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New age constraints for the Proterozoic Aravalli–Delhi successions of India and their implications

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ABSTRACT

Proterozoic sedimentary successions of India are important archives of both the tectonic history of the Indian subcontinent and the geochemical evolution of Earth surface processes. However, the lack of firm age constraints on many of these stratigraphic units limits their current utility. Here, we present new detrital zircon age data from strata of the southern Aravalli–Delhi Orogenic Belt (ADOB) and the Rajasthan Vindhyan successions. The Alwar Group of the southern Delhi Supergroup yielded a large population of ~1.2 Ga detrital zircon grains, which refutes the 1.9–1.7 Ga age assertion for this unit. Detrital zircon age distributions from the southern Alwar Group differ strongly from the Alwar Group of the "North Delhi Belt", demonstrating miscorrelation between these two regions. The Jhamarkotra Formation of the Lower Aravalli Group contains a large population of 1.9–1.7 Ga detrital zircon grains. Therefore, the unit cannot be ~2.1 Ga as traditionally assumed. Age distributions of the Aravalli and Delhi supergroups are similar to those of the lower and upper Vindhyan successions, and we postulate contiguous sediment sources for both regions, with strata of the tectonically deformed ADOB representing the distal margin equivalents of the Vindhyan successions. Additionally, a late Paleoproterozoic age for the Jhamarkotra Formation nullifies the hypothesis that the markedly positive carbonate $\delta^{13}C$ values in this unit are linked to the 2.3–2.0 Ga Lomagundi–Jatuli positive isotope excursion. The potential of a large late Paleoproterozoic (ca. 1.7 Ga) positive $\delta^{13}C$ excursion contrasts with the long-held view of a prolonged period of carbon isotope stasis during the so-called 'boring billion'.

1. Introduction

Thick Proterozoic sedimentary successions that cover the Indian shield are considered deposits of discrete isolated basins that are often referred to as the "Purana Basins" (Purana means ancient) (e.g., Holland, 1909; Valdiya, 1995; Chakraborty, 2006; Chakraborty et al., 2010). Modern physiographic features and differences in tectonic deformation typically define the boundaries of the so-called Purana Basins. The degree of continuity or isolation of these basins from one another during the time of sediment accumulation remains unclear. Interbasinal correlation has largely been hindered by a lack of depositional age constraints on the strata within them. However, there are recently developed chronostratigraphic frameworks for these various successions (e.g., Patranabis-Deb et al., 2007; Bengtson et al., 2009; Malone et al., 2008; Pradhan et al., 2010; Bickford et al., 2011; McKenzie et al., 2011; Mukherjee et al., 2012; Pradhan et al., 2012). These are critical to furthering understanding of the tectonic–sedimentary evolution of the Indian subcontinent. Additionally, these successions preserve critical information about the Proterozoic evolution of the biosphere (e.g., Bengtson et al., 2009; Papineau et al., 2009, 2013). The Aravalli Supergroup, in particular, contains carbonate rocks with markedly positive carbonate $\delta^{13}C$ values that have been linked to the ~2.3–2.1 Ga Paleoproterozoic Lomagundi–Jatuli carbonate carbon isotope excursion (Sreenivas et al., 2001; Maheshwari et al., 2002, 2010; Purohit et al., 2010). The Aravalli Supergroup has also been proposed to contain the oldest phosphorites in the rock record, which along with additional geochemical data, have been used for inferences on biogeochemical cycling following the ~2.4 Ga Great Oxidation Event (Papineau et al., 2009, 2013; Papineau, 2010).

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In this study we present new U-Pb detrital zircon age data from major stratigraphic units of the southern Aravalli and Delhi supergroups and the Vindhyan successions of Rajasthan, India. These data provide new constraints that drastically revise the depositional ages of the Aravalli and Delhi supergroups. Furthermore, these new age constraints appear to redefine the significance of carbonate carbon isotope trends from Proterozoic Aravalli strata.

2. Geologic setting

2.1. Aravalli–Delhi Orogenic Belt

The roughly north–south trending Aravalli–Delhi Orogenic Belt (ADOB) of western India exceeds 700 km in length (Deb et al., 1989; Roy and Jakhar, 2002) (Fig. 1). Two major stratigraphic units are defined in the ADOB: the lower Aravalli Supergroup and the upper Delhi Supergroup (Fig. 2). The ADOB is divided into northern and southern "belts" with strata of both the Aravalli and Delhi supergroups recognized in the southern belt, whereas all strata of the northern belt are classified as Delhi Supergroup, and thus it is commonly termed the "North Delhi Belt". At least two major tectonothermal events are recorded in the ADOB that can be broadly defined as late Paleoproterozoic (1.9–1.6 Ga) and late Mesoproterozoic–early Neoproterozoic (1.1–0.8 Ga) in age (Deb et al., 1989, 2001; Buick et al., 2006; Bhowmik et al., 2010; Meert et al., 2010).

The Aravalli Supergroup overlies the ~2.5 Ga Banded Gneiss Complex-I (BGC-I) Deb and Sarkar, 1990 (Deb et al., 1989; Wiedenbeck et al., 1996; Buick et al., 2006; Meert et al., 2010; Pradhan et al., 2010) and is divided into lower, middle and upper groups. The Lower Aravalli Group includes the basal Delwara Formation, which consists mostly of siliciclastic strata with interspersed volcanics, and the overlying carbonate-dominated

ARAVALLI-DELHI OROGENIC BELT

Delhi Sgr.
- Ajabgarh Gr. ---------- mixed siliciclastic-carbonate
- Alwar Gr. ---------- siliciclasitic dominated

Aravalli Sgr.
- Upper Aravalli Gr. ----- siliciclastic dominated
- Middle Aravalli Gr. ----- siliciclastic dominated
- Lower Aravalli Gr.
  - *Jhamarkotra Fm.* ------ carbonate dominated
  - *Delwara Fm.* ------ siliiclastic with interspersed mafic volcanics

VINDHYAN SUCCESSIONS

Upper Vindhyan
- Bhander Gr. ---------- mixed siliciclastic-carbonate
- Rewa Gr. ---------- siliciclastic dominated
- Kaimur Gr. ---------- siliciclastic dominated

Lower Vindhyan
- Semri Gr. ---------- mixed siliciclastic-carbonate

Fig. 2. Simplified stratigraphic nomenclature and general lithologies for strata of the Aravalli–Delhi Orogenic Belt and the Vindhyan successions (units listed in stratigraphic order). Sgr. = Supergroup; Gr. = Group; Fm. = Formation.

Jhamarkotra Formation, which contains localized phosphorite (Banerjee, 1971; Banerjee et al., 1986). It has been suggested that the Aravalli Supergroup was deposited in a series of "sub-basins" along an active rift margin (Roy and Paliwal, 1981; Roy and Jakhar, 2002) but, just as with the definition of the Purana Basins, the so-called "sub-basins" of the Aravalli Supergroup are defined by modern day outcrop limits and lithological facies variations, primarily the presence or absence of phosphatic stromatolites. As a result, these sub-basins have been subsequently divided into "phosphatic" and "non-phosphatic" domains (Papineau et al., 2009, 2013; Purohit et al., 2010). Their status as isolated basins during deposition has yet to be adequately verified, as there are no

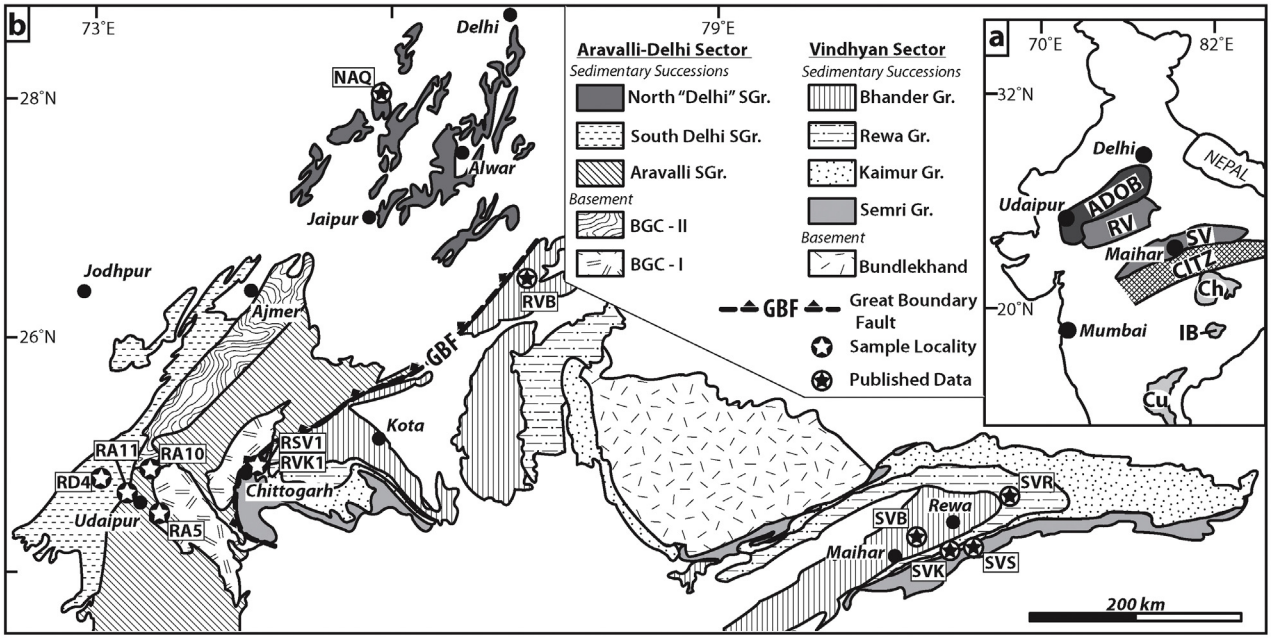

Fig. 1. (a) Small-scale map illustrating locations of major Purana Basins of India (ADOB = Aravalli–Delhi Orogenic Belt; RV = Rajasthan Vindhyan; SV = Son Valley Vindhyan; Ch = Chhattisgarh Basin, IB = Indravati Basin; Cu = Cuddapah Basin; CITZ = Central Indian Tectonic Zone). (b)Simplified Geologic map of Vindhyan and Aravalli successions (modified after Buick et al., 2006; Malone et al., 2008). Published data: NAQ = Northern Alwar Quartzite (Kaur et al., 2011); RVB = Rajasthan Vindhyan Bhander Group (Malone et al., 2008); SVS, SVK, SVR, and SVB = Son Valley Semri, Kaimur, Rewa, and Bhander groups, respectively (McKenzie et al., 2011). GPS coordinates for sample localities: RSV1 = 24° 50.513′ N, 74° 35.458′ E; RSK1 = 24° 53.750′ N, 74° 38.586′ E; RA05 = 24° 27.492′ N, 73° 52.372′ E; RA10 = 24° 49.971′ N, 73° 46.029′ E; RA11 = 24° 36.002′ N, 73° 40.688′ E; RD4 = 24° 45.173′ N, 73° 21.510′ E.