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Research paper

Sedimentary sources and processes in the eastern Arabian Sea: Insights from environmental magnetism, geochemistry and clay mineralogy

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ABSTRACT

The spatial distribution patterns of surficial sediment samples from different sedimentary domains (shallow to deep-sea regions) of the eastern Arabian Sea were studied using sediment proxies viz. environmental magnetism, geochemistry, particle size and clay mineralogy. Higher concentrations of magnetic minerals (high χ_{lf}) were recorded in the deep-water sediments when compared with the shallow water sediments. The magnetic mineralogy of one of the shallow water samples is influenced by the presence of bacterial magnetite as evidenced from the χ_{ARM}/χ_{lf} *vs.* χ_{ARM}/χ_{fd} biplot. However, the other samples are catchment-derived. The high correlation documented for χ_{lf}, anhysteretic remanent magnetisation (χ_{ARM}) and isothermal remanent magnetisation (IRM) with Al indicates that the deep-sea surficial sediments are influenced by terrigenous fluxes which have been probably derived from the southern Indian rivers, the Sindhu (the Indus) and the Narmada-Tapti rivers. A lower Mn concentration is recorded in the upper slope sediments from the oxygen minimum zone (OMZ) but a higher Mn/Al ratio is documented in the lower slope and deep-sea sediments. Clay minerals such as illite (24–48.5%), chlorite (14.1–34.9%), smectite (10.6–28.7%) and kaolinite (11.9–27.5%) dominate the sediments of shallow and deep-sea regions and may have been derived from different sources and transported by fluvial and aeolian agents. Organic carbon (OC) data indicate a low concentration in the shallow/shelf region (well oxygenated water conditions) and deeper basins (increased bottom-water oxygen concentration and low sedimentation rate). High OC concentrations were documented in the OMZ (very low bottom-water oxygen concentration with high sedimentation rate). The calcium carbonate concentration of the surface sediments from the continental shelf and slope regions (<1800 m) up to the Chagos-Laccadive Ridge show higher concentrations (average = 58%) when compared to deep basin sediments (average = 44%). Our study demonstrates that particle size as well as magnetic grain size, magnetic minerals and elemental variations are good indicators to distinguish terrigenous from biogenic sediments and to identify sediment provenance.

1. Introduction

The Arabian Sea differs from other oceans as it is strongly influenced by the seasonal reversal of winds which blow from the southwest during June–September but also from the northeast during November–February. This results in large variations in upwelling intensity and primary productivity (Haake et al., 1993; Honjo et al., 1999). Lithogenic material from several sources is delivered to the Arabian Sea via transporting agencies, both fluvial and eolian (Sirocko and Lange, 1991; Dahl et al., 2005). The primary fluvial agencies are the Sindhu (the Indus), the Tapti and the Narmada rivers; the singularly important agency among

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them is the Sindhu River (Ramaswamy et al., 1991; Prins et al., 2000). The several small rivers that originate in the *Sahyadri* (the western Ghat) and debouch into the Arabian Sea via the west coast of India also contribute lithogenic sediments (Manjunatha and Shankar, 1992). Eolian sediments are transported from the Thar and the Arabian Deserts (Sirocko and Lange, 1991; Schnetger et al., 2000). Sediments could be derived from natural processes (lithogenic and pedogenic) and/or anthropogenic activities (Karbassi and Shankar, 1994). Sedimentary provenance studies are important as they help in deducing the sources of sediment and the processes involved thereof. In the past, provenance studies have been made using different approaches like environmental magnetism, geochemistry, sedimentology and clay mineralogy (Sirocko and Lange, 1991; Karbassi and Shankar, 1994; Schnetger et al., 2000; Sirocko et al., 2000; Alagarsamy, 2009).

Textural, chemical and biological characteristics of marine sediments are strongly influenced by factors such as source-area composition (Paropkari et al., 1980), climatic conditions, length and energy of sediment transport (Borole et al., 1982), primary productivity of overlying waters, dissolved oxygen in bottom waters and redox conditions in the depositional environment (Shankar et al., 1987; Ramaswamy et al., 1991; Schnetger et al., 2000; Sirocko et al., 2000). Hitherto, several investigations have been carried out on surficial sediments from the Arabian Sea. However, they have used only single proxies (Shankar et al., 1987; Prakash Babu et al., 1999; Alagarsamy, 2009; Pattan and Pearce, 2009) and have been restricted to either shallow sea or deep-sea regions. In this paper, we present data on surficial sediments from both *shallow* and *deep-sea* regions of the eastern Arabian Sea (Fig. 1) using a *multi-proxy* approach (rock magnetism, geochemistry, sedimentology and clay mineralogy). Utilising the data that we obtained and those available in the literature for the eastern Arabian Sea (Prakash Babu et al., 1999; Alagarsamy, 2009; Pattan and Pearce, 2009), we attempted to identify the sources of sediments based on the spatial distribution patterns of magnetic minerals (Karbassi and Shankar, 1994; Alagarsamy, 2009), clay minerals (Sirocko and Lange, 1991), organic carbon, calcium carbonate and geochemical parameters (Schnetger et al., 2000; Sirocko et al., 2000).

2. Area of study

The Arabian Sea is surrounded by arid land masses like Africa, the Arabian Peninsula, and the Iran-Makran-Thar desert region to the west and north, and by the coastal highlands of western India to the east (Fig. 1). The area is geographically surrounded by the Owen Ridge (Murray Ridge) on the western side (north-western side), and the Carlsberg Ridge (Chagos-Laccadive Ridge) on the southern side (eastern side). The climate of the Arabian Sea is dominated by seasonal reversal of winds, resulting in large seasonal physical/hydrographic/biological/chemical variations in water column and sediment transport (Nair et al., 1989). The Arabian Sea is strongly influenced by the southwest monsoon (June–September) and moderately by the northeast monsoon (December–February) and the associated reversal of surface currents. It is well known for upwelling, which is coupled with the intensity of the southwest (SW) monsoon (Naidu, 1998). Summer upwelling along the coasts of Somalia, Arabia and India occurs during the SW monsoon period, leading to high primary productivity. Surface winds during the SW monsoon blow from the SW, which lead to an increase in continental humidity and precipitation over the Indian Peninsula.

The study area is located in the eastern part of the Arabian Basin and the western side of the Chagos–Laccadive Ridge. The major rivers draining into the Arabian Sea are the Sindhu, the Narmada

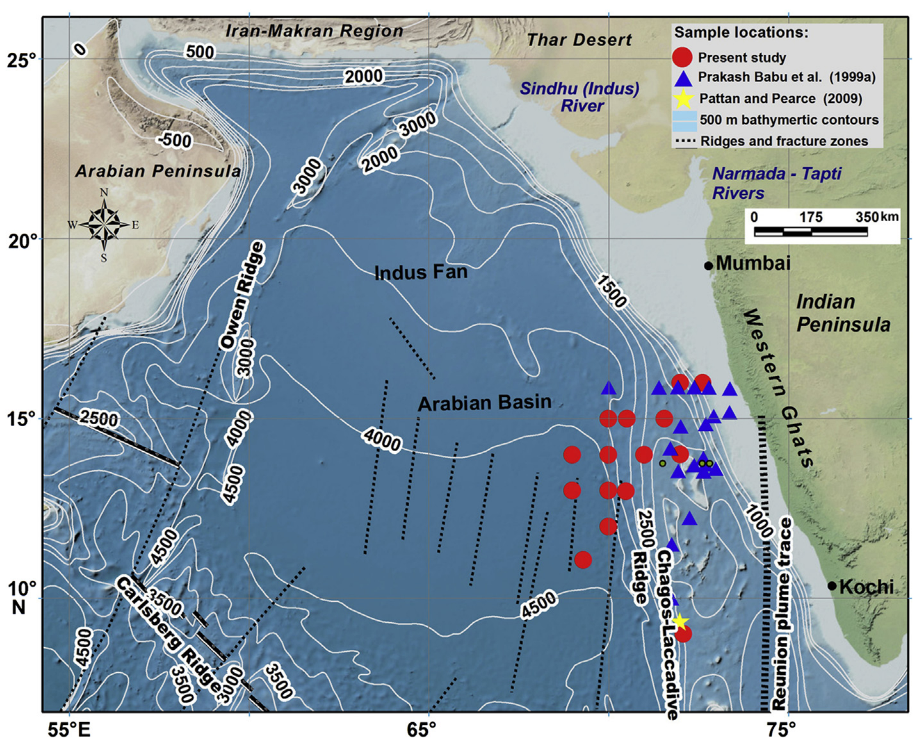

Figure 1. Map showing the locations of sediment samples analysed in this study (red circle) from the eastern Arabian Sea. Also shown are locations of samples used by Prakash Babu (1999; blue triangle) and Pattan and Pearce (2009; yellow star). Tectonic features shown in the map are from Campanile et al. (2007). The bathymetric contours were obtained using GEBCO v 2.0 (General Bathymetric Chart of the Oceans, 2008). Contouring was done using ArcGIS.