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Palaeomagnetic, geochronological and geochemical study of Mesoproterozoic Lakhna Dykes in the Bastar Craton, India: Implications for the Mesoproterozoic supercontinent

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ABSTRACT

Palaeomagnetic analysis of the Lakhna Dykes (Bastar Craton, India) yields a palaeopole at 36.6°N, 132.8°E, dp = 12.4°, dm = 15.9°, and the U–Pb zircon age obtained from one of the rhyolitic dykes is 1466.4 ± 2.6 Ma (MSWD = 0.21, concordia age based on two analyses with identical Pb/U ages), similar to previously published U–Pb ages. Major and trace element analyses of the Lakhna Dykes show shoshonitic and high-K calc-alkaline affinities consistent with a subduction related characteristics suggesting an active continental margin setting. This is in keeping with the Palaeo- to Mesoproterozoic tectonic environments in the eastern Indian margin. The new 1460 Ma Indian palaeopole was used to test possible palaeopositions of India within the Mesoproterozoic supercontinent Columbia. Of the four palaeomagnetically permissible reconstructions, juxtaposing western India against south-west Baltica is geologically the most reliably constrained and best fitting model. Our preferred reconstruction implies a long Palaeo- to Mesoproterozoic accretionary orogen stretching from south-eastern Laurentia through south-western Baltica to south-eastern India. Breakup of India and Baltica probably occurred in the Late Mesoproterozoic, but additional constraints are needed.

1. Introduction

An increasing number of publications indicates a growing interest in the Mesoproterozoic palaeogeography and to a hypothetic pre-Rodinian supercontinent variously called Nuna, or Columbia, or Hudsonland (e.g., Condie, 2000; Evans and Mitchell, 2011; Hoffman, 1996; Meert, 2002, 2012; Pesonen et al., 2003; Pisarevsky and Bylund, 2010; Rogers and Santosh, 2002, 2009; Wingate et al., 2009; Zhao et al., 2004). One of the main reasons for the Columbia hypothesis lies in the widespread evidence for 2.1-1.8 Ga orogens in the majority of Mesoproterozoic continents (e.g., Condie, 2000; Zhao et al., 2004 and references therein) and the suggestion that some or all of these orogens resulted from a supercontinental assembly. Unfortunately, most Columbia reconstructions are highly speculative and sometimes technically incorrect mostly due to a deficit of high quality Late Palaeoproterozoic and Mesoproterozoic palaeomagnetic data. For example, Evans and Pisarevsky (2008) argue that out of 600 published 1600–1200 Ma palaeopoles (Pisarevsky, 2005) for all Precambrian cratons, only eight satisfy all necessary reliability criteria. A few more recently reported palaeomagnetic poles (e.g., Bispo-Santos et al., 2008, 2012; Halls et al., 2006; Lubnina et al., 2010; Pisarevsky and Bylund, 2010; Salminen and Pesonen, 2007) have improved the situation somewhat, but there are still not enough poles to construct an adequate Apparent Polar Wander Path (APWP) for any one craton, let alone the globally disparate cratons. However, the presence of pairs of precisely coeval palaeopoles from the same two cratonic blocks can provide a palaeomagnetic test of the assumption that these two continents drifted together as parts of a larger supercontinent (Buchan, 2007; Evans and Pisarevsky, 2008). Luckily there are a few such pairs between 1800 and 1000 Ma: there are reliable palaeopoles from both Laurentia and Baltica at 1780–1740 Ma, 1480–1460 Ma and 1270–1260 Ma (see Table 2 of Pisarevsky and

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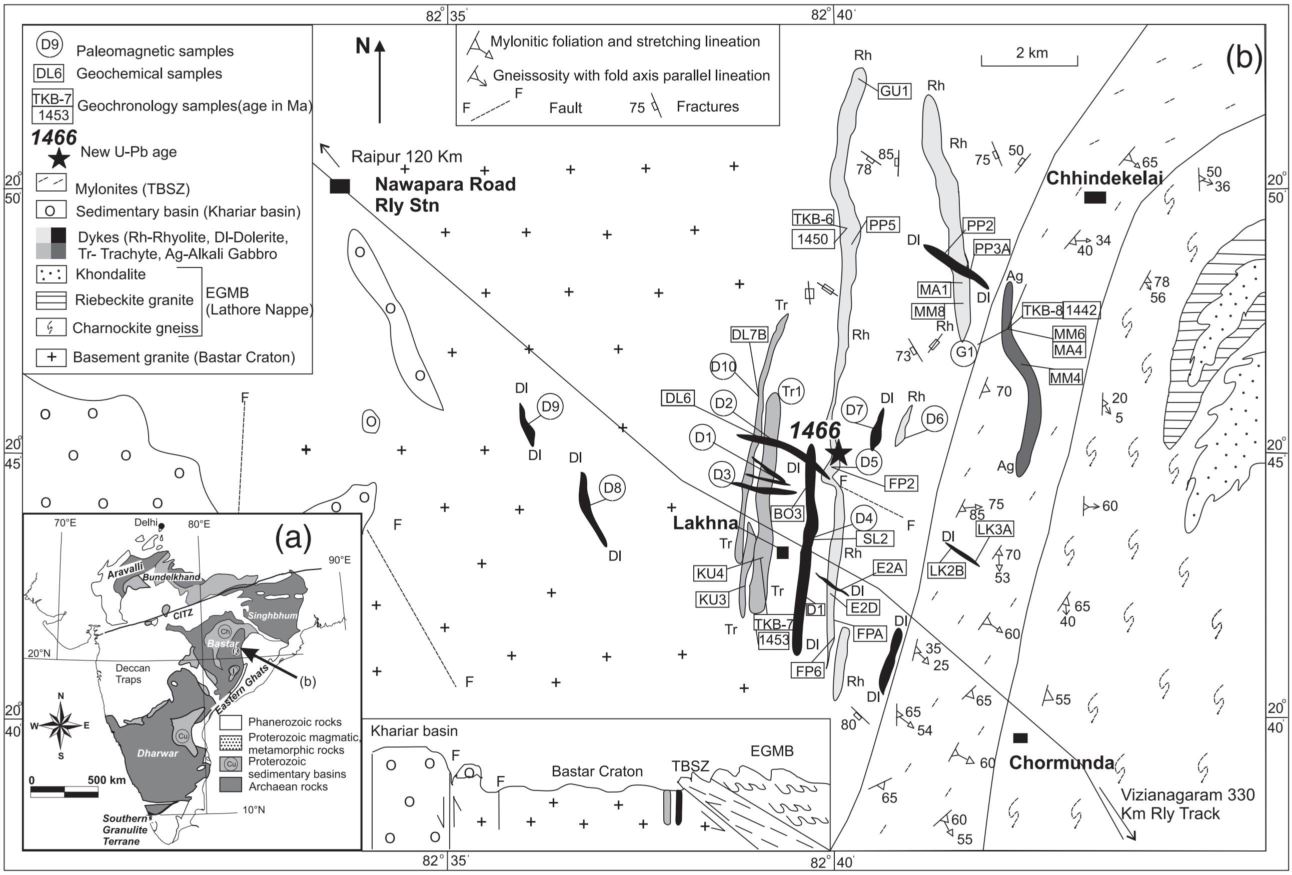

Fig. 1. (a) Location and geological province map of India (geology based on, Commission for the Geological Map of the World, 2000); (b) Geological map of the Lakhna area and sampling sites. The cross-section is approximately along 20°40′ 30″ N.

Bylund, 2010). Additionally there are coeval poles from Siberia and Laurentia at 1480–1460 Ma and even coeval fragments of APWPs for these two continents for ca. 1050–1000 Ma (Pisarevsky et al., 2008; Wingate et al., 2009). These data suggest that these three continents (Laurentia, Baltica and Siberia) could all have been part of a single supercontinent between 1500 and 1270 Ma (Wingate et al., 2009). Published palaeomagnetic data from other continents are not sufficient to establish their relationships with this supercontinent.

Ratre et al. (2010) reported a ca. 1450 Ma U – Pb SHRIMP age for the Mesoproterozoic Lakhna dyke swarm located in the eastern part of the Bastar Craton in India (Fig. 1). This age is very close to the 1480–1460 Ma ages of the abovementioned reliable palaeopoles for Laurentia, Baltica and Siberia. Here we report the results of palaeomagnetic and geochemical studies of the Lakhna Dykes and their implications for the relationship of India and the proposed Mesoproterozoic supercontinent Columbia.

2. Geology and sampling

Cratonic India comprises the Dharwar, Bastar, Singhbhum, Aravalli and Bundelkhand cratons (e.g. Meert et al., 2010 and references therein; Fig. 1a). The southern cratons (Dharwar, Bastar and Singhbhum) are separated from the northern cratons (Aravalli and Bundelkhand) by the Central India Tectonic Zone (CITZ) or the Satpura Belt. The eastern part of the CITZ was formed during accretion of the Bastar and the Singhbhum cratons to the northern Bundelkhand Craton (Meert et al., 2010 and references therein). The timing of this amalgamation is contentious. Some workers suggest that the main collision occurred at ca. 1500 Ma (Roy and Prasad, 2003; Yedekar et al., 1990), but significant crustal shortening is also reported at ca. 1100 Ma (Roy and Prasad, 2003; Roy et al., 2006). On the other hand, Stein et al. (2004) suggest that the entire Indian cratonic assemblage stabilised during the interval 2.50–2.45 Ga and that all younger displacements were minor.

The Archaean Bastar Craton is located in the eastern part of India (Fig. 1a). It mostly consists of Palaeoarchaean (3.5–3.6 Ga) TTG basement gneisses and granites (Ghosh, 2004; Rajesh et al., 2009; Sarkar et al., 1993) and relatively undeformed and unmetamorphosed Late Archaean - Early Palaeoproterozoic (~2.5 Ga) granites (Sarkar et al., 1993; Stein et al., 2004), with a number of ca. 3500 Ma old large gneissic xenoliths. The Bastar Craton is bounded by the Meso- to Neoproterozoic Eastern Ghats Mobile Belt (EGMB) in the south-east along the Terrane Boundary Shear Zone (TBSZ). The 1650–1550 Ma deformational and metamorphic events in the EGMB (Dobmeier and Raith, 2003; Mezger and Cosca, 1999; Rickers et al., 2001), the occurrences of ophiolitic mélange with ages between 1890 and 1330 Ma (Dharma Rao et al., 2011), and the development of foreland basins (Biswal et al., 2003; Chakraborty et al., 2010) all suggest a long-lived Mesoproterozoic active margin setting along the south-eastern edge of India in the late Palaeoproterozoic and Mesoproterozoic (e.g. Meert et al., 2010) . The EGMB also records pervasive high-grade metamorphism and deformation at 985–950 Ma, similar to that identified in the Rayner Complex of Eastern Antarctica (e.g., Harley, 2003; Collins and Pisarevsky, 2005 and references therein; Korhonen et al., 2011), and on the basis of which an earliest Neoproterozoic collision is postulated between proto-India (including the Napier Complex) and the Archaean Ruker Terrane of the southern Prince Charles Mountains, to form the India-Napier-Ruker-Rayner continent (Harley, 2003).

Proterozoic dykes are wide spread in the Bastar Craton (e.g. Ernst and Srivastava, 2008; French et al., 2008; Meert et al., 2010, 2011; Srivastava, 2006). Many are undated, but there are at least two mafic igneous events at ~2.3 Ga and at ~1.9 Ga. There are also younger dykes, but many of them are still undated (Meert et al., 2010 and references therein).