Scientific Research Publishing

Journal of Environmental Protection, 2024, 15, 13-25
https://www.scirp.org/journal/jep
ISSN Online: 2152-2219
ISSN Print: 2152-2197

# Diversity, Ecology, and Environmental Significance of Foraminifera in Al Hamama and Susah Coastal Regions, Northeastern Libya: Insights from Holocene Sediments

**Belkasim Khameiss[1,2], Husamaldeen Zubi[3,4]**

[1]Kansas Geological Survey, Lawrence, USA
[2]Department of Earth Sciences, Faculty of Science, University of Benghazi, Benghazi, Libya
[3]Department of Geology and Geological Engineering, University of Mississippi, Oxford, USA
[4]Department of Geology, Omar Al-Mukhtar University, Al Bayda, Libya
Email: bkb28_1981@yahoo.com

**How to cite this paper:** Khameiss, B., Zubi, H. (2024) Diversity, Ecology, and Environmental Significance of Foraminifera in Al Hamama and Susah Coastal Regions, Northeastern Libya: Insights from Holocene Sediments. *Journal of Environmental Protection*, **15**, 13-25.
https://doi.org/10.4236/jep.2024.151002

**Received:** December 1, 2023
**Accepted:** January 9, 2024
**Published:** January 12, 2024



## Abstract

This research initiative, conducted along the coastal zones of Al Hamama and Susah in northeastern Libya, aimed to enhance our understanding of Holocene benthic foraminifera assemblages and the paleoenvironmental parameters in the region. We meticulously gathered five sediment samples to analyze the composition of foraminifera populations within the unconsolidated sedimentary deposits adjacent to these locations. We successfully identified nine distinct benthic foraminifera species, including *Amphistegina lobifera*, *Eliphidium crispum*, *Sigmoilinita tenuis*, *Sorites orbiculus*, *Stomatorbina concentrica*, *Peneroplis planatus*, *Pseudotriloculina rotunda*, *Pyrgoella sphaera*, and *Triloculina schreberiana*. Notably, *Eliphidium crispum* and *Amphistegina lobifera* emerged as the most prevalent species. These foraminifera species exhibited distinct ecological preferences, shedding light on paleoenvironmental conditions and climatic fluctuations during the Quaternary Period in the Susah and Al Hamama coastal regions. The presence of Orbulina universa, a planktonic foraminifera species, further enriched our understanding of the paleoenvironment by providing insights into specific water depths and temperature ranges. This research significantly contributes to paleoceanography and environmental reconstruction, highlighting the invaluable use of foraminifera as proxies for exploring past environmental changes. Additionally, the study investigated the impacts of anthropogenic influences on benthic ecosystems in the Al Hamama and Susah coastal areas. These influences included reworked foraminifera specimens and the effects of karst formations, acid rain, and eutrophication. Notably, human-induced factors have visibly affected biogenic fauna and ecosystem dynamics in the study area. Consequently, this research provides valuable insights into paleoenvironmental conditions and ecological dynamics within the Susah and Al Hamama coastal regions, emphasizing the crucial role of foraminifera in reconstructing historical environmental fluctuations.

## Keywords

Al Hamama, Susah, Northeastern Libya, Holocene Sediments

## 1. Introduction

Foraminifera, minute marine organisms, serve as crucial indicators of past environmental conditions due to their high sensitivity to climate variations. Their species composition, shell chemistry, and physical attributes are valuable proxies for reconstructing historical environments. Notably, the coiling direction of trochoidal foraminifera has been employed in paleoceanographic analyses. Interestingly, as far back as 1846, [1] D'Orbigny's discovery revealed the existence of approximately 1000 undiscovered foraminifera species within modern oceanic realms. Regional studies in the Mediterranean Sea have comprehensively documented the prevalence and distribution of shelf foraminifera. These investigations have unveiled geographical disparities in shelf fauna composition. The fauna exhibits distinctive microhabitat zonation within the fine-grained sediments of the Adriatic Sea and the Gulf of Lions, influenced by factors such as food availability and oxygen penetration into the sediment [2]-[7]. Our research endeavors to contribute novel insights into the diversity, distribution patterns, and ecological aspects of recent cool-water carbonate taxa in the Western Mediterranean. By establishing correlations between benthic foraminiferal faunas and environmental parameters, we aim to reconstruct historical environmental fluctuations, including quantitative sea-level reconstructions.

The environmental characteristics of the Mediterranean Sea are profoundly influenced by its geographical proximity to land. The narrow connection to the Atlantic Ocean significantly restricts tidal dynamics. A distinct and instantly recognizable feature of the Mediterranean is its vivid blue hue. Regarding hydrology, the Mediterranean experiences a substantial imbalance between evaporation and precipitation, as well as river runoff, which plays a pivotal role in determining the basin's water balance [8]. The eastern sector of the Mediterranean is characterized by notably high rates of evaporation, leading to declining water levels and a consequent rise in salinity as one moves eastward. At a depth of 5 meters, the average salinity registers at 38 Practical Salinity Units (PSU). Notably, the Mediterranean Sea's deepest point maintains a temperature of 13.2 degrees Celsius. Furthermore, the Mediterranean Sea contributes a substantial volume of water to the Atlantic Ocean, estimated at approximately 70,000 cubic meters per second, or an annual flow rate of $2.2 \times 10^{12}$ cubic meters ($7.8 \times 10^{13}$ cubic feet) [9] [10] [11] [12]. The Mediterranean Sea, covering an expanse of approximately 2,500,000 square kilometers (970,000 square miles), represents just 0.7% of the Earth's total oceanic surface. Despite its relatively modest size, its connection to the Atlantic Ocean through the narrow Strait of Gibraltar spans a mere 14 kilometers (9 miles) in width. This maritime domain is punctuated by numerous islands, some of which are of volcanic origin, with Sicily and Sardinia ranking as the largest in terms of land area and population.

The Mediterranean's average depth reaches 1500 meters (4900 feet), with the deepest point, recorded at 5109 meters (16,762 feet), located in the Calypso Deep within the Ionian Sea. Geographically, the Mediterranean is situated between the latitudes of 30 V and 46˚ North and the longitudes of 6˚ and 36 V East. Its elongated extent stretches approximately 4000 kilometers (2500 miles) from west to east, spanning from the Strait of Gibraltar to the Gulf of Alexandretta along Turkey's southern coast. The north-south axis of this maritime expanse exhibits significant variability, contingent upon the specific shoreline considered and the inclusion of only direct routes. The shortest navigational distance between the multinational Gulf of Trieste and the Libyan shores of the Gulf of Sidra measures approximately 1900 kilometers (1200 miles). The Mediterranean climate, characterized by mild winters and warm summer water temperatures, derives its nomenclature from the preponderance of precipitation during the cooler months. Coastal areas bordering the Mediterranean are subject to substantial maritime influences, while the southern and eastern coastlines are closely aligned with arid desert regions situated a short distance inland. [9] [11] [12].

## 2. Study Area

The Mediterranean Sea is made up of four major water bodies. The surface waters are made up of incoming Atlantic Water. At intermediate depths, Levantine Intermediate Water, which forms in the eastern Mediterranean Sea, is found. Both the Western and Eastern Mediterranean Deep Waters, which originate in the Gulf of Lions and the Adriatic and Aegean seas, bathe the basins with water that is less than 600 meters deep [12] [13] [14] [15]. The Susah and Al Hamamah Beaches in the Mediterranean Sea are two locations where the study area is situated in northeastern Libya as you see in **Figure 1**.

## 3. Materials and Methods

In the present investigation, five surface sediment samples were acquired from the designated locations. The estimation of sample volumes involved a wet-sieving process utilizing a 63 μm sieve. Subsequently, a portion of the material retained on the 63 μm sieve was subjected to drying at 60˚C. The samples underwent wet-sieving to ascertain the weight percentages within specific size fractions, namely >1000 μm, 1000 μm - 500 μm, 500 μm - 200 μm, 200 μm - 100 μm, 100 μm - 63 μm, and the <63 μm fraction. This meticulous procedure was conducted to elucidate the grain-size distribution of the sediment samples.

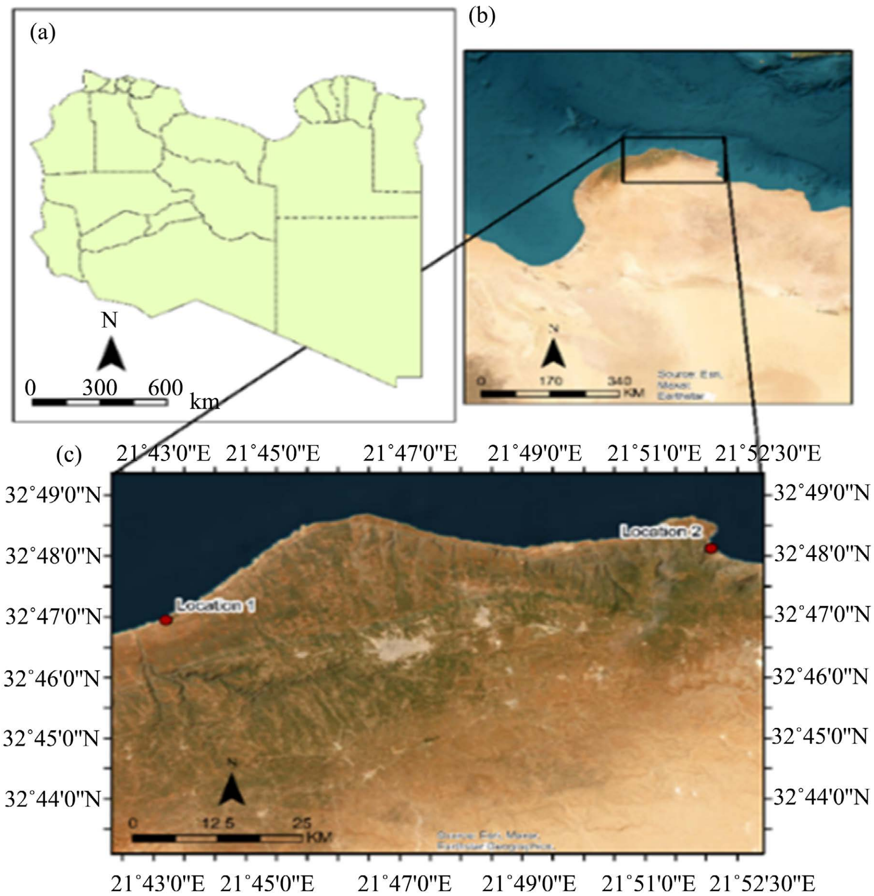


Figure 1. Shows the locations of the study areas. Google map.

## 4. Results

The results revealed that Amphisteginidae, Elphiididae, Haauerinidae, Mississippiinidae, Peneroplidae, and Soritidae are the only documented families. Considering the outcomes, the majority of benthic foraminifera species belong to the Haurinidae family, as seen in Figure 2.

In addtion, nine benthic foraminifera samples were collected: *Amphistegina lobifera*, *Eliphidium crispum*, *Sigmoilinita tenuis*, *Sorites orbiculus*, *Stomatorbina concetrica*, *Peneroplis planatus*, *Pseudotriloculina rotunda*, *Pyrgoella sphaera*, *and Triloculina schreberiana* . The highest species are *Eliphidium crispum*, *and Amphistegina lobifera* (Figure 3).

Only one family of planktonic foraminifera was found within the studied samples (Figure 4), which is the Globigernidae family. *Orbulina universa* is the only present species of the family (Figure 5), and no other species were found.

## 5. Discussion

**Biostratogphy and Paleoenviroment Impilication**

**Benthic Foraminifera**

*Amphistegina lobifera* thrives in warm and shallow waters, typically found at

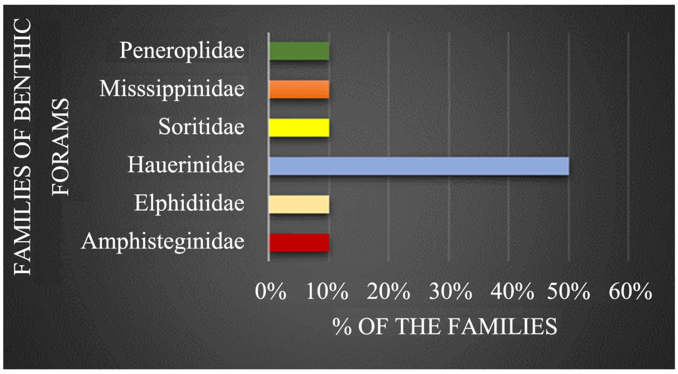


**Figure 2.** Shows the different families of benthic foraminifera.

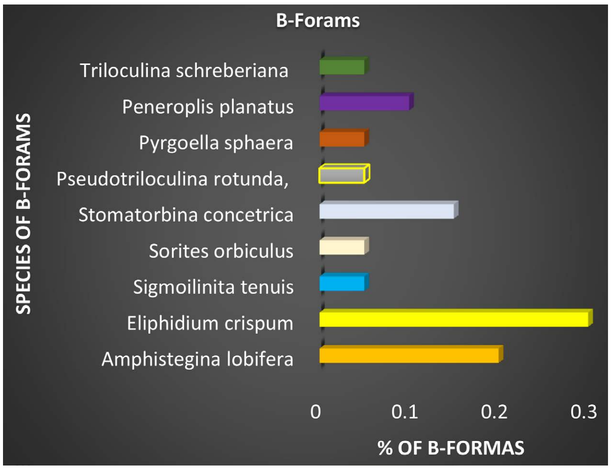


**Figure 3.** Shows the species of benthic foraminifera.

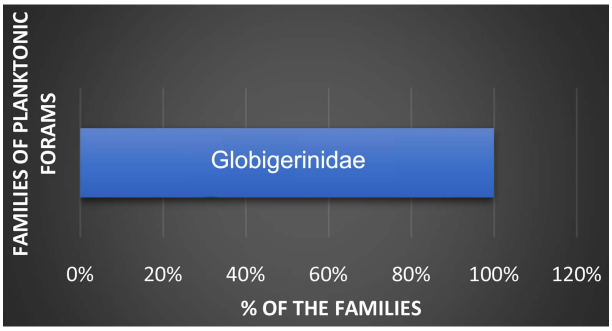


**Figure 4.** Shows the family of planktonic foraminifera.

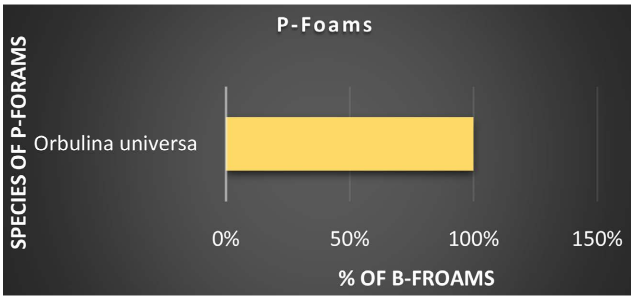


**Figure 5.** Shows the species of planktonic foraminifera.

depths of 50 meters (**Figure 6**). They mainly inhabit the seafloor areas between the coastline and coral reefs. Their tests are harder compared to other more fragile foram tests, making it possible for them to survive in water that is agitated by waves, found in quaternary by Larsen, A. R., 1976. *Eliphidium crispum* compared to the cold-water specimens (200 m) found by Cushman and Grant in 1927, this fauna is known from brackish-water paleoenvironments, found in quaternary [12] [16] [17] in the warm waters of Mexico. *Sigmoilinita tenuis* is a species of foraminifera that has been found from the Upper Aptian to the lower Albian stages of the Cretaceous period up to the recent times in Araripe [18] [19]. *Sorites orbiculus* Anthropogenic nutrient pollution is causing increased growth of epiphytic algae on seagrasses and macroalgae in the subtidal zone [20] *Stomatorbina concetrica* During the early stages of development, some marine organisms have an affinity for shallow environments that are associated with coralline algae (early Oligocene to recent). [21] *Peneroplis planatus* Lives under plants on the sand, preferring only sand. Light depth affects distribution beyond 40 m [22] [23] *Pseudotriloculina rotunda* is indicative of coastal lagoons, marshes, and other partially-barred brackish environments [24]. *Pyrgoella sphaera* this species is an Epinfaunal species found in well-ventilated lower bathyal and abyssal regions of the Mediterranean Sea, indicative of oligotrophic to mesotrophic environments [25] [26]. *Triloculina schreberiana* this species indicates that the period was marked by several sub-environments that were favorable to a variety of species. This could suggest the occasional opening of the barrier, heightened storm activity, or other factors that caused fluctuations in salinity and water depth during this time [27].

**Planktonic Foraminifera**

*Orbulina universa* was first found in the N9 zone during the Langhian stage and still exists to date. It is distributed globally from the Equator to subpolar regions, in both low and high latitudes. This means that it can be found in the sunlit waters of the euphotic zone in oceanic waters that are shallower than 100 m. In laboratory experiments, it has been observed to tolerate temperatures ranging from 17˚C - 23˚C [28] [29] [30] [31] [32].

**Paleobathymetric indicators**

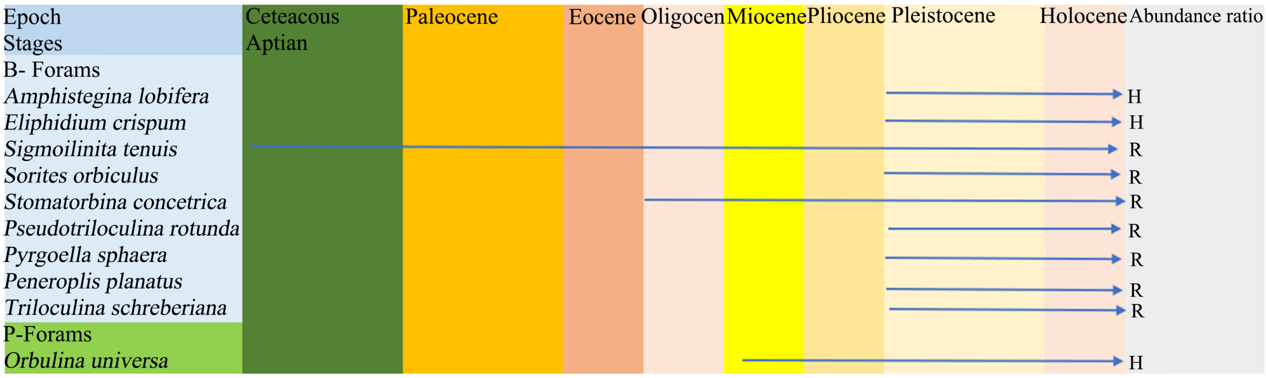


**Figure 6.** Age distribution of the planktonic and benthic foraminifera and their relative abundance (H-High).

The delineation of water depth is ascertained through the presence of benthic and planktonic foraminifera. These foraminifera, encompassing both the benthic and planktonic varieties, exhibit a consistent occurrence within the depth interval spanning from 50 to 100 meters beneath the sea's surface, as seen in **Figure 7**.

**Anthropogenic impacts**

In recent investigations, numerous benthic foraminifera originating from the Paleogene and Neogene epochs were unearthed along the coastal region, notably including specimens such as *Nummulite fabianii* and *Numulite Lyelli* [12]. These foraminifera represent reworked specimens likely originating from geological outcrops within the valley region, such as caves in the Darna and Al Baydah Formations.

One of the primary sources of potable freshwater is found within karst formations. This is attributed to the intrinsic porosity and permeability of the rock, enabling the diffusion of water throughout the entire mass of carbonate rock, rather than being confined solely to the principal discontinuity networks. The phenomenon popularly recognized as "acid rain" results from a combination of both wet and dry deposition processes from the atmosphere, typically characterized by elevated levels of nitric and sulfuric acids. This environmental issue has been exacerbated by recent increases in atmospheric carbon, leading to the creation of additional karst features and intensified acid rain, with direct consequences for the carbonate biogenic fauna present in the coastal areas. Subsequently, carbonate rocks began to undergo degradation, thereby compromising the preservation of these fossil remains by human-induced factors as you have seen in **Figure 8**.

The observed high-productivity indicators within the biocoenosis and their notable distinctions from the thanatocoenoses can be correlated with contemporary anthropogenic eutrophication within this region, primarily induced by the influx of sewage and litter due to acts of terrorism within the coastal areas of A Hamamah and Susah. Initial data from sediment cores obtained in this area, depicting benthic foraminiferal faunas during the preindustrial era, substantiate the notion of anthropogenic influences on the benthic ecosystems in A Hamamah and Susah. These faunas reveal the presence of only scant infaunal taxa.

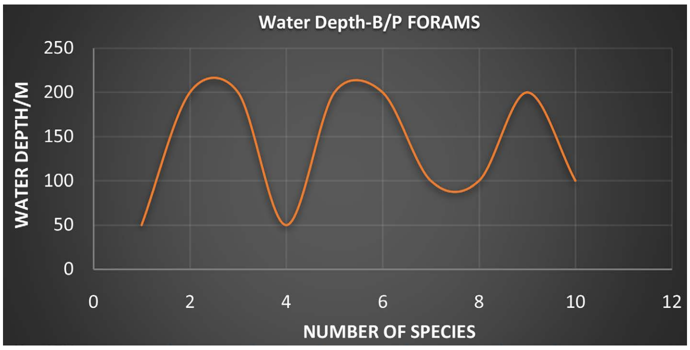


**Figure 7.** Displays the range of water depths for benthic and planktonic foraminifera.

Figure 8. Displays a doline located in the Darnah Formation, which is of Middle Eocene age and is situated in NE Libya.

**Paleontological Taxonomy**

**1) Benthic Foraminifera**

Amphisteginidae Cushman, 1927 [33]

Amphistegina d'Orbigny, 1826 [34]

*Amphistegina lobifera* Larsen, 1976 [35] (**Figure 9(a)**)

Elphidiidae Galloway, 1933 [36]

Elphidium de Montfort, 1808 [37]

*Eliphidium crispum* Linnaeus, 1758 [38] (**Figure 10(a)**)

Hauerinidae Schwager, 1876 [39]

Sigmoilinita Seiglie, 1965 [40]

*Sigmoilinita tenuis* Czjžek, 1848 [41] (**Figure 9(e)**)

Pseudotriloculina Cherif, 1970 [42]

*Pseudotriloculina rotunda* d'Orbigny in Schlumberger, 1893 [43] (**Figure 10(e)**)

Pyrgoella Cushman, and White, 1936 [44]

*Pyrgoella sphaera* d'Orbigny, 1839 [45] (**Figure 9(d)**)

Triloculina d'Orbigny, 1826 [34]

*Triloculina schreiberiana* d'Orbigny, 1839 [45] (**Figure 10(c)**)

Soritidae Ehrenberg, 1839 [45] in Loeblich, and Tappan, 1987 [46]

Sorites Ehrenberg, 1839 [45] in Loeblich, and Tappan, 1987 [46]

*Sorites orbiculus* Forsskål in Niebuhr, 1775 [47] (**Figure 9(c)**)

Mississippinidae Saidova, 1981 [48]

Stomatorbina Dorreen, 1948 [49]

*Stomatorbina concentrica*, [21] Parker, and Jones, 1864 (**Figure 9(b)**)

Peneroplidae Schultze, 1854 [20]

Peneroplis de Montfort, 1808 [37]

*Peneroplis planatus* Fichtel, and Moll, 1798 [50] (**Figure 10(b)**)

**2) Planktonic Foraminifera**

*Globigerinidae Carpenter* Parker, and Jones, 1862 [51]

Orbulina d'Orbigny, 1839 [45]

*Orbulina universa* d'Orbigny, 1839 [45] (**Figure 10(d)**)

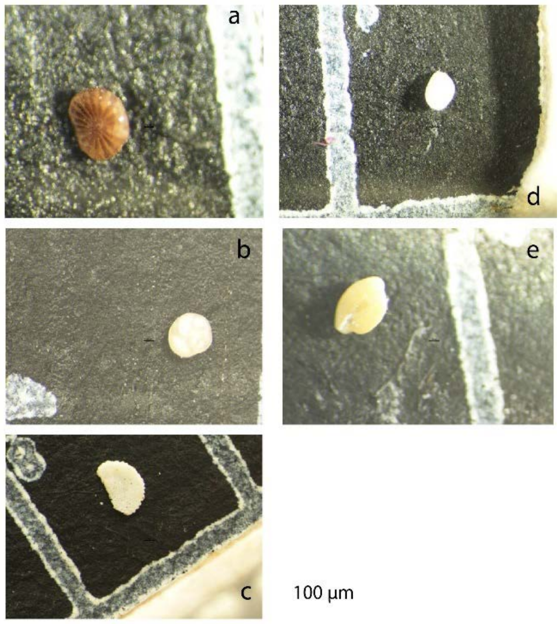


**Figure 9.** Benthic foraminifera species: (a) *Amphistegina lobifera*, (b) *Stomatorbina concentrica*, (c) *Sorites orbiculus*, (d) *Pyrgoella sphaera*, (e) *Sigmoilinita tenuis.*

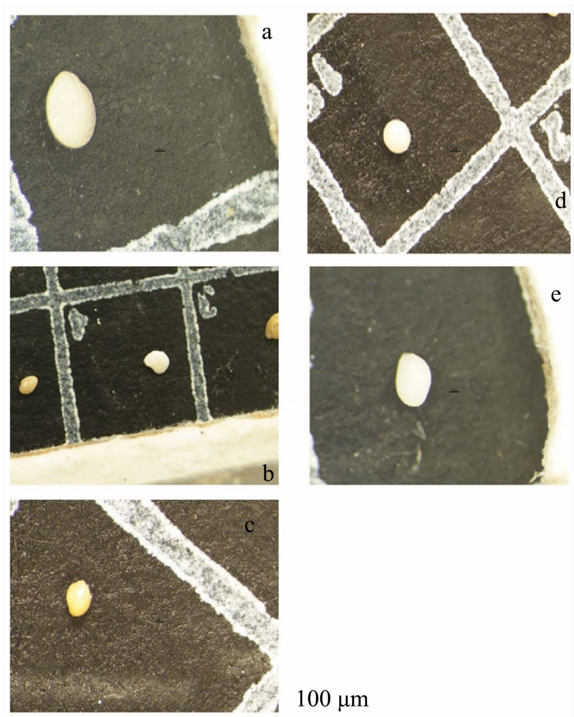


**Figure 10.** Benthic and planktonic foraminifera species: (a) *Eliphidium crispum*, (b) *Peneroplis planatus*, (c) *Triloculina schreberiana*, (d) *Orbulina universa*, (e) *Pseudotriloculina rotunda.*

## 6. Conclusions

The study conducted along the coastline of northeastern Libya's Al Hamama and Susah areas has provided valuable insights into the Holocene benthic foraminifera assemblage and paleoenvironmental conditions in this region. Nine benthic foraminifera species, including *Amphistegina lobifera*, *Eliphidium crispum*, *Sigmoilinita tenuis*, *Sorites orbiculus*, *Stomatorbina concetrica*, *Peneroplis planatus*, *Pseudotriloculina rotunda*, *Pyrgoella sphaera*, and *Triloculina schreberiana*, were identified, with *Eliphidium crispum* and *Amphistegina lobifera* being the most prominent species. These foraminifera species exhibited unique ecological preferences, shedding light on the environmental conditions of the Susah and Al Hamamah coastal regions during the Holocene.

Furthermore, the presence of *Orbulina universa*, a planktonic foraminiferal species, in the region provides additional insights into the paleoenvironment, as this species is indicative of specific water depths and temperature ranges. The study's findings contribute to the broader field of paleoceanography and environmental reconstruction, emphasizing the significance of foraminifera as valuable proxies for studying past environmental changes. The study also discussed the impact of anthropogenic factors on the benthic ecosystems in the A Hamamah and Susah coastal areas, including the presence of reworked foraminifera specimens and the influence of karst formations, acid rain, and eutrophication. These human-induced factors have had notable effects on the biogenic fauna and ecosystem dynamics in the study area. Overall, this research enhances our understanding of the paleoenvironment and ecological dynamics in the Susah and Al Hamamah coastal regions and underscores the importance of studying foraminifera in reconstructing past environmental changes.

## Acknowledgements

I express my sincere gratitude for the generous financial support provided, including funding for the project and photography by Dr. Ishamn. Special thanks are extended to Dr. Brendan for the invaluable funding assistance. Additionally, my appreciation goes to the entire Kansas Geological Survey for their support throughout this endeavor.

## Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

## References

[1] d'Orbigny, A.D. (1846) Die fossilen Foraminiferen des tertiären Beckens von Wien. Foraminifères fossiles du bassin tertiaire de Vienne, 312.

[2] Jorissen, F.J. (1987) The Distribution of Benthic Foraminifera in the Adriatic Sea. *Marine Micropaleontology*, **12**, 21-48. https://doi.org/10.1016/0377-8398(87)90012-0

[3] Cimerman, F. and Langer, M.R. (1991) Mediterranean Foraminifera. S.A.Z.i. Umetnosti. Academia Sciertiarum et Artium Slovenca.

[4] Mojtahid, M., Jorissen, F., Lansard, B., Fontanier, C., Bombled, B. and Rabouille, C. (2009) Spatial Distribution of Live Benthic Foraminifera in the Rhone Prodelta: Faun-

al Response to a Continental-Marine Organic Matter Gradient. *Marine Micropaleontology*, **70**, 177-200. https://doi.org/10.1016/j.marmicro.2008.12.006

[5] Barmawidjaja, D.M., Jorissen, F.J., Puskaric, S. and Van der Zwaan, G.J. (1992) Microhabitat Selection by Benthic Foraminifera in the Northern Adriatic Sea. *Journal of Foraminiferal Research*, **22**, 297-317. https://doi.org/10.2113/gsjfr.22.4.297

[6] Jorissen, F.J., Barmawidjaja, D.M., Puskaric, S. and Van der Zwaan, G.J. (1992) Vertical Distribution of Benthic Foraminifera in the Northern Adriatic Sea: The Relation with the Organic Flux. *Marine Micropaleontology*, **19**, 131-146. https://doi.org/10.1016/0377-8398(92)90025-F

[7] Schmiedl, G., de Bovée, F., Buscail, R., Charrière, B., Hemleben, C., Medernach, L. and Picon, P. (2000) Trophic Control of Benthic Foraminiferal Abundance and Microhabitat in the Bathyal Gulf of Lions, Western Mediterranean Sea. *Marine Micropaleontology*, **40**, 167-188. https://doi.org/10.1016/S0377-8398(00)00038-4

[8] El Sakran, S., Khameiss, B. and Faraj, H. (2016) Tertiary Stratigraphic Map, Correlation and Cross Section of the Daryanah Al Abyar Area, Al Jabal Al Akhdar, NE Libya. *International Journal of Scientific & Engineering Research*, **7**, 2193-2208. https://doi.org/10.1130/abs/2016AM-277641

[9] Pinet, P.R. (2008) Invitation to Oceanography. *Paleoceanography*, **30**, 220.

[10] Ellenberg, L. (1981) Die Meerenge von Gibraltar: Küstenmorphologie zwischen Mittelmeer und Atlantik. *Geographica Helvetica*, **36**, 109-120. https://doi.org/10.5194/gh-36-109-1981

[11] Khameiss, B., Hamed, A., Hdhireia, A.L. and Al bagaa, N. (2015) Geological Tourism Northeast Libya. *AEG* 58 *Annual Meeting* 2015, Pittsburgh, 19-26 September 2015, 67.

[12] Khameiss, B. and Zubi, H. (2020) A Primarily Study of Benthic Foraminifera from Susah and Al Hamamah Beaches, Northeast Libya. *Abstracts with Programs*, **52**, Paper No. 187-7. https://doi.org/10.1130/abs/2020AM-359379

[13] Robinson, A.R., Leslie, W.G., Theocharis, A. and Lascaratos, A. (2001) Mediterranean Sea Circulation. *Encyclopedia of Ocean Science*, **3**, 1689-1705. https://doi.org/10.1006/rwos.2001.0376

[14] Masque, P., Fabres, J., Canals, M., Sanchez-Cabeza, J.A., Sanchez-Vidal, A., Cacho, I., Calafat, A.M. and Bruach, J.M. (2003) Accumulation Rates of Major Constituents of Hemipelagic Sediments in the Deep Alboran Sea: A Centennial Perspective of Sedimentary Dynamics. *Marine Geology*, **193**, 207-253. https://doi.org/10.1016/S0025-3227(02)00593-5

[15] Rixen, M., Beckers, J.-M., Levitus, S., Antonov, J., Boyer, T., Maillard, C., Fichaut, M., Balopoulos, E., Iona, S., Dooley, H., Garcia, M.-J., Manca, B., Giorgetti, A., Manzella, G., Mikhailov, N., Pinardi, N., Zavatarelli, M. and Medar Consortium (2005) The Western Mediterranean Deep Water: A Proxy for Climate Change. *Geophysical Research Letters*, **32**, L12608.

[16] Yanko, V. and Troitskaja, T.S. (1987) Late Quaternary Foraminifera of the Black Sea. Trudy Instituta Geologii i Geofisiki, Akademiya Nauk SSSR, Novosibirsk, 694, 111. (In Russian)

[17] Yanko, V. (1990) Stratigraphy and Paleogeography of the Marine Pleistocene and Holocene Deposits of the Southern Seas of the USSR. *Memorie della Societa Geologica Italiana*, **44**, 167-187.

[18] Araripe, R., Lemos, F., Prado, L., Tomé, M., Oliveira, D., Pereira, P., Asakura, L.Y., Ng, C., Viviers, M. and Barreto, A. (2022) Upper Aptian-Lower Albian of the Southern-Central Araripe Basin, Brazil: Microbiostratigraphic and Paleoecological

Inferences. *Journal of South American Earth Sciences*, **116**, Article ID: 103814. https://doi.org/10.1016/j.jsames.2022.103814

[19] Kaminski, M.A., Aksu, A., Box, M., Hiscott, R.N., Filipescu, S. and Al-Salameen, M. (2002) Late Glacial to Holocene Benthic Foraminifera in the Marmara Sea: Implications for Black Sea-Mediterranean Sea Connections Following the Last Deglaciation. *Marine Geology*, **190**, 162-202. https://doi.org/10.1016/S0025-3227(02)00347-X

[20] Fujita, K. and Hallock, P. (1991) A Comparison of Phytal Substrate Preferences of *Archaias angulatus* and *Sorites orbiculus* in Mixed Macroalgal-Seagrass Beds in Florida Bay. *Journal of Foraminiferal Research*, **29**, 143-151. https://doi.org/10.2113/gsjfr.29.2.143

[21] Parker and Jones (1864) On the Foraminifera of the Crag. (Ann. Nat. Hist. 3rd ser. vol. xiii) London.

[22] Faber, W. (1991) Distribution and Substrate Preference of *Peneroplis planatus* and *P. arietinus* from the Halophila Meadow near Wadi Taba, Eilat, Israel. *Journal of Foraminiferal Research*, **21**, 218-221. https://doi.org/10.2113/gsjfr.21.3.218

[23] Rottger, R. (1972) Die Kultur von *Heterostegina depressa* (Foraminifera: Nummulitidae). *Marine Biology*, **15**, 150-159. https://doi.org/10.1007/BF00353643

[24] Curzi, P., Dinelli, E., Lucchi, M. and Vaiani, S. (2006) Palaeoenvironmental Control on Sediment Composition and Provenance in the Late Quaternary Deltaic Successions: A Case Study from the Po Delta Area (Northern Italy). *Geological Journal*, **41**, 591-612. https://doi.org/10.1002/gj.1060

[25] Mullineaux, L.S. and Lohmann, G.P. (1981) Late Quaternary Stagnations and Recirculation of the Eastern Mediterranean: Changes in the Deep Water Recorded by Fossil Benthic Foraminifera. *Journal of Foraminiferal Research*, **11**, 20-39. https://doi.org/10.2113/gsjfr.11.1.20

[26] De Rijk, S., Troelstra, S.R. and Rohling, E.J. (1999) Benthic Foraminiferal Distribution in the Mediterranean Sea. *Journal of Foraminiferal Research*, **29**, 93-103. https://doi.org/10.2113/gsjfr.29.2.93

[27] Peros, M., Gregory, B., Matos, F., Reinhardt, E. and Desloges, J. (2015) Late-Holocene Record of Lagoon Evolution, Climate Change, and Hurricane Activity from Southeastern Cuba. *The Holocene*, **25**, 1483-1497. https://doi.org/10.1177/0959683615585844

[28] Be, A.W.H. (1968) Shell Porosity of Recent Planktonic Foraminifera as a Climatic Index. *Science*, **161**, 881-884. https://doi.org/10.1126/science.161.3844.881

[29] Vilks, G. and Walker, D.A. (1974) Morphology of *Orbulina universa* d'Orbigny in Relation to Other Spinose Planktonic Foraminifera. *Journal of Foraminiferal Research*, **4**, 1-8. https://doi.org/10.2113/gsjfr.4.1.1

[30] Aze, T., Ezard, T.H., Purvis, A., Coxall, H.K., Stewart, D.R. and Wade, B.S. (2011) A Phylogeny of Cenozoic Microperforate Planktonic Foraminifera from Fossil Data. *Biological Reviews of the Cambridge Philosophical Society*, **86**, 900-927. https://doi.org/10.1111/j.1469-185X.2011.00178.x

[31] Kennett, J.P. and Srinivasan, M.S. (1983) Neogene Planktonic Foraminifera: A Phylogenetic Atlas. Hutchinson and Ross, Stroudsburg, 265.

[32] Khameiss, B., Ishman, S., Ariza D., Zamora, A. and Franseen, E. (2023) Chapter Six. The Importance of Foraminifera in Providing Paleoecologic and Biostratigraphic Information for a Miocene Tropical Carbonate System: Cicuco Field, NW Colombia. In: Montenari, M., Ed., *Stratigraphy & Timescales*, Volume 8, Academic Press, Cambridge, 237-263. https://doi.org/10.1016/bs.sats.2023.08.008

[33] Cushman, J.A. and Grant, U.S. (1927) Late Tertiary and Quaternary Elphidiums of the West Coast of North America. *Transactions of the San Diego Society of Natural History*, **5**, 69-82. https://doi.org/10.5962/bhl.part.11740

[34] d'Orbigny, A.D. (1826) Tableau méthodique de la classe des Céphalopodes. *Annales des Sciences Naturelles*, **7**, 96, 245-314.

[35] Larsen, A.R. (1976) Studies of Recent Amphistegina, Taxonomy and Some Ecological Aspects. *Israel Journal of Earth-Sciences*, **25**, 1-26.

[36] Galloway, J.J. (1933) A manual of Foraminifera. James Furman Kemp Memorial Series. Publication No. 1, Principia Press, Bloomington, 483.

[37] de Montfort (1808) Conchyliologie Systématique et Classification Méthodique de Coquilles, 1.

[38] Linnaeus, C. (1758) Systema Naturae per regna tria naturae, secundum classes, ordines, genera, species, cum characteribus, differentiis, synonymis, locis. Editio decima, reformata, 1, 824.

[39] Schwager, C. (1876) Saggio di una classificazione dei foraminiferi avuto riguardo alle loro famiglie naturali, Bolletino R. *Comitato Geologico d'Italia*, **7**, 475-485.

[40] Seiglie, G.A. (1965) Some Observations on Recent Foraminifers from Venezuela, Part I. *Contributions from the Cushman Foundation for Foraminiferal Research*, **16**, 70-73.

[41] Cžjžek, J. (1848) Beitrag zur Kenntniss der fossilen Foraminiferen des Wiener Beckens. *Haidinger's Natur-wissenschaftliche Abhandlungen*, **2**, 137-150.

[42] Cherif, O.H. (1970) Die Miliolacea der Westküste von Naxos (Griechenland) und ihre Lebensbereiche. Dissertation Facultät Natur-und Geisteswissenschaften Technischen Universität Clausthal, Clausthal, 176.

[43] Schlumberger, C. (1893) Monographie des Miliolidées du Golfe de Marseille. *Mémoires de la Société zoologique de France*, **6**, 57-80.

[44] Cushman, J.A. and White, E.M. (1936) Pyrgoella, a New Genus of the Miliolidae. *Contributions from the Cushman Laboratory for Foraminiferal Research*, **12**, 90-91.

[45] d'Orbigny, A.D. (1839) Voyage dans l'Amérique Méridionale. *Foraminifères*, **5**, 1-86.

[46] Loeblich, A.R. and Tappan, H. (1987) Foraminiferal Genera and Their Classification. Van Nostrand Reinhold Company, New York, 970. https://doi.org/10.1007/978-1-4899-5760-3

[47] Niebuhr, C. (1775) Descriptiones animalium avium, amphibiorum, piscium, insectorum, vermium; quae in itinere orientali observavit Petrus Forskål. Post mortem auctoris edidit Carsten Niebuhr. Hauniae, 22-76.

[48] Saidova, K.M. (1981) Taxonomy of Cenozoic Benthic Foraminifera. On an Up-to-Date System of Supraspecific Taxonomy of Cenozoic Benthonic Foraminifera. Akademiya Nauk, Kamchatka, 1-73.

[49] Dorreen, J.M. (1948) A Foraminiferal Fauna from the Kaiatan Stage (Upper Eocene) of New Zealand. *Journal of Paleontology*, **22**, 281-300.

[50] Fichtel, L.V. and Moll, J.P.C. (1798) Testacea microscopica aliaque minuta ex generibus argonauta et nautilus ad naturam delineata et descripta.

[51] Carpenter, W.B., Parker, W.K. and Jones, T.R. (1862) Introduction to the Study of the Foraminifera. The Ray Society by R. Hardwicke, London, 1-319.