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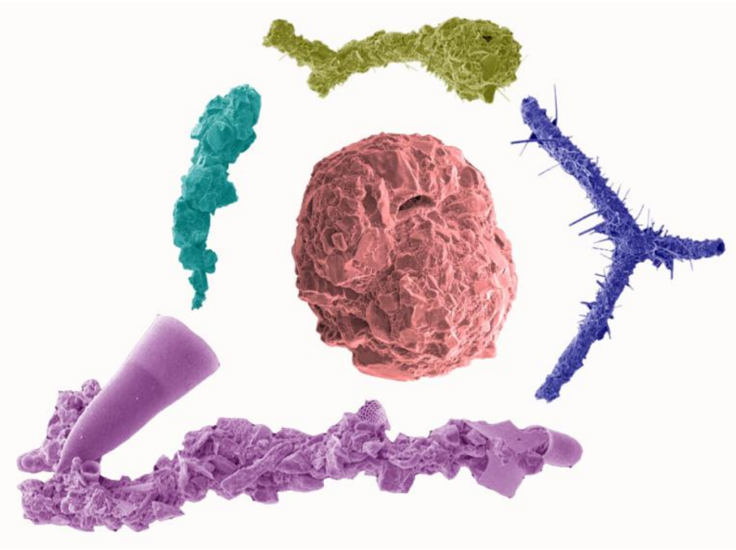
THE BIOGENIC CONTENT IN THE SURFACE SEDIMENTS FROM THE DEEP SOUTH AEGEAN BASINS



MASTER THESIS

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THE BIOGENIC CONTENT IN THE SURFACE SEDIMENTS FROM THE DEEP SOUTH AEGEAN BASINS

Το βιογενές περιεχόμενο των επιφανειακών ιζημάτων στις βαθιές λεκάνες του Νοτίου Αιγαίου

Υποβλήθηκε στο ΔΠΜΣ Παλαιοντολογία-Γεωβιολογία

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The biogenic content in the surface sediments from the deep South Aegean basins–
Master Thesis

Το βιογενές περιεχόμενο των επιφανειακών ιζημάτων στις βαθιές λεκάνες του Νοτίου
Αιγαίου– *Μεταπτυχιακή Διπλωματική Εργασία*

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Περίληψη

Η παρούσα διπλωματική εργασία, πραγματοποιήθηκε σε επιφανειακά ιζήματα σε βάθη από 335m-2150m, στην θαλάσσια περιοχή του Κεντρικού-Νοτίου Αιγαίου και τη βορειοδυτική θάλασσα του Λεβάντε. Ανέδειξε βιογενές περιεχόμενο, αποτελούμενο από πλαγκτονικά, βενθονικά τρηματοφόρα, οστρακώδη, ωτόλιθους και πτερόποδα.

Παρατηρήθηκαν διακυμάνσεις στη συγκέντρωση του βιογενούς περιεχομένου μεταξύ των σταθμών δειγματοληψίας: Τα δείγματα που συλλέχθηκαν από τους σταθμούς 2MSFD6 και 2MSFD7 παρουσιάσαν την υψηλότερη συγκέντρωση βιογενούς περιεχομένου σε σύγκριση με όλα τα άλλα δείγματα. Τα δείγματα αυτά παρουσίασαν επίσης τα υψηλότερα ποσοστά συμμετοχής των πλαγκτονικών τρηματοφόρων και τα χαμηλότερα ποσοστά των βενθονικών τρηματοφόρων (κυρίως συμφυρματοπαγών) και των οστρακωδών ενώ τα πτερόποδα ηταν ιδιαίτερα άφθονα.

Στα δείγματα 2MSFD9 και 2MSFD10, τα οποία συλλέχθηκαν δειγματοληπτικά από τη κατώτερη βαθύαλη ζώνη βόρεια της Κρήτης, παρουσίασαν παρόμοια χαρακτηριστικά στο βιογενές περιεχόμενο με τα δείγματα 2MSFD6 και 2MSFD7. Ωστόσο ο σταθμός 2MSFD9, έχει υψηλή συγκέντρωση βιογενούς περιεχομένου ενώ ο σταθμός 2MSFD10, οποίος είναι ο βαθύτερος σταθμός δειγματοληψίας, περιείχε τη χαμηλότερη συγκέντρωση βιογενούς περιεχομένου σε σύγκριση με τους άλλους σταθμούς χαμηλότερου βάθους.

Το βιογενές περιεχόμενο του δείγματος 2MSFD5(νοτιοανατολικά της Κρήτης, κατώτερη βαθύαλη ζώνη), είναι συγκρίσιμο με αυτό του δείγματος 2MSFD8 (νοτιοανατολικά της Πελοποννήσου, ανώτερη βαθύαλη ζώνη), τόσο σε αφθονία όσο και σε σύνθεση, παρουσιάζοντας τα υψηλότερα ποσοστά συμμετοχής βενθονικών ασβεστολιθικών τρηματοφόρων.

Τέλος τα δείγματα 2MSFD11 και 2MSFD12,τα πιο ρηχά δείγματα που συλλέχθηκαν από την θαλάσσια περιοχή των Κυκλάδων παρουσίασαν τις χαμηλότερες συγκεντρώσεις βιογενούς περιεχομένου. Το βιογενές περιεχόμενο των σταθμών αυτών χαρακτηρίζεται από χαμηλή παρουσία πτεροπόδων. Τα βενθονικά ασβεστιτικά τρηματοφόρα παρουσίασαν την υψηλότερη σχετική αφθονία από τα συμφυρματοπαγή βενθονικά τρηματοφόρα. Επιπλέον στους σταθμούς αυτούς τα οστρακώδη παρουσίασαν υψηλά ποσοστά συμμετοχής.

Όσον αφορά τη μελέτη των συνανθροίσεων των βενθονικών τρηματοφόρων , είναι η πρώτη φορά που περιγράγονται οι συνανθροίσεις των βενθονικών συμφυρματοπαγών τρηματοφόρων, της βαθύαλης ζώνης, σε βάθη έως και 2150m στην θαλάσσια περιοχή του Νοτίου Αιγαίου Πελάγους.

Ο δείκτης διαφοροποίησης Shannon-Wiener (H’), για τα βενθονικά τρηματοφόρα παρουσιάζει κανονική τάση, καθώς μειώνεται από τα ρηχότερα στα βαθύτερα περιβάλλοντα. Τα ποσοστά συμμετοχής των υαλωδών έναντι των συμφυρματοπαγών τρηματοφόρων υποδεικνύουν πως τα συμφυρματοπαγή είδη επικρατούν έναντι των πρώτων, στα βαθύτερα δείγματα (με εξαίρεση το δείγμα 2MSFD5), ενώ υπάρχει αντίθετη τάση για τα ρηχότερα δείγματα.

Στα δείγματα διακρίθηκαν τρεις διαφορετικές συναθροίσεις ασβεστολιθικών τρηματοφόρων. Η συνάθροιση των ανώτερων βαθύαλων δειγμάτων (2MSFD8, 2MSFD11, 2MSFD12) η οποία αποτελείται από τα ρηχά ενδοπανιδικά είδη, *Bolivina*, *Bulimina*, *Cassidulina* and *Globocassidulina*. Η συνάθροιση των δειγμάτων 2MSFD9 and 2MSFD10 (τα βαθύτερα δείγματα νότια της Κρήτης), στην οποία κυριαρχεί το επιφανειακό είδος *Gyroidina*. Τέλος, η συνάθροιση των τριών σταθμών δειγματοληψίας προς τη θάλασσα του Λεβάντε, η οποία αποτελείται από τους σταθμούς (2MSFD5, 2MSFD6, 2MSFD7) και αποτελείται από ενδοπανιδικά και επιφανειακά είδη, *Gyroidina*, *Melonis*, *Uvigerina Bolivina* and *Bulimina*.Τα συμφυρματοπαγή τρηματοφόρα παρουσιάζουν δενδροειδή, σωληνοειδή και σφαιρικά είδη και συνολικά 13 γένη και 9 είδη έχουν αναγνωριστεί μέχρι στιγμής.

Στα συμφυρματοπαγή τρηματοφόρα, το είδος *Saccorhiza ramosa* είναι το πιο άφθονο ενώ τα άλλα είδη που μελετήθηκαν είναι τα *Rhabdamminella* cylindrica, *Rhizammina algaeformis*, *Glomospira charoides* και *Psammosiphonella* spp. Επίσης το *Psammosphaera fusca* και είδη *Bathysiphon*, *Marsipella*, *Hyperammina*, *Reophax*, *Cribrostomoides*,

Ammoscalaria και *Ammodiscus*. Τέλος τα συγκεκριμένα τάξα είναι επιφανειακά είδη εκτός του *Reophax*, το οποίο ζει σε ολιγοτροφικές συνθήκες.

Η αφθονία των των επιφανειακών συμφυρματοπαγών τρηματοφόρων και η κυριαρχία των ειδών *Gyroidina*, στα βαθύτερα δείγματα βόρεια της Κρήτης, υποδηλώνουν ολιγοτροφικές συνθήκες υψηλού οξυγόνου.

Τέλος, η μελέτη των πολυκυκλικών αρωματικών υδρογονανθράκων (PAHs), πραγματοποιήθηκε από το ΕΛΚΕΘΕ προκειμένου να εκτιμηθούν τυχόν χημικοί ρύποι στο θαλάσσιο περιβάλλον. Οι συνολικές συγκεντρώσεις των (PAHs), μπορούν να συγκριθούν με εκείνες που αναφέρονται σε μη μολυσμένες παράκτιες τοποθεσίες της Μεσογείου και υπεράκτιες τοποθεσίες ανοιχτής/ βαθιάς θάλασσας στο Αιγαίο Πέλαγος, καθώς και σε άλλες περιοχές της βορειοδυτικής, κεντρικής και ανατολικής Μεσογείου.

Abstract

The present thesis was conducted on surface sediments at depths ranging from 335m-2150m of the deep southern Aegean Sea and the northwestern Levantine Basin in the eastern Mediterranean. The study emphasizes on the biogenic content, consisting of planktonic, benthic foraminifera, ostracods, otoliths, and pteropods.

Variations were observed in the concentration of the biogenic content between the sampling stations:

Samples collected from the stations towards the northwestern Levantine basin (2MSFD6 and 2MSFD7) presented the highest concentration of biogenic component compared to all the other samples. These samples presented also the highest participation rates of planktonic foraminifera and the lowest ones of benthic foraminifera (mainly agglutinated) and ostracods, while pteropods were particularly abundant. The biogenic component of samples 2MSFD9 and 2MSFD10, which were sampled from the lower bathyal zone northern of Crete Island, present similar characteristics with samples 2MSFD6 and 2MSFD7. However, 2MSFD9 has a high concentration of biogenic component, while 2MSFD10 from the deepest station contained the lowest concentration of biogenic component compared to the other lower bathyal stations.

The biogenic component of sample 2MSFD5 (southeastern of Crete, lower bathyal zone) is comparable to the one of 2MSFD8 (southeastern of Peloponnese, upper bathyal zone), both in abundance and composition, presenting the highest participation rates of benthic calcareous foraminifera.

Finally, samples 2MSFD11 and 2MSFD12, the shallowest samples collected from the Cyclades plateaux area, presented the lowest concentrations of biogenic component. Their biogenic component is characterized by the low presence of pteropods, calcareous BF have higher relative abundances than agglutinated BF and the high participation rates of ostracods.
Concerning benthic foraminiferal assemblages, it is the first time that such deep-lower bathyal assemblages of agglutinated taxa are described from the broader area of the Aegean Sea.

The Shannon-Wiener diversity index (H') for benthic foraminifera exhibits a regular trend, decreasing from shallower to deeper environments. The participation rates of planktonic foraminifera versus agglutinated foraminifera indicate that agglutinated species prevail over the former in deeper samples (except 2MSFD5), while there is an opposite trend for shallower samples.

Three different assemblages of calcareous foraminifera were distinguished. The assemblage of upper bathyal samples (2MSFD8, 2MSFD11, 2MSFD12) consists of shallow infaunal species, while the assemblage of samples 2MSFD9 and 2MSFD10 (the deepest samples south of Crete) is dominated by the epifaunal species *Gyroidina*. Finally, the assemblage of the three sampling stations towards the Levantine Sea consists of both infaunal and epifaunal species.

At the agglutinated foraminifera, the species *Saccorhiza ramosa* is the most abundant, while other studied species include *Rhabdamminella cylindrica, Rhizammina algaeformis, Glomospira charoides*, and *Psammosiphonella* spp., as well as *Psammosphaera fusca* and species of *Bathysiphon*, *Marsipella*, *Hyperammina*, *Reophax*, *Cribrostomoides, Ammoscalaria, and Ammodiscus*. These taxa are mainly epifaunal species, except of *Reophax*, which lives in oligotrophic conditions.

The abundance of epifaunal agglutinated foraminifera and the dominance of *Gyroidina* species in deeper samples north of Crete indicate oligotrophic conditions with high oxygen levels.

Finally, the study of polycyclic aromatic hydrocarbons (PAHs) was conducted by HCMR to assess any chemical pollutants in the marine environment. The total concentrations of PAHs can be compared to those reported in non-polluted coastal sites of the Mediterranean and offshore open deep sea locations in the Aegean Sea, as well as in other areas of the northwestern, central, and eastern Mediterranean.

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Sincerely I thank my supervisor Assistant Professor Tsourou Theodora for believing in me and helping me to explore the micropaleontology and the micro-world of deep sea. Her support, knowledge and guidance were decisive for the completion of this master thesis.

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I dedicate my thesis to my grandmother Panagiota.

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List of Abbreviations

AEDW	Aegean Deep Water
AEIW	Aegean Intermediate Water
BC	Box Corer
BF	Benthic Foraminifera
BSW	Black Sea Water
EMDW	Eastern Mediterranean Deep Water
IOL	Inner Organic Layer
LIW	Levantine Intermediate Water
LSW	Levantine Surface Water
MAW	Modified Atlantic Water
Ma	Million years
MMJ	Mid Mediterranean Jet
MSFD	Station
NE	Northeast
SST	Sea Surface Temperature
SSS	Sea Surface Salinity
OOL	Outer Organic Layer
P/B	Planktonic/ Benthic
SE	Southeast
SEM	Scanning Electron Microscope
WoRMS	World Register of Marine Species

1. Introduction

1.1 Aim of Study

Aim of this research is to record the biogenic content of the samples collected from the surface sediments of the deep southern Aegean Sea and the northwestern Levantine Basin in the eastern Mediterranean. This is the first time that such an effort is taking place for the bathyal Aegean environments. The study emphasizes on the qualitative and quantitative analysis of the benthic foraminifera group, focusing on the agglutinated forms.

1.2 Distribution of recent microfaunal assemblages from the deep sea bottom sediments

The study of the biogenic material of the deep ocean is a significant research item because it offers important information in understanding the deposition of organic and inorganic matter in the Ocean (e.g., Honjo et al., 1982), the distribution, classification and succession of micropaleontological groups such as planktonic (e.g., Mohtadi et al., 2007) and benthic foraminifera (e.g., Herguera, 1992; Rijk et al., 2000).In addition, it contributes to the study of oxygen and carbon isotopic values (δ18O), (δ13 C), the minerals such as opal and the CaCO3 contents in the bottom sediments (e.g., Mohtadi et al., 2007).

The biogenic particles which are deposited through the water column at the ocean, consist of particulate organic matter and carbonate and opaline shells (Honjo et al., 1981). The Mediterranean Sea is characterized by 10ºC warmer water compared with the deep-sea oceanic water, leading to accelerated degradation of organic matter in the water column (Rijk et al., 2000). In the Atlantic and Pacific Oceans, the 60-90% of the total organic flux is of biogenic origin (Honjo et al., 1981)

The patterns of presence – absence and distribution of the recent benthic foraminifera present differences between the main eastern and western Mediterranean Sea. The foraminiferal distribution, abundance and diversity decrease from the western to eastern Mediterranean basins, following the general decrease of surface productivity (De Rijk et al., 1999; 2000). most eutrophic taxa became increasingly rare eastward as a result of the decreasing organic flux towards the east, eutrophic taxa decrease in abundance, while oligotrophic taxa move to shallower environments (De Rijk et al., 2000). Of course, there are exceptions especially in small basins, as for example the case of Alkyonides Bay (Gulf of Corinth, central Greece) where intense river flow and seismic activity enriched in nutrients the bottom sediments forming eutrophic conditions (Triantaphyllou et al., 2022).

The recent assemblages of deep-sea benthic foraminifera have been extensively studied by scientists in both the Atlantic (e.g., Schnitker, 1980; Lintner et al., 2021), as well as throughout the Mediterranean (e.g., Jorissen, 1987; Rostami et al., 2023; in the Adriatic Sea; Lubinevsky et al.,2017; Hyams-Kaphzan et al., 2018 in the Levantine Basin; Triantaphyllou et al., 2022 in the Alkyonides Bay (Corinth Gulf, Greece); Frontalini 2014; 2015; 2018 in the Northern Aegean Sea, the Saros Bay) and the Marmara Sea (e.g., Alavi, 1988; Chendes et al., 2004)

In the present master thesis, the distribution of the recent microfaunal assemblages was studied from the bathyal bottom sediments from the South Aegean Sea. The sampling depths are up to 335m with deeper the 2150m. Mainly qualitative as well as general quantitative data are presented about planktonic and benthic foraminifera, ostracods, otoliths and pteropods. Finally, the study focuses on benthic foraminifera including deep sea agglutinated foraminifera, which are described for the first time from this area.

Concerning eastern Mediterranean area, there are some studies about agglutinated foraminifera from the Northern Aegean Sea at Saros Bay, from the easternmost part of the Mediterranean Sea at the Levantine Basin. Also, there are studies about this group from the Marmara Sea.

Frontalini et al. (2014) studied the distribution of the agglutinated foraminifera at the inner neritic- to mid-bathyal zones of the Saros Bay and they founded 96 agglutinated species which belonging to 51 genera. At the shallowest environments they observed the lowest species richness because of the salinity of the Black Sea. At depths 80-200m they observed the highest diversity and lowest dominance. At depths 200-500m they found mainly epifaunal taxa and good diversity. Also, in another study Frontalini et al. (2015) studied the biodiversity of the calcareous and agglutinated foraminifera at the inner-middle neritic zone (<100m depth), the outer neritic zone (100-200m depth) and the upper bathyal zone (200-500m depth). Frontalini et al. (2018) studied the agglutinated vs. calcareous assemblages as bathymetric proxies. This study concluded that the agglutinated and calcareous benthic foraminifera provide robust quantitative proxies of water depth.

Hyams-Kaphzan et al. (2018) studied live and dead deep-sea foraminifera from the Levantine Sea and their ecological characteristics. In total, they found 200 dead and live taxa, of which 152 identified to species level and 44 taxa to genus level. They distinguished six live foraminiferal assemblages inhabiting six biotopes (based on their bathymetric distribution) and dead communities were divided into four biotopes.

Frontalini et al. (2011) studied the bathymetric distribution and ecology of agglutinated foraminifera along the inner neritic to upper transect in the Marmara Sea, and they found 50 agglutinated species belonging to 36 genera. They suggested that high diversity is found at water depths shallower than 150 m, associated with the inflow of Mediterranean counter-current bringing more oxygenated and saline waters. Also, other studies about agglutinated foraminifera in this area are e.g., Chendes et al. (2004) which they found large numbers of some agglutinated taxa in the mixing zone between the water masses and Chatelet et al. (2013) who studied the agglutinated foraminifera and the mineral diversity of their shells from the Marmara Sea, Saros Bay and western – northern Lesbos Island. They concluded that the test chemistry is controlled by the availability of minerals and the geological setting of the study area. The agglutinated tests of this area are characterized by a high content of fresh mafic feldspar and amphibole due to the active tectonic setting of the Aegean and Marmara Seas.

1.3 Benthic Foraminifera

Benthic foraminifera (Kingdom Protista) are single-celled, eukaryotic, marine organisms found throughout all the marine realm from the coastal brackish environments down to the deep sea (Holbourn et al., 2013; Holzmann et al., 2021)**.** Living individuals have been also found in freshwater, and terrestrial habitats (Lejzerowicz et al., 2010; Holzmann et al., 2021).

Benthic foraminifera live at the sediment surface (epifaunal), or they dwell in the sediment surface at 2–4 cm (shallow infaunal) or below 4cm (deep infaunal) (Gooday, 2001; Binczewska et al., 2015). They constitute the most important component of the meiofaunal biomass, and their distribution highly depends on the flux of particulate organic matter to the sea floor (Gooday, 2003)**.**

Benthic foraminifera are included in the oldest group of organisms ever lived in the sea, as molecular phylogenetic studies determine the divergence of the eukaryotic supergroups well before 635 Ma (Pawlowski et al., 2003)**.** In particular, Groussin et., al. (2011) estimated that foraminifera emerged during the Cryogenian, at 650-920 Ma (Neo-Proterozoic), based on the multigene phylogenetic analysis). The mean time is calculated at around 770 Ma. This is 220 Myr before the first appearance of reliable fossil foraminifera in sediments at about 545 Ma (Groussin et., al., 2011).

1.3.1 Biology and Test Morphology

Benthic foraminifera are marine amoeboid protists (Holbourn et al, 2013)**,** characterized by a netlike system of pseudopodia (rhizopodia) and a test single or multi-chambered test, although naked or soft-shelled forms have been included at the higher taxonomic level (Pawlowski et. al., 2003). The life cycle of these species involves alternation of sexual and asexual generations (Gooday, 2001). The definition of foraminifera is based on the test morphology, the reproductive cycle, and the granulo-reticular pseudopodia (Holboun, 2013).

The morphological classification of benthic foraminifera in based on the wall structure of the test, specifically agglutinated or calcareous (porcelaneous or hyaline), the number of chambers (monothalamous or polythalamous), the mode of coiling, the chamber arrangement and the apertural system (Hottinger, 2006).

The tests of benthic foraminifera can be calcareous (both calcite and aragonite) when calcium carbonate is secreted by the organism or agglutinated when grains from the bottom sediment are cemented together, while some freshwater forms (allogromids) have no test (Saraswat & Nigam, 2013). The different types of the biomineralization create different types of wall structures for example hyaline and porcelaneous tests (Debenay, 2000; Erez, 2003).

Benthic foraminifera have many ways of feeding. They can be suspension feeders, deposit feeders, carnivorous, use symbiosis etc. (Pawlowski, 2012; Bincezewska et al., 2015). Its diets may consist of phytoplankton, zooplankton, small invertebrates, diatoms, bacteria, and organic detritus etc. (Bincezewska et al., 2015). Studies on deep sea sediments from oceanic basins with high concentrations of hydrogen sulfide and oxygen depletion, foraminifera, or cold seeps or at the edge of silled basins have bacteria as endosymbionts as chemosynthetic autotrophy supports these associations (Bernhard et al., 2001)**.** In oligotrophic areas, the organic export flux is low, surface dwellers consist mainly of epifaunal suspension feeders and the infaunal detritivores are rare (Murray, 1991) Finally, the dissolved organic matter may provide an important source of food for some species of benthic foraminifera (Nomaki et al., 2005).

1.3.2 Ecology of the deep-sea benthic foraminifera

An important field of ecological research is the distribution of the deep-sea benthic foraminifera in the water - sediment interface (Holbourn et al., 2013). Some deep-water calcareous foraminifera inhabit epifaunal or infaunal microhabitats and are not limited to the upper 1 cm of sediment (Gooday, 1994). Additionally, most epifaunal taxa live on the sediment surface but also on surfaces above the substrate (Gooday et al., 1992b), while infaunal taxa are mobile moving freely into the sediment (Corliss, 1991). Generally, the motile benthic foraminifera can easily adapt to changes in microhabitat in food availability and oxygenation (Linke and Lutze, 1993; Jorissen, 1999a). TROX model (Trophic Oxygen model) is developed to explain that the depth of the foraminiferal microhabitat is controlled by the availability of food particles in the sediment of oligotrophic ecosystems and in eutrophic ecosystems the oxygen level determines the depth that species can live (Jorissen, et al., 1995, 2007).

Furthermore, test morphology of calcareous taxa is related to the type of microhabitat (Corliss, 1985, Corliss and Chen, 1988). Those taxa associated with epifaunal taxa living in well oxygenated environments usually bear rounded, planoconvex or bioconvex shell with trochospiral or milioline coiling (Corliss and Chen, 1988; Kaiho, 1991). On the other hand, infaunal foraminifera are uniserial, triserial, or planispirally coiled (Gooday, 1994)**.**

In general, most deep sea recent benthic foraminifera are cosmopolitan and similarly their fossil populations were also cosmopolitan (Holbourn et al., 2013). This distribution is due to their ability to disperse and colonize new substrates rapidly (Murray, 2006). This probably is due to the appearance of propagules (Alve and Goldstein, 2003). The main environmental factors that determine the distribution of the benthic foraminifera in the deep-sea environments are the carbonate dissolution and the flux rate nutrients from the surface water to the sea bottom (Jorissen et al., 2007)**.** According to Gooday (1988), Corlis and Chen (1988), Altenbach (1992), Gooday (2002) and Heinz et al. (2001) there is a close relationship between the recent deep-water benthic foraminifera assemblages with the organic carbon flux and the changes in surface ocean productivity Oligotrophic environments present low density, high diversity populations, while eutrophic surface conditions present low diversity with blooms of opportunistic species (Ohga and Kitazato, 1997; Gooday, 1999). The diversity of deep-sea benthic foraminiferal assemblages, at high latitudes is related to the seasonality of pelagic productivity (Corliss et al., 2009).

1.4 Agglutinated Foraminifera

Agglutinated foraminifera are among the most widespread and abundant groups of marine meiofauna in deep-sea environments (Gooday, 1994). Agglutinated foraminifera made their first appearance, during the earliest Cambrian and the characteristic of this taxa is that their tests are built from sedimentary particles which were picked from the substratum, and which held together by an organic, siliceous, or calcareous cement (Hemleben and Kaminski,1990). Living agglutinated foraminifera secret the organic cement by the cytoplasmic vacuoles (Hemleben and Kaminski,1990). The sedimentary particles may include sand or silt grains, mineral grains as quartz, apatite, magnetite, etc. and/or biogenic components such as sponge spicules, diatoms, radiolaria, or tests from smallest planktonic or benthic foraminifera (Gooday, et al. 1995; 2010; Thomsen and Rasmussen, 2008; Pawlowski and Majewski, 2011; Mancin et al., 2012; 2015, Capotondi et al., 2019).

1.4.1 Test Morphology, Classification and Ecology

In the last four decades many published studies have highlighted the importance of wall structure and cement composition for supergenetic classification (Bender, 1995; Loeblich & Tappan, 1987; 1988; 1989; 1992; Kaminski, 2004; 2014). Nevertheless, there was no consensus on the use of these morphological features namely the taxonomic level that they should be used, until the taxonomic scheme proposed by Kaminski at 2000 (Kaminski, 2004). This classification updated Loeblich and Tappan’s (1992; 1994), which divided the agglutinated foraminifera into 19 superfamilies, 87 families, and 100 subfamilies. Kaminski incorporated the new genera and higher taxa, used in a more complete way subclasses, orders etc., as foraminifera elevated from order to class (Kaminski, 2004).

The reclassification of 2000 (Kaminski, 2004) places all agglutinated foraminifera in subclass Textulariia, which includes 4 orders, 17 suborders, 27 superfamilies, 107 families, 125 subfamilies with totally 747 species. Later, Kaminski’s 2010 reclassification (Kaminski, 2014), improves and updates the previous one proposing 3 subclasses, 7 orders, 18 suborders, 32 superfamilies, 122 families, 148 subfamilies, and consists of 832 species.

Several authors have demonstrated that agglutinated foraminifera show apparent selectivity forcertain types of grains (e.g., Tapan and Loeblich, 1988; Allen et al., 1999). The composition of the bottom sediments is very important as determines the availability of certain type of particles and thereby defines the composition of the test in agglutinated foraminifera (Capotondi et al., 2019). Two types of grain selection have been recorded (Capotondi et al., 2019): Particle selection according to grain composition (e.g., Allen et al., 1999; Thomsen and Rasmussen, 2008; Mancin et al., 2015; Makled and Langer, 2010; Stefanoudis et al., 2016) and particle selection according to the particle size and/or shape (e.g., Gooday et al., 1995; Allen et al., 1998; Bowser et al., 2002; Mancin et al., 2012). Also, some studies suggest that certain agglutinated foraminifera, place the grains in their tests with certain orientation (Bowser & Bernhard, 1993; Allen et al.,1999; Thomsen and Rasmussen, 2008).

Bender (1995) analyzing the microstructure of the shell in 142 recent agglutinated species using Scanning electron microscope aiming to record in a catalog the cement composition, cement microstructures, pore systems and organic layers and finally to use them as diagnostic test characteristics for classification. Fundamental structural characteristics of the agglutinated foraminiferal test are (Bender, 1995): the Inner Organic Layer (IOL) which is attached to chamber wall interiorly, the Outer organic Layer (OOL) that seems to be present only in organically cemented polythalamous tests, the type of cement (most of the species bear organically-cemented tests, while about 20% bear calcareous cement) and the pore systems (species with calcareous cement have organically lined pores, while species with organic cement have no pores).The distribution of the agglutinated foraminifera at the modern environments present that are separated into different morpho groups depending on the depth; the unilocular, tubular and branching agglutinated foraminifera located at the deep-sea (Murray, 1991). In the deep-sea basins, the vertical particle flow is low, there is limited disturbance of the substrate, oligotrophic conditions prevail and as a result a complex ecosystem is formed where adapted organisms have developed special mechanisms against energy loss and maximum utilization of the available food resources (Kuhnt et al., 1996). Concerning benthic foraminifera, Kuhnt et al. (1996) point out that diversity of the assemblages decreases in eutrophic conditions and hyaline calcareous benthic foraminifera are dominant.

Kuhnt et al. (1996) presented a model which regulates the appearance of calcareous and agglutinated foraminifera in relation to the trophic resource, while different groups of deep water agglutinated foraminifera are arranged according to their trophic behavior in a trophic resource model (Figure 1). As observed in Figure 1 calcareous foraminifera and agglutinated foraminifera present an inversely proportional relation with agglutinated foraminifera dominate in the ocean desert niche as specialists and on the other hand calcareous foraminifera dominate in the infaunal detritus feeding niche as low oxygen specialists.

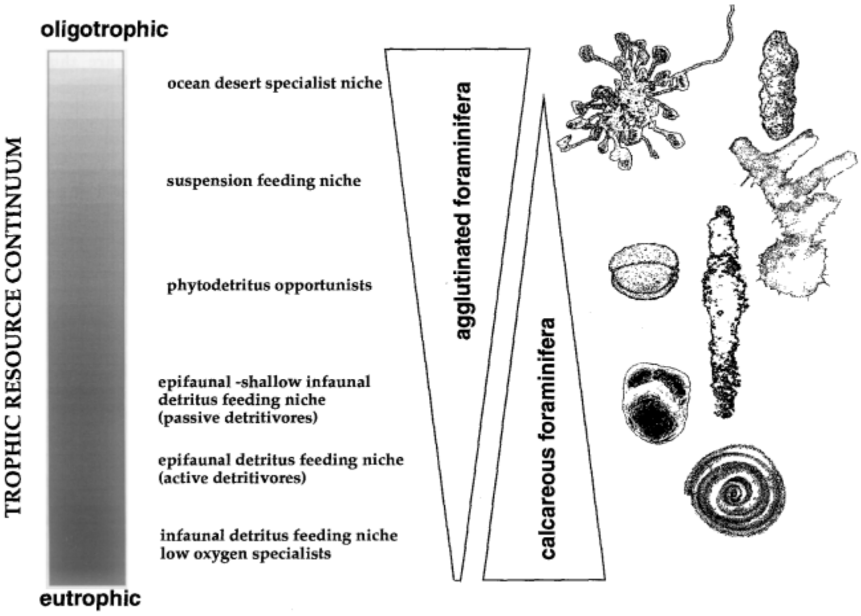


Figure 1. Benthic foraminifera niches in relation to the trophic resource after Kuhnt et al. (1996).

2. Study Area

The study area is located at the southern Aegean Sea and the NW Levantine Basin in the eastern Mediterranean (Figure 2).

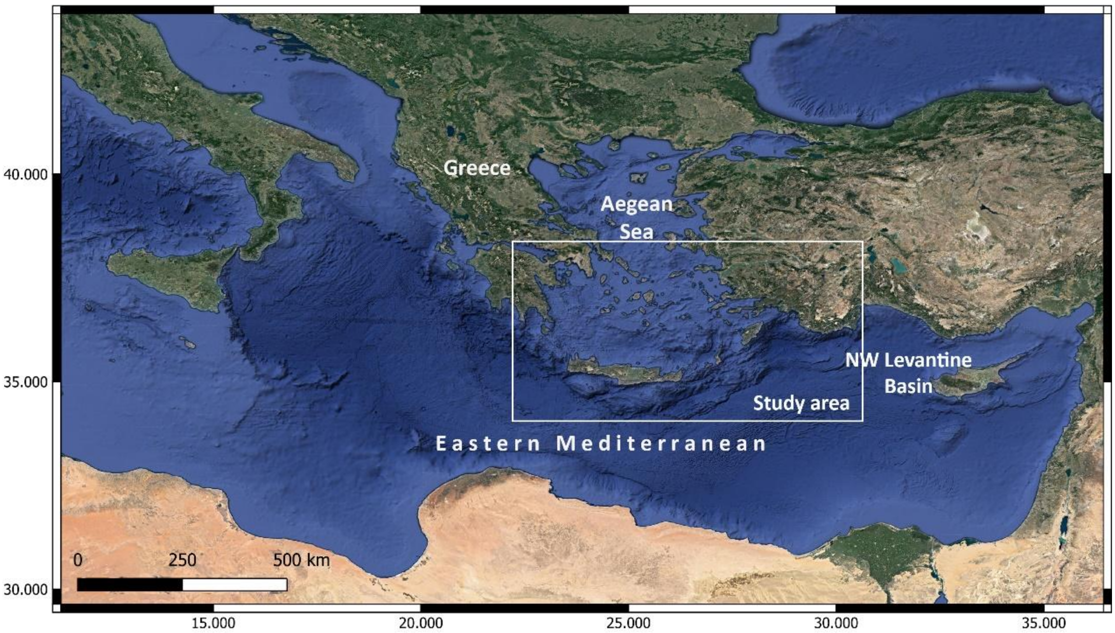


Figure 2. Map of eastern Mediterranean region and the location of the study area.

2.1 Geological setting

The Eastern Mediterranean Basin (Figure 3) formed before the Middle Jurassic and constitutes a relic of the Mesozoic Neotethys Ocean (Garfunkel, 2004). The eastern and southern original passive margins retained, while its northern and western margins formed by later subduction and plate convergence (Garfunkel, 2004). The collision of the Arabia and Africa plates with Eurasia has determined the evolution of eastern Mediterranean region (Figure 3) and, in particular, the African plate is subducted northward beneath western Turkey and the Aegean region is causing extension of the continental crust and volcanism in the Aegean region (Taymaz et al., 2007). The Africa plate is moving northward (6 ±2 mm/yr), while the Arabia plate is moving north-northwest at a rate of ~18-25 mm/yr, both relative to stable Eurasia (De Mets et al., 1990). This difference in the movement between these two plates is due to the westward extrusion and counterclockwise rotation of Anatolia plate (McClusky et al., 2000). The Central and Southern Aegean region moves (Figure 3) toward the southwest at a rate of 30±2 mm/yr relative to Eurasia (McClusky et al., 2000). Consequently, all the above-mentioned dynamic movements between plates lead to crustal deformation and seismicity/volcanism in Aegean region and Anatolia (Taymaz et al., 2004).

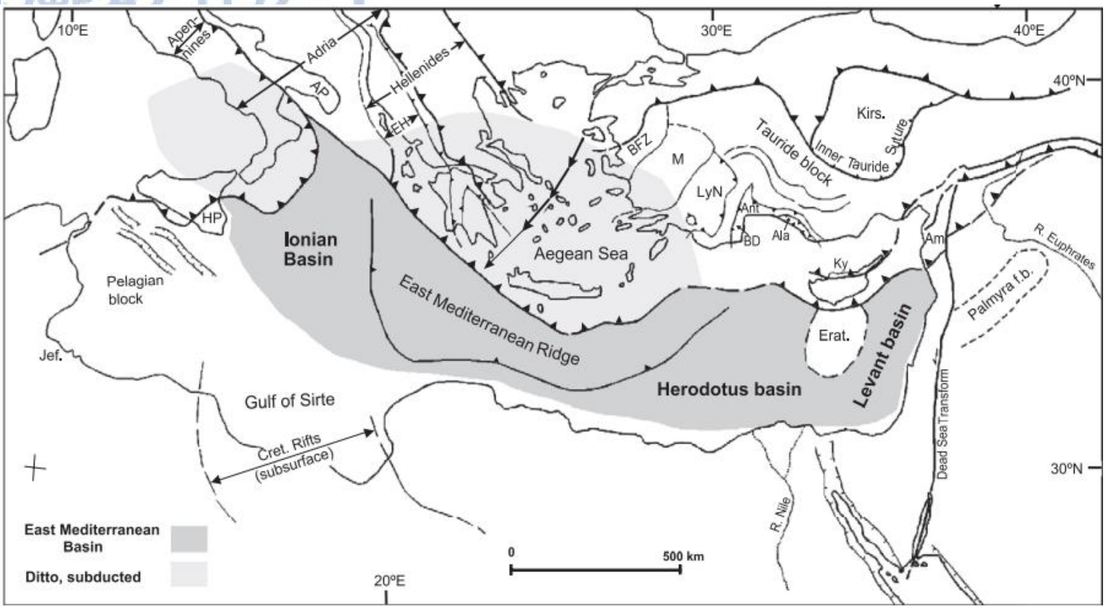


Figure 3. The location of the subducted parts in the Eastern Mediterranean and the rotation of the margin of the External Hellenides indicated by the arc with arrows in the Aegean Sea (figure from Garfunkel, 2004).

The External Hellenides (Figure 3) include a sequence of Mesozoic to Tertiary deposits which can be followed along the Hellenic Arc, representing platforms, and basins that shaped the rifted eastern margin of the Apulian microcontinent bordering in the Pindos Ocean (Robertson et al., 1991). During Tertiary the External Hellenides suffered the consequences of the the closure of the Pindos Ocean and the collision of the Apulian and Pelagonian microcontinent (Doutsos et al., 1993). Rotations are the characteristic of the late orogenic evolution of the Aegean region (Kokkalas et al., 2006, cum lit.). In particular, concerning central and southern Aegean area, both clockwise and counterclockwise rotation took place in the basement of the Cyclades area around 10 Ma, suggesting the braking of Cycladic massif into microplates and fault blocks (Kokkalas, et al., 2006, cum lit.). There has been observed clockwise rotation (20º-30º) in the post-Messinian sediments for the area between eastern Crete and Rhodes Island, but no rotations older than 10 Ma years have been observed (Kokkalas, et al., 2006, cum. lit.).

The Aegean active volcanic arc is located at the southern Aegean area, and it is extended from Sousaki (Figure 3) in the northwest, Milos, Santorini, Kolumbo Bank, to Nisyros in the southeast (Pe-Piper and Piper 1972). The Aegean volcanic arc is of Pliocene-Quaternary age, and it is characterized by a very quick expansion that caused the crustal thinning of the microplate (Anastasakis and Piper, 2005, cum lit.).

2.2 Oceanographic setting

The Aegean Sea is the third major Sea of the Eastern Mediterranean (Theocharis et al., 1993), it is located between Turkey and Greece and, generally, it is separated into three parts, based on its bottom topography (Theocharis et al., 1993; Zervakis et al., 2000; Poulos, 2009): The North Aegean through, which includes the sub-basins of Saros (1061 m), Limnos (1590 m), Athos (1149 m), Sporades (1470 m) and the North Skiros basin (800m of water depth). The central Aegean Sea, of which main geomorphological characteristic is the Cyclades Plateau, along with Chios (up to 1160 m depth) and Ikarian (1219m depth) basins (Figure 4). There is also the Myrtoon Basin (1314mdepth), located at the west of the Cyclades plateau and to the north of the volcanic arc. The South Aegean, which is located in between the volcanic arc to the north and the islands of Crete, Karpathos and Rhodes to the south presenting the characteristics of a true back-arc basin. Its main geomorphological characteristic is the shallow shelf of the Cyclades Plateau, the Cretan Sea (>1000 m depth), which incorporates three distinct sub-basins; these are (from W to E): the Antikithira basin (1265 m), the Kamilonisi basin (2509 m) and the deepest Karpathos basin (2509 m).

The climate of the Aegean Sea is characterized as a typical Mediterranean type (Poulos et. al. 1997). The annual air temperatures vary between 16° C to 19,5° C (Dimiza et. al. 2015).

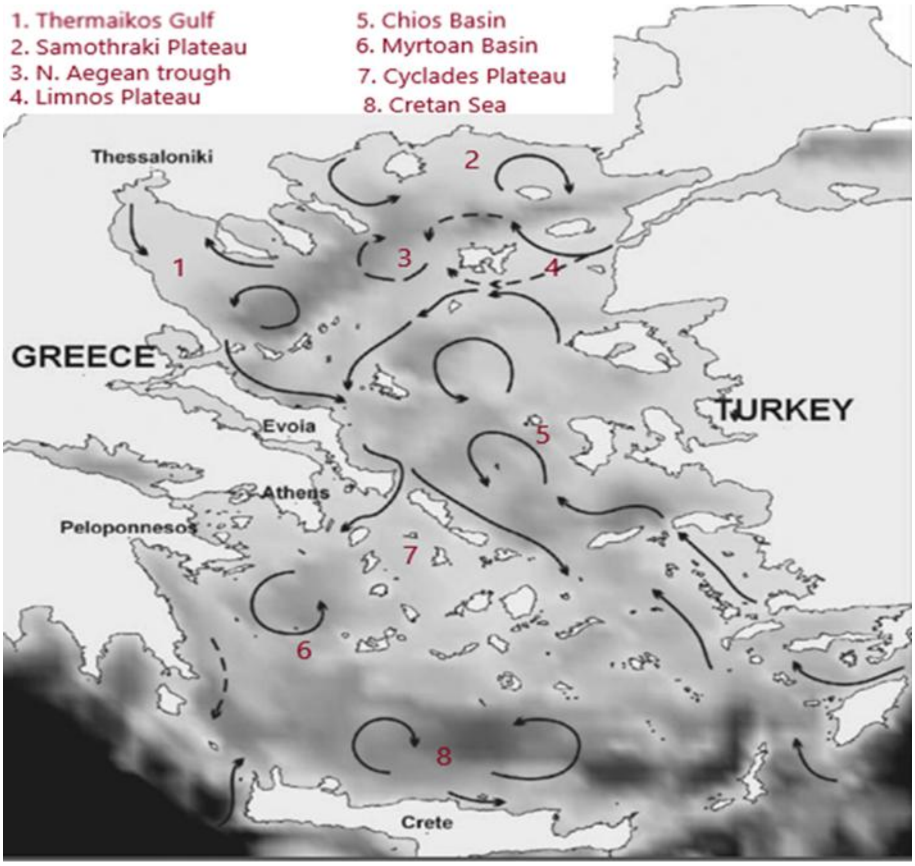


Figure 4. Generalized pattern of the Surface water circulation of the Aegean Sea (modified from Poulos, 2009).

The main water masses in the eastern Mediterranean Basin are the Modified Atlantic Water (MAW), the Levantine Intermediate Water (LIW), and the Eastern Mediterranean Deep Water (EMDW) (Theocharis et. al. 1999) (Figure 4). The Aegean Sea presents discrete hydrodynamic characteristics like strong currents, upwelling regions, mesoscale eddies, and frontal zones (Lykousis et al., 2002; Skliris et al., 2010).

The water circulation in the Aegean Sea is a generally cyclonic, but the most active dynamic features of the Aegean are the mesoscale cyclonic and anticyclonic eddies ((Lykousis et al., 2002; Skliris et al., 2010). Some of these features seem to be transient and others have a permanent character (Skliris et al., 2010).

In the northeastern Aegean Sea, there is an input of brackish waters from the Black Sea (BSW), through the Straits of Dardanelles, causing cyclonic circulation

(Theocharis et. al. 1993). As a result, a shallow thermohaline front (< 40 m thick) developes along the borders of these brackish waters with the saline waters from the South (Lykousis et. al., 2002).

The Levantine Surface Waters (LSW) enters to the Aegean through the eastern Straits of the Cretan Arc (Theocharis et. al., 1999). They can be detected during summer in most the regions of the eastern Mediterranean, they are produced by intense evaporation, thus they develop high salinity, especially in the area of Rhodes Island (Theocharis et. al., 1999 cum lit.).

The MAW enters to the Ionian Sea through the Sicily Straits, and it reaches the Cretan Passage becoming the Mid-Mediterranean Jet (MMJ) and moves to the east enting the Levantine Basin and so it becomes more saline and denser (Theocharis et. al., 1999 cum lit.) (Figure 4).

LIW is produced during February and March in the South Aegean Sea and the Levantine Basin, and it lays mainly under the MAW, and it overlies the colder and less saline EMDW (Theocharis et. al., 1999 cum lit.). LIW spreads westward, enters the Aegean through the Straits of the Cretan Arc, but it moves very slow, and this is also indicated by its low oxygen content (Theocharis et. al., 1999 cum lit.).

Aegean Intermediate Water (AEIW) comes from the LIW (Casford et. al., 2002). AEIW moves northward along the Turkish coast and the offshore winds allow upwelling of the intermediate water to the surface, creating a uniform water mass from the surface to the seafloor (Casford et. al., 2002 cum lit.). As this upwelled water mass travels towards the north, evaporation increases its salinity, as well as the winter winds in the north and additionally, winter cooling enhance density, leading to the formation of the Aegean Deep Water (AEDW) (Casford et. al. 2002 cum lit.) (Figure 4).

The sea surface temperature (SST) of the Aegean waters is affected by seasonality (Poulos et al., 1997): The annual maximum SST values (about 24°C) are observed during August/September at the South Aegean, and the minimum ones (about 13°C) during the winter. The sea surface salinity (SSS) varies both spatially and seasonally ranging from 31 psu minimum in the North to over 39 psu maximum in the Southeast Aegean, while during the summer presents its higher fluctuations (Poulos et al., 1997). Finally, although the Aegean Sea is considered an oligotrophic environment, there are areas with high primary productivity (Ignatiades et al., 2002) (Figure 4).

3. Materials and Methods

3.1 Sampling

A total of eight surface sediment samples were used for the purposes of the current study, which were collected during R/V Aegaeo MSFD cruise in March 2019. Five sampling stations are in the area of central-southern Aegean Sea (Figure 5): 2MSFD 11 from depth 365m, 2MSFD 8 from depth 485m, 2MSFD 9 from depth 1689m, 2MSFD 10 from depth 2150m, and station 2MSFD 12 from depth 335m. Three sampling stations are towards the Levantine (Figure 5): 2MSFD 05 from depth 1150m, 2MSFD 06 from depth 1470m, 2MSFD 07 from depth 1680m. Details such as the exact selection date and the coordinates of the stations are presented in Table 1.

Figure 5. Map of the study area and the samples collected during R/V Aegaeo MSFD cruise in March 2019.

Cruise/Station	Date	Time Start	Time End	Latitude	Longitude	Depth(m)
2MSFD 11	18.03.2019	21:50	0:32	37.477	24.068	365
2MSFD 08	19.03.2019	5:20	9:15	36.805	23.465	485
2MSFD 09	20.03.2019	18:10	0:35	36.120	25.228	1689
2MSFD 10	20.03.2019	5:30	12:13	35.753	26.228	2150
2MSFD 05	21.03.2019	2:40	9:48	34.815	26.131	1150
2MSFD 06	22.03.2019	22:55	4:55	36.089	28.222	1470
2MSFD 07	22.03.2019	11:30	17:55	36.022	29.563	1680
2MSFD 12	23.03.2019	9:10	11:15	37.009	26.621	335

Table.1. This table presents the depth, date, time (start/end of collection) and the coordinates (latitude and longitude) of the studied samples.

Each sample was collected from the sampling station with a Box Corer sampler. Benthic communities of the deep-sea environments are more abundant in the soft surface layer, so it is essential to collect quantitatively this layer, which is fluffy and easy to get disturbed, but the Box Corer sampler minimizes the vertical disturbance of the sediment during the sampling (Gooday and Turley, 1990; Shirayama and Fukushima, 1995).

The considered sediment samples (undisturbed top 1-cm) were analysed by Hellenic Center of Marine Research for 31 polycyclic aromatic hydrocarbons (PAHs) compounds/groups by gas chromatography-mass spectrometry following the methodology of Parinos et al. (2013) and Hatzianestis et al. (2020), in order to estimate any persistent chemical contaminants in the marine realm. Many PAHs may cause detrimental effects on biota and are thus listed as priority pollutants by national/international environmental agencies (Samanta et al., 2002). The results are discussed in chapter 6.1.

3.2 Laboratory treatment and micropalaeontological analysis

In the laboratory the samples were carefully washed through a 63 μm and 125 μm sieves and oven dried at 60°C. The dried residue was weighed and placed in petri dishes.

The sediment fraction >125 μm was examined for the included biogenic content under a stereomicroscope Zeiss Stemi 508 and all group of organisms were collected from this fraction. In particular, faunal analysis revealed rich assemblages consisting of pteropods, planktonic and benthic foraminifera, ostracods as well as otoliths.

The agglutinated foraminifera studied like different assemblage from the calcareous benthic foraminifera. For the study of agglutinated tubular benthic foraminifera only the fragments larger than 1mm and those with a proloculus regardless of the length were considered as single individuals (Hess, 1998). With this method we can get a rough estimation of the tubular specimens.

In order to determine the participation of its group the following procedures took place: A subset containing about 300 planktonic foraminifera for each sample was obtained using an Otto microsplitter and the total number of specimens per sample was calculated. Concerning benthic foraminifera, all specimens were collected from each sample and in cases where the abundance was too high, aliquots were examined using a microsplitter in order to collect about 300 specimens and, subsequently, the total number of specimens was calculated. Accordingly, all ostracods were collected from each sample and in cases where the abundance was too high aliquots were examined using a microsplitter in order to collect about 200 specimens and, subsequently, the total number of specimens was calculated. Complete carapaces were calculated as two valves. Finally, all otoliths were collected from each sample.

Benthic foraminifera were determined to the genera and species level when possible, by using a stereomicroscope Zeiss Stemi 508 with Zeiss Axiocam 208 color and Scanning Electron Microscope (SEM).

The taxonomy and identification of benthic foraminifera was based mainly on Kaminski, (2014), Sgarella & Moncharmozei (1993), Tappan & Loeblich (1988) and Holbourn et al. (2013) ,Loeblich and Tappan (1988), as well as Kaminski (2004), and Milker and Schmiedl (2012) and World Register of Marine Species (WoRMS, 2022).

3.3 Quantitative analysis

Concerning quantitative analysis, Microsoft Excel 2019, used to calculate the relative abundances of each group/taxa/species in every sampling station. In particular, the participation rates of calcareous versus agglutinated benthic foraminifera, and the relative abundances of each taxon of benthic foraminifera in every sample were calculated. Furthermore, distribution charts of the most abundant taxa of benthic foraminifera were constructed.

Finally, the Shannon-Wiener diversity index (H΄) was also calculated for every sample by using PAST 2.12 software package.

The percentage of benthic foraminifera in the total assemblage is proportional to depth, like the organic matter which is the result of the primary productivity reaching the sea bottom. The range of P/B ratio appears to be strongly dependent on the amount of the living benthic foraminifera (Zwaan et al., 1990).

The Shannon-Wiener diversity index (H΄), considers the proportions of non-distributed species and is calculated from the relation,

$$H = - \sum_{i=1}^{s} pilnpi$$

, R is the number of species and pi is the percentage of the total number of individuals belonging to type I (Shannon & Wiener, 1963).

4. Results

4.1 The biogenic content of the deep-sea bottom sediments

The assemblages in the studied samples consist of planktonic foraminifera, benthic (agglutinated and calcareous) foraminifera, transported (from shallower environments) benthic foraminifera, otoliths and ostracods (Table 2), as well as pteropods. Three samples correspond to the upper bathyal zone with depths 335-485m and five samples correspond to the lower bathyal zone with depths 1150-2150m.
The results of the qualitative and quantitative analysis are detailed presented in Table 2.

Samples	**2MSFD05**	**2MSFD06**	**2MSFD07**	**2MSFD08**	**2MSFD09**	**2MSFD10**	**2MSFD11**	**2MSFD12**
water depth (m)	1150	1470	1680	485	1689	2150	365	335
No of microorganisms/1gr								
Planktonic Foraminifera	6,076	140,488	88,926	6,908	17,133	4,564	1,371	1,000
Agglutinated Benthic Foraminifera	124	693	754	580	139	101	58	18
Calcareous BF	5,01	325	516	5,873	124	98	89	43
Otoliths	4	30	48	0	4	9	1	1
Ostracod valves	223	599	463	562	224	138	119	33
total	11,438	142,135	90,707	13,923	17,624	4,910	1,638	1,095
Pteropods	abundant	abundant	abundant	abundant	abundant	abundant	Present	present
% of the total microfauna	**2MSFD05**	**2MSFD06**	**2MSFD07**	**2MSFD08**	**2MSFD09**	**2MSFD10**	**2MSFD11**	**2MSFD12**
Planktonic Foraminifera	53.12	98.84	98.04	49.62	97.22	92.96	83.68	91.36
Agglutinated Benthic Foraminifera	1.08	0.49	0.83	4.17	0.79	2.06	3.52	1.66
Calcareous BF	43.81	0.23	0.57	42.18	0.7	1.99	5.47	3.88
Otoliths	0.04	0.02	0.05	0.00	0.02	0.18	0.06	0.06
Ostracod valves	1.95	0.42	0.51	4.04	1.27	2.81	7.26	3.04

Table 2. Absolute and relative abundances of the microorganisms that constitute the biogenic component of the studied samples from the cluster >125μm.

The most abundant groups were pteropods and planktonic foraminifera (49.62-98.84%) (Table 2), although the participation of pteropods was not estimated quantitatively. The other identified groups were the agglutinated benthic foramifera, ranging from 0.49 to 4.17%, the calcareous BF, with participation rates 0.23-43.81%, the otoliths, ranging from 0.02 to 0.18% and the ostracods from 0.42 to 7.26%.

Figure 6. The distribution of Shannon-Wiener diversity index in the studied samples.

This study focuses on benthic foraminifera which is the most diverse group in the samples. Benthic foraminiferal assemblages are composed of calcareous and agglutinated foraminifera.

The Shannon -Wiener diversity index shows the following values in the studied samples (Figure 6): For the samples 5 and 6 is 1.91, for sample 7 is 2.54, for sample 8 is 2.76, for sample 9 is 2.10, for sample 10 is 1,92, while for samples 11 and 12 is 2.61 and 2.73 respectively. In conclusion, samples from the upper bathyal zone (335 - 485m) present the higher values of the Shannon Wiener diversity index (2.61-2.76), while samples from the lower bathyal zone (1150 - 2150m) present decreased values (1.91 - 2.54).

The Calcareous/Agglutinated participation rates shows the following pattern for the samples from the shallower environments (Figure 7): station 2MSFD8 (485m) the calcareous BF, occupied a percentage 89.11% while the agglutinated BF, are in 10.89%. At the other two stations (2MSFD11, 2MSFD12) the percentage of calcareous BF are in 54.68% and 65.06% respectively.

Concerning the stations from the lower bathyal zone, agglutinated BF dominate in samples 2MSFD7 (70.20%). At the sample 2MSFD5 the calcareous BF range (96.64%), while sample 2MSFD6 shows a percentage of 76.17% agglutinated BF. This station presents the highest percentages of agglutinated BF. Samples 2MSFD9, 2MSFD10 (from the deepest stations) present similar participation rates of agglutinated BF, that is about 55%, (2MSFD9: 55.34% & 2MSFD10: 55.50%) (Figure 7).

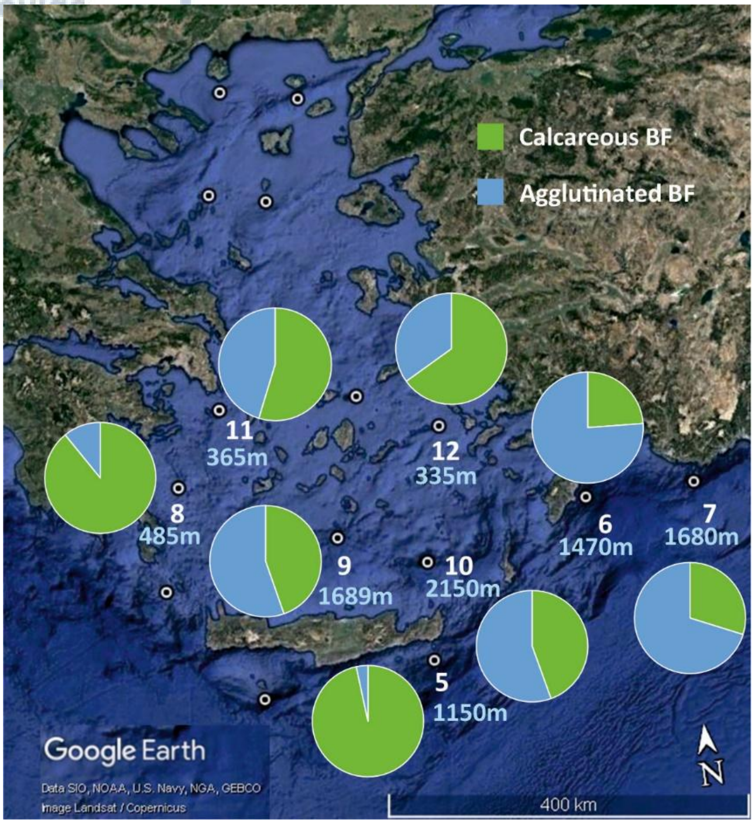


Figure 7. The participation rates of Calcareous/Agglutinated BF in the studied samples.

4.2 Distribution of Benthic Foraminifera in the studied samples

A taxonomic survey of the calcareous benthic foraminiferal fauna found 10 genera of hyaline benthic foraminifera in the studied samples (Table 3). The calcareous BF assemblages in the samples from the shallower environments are composed mainly of species of *Bolivina*, *Bulimina*, *Melonis*, *Cassidulina*, *Amphicoryna*. The calcareous BF assemblages in the samples from the deeper bathyal environments are characterized by the taxa *Gyroidina* cf. *umbonata (Gyroidina soldanii)*, *Gyroidina orbicularis*, *Melonis* spp., *Uvigerina* spp. *Gyroidina* spp., presenting their highest relative abundances at the depths of 1670-2000m.

The agglutinated benthic foraminiferal fauna is composed of 13 genera and 15 species of arborescent, tubular, and globular taxa**.** The most abundant species of agglutinated benthic foraminiferal assemblages were *Saccorhiza* sp., *Glomospira* spp., *Rhizammina* sp. and *Reophax* spp. (Table 4). The group of agglutinated foraminifera presents its highest values of diversity and abundance in the deep bathyal environments.

Sampling station 2MSFD 5.

This station is located at the lower bathyal zone, at 1150m depth. The calcareous benthic foraminiferal assemblage is composed mainly of *Melonis* spp. (27.4%), *Gyroidina* spp. (31.11%) and *Uvigerina* species (8.45%), *Bolivina* species (3.70%) and *Bulimina* species (0.74%), as well as other rotaliids species (26.67 %).

The agglutinated benthic foraminiferal assemblage is dominated by *Saccorhiza ramosa*, which represents 66.75% of the assemblage, accompanied mainly by *Rhizammina algaeformis* (25.58%). *Bathysiphon rufescens* (1.79%), *Psammosphaera fusca* (2.30%) and also species of *Ammodiscus*, *Cibrostomoides*, *Glomospira*, *Marsipella* are present with very low participation rates.

Sampling station 2MSFD6

This station is located at the lower bathyal zone, at 1470m depth. Concerning the assemblage of calcareous benthic foraminifera, it is composed mainly of *Gyroidina* spp.(63.05%) and *Melonis* spp. (18.47%). Also *Uvigerina* species (6.43 %), *Bolivina* species (0.80%). Other taxa such as *Robulus* species, *Nodosoria* species, *Pullenia quadriloba* (with participation rates lower than 1%) and other rotaliids species (3.61%).participate in this assemblage.

The agglutinated benthic foraminiferal fauna is dominated by *Saccorhiza ramosa*, which represents 83% of the assemblage, accompanied by *Rhizammina algaeformis* (5.03%), *Bathysiphon rufescens* (1.76%), *Psammosphaera fusca* (1.51%), *Reophax* species (0.25%) and t *Glomospira charoides* (4.77%). Additionally, species of *Ammodiscus*, *Cibrostomoides*, occupy percentages >1%.

Sampling station 2MSFD7

This station is located at the lower bathyal zone, at 1680m depth. Concerning the assemblage of calcareous benthic foraminifera, it is composed of *Gyroidina*spp.(37.50%) , *Melonis* spp. (15.79%) , *Uvigerina* species (11.18 %), *Cassidulina* spp. (4.69%) *Bolivina* species (2.63%), *Bulimina* spp. (1.97%) and as well as other rotaliids species (up to 22.37 %).

The agglutinated BF assemblage is consisted mainly of *Saccorhiza ramosa* (52.51%), *Reophax* species (4.47%), and *Cibrostomoides* spp. (10.34%).

Samples	2MSFD5	2MSFD6	2MSFD7	2MSFD8	2MSFD9	2MSFD10	2MSFD11	2MSFD12
Depth(m)	1110	1470	1680	485	1670	2150	365	335
Amphicoryna spp.	0.00	0.00	0.00	2.26	0.00	0.00	2.05	12.04
Bolivina spp.	3.7	0.80	2.63	30.45	1.35	0.27	22.60	6.02
Gyroidina spp.	31.11	63.05	37.50	2.63	82.43	83.24	2.40	6.94
Bulimina spp.	0.74	0.00	1.97	15.41	0.00	0.82	12.33	6.94
Cassidulina spp.	0.00	0.00	4.61	14.80	0.19	0.82	17.81	17.13
Globocassidulina spp.	0.00	0.00	0.00	4.89	0.00	0.27	2.74	6.02
Lagena spp.	0.00	4.82	1.97	0.75	1.16	1.37	1.03	6.48
Melonis spp.	27.41	18.47	15.79	3.76	8.30	6.59	8.90	6.94
Uvigerina spp.	8.45	6.43	11.18	7.52	0.97	1.92	2.05	6.48
Rotalids spp.	26.67	3.61	22.37	9.02	2.51	3.02	18.15	0.93
Other taxa	2.22	2.81	1.97	4.51	3.09	1.65	9.93	24.07

Table 3. Relative abundances of the calcareous benthic BF in the studied samples from the cluster >125μm.

Samples	2MSFD5	2MSFD6	2MSFD7	2MSFD8	2MSFD9	2MSFD10	2MSFD11	2MSFD12
Depth(m)	1110	1470	1680	485	1670	2150	365	335
Ammodiscus spp.	0.26	0.25	0.56	0.00	2.02	0.22	0.00	0.00
Ammoscalaria pseudoscalaris	0.00	0.00	0.00	3.08	0.00	0.00	0.00	0.00
Bathysiphon rufescens	1.79	1.76	0.00	1.54	3.58	0.00	1.24	4.31
Cribrostomoides spp.	0.26	2.51	10.34	1.54	0.16	7.05	1.65	10.34
Glomospira charoides	0.77	4.77	8.38	0.00	16.20	57.27	0.00	0.00
Marsipella elongata	0.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Psammosphaera fusca	2.30	1.51	0.00	0.00	4.36	0.44	0.00	0.00
Psammosiphonella cylindrica	0.00	0.00	0.00	43.08	0.00	0.00	7.85	62.93
Reophax spp.	0.00	0.25	4.47	9.23	0.00	0.00	4.13	7.76
Saccorhiza ramosa	66.75	83.67	52.51	10.77	64.64	26.87	66.12	12.07
Rhabdamminella cylindrica	2.05	0.00	0.00	12.31	0.16	0.22	6.61	0.00
Rhizammina algaeformis	25.58	5.03	0.00	0.00	1.09	0.22	6.61	0.00
Other taxa	0.00	0.25	23.74	18.46	7.79	7.71	5.79	2.59

Table 4. Relative abundances of the agglutinated BF in the studied samples from the cluster >125μm.

Sampling station 2MSFD8

This station is located at the upper bathyal zone, at 485m depth. The assemblage of calcareous BF is composed mainly of *Bolivina* species (30.45%), *Cassidulina* species (14.80%), *Bulimina* spp. (15.41%), *Uvigerina* species (7.52%) and *Globocassidulina* spp. (4.89%). The assemblage is completed by *Gyroidina* spp. (2.63%) *Melonis* spp. (3.76%). Other taxa such as, *Robulus* species, *Nodosoria* species, *Pullenia quadriloba*, *Reussella* spp., *Lagena* spp., with rates lower than 4% and other rotaliids species (9.02%).

The agglutinated BF assemblage is consisted mainly of *Psammosiphonella cylindrica* (43.08%), *Rhabdamminella cylindrica* (12.31%), *Saccorhiza ramosa*, (10.77%), *Reophax* species (9.23%), The assemblage is completed by *Bathysiphon rufescens* , (1.54%) , *Ammoscalaria* spp. (3.08%) and *Cibrostomoides* spp. (1.54%).

Sampling station 2MSFD9

This station is located at the lower bathyal zone, at 1670m depth. The assemblage of calcareous benthic foraminifera is dominated by *Gyroidina* spp.82.43% *Melonis affinis* (8.3 %), *Uvigerina* species (0.97 %), *Bolivina* species (1.35 %) and species *Robulus*, *Nodosoria* and *Cassidulina* with rates lower than 1%. The assemblage is completed by other rotaliids species (3.09 %).

The agglutinated BF assemblage is dominated by *Saccorhiza ramosa* (64.64%), accompanied mainly by *Glomospira charoides* (16.20%), *Psammosphaera fusca* (4.36%), *Bathysiphon rufescens* (3.58%), *Rhizammina algaeformis* (1.09%), and species of *Ammodiscus* (2.02%).

Sampling station 2MSFD10

This station is located at the lower bathyal zone, at 2150m depth. Concerning the assemblage of calcareous benthic foraminifera, it is dominated by *Gyroidina* spp.(83.24%) and *Melonis* spp.(6.59%). The assemblage is completed by *Uvigerina* species (1.92%), *Bolivina* species (0.27%), as well as *Robulus* species, *Nodosoria* species, *Pullenia quadriloba*, *Globocassidulina* species and *Cassidulina* spp. with rates lower than 2% and other rotaliids species (up to 3.02 %).

The agglutinated benthic foraminiferal group is consisted of *Glomospira charoides*. (57.27 %), *Saccorhiza ramosa* (26.87%), *Cibrostomoides* species (7.05%), *Rhizammina algaeformis*, *Rhabdamminella cylindrica* (0.22%), and *Ammodiscus* (>1%).

Sampling station 2MSFD11

This station is located at the upper bathyal zone, at 365m depth. The assemblage of calcareous BF is composed mainly of *Cassidulina* species (17.8%), *Melonis* spp. (8.90%), *Amphicoryna* species (2.05%), while *Bolivina* and *Bulimina* species participate in the assemblage with 22.60% and 12.33% respectively. Other taxa such us *Planulina* spp., *Lagena* spp. constitute 9.93% of the calcareous BF asemblage. The assemblage is completed by the presence of *Gyroidina* spp. (2.30%).

The agglutinated BF group is consisted mainly of *Saccorhiza ramosa*, (66.12 %), *Rhizammina algaeformis, Rhabdamminella cylindrica and Psammosiphonella cylindrica* (6.61%), *Reophax* species (4.13%) The assemblage is completed by the presence of *Bathysiphon rufescens* (1.24%) and species of *Ammodiscus, Cibrostomoides* , which occupy percentages 1.5%.

Sampling station 2MSFD12

This station is located at the upper bathyal zone, at 335m depth. Concerning the assemblage of calcareous benthic foraminifera, it is composed mainly of *Cassidulina* species (17.13%), *Amphicoryna* species (12.04%). The other calcareous taxa such us *Melonis* spp., *Uvigerina* species, *Planulina* spp., *Lagena* spp., *Globocassidulina* species, *Bolivina and Bulimina* species range in percentages 6.5%. The *Gyroidina* spp. founded in ranges 6.94%. The other Rotaliids species which founded occupy the percentages of 0.93 %.

The agglutinated benthic foraminiferal assemblage is consisted mainly of *Psammosiphonella cylindrica* (62.93%), *Saccorhiza ramosa* (12.07%), *Cibrostomoides* spp. (11.3%), *Rhizammina algaeformis* (5%), *Bathysiphon rufescens* (4.31%), *Reophax* species (7.76%).

5. Identification and Classification of Benthic Foraminifera

5.1 Introduction

This chapter presents the identified benthic foraminiferal taxa and their systematic classification.

Identification and classification of the benthic foraminifera in this study are based on the test morphology (shape, wall structure, sutures, aperture, chamber arrangement, decoration of the test, etc.) and size (Loeblich and Tappan 1988).

benthic forams in particular were discriminated and classified based on the shape and type of the granules, shape and size of the test, the sutures the number of the chambers and the aperture where this existed (Sgarella and Moncharmot, 1993; Kaminski, 2014).

The classification of the taxa is based on Loeblich and Tappan (1988) and the World Register of Marine Species (Worms, 2022).

All-important taxa are identified to the species level; others such as small epiphytic forms and shallow living miliolids such as *Quinqueloculina* species are lumped. The identification of the taxa is mainly based on Loeblich and Tappan (1988), Dermitzakis and Georgiades-Dikeoulia (1993), Milker and Schmiedl (2012) and Holbourn et al. (2013). For the agglutinated benthic foraminifera identification were mainly used Loeblich and Tappan (1988), Sgarella & Moncharmot (1993), Holbourn et al. (2013), and Kaminski (1994; 2004; 2014), Kender and Kaminski 2007, Frontalini et al. (2014; 2015).

5.2 Benthic Foraminifera Identification

A total of 13 genera of agglutinated benthic foraminifera were identified, and 9 species have been differentiated so far (Table 3). Concerning the hyaline benthic foraminifera, 10 genera were identified, (Table 4).

5.3 Taxonomic classification of Benthic Foraminifera

This chapter presents the classification of the identified benthic foraminiferal taxa, emphasizing to the agglutinated forms. The classification of the taxa is based on Loeblich and Tappan (1988) and the World Register of Marine Species (WoRMS, 2022).

Descriptions are provided for the genus level, based mainly on Loeblich and Tappan (1988), as well as Kaminsky (2004), and Milker and Schmiedl (2012). Additional comments were added where necessary, concerning the studied material.

Order Rotaliida

Superfamily Asterigerinoidea d'Orbigny, 1839
Family Asterigerinidae d'Orbigny, 1839
Genus *Asterigerina* d'Orbigny, 1839
(Plate 3, Figure 3)

The test is lenticular with smooth surface, with fine pores. It is trochospiral, slightly lobulate in outline with a carinate periphery. The chambers, arranged in three to five whorls, increasing slowly in size, and are all visible on the spiral side. About nine final chambers are visible on the umbilical side. The primary aperture is an interiomarginal slit at the base of the last chamber, extending from the umbilicus nearly to the periphery.

Superfamily Buliminoidea Jones, 1875
Family Buliminidae Jones, 1875
Subfamily Verneuilinoidinae Suleymanov, 1973
Genus *Bulimina* d'Orbigny, 1826
(Plate 2, Figures 3-4)

Test is oblong, triserial but the last chambers tend to arrange in the center of the test like in a uniserial one. Wall is calcareous, perforate, and often partially translucent. The marginal surfaces at the bottom of the chambers could be ornamented with crenulations, often extending into short, sharp spines. The aperture is a loop-shaped opening that extends up from the base of the final chamber and is bordered by a lip that merges with an internal tooth plate.

Superfamily Cassidulinoidea d'Orbigny, 1839
Family Bolivinitidae Cushman, 1927
Subfamily Bolivinitinae Cushman, 1927
Genus *Bolivina* d'Orbigny, 1839
(Plate 2, Figures 5-6)

Test is elongate, compressed, biserial, slightly lobulate, tapered in outline. Chamber walls are calcareous and finely perforate, with short spines at the base of chambers. The aperture is a loop - shaped opening bordered by a lip, with an internal tooth plate.

Family Cassidulinidae d'Orbigny, 1839
Subfamily Cassidulininae d'Orbigny, 1839
Genus *Cassidulina* d'Orbigny, 1826

Test is lenticular (biconvex) planispiral, with a clear calcitic umbilical boss on each side and an acute, keeled periphery. Approximately eight to ten moderately inflated, biserial chambers are separated by distinct sutures. Chambers extend from the umbilical boss on one side, to approximately halfway the umbilical boss of the opposite side. Chamber walls are calcareous, perforate and smooth, but look granular. The aperture is a narrow, arched slit, extending from the base of the final chamber to the marginal keel.

***Genus Globocassidulina* Voloshinova, 1960**

Test is lenticular to ovate, biserial but chambers are enrolled and separated by slightly depressed sutures. Chambers are ovate in outline and with a broadly rounded initial portion, a tapered apertural end, and a rounded periphery. Chamber walls are calcareous,perforate, appearing granular orstrongly pitted. The aperture is a straight or curved slit extending up the apertural face, with a toothplate on the posterior side.

Family Uvigerinidae Haeckel, 1894
Subfamily Uvigerininae Haeckel, 1894
Genus *Uvigerina* d'Orbigny, 1826
(Plate 2, Figures 1-2)

Test is oblong, triserial where the first chambers placed very closed each other, while the others are more robust, showing a tendency to become loosely triserial. These chambers are inflated and increase markedly in height and are separated by strongly depressed sutures. Wall is calcareous, perforate, and ornamented longitudinal striations or ridges. The aperture is terminal, round opening at the end of a short, broad neck, with an internal tooth plate, bordered by a phialine lip.

Superfamily Chilostomelloidea Brady, 1881
Family *Gavelinellidae* Hofker, 1956
Subfamily Gyroidinoidinae Saidova, 1981
Genus *Gyroidina* d'Orbigny, 1826
(Plate 1, Figures 1-6)

Test is trochospiral with a strongly convex umbilical side and a rounded periphery. The spiral view of the test is evolute flat or low convex, with all the chambers visible. The umbilical side is involute, with closed umbilicus and the sutures are radial to oblique, elevated. Chamber walls are calcareous, smooth, with large pores. The primary aperture is a low intramarginal slit from the periphery to mid-distance to the umbilicus.

Superfamily Discorboidea Ehrenberg, 1838
Family Rosalinidae Reiss, 1963
Genus *Rosalina* d'Orbigny, 1826
(Plate 3, Figure 5)

The wall is calcareous with small pores and rounded periphery. The test is trochospiral with a the spiral side is convex with crescentic and densely and coarsely perforate chambers. The umbilical side is concave or flat with triangular and imperforate chambers, strongly increasing in size as added and overlapping each other. The umbilicus is open. Sutures are depressed and backward curved on the spiral side. The primary aperture is an interiomarginal, extraumbilical arched slit, extending from the periphery to the umbilicus, and is provided with a thickened lip.

Family Reussellidae Cushman, 1933
Genus *Reussella* Galloway, 1933

Test is triserial that is triangular with sharp angles, pyramid-like, with concave sides. Chambers low and oblique, increasing gradually in size. Chamber walls are calcareous, perforate, and ornamented by sharp, projecting spines at the edges of adjacent sides. The proloculus may have a basal spine. The aperture is a slit at the base of the final chamber, with an internal toothplate.

Superfamily Nonionoidea Schultze, 1854
Family Melonidae Holzmann & Pawlowski, 2017
Subfamily Astrononioninae Saidova, 1981
Genus *Melonis* Montfort, 1808
(Plate 2, Figure 7)

Test is planispiral, involute with 10-12 chambes in the last whorl. It is symmetrical, with deep, open umbilici, subcircular in outline, and with a broadly rounded periphery. Chamber walls are calcareous, smooth, and coarsely perforate, except for the imperforate apertural face. The aperture is a low interiomarginal, equatorial slit extending to the open umbilici, and bordered with a distinct lip.

Order Nodosariida
Superfamily Nodosarioidea Ehrenberg, 1838
Family Lagenidae Reuss, 1862
Genus *Lagena* Walker & Jacob, 1798

Test unilocular, globular, ovate in outline, circular in cross - section. Chamber walls are calcareous, hyaline surface with longitudinal striations or ridges. The primary aperture is terminal, rounded, at the end of a neck and may have a phialine lip.

Order Vaginulinida
Family Vaginulinidae Reuss, 1860
Subfamily Marginulininae Wedekind, 1937
Genus *Amphicoryna* Schlumberger in Milne-Edwards, 1881

Test oblong with a pointed base, and an initially coiled (microsphere) or globular (megalosphere) proloculus that later uncoils into a rectilinear, uniserial test. Chambers are inflated, slowly increasing in size, circular in cross - section, and separated by straight, constricted sutures in the rectilinear portion. Chamber walls are calcareous, optically radial, finely perforate, and ornamented by fine striations. The primary aperture is terminal, radiate opening at the end of a distinct neck with ring - like concentric ridges.

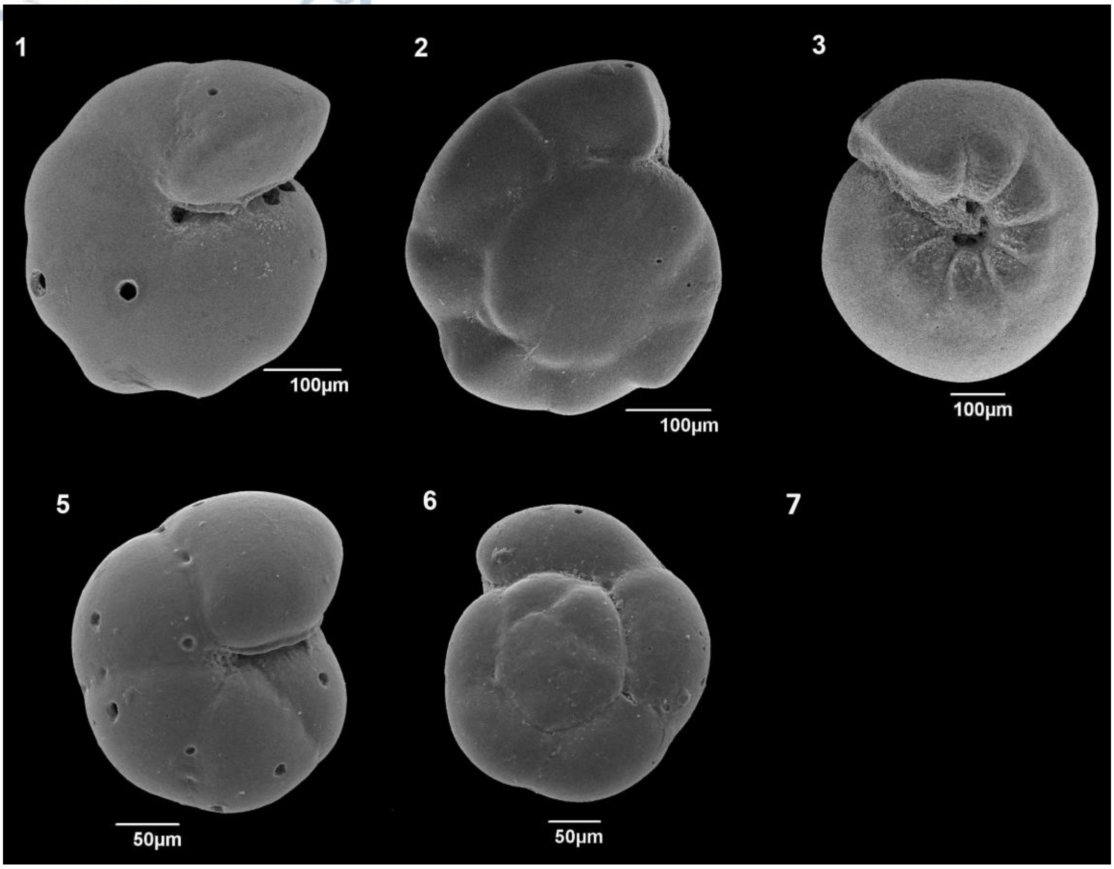
Order Polymorphinidae
Superfamily Polymorphinoidea
Family Ellipsolagenidae A. Silvestri, 1923
Subfamily Oolininae Loeblich & Tappan, 1961
Genus Oolina d'Orbigny, 1839

Test unilocular, globular to pear-shaped. Wall calcareous, perforate and smooth.The test surface is ornamented with polygonally arranged ridges. The aperture is round, terminal and rounded on a short neck.

Family Vaginulinidae Reuss, 1860
Subfamily Lenticulininae Chapman, Parr & Collins, 1934
Genus *Lenticulina* Lamarck, 1804

Test mainly planispiral, evolute, elongate and biconvex in cross-section with keeled, subacute periphery. Approximately six to nine chambers in the final whorl, increasing gradually in size and tending slightly to uncoil, are separated by thin, flush, or slightly raised, curved sutures. Chamber walls are calcareous, smooth, and finely perforate. The primary aperture is radiate and terminal.

Plate 1

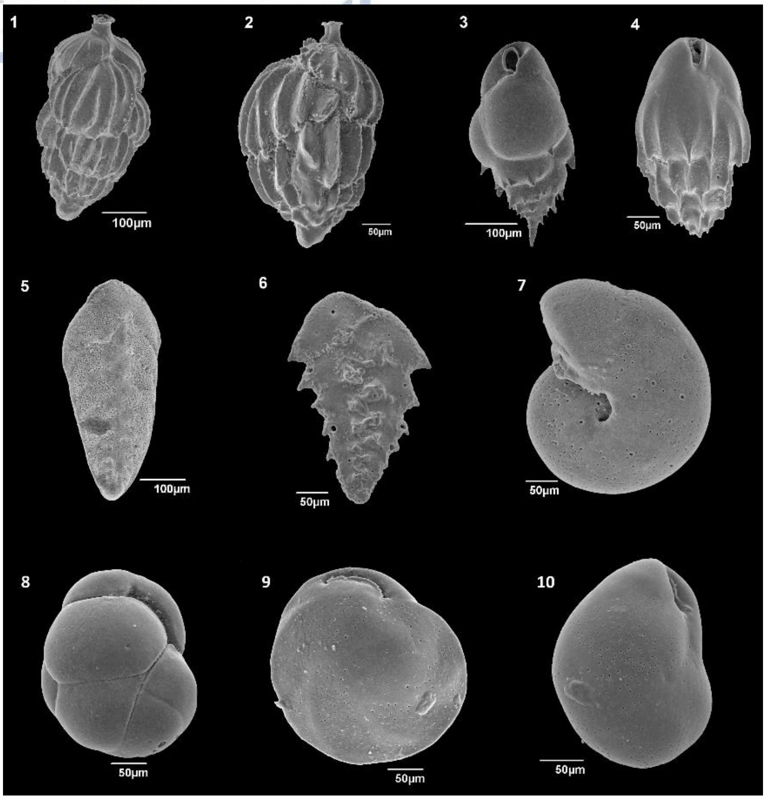


1-2. Gyroidina orbicularis (d'Orbigny in Parker, Jones & Brady, 1865) 1. Umbilical side. 2. Spiral view, (Sample 2MSFD9, water depth=1689m).

3. Gyroidina altiformis (Stewart & Stewart, 1930). Umbilical side. (Sample 2MSFD8, water depth=1680m).

5-6. Gyroidina umbonata (Silvestri, 1898). 5. Umbilical side. 6. Spiral side. (Sample 2MSFD7, water depth=1680m).

Plate 2



1-2. Species of *Uvigerina*. 1. *Uvigerina peregrina* Sample 2MSFD5, water depth=1150m. 2. *Uvigerina mediterranea* Sample 2MSFD7, water depth=1680m.

3-4. Species of *Bulimina* 3. *Bulimina aculeata* (Sample 2MSFD8, water depth=485m). 4. *Bulimina costata* (d' Orbigny, 1826) Sample 2MSFD5, water depth=1150m.

5. *Bolivina spathulata*. Sample 2MSFD5, water depth=1150m.

6. *Bolivina difformis* (Williamson, 1858) Sample 2MSFD6, water depth=1470m.

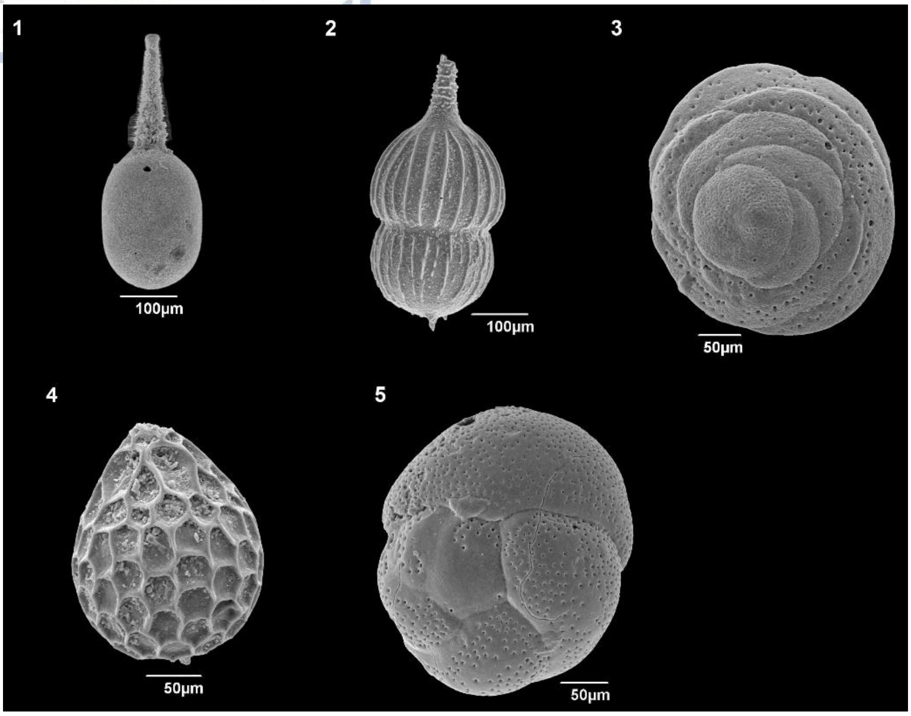
7. *Melonis affinis* Sample 2MSFD5, water depth=1150m).

8. *Cassidulina crassa* Sample 2MSFD12, water depth=335m.

9. *Cassidulina laevigata* (d' Orbigny, 1826) Sample 2MSFD10, water depth=2150m.

10. *Globocassidulina* sp.Sample 2MSFD11, water depth=365m.

Plate 3



1. *Lagena* sp. Sample 2MSFD9, water depth=1689m.

2. *Amphicoryna scalaris* Sample 2MSFD6, water depth=1470m.

3. *Asterigerinata* sp. Sample 2MSFD6, water depth=1470m.

4. *Oolina* sp. Sample 2MSFD7, water depth=1680m.

5. *Rosalina* sp. Sample 2MSFD6, water depth=1470m.

Order Astrorhizida

Superfamily Hippocrepinoidea Rhumbler, 1895
Family Hyperamminidae Eimer & Fickert, 1899
Subfamily Saccorhizinae Eimer & Fickert, 1899
Genus *Saccorhiza* Eimer & Fickert, 1899

The test forms a large, elongate, tubular mash. A globular proloculus followed by irregular or branching tubular chamber with terminal stolons. Wall agglutinated with non-calcareous cement. many outwardly projecting sponge spicules and mineral grains. The aperture is rounded observed at the open end of stolons.

This genus is the most abundant agglutinated benthic foraminifer in the deep-sea sediments of the southern Aegean Sea. In this material it was observed that in some cases (samples 2MSFD5, 2MSFD7, 2MSFD9, 2MSFD10) the test also contained radiolarians.

***Saccorhiza ramosa* (Brady, 1879)**
(Plate 4, Figures 1-6)

Hyperammina ramosa n. sp. Brady 1879, *Quarterly Journal of Microscopical Sciences.* 19: 20-67, p. 33, pl. 3, figs. 14–15.

Saccorhiza ramosa (Brady, 1879), Holbourn et al 2013, Natural History Museum, p.502. Fig.1; Frontalini et al. 2014, Micropaleontology, 60(1), p.30; Frontalini et al. 2015, Marine Biodiversity, 45, Fig. 3 photos 5-6.; Kender and Kaminski, 2017, Journal of Micropalaeontology, V. 36. Fig. 7 photo 3; Lintner et al. 2021, Deep Sea Research I, 171, Pl. 1 Fig 12

Subfamily Hyperammininae Eimer & Fickert, 1899
Genus *Hyperammina* Brady, 1878
(Plate 5. Figure 1)

Individuals of *Hyperammina* are mainly broken in the studied samples. The large proloculus is preserved in just two of them. The wall is agglutinated with firmly cemented mineral particles.

Superfamily Psammosphaeroidea Haeckel, 1894
Family Psammosphaeridae Haeckel, 1894
Subfamily Psammosphaerinae Haeckel, 1894
Genus *Psammosphaera* Schulze, 1875

The test is unilocular, spherical to subspherical. The chamber walls are agglutinated, consisting of a single layer of sand grains of, in many cases, uneven size or coarsely arenaceous. No distinct aperture in the studied samples.

***Psammosphaera fusca* Schulze, 1875**
(Plate 5, Figures 2-3)
Psammosphaera fusca Schulze. – Brady, 1884 , p. 250, pl. 18, figs. 1 – 8. – Loeblich and Tappan, 1987 , p. 28, pl. 19, figs. 2 – 3.
Kaminski et al., 1992 , p. 255, pl. 1, figs. 16 – 17.
Jones, 1994 , p. 31, pl. 18, figs. 1 – 8.
Psammosphaera fusca Schulze, emend. Heron - Allen and Earland, 1913 . – Kaminski and Gradstein, 2005 , pp. 125 – 128, fig. 8, pl. 8

Superfamily Astrorhizoidea Brady, 1881
Family Rhabdamminidae Brady, 1884
Subfamily Bathysiphoninae Avnimelech, 1952
Genus *Bathysiphon* Sars, 1872
(Plate 5, Figure 4)

The test is a straight unbranched elongate tube, open at both ends. There are no septa, while constrictions are present due to the periodic growth. The agglutinated wall is thick, composed of sponge spicules and sand grains.

Bathysiphon is rare in the studied samples, presented thick walls mostly composed of sand grains.

Genus *Psammosiphonella* Avnimelech, 1952
(Plate 5, Figure 5)

The test is a straight unbranched elongate tube, open at both ends, not compressed. The wall is thick with medium sized sharps angled grains and rough surface. The agglutinated wall does not contain sponge spicules

***Psammosiphonella* spp.**
All specimens with straight (or sometimes slightly bent) tubes with open ends, not constricted, thick walls, composed of mineral grains and organic cement. The size of the tube varies as well as the size of the agglutinate grains.

Genus *Rhabdamminella* Folin, 1887
(Plate 5, Figure 6)

The test is elongate and consists of a slender tube of constant diameter, may be slightly arcuate. Wall constructed of firmly cemented acicular sponge spicules, aligned parallel to the long axis of the test in irregular overlapping tiers. The aperture is at the open ends of the tubes.

***Rhabdamminella cylindrica* (Brady, 1882)**
Marsipella cylindrica n. sp. Brady, 1882, Proceedings of the Royal Society of Edinburgh. 11: p. 638-720

Rhabdamminella cylindrica (Brady, 1882), Milker and Schmiedl, 2012, Palaeontologia Electronica, 15(2), Fig.9, photo 1; Kender and Kaminski, 2017, Journal of Micropalaeontology, V. 36, Fig. 7 photos 12-13; *Marsipella cylindrica* Brady, Lintner et al., 2021, Deep Sea Research Part I, 17(1), Plate 1, photo 7.

Genus *Marsipella* Norman, 1878

The test is large, elongate, fusiform, tubular, cylindrical or tapering and undivided, maybe be slightly twisted; wall thin of agglutinated sand, sponge spicules or tests of other foraminifers, firmly cemented; apertures at the open ends of the tube.

This genus was present only in sample 2MSFD5, with one individual. The test was elongate, tubular, cylindrical and the wall was firmly cemented with agglutinated sand, sponge spicules and tests of other organisms such as diatoms and foraminifers.

Superfamily Komokioidea Tendal & Hessler, 1977
Family Rhizamminidae Wiesner, 1931
Genus *Rhizammina* Brady, 1879
(Plate 6, Figures 1-3)

The test forms an elongate, tubular, branched dichotomously tube, seldom straight and in a lot of cases tapered toward the ends, with a circular cross-section. The wall is flexible, thin and coarsly agglutinated, and adorned with planktonic foraminifera, radiolaria and sand grains. Appearing transversely wrinkled. The primary aperture is the terminal opening at the end of the tube.

***Rhizammina algaeformis*, Brady, 1879**

Rhizammina algaeformis n.sp. Brady, 1879, Quarterly Journal of Microscopical Sciences. 38, pl. 4, Figs 16, 17

Kender and Kaminski, 2017, *Journal of Micropalaeontology*, V. 36. Fig. 6 photos 14a-b

Lintner et al. 2021, Deep Sea Research I, 171, Pl. 1 Fig 10

Order Spirillinida
Superfamily Ammodiscoidea Reuss, 1862
Family Ammodiscidae Reuss, 1862
Subfamily Ammodiscinae Reuss, 1862
Genus *Ammodiscus* Reuss, 1862

The test is circular outline and the periphery rounded. Globular proloculus followed by a planospirally enrolled, undivided tubular second chamber. Surface with accasional transverse growth constructions, the growth steps, but without internal subdivisions. The wall is densely and finely agglutinated. At the open end of the tube observed aperture in arch shape.

Ammodiscus minimus **(Horglund,1947)**
(Plate 6, Figure 4)
Ammodiscus minimus Hoeglund: p. 124, pl. 8, figs., 5, 10; text-figs. 90, 105, 110.
Ammodiscus minimus Hoeglund; Hofker, p. 236, pl. A, fig. 13

Subfamily Usbekistaniinae Vyalov, 1968
Genus *Glomospira* Rzehak, 1885

The test consists of a proloculus with globular shape. The proloculus followed by a tubular second chamber which is trochospirally enrolled, undivided, and coiled about a vertical axis. Typically, there are three layers of coils with six to seven whorls in the outer layer. Walls of the cambers are finely agglutinated and cemented with organic matter with inner and outer organic linings, and smooth finish. The primary aperture has is at the open end of the tube.

Glomospira charoides **Jones & Parker, 1860(Plate 6, Figure 5)**
Trochammina squamata var. charoides n. sp. Jones & Parker, 1860, Quarterly Journal of the Geological Society of London. 16: 292-307. p. 340.
Usbekistania charoides, Frontalini et al. 2015, Marine Biodiversity, 45, Fig. 3 photo 2.
Glomospira charoides Jones & Parker, 1860, De Rijk et al., 2000, Marine Micropaleontology 40:150-166, Ap. A
Holbourn et al 2013, Natural History Museum, p.268. Fig.1
Lintner et al. 2021, Deep Sea Research I, 171, Pl. 1 Fig 11

Superfamily Hormosinoidea Haeckel, 1894
Family Reophacidae Cushman, 1927
Genus *Reophax* Montfort, 1808
(Plate 6, Figure 6)

The test consists of 6 chambers which increase rapidly in size. The form is uniserial, initially curved and later straight. The last two chambers making up more than half of the test. The final chamber is distinctly asymmetric inside view and ventricose. The side which lies outside curvature of the test, is almost straight, while that on the inside is curved. The early cambers cylindrical. The sutures are well defined, transverse with a little overlap of the chambers. The terminal aperture is rounded and flush and the rim made up of large angular quartz grains. The early cambers more coarsely agglutinated than final ones.

Order Lituolida
Superfamily Ammosphaeroidinidae Cushman, 1927
Family Ammosphaeroidinidae Cushman, 1927
Subfamily Recurvoidinae Alekseychik-Mitskevich, 1973
Genus *Cribrostomoides* Cushman, 1910

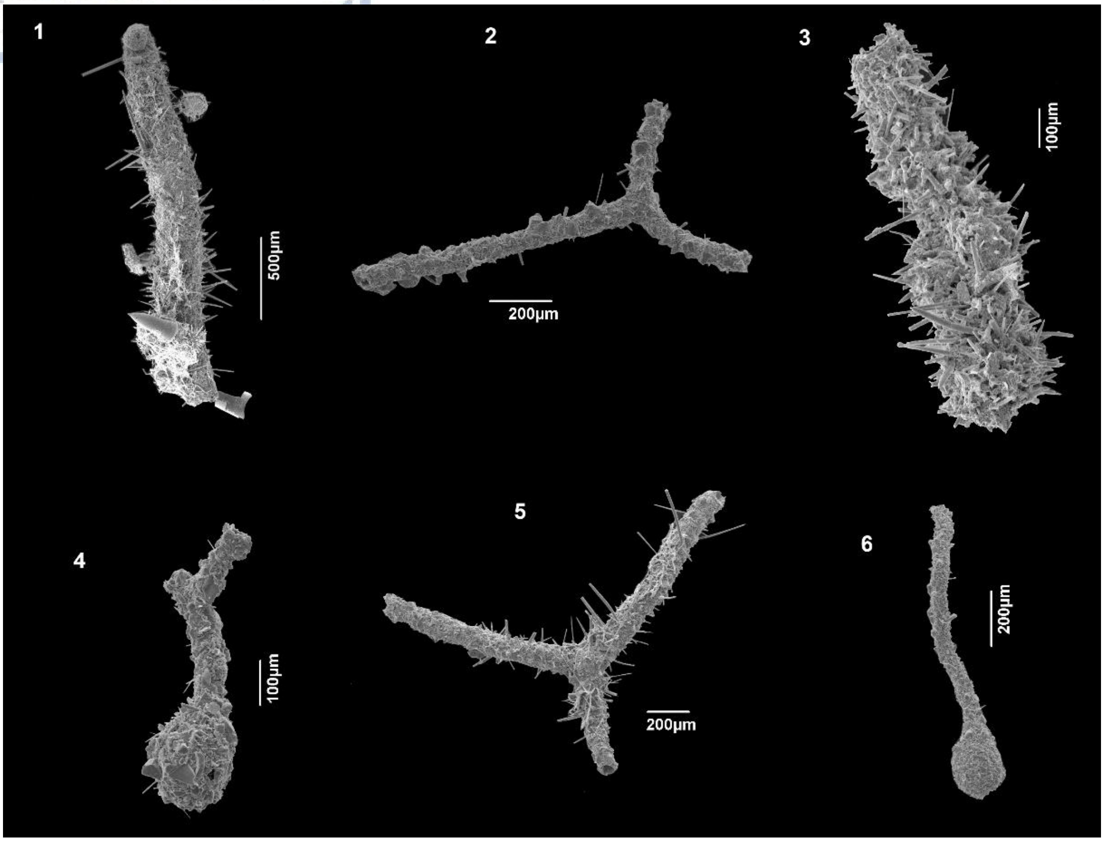
(Plate 6, Figure 5)

The test is free, enrolled and involuted. There are few chambers per whorl. In the early stage is growth gently streptospiral and later becoming planispiral and symmetrical. The wall is agglutinated, thin and simple in stracture, the surface haw smooth finish and the aperture is equatorial, just above the base of the final chamber face with a narrow lip of finer sand presented on both margins. A simple slit in the early chambers, later becoming irregular with fine projections from both margins that may separate the primary aperture into a linear series of irregular to rounded openings near the base of the chamber face (Loeblich and Tappan 1988).

Superfamily Lituoloidea
Family Discamminidae Mikhalevich, 1980
Genus *Ammoscalaria* Höglund, 1947

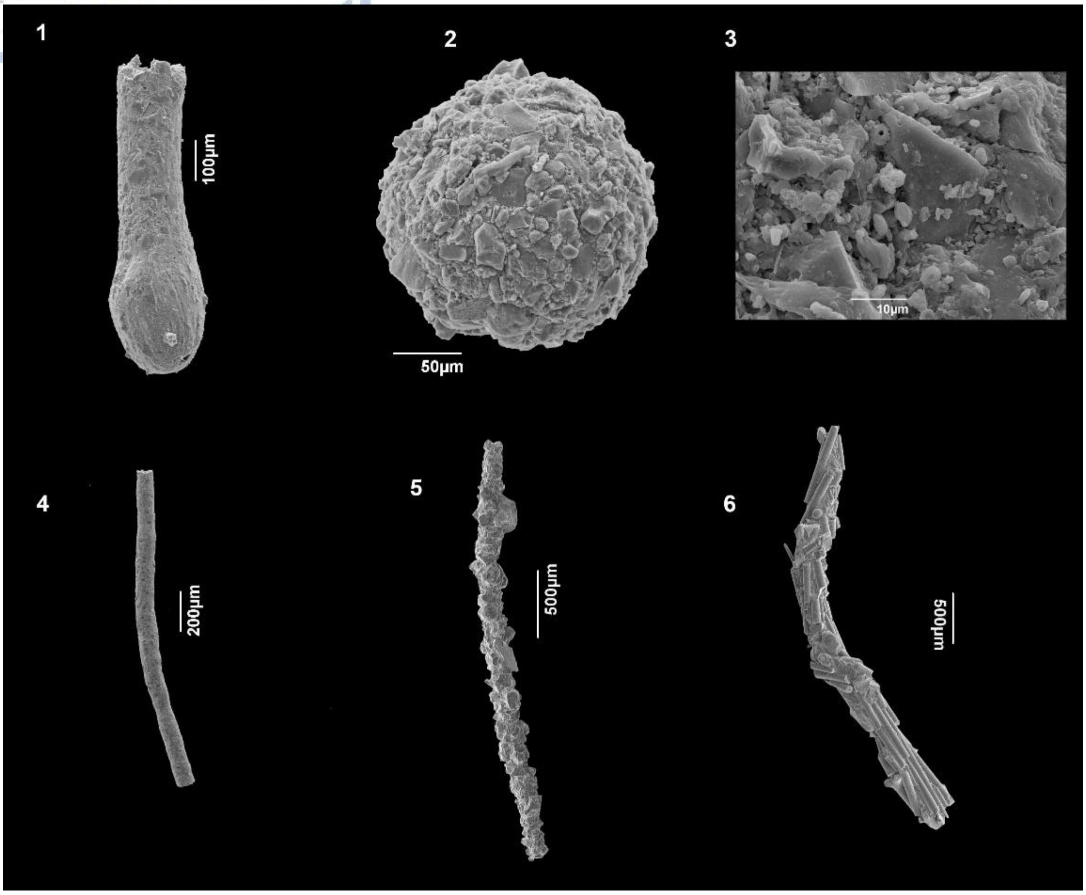
The test is free, elongate, flattened, early portion with one to two planispiral whorls, later uncoiling and rectilinear, with short and broad chambers separated be the very thin straight and horizontal partitions comprised only of the organic material and pierced centrally by an intercameral foramen that has a short tubular neck. The outer wall is thick and coarsely agglutinated on an organic lining, surface rough, that on the region near the aperture much thinner and more fine grained. The aperture is terminal and rounded, slightly produced (Loeblich and Tappan 1988).

Plate 4



1. *Saccorhiza ramosa* (Brady, 1879).Fragment, elongate, tubular chamber, absence of globular proloculus. Wall structure: sponge spicules, diatoms, coccocliths and fragments of pteropods. No aperture., (Sample 2MSFD11, water depth=365m).
2. *Saccorhiza ramosa* (Brady, 1879). Fragment, elongate, branching tubular chamber, absence of globular proloculus. Wall stracture: mineral grains and less sponge spicules, coccoliths. Rounded aperture. (Sample 2MSFD8, water depth=485m).
3. *Saccorhiza ramosa* (Brady, 1879). Fragment, elongate, tubular chamber, absence of globular proloculus. Wall stracture: mainly with sponge spicules, diatoms, coccocliths and fragments of pteropods. No aperture. (Sample 2MSFD12, water depth=335m).
4. *Saccorhiza ramosa* (Brady, 1879). Fragment, elongate, branching tubular chamber, globular proloculus. Wall stracture: large size mineral grains and less sponge spicules, coccoliths. No rounded aperture. (Sample 2MSFD10, water depth=2150m).
5. *Saccorhiza ramosa* (Brady, 1879).The test is elongate, branching tubular chamber, absence of globular proloculus. Wall stracture: mineral grains and sponge spicules, diatoms, coccoliths, and pteropods.Rounded aperture. (Sample 2MSFD9, water depth=1689m).
6. *Saccorhiza ramosa* (Brady, 1879). The test is elongate, tubular chamber, globular proloculus. Wall stracture: few mineral grains and less sponge spicules, coccoliths. No rounded aperture. (Sample 2MSFD6, water depth=1470m).

Plate 5



1. *Hyperammina sp*. .Fragment, tubular chamber, large globular proloculus. Wall structure: firmly cemented mineral particles, no sponge spicules. No rounded aperture. (Sample 2MSFD10, water depth=2150m).

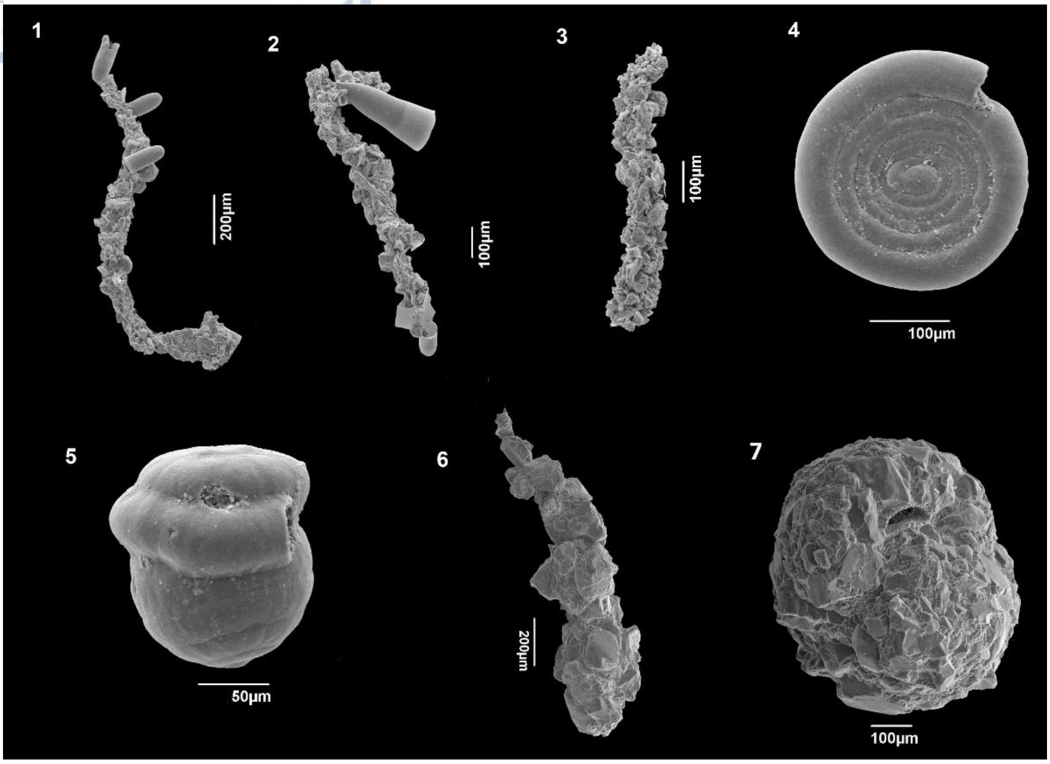
2-3 *Psammosphaera fusca*. (Schulze, 1875). 2. Unilocular, spherical chamber. Wall stracture: sand grains uneven size, with coccoliths, no sponge spicules. No aperture. (Sample 2MSFD8, water depth=485m). 3. Detail *of 2* (Sample MSFD11, water depth=365m).

4. *Bathysiphon* sp. Straight elongate, open both ends, no septa. Wall structure: thick sand grains, no sponge spicules. No aperture (Sample 2MSFD8, water depth=485m).

5. *Psammosiphonella* sp. Straight elongate, open both ends. Wall structure: thick medium sharped sand grains, no sponge spicules.Rounded aperture. (Sample 2MSFD10, water depth=2150m).

6. *Rhabdamminella cylindrica* (Brady,1882). Slightly arcuate elongate tube, open both ends. Wall structure: acicular parallel sponge spicules, no sand grains. Rounded aperture at the open ends. (Sample 2MSFD7, water depth=1680m).

Plate 6



1-3 . *Rhizammina* sp. (Brady, 1879). Elongate, tubular, with a circular cross-section. Wall stracture: densely and finely agglutinated flexible, thin, and coarsly agglutinated, and adorned with planktonic foraminifera, radiolaria, pteropods and sand grains. primary aperture is the terminal opening at the end of the tube. No sponge spicules. (1) (Sample 2MSFD7, water depth=1680m). (2). Sample 7,(South Aegean Base, depth=1680m). (3). (Sample 2MSFD7, water depth=1680m).

4. *Ammodiscus minimus* (Horglund,1947). Circular outline and the periphery rounded. The proloculus followed f by a planospirally enrolled, undivided tubular second chamber. Wall structure: densely and finely agglutinated. At the open end of the tube observed aperture in arch shape. No sponge spicules. (Sample 2MSFD6, water depth=1470m).

5. *Glomospiracharoides* (Jones & Parker, 1860).Proloculus with globular shape. The proloculus followed by a tubular second chamber which is trochospirally enrolled, undivided, and coiled about a vertical axis. Wall stracture: finely agglutinated with smooth finish. No sponge spicules. No rounded aperture. (Sample 2MSFD7, water depth=1680m).
6. *Rheophax* sp. (Montfort, 1808). Uniserial, curved later straight. Six chambers increased in size. Last two chambers bigger than the half of the test. Early cambers cylindrical. Wall stracture: large angular quartz grains, early cambers more coarsely agglutinated than final. No sponge spicules. No rounded aperture . (Sample 2MSFD11, water depth=365m).
7. *Cribrostomoides* sp. (Cushman, 1910). Free, enrolled and involuted. Planispiral and symmetrical.Wall stracture: medium shaped sand grains. Aperture at the end of the chamber.The grain size is smaller at the aperture. No sponge spicules. (Sample 2MSFD11, water depth=365m).

6. Discussion

The biogenic content of 8 surface sediment samples was studied from central-southern Aegean basins, three of which were towards the Levantine (Figure 5). The samples were rich in biogenic content, consisted of planktonic and benthic foraminifera, ostracods, otoliths and pteropods, with most abundant groups pteropods and planktonic foraminifera (Table 2). This composition of the bottom sediments is common in deep marine environments (for example, Honjo et al., 1982; Lampadariou et al., 2009; Guidi-Guilvard et al., 2009; Lin et al., 2017).

The current study focused on benthic foraminiferal assemblages as they were the most diverse group and there are not many studies from deep eastern Mediterranean environments, particularly from the Aegean Sea. The Shannon-Wiener diversity index (H΄) for the benthic foraminiferal assemblages (Figure 6) presents high values that seem to decrease with depth, being highest at the sampling stations from the upper bathyal environments. This is in accordance with other studies such as the one of Hyams-Kaphzan et al. (2018) from the Levantine basin.

The calcareous versus agglutinated participation rates indicate that agglutinated taxa prevail (55.34-76.17%) over calcareous (mostly hyaline) ones in the samples from the lower bathyal stations (samples 2MSFD6, 2MSFD7, 2MSFD9, 2MSFD10), with the exception of sample 2MSFD5, where calcareous forms are dominant (96.64%) (Figure 7). Concerning the samples from the upper bathyal zone (samples 2MSFD8, 2MSFD11, 2MSFD12) Figure 7), calcareous taxa prevail over agglutinated, and they are dominant in sample 2MSFD8 (89.11%); this high abundance cannot exclude transportation mechanisms via currents, submarine landslides etc.

The agglutinated foraminifera group in the studied material was composed of arborescent, tubular, and globular taxa and a total of 12 genera and 9 species have been so far identified. *Saccorhiza ramosa* (Brady, 1879) is the most abundant taxon (11-84% of the agglutinated fauna), constantly present in all the samples (Figure 8). Its wall is made of mineral grains, coccoliths and sponge spicules, while in certain samples spumellarian radiolaria and pteropods are also incorporated in the test structure. Other common taxa are *Rhabdamminella cylindrica* (Brady, 1882) (present in six samples; 0.2-12.5%); *Rhizammina algaeformis*, Brady, 1879 (present in five samples; 1-26%), being coarsely agglutinated, beside inorganic grains, with planktonic foraminifera, radiolaria and pteropods; *Glomospira charoides* (present in four samples; 1-57%) and *Psammosiphonella* spp. (present in four samples; 7.85-63%). Other taxa with scarce presence in the studied samples are *Psammosphaera fusca* Schulze, 1875 and species of *Bathysiphon*, *Marsipella*, *Hyperammina*, *Reophax*, *Cribrostomoides*, *Ammoscalaria* and *Ammodiscus* (Figure 8).

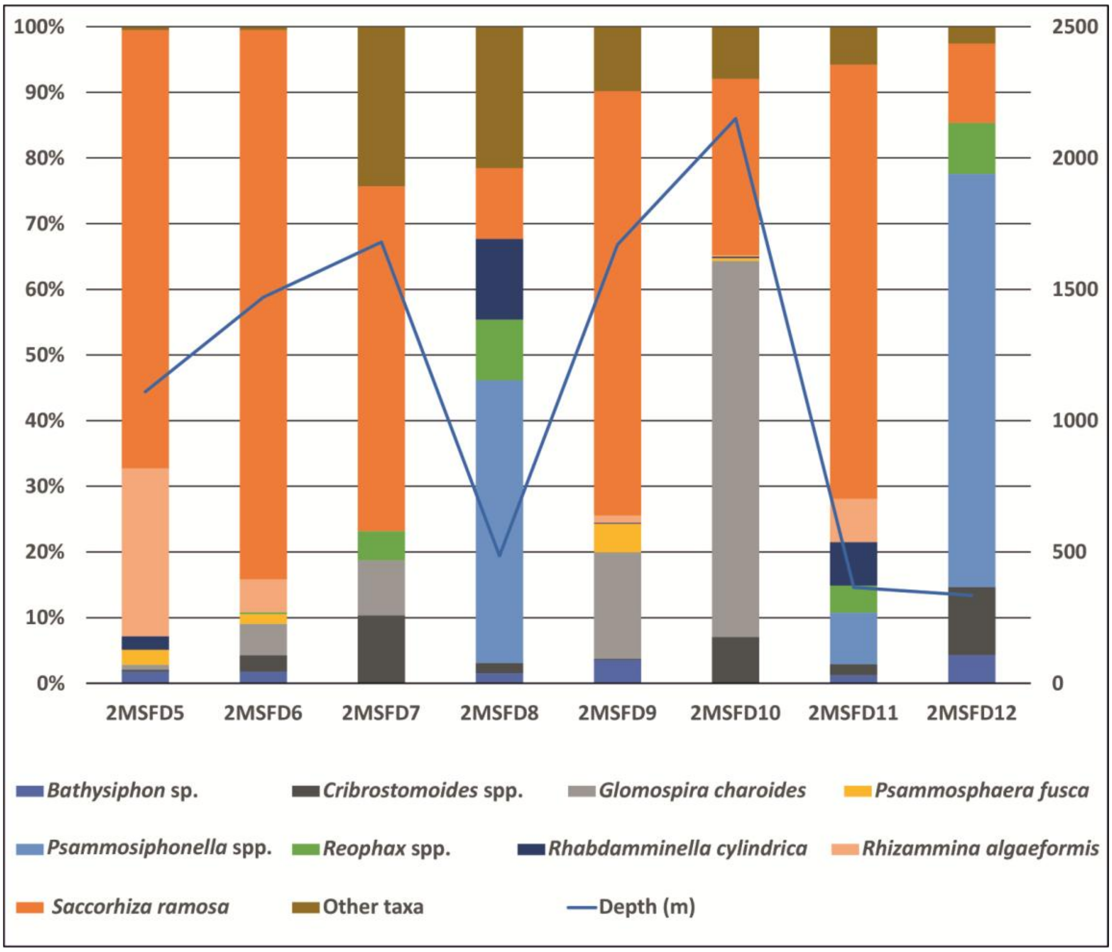


Figure 8. Relative abundances of the agglutinated BF of the studied samples from the cluster >125μm, plotted against depth of the sampling stations.

All the arborescent/tubular forms (*S. ramosa*, *R. cylindrica*, *R. algaeformis*, *Bathysiphon*, *Hyperammina*, *Psammosiphonella*, *Marsipella*), belong to Morphogroup 1 (M1) of Kaminski and Gradstein (2005) and they are epifaunal forms, suspension feeders, preferring quite bathyal-abyssal (Schröder, 1986) oligotrophic environments. *Cribrostomoides* belongs to Morphogroup 2b (M2b) of rounded streptospiral forms, they are epifaunal foraminifera, deposit feeders and they occur in shelf and deep marine environments (Kaminski and Gradstein, 2005). *Glomospira* and *Ammodiscus* belong to Morphogroup 3a (M3a) of Kaminski and Gradstein (2005) and they are epifaunal forms, deposit feeders. Finally, *Reophax* belongs to Morphogroup 4b (M4b) of Kaminski and Gradstein (2005) and they are deep infaunal forms, deposit feeders, prefering inner shelf to upper bathyal environments and increased organic matter flux. Also, *S. ramosa* according to Koho et al. (2007) seems to have developed the skill to survive for long time without any food, benefiting from episodic sedimentation events e.g. in canyon environment.

Agglutinated foraminifera constitute a significant part of the Mediterranean benthic faunas deeper than 1000m and the decrease in primary productivity causes reduction in food availability from the western to the eastern basins, affecting these populations (De Rijk et al., 1999). So, the dominance of epifaunal species in the samples of this study indicates low food supply (Koho et al., 2007; Frontalini et al., 2015) and it is in accordance with the oligotrophic character of the South Aegean Sea (Lykousis et al., 2022).

It is the first time with this study that the deep assemblages of agglutinated taxa are described from the broader area of the Aegean Sea. Frontalini et al. (2015) studied in detail agglutinated foraminiferal assemblages from Saros Bay (northern Aegean Sea) and their deepest assemblages, from 200-500m, are very well diversified and represented mainly by tubular, epifaunal taxa (*Hyperammina*, *Bathysiphon*, *Rhabdammina* and *Saccorhiza*). These taxa present their highest percentages (about 70%) at the deepest (500m) parts, as in most of the samples of the current study. In the broader area of eastern Mediterranean Sea, Hyams-Kaphzan et al. (2018) analyzed benthic foraminiferal assemblages from the deep southeastern Levantine basin (up to 1900m) and they recorded similar agglutinated species with the deep southern Aegean Sea, but with different abundances.

Concerning calcareous (mostly hyaline) benthic foramininfera assemblage, we can distinguish different assemblages in the studied samples:

- The assemblage of the upper bathyal samples (2MSFD8, 2MSFD11, 2MSFD12), which consists mainly of *Bolivina* species (6.5-30.5%), *Bulimina* species (6.5-15.41%), *Cassidulina* spp. (14.8-17.8%), *Globocassidulina* spp. and *Amphicoryna* species.
- The assemblage of samples 2MSFD9 and 2MSFD10 (the deepest samples northern of Crete), which is consisted mainly of *Gyroidina* species (82.43-83.24%) and *Melonis* species (6.6-8.3%).

- The assemblage of the three sampling stations towards the Levantine (2MSFD5, 2MSFD6, 2MSFD7), which is consisted mainly of *Gyroidina* species (31.1-63%), *Melonis* species (15.8-27.4%), *Uvigerina* (6.43-11.18%), *Bolivina*, *Bulimina* and many small rotalids.

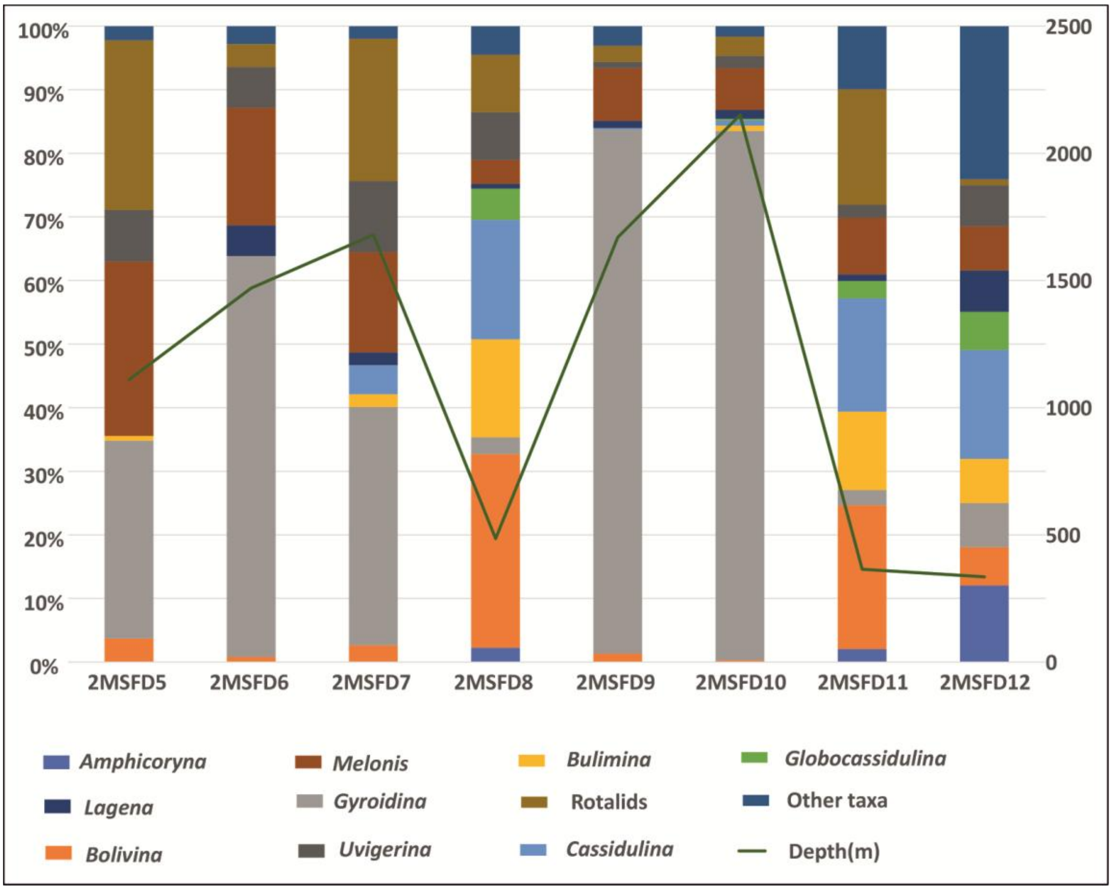


Figure 9. Relative abundances of the calcareous (mostly hyaline) BF of the studied samples from the cluster >125μm, plotted against the depth of the sampling stations.

Gyroidina species are rounded trochospiral forms and according to their morphotype they are epifaunal to shallow infaunal dwellers (Corliss and Chen, 1988; De Stigter et al., 1998). They are adapted to high oxygene conditions, and they are probably phytodetritus feeders (Nolet and Corliss, 1999; Cornuault et al., 2016).

According to the distinguished morphotypes of Corliss and Chen (1988) the elongated biserial-triserial species of *Bolivina*, *Bulimina* and *Uvigerina* are infaunal. *Bolivina* and *Uvigerina* are considered mainly shallow infaunal, *Bulimina* deep infaunal and they are eutrophic and tolerate lower oxygene conditions (Jorissen 1999; Fontanier et al., 2002). *Melonis* (rounded planispiral), *Cassidulina* spp. (flattened ovoid) and *Globocassidulina* spp. (spherical) are considered shallow infaunal (Corliss and Chen, 1988; Fontanier et al., 2002).

6.1 The biogenic component

The biogenic component in all studied samples (>125μm) overall consists of pteropods, otoliths, ostracods, planktonic foraminifera, and both agglutinated and calcareous benthic foraminifera. Variations were observed in the concentration of the biogenic content between the sampling stations (Table 2).

Samples 2MSFD6 and 2MSFD7, collected from the stations towards the northwestern Levantine basin, had by far the highest concentration of biogenic component compared to the other stations (Table 2). On the other hand, samples 2MSFD11 and 2MSFD12 from the shallower depths of the Cyclades plateaux area, as well as the sample 2MSFD10 from the deepest station northeastern of Crete Island had the lowest concentration of biogenic component.

The biogenic component of the sampling stations from the upper bathyal zone of the Aegean Sea, 2MSFD8, 2MSFD11, 2MSFD12 (with depths 485m, 365m and 335m, respectively) presents the highest participation rates of ostracods and calcareous BF have higher relative abundances than agglutinated BF. Additionally, the calcareous BF assemblages are consisted mainly of the shallow infaunal hyaline species *Bolivina*, *Bulimina*, *Cassidulina* and *Globocassidulina*.

Sample 2MSFD8 is differentiated from the other two as the concentration of biogenic component is relatively high. Pteropods are abundant and planktonic foraminifera and benthic foraminifera dominate in the sample with similar percentages (49.62% and 46.35% respectively). The agglutinated foraminifera are observed at a very low rate of 4.17%, while no otoliths were found in this sample.

Finally, samples 2MSFD11 and 2MSFD12, presents similar characteristics both in the quality and quantity of the total biogenic material. The total biogenic component is the lowest and pteropods are very few. In the sample 2MSFD11 planktonic foraminifera occupy 83.68% of the total sample, agglutinated BF 3.52%, calcareous BF 5.47%, while ostracods 7.26%, and otoliths 0.06%. In sample 2MSFD12 planktonic foraminifera are found in a percentage of 91.36%, agglutinated BF 1.66%, calcareous BF 3.88%, while ostracods 3.04% and otoliths 0.06%.

The biogenic component of the sampling stations 2MSFD9 and 2MSFD10, which are located northern of Crete and they are the deepest sampling stations (at depths of 1689m and 2150m respectively) is dominated by planktonic foraminifera. In particular, the first sample presented 97.22% of planktonic foraminifera, 0.79% agglutinated BF, 0.7% calcareous BF and 1.27% ostracods. Station 2MSFD10 consists of 92.96% planktonic foraminifera, 2.06% agglutinated BF, 1.99% calcareous BF and 2.81% ostracods. Pteropods were abundant in both samples. Additionally, the calcareous BF assemblages are dominated by the epifaunal *Gyroidina* species.

The stations 2MSFD5, 2MSFD6 and 2MSFD7 are located southern of Crete and toward to Levantine Sea at depths of 1150m, 1470m and 1680m respectively. The biogenic component of these sampling stations is differentiated. At the stations 2MSFD6 and 2MSFD7, the samples with the highest concentration of biogenic component, present similar characteristics both in the quality and quantity of the total biogenic material. In particular they present great abundance of pteropods, they show the highest participation rates (>98%) of planktonic foraminifera and the lowest percentages of ostracods (about 0.5%) from all the studied samples. Furthermore, agglutinated BF present higher participation rates from calcareous BF.

Sample 2MSFD5, is differentiated from the other two presenting similar biogenic component to sample 2MSFD8 (Table 2): Pteropods are abundant and planktonic foraminifera and benthic foraminifera dominate in the sample with similar percentages (53,12% and 44.89% respectively). The agglutinated foraminifera are observed at a very low rate of 1.08%, ostracods represent 1.95% of the total component while otoliths 0.04%.

Summarizing, samples collected from the stations towards the northwestern Levantine basin (2MSFD6 and 2MSFD7) presented the highest concentration of biogenic component compared to all the other samples. These samples presented also the highest participation rates of planktonic foraminifera and the lowest ones of benthic foraminifera (mainly agglutinated) and ostracods, while pteropods were particularly abundant. The biogenic component of samples 2MSFD9 and 2MSFD10, which were sampled from the lower bathyal zone northern of Crete Island, present similar characteristics with samples 2MSFD6 and 2MSFD7. However, 2MSFD9 has a high concentration of biogenic component, while 2MSFD10 from the deepest station contained the lowest concentration of biogenic component compared to the other lower bathyal stations.

The biogenic component of sample 2MSFD5 (southeastern of Crete, lower bathyal zone) is comparable to the one of 2MSFD8 (southeastern of Peloponnese, upper bathyal zone), both in abundance and composition, presenting the highest participation rates of benthic calcareous foraminifera.

Finally, samples 2MSFD11 and 2MSFD12, the shallowest samples collected from the Cyclades plateaux area, presented the lowest concentrations of biogenic component. Their biogenic component is characterized by the low presence of pteropods, calcareous BF have higher relative abundances than agglutinated BF and the high participation rates of ostracods.

Concerning the pollutants' analysis, the results are presented in Figure 10. The total concentrations of the considered PAH compounds ($TPAH_{31}$) ranged from 78.0 to 274 ng g^{-1}, 132±63.5 ng g^{-1} on average. The highest concentrations were recorded in stations MSFD5-7 located in the NW Levantine Basin, while the lowest ones in stations MSFD8-12 located within the Aegean Sea.

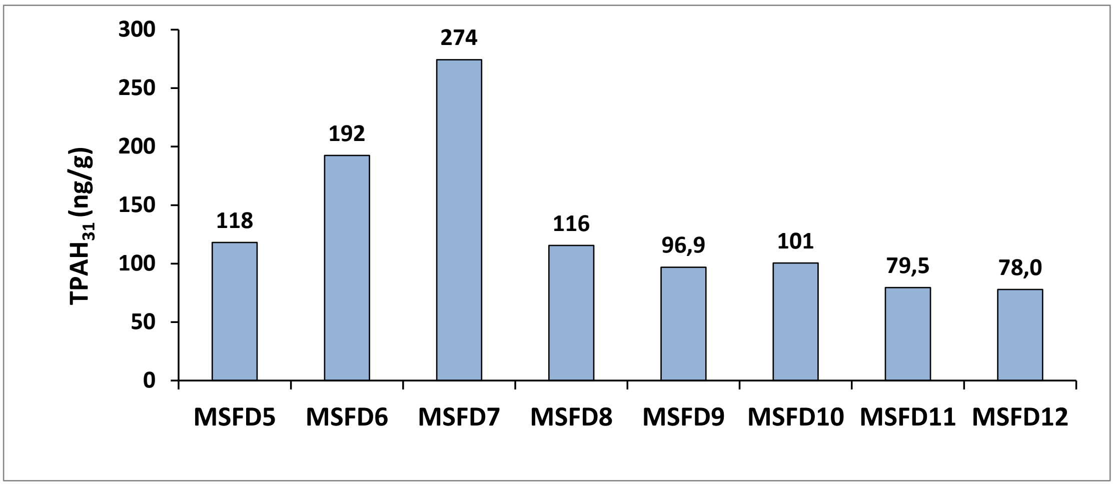


Figure 10. The concentrations of the polycyclic aromatic hydrocarbons (PAHs) compounds/groups in the studied samples (Constantine Parinos, HCMR; personal communication).

The total sedimentary PAH concentrations reported herein are significantly lower than those reported for surface sediments in coastal/estuarine areas in the Mediterranean Sea and worldwide, receiving enhanced anthropogenic inputs. They rather fall within a range comparable to those reported for non-polluted coastal Mediterranean sites (e.g. Bonsignore et al., 2018; Darilmaz et al., 2019) and offshore - open/deep sea locations in the Aegean Sea (Gogou et al., 2000), the open Ionian/NW Levantine Sea (e.g. Parinos et al., 2013), the Adriatic Sea (e.g. DeLazzari et al., 2004), the northwestern Mediterranean Sea (e.g. Bouloubassi et al., 2012) and the Levantine basin (e.g. Astrahan et al., 2017).

Tracing the mechanisms of pollutant export to the surface sediments of the deep South Aegean basins along with the composition and distribution of the benthic foraminiferal assemblages, may provide further information for the transportation of the organic matter and the sedimentation processes in these oligotrophic basins.

7. Conclusions

The micropaleontological analysis of 8 surface sediment samples from central-southern Aegean basins highlighted a biogenic content, consisted of planktonic and benthic foraminifera, ostracods, otoliths and pteropods, with most abundant groups pteropods and planktonic foraminifera.

Variations were observed in the concentration of the biogenic content between the sampling stations:

Samples collected from the stations towards the northwestern Levantine basin (2MSFD6 and 2MSFD7) presented the highest concentration of biogenic component compared to all the other samples. These samples presented also the highest participation rates of planktonic foraminifera and the lowest ones of benthic foraminifera (mainly agglutinated) and ostracods, while pteropods were particularly abundant. The biogenic component of samples 2MSFD9 and 2MSFD10, which were sampled from the lower bathyal zone northern of Crete Island, present similar characteristics with samples 2MSFD6 and 2MSFD7. However, 2MSFD9 has a high concentration of biogenic component, while 2MSFD10 from the deepest station contained the lowest concentration of biogenic component compared to the other lower bathyal stations.

The biogenic component of sample 2MSFD5 (southeastern of Crete, lower bathyal zone) is comparable to the one of 2MSFD8 (southeastern of Peloponnese, upper bathyal zone), both in abundance and composition, presenting the highest participation rates of benthic calcareous foraminifera.

Finally, samples 2MSFD11 and 2MSFD12, the shallowest samples collected from the Cyclades plateaux area, presented the lowest concentrations of biogenic component. Their biogenic component is characterized by the low presence of pteropods, calcareous BF have higher relative abundances than agglutinated BF and the high participation rates of ostracods.

Concerning benthic foraminiferal assemblages, it is the first time that such deep-lower bathyal assemblages of agglutinated taxa are described from the broader area of the Aegean Sea.

The calculated Shannon-Wiener diversity index (H´) for the BF assemblages presents normal trend, as it decreases from the upper bathyal to lower bathyal environments. Furthermore, the calcareous versus agglutinated participation rates indicate that agglutinated taxa prevail over calcareous ones in the samples from the lower bathyal stations (except of 2MSFD5), while there is an opposite trend for the samples from the upper bathyal zone.

The agglutinated foraminifera group is composed of arborescent, tubular, and globular taxa and a total of 13 genera and 9 species have been so far identified. *Saccorhiza ramosa* is the most abundant species and other common taxa are *Rhabdamminella* cylindrica, *Rhizammina algaeformis*, *Glomospira charoides* and *Psammosiphonella* spp. Also *Psammosphaera fusca* and species of *Bathysiphon*, *Marsipella*, *Hyperammina*, *Reophax*, *Cribrostomoides*, *Ammoscalaria* and *Ammodiscus* where present. All these taxa are epifaunal forms -except of *Reophax*- indicating oligotrophic conditions.

Three calcareous (mostly hyaline) benthic foramininfera assemblages were distinguished in the studied samples: The assemblage of the upper bathyal samples (2MSFD8, 2MSFD11, 2MSFD12), which is consisted mainly of the shallow infaunal species *Bolivina*, *Bulimina*, *Cassidulina* and *Globocassidulina*. The assemblage of samples 2MSFD9 and 2MSFD10 (the deepest samples northern of Crete), which is dominated by the epifaunal *Gyroidina* species. The assemblage of the three sampling stations towards the Levantine (2MSFD5, 2MSFD6, 2MSFD7), which is consisted of both infaunal and epifaunal taxa such as *Gyroidina*, *Melonis*, *Uvigerina Bolivina* and *Bulimina*.

The pollutants' analysis showed that the total concentrations of the considered PAH compounds ($TPAH_{31}$) had higher values in stations MSFD5-7 located in the NW Levantine Basin and the lowest ones in stations MSFD8-12 located within the Aegean Sea. But the total sedimentary PAH concentrations reported herein are comparable to those reported for non-polluted coastal Mediterranean sites and offshore - open/deep sea locations in the Aegean Sea, as well as other studied areas of northwestern, central and eastern Mediterranean Sea.

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