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Doğu Akdeniz epibatiyal kıyı çökelleri arşivlerinden Kalabriyen-Kibaniyen yaşlı planktik foraminifer topluluklarının sayısal analizi ve paleoekolojisi (Mersin, Türkiye)

Quantitative analysis of Calabrian-Chibanian planktic foraminifer assemblages and paleoecology of the Eastern Mediterranean Sea from the onshore epibathyal sedimentary archives (Mersin, Turkey)

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ÖZ

Doğu Akdeniz'de epibatiyal derinlikte oluşmuş en genç denizel çökeller Kalabriyen-Kibaniyen yaşlı olup, Orta Anadolu Platosu'nun güney kesiminde yakın zamanda keşfedilmiştir. Dolayısıyla Kalabriyen-Kibaniyen yaşlı planktik foraminiferlerin yaşadığı Doğu Akdeniz'in o döneme ait ekolojisi bu zamana kadar incelenmemiştir. Bu çalışma Türkiye'nin güneyinde Mersin civarında bulunan Kalabriyen ve Kibaniyen yaşlı iki adet denizel birime ait planktik foraminifer topluluklarını ve Doğu Akdeniz'in yüzey sularının sıcaklık ve besin gibi çevresel parametreler bağlamında ekolojik özelliklerini ortaya koymaktadır. Burada planktik foraminiferler arasındaki baskın toplulukları belirlemek için Küme Analizi, çok değişkenli istatiksel verisetindeki etkin ekolojik değişkenleri belirlemek için ise Temel Bileşen Analizi uygulanmıştır. Çok değişkenli istatiksel analiz sonuçları, Kalabriyen yaşlı Doğu Gülnar denizel biriminin *Globorotalia*, *Globigerinella*, *Globigerina*, ve *Orbulina* olarak dört ana toplulukla temsil edildiğine işaret etmektedir. Çökelme ortamının Kibaniyen yaşlı daha genç kesimi olan Tol istifinin ise *Globigerinoides* ve *Globigerinella obesa*, *Orbulina* ve *Globigerinoides*, ve *Orbulina* olmak üzere üç ana toplulukla temsil edildiğine işaret etmektedir. Topluluklar arasındaki istatistiksel ilişki incelendiğinde Doğu Gülnar denizel birimi için üç temel ekolojik faktör (sıcaklık, besin, kıyıdan uzaklık), Tol birimi için ise tek bir ekolojik faktör (su derinliği) tanımlanabilmiştir. Bu durum, kesitlerin farklı iklimsel koşullarda oluştuğunu göstermektedir.

Anahtar Kelimeler: planktik foraminiferler; Doğu Akdeniz; paleoekoloji; Erken-Orta Pleyistosen

ABSTRACT

The youngest epibathyal marine deposits in the Eastern Mediterranean Region giving Calabrian-Chibanian age have been recently discovered around the southern Central Anatolian Plateau, Turkey. Hence the Calabrian-Chibanian planktic foraminifer paleoecology of the Eastern Mediterranean surface waters has not been investigated yet. This study reports the planktic foraminifer assemblages of the Calabrian and Chibanian aged two marine successions in the Mersin district in southern Turkey. Here, the ecological properties of the Eastern Mediterranean sea-surface waters and their controlling environmental parameters such as temperature and nutrient availability are documented through quantitative analysis. Quantitative analysis includes the Cluster Analysis to find dominant associations among planktic foraminifers and the Principal Component Analysis to quantify the (ecological) variables within the multivariate dataset. The multivariate statistical analysis revealed that the Calabrian marine succession, Gülnar East (1.72-1.08 My), is represented by four main assemblages: Globorotalia, Globigerinella, Globigerina, and Orbulina assemblage. The second and the younger Chibanian section, Tol (<0.61 and >0.46 My), is represented by three assemblages: Globigerinoides and Globigerinella obesa assemblage, Orbulina and Globigerinodes assemblage, and Orbulina assemblage. Examining the statistical correlations between the assemblages, three ecological variables for the Gülnar East section (temperature, nutrient, and coastal distance) and one variable for the Tol section (water depth) were identified. This outcome points to different climatic conditions prevailed during the deposition of the two sections.

Keywords: *planktic foraminifers; Eastern Mediterranean; paleoecology; Early-Middle Pleistocene*

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INTRODUCTION

The Mediterranean Region has been of interest to researchers for several decades since it has recorded several tectonic and climatic events in its Neogene aged sedimentary archives given the uniquity of the Messinian Salinity Crisis (MSC) that occurred at ~5.6 My (Hsü et al., 1973; Cita et al., 1977; Bizon, 1985; Ryan, 2009). The MSC, the event that was triggered by the uplift of the Gibraltar Strait, resulted in almost complete desiccation of the Mediterranean Sea (Hsü et al., 1973, 1977; Krijgsman et al., 1999, 2018; Loget and van den Driessche, 2006). The MSC was followed by the "Lago-Mare" event, the megaflood that occurred during the Zanclean at around 5.33 My when the Atlantic waters filled the Mediterranean Basin as the Strait of Gibraltar opened, which marked the ending of the Miocene and starting of the Pliocene stage (van Couvering et al., 2000; Garcia-Castellanos et al., 2009, 2020; Guerra-Merchán et al., 2010; Cipollari et al., 2012; Cosentino et al., 2013; Roveri et al., 2019). In Turkey, Zanclean and post-Zanclean marine deposits are found onshore in the southern (Yıldız et al., 2003; Cipollari et al., 2012; Faranda et al., 2013; Tekin et al., 2019) and southwestern (Akay et al., 1985; Glover and Robertson, 1998; Poisson et al., 2003; Nazik, 2004; Çiner et al., 2008) Central Anatolian Plateau as well-preserved outcrops. However, Quaternary deposits onlapping these Neogene units are poorly investigated (Yıldız et al., 2003; Öğretmen et al., 2018a, 2018b; Kanbur and Öğretmen, 2022). In fact, given the semi-enclosed nature of the Mediterranean Sea and consequent ecological adaptation of the foraminifers habiting in the Mediterranean waters paved the way to establish a special biozonation scheme for the Mediterranean Region since several foraminiferal bioevents different from the global bioevents were identified (Iaccarino et al., 2007; Cita et al., 2008; Lirer et al., 2019). Indeed, the Pleistocene stratigraphy of the Eastern Mediterranean Region has been updated applying micropaleontological analyses on recently discovered marine successions in the Mersin district, southern Turkey (Öğretmen et al., 2018a) which are the focus of this present study. Nonetheless, to date, paleoecological conditions of the surface waters during the sedimentation of these youngest epibathyal marine deposits of the Eastern Mediterranean realm have remained uninvestigated. In this study, planktic foraminifer assemblages of the Pleistocene Eastern Mediterranean waters are presented and corresponding paleoecological factors from these marine sediments are examined quantitatively applying multivariate statistical analysis.

GEOLOGICAL SETTING

The study area is located at the southern margin of the Central Anatolian Plateau at >1000 meters above sea level (asl) close to the eastern part of Gülnar village in Mersin (Figure 1). The Central Anatolian Plateau (CAP) has been uplifting as a response to the convergent tectonics between the African, Arabian, and Eurasian plates (Ketin, 1966; Dewey and Şengör, 1979; Şengör et al., 1985; Faccenna et al., 2006; Okay et al., 2020). Recent studies suggest an ongoing mantle driven uplift of the southern margin of the CAP since the Miocene times (Cosentino et al., 2012; Schildgen et al., 2012; Bartol and Govers, 2014; Radeff et al., 2015; Öğretmen et al., 2018a; Racano et al., 2020). This uplift allowed the preservation of the late Cenozoic epibathyal marine sediments along the southern flank of the CAP (Yıldız et al., 2003; Cipollari et al., 2012; Faranda et al., 2013; Öğretmen et al., 2018a, 2018b).

The marine successions (Gülnar East; referred GÜLE from now on, and Tol) examined in this study, make part of the Sarıkavak Formation onlapping the Miocene shallow-water limestone sequence lies at ~1500 m asl and consist of Plio-Pleistocene deposits which are the youngest deep marine sediments of the Eastern Mediterranean Region found as yet (Figure 1; Öğretmen et al., 2018a). The GÜLE and Tol sections unconformably overlie the middle Miocene limestones of the Mut Formation (Figure 1). The GÜLE section (36° 20’ 8.26″ N; 33° 25’ 51.44″ E), found at ~1000 m asl, is represented by grey-beige colored marls with five sapropel layers at the bottom part of the section (Figure 2a). The Tol section (36°23’ 05.9″ N; 33°25’ 25.9″ E) is located ~1200 m asl and its bottom part unconformably lies on top of an erosional surface that cuts the middle Miocene shallow-water limestones of the Mut Formation. This marine succession shows some carbonate layers in the upper part. It consists of mainly clayey marls and marly clays including a few dark horizons of bioturbated marly clays. Within these layers some plant remains are present (Figure 2b). These two sections have been studied for their biostratigraphy from foraminifers, ostracods, and calcareous nannoplanktons (Öğretmen et al., 2018a). Based on the identified foraminiferal bioevents first occurrence (FO) of *Neogloboquadrina pacyhderma* sx (1.79 My), first influx of *Globorotalia crassaformis* (1.72

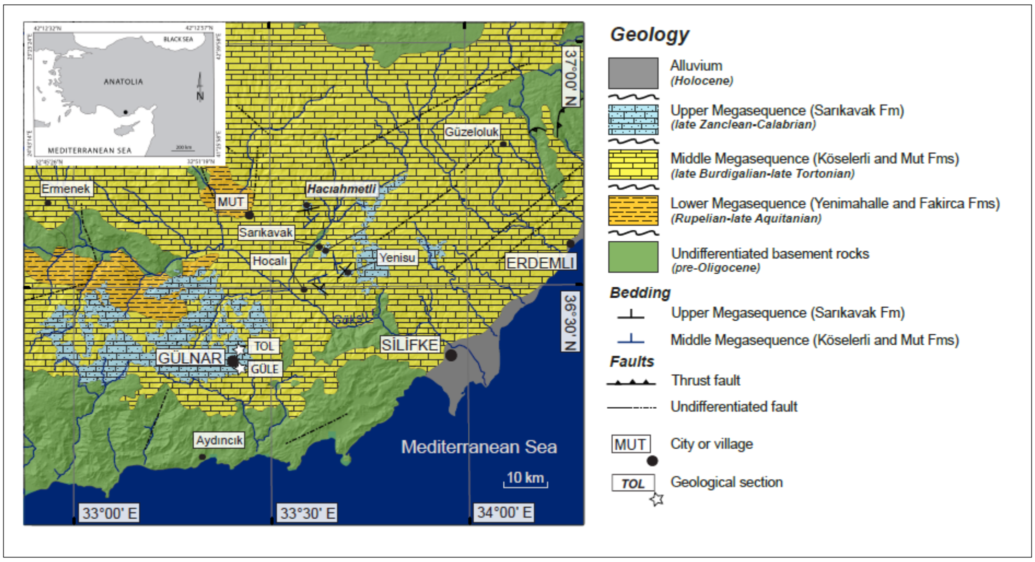

Figure 1. Geological map of the study area showing sampled Gülnar East (GÜLE) and Tol sections (according to Öğretmen et al., 2018a).

Şekil 1. *Doğu Gülnar (GÜLE) ve Tol kesitlerinin örneklendiği çalışma alanını gösteren jeoloji haritası (Öğretmen vd., 2018a'dan alınmıştır).*

My), FO of modern morphotype of *Bulimina marginata* (1.54 My), bottom and top paracme of *Neogloboquadrina* spp. sx (1.36 and 1.2 My, respectively) (Lourens et al., 2004; Iaccarino et al., 2007; Cita et al., 2008; Lirer et al., 2019); and nannoplankton bioevents medium *Gephyrocapsa* (<1.73 My), large *Gephyrocapsa* (<1.6 My), last occurrence of *Helicosphaera sellii* (1.245 My) (Raffi, 2002; Raffi et al., 2006), the age of the GÜLE section was identified as Calabrian within MPle1 *Globigerina cariacoensis* Interval Zone of the Mediterranean planktic foraminifer biozonation (Öğretmen et al., 2018a). Accordingly, the GÜLE section covers the age interval between 1.72 My and 1.08 My. Whereas the Tol section covers the period between <0.61 My and >0.46 My (Öğretmen et al., 2018a) based on the foraminifer bioevents last common occurrence of *Neogloboquadrina* spp. sx (0.61 My) and FO of *Globigerinella calida* (0.78 My) (Lourens et al., 2004; Iaccarino et al., 2007); and nannoplankton bioevent LCO of *Pseudoemiliania lacunosa* (0.46 My) (Raffi et al., 2006).

MATERIAL AND METHOD

The sampling was conducted from the 27 m-thick GÜLE section and 18.5 m-thick Tol section with 50 cm of intervals resulting in total 54 and 26 samples, respectively, for micropaleontological analyses. For the microfaunistic studies, all samples (except for the uppermost GÜLE samples 52, 53, and 54) were disaggregated in an H_2O_2 5% solution for 24–48 hour, washed through 63 µm and 125 µm mesh sieves, and dried in an oven at 40°C at the Roma Tre University facilities. Quantitative and qualitative planktic foraminifer analyses were carried out by counting, when possible, up to 300 specimens from the dry residue fraction >125 µm.

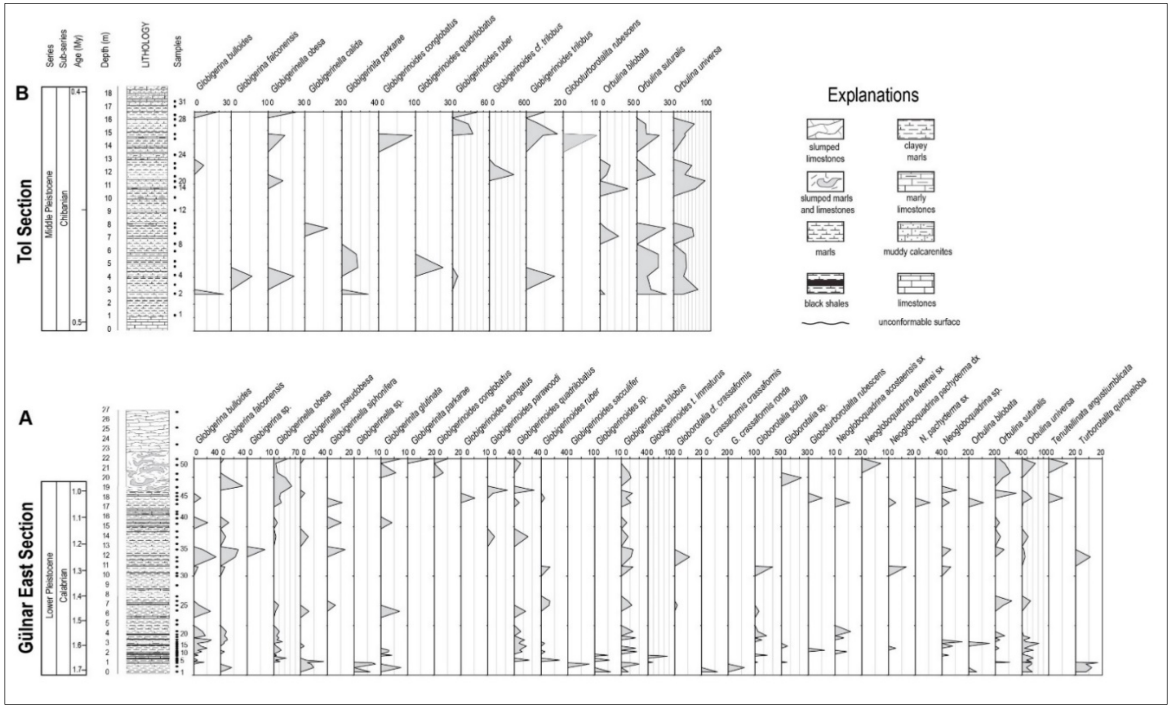

Figure 2. Stratigraphic logs (from Öğretmen et al, 2018a) and planktic foraminifer relative abundance plots of older GÜLE (A) and younger Tol (B) sections. Age model adapted from Öğretmen et al. (2018a).

Şekil 2. *Daha yaşlı GÜLE (A) ve daha genç Tol (B) kesitlerine ait planktik foraminifer göreceli çokluk grafikleri ve stratigrafik kayıtları (Öğretmen vd. (2018a)'dan değiştirilerek). Yaş modeli Öğretmen vd. (2018a)'dan alınmıştır.*

The taxonomic identification of the species was performed referring to Parker (1962), the Practical Manual of Neogene Planktonic Foraminifera of Iaccarino et al. (2007), and online databases www.foraminifera.eu and World Register of Marine Species (www.marinespecies.org). Percentage calculation of each species was performed simply by calculating the number of each species relative to the total assemblage of each sample. For statistical analyses, only species with more than 5% of abundance were taken into account (Figure 2).

To obtain a reasonable ecological model, species were grouped according to their genera based on their ecological requirements following Bé (1977) and Schiebel and Hemleben (2017). Two algorithms were used: the unconstrained Cluster Analysis (Chord distance measure and the un-weighted pair group method using arithmetic average-UPGMA) in Q-mode (column mode) and the Principal Component Analysis (PCA) using the PAST software, ver. 4.04 (Figures 3-8) (Hammer, 2020). The Cluster Analysis was applied in Q-mode to find dominant associations throughout the sections (Figures 3 and 6). The Cluster Analysis dendrogram was tested through the cophenetic correlation coefficient (c) (Sokal and Rohlf, 1962; Mouchet et al., 2008). The highest cophenetic correlation coefficient points to the cluster that holds most of the information (Borcard et al., 2018).

The PCA was applied to quantify variables (components) within the multivariate dataset (Hammer, 2020 and references therein). To test the accuracy of the PCA, bootstrap was used to estimate the variances of factor loadings (Figures 5 and 8) (Chatterjee, 1984). The bootstrapping was carried out with 999 bootstrap replicates for all analyses. In the scree plots, 95% bootstrapped confidence intervals are given for each Eigenvalue, and the broken stick values are reported in Figure 3. The results of the multivariate statistical analyses for both sections are provided as Supplementary Information (SI) and can be accessed via http://dx.doi.org/10.17632/n3skhm7tz6.1.

The relative abundance of each planktic foraminifer species above 5% throughout the GÜLE and Tol sections were reported in figures 4 and 7.

RESULTS

Throughout the GÜLE and Tol sections, several sample levels were not identified for their foraminifer assemblages due to strong recrystallization as indicated also in the previous studies conducted on these two marine successions (Öğretmen et al., 2018a, 2018b). For this reason, in the GÜLE section, samples 8, 9, 11, from 27 to 31, 40 to 42; and in the Tol section samples 1, 5, 8, 11-13, 23, 24, 28, 30, and 31 were excluded from the statistical calculations. Therefore from the GÜLE section in total, 38 and the Tol section in total 15 samples were investigated for their planktic foraminifer assemblages.

The GÜLE section multivariate statistical analyses

Cluster Analysis

The Cluster Analysis in Q-mode (c=0.73) yields four main clusters that are discriminated in the GÜLE section at a distance value >0.75 including in total 35 taxa showing more than 5% abundance (Figure 2a). The four clusters of this section were investigated in 10 groupings as *Globigerina*, *Globigerinella*, *Globigerinita*, *Globigerinoides*, *Globorotalia*, *Neogloboquadrina*, *Orbulina*; however, *Globoturborotalita rubescens, Tenuitellinata angustiumbilicata,* and *Turborotalita quinqueloba* were left as single species since they are the only representatives of their genera throughout the section. *Globigerina* group consists of *Globigerina bulloides*, *G. falconensis*, and *Globigerina* sp.;

Globigerinella consists of *Globigerinella obesa*, *G. pseudobesa*, and *G. siphonifera*; *Globigerinita* group includes *Globigerinita glutinata* and *G. parkerae*; *Globigerinoides* group includes *Globigerinoides* cf. *tenellus, G. conglobatus, G. elongatus, G. parawoodi, G. quadrilobatus, G. ruber, G. sacculifer,* and *G. immaturus*. The groupings of *Globigerinoides* sp., *G.* cf. *trilobus, G. trilobus, Globorotalia* includes *Globorotalia* cf. *crassaformis, G. crassaformis crassaformis, G. crassaformis ronda, G. scitula,* and *Globorotalia* sp.; *Neogloboquadrina* consists of *Neogloboquadrina acostaensis* sx, *N. dutertrei* sx, *N. pachyderma* dx, *N. pachyderma* sx, and *Neogloboquadrina* sp.; and finally *Orbulina* group consists of *O. bilobata, O. suturalis,* and *O. universa*. In this study, right coiled and left coiled neogloboquadrinids are grouped under *Neogloboquadrina* since *N. pachyderma* sx is never the dominant species within the corresponding planktic foraminifer assemblage, except only in sample 32 it shares the same percentage as *N. pachyderma* dx. Nonetheless, also in sample 32, the dominant assemblage is not *Neogloboquadrina* (Figure 2a).

Accordingly, four clusters of the section reported in Figure 2 are the following: (1) cluster A, including three samples, is dominated by *Globorotalia scitula* assemblage where sample 20 is almost equally dominated by *Globigerina*, and sample 32 by *Neogloboquadrina*; (2) cluster B includes seven samples and is dominated by *Globigerinella* assemblage consisting of mainly *G. obesa*, and sample 51 bearing only *G. obesa*; and all the other samples accompanied by other species and taxa groups such as *O. universa*, *G. falconensis*, *Globorotalia*, *Neogloboquadrina*, and *Globigerinoides*, where sample 8 is almost equally dominated by *O. universa*, and sample 46 is equally dominated by *Globigerinodes*; (3) cluster C is dominated by *Globigerina* assemblage consisting of 10 samples in which *Globigerina* group is accompanied by several other taxa and species only sample 12 is subordinated to *Globigerinoides* while *Globigerina* group is still being abundant and *Globigerinella obesa* is

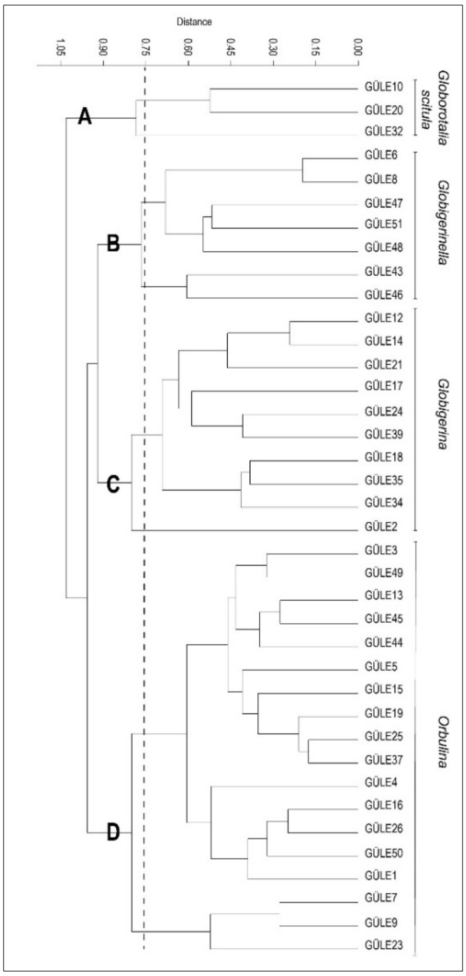

Figure 3. Dendrogram in Q-mode of the Cluster Analysis (UPGMA, Chord algorithm) performed on the planktic foraminifers from the GÜLE section. On the right side of the dendrogram, sample numbers are given.

Şekil 3. *GÜLE kesiti planktik foraminiferlerine uygulanan Q-tipi Küme Analizi (Aritmetik Ortalama ile Ağırlıksız Çift Grup Metodu, Chord algoritması) dendrogramı. Dendrogramın sağında örnek numaraları verilmiştir.*

equally dominant, sample 17 is subordinated to *Globigerinella obesa*, *Globigerina* being the second most abundant taxa group, and sample 14 is subordinated to Globigerinoides (*G. quadrilobatus* and *G. trilobus*), *Globigerina* (*G. bulloides*) and *Globigerinella* (*G. obesa*) are being the second and most abundant species, and finally (4) cluster D is represented by *Orbulina* assemblage including 18 samples and accompanied by other taxa groups and species, only in samples 7, 9, 23 are subordinated by *Globigerinoides* while *Orbulina* being the second most abundant taxa group.

Principal Component Analysis

The PCA of the GÜLE section demonstrates three Principal Components completely lie above the broken stick values falling inside the 95% confidence interval (Figure 4). The GÜLE section was deposited in a marine setting controlled by three ecological factors (PC 1, PC 2, and PC 3) and is represented by four planktic foraminifer assemblages (*Globorotalia scitula*, *Globigerinella*, *Globigerina*, and *Orbulina*) (Figures 3 and 4). The Component 1 explains 37.8% of the variance, Component 2 explains 25.4%, and Component 3 explains 20.4%. The Principal Component (PC) loadings >0.3 were considered for the PCA interpretation (Figures 5a, 5b, and 5c). Accordingly, PC 1 is positively correlated with *Globigerina* (loading 0.37) and *Globigerinella* (loading 0.43), but negatively correlated with *Orbulina* (loading -0.8). PC 2 is positively correlated with *Globigerinella* (loading 0.74) and *Orbulina* spp. (loading 0.32), negatively correlated with *Globigerinoides* (loading -0.45). PC 3 is positively correlated with *Globigerinella* (loading 0.31) and *Globigerinoides* (loading 0.73), negatively correlates with *Globigerina* (loading -0.52) (Figures 5a-5c).

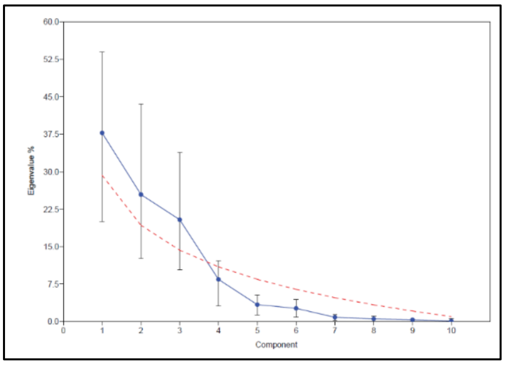

Figure 4. Scree plot of the GÜLE section showing the three Principal Components lie above the broken stick values (red-dashed line) falling inside the 95% confidence interval.

Şekil 4. *GÜLE kesitinin kırmızı kesik çizgi ile gösterilen %95'lik güven aralığında kalan üç adet Temel Bileşeni'ni gösteren yamaç birikinti grafiği.*

The Tol section multivariate statistical analyses

Cluster Analysis

In the Tol section, in total 14 taxa showing more than 5% of abundance were identified (Figure 2b) and examined in six groupings, two being represented only by a single species *Globoturborotalita rubescens* and *Globigerinita parkarae*. Other four groupings are *Globigerina*, *Globigerinella*, *Globigerinoides*, and, *Orbulina. Globigerina* consist of *G. bulloides* and *G. falconensis*; *Globigerinella* includes *G. obesa* and *G. calida*; *Globigerinoides* consists of *G. conglobatus, G. quadrilobatus, G. ruber, G. cf. trilobus,* and *G. trilobus;* and *Orbulina* comprises *O. bilobata*, *O. suturalis*, and *O. universa* (Figure 2b).

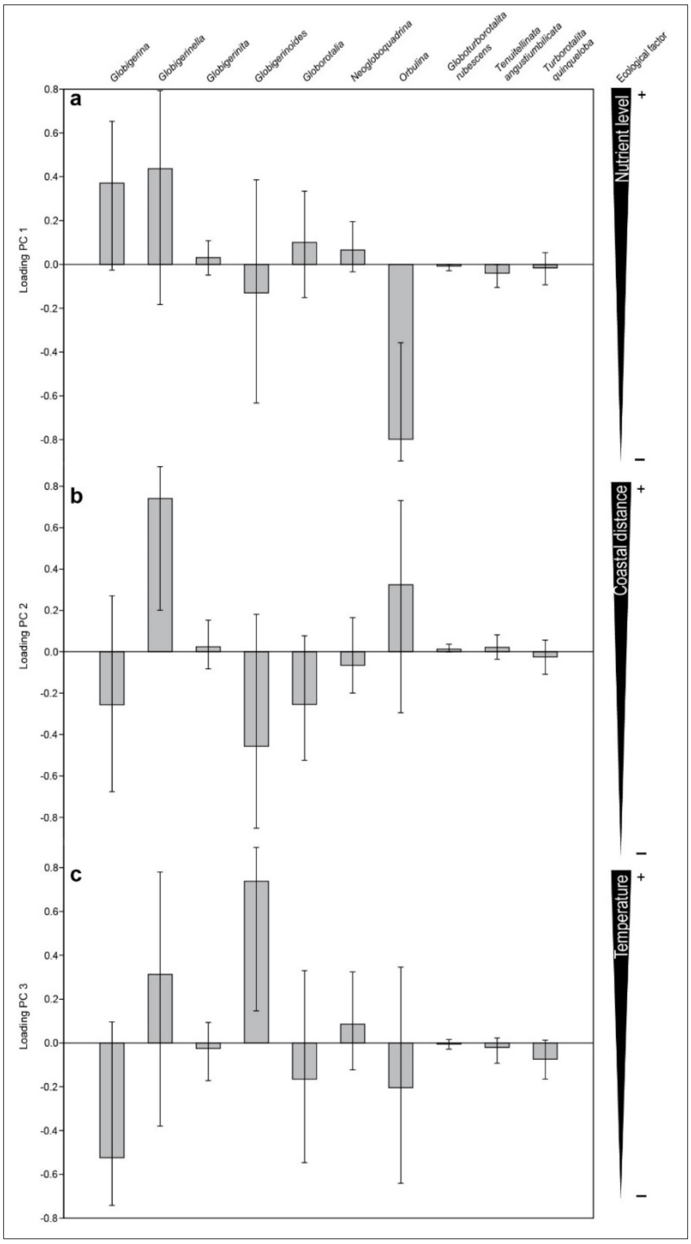

Figure 5. Loadings of the three Principal Components, corresponding foraminiferal assemblages, and interpreted ecological factors of the GÜLE section.

Şekil 5. *GÜLE kesitinin Temel Bileşen yüklemeleri ve bunlara karşılık gelen foraminifer toplulukları ile beraber yorumlanmış ekolojik parametreleri.*

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The Cluster Analysis applied in Q-mode (c=0.90) for the planktic foraminifer groupings of the Tol section yielded three main clusters at a distance level >0.5 (Figure 6). These clusters are as following: **(1)** cluster A includes only sample 29 and is dominated by *Globigerinella obesa* being accompanied by *Globigerinoides* (*G. ruber* and *G. trilobus*); **(2)** cluster B consists of six samples and is dominated by *Orbulina*, only sample 26 is subordinated by *Globigerinoides* but *Orbulina* being second most abundant taxa group; and **(3)** cluster C includes eight samples being dominated by *Orbulina* and accompanied by other taxa including *Globigerinella* (*G. calida* in sample 10 and *G. obesa* in sample 20), *Globigerina* in sample 22, *Globigerinita parkarae* in sample 7, and *G. parkarae* and *Globigerina bulloides* in sample 2. Samples 3, 9, and 14 are represented only by *Orbulina* (Figure 5).

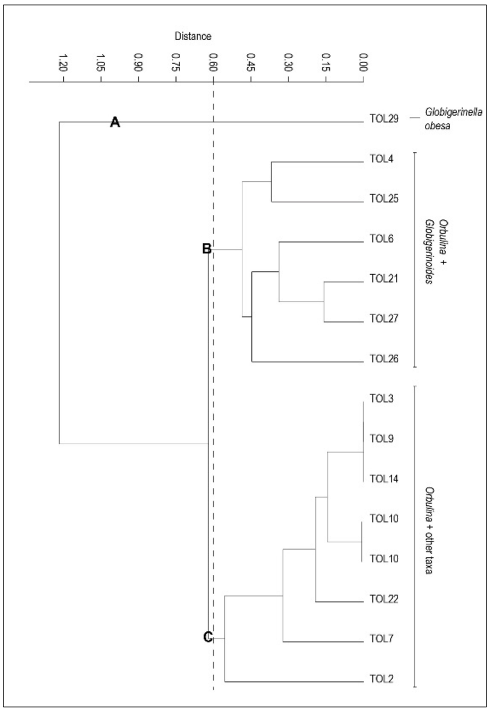

Figure 6. Dendrogram in Q-mode of the Cluster Analysis (UPGMA, Chord algorithm) performed on the planktic foraminifers from the Tol section. On the right side of the dendrogram, sample numbers are given.

Şekil 6. *Tol kesiti planktik foraminiferlerine uygulanan Q-tipi Küme Analizi (Aritmetik Ortalama ile Ağırlıksız Çift Grup Metodu, Chord algoritması) dendrogramı. Dendrogramın sağında örnek numaraları verilmiştir.*

Principal Component Analysis

The PCA of the Tol section reveals only one Principal Component which completely lies above the broken stick value falling within the 95% confidence interval (Figure 7). The Tol section was deposited in an environment with a single controlling parameter and it hosts three planktic foraminifer assemblages (*Globigerinoides* assemblage, *Orbulina* and *Globigerinoides* assemblage, and *Orbulina* assemblage) (Figures 6 and 7). This PC explains 75.4% of the variance (Figure 6). Analyzing the loadings of the PC of the Tol section, it is evident that *Orbulina* shows a positive correlation (loading 0.81) with the PC whereas *Globigerinoides* shows a negative correlation (loading -0.56) (Figure 8).

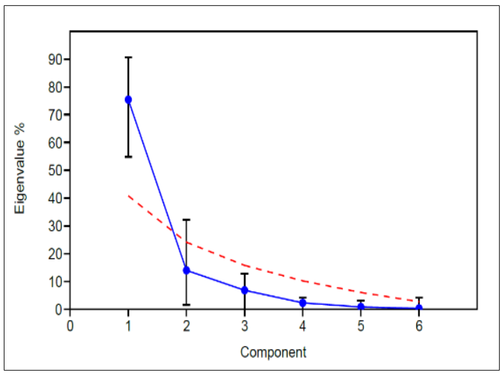

Figure 7. Scree plot of the Tol section showing the Principal Component lies above the broken stick values (red-dashed line) falling inside the 95% confidence interval.

Şekil 7. *Tol kesitinin kırmızı kesik çizgi ile gösterilen %95'lik güven aralığında kalan tek bir adet Temel Bileşeni'ni gösteren yamaç birikinti grafiği.*

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DISCUSSION

Ecological factors of the GÜLE section

The PCA analysis from the GÜLE section has revealed that PC 1 shows a positive correlation with *Globigerina* and *Globigerinella*, but *Orbulina* is weighted negatively for PC 1 (Figure 5a). *Globigerina,* consisting of mainly *G. bulloides* and *G. falconensis*, is suggestive for food availability. Examining in more detail, even though *G. falconensis* is a symbiont-bearing species (Rink et al., 1998), *G. bulloides* is considered as a non-symbiont bearing opportunistic species (Schiebel and Hemleben, 2017) and, in the modern-day Mediterranean Sea, *G. bulloides* is less abundant in oligotrophic waters of the Eastern Mediterranean (Mallo et al., 2017). Therefore, symbiosis as an ecological factor can be eliminated to explain PC 1. However, in the same study (Mallo et al., 2017) it has also been reported that in the Eastern Mediterranean, the abundance of *G. bulloides* increases during winter related to phytoplankton blooms. In fact, *G. bulloides* and *G. falconensis* are two species commonly used for surface water (paleo)productivity studies (Vénec-Peyré and Caulet, 2000; Jonkers and Kučera, 2015). Reichart and Brinkhuis (2003) reported an increase in *G. bulloides* and *G. falconensis* in the late Quaternary Arabian Sea as a result of surface water mixing during winters. On the other hand, *Globigerinella* in the GÜLE planktic foraminifer assemblage is mainly dominated by *G. obesa*, except for samples 2, 3, 4, and 5, which are represented by *G. pseudobesa*- a species that is closely related to *G. obesa* in terms of morphological features (Kennett and Srinivasan, 1983), and sample 35 is dominated by *G. siphonifera*.

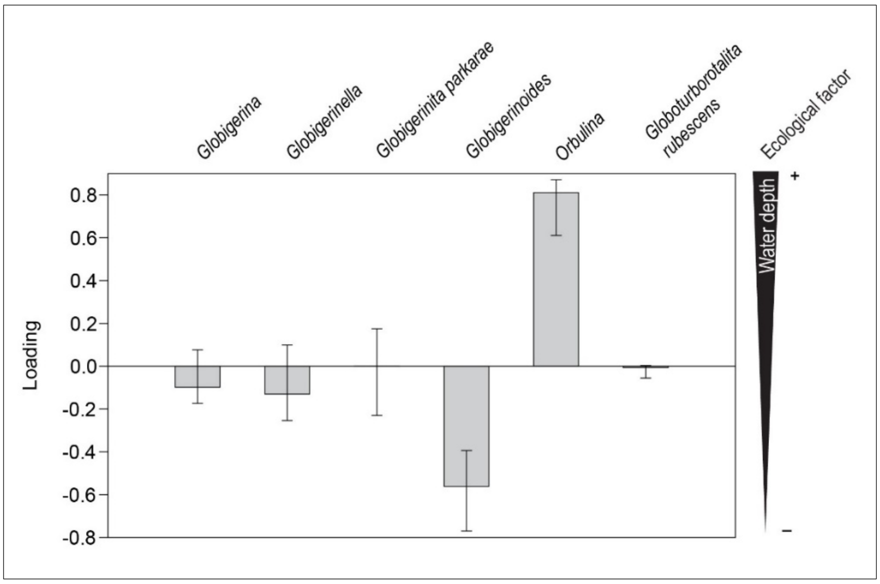

Figure 8. Loadings of the Principal Component of the Tol section and corresponding foraminiferal assemblages are given together with interpreted ecological parameter.

Şekil 8. *Tol kesitinin Temel Bileşen yüklemeleri ve bunlara karşılık gelen foraminifer toplulukları ile beraber yorumlanmış ekolojik parametreleri.*

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Regarding the ecological preference of *Globigerinella obesa* the studies are scarce and only its latitudinal distribution has been reported which is tropical to temperate (Kennett and Srinivasan, 1983). This species is commonly found in the Miocene marine successions. For example, *G. obesa* is among the representative species of the Middle Miocene (Badenian) gypsum deposits of Paratethys (Bicchi et al., 2003; Bojar et al., 2020) and the Messinian syn-evaporatic unit in the Iberian Peninsula (Corbí et al., 2020). In a recent study, nutrient availability in hypersaline environments, such as evaporitic basins, was investigated and suggested that sufficient supply of ammonia sustains the primary productivity through nitrification, denitrification, and anammox processes and might have been the case during the Messinian Salinity Crisis (Isaji et al., 2019). And hence, the intervals of *G. obesa* as the dominant species together with *Globigerina* may potentially indicate the periods of increased sea-surface salinity and (paleo)productivity during the sedimentation of the GÜLE section.

Orbulina, instead, is known to tolerate wide ranges of temperature and salinity throughout the tropical and temperate waters being cosmopolitan taxa (Schiebel and Hemleben, 2017). *Orbulina universa* is an indicator species of the Indian Ocean of high salinity, intermediate temperature and oxygen, and low phosphate values (Bé, 1977), whereas in the Mediterranean Sea a significant pattern for its distribution was not observed (Mallo et al., 2017). However, Lekieffre et al. (2020) state that *Orbulina universa* is abundant in oligotrophic environments. This information suggests that PC 1 stands for paleoproductivity of the surface waters pointing to foraminifer assemblages dominated by *Globigerina* and *Globigerinella* represent high nutrient surface waters, whereas, oligotrophic (low nutrient) surface waters were represented by the *Orbulina* assemblage.

The PC 2 for the GÜLE section positively correlates with *Globigerinella* and *Orbulina*, but negatively correlates with *Globigerinoides* (Figure 5b). *Globigerinoides* in the GÜLE section is mainly represented by *G. quadrilobatus*, *G. ruber*, *G. trilobus*, and *G. immaturus*. In fact, *G. quadrilobatus*, *G. immaturus*, and *G. trilobus* can be categorized as morphotypes of *G. sacculifer* (André et al., 2013) and they live in the euphotic zone of the water column; however, they may show differences during their reproductive cycles (Bijma and Hemleben, 1994). Another study suggests that *G. trilobus* and *G. sacculifer* should belong to a new taxonomic classification "*Trilobatus*" (Spezzaferri et al., 2015). In this study, they are kept as separate species but grouped under *Globigerinoides* due to their similar ecological preferences. Accordingly, *G. ruber* mainly lives in the upper 50 meters of the water column (Bé, 1977). It is a salinity tolerant species that can survive in regions of freshwater runoff and can be found in different ecological habitats (Schiebel and Hemleben, 2017). It is positively correlated with primary productivity and can tolerate neritic conditions (Schmuker and Schiebel, 2002). *Globigerinoides quadrilobatus*, similar to *G. ruber*, prefers oligotrophic conditions affected by enhanced continental runoff which increases the quantity of preferred food of this species during the spring (Sprovieri et al., 2006). *Globigerinoides immaturus* and *G. trilobus* are indicators of low sea-surface productivity, hence oligotrophic environments (Wilson, 2012). Even though *Orbulina* is abundant in oligotrophic environments, it prefers open ocean settings similar to *Globigerinella* (BouDagher-Fadel, 2013). Therefore, one can conclude that PC 2 points to distance from the coast as *Orbulina* and

Globigerinella dominance is related to the increased sea levels, and dominance of *Globigerinoides* refers to the decreased sea levels and hence adaptation to neritic conditions.

The PC 3 positively correlates with *Globigerinoides* and *Globigerinella*, and negatively correlates with *Globigerina* (Figure 5c). The main difference between these taxa groups is that *Globigerina* simply prefers cool waters, whereas *Globigerinella* is found in temperate-warm waters (Kennett and Srinivasan, 1983; Schiebel et al., 2017). This suggests PC 3 refers to temperature. In a previous study, samples 10, 18, and 20 were collected from the three sapropel levels at the bottom portion of the GÜLE section (Öğretmen et al., 2018a). The researchers conducted a paleoclimate analysis and revealed that sapropel layers of samples 10, 18 and 20 were deposited during cool/cold climate conditions; and the other two sapropel layers (samples 7 and 15) were deposited in warm-climate settings (Öğretmen et al., 2018b). The results demonstrated here confirm this finding as samples 10, 18, and 20 weigh negatively and sample 7 weighs positively for PC 3 (see SI). Even though sample 15 does not show any significant correlation for this PC, it was resulted in *Orbulina* assemblage (Figure 3), which is oligotrophic taxa of temperate-warm waters as explained above, confirming previous findings.

In summary, the age interval of the GÜLE section comprises 41-kyr cycles (Öğretmen et al., 2018a) before the onset of the Early-Middle Pleistocene Transition (EMPT) that occurred ~1.2-700 ka. The EMPT refers to the onset of the abrupt and repeated shifts in glacial-interglacial cycles occurred due to the change of Earth's axial tilt and eccentricity (Berger, 1988; Clark et al., 2006). As a result of this change, 41-kyr climate cycles were replaced by 100-kyr cycles. Hence ecologically varying environment of the Eastern Mediterranean Sea detected from the GÜLE section is parallel to global climate conditions carrying the signatures of short-term changes in sea-level and climate (i.e. temperature), eventually influencing the nutrient conditions.

Ecological factors of the Tol section

The Tol section revealed only one PC, which shows a positive correlation with *Orbulina* and a negative correlation with *Globigerinoides* (Figure 8). Similar to *Globigerinoides*, also *Orbulina* is symbiont-bearing (Bé, 1977; Spero, 1987) and they share a similar diet (Schiebel and Hemleben, 2017). In terms of seasonality, they both are categorized as summer taxa, however, *Globigerinoides* species such as *G. ruber*, *G. sacculifer*, *G. trilobus*, and *G. conglobatus* are found mainly in the upper 50 m of the water column, whereas *Orbulina universa* can be found in deeper water column reaching down to 100 m (Bé, 1977). Indeed, the paleodepth of the Tol section was estimated to be deeper than that of the GÜLE section. The Tol section, being deposited after the EMPT, was deposited in climate conditions with 100-kyr cycles as observed with a single controlling factor. The age interval of the Tol section between ~0.6 and 0.46 My comprises two interglacial marine isotope stages which are MIS13 at the bottom and MIS11 at the top part of the succession which might have resulted in increased sea-levels (Öğretmen et al., 2018a). Consequently, it is possible to argue that PC for the Tol section points to the depth habitat of these *Globigerinoides* and *Orbulina* groups.

CONCLUSION

This study quantitatively demonstrates the controlling paleoecological factors of the surface waters of the Eastern Mediterranean during the Calabrian and Chibanian derived from the planktic foraminifer assemblages of the Gülnar East (GÜLE) and Tol sections, respectively, in Mersin district in southern Turkey. To unravel the controlling paleoecological factors of the surface waters of the Calabrian-Chibanian Eastern Mediterranean Sea, the Cluster Analysis to find dominant associations and the Principal Component Analysis to quantify the (ecological) variables within the multivariate dataset were applied. The results highlight that the older marine succession (GÜLE) was deposited under varying trophic conditions recording sea-level fluctuations during different climatic episodes (varying temperatures) as inferred from the planktic foraminifer assemblages from 38 samples. The planktic foraminifer assemblages of the Tol section particularly mark the increased water depth of the sedimentary environment and a less diverse fauna inferred from the lower number of taxa compared to the GÜLE section dominated by a rather cosmopolitan assemblage suggestive of an open sea setting as inferred from 15 samples. The GÜLE section was represented by four main assemblages, namely *Globorotalia*, *Globigerinella*, *Globigerina*, and *Orbulina* assemblage. The Tol section, on the other hand, was represented by three main assemblages, which are *Globigerinoides* and *Globigerinella obesa* assemblage, *Orbulina* and *Globigerinodes* assemblage, and *Orbulina* assemblage. Accordingly, the GÜLE section with its diverse fauna points to three different ecological variables which are coastal distance, nutrient, and temperature that played an important role during the sedimentation of the succession between ~1.72 and 1.08 My. The controlling ecological factor for the Tol section, instead, is water depth during the sedimentation of the succession between <0.6 Ma and >0.46 Ma.

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