*Biloculinella globula*. apartural view (x 600); 9-*Miliolinella labiosa*. side view (x 400)

APPENDIX B (cont.)

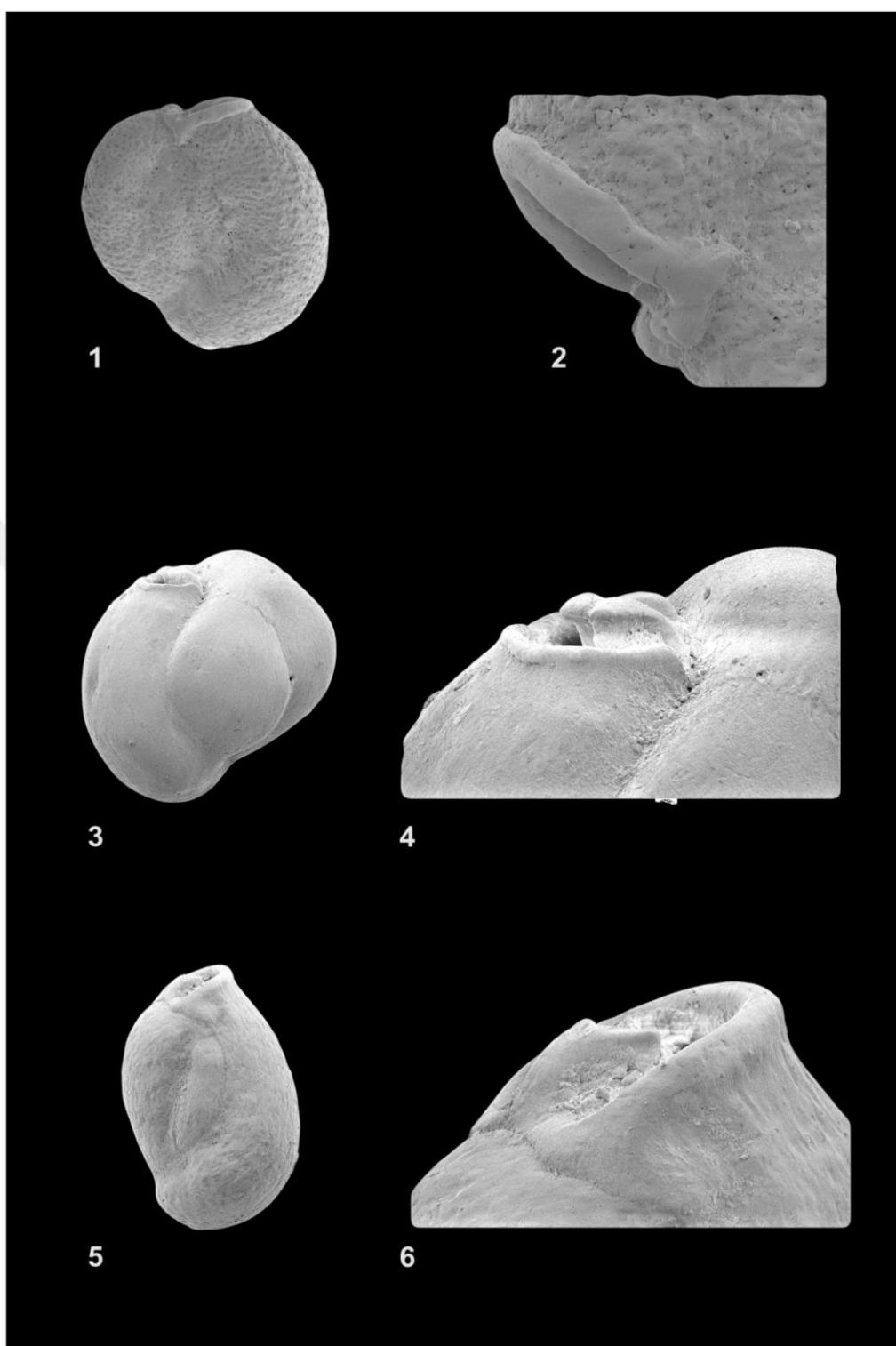


Figure B. 9 1-*Milionella* sp1. Side view (x 250); 2-*Milionella* sp1. Apartural view (x 800); 3-*Milionella* sp2. Side view (x 350); 4-*Milionella* sp2. Apartural view (x 1000); 5-*Milionella* sp3. Side view (x 600); 6-*Milionella* sp3. Apartural view (x 2400)

APPENDIX B (cont.)

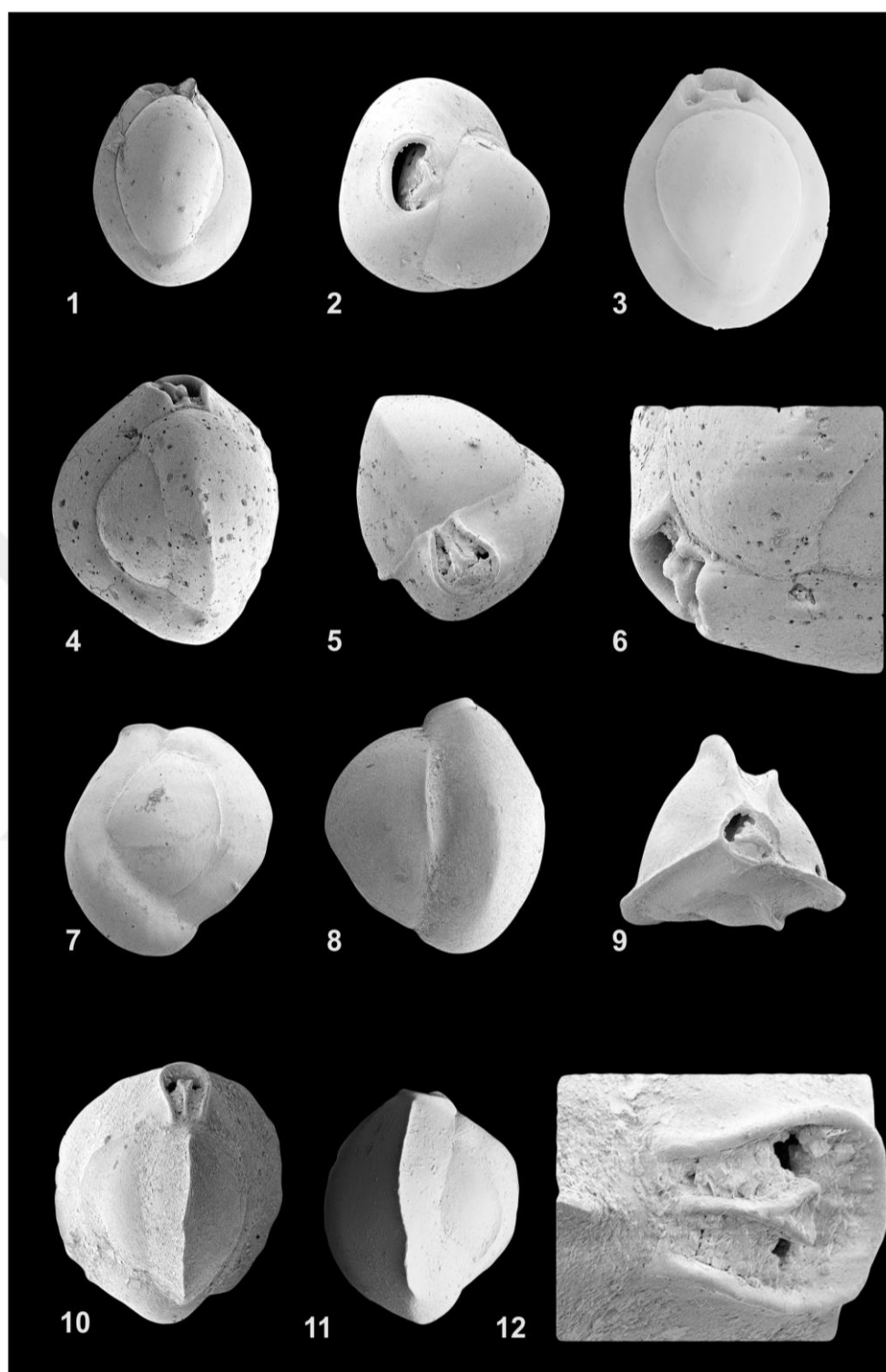


Figure B. 10 1-*Pyrgo anomala*. side view (x 400); 2-*Pyrgo anomala*. apartural view (x 500);
3-*Pyrgo anomala*. side view (x 500); 4-*Triloculina marioni*. side view (x 500);
5-*Triloculina marioni*. apartural view (x 450); 6-*Triloculina marioni*. apartural view (x 900);
7-*Triloculina tricarinata*. side view (x 400); 8-*Triloculina tricarinata*. side view (x 400);
9-*Triloculina tricarinata*. apartural view (x 500); 10-*Triloculina tricarinata*. lateral view (x 600);
11-*Triloculina tricarinata*. lateral view; 12-*Triloculina tricarinata*. apartural view (x 2400)

APPENDIX B (cont.)

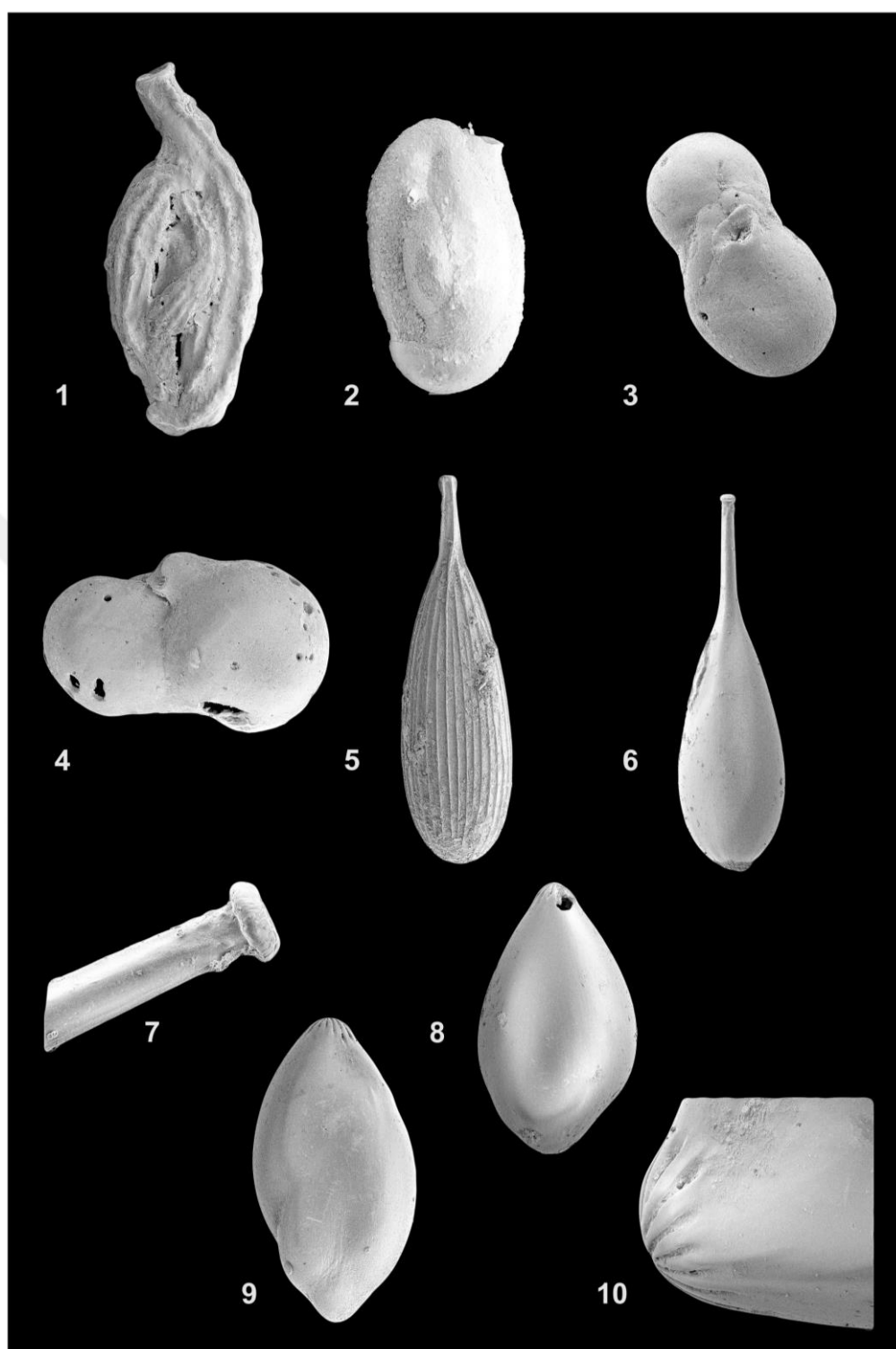


Figure B. 11 1-*Sigmoilinita costata*. side view (x 800); 2-*Sigmoilinita edwardsi*. side view (x 400); 3-*Parrina bradyi*. apartural view (x 600); 4-*Parrina bradyi*. side view (x 600); 5-*Lagena striata*. side view (x 1000); 6-*Lagena laevis*. side view (x 1000); 7-*Lagena laevis*. apartural view (x 4000); 8-*Polymorphina* sp. side view (x 800); 9-*Polymorphina* sp. side view (x 500); 10-*Polymorphina* sp. apartural view (x 2000)

APPENDIX B (cont.)

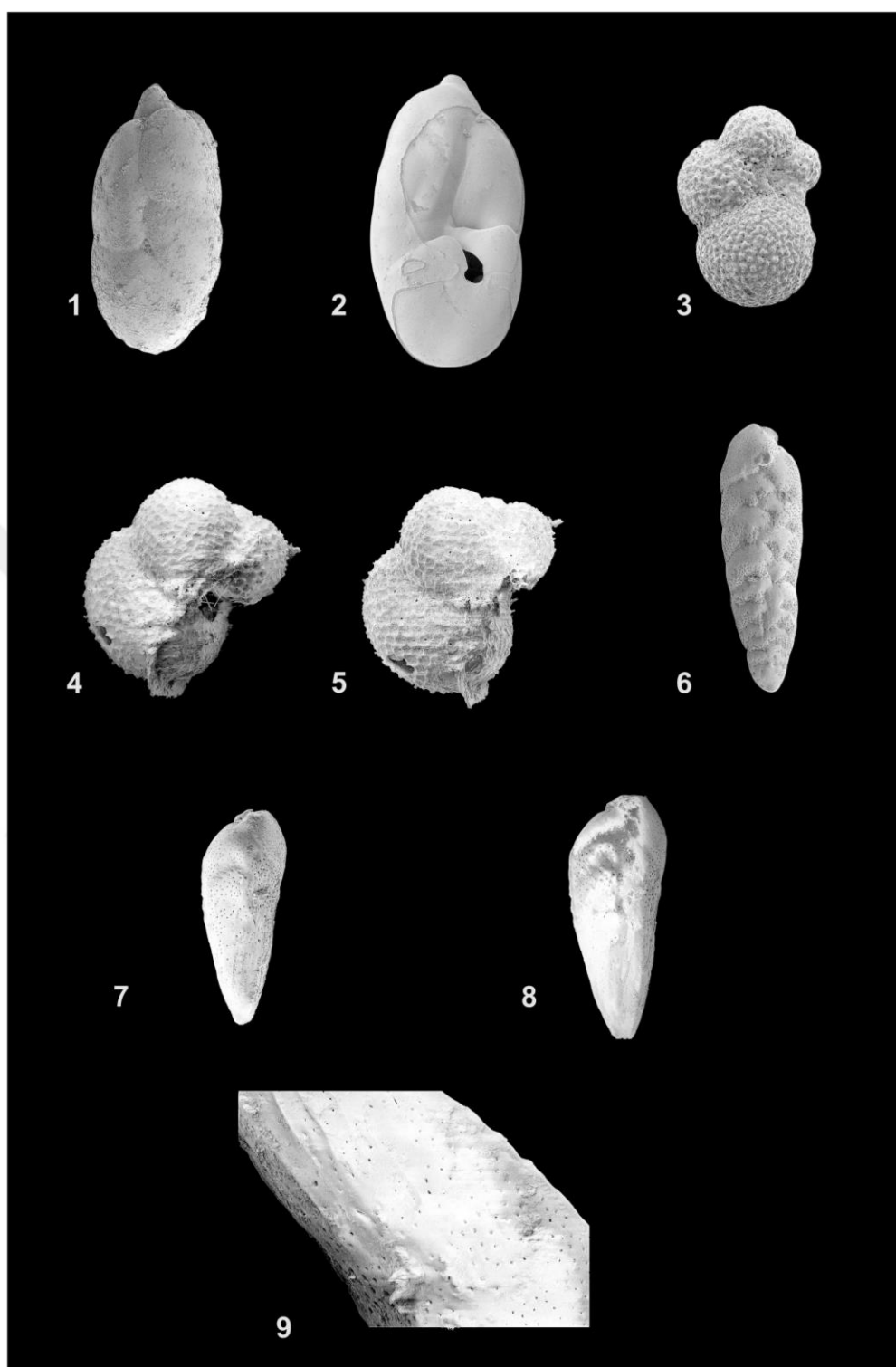


Figure B. 12 1-*Robertina translucens*. side view (x 1000); 2-*Robertina translucens*. side view (x 1000); 3-*Globigerina calida*. side view (x 700); 4-*Globigerinella aequilateralis*. side view (x 800); 5-*Globigerinella aequilateralis*. side view (x 800); 6-*Brizalina spathulata*. side view (x 800); 7-*Brizalina striatula*. side view (x 800); 8-*Brizalina striatula*. side view (x 800); 9-*Brizalina striatula*. pore view (x 2400)

APPENDIX B (cont.)



Figure B. 13 1-*Rectuvigerina phlegeri*. side view (x 1000); 2-*Rectuvigerina phlegeri*. side view (x 700); 3-*Rectuvigerina phlegeri*. side view (x 700); 4-*Rectuvigerina phlegeri*. apartural view; 5-*Rectuvigerina phlegeri*. apartural view; 6-*Bulimina elongata*. side view (x 765); 7-*Bulimina elongata*. side view (x 1300); 8-*Bulimina elongata*. side view (x 1000)

APPENDIX B (cont.)

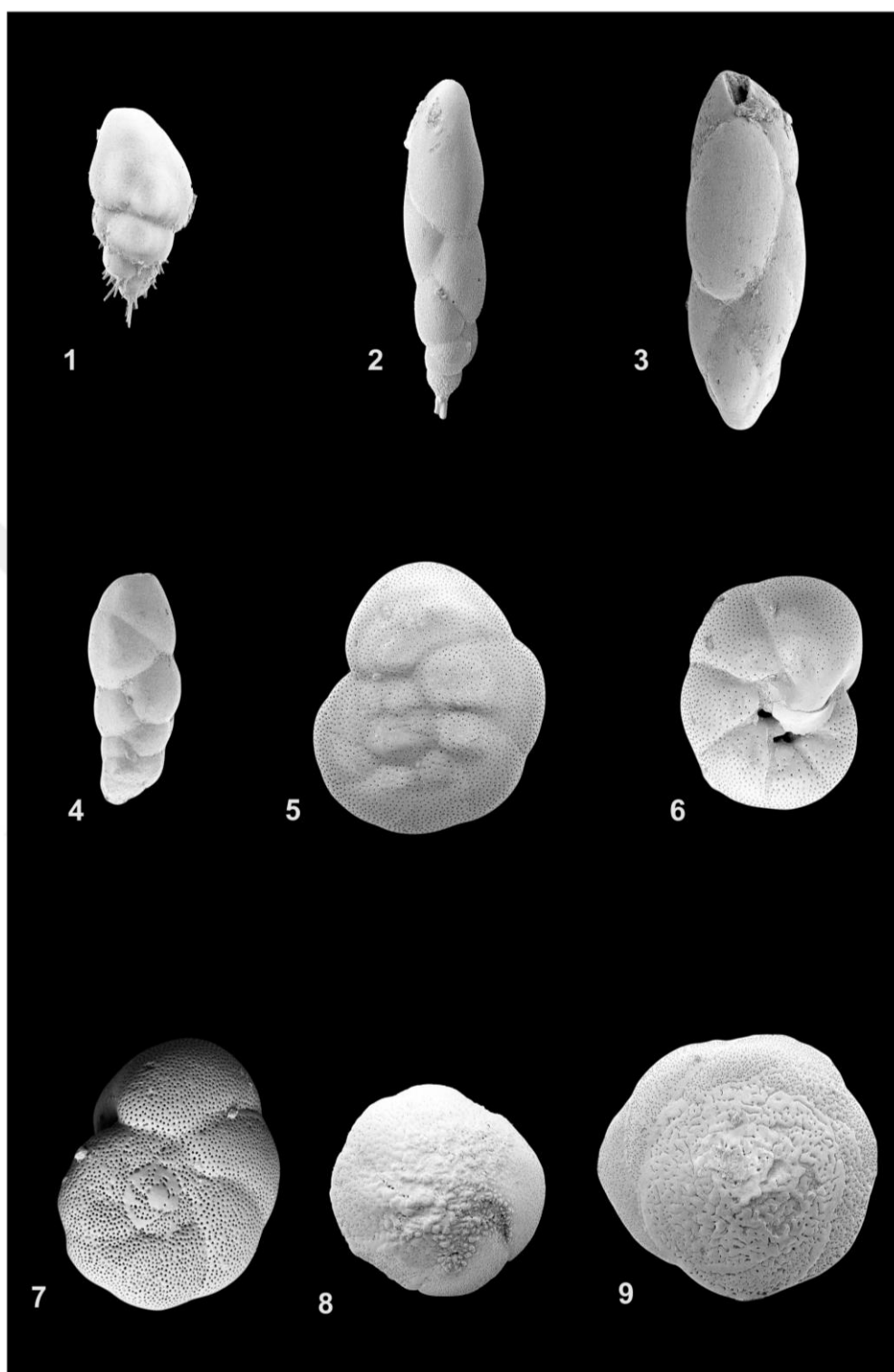


Figure B. 14 1-*Bulimina marginata*. side view (x 800); 2-*Fursenkoina acuta*. side view (x 800);
3-*Fursenkoina acuta*. face view (x 600); 4-*Fursenkoina acuta*. side view (x 600);
5-*Valvulineria bradyana*. spiral view (x 500); 6-*Valvulineria bradyana*. edge view (x 600);
7-*Valvulineria bradyana*. spiral view; 8-*Neoeponides bradyi*. side view (x 600);
9-*Neoeponides bradyi*. side view (x 600)

APPENDIX B (cont.)

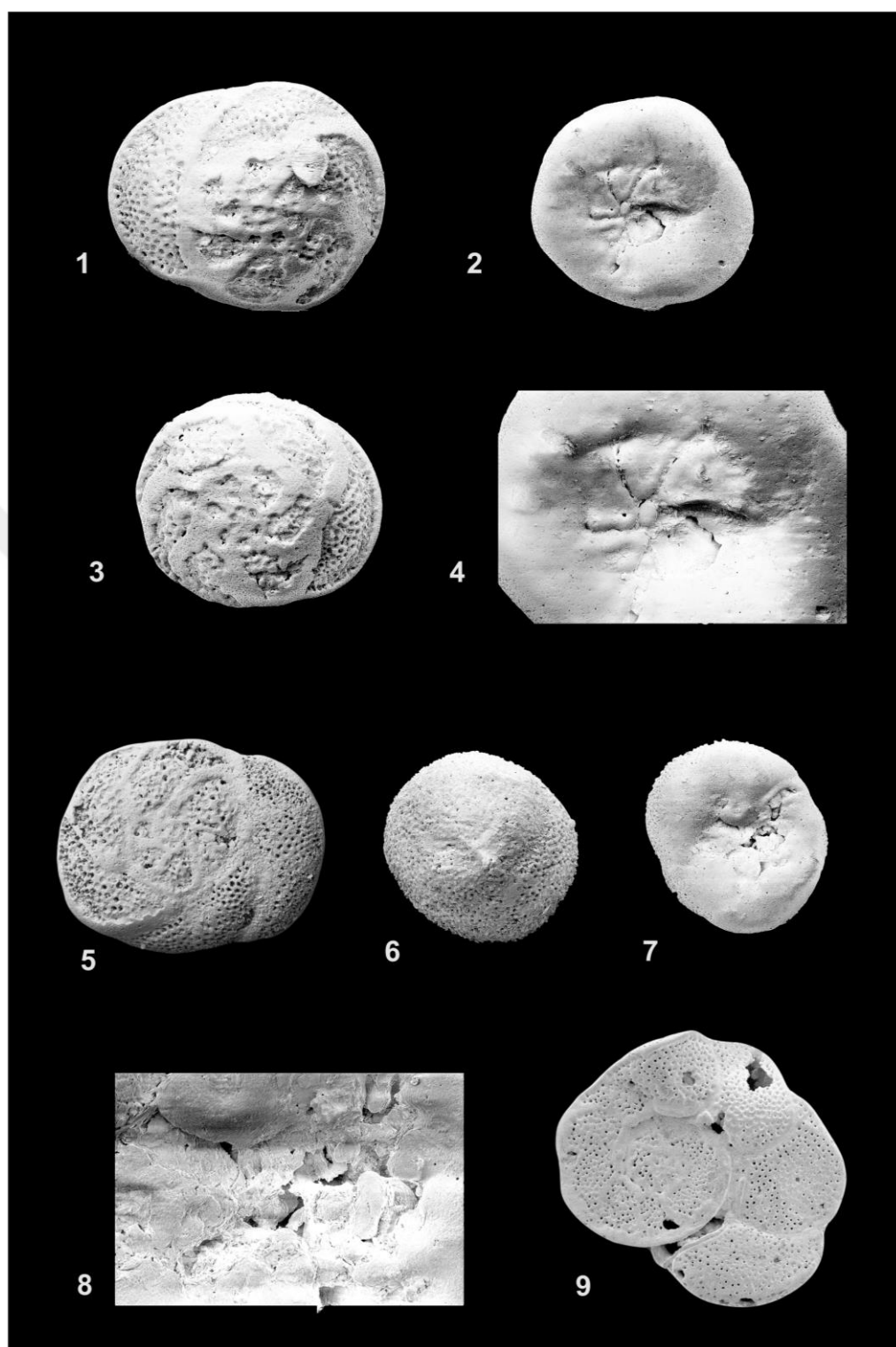


Figure B. 15 1-*Rosalina macropora*. spiral side view (x 800); 2-*Rosalina macropora*. umbilical side view (x 400); 3-*Rosalina macropora*. spiral side view (x 500); 4-*Rosalina macropora*. umbilical side view (x 800); 5-*Rosalina macropora*. spiral side view; 6-*Rosalina obtusa*. spiral side view (x 500); 7-*Rosalina obtusa*. umbilical side view (x 400); 8-*Rosalina obtusa*. umbilical side (x 1600); 9-*Cibicides advenum*. spiral side view (x 280)

APPENDIX B (cont.)

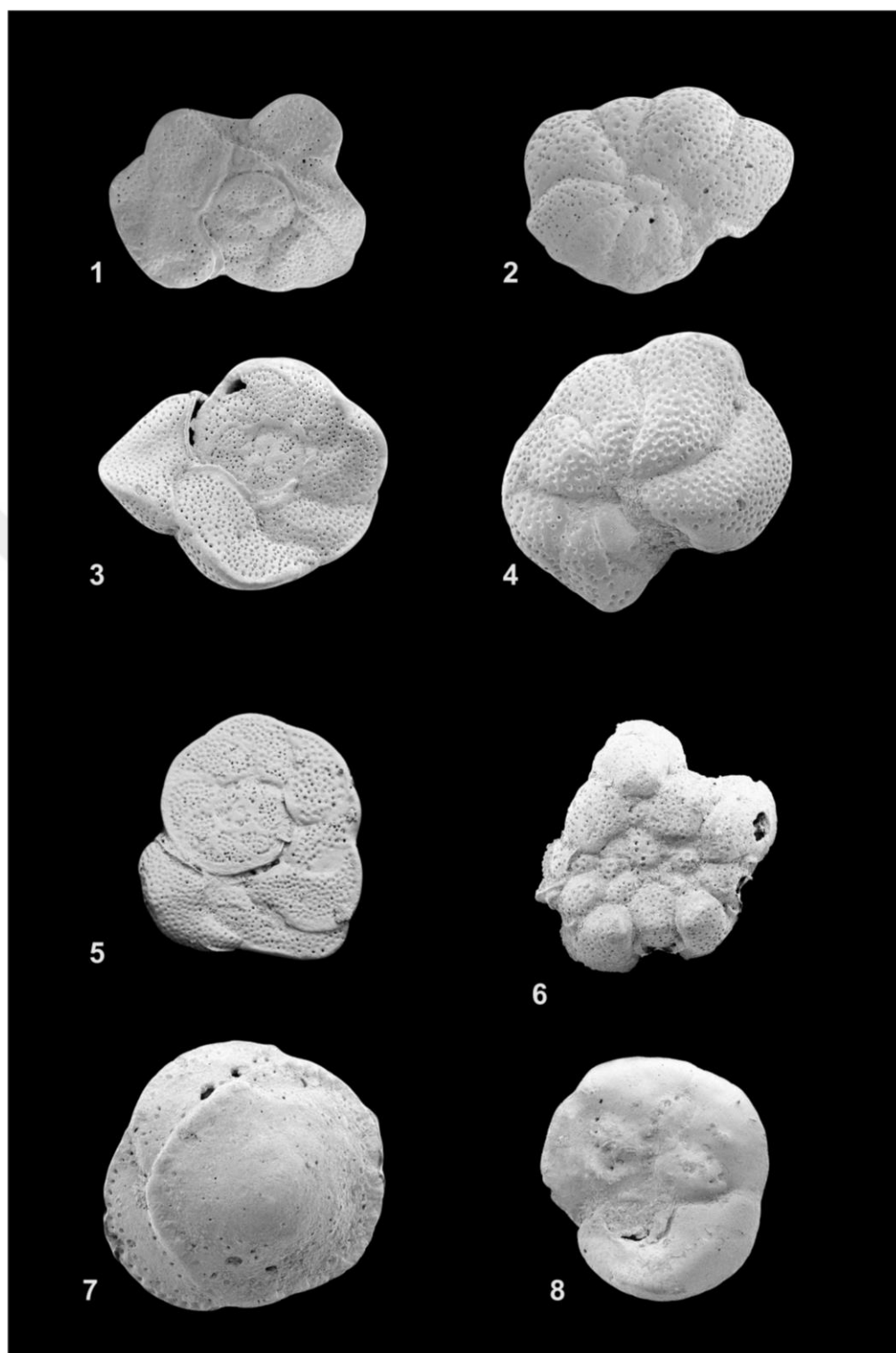


Figure B. 16 1-*Lobatula lobatula*. spiral side (x 300); 2-*Lobatula lobatula*. umbilical side (x 280); 3-*Lobatula lobatula*. spiral side (x 300); 4-*Lobatula lobatula*. umbilical side (x 450); 5-*Lobatula lobatula*. spiral side; 6-*Planorbulina mediterraneensis*. spiral side (x 400); 7-*Asterigerinata mamilla*. spiral view (x 800); 8-*Asterigerinata mamilla*. umbilical view (x 900)

APPENDIX B (cont.)

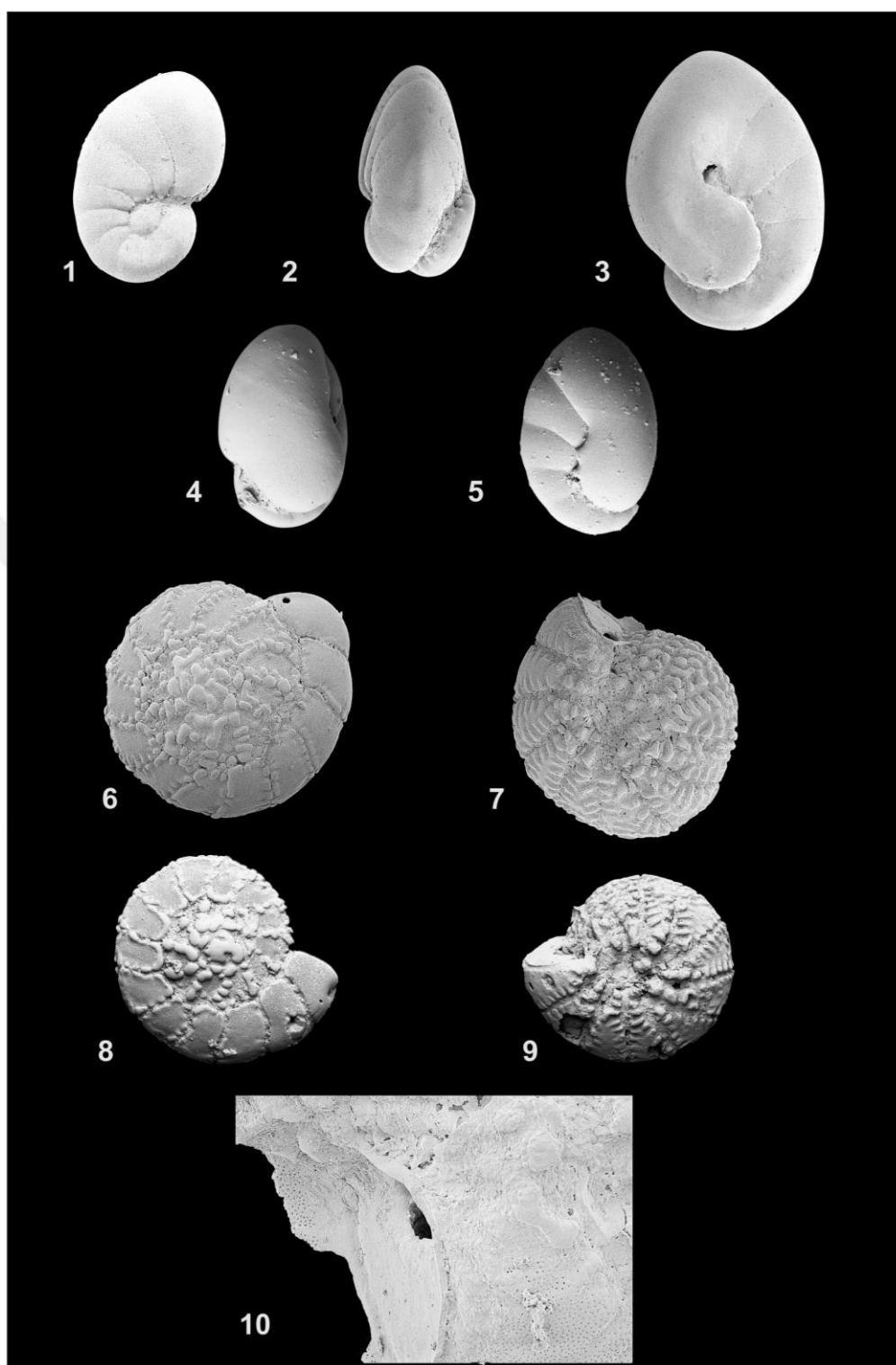


Figure B. 17 1-*Nonion* sp. side view (x 800); 2-*Nonionella turgida*. face view (x 800); 3-*Nonionella turgida*. side view (x 800); 4-*Nonionella turgida*. face view; 5-*Nonionella turgida*. side view; 6-*Ammonia beccarii*. spiral view (x 220); 7-*Ammonia beccarii*. umbilical view (x 300); 8-*Ammonia beccarii*. spiral view; 9-*Ammonia beccarii*. umbilical view; 10-*Ammonia beccarii*. apartural view (x 1200)

APPENDIX B (cont.)

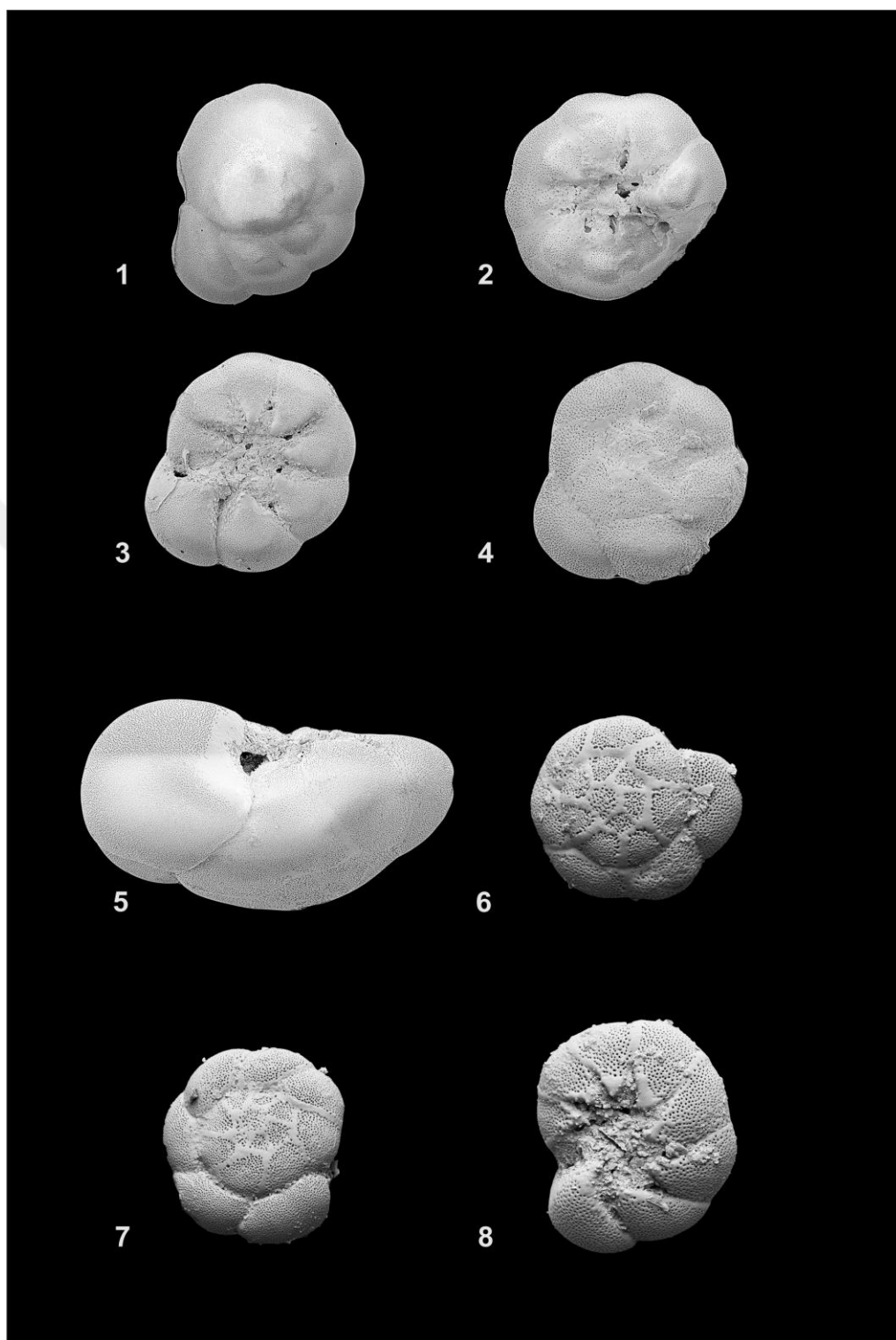


Figure B. 18 1-*Ammonia parkinsoniana*. side view (x 400); 2-*Ammonia parkinsoniana*. umbilical view (x 600); 3-*Ammonia tepida*. umbilical view (x 700); 4-*Ammonia tepida*. spiral view (x 600); 5-*Ammonia tepida*. apartural view (x 800); 6-*Ammonia tepida*. spiral view; 7-*Ammonia tepida*. spiral view; 8-*Ammonia tepida*. umbilical view

APPENDIX B (cont.)

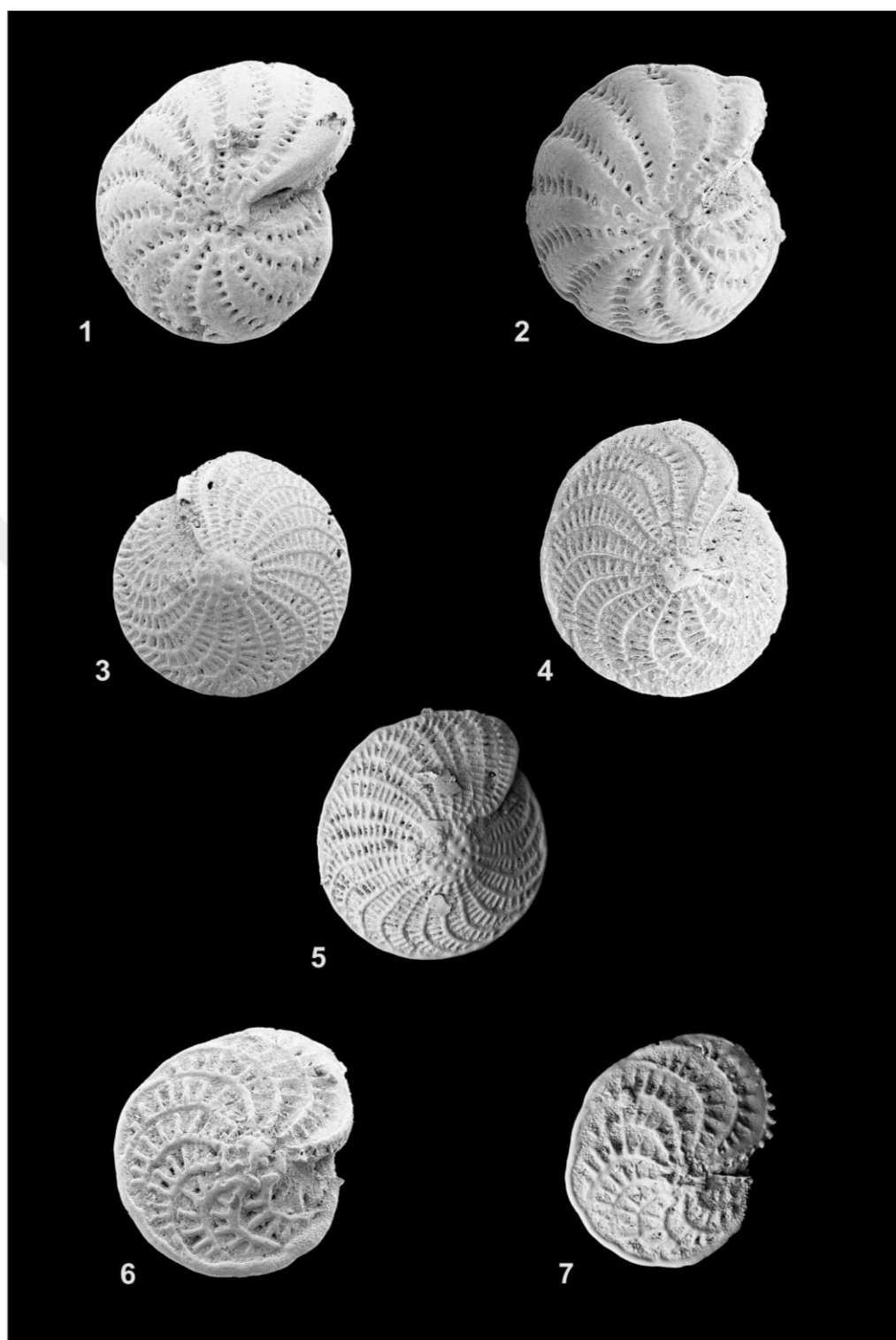


Figure B. 19 1-*Elphidium cf. E advenum*. side view (x 400); 2-*Elphidium cf. E advenum*. side view (x 400); 3-*Elphidium crispum*. side view (x 200); 4-*Elphidium crispum*. side view (x 200); 5-*Elphidium crispum*. side view; 6-*Elphidium jenseni*. side view; 7-*Elphidium jenseni*. side view

APPENDIX B (cont.)

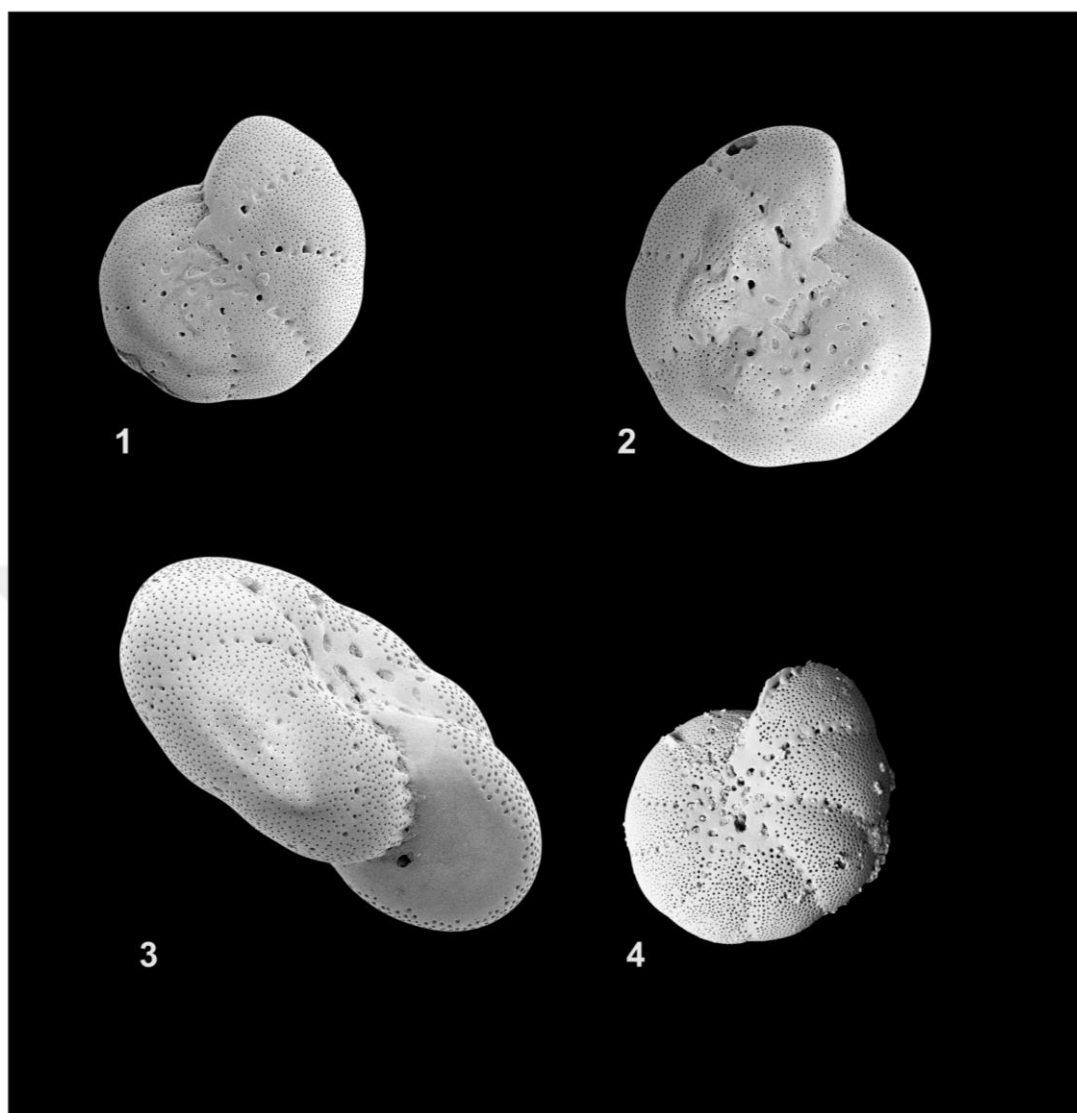


Figure B. 20 1-*Elphidium translucens*. side view (x 500); 2-*Elphidium translucens*. side view (x 500); 3-*Elphidium translucens*. apertural view (x 800); 4-*Elphidium translucens*. side view (x 450)

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Education

Alınan Derece	Aldığı Kurum/Üniversite	Graduation year
High School	Fındıklı Lisesi	2009
Undergraduate	Muğla Sıtkı Koçman University Biology Department (Grade: 76/100)	2009-2014
	Anadolu University Laborant and Veterinary Healthy Department (72/100)	2010-2012
Master Degree	Muğla Sıtkı Koçman University Geology Engineering Department	2014-present
	Muğla Sıtkı Koçman University Bioinformatics Department	2015-present

Publication

Peer Review Publication

Gül, M., **Salihoğlu, R.**, Dinçer, F., & Darbaş, G. (2018). Coastal geology of Iztuzu Spit (Dalyan, Muğla, SW Turkey). Journal of African Earth Sciences.

International Symposiums

Salihoglu, R., Akçer-Ön, S., Langer, M., & Viehber, F. (2018, April). Holocene Environmental Reconstruction of Lake Bafa (SW, Anatolia) by Statistical Analyses of Ostracod and Benthic Foraminifer Assemblages. In EGU General Assembly Conference Abstracts (Vol. 20, p. 1108).

Danladi, I. B., **Salihoglu, R.**, Ön, Z. B., & Akçer-Ön, S. High-Resolution Multi Proxy Evidences of Climate Changes During the Past 1400 Years from Lake Salda Sediment Records (SW Turkey).

Akçer-Ön, S., Ön, Z.B., Çağatay, M.N., Eriş, K.K., Sakınç, M., Wulf, S., Helvacı, C., Acar, D., Gündoğan, İ., Akkiz, S., Sancar, Ü. S., Veigas, G.J., Danladi, I.B., **Salihoğlu, R.**, Büyükmeriç, Y., Appelt, O., Şen, Ö.L., Özdoğan, M. High Resolution Middle-Late Holocene Climatic Records from Lake Salda (W. Anatolia) Sediments.

National Symposium

Salihoğlu, R. and Akcer-Ön, S., Salda Gölü Orta-Geç Holosen Çökellerinin Çoklu Belirteç Yöntemleriyle İncelenmesi, 70. Türkiye Jeoloji Kurultayı Bildiri Özleri, April, 2017

Sertificates

Good Manufacturing Practice (GMP) -2013

ISO/IEC 17025: 2005 Competence of Testing and Calibration Laboratories -2013

Good Laboratory Practice (GLP) -2013

Oyak-TUBİTAK Inter-High School Mathematics Competitions