Palaeogeography, Palaeoclimatology, Palaeoecology 397 (2014) 20–30

Contents lists available at ScienceDirect

Palaeogeography, Palaeoclimatology, Palaeoecology

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

Major and trace element geochemistry of Bay of Bengal sediments: Implications to provenances and their controlling factors

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ARTICLE INFO

Article history:
Received 21 May 2012
Received in revised form 28 February 2013
Accepted 14 April 2013
Available online 22 April 2013

Keywords:
Bay of Bengal sediments
Geochemistry
Provenances
Himalaya
Deccan Traps
Climate

ABSTRACT

Major and trace elements of sediments from a ~13-m long piston core (SK187/PC33) from the western Bay of Bengal have been investigated in this study to infer about the changes in provenances and related controlling factors during the last glacial–interglacial period. Factor analysis of these geochemical dataset ascertains dominant role of riverine supply of sediments in regulating the geochemistry of SK187/PC33 sediments. The Al-normalized major (K and Ti) and trace elemental (Cu and Cr) ratios of these marine sediments fall within the ranges observed for their major provenances, *viz.* sediments from the Ganga, Brahmaputra and the Godavari–Krishna (GK) rivers and depth profiles of these ratios showed significant variations with synchronous excursion at around the last glacial maxima (LGM), implying a change in their provenances with relatively reduced Himalayan contribution during this climatic event. Inverse model calculation of Al-normalized elemental ratios of the sediments estimated an average sediment contribution of 66 ± 13% and 34 ± 13% from the Himalayan and the peninsular Indian rivers to the core site respectively. Consistent with the depth profiles of elemental ratios, the estimated sediment contributions from the Himalayan rivers are observed to decrease by ~30% from the Himalayan rivers, particularly that of the Ganga, to the studied location during the LGM. Lowering of sediment supply from the Himalaya (Ganga) during the LGM is due to weakening of south-west monsoon and reduction in available exposure area for weathering due to extent of glacier cover. Outcomes of this study underscore the strong linkage between erosion and climate.

1. Introduction

Sediments of the western Bay of Bengal (BoB) are supplied mainly by the major rivers draining the Himalaya (*e.g.* the Brahmaputra and the Ganga) and the peninsular India (*e.g.* the Godavari, Krishna and the Mahanadi). Presently, these rivers together supply about 1350 million tons of sediments per year to the BoB, which accounts for ~8% of the total riverine supply to the oceans (Milliman and Syvitski, 1992; Milliman, 2001). This sediment load is disproportionally (~4 times) higher compared to the fraction of areal coverage of these rivers to the global drainage area underscoring the important role of physical erosion in these river basins on the global sedimentary budget. Further, the erosion patterns of these river basins and their spatio-temporal variations have received significant attention due to their key role in the global carbon budget (Galy and France-Lanord, 1999; Dalai et al., 2002; Das et al., 2005; Singh et al., 2005; Rahaman et al., 2009; Huh, 2010; Krishnaswami and Tripathy, 2012). Researches based on sediment flux and their chemical and isotopic properties have demonstrated that the ongoing physical erosion in these river basins is by and large regulated by climate (rainfall) over millennium timescale (Islam et al., 1999; Singh and France-Lanord, 2002; Goodbred, 2003; Singh et al., 2008; Chakrapani and Saini, 2009; Panda et al., 2011). It has also been documented that the climate over this region has varied appreciably over ka timescale (Duplessy, 1982; Prell and Kutzbach, 1987; Sarkar et al., 1990; Tiwari et al., 2005). It is therefore, expected that physical erosion pattern over these river basins could also have varied in the past in response to these climate changes. Sediment archived in the western BoB can provide useful information on the paleo-erosion pattern of these river basins and therefore on climate–erosion link, which continues to be a topic of debate (Tripathy et al., 2011a).

Existing studies on the reconstruction of erosion pattern of river basins from the Himalaya and the peninsular India over ka timescale have led to diverging views. Temporal variations in the sedimentological and Sr–Nd isotopic properties of the BoB sediments indicated relative changes in the supply of sediments from different sources which have been attributed to variability in monsoon intensity in the past (Ahmad et al., 2005; Kessarkar et al., 2005). Prakashbabu et al. (2010), based on down-core variations in the granulometric, geochemical and mineral magnetism in a core from the eastern BoB observed a shift in sediment provenance from the Brahmaputra to the Ganga since early Holocene which has been attributed to climatic changes. More recently, Sr–Nd isotopic study of the Bay of Bengal sediments by Tripathy et al. (2011b) observed

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0031-0182/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.palaeo.2013.04.012

reduced sediment supply from the Himalaya to the western BoB during last glacial maximum (LGM) due to weakening of south-west monsoon (Prell and Kutzbach, 1987) and larger glacier cover over the Higher Himalaya (HH) (Owen et al., 2002); all these studies providing additional support for the climate–erosion link. The hypothesis of climate–erosion link was further strengthened by the studies of Clift et al. (2008) and Rahaman et al. (2009), both of which showed varying erosion rate over the Higher and the Lesser Himalaya in response to climatic changes during last tens of ka. In contrast to these results, there are also lines of evidence that suggest lack of major changes in sediment provenance during climatic events, challenging the climate–erosion relation. For example, Galy et al. (2008) based on Sr–Nd isotopic composition of BoB sediments showed no systematic change in sediment source despite changes in climate. Similar studies on tracking provenances of sediments from the Eastern Arabian Sea also have not indicated any major changes in supply from the peninsular Indian river basins over a ka timescale (Kessarkar et al., 2003; Goswami et al., 2012). In order to evaluate the impact of climate change on the erosion patterns of the Himalaya and peninsular Indian river basins, it would be interesting to compare the temporal variations in relative sediment contribution from these rivers to the western BoB.

Earlier studies on the provenances of BoB sediments relied mainly on their clay mineral and Sr–Nd isotopic composition. Prior to this, there have been a few studies on the chemical composition of BoB sediments (Sarin et al., 1979; Colin et al., 2006; Prakashbabu et al., 2010), which provide useful information about both chemical and physical erosion patterns of the river basins. The present study attempts to track the provenances of sediments from the western Bay of Bengal using down-core variations of their major and trace elemental composition and to reconstruct the paleo-erosion pattern of the river basins draining the Himalaya and peninsular India. Further, this study employs an integrated approach of factor analysis and inverse modeling to quantitatively estimate the sediment contribution from various sources to the core site and their temporal variations. The results of this study on temporal variations in provenances are used to assess the role of climate in regulating the erosional pattern of the river basins of the Himalaya and peninsular India.

2. Material and methods

The sediments analyzed in this study are from a ~13-m long piston core (SK187/PC33; Tripathy et al., 2011b) raised from the western BoB (Fig. 1; 16° 16′ N, 84° 30′ E; water depth: 3003 m) during the 187th expedition of ORV *Sagar Kanya*. This core was examined onboard for some of its physical properties (P-wave velocity, bulk density and gamma ray attenuation) using a Geotek® multi-sensor core logger. These measurements indicate that the core is turbidite-free and preserves a continuous record of sedimentation. The core was sub-sampled at 1–2 cm interval and stored at the National Institute of Oceanography core repository. Chemical analysis and Sr–Nd isotopic composition of the sediments were carried out at an interval of ~50 cm, at the Physical Research Laboratory, India. Tripathy et al. (2011b) in an early study reported the depth–age model, magnetic susceptibility and Sr–Nd isotopic composition of these sediments. Present study is limited to major and trace element composition of the sediment core and its potential as a tool to reconstruct the paleo-erosion pattern of the river basins supplying sediments to the core-site. The depth–age model for the SK187/PC33 was developed based on the ^{14}C ages of inorganic carbon ($CaCO_3$) and magnetic susceptibility stratigraphy. The ^{14}C depth–age model was developed after critically evaluating the impact of contribution from detrital carbonates (Tripathy et al., 2011b). This model suggests that sediments deposited in the depth interval 600–700 cmbsf corresponds to the LGM. The sedimentation rate of the core shows significant variation with

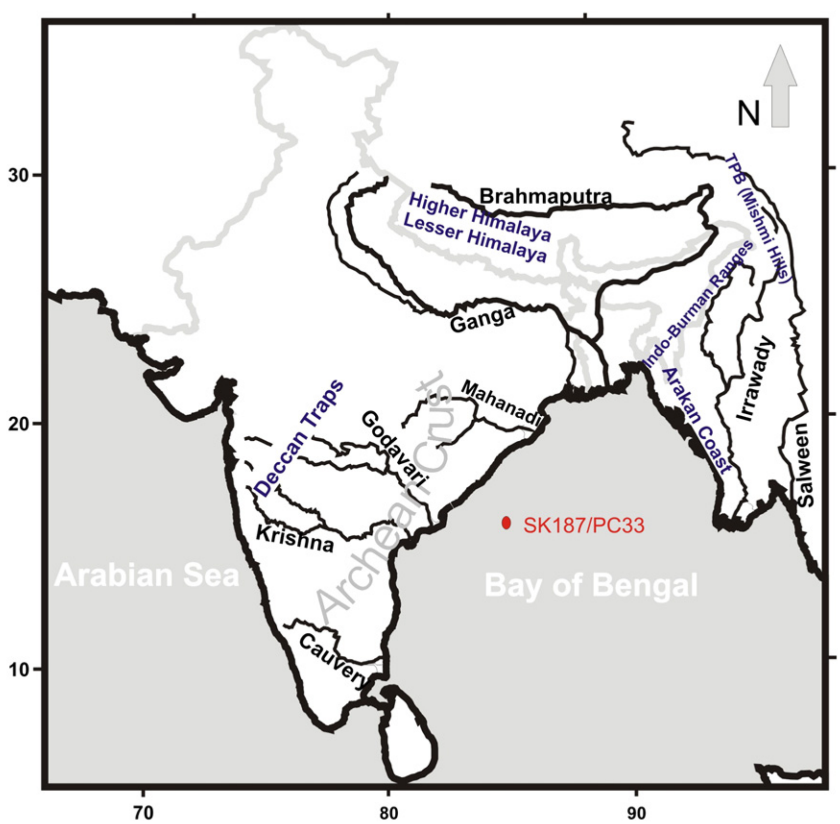

Fig. 1. Location of the sediment core SK187/PC33 in the western BoB. The major sources of sediments to this location are the rivers draining the Himalaya (Ganga–Brahmaputra), Deccan Traps and alluvium (Godavari–Krishna). These basins are also shown.