Marine Geology 391 (2017) 36–47

Contents lists available at ScienceDirect

Marine Geology

journal homepage: www.elsevier.com/locate/margo

Micropaleontological and taphonomic characteristics of mass transport deposits in the northern Gulf of Eilat/Aqaba, Red Sea

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ARTICLE INFO

Keywords:
Mass transport deposits
Taphonomy
Continental slope
Gulf of Eilat/Aqaba
Symbiont-bearing larger benthic foraminifera
Earthquakes

ABSTRACT

Submarine mass transport deposits (MTDs) are a well-known phenomenon in tectonically active regions. Evidence for such deposits is commonly found in the continental slope sedimentary records, as distinct units with coarser grain size compared to the usual and continuous pelagic sedimentation. The Gulf of Eilat/Aqaba is located between the southernmost end of the Dead Sea transform and the spreading center of the Red Sea, and is considered as an active tectonic region.

In this study, an innovative approach using symbiont-bearing Larger Benthic Foraminifera (LBF) to identify MTDs in the Gulf of Eilat/Aqaba (GEA) sedimentary record is presented. The abundance, size and preservation state of LBF shells were analyzed in two radiocarbon dated sediment cores collected at different deposition environments, at water depth of 532 m and 316 m.

The microfaunal and taphonomic results show that the coarse units are characterized by a generally higher numerical abundance of LBF, dominated by *Operculina ammonoides*, *Amphistegina papillosa* and *Amphistegina bicirculata*. These benthic assemblages are found in deeper depths than their original habitat, ranging between 50 and 120 m, in accordance with their symbionts light requirements. In the coarse units, LBF $>$ 1 mm appear in high frequency, up to 161 specimens per g sediment, and poorly preserved shells are also abundant, containing up to 247 specimens per g sediment. In addition, these units also contain high numbers of yellowish and blackish colored LBF shells, as opposed to null in the non-disturbed units, and unlike their natural white color.

The large shell size indicates that high energy is involved in the displacement of the sediments. The poor state of preservation also suggests a turbulent flow during transportation, which requires a high-energy triggering mechanism. The color alteration is probably associated with a diagenetic process related to increasing burial time/depth, also supported by the stratigraphic older ages of the MTDs, suggesting a long burial before the sediments were displaced. In addition, according to the dating of the record, some units correlate with historical and pre-historical earthquakes, reinforcing LBF species as a reliable proxy for mass transport events.

1. Introduction

Submarine mass transport deposits (MTDs) are recognized as important sedimentary facies in the marine environment. These deposits exhibit distinct characteristics (Ducassou et al., 2013; Gao and Collins, 1994; Masson et al., 2006) and are used to infer transport processes in different geodynamic settings. The displacement process is known to be associated with sea level fluctuations, ice rifting, river mouths, high sedimentation rates, tropical storms, tsunami backwash, and particularly in tectonically active continental margins (Griggs, 2011; Hampton et al., 1996; Maslin et al., 2005; Polonia et al., 2015; Sugawara et al., 2009; Wright and Anderson, 1982; Yordanova and Hohenegger, 2002; Zabel and Schulz, 2001).

Mass transport deposits consist of recycled sediments initially deposited at the continental shelf and gravitationally transported down the continental slope to deeper water depths. The transport and deposition are strongly grain size selective, resulting in a distinctive texture of coarser sediments, often finning upwards, distinguishable from the finer pelagic continuous deposition (Ducassou et al., 2013; Gao and Collins, 1994; Masson et al., 2006). In some cases, increased organic carbon concentrations point to rapid burial and high preservation that also serve as indicators for MTDs (de Haas et al., 2002; Ducassou et al.,

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http://dx.doi.org/10.1016/j.margeo.2017.07.009
Received 22 December 2016; Received in revised form 5 July 2017; Accepted 6 July 2017

2013; Zabel and Schulz, 2001).

Benthic foraminifera species, which are generally restricted to a specific depth range due to their ecological adaptations, can also serve as indicators for MTDs. In undisturbed conditions, their assemblages vary depending on increasing water depth, substrate type, oxygen content and organic matter flux (Edelman-Furstenberg et al., 2001; de Stigter et al., 1998; Hohenegger, 2004; Jorissen et al., 1995; Murray, 2006). However, instantaneous mass movement events can transport benthic foraminifera along with the sediments and re-deposit them downslope, in a deeper environment compared to their natural habitat. Considering the depth ranges and the ecological requirements of the transported species, it is possible to infer the original deposition depth of the displaced sediments (e.g. Ducassou et al., 2013).

Large symbiont-bearing benthic foraminifera (LBF), which are restricted to the photic zone, are particularly good indicators for MTDs as their depth range is more limited than that of deep sea species (Hallock and Hansen, 1979; Hohenegger et al., 1999; Reiss and Hottinger, 1984). Therefore, sediments derived from a shallow water depth may be easier to recognize and their original depth of deposition can be determined accurately.

The state of shell preservation (taphonomy) can also be used to characterize mass transport processes. In a laboratory experiment, Beavington-Penney (2004) examined the effect of transport distances on shell breakage. Distinguishing between different preservation states of *Palaeonummulites venosus*, lead them to conclude that the most poorly preserved shells were transported under turbidity current conditions.

Shell coloration is also a taphonomic parameter that can be used to detect sediment mixing in transportation and resuspension processes. Yordanova and Hohenegger (2002) studied black and/or brown LBF shells at water depths of up to 100 m off the shore of western Okinawa, Japan, and suggested that the blackish color is the result of pyritisation and iron sulfides precipitation under anoxic conditions due to sediment burial. Furthermore, the yellowish-brown color is the outcome of limonitisation, a re-oxidation of the pyrite into ferric oxide, due to sediment mixing caused by tropical storms typical to the area.

Here, we focus on fossilized LBF assemblages as a biomarker for the identification and characterization of MTDs in the seismically active region of the northern Gulf of Eilat/Aqaba (GEA). The foraminiferal analysis of sediments in piston cores collected from the gulf enables to establish LBF as a reliable proxy for mass transport events.

1.1. Regional setting

The GEA is part of the East African Rift system, located at the north-eastern end of the Red Sea and the south end of the Dead Sea Transform, and active since the Miocene (Freund et al., 1970). A recent large earthquake (7.2M_W) occurred in November 22, 1995 offshore of Nuweyba (Sinai Peninsula), causing landslides and infrastructure damage along the Egyptian coast (Baer et al., 2008; Klinger et al., 1999).

The gulf is a semi-isolated basin separated from the Red Sea by the Straits of Tiran. It is long (180 km), narrow (~15 km), deep (up to 1830 m) and surrounded by deserts. The overall difference in elevation between the GEA deeps and the surrounding desert mountains is over 4 km, suggesting that the tectonic processes occur faster than the erosive processes to maintain this relief. The continental shelf of the western sub-basin is, on average, 585 m wide, with an average slope angle of 14° (Tibor et al., 2010).

1.2. Characteristic foraminifera assemblages of the GEA

The combination of the GEA's sub-tropical location, arid climate and carbonate oversaturation, contributes to the formation of well-developed coral reef ecosystems along its coasts. This enables high biodiversity and species abundance of both pelagic and benthic organisms. Over 300 species of recent foraminifera from the GEA were classified and described by Hottinger et al. (1993). A few of these species are symbiont-bearing, therefore dependent on light penetration and confined to the photic zone. Previous studies show the depth distribution of some common LBF in the gulf, as shown in Fig. 1 (Perelis-Grossowicz et al., 2008; Reiss and Hottinger, 1984).

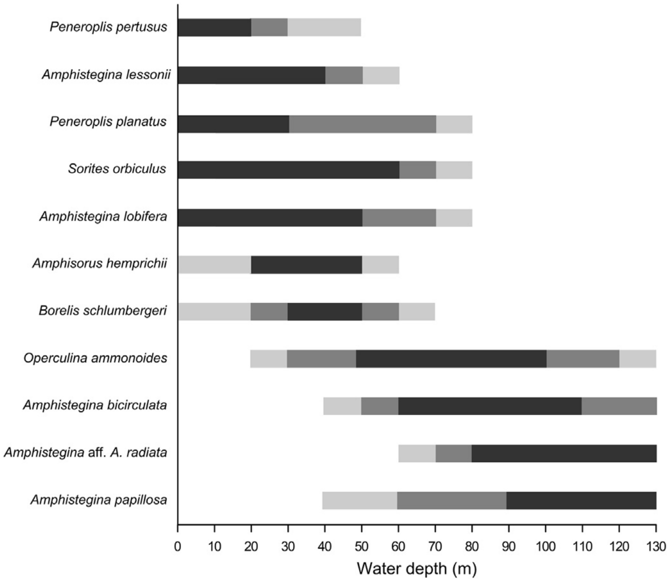

Fig. 1. The bathymetric distribution of common larger symbiont-bearing foraminifera (LBF) from the Gulf of Eilat/Aqaba (GEA). The darker color represents the maximum abundance depth interval. Based on Haunold et al. (1997), Hottinger et al. (1993), Oron et al. (2014), Perelis-Grossowicz et al. (2008) and Reiss and Hottinger (1984).

According to these studies, two main assemblages occur in the gulf. A shallow water assemblage, at water depths of up to 50 m, includes *Amphisorus hemprichii*, *Sorites orbiculus*, *Peneroplis planatus*, *Peneroplis pertusus*, *Amphistegina lessonii* and *Amphistegina lobifera*, and a deeper water assemblage, at water depths of 50–120 m, includes *Amphistegina papillosa*, *Amphistegina* aff. *A. radiata*, *Amphistegina bicirculata*, *Heterocyclina tuberculata* and *Operculina ammonoides*. Hottinger et al. (1993) distinguished the *A.* aff. *A. radiata*, found in the GEA, from the Indo-Pacific species, *A. radiata*, by its smaller size, broader peripheral main chamber cavities and much shorter peripheral stellar chamberlet extensions. In addition, the former is found in the GEA at water depths of 80–160 m, whereas the latter occurs at water depths of 15–60 m water depth around southeast Africa (Pignatti et al., 2012).

Extensive foraminiferal studies were conducted in the GEA, some dedicated to the ecology of foraminifera, such as distribution, classification and their physical adaptations to anthropogenic activity (Oron et al., 2014). Other studies used foraminifera for climatic and oceanographic reconstruction (Arz et al., 2003; Edelman-Furstenberg et al., 2009, 2001; Haunold et al., 1997; Hottinger et al., 1993; Perelis-Grossowicz et al., 2008; Reiss et al., 1980; Reiss and Hottinger, 1984).

In this study, we refer to foraminifera as sediment particles and use their known ecological preferences, as well as shell taphonomy, to better understand sediment source, transportation and accumulation patterns.

2. Materials and methods

2.1. Cores collection

Two cores were retrieved in February 2010 by *R/V Mediterranean Explorer* during the MG10 survey using a piston corer. After extraction, the cores were held in a cooling container at 4 °C, until splitting. The cores contained fine-grain pelagic deep-sea sediments interlayered with units of distinctively coarser sediments. The first core, MG10P22 (253 cm long) was taken from the western slope of the gulf at a water depth of 316 m, down slope from the developed fringing coral reef