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Deformation and granite intrusion in the Sirohi area, SW Rajasthan—Constraints on Cryogenian to Pan-African crustal dynamics of NW India

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ABSTRACT

This study provides further evidence for a Cryogenian (~770–760 Ma) deformation event in NW India, a region generally regarded tectonically stable during the Rodinia to Gondwana transition. This deformation is prominent in the Sirohi region (southwestern Rajasthan State), previously referred to as the 'Sirohi Orogeny', younger to and independent of the ~1 Ga to 820 Ma Delhi Orogeny. Synkinematic intrusion of the Balda Granite during the NW-directed thrusting and folding of sediments of the Neoproterozoic Sirohi Group is constrained by combined field, microstructural and magnetic fabric analyses. Thrusting (D_1) occurred under medium grade deformation conditions along mylonitic to ultramylonitic shear zones featuring quartz and feldspar recrystallization. Steepening of thrust planes and transition from dip-slip kinematics to oblique and dextral strike-slip in high strain areas indicate transpressive kinematics during the late-stage of D_1 deformation. A second deformation event (D_2) is documented in strain concentration along a conjugate set (N–S & E–W) of shear zones wherein dilation along the N–S trending structures provided space for voluminous synkinematic quartz mineralization. This linear structure, traceable for ~10 km and named 'Balda-Paladi Shear Zone', has overprinted the NE–SW trending magmatic fabrics in the Balda Granite by N–S oriented shearing. Brittle behavior of feldspar constrains this overprint as a low temperature deformation event that also represents the terminal Cryogenian imprint in the Sirohi sector. The findings of this study indicate that an early Cryogenian imprint, seen in three different tectonomagmatic zones, from E to W referred to as South Delhi high-grade metamorphic terrane, Sirohi anatectic terrane and Sirohi fold and thrust terrane, is coeval with the initial closure of the Mozambique Ocean as constrained for central and northern Madagascar. A continuation of early Cryogenian mobile belts extending from southern India, crossing Madagascar into NW India is proposed. Related structures could have served as pathways for heat convection and triggered local late Pan-African thermal resetting in NW India.

1. Introduction

The period between Neoproterozoic assembly and dispersal of Rodinia and early assembly of Gondwana was marked by rapid changes in continental configurations (e.g. Kirschvink et al., 1997; Hoffman, 1999; Meert et al., 2003). The geological history and role of the north-western Indian terrane in the Rodinia to Gondwana transition continues to be debated as in contrast to other key areas the records of this geodynamically important time span (~800–750 Ma) are mostly obliterated by the vast expanse of volcanic and plutonic rocks of the coeval (770–750 Ma, Gregory et al., 2009) Malani magmatism (Malani Igneous Suite—MIS; Bhushan, 2000). The MIS covers >50,000 km^2 in NW India with possible counterparts in southern Pakistan (Khan et al., 2012), both separated by the sand cover of the Thar Desert.

There are now ample paleomagnetic, geochronological and geochemical evidences (Torsvik et al., 2001a; Tucker et al., 2001; Ashwal et al., 2002; Meert et al., 2013) to indicate that at ~750 Ma India was part of a land mass including Madagascar, Seychelles and parts of East Antarctica (Enderby Land–Prydz Bay region). Robust paleomagnetic data indicate a position of this landmass at a higher latitude (~45°, Meert et al., 2013) and far off the continental blocks

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forming proto-East Gondwana (Australia/Mawson block, Kalahari block, e.g. Collins and Pisarevsky, 2005). Subduction of the Mozambique Ocean along the western margin of this assemblage and formation of a linear continental arc comprising northern Madagascar and the Seychelles is well constrained (Ashwal et al., 2001b; Tucker et al., 2001; Ashwal et al., 2002; Bybee et al., 2010). Continuation of this convergent margin into the NW Indian sector is not clear yet. Recent models propose a late Grenvillian subduction in front of the Delhi Fold Belt that continued into the Cryogenian (Dharma Rao et al., 2012) or discuss the continuation of the trace of the Madagascar Ocean into the southern Delhi fold belt (Singh et al., 2010).

On account of the generally undeformed and unmetamorphosed nature of MIS, NW India has been regarded to have become tectonically stable after the Delhi Orogeny during the (~1 Ga) collision of Marwar block and Aravalli Bundelkhand craton. However, there are indications for a NE–SW trending tectonically active corridor along the eastern margin of the MIS, parallel to the NE–SW trending Delhi-Fold Belt and characterized by localized shear zones and synkinematically emplaced granitoids (Just et al., 2011; Pandit et al., 2011; de Wall et al., 2012). As timing of the tectono-magmatic activity within this corridor (770–765 Ma) overlaps with the plate convergence and closure of the Mozambique Ocean in the west this region holds vital clues in understanding the process of subsequent amalgamation of continental blocks to form the Gondwana Supercontinent. There is still no satisfactory kinematic model to explain the tectonic frame that initiated this localized deformation in the NW Indian block. The possibility of collision-related far field stresses during closure of the Mozambique Ocean has been suggested by de Wall et al. (2010, 2012) however, they do not rule out the possibility of these events being a consequence of late-tectonic movements related to a late-stage of the ~1 Ga to 850 Ma collision of Marwar terrane and Bundelkhand cratons in NW India (Delhi Orogeny).

The region around Sirohi in NW India (Fig. 1) offers suitable exposures to study the tectonic imprint of these Neoproterozoic events. In this area metasediments of the Sirohi Group are folded and thrusted, and subsequently intruded by the Balda Granite (Fig. 2). Since the sedimentation of the Sirohi Group post-dates the Delhi Orogeny, the structural imprint and associated metamorphism are seen as a younger event independent, of the Delhi Orogeny, and termed as the 'Sirohi Orogeny' (Roy and Sharma, 1999). However, the significance of this event has not been emphasized so far. Metasediments of the Sirohi Group can be traced all along the western margin of the DFB (Fig. 1). Intrusion of the Balda Granite (763 Ma; Rb–Sr whole rock age; Sarkar et al., 1992) into the deformed Sirohi metasediments has been regarded as a post-tectonic event with respect to the Sirohi deformation on account of preservation of magmatic fabric and intrusive relationship (Roy and Sharma, 1999).

This study focuses on the analysis of the structural inventory in the Sirohi region and evaluates the timing of intrusion of Balda Granite with respect to the regional deformation, using magnetic fabrics and petrogenetic characteristics. As these findings seriously question the conventional notion of a tectonically stable NW Indian block during the Cryogenian times the significance of our results is discussed in the context of Rodinia to Gondwana transition.

2. Geological setting

2.1. Regional geological setting

The NE–SW trending Aravalli–Delhi Fold Belt (ADFB) is the most prominent tectono-stratigraphic feature of the NW Indian block that runs over more than 750 km as a NE-trending linear orogenic belt. The ADFB separates the Archean basement (Banded Gneiss Complex–Bundelkhand craton) in the east and a vast, predominately felsic Neoproterozoic magmatic terrane (Malani Igneous suite—MIS) in the west (Marwar terrane). The Meso-Neoproterozoic Delhi Fold Belt (DFB), the western segment of the ADFB (Fig. 1), was deformed during the collision of the Aravalli-Bundelkhand craton and Marwar terrane, also resulting in the amalgamation of the NW Indian blocks at ~1 Ga (Bhowmik et al., 2010, and references therein). Closure of orogenic processes is indicated by a late-stage thermal event that led to several granitic intrusions parallel to the NE-trend of the DFB and in the Marwar terrane, further west. These intrusions, generally characterized as S-type granites (e.g. Naik, 1993), are collectively termed as 'Erinpura Granite' (Heron, 1953) that often show a gneissic fabric. For a long time the 830 Ma (whole rock Rb–Sr data; Choudhary et al., 1984) was cited as the emplacement age for Erinpura Granite, however recent studies have identified multiple episodes of magmatism spanning from 873 to 820 Ma (Deb et al., 2001; Pradhan et al., 2010; Singh et al., 2010; Just et al., 2011; Purohit et al., 2012).

The Sirohi Group sediments (carbonates, pelites) were deposited in a shallow basin with an already peneplained provenance as indicated by the absence of conglomerates (e.g. Roy and Sharma, 1999). The sediments have been metamorphosed to greenshist/lower amphibolite facies conditions as can be inferred from the mineral assemblage in the meta-calcsilicate rocks (tremolite bearing). Minor occurrences of diopside and wollastonite have also been reported but these are confined to localized contact metamorphism (Sharma, 1996). Relicts of metasediments, generally aligned NE–SW to the west of the DFB, occur as small isolated troughs within the Erinpura granite terrane and swing into an E–W orientation in the north (Fig. 1). A vast regional coverage of the Marwar block with Sirohi Group sediments can also be inferred from xenoliths picked up by MIS granites, e.g. as observed in Siana village (N 25°08.268, E 72°40.971) northwest (app. 45 km) of Sirohi. In the Sirohi region, the type locality for the Sirohi Group, the lithological boundaries between basement rocks and metasediments are bound by steeply dipping shear zones (Sharma, 1996; Just et al., 2011) and define a NE–SW trending ~20 km long eye shaped structure with a maximum width of ~6 km (Fig. 2).

2.2. The Balda Granite

A NE–SW trending elongate leucocratic granite body (4 km long with a maximum width of 1 km), the Balda Granite, intrudes the Sirohi Group rocks along the axial zone of folded and thrusted metasediments (Fig. 2). Along its western margin, the Balda Granite shows intrusive relationship with the host metasediments as seen in contact metamorphic growth of andalusite in the pelites. The granite also cuts across the foliations in the metasediments, cited as an argument to support its post-tectonic emplacement (Roy and Sharma, 1999). Along the eastern margin the granite intrudes both metasediments and Erinpura Granite and at many places the contact is sheared. The general NE–SW trend of the Balda Granite parallels the strike of tectonic fabrics in the host rocks (metasediments, Erinpura granite-gneiss), however, the granite body swerves to a N–S orientation in the northern part (Fig. 2). This orientation also corresponds to a N–S trending, large-scale shear zone which can be traced over a distance of more than 10 km between Balda and Paladi villages and named and henceforth referred to as the Balda-Paladi Shear Zone (BPSZ, Fig. 2).

The Balda Granite is essentially leucocratic with quartz, K-feldspar (microcline and orthoclase), sodic plagioclase and muscovite as major minerals. Biotite is either conspicuously absent or present only in trace quantity as streaks and diffused patches,