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Research paper

Geochemical characterization of the Krishna–Godavari and Mahanadi offshore basin (Bay of Bengal) sediments: A comparative study of provenance

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ABSTRACT

The Krishna–Godavari and Mahanadi rivers drain the east coast of India and deposit the sediment load into the Krishna–Godavari and Mahanadi offshore basins along the western margin of the Bay of Bengal. Here we report the bulk major, trace and rare earth element (REE) compositions and clay mineralogy of the fine grained sediments from the cores collected on board *JOIDES Resolution* and *Marion Dufresne* as part of India's gas hydrate program. The geochemical composition and clay mineralogy of sediments have been used to constrain the provenance. The results show that the Mahanadi sediments are primarily derived from the felsic rocks belonging to the late Archean-early Proterozoic peninsular gneissic complexes, whereas the Krishna–Godavari sediments are derived from the mixing of late Archean-early Proterozoic peninsular gneissic complexes and Late Cretaceous Deccan basalt sources. This paper presents the first comparative analysis of provenance of the Krishna–Godavari (K–G) and Mahanadi offshore basin sediments. The sediment geochemistry enables distinction of specific contributing sources, which could potentially be related to modern climatic and geomorphological conditions. The present study could also provide the opportunity for high resolution paleoclimatic analysis using clay mineralogical contents and weathering indices (Haughton et al., 1991).

1. Introduction

Geochemical and mineralogical compositions can be used to evaluate the provenance of marine sediments and sedimentary rocks (Wronkiewicz and Condie, 1987; Cullers, 1994, 1995; Fralick and Kronberg, 1997; Young and Nesbitt, 1998; Weltje and Eynatten, 2004; Wei et al., 2003, 2004; Whitmore et al., 2004; Hongxia et al., 2007; Roy et al., 2007; Perri et al., 2011a,b, 2012, 2013). Homogenous, fine grained sediments composed of clay and silt size particles presumably represent the average composition of the source rocks (Rudnick and Gao, 2003; Weltje and Eynatten, 2004). Using major/trace element composition and clay mineralogical assemblages, the marine sediments may be linked to different source rocks (Nesbitt and Young, 1989). The chemical weathering of the source rock is primarily carried out by the carbonic and organic acids in percolating ground water (Huang and Keller, 1970; Berner, 1992; Welch and Ullman, 1993). Several factors such as grain size, adsorption of ions by clays, mobilization of elements during diagenesis, climate, bulk composition of the source terrain, and tectonic setting influence the chemical composition of marine sediments (Bhatia and Crook, 1986; Wronkiewicz and Condie, 1989; Cullers, 1994; Nagender Nath et al., 2000). Thorium, Zr, Hf, Nb, Sc, Cr, Ni, V, Ba, Rb and rare earth elements are thought to be the most suitable components for provenance determination because of their refractory nature and very low mobility during weathering and diagenetic processes (Taylor and McLennan, 1985). These elements are incorporated into the clastic sediments during weathering and transportation with little fractionation and are expected to reflect the signature of the parent material (Taylor and McLennan, 1985; McLennan et al., 1993; McLennan, 2001). The relative distribution of immobile elements can help to infer the relative contribution of silicic and mafic source rocks in the sediments. High ratios of La or Th to Co, Sc, Cr and Ni

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suggest derivation from silicic sources whereas lower ratios indicate basic provenance (Cullers, 2002). REE concentration in marine sediments is believed to reflect the REE distribution pattern of the source material (Ronov et al., 1974; Taylor and McLennan, 1985; Cullers et al., 1987; Condie, 1991) and may help to discriminate between mafic and felsic source rocks using the Eu anomaly, and C1-chondrite normalized ΣLREE/ΣHREE and La/Yb ratios (Cullers and Graf, 1983; Taylor and McLennan, 1985; McLennan, 1989).

In the present study major, trace and REE data of three cores (NGHP-EXP1-3B, 5C and 18A) collected on-board *JOIDES Resolution* off the Krishna–Godavari and Mahanadi basins in the Bay of Bengal are presented and discussed in terms of the relative contributions of mafic and silicic source detritus from peninsular India. In addition, we present clay mineralogical data from two cores, MD161-8 and 19 collected on board the *Marion Dufresne* off the Krishna–Godavari and Mahanadi basins, respectively.

2. Geology

2.1. Krishna–Godavari basin

The Krishna–Godavari basin (K–G basin) is a pericratonic rift basin (Fig. 1) with onshore and offshore extensions. The rift basin extends offshore along the eastern continental margin of India (ECMI). The K–G basin covers an area of 28,000 km^2 onshore and 145,000 km^2 offshore (Rao, 2001; Bastia, 2007). Geographically, it lies between Kakinada in the northeast and Ongole in the southwest of Andhra Pradesh. The ECMI represents a passive continental margin that evolved through the break-up of the eastern Gondwana landmass ~130 My ago when India separated from East Antarctica (Ramana et al., 1994). The basin is characterized by en echelon type horst and graben-like structures (Rao and Mani, 1993; Rao, 2001; Gupta, 2006). The initial rifting and drifting phase during the Cretaceous resulted in extensive deposition of fluvio-lacustrine sediments throughout the basin. A sediment thickness of 3–5 km in the onshore region and around 8 km in the offshore region have been reported by Bastia (2007) and Prabhakar and Zutshi (1993). A south-easterly tilt in the Late Cretaceous resulted in an extensive marine transgression which led to the deposition of the Ragavapuram shale (Sastri et al., 1973). The Ragavapuram shale is overlain successively by the Razole Formation, Palakollu Shale, Vadaparru shale, Narsapur claystone, Ravva Formation and Godavari clay. The Godavari Clay ranges in age from mid Pliocene to Holocene.

The Krishna and Godavari rivers are the main drainage systems through the source rocks of the Krishna–Godavari basin. The Krishna river catchment lies between 13° and 19°30′ N and 73°23′–80°30′ E and its area is 258,948 km^2. The river originates in the Western Ghats at an elevation of 1337 m above mean sea level. Estimated annual sediment flux is 67.72×10^6 ton yr^{-1} (Ramesh and Subramanian, 1988). The Bhima and Tungabhadra are the major tributaries whereas Ghataprabha and Malaprabha are the minor tributaries.

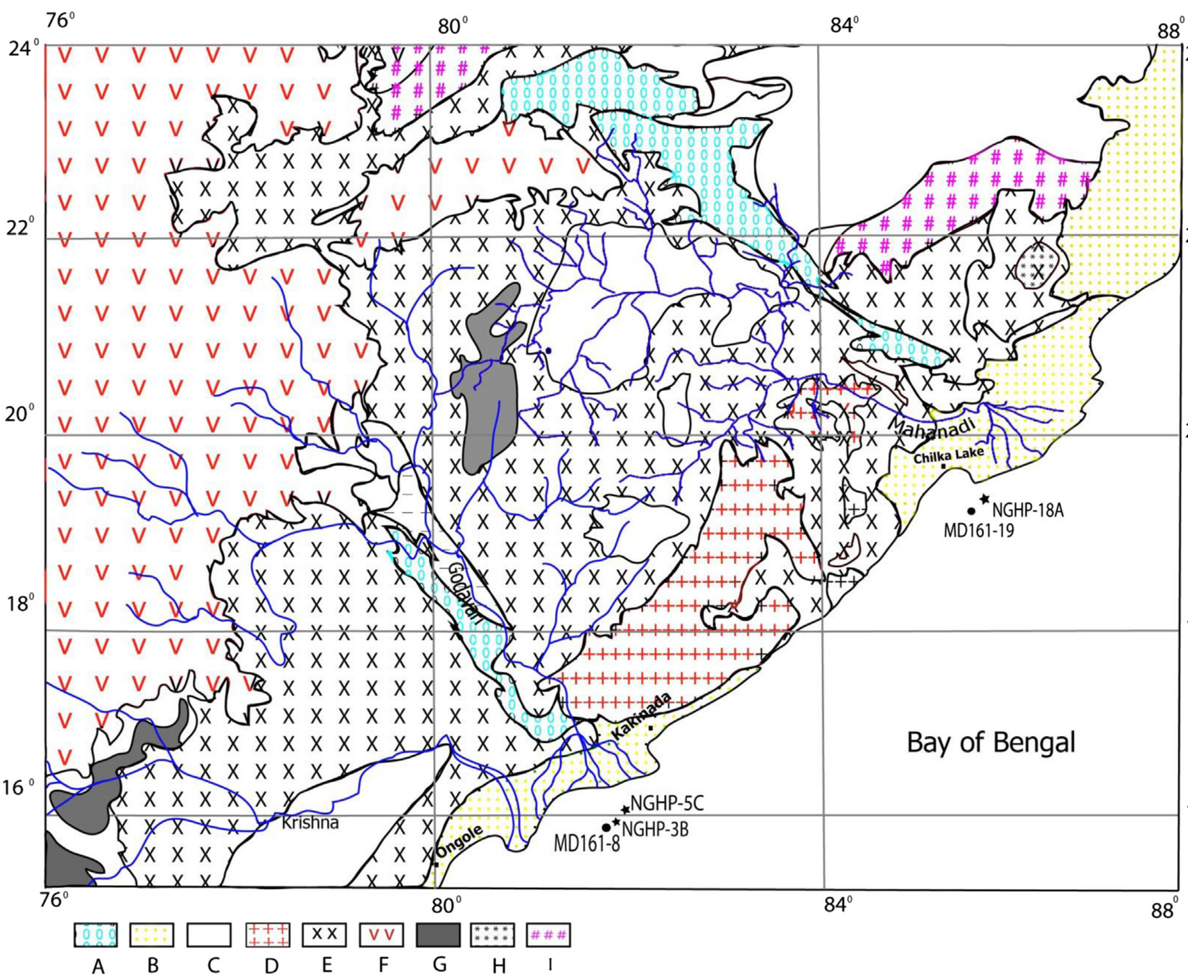

Figure 1. Geological map of K–G and Mahanadi drainage basins and locations of the offshore sediment cores. A = Gondwana sediments, B = Quaternary sediments, C = Mid-Late Proterozoic sediments, D = Archean charnockite and khondalite, E = Archean Proterozoic gneissic complex, F = Deccan basalt, G = Early Proterozoic granites, H = Archean-Proterozoic Singhbhum metamorphic complex. Modified after geological map published by Geological Survey of India (Dasgupta et al., 1993).