Gondwana Research 23 (2013) 1163–1171

Contents lists available at SciVerse ScienceDirect

Gondwana Research

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

Climatic control on the composition of Carboniferous–Permian Gondwana sediments, Khalaspir basin, Bangladesh

Dhiman Kumer Roy *, Barry P. Roser

Department of Geoscience, Shimane University, 1060 Nishikawatsu, Matsue, Shimane 690-8504, Japan

ARTICLE INFO

Article history:
Received 13 January 2012
Received in revised form 28 April 2012
Accepted 19 July 2012
Available online 2 August 2012

Handling Editor: P. Eriksson

Keywords:
Gondwana
Geochemistry
Bangladesh
Climate
Weathering

ABSTRACT

Late Paleozoic or Permo-Carboniferous Gondwana successions world-wide are marked by widespread and lengthy glaciation (~67 Ma), and multiple transitions from Icehouse to Greenhouse state. Mineralogical and compositional changes in sandstones and mudstones of the Gondwana succession in drill hole GDH-45 from the Khalaspir basin of Bangladesh are interpreted in a climatic framework, using the proxies of the Mineralogical Index of Alteration (MIA) and the Chemical Index of Alteration (CIA). Low MIA (<75) and CIA (<70) values in the lowermost unit (Unit 1) of the Khalaspir Gondwana sequence indicates minimal chemical weathering of the source and imply cold and dry glacial climatic conditions. Values increase progressively in the overlying Unit 2, suggesting warming and deglaciation. Very high MIA (80–100) and CIA (90–100) values in Unit 3 indicate intense chemical weathering associated with warm and humid climatic conditions in a post-glacial setting. These changes are recorded in both sandstones and mudstones, illustrating the value of acquiring data for a variety of size grades. The stratigraphic changes are also well recorded by progressively decreasing K_2O/Al_2O_3 and increasing Ga/Rb ratios, the combination of which may comprise a new geochemical proxy of climate and weathering. Upward increase in the modal Q/(F+L) and Qp/(F+L) ratios are also consistent with change from cool to warm and humid climate in the source region. The change in climatic conditions within the Khalaspir sequence is also well correlated with the Gondwana successions of other continental blocks, and records the climatic fluctuations and extent of climatic impact in Gondwanaland during the Permo-Carboniferous.

1. Introduction

Permo-Carboniferous Gondwana sediments on several continental blocks (India, Australia, Antarctica, South Africa and South America) record evidence of the Late Paleozoic Ice Age (LPIA), and global climatic fluctuation from icehouse to greenhouse state (Frakes et al., 1992; Isbell et al., 2003, 2012; Fielding et al., 2008a). These changes are documented by stratigraphic and sedimentological features (Fielding et al., 2008a, 2008b; Isbell et al., 2008a, 2008b; Rocha-Campos et al., 2008), paleosol characteristics (Tabor et al., 2008), paleobotany (Pfefferkorn et al., 2008), petrography and geochemistry (Suttner and Dutta, 1986; Visser and Young, 1990; Scheffler et al., 2003), and isotopic geochemistry (Montañez et al., 2007; Zeng et al., 2012).

The conventional view of the LPIA is that it represents the longest icehouse period of the Phanerozoic, and was previously thought (1980–1990s) of as a single, long-lived (60–80 Ma) glacial epoch (Veevers and Powell, 1987; Frakes et al., 1992). However, recent investigations have found that the LPIA was a series of shorter (1–8 m.y.) discrete glacial episodes separated by interglacial events, spanning an interval of ~67 m.y. from the mid-Carboniferous (ca. 327 Ma) to the early Late Permian (ca. 260 Ma) (Isbell et al., 2003; Fielding et al., 2008a, 2008b).

Based on stratigraphic investigation of Gondwana basin, Isbell et al. (2003) suggested that the LPIA was characterized by three discrete glaciation events, namely Carboniferous Glacials I and II (local Alpine glacier), and a widespread Late-Carboniferous to Sakmarian Glacial III. Based on stratigraphic and sedimentological data of the LPIA succession of eastern Australia Fielding et al. (2008a) suggested at least eight discrete glacial events (Carboniferous C1, C2, C3 and C4, and Permian P1, P2, P3 and P4; see text in Fielding et al. (2008a) for timing, duration and character), separated by non-glacial events. These events were well constrained by radiogenic isotopic and biostratigraphic data. However, the Glacial III (Isbell et al., 2003) or P1 (Fielding et al., 2008a) events of latest Carboniferous to early Permian age provide evidence of intense and widespread glaciation spanning 8 m.y. (299–291 Ma, Fielding et al., 2008a).

Mineralogical and geochemical compositions of Gondwana sediments from different continental blocks have been used to evaluate provenance and reconstruct paleoclimatic conditions (Suttner and Dutta, 1986; Visser and Young, 1990; Skilbeck and Cawood, 1994; Diekmann and Wopfner, 1996; Scheffler et al., 2003; Islam et al., 2004; Ghosh and Sarkar, 2010; Ghosh et al., 2012). Suttner and Dutta (1986) used petrographic framework compositions to identify

* Corresponding author. Tel.: +81 80 30521671.
E-mail address: dhimans14@yahoo.com (D.K. Roy).

1342-937X/$ – see front matter © 2012 International Association for Gondwana Research. Published by Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.gr.2012.07.006

climatic fluctuations in the Gondwana sediments of India and Australia. That petrographic work was confined to sand-sized sediments. In Bangladesh the only previous related work was that of Islam et al. (2004), who examined the petrographic and geochemical compositions of a small suite of Gondwana sandstones from the Barapukuria basin, mainly to identify source rock composition.

In this study we examine the mineralogical and geochemical variations in Permo-Carboniferous Gondwana sediments in the Khalaspir basin of Bangladesh (Fig. 1A), with the aim of reconstructing paleoclimatic changes within the succession, based on the Mineralogical Index of Alteration (MIA) and Chemical Index of Alteration (CIA). Geochemical proxies are applied to both sandstones and mudstones for the first time, in contrast to previous studies that utilize single lithotypes. We have also developed a new binary elemental ratio–ratio proxy model

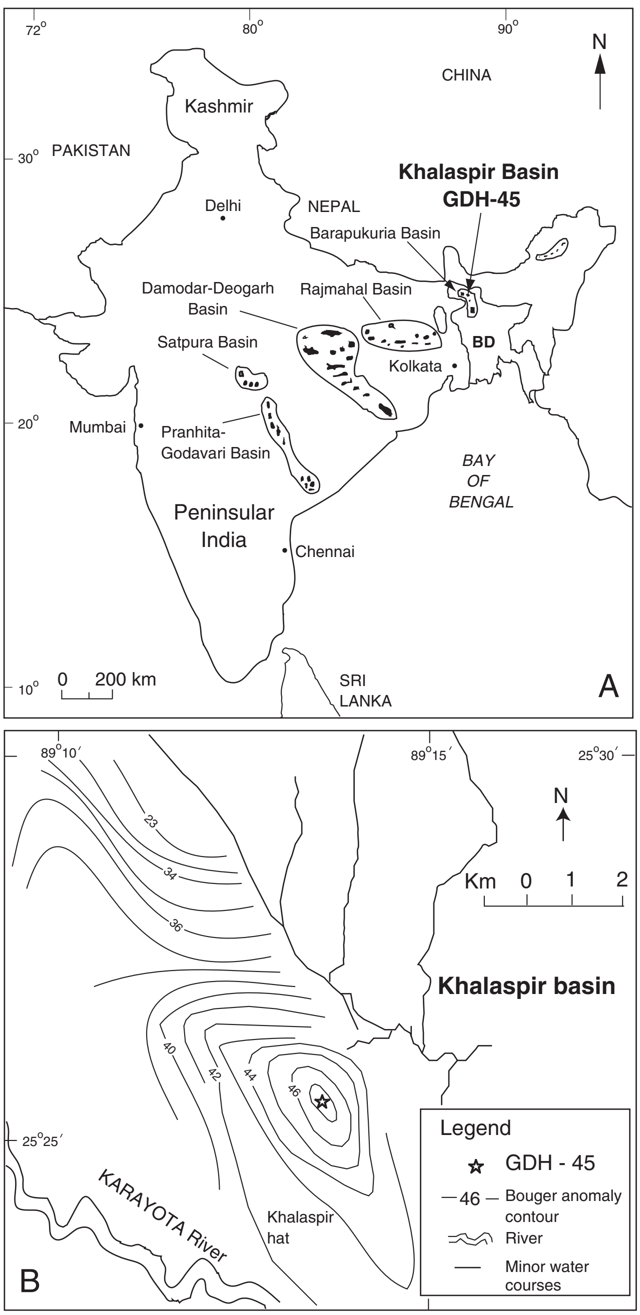

Fig. 1. (A) Regional location map of Gondwana basins in the Indian subcontinent (after Islam et al., 1992; Singh and Singh, 2004; Islam, 2009). Arrow indicates the location of GDH-45 in the Khalaspir basin. BD = Bangladesh. (B) Location of GDH-45 in the Khalaspir basin (after Islam et al., 1992).

(K_2O/Al_2O_3 vs. Ga/Rb) to reconstruct the paleoclimatic history of ancient sediments. This newly developed binary model can potentially be used to detect climatic shifts from dry and cold to warm and humid conditions. Systematic changes for both mineralogical and geochemical proxies in the Khalaspir sediments record a distinct shift from dry and cool climate to warm and humid climate, compatible with change from glacial to post-glacial conditions.

2. Geological background

Gondwana Group (Permo-Carboniferous) sediments occur in Bangladesh within several discrete faulted troughs or fault-bounded grabens underlain by crystalline Paleoproterozoic basement (Islam et al., 1992; Reimann, 1993; Hossain et al., 2007). The Gondwana Group sediments are about 1000 m thick, and are the oldest sedimentary unit in the country. The Gondwana sediments in Bangladesh are much less studied than the Tertiary succession, although several studies have examined their depositional environment and provenance (Islam et al., 1992; Hossain et al., 2002, 1999).

The Permo-Carboniferous Gondwana sediments examined here were intersected in drill hole GDH-45 in the Khalaspir basin (Islam et al., 1992). Gondwana sediments are not exposed at the surface in Bangladesh. The Khalaspir basin is situated in the stable shelf zone, and is elongated roughly NW–SE (Fig. 1B). The Khalaspir sediments were deposited in an isolated asymmetric and fault-bounded intracratonic half-graben basin floored by Paleoproterozoic basement (Islam et al., 1992; Hossain et al., 2002, 2007). The sediments in the Khalaspir basin have been divided into five lithostratigraphic groups, namely the Gondwana, Surma and Dupitila Groups, the Barind Clay, and recent Alluvium, in ascending order (Table 1) (Islam et al., 1992). GDH-45 provides a continuous 808 m (290–1098 m below surface) section through the Gondwana succession. We have informally divided the succession into three units, based on facies and depositional environment change (Fig. 2). The lowermost Unit 1 (U1, 753–1098 m) is composed of feldspathic sandstones, sandstones, siltstones and mudstones, and was deposited in a lacustrine or back swamp environment (Islam et al., 1992). Unit 2 (U2, 640–753 m) consists mainly of conglomerates and sandstones that were deposited in a braided river environment, whereas Unit 3 (U3, 290–640 m) is mainly composed of sandstones and mudstones, with coals in its uppermost part (Islam et al., 1992). Unit 3 was deposited by braided to sinuous streams (Hossain et al., 2002). The coal-bearing sediments (U3) in the Khalaspir basin can be correlated with Permian strata in India and other Gondwana basins in South Africa, South America, Australia and Antarctica, based on spore-pollen study of coal, and have been assigned to the Lower Gondwana Group, of Late Carboniferous–Permian age (Islam et al., 1992; Akthar, 2001). The age of the underlying sediments is not constrained. A summary of the lithology, depositional conditions and tentative age of the Khalaspir succession is given in Table 1.

3. Sampling and analytical methods

Ninety-three samples (41 sandstones, 52 mudstones) were collected from drill hole GDH-45. Modal compositions of 23 selected medium-grained sandstones were determined (Table 2) using the Gazzi-Dickinson point-counting method, as described by Ingersoll et al. (1984). Fresh samples from drill core were selected for geochemical analysis. All samples were crushed into small chips, cleaned in distilled water, dried, and then powdered in a tungsten carbide ring mill. Total loss on ignition (LOI) was determined gravimetrically on oven-dried powder (>24 h at 110 °C) by ignition for at least 2 h at 1020 °C. Major and trace element compositions of all samples (Table S1) were determined from glass beads prepared with an alkali flux (80% lithium tetraborate (LiB_4O_7) and 20% lithium metaborate ($LiBO_2$)), and flux to sample ratio of 2:1 (Kimura and Yamada, 1996), using a Rigaku RIX 2000 X-ray fluorescence spectrometer