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Nature of magmatism and sedimentation at a Columbia active margin: Insights from combined U–Pb and Lu–Hf isotope data of detrital zircons from NW India

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ABSTRACT

Detrital zircons from a Palaeoproterozoic quartzite, deposited between 1.85 and 1.82 Ga in the northern Aravalli orogen of NW India, show a distinctive age peak of ca. 1.85 Ga and variable, but largely subchondritic $\varepsilon Hf_{1.85\ Ga}$ between −1.3 and −21.0 corresponding to hafnium model ages of 2.5 to 3.6 Ga. These data indicate an important period of reworking of ancient (Eo- to Neoarchaean), strongly heterogeneous continental crust at this time. Prevalence of ca. 1.85 Ga subduction-related granitoids, almost identical U–Pb age spectra and εHf_t of detrital zircons in ca. 1.85 Ga metasedimentary rocks in the Aravalli orogen and the inner Lesser Himalaya indicate similar sediment provenances and thus a geological connection between these two terranes during late Palaeoproterozoic. All together, the data constrain a rapid succession of sedimentation, metamorphism and subduction-related magmatic activity and support the interpretation of an active geodynamic realm along the entire north Indian margin at ca. 1.85 Ga. Comparison of detrital zircon data in conjunction with published paleomagnetic data from north India and other crustal blocks of the Columbia supercontinent, additionally, suggest a close affinity of north India with Madagascar, the Cathaysia block of South China and South Korea during Columbia times.

1. Introduction

Based on palaeogeographic reconstructions and palaeomagnetic evidence, it is proposed that a large tract of the proto-Indian continent formed an integral part of a Palaeo-Mesoproterozoic supercontinent, recommended to be termed more appropriately as “Columbia” (Meert, 2012), which is assumed to have amalgamated during the late Palaeoproterozoic between 1.9 and 1.85 Ga (e.g., Rogers and Santosh, 2002, 2009; Zhao et al., 2002, 2004; Hou et al., 2008; Meert et al., 2011). There are, however, divergent views regarding the position of India within the Columbia “puzzle” (see Santosh, 2012, for a recent review), as well as about tectono-metamorphic–magmatic processes and the geotectonic settings along the margin(s) of the supercontinent. Rogers and Santosh (2002, 2009) and Zhao et al. (2002, 2004) proposed a passive margin for the (recent) northern part of India, whereas Hou et al. (2008) speculated an active margin or subduction zone for the northern edge of India. Evidence for the existence of such an active continental margin at 1.85 Ga has been provided, recently, by petrological and geochronological data from the Lesser Himalaya (Kohn et al., 2010) as well as from the Aravalli orogen of NW India (Kaur et al., 2009). For the latter, Kaur et al. (2009, 2011a) reported an Andean style subduction-related episode of ca. 1.85–1.82 Ga, and presented U–Pb data of detrital zircons from a siliciclastic rock (deposited <1.7 Ga) that shows a major age peak at 1.87 Ga. These results hint that the northern India apparently preserves partial records of Columbia's supercontinent cycle, and it might be an active late Palaeoproterozoic margin.

There are, however, still many open questions, in particular about the continuation of the proposed active margin beyond the north Indian margin during “Columbia” times. Furthermore, the U–Pb–Hf isotope record, which constrains the tectonothermal events in the Aravalli region and the timing of sediment deposition, is still minor and inadequate to understand the role of various crustal growth processes at ca. 1.85 Ga and their relation with the assembly of Columbia supercontinent. For this reason, we present new detrital zircon U–Pb ages and Hf-isotope compositions from a quartzite of a late Palaeoproterozoic subduction-related terrane in the Khetri complex of the Aravalli orogen, NW India. In recent times, such combined zircon data have emerged as a remarkable tool to reconstruct global events of crustal evolution and their relation to supercontinent cycles (e.g., Hawkesworth et al., 2009; Zeh et al., 2009; Belousova et al., 2010; Iizuka et al., 2010; Safonova et al., 2010; Zeh and Gerdes, 2010; Condie et al., 2011; Lancaster et al., 2011; Roberts, 2012).

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These data allow us to show for the first time that at around 1.85 Ga, the northern margin of the proto-Indian continent experienced an apparent synchronicity in sedimentation-metamorphism-magmatism, and that diverse north Indian terranes have a similar sediment provenance. It thus provides robust evidence of an active geodynamic realm in this part of India during the amalgamation of Columbia. Finally, a correlation with other Columbia-related terranes, such as Madagascar, China, South Africa and Antarctica is discussed.

2. Regional geological framework

The Precambrian rocks in the ca. 700 km long NE-SW trending Aravalli orogen of NW India (Fig. 1b) include a cratonic nucleus, the Banded Gneissic Complex (BGC, 3.3–2.5 Ga), which is discordantly overlain by two Proterozoic supracrustal successions (for details see Sinha-Roy et al., 1998; Roy and Jakhar, 2002; Meert et al., 2010). The oldest supracrustal sequence is the Aravalli fold belt, a dominantly sedimentary succession deposited at ~2.2–1.85 Ga (e.g. Roy, 2000; Bhattacharya and Bull, 2010). The Delhi fold belt forms the younger cover sequence, comprising largely of pelitic–psammitic metasedimentary rocks with minor carbonate and mafic components. In the northern domain (North Delhi fold belt), the Delhi sediments were deposited at < 1.70 Ga (Kaur et al., 2011a), while in south (South Delhi fold belt) the sedimentary succession was deposited between 1.24 and 0.86 Ga (Singh et al., 2010). The important tectonothermal events in the Aravalli orogen are reviewed in Kaur et al. (2011a).

The Khetri complex, our study area, forms a part of the North Delhi fold belt (Fig. 1) and comprises Precambrian basement rocks (perhaps equivalents of the Aravalli supracrustals), which were emplaced by subduction-related granitoids at ~1.82 Ga and rift-related A-type granites at 1.72–1.70 Ga (Kaur et al., 2007, 2009, 2011b). These basement rocks are unconformably overlain by the medium- to high-grade metasediments of the Delhi Supergroup comprising, from bottom to top, the quartzite-dominated Alwar Group, which grades into the schist-dominated Ajabgarh Group. This sequence is in normal order of disposition (see Sarkar and Dasgupta, 1980), and the metasediments show westerly dip directions (Fig. 1c).

In this study, we investigate detrital zircons from a quartzite sample (RK-19, GPS co-ordinates: 28°03′53.4″N; 75°47′13.5″E) from the northwesternmost part of the Khetri complex (Fig. 1c). Field relationships indicate that the quartzite was intruded by a granite–granodiorite pluton, which yield a Pb–Pb zircon evaporation age of 1821.7 ± 0.4 Ma and a Sm–Nd whole-rock age of 1800 ± 50 Ma (Kaur et al., 2009). There is, however, considerable disagreement concerning the field chronostratigraphic relations of this quartzite-granitoid terrane. Previous workers correlated it either with the Ajabgarh sequence (Heron, 1923) or with the Alwar sequence (Das Gupta, 1968) of Delhi Supergroup and others with the pre-Delhi basement sequence (Gupta et al., 1998). Kaur et al. (2009) considered it as an exotic terrane that is now juxtaposed

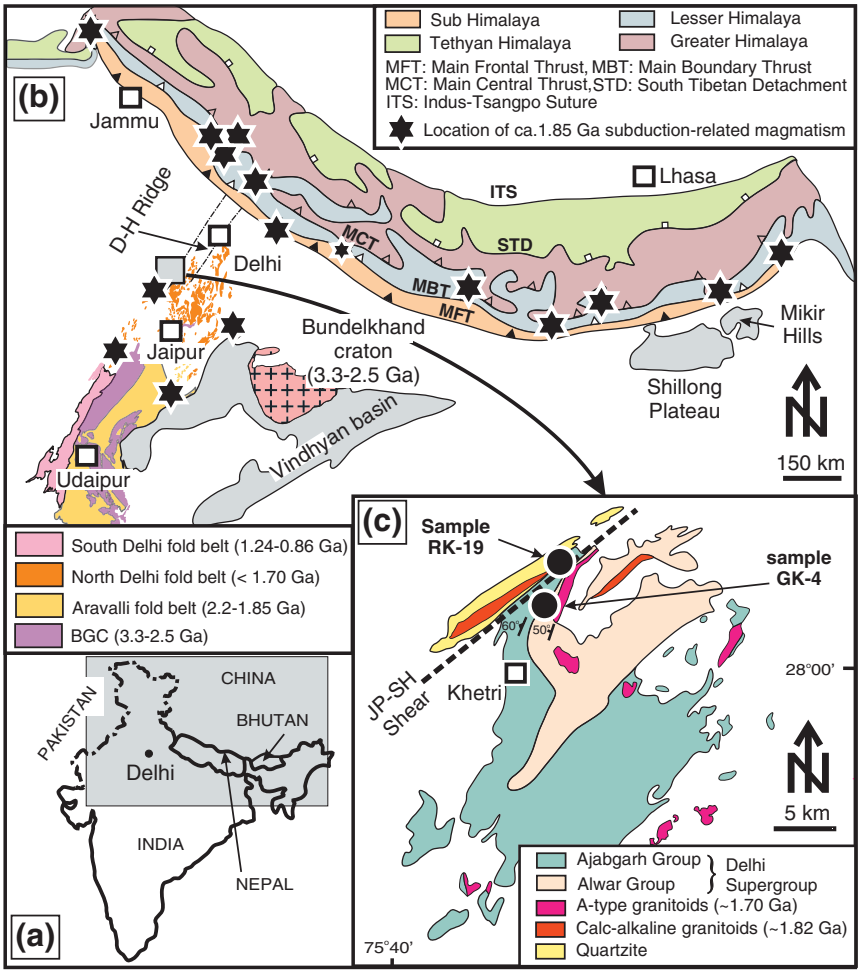

Fig. 1. (a) Map of India showing the location of Fig. 1b. (b) Simplified geological map of northern India (compiled from Valdiya, 1995; Roy and Jakhar, 2002). Locations of 1.85 Ga granitoids are as summarized in Kohn et al. (2010) and Kaur et al. (2011a) and updated from Long et al. (2011); Webb et al. (2011). D–H: Delhi-Hardwar. (c) Geological map of the northern Khetri complex showing major lithological units and the location of quartzite sample RK-19 (this study) and of a previously analyzed feldspathic quartzite sample GK-4 (compiled after Heron, 1923; Geological Survey of India, 1997; Gupta et al., 1998). JP–SH: Jasrapur–Singhana.