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Environmental control on shell structure and composition of agglutinated foraminifera along a proximal–distal transect in the Marmara Sea

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ABSTRACT

The study of benthic foraminifera in a complex marine system, like the Marmara Sea, is a key for understanding the influence of environmental factors on foraminiferal species, density, assemblage composition, and shell construction. This kind of study is important for further extensive use of foraminifera-based investigation of water mass and sediment exchange between the eastern Mediterranean and Black Sea through the Marmara Sea. Based on proximal–distal transect from the southwest coast of the Erdek Bay to the top of canyon close to the North Anatolian Fault, this study aims at defining the geochemical conditions at the seafloor and identifying the sediment constraints that act upon agglutinated test construction for selected species (*Eggerelloides scaber*, *Textularia agglutinans*, *Textularia sagittula*, *Textularia truncata* and *Textularia bocki*). Grain size, mineralogical, and chemical analyses of their shells were investigated and confronted with the main geochemical conditions prevailing during deposition and within the sediment. Among grains used to construct the agglutinated foraminiferal tests from available grains, both grain size selection and sorting have been evidenced. This suggests that the mineralogical composition is related to the species and the sample localization within the basin. Our observations further suggest that bottom water conditions of the Marmara Sea do not have a significant influence on agglutinated foraminiferal shell development, which is primarily driven by sediment characteristics. Our results are thus transposable to other environments.

1. Introduction

It is well known that the composition, species diversity and spatial distribution of benthic foraminiferal assemblages are strongly controlled by environmental parameters (Murray, 2006). However, there is still much debate as to which environmental factors have the most significant effect on foraminifera in a specific habitat.

Very few papers address the question of sediment control on the agglutinated foraminifera and their shell mineralogy/chemistry. Although the phenomenon of grain selection among agglutinated foraminifera has been known for over a century (Heron-Allen and Earland, 1909; Heron-Allen, 1915), the mechanisms involved are still not well understood. More recently, Allen et al. (1999), Kaminski et al. (2008) or Armynot du Châtelet et al. (2009) focused on the mineral phases used by agglutinated foraminifera. Makled and Langer (2010), Rothe et al. (2011) or Gooday et al. (2011) studied heavy minerals that can be agglutinated and the mechanisms of agglutination. Additional common species need to be studied with emphasis on the potential environment controls on test construction.

The Marmara Sea is a complex marine system, comprising water masses derived from both high salinity Mediterranean waters (salinity 31–38) and brackish waters from the Black Sea (salinity ~14–25) (Aksu et al., 2002b; Mudie et al., 2004). Many studies focus on foraminifera as tool for understanding the influence of water mass movement on sediment distribution in that region because of the reconnection of the Marmara Sea to the Mediterranean Sea after the last glacial episode (e.g., Aksu et al., 2002a; Mudie et al., 2002; McHugh et al., 2008) or sediment dynamics in that sensitive region (North Anatolian active fault with a potentially high human impact (Gökasan et al., 2005). A study of benthic agglutinated benthic foraminifera in this marine system is a key for understanding environmental controls on foraminiferal species density, diversity, and shell construction.

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The objective of this study is to expand agglutinated foraminiferal knowledge on ecological and biogeochemical directions in this exceptional environment. The main goals are:

(1) to geochemically characterise the bottom sediment (major elements and redox proxies, organic matter quality) and to assess whether these parameters are limiting factors for foraminifera;
(2) to identify the sedimentary constraints on agglutinated foraminiferal test construction (grain size, and mineralogical nature). In our study we concentrate on the agglutinated foraminifera as their shell microstructure directly depends on the sediment characteristics, and may even influence the latter.

2. Study area and previous benthic foraminifera investigation

The Marmara Sea is a small intercontinental basin situated between the world's largest permanently anoxic basin, the Black Sea, and the northeastern extension of the eastern Mediterranean basin, the Aegean Sea (Fig. 1). Two relatively shallow and narrow straits known as the Dardanelles and the Bosphorus, respectively, are the only connections between the Black Sea and Mediterranean Sea (Fig. 1A and B). Several sills with depths of ~60–70 m prevent the deep water transfer between the Aegean Sea, Marmara Sea and Black Sea (Gökasan et al., 2005, 2008). At present, brackish surface water from the Black Sea (salinity down to 14) outflows into the Marmara Sea through the Bosphorus Strait, while saline deeper water from the Aegean Sea (salinity up to 38) flows northwards as a countercurrent (Aksu et al., 2002b; Mudie et al., 2004). This two-way flow is repeated in the Dardanelles Strait, creating an overall estuarine circulation within the Marmara Sea. Due to the outflow of brackish Black Sea water, a strong halocline is present throughout the Marmara Sea, generating low-oxygen and stratified conditions below a thin, well-mixed and oxygenated surface layer (Kaminski et al., 2002; Chendeş et al., 2004).

Studies on foraminifera have been carried out in all three basins, the Eastern Mediterranean Sea (Parker, 1958; Cimerman and Langer, 1991), the Black Sea (Yanko and Troitskaja, 1987; Yanko, 1990) and the Marmara Sea (Alavi, 1988; Meriç et al., 1995; Kaminski et al., 2002; Avsar et al., 2006; McHugh et al., 2008). The examination of the diversity of this area had been expanded by Sgarrella and Zei (1993) in Italy, by Rasmussen (2005) in Greece and by Basso and Spezzaferri (2000) in Turkey. The lacustrine to marine transition in the Marmara Sea at ~12 ka BP was specifically investigated by McHugh et al. (2008).

Several studies (Chendeş et al., 2004; Phipps, 2007; Frontalini et al., 2011) documented the influence of water mass properties on modern benthic foraminiferal assemblages and identified distinct assemblages across a N–S transect on the southern shelf of the SW Marmara Sea. Phipps et al. (2010) studied calcareous foraminifera in relation to water masses properties without considering the in situ physical and chemical conditions of the sediment. The agglutinated foraminifera in the transect were studied by Frontalini et al. (2011) who focused on the extraordinarily diversified fauna but also characterised it with respect to the water mass properties. None of these studies took into

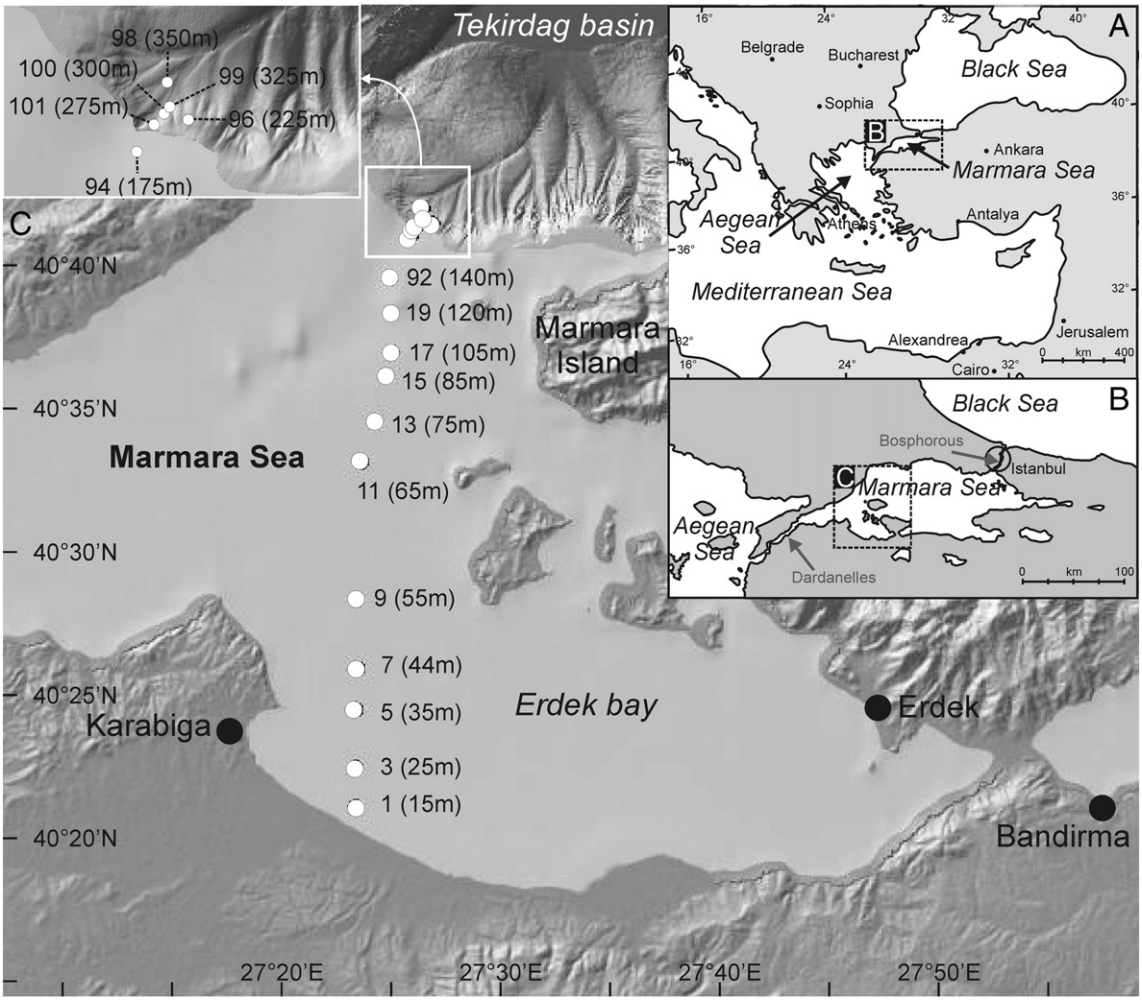

Fig. 1. Study area. (A) Localisation of the Marmara Sea between the Black Sea and the Mediterranean Sea. Base map is extracted from GeoMapApp database http://www.geomapapp.org (Ryan et al., 2009). (B) Details of the Marmara Sea. (C) Sampling area and location of the sample along the profile. The sampling depth is indicated in brackets.