Mud volcanism, Gas Hydrates and associated Deep Sea Ecosystems in the Gulf of Cadiz

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Since the discovery of the first mud volcanoes in the Gulf of Cadiz in 1999 [1,2,3], thanks to several national and international projects, some of which coordinated by Portuguese teams, the S. Portuguese, Spanish and Moroccan margins of the Gulf of Cadiz have been intensely investigated through more than 25 research cruises. Until present, 43 mud volcanoes, resulting from the extrusion at the sea-bottom of gas-rich sediments, have been confirmed by coring, although a much larger number of similar structures were identified on side-scan sonar imagery, multibeam bathymetry and reflection seismic [4,5,6]. The mud volcanoes form conical edifices that can reach a few hundreds of meters height and can have diameters of up to 4-5 km. They are often associated with diapirs at depth and the origin of the fluids is often more than 5 km deep [4,5,6,7]. Thermogenic gas hydrates, suggesting the presence of hydrocarbons at depth, were recovered from 4 mud volcanoes (2 from the Deep Portuguese Field), and indications of their presence were found in several other structures [3,7,9]. In the eastern sector of the Gulf of Cadiz, there is a widespread occurrence of methane-related authigenic carbonates, forming crusts and chimneys, giving evidence of large past episodes of extensive fluid seepage [8,9,10]. The gas hydrates, the gas and potential oil occurrences at depth have a potential economic interest in the future. It is also crucial to evaluate the past releases of methane to the hydrosphere/atmosphere, since these may have had a possible contribution to past climate changes (methane is a powerful greenhouse gas) and the same may happen in the future [8,11].

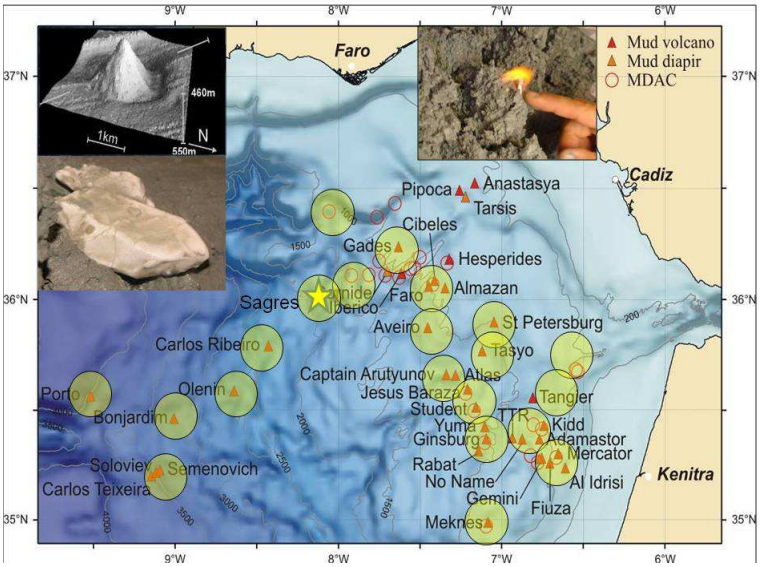

Figure 1. Distribution of mud volcanoes, mud diapirs and Methane-Derived Authigenic Carbonates (MDAC) in the Gulf of Cadiz. The yellow circles highlight the areas in which the Portuguese teams have worked. Insets: (a) a 3D high resolution bathymetry image of a mud volcano - Tasyo (top left); a crystal of gas hydrate recovered during the TTR17 cruise, in 2008 (left, below the image of the mud volcano); an image of a core retrieved during the TTR-17 cruise (2008) showing burning gas hydrate.

The deep-sea environment in the Gulf of Cadiz shows a high diversity of benthic habitats including octocoral “gardens”, mostly dead cold water coral reefs, provinces of carbonate concretions, channels and escarpments shaped by tectonic activity and erosion, and mud volcanoes at depths from 200 to 4000 m. The area is subjected to numerous sources of abiotic and biotic heterogeneity (depth, physiographic and biogenic features, properties of water masses and oceanographic circulation, fluid geochemistry and fluxes of methane and sulphide, surface productivity, etc.) and the seabed supports a high biodiversity [12]. During the past decade, studies in the Gulf of Cadiz, contributed to a dataset of over thousand species including both recording of epibiota through in situ surveys (deep-towed video, ROV) and sampling of sediments.

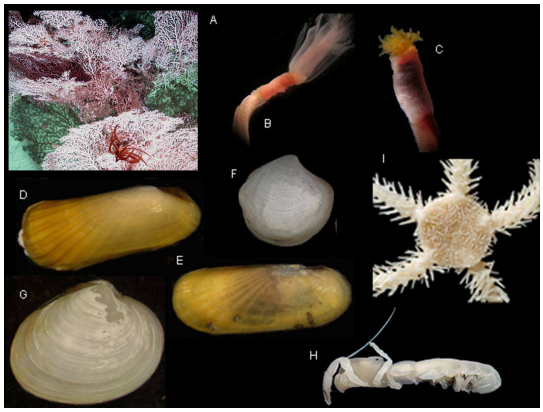

Figure 2. Some new species from the Gulf of Cadiz.
A. *Corallium* sp nov (in prep.); B. *Spirobrachia tripeira* Hilario & Cunha, 2008; C. *Bobmarleya gadensis* Hilario & Cunha, 2008; D. Acharax sp nov (submitted); E. Petrasma sp nov (submitted); F. *Thyasira vulcolutre* Rodrigues, Oliver & Cunha, 2008; G. *Isorropodon* sp nov (submitted); I. *Ophiopristis* sp nov (submitted); H. *Vulcanocalliax arutyunovi* Dworschak & Cunha, 2007.

These studies were focused on target physiographic features and mostly biased towards the sampling of mud volcanoes and adjacent habitats (carbonate concretions and coral thickets). The database has enabled the analysis of species occurrences using a variety of approaches and suggests that the the Gulf of Cadiz can be considered a biodiversity hotspot in the NE Atlantic. The number of chemotrophic species (30 species of bivalves and siboglinid polychaetes) recorded from the Gulf of Cadiz is remarkably high when compared to other cold seep regions in the Atlantic and Mediterranean [13,14]. Most of these chemotrophic taxa are new to science but our samples also yield new anthozoan, hydrozoan, decapod, tanaid and ophiurid species [15,16,17], a high "hidden" diversity revealed by molecular approaches in some faunal groups [18,19], and a still undetermined number of new taxa of other faunal groups. Habitat heterogeneity, oceanographic circulation, the geologic evolution of the region and its biogeographic context are of utmost importance for understanding biodiversity patterns in the Gulf of Cadiz.

Marine Geology and Geophysics and the Deep Sea Biology Groups, CESAM

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Figure captions:

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