Journal of Marine Systems 164 (2016) 53–66

Contents lists available at ScienceDirect

Journal of Marine Systems

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

The response of benthic meiofauna to hydrothermal emissions in the Pontine Archipelago, Tyrrhenian Sea (central Mediterranean Basin)

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ARTICLE INFO

Article history:
Received 1 April 2016
Received in revised form 26 July 2016
Accepted 3 August 2016
Available online 7 August 2016

Keywords:
Benthic foraminiferal assemblages
Seafloor venting
CO_2 emissions
Giant depression
Pontine Archipelago
central Mediterranean Sea

ABSTRACT

Recent investigations highlighted the occurrence of a giant depression related to hydrothermal activity off the Pontine Archipelago (central Mediterranean Sea, Italy). The new record of a giant seeping depression (Zannone Giant Pockmark, ZGP) in shallow-water provides the opportunity to study fluid vent impact on meiobenthic communities. The micropaleontological analyses on living (Rose Bengal stained) and dead assemblages recorded inside and outside the Zannone Giant Pockmark, allow to highlight changes in the structure and composition of the foraminiferal community that suggest variations of fluid emissions in different sectors of the study area. Inside the ZGP, under the direct influence of venting activity, a very peculiar living foraminiferal assemblage is found. It consists of agglutinated species (*Spiculosiphon oceana*, *Jaculella acuta*, *Deuterammina rotaliformis*) never found or very rare in the Mediterranean Sea. On the contrary dead assemblage testifies the changes on foraminiferal assemblages under carbonate dissolution process. Outside the pockmark in the nearby area of ZGP, the integrated meiofaunal and geochemical data suggest a transitional condition between vent influenced sedimentation and the typical carbonate sedimentation recorded in the rest of the Pontine Archipelago. In particular a possible spread of the venting activity in the northern and southern sectors of the study area, towards the edge of the Zannone insular shelf, is inferred.

The impact of fluid emissions on foraminiferal assemblages can be summarized in the following observations: reduced biodiversity, increase of agglutinated species with predominant siliceous component in the test structure, limited distribution of living specimens inside the sediment, disappearance of porcelaneous taxa and presence of carbonate loss tests. As the result, the venting activity is likely to be the main environmental driver on the meiofaunal distribution.

We also report, at the emission sites in the Pontine Archipelago, the presence of agglutinated species such as *Spiculosiphon oceana*, *Jaculella acuta*, *Deuterammina rotaliformis*, never found earlier in the Mediterranean Sea.

1. Introduction

Underwater hydrothermal vents or CO_2 fluid discharges represent seafloor areas characterized by the occurrence of peculiar physical and biological conditions. These submarine sites have been found in different tectonic settings at different depths, from shallow to deep water, and in substrates with various composition (Tivey, 2007). In particular, shallow-water hydrothermal vents have been reported especially in close relation to recent subaerial and submarine volcanic activity (e.g. Dando et al., 1999, 2000; de Ronde et al., 2001; Geptner et al., 2002; Italiano and Nuccio, 1991; Prol-Ledesma et al., 2005; Stoffers et al., 1999; Zhirmunsky and Tarasov, 1990), although some of them were discovered on mid-ocean ridges (Cardigos et al., 2005; Fricke et al., 1989; German et al., 1994) and in continental margin settings undergoing tectonic extension (e.g. Melwani and Kim, 2008; Prol-Ledesma et al., 2004; Vidal et al., 1978). Since their first discovery in the marine realm, hydrothermal vents attracted an increasing attention of scientific community mainly due to: 1) their importance in commercial resource exploration (e.g. hydrothermal related deposits; Hannington et al., 2011; Hein et al., 2013; Rona, 2008); 2) highly sensitive marine ecosystems they host; 3) possible implications for ocean chemistry, i.e. ocean acidification (e.g. Davis et al., 2003; Hall-Spencer et al., 2008; Jupp and Schultz, 2004; Vance et al., 2009).

The environmental conditions in shallow-water vents strongly differ from the surrounding seafloor in terms of both increased temperature and enrichment in reduced chemical compounds such as sulphide and methane (Tarasov et al., 2005). Temperature generally ranges from 10 to 13 °C (Caramanna et al., 2011; Dando et al., 1999 and reference therein; Tarasov et al., 1999, 2005) and fluids formation commonly take place from relatively shallow sources (1–2 km depth). These natural fluid emissions may be able to produce thermal and chemical weathering of sediment substrate as well as alter sea-water geochemistry including reduction in calcifying capacity of marine organisms (Doney et al.,

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http://dx.doi.org/10.1016/j.jmarsys.2016.08.002
0924-7963/

2009). Moreover, CO_2 fluid emissions escaping from the seafloor can be responsible of the formation of specific morphological features such as pockmark structures (e.g. Hovland, 1992).

Regarding the biological features commonly found in shallow-water active pockmarks, several studies were focused on the characterization of microbial communities showing that hydrothermal activity strongly enhances biological activity both within the water column and on the seabed. At shallow water sites, the primary production is based both on chemosynthetic and photosynthesis processes (Namsaraev et al., 1994; Sorokin et al., 1998; Tarasov et al., 2005) leading to the scarce occurrence of vent-obligate taxa, which are mainly represented by bivalves belonging to the Solemyidae, Lucinidae and Thyasiridae. At such environment, Prokaryotes (Bacteria and Archea) represent the main biological component so that they are generally used as optical proxies to recognize dispersed emissions at the ground floor. The most common bacteria found on seafloor areas affected by hydrothermal activity are the genera *Thiobacillus*, *Thiomicrospira* and *Thiosphaera*, or the filamentous sulphur bacteria such as *Thiothrix* or *Beggiatoa* (Tarasov et al., 2005). The major biogeochemical processes observed in association to these mats are the oxidation of reduced sulphur compounds (hydrogen sulphide or thiosulphate) to elemental sulphur, thiosulphate or sulphate and organic matter synthesis (Dubinina, 1989; Namsaraev et al., 1991; Sorokin, 1991).

Studies focusing on the characterization of meio- and macrofaunal organisms dwelling in such environments are rare (Jones, 1993; Judd and Hovland, 2007; Panieri, 2006a, 2006b; Panieri et al., 2005). The few available studies (see above) show that shallow-water pockmarks can differ in faunal composition from the surroundings and from each other, depending on the degree and effects of the venting activity. Particularly, the distinction is in terms of faunal density, diversity, dominance and infaunal/epifaunal ratio (Jones, 1993; Melwani and Kim, 2008; Panieri, 2006a; Panieri et al., 2005; Wildish et al., 2008). The new record of a giant complex venting pockmark (named Zannone Giant Pockmark – ZGP; Ingrassia et al., 2015a) located in the shallow-water of the central Mediterranean Sea, provides the opportunity to study the impact of fluid vent (mainly regarding the CO_2 emission) on benthic communities.

Particularly, this study examines the meiofaunal communities of the ZGP located 3 km off the eastern coast of Zannone Island (western Pontine Archipelago, Tyrrhenian Sea). Judging by the previous studies and observations in the area, bottom water topography and sediment characteristics suggest higher vent activity (and hence higher CO_2 content) within the Zannone Giant Pockmark. To address this hypothesis and to describe the influence of venting activity on sediment characteristics and meiobenthic (foraminifera) assemblages found on the seafloor sites affected and non-affected by venting activity, this study uses direct observations (through video-imaging), sedimentological, micropaleontological and geochemical analyses.

2. Geological setting and methods

2.1. Geological setting

The Pontine Archipelago (Fig. 1a) is located on the eastern Tyrrhenian margin about 30 km off the Latium coastline (central Tyrrhenian Sea, Italy). The Archipelago represents a Plio-Pleistocene volcanic structure formed by two groups of islands. The western group (Palmarola, Ponza and Zannone) and the eastern one (Ventotene and S. Stefano) developed in different geological settings: the western group lies on a structural high where volcanic activity developed along normal faults and ended about 0.9 Ma BP (Bellucci et al., 1997; Cadoux et al., 2005); the eastern group is located in the Ventotene sedimentary basin and represents the summit of a large volcanic edifice, where volcanic activity ended more recently, about 0.3 Ma (Perrotta et al., 1996).

Grab samples studied in this paper come from the seafloor off the western Pontine Archipelago, which is a narrow and steep insular shelf characterized by different morphological features, represented by volcanic and biogenic buildups (Chiocci and Martorelli, 2015; Martorelli et al., 2011), isolated morphological highs and several fluid related features (i.e. pockmarks, giant pockmark, authigenic mounds; Ingrassia et al., 2015a, 2015b) making this environment highly heterogeneous. In particular, the Zannone Giant Pockmark (Fig. 1b–c) recently discovered by Ingrassia et al. (2015a) represents a peculiar submarine area affected by vigorous venting activity and occurrence of peculiar benthic communities (Ingrassia et al., 2015b), related to the occurrence of a hydrothermal field (Martorelli et al., accepted).

The seafloor unaffected by venting activity consists of bioclastic sandy sediment mainly composed of foraminifera, coralline algae, bryozoans, ostracods and sponge spicules (Brandano and Civitelli, 2007; Martorelli et al., 2011). Bioclastic sedimentation at the Pontine Archipelago seems to be favored by the low influx and sedimentation rate of continental sediments and high-energy hydrodynamics (Martorelli et al., 2011). The continental slope is characterized by a seabed floored by muddy hemipelagic sediment and occurrence of several canyons, gullies and landslide scars, resulting from widespread mass-wasting phenomena (Chiocci et al., 2003). Two tectonically-controlled intra-slope basins (Palmarola and Ventotene) occur adjacent to the western Archipelago, in a water depth ranging from 500 to 800 m and are characterized by high Plio-Quaternary sedimentation rates (Zitellini et al., 1984).

2.2. Materials and methods

In June 2014, during the research cruise "Bolle 2014" carried out by R/V Urania, several seafloor sediment samples were collected by means of a 30L Van Veen grab. Although grab sampling is not a very satisfactory method for micro- and meiofaunal analyses, as it does not recover sediment-bottom water interface (Murray, 2006), the occurrence of lithified crusts and coarse-grained sediments prevented us from using a more suitable sampling gear like multiple corer or box corer.

On the base of the geomorphological and geochemical features the 6 most representative site stations were chosen at 127–137 m water depth. Four stations are located within three sectors (northern, central and southern) inside the ZGP, whereas two are outside (close to the shelf margin; Fig. 1b–c). For each station 3 grab sediment replicates, are from separate deployments as in Schönfeld et al. (2012), and a total of 18 samples were collected (Table 1). For a comparison with the background condition of the "normal" (undisturbed) seafloor at the Pontine Archipelago, the benthic foraminiferal data reported by Frezza et al. (2010) were considered.

Water column data (temperature, salinity, oxygen content) and beam transmission (which provides both an indication of the total concentrations of matter in the water as well as a value of the water clarity) were acquired by mean of CTD SBE 911 and a WET Labs Transmissometer, both inside and outside the Zannone Giant Pockmark (Fig. 2). Geochemical composition data from Martorelli et al. (accepted) were considered. The gas compositions of the most significant stations are summarized in Table 2.

2.2.1. Grain size analysis

One replicate for each site station was cleaned with hydrogen peroxide, dried at 60 °C and used to perform the grain size analysis by sieving (grain size > 63 μm) 100 g of unconsolidated sediment sample. The finer fraction (< 63 μm) was analyzed by a high resolution laser diffraction instrument (Helos Sympatec). By means of GranulGraf software the grain size distribution was obtained and the percentage of each sediment fraction (sand, silt and clay) was plotted on ternary granulometric diagram (Tortora, 1999). The information was used to interpret the sediment types occurring in both vent and non-vent seafloor areas.