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Short communication

Stratigraphic position of the ~1000 Ma Sukhda Tuff (Chhattisgarh Supergroup, India) and the 500 Ma question

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ABSTRACT

U-Pb ages of magmatic zircons in tuff horizons in the Chhattisgarh and the Vindhyan Supergroups in India, backed up by paleomagnetic data, suggest that most Proterozoic basins in India are about 500 Ma older than the current consensus. The issue is hotly debated including questions about the stratigraphic positions of the tuff horizons. Thus, the geologic significance of the ~1000 Ma age of the rhyolitic tuff near Sukhda and Sapos villages in the Chhattisgarh Supergroup in central India hinges on its proper stratigraphic placement. If the tuff is near the top of the Chhattisgarh Supergroup, then the Chhattisgarh and its equivalent sediments were deposited in the Mesoproterozoic and not, as has been the general notion, in the Neoproterozoic. The tuff lies conformably on the platform-facies Saradih Limestone of the Raipur Group (upper Chhattisgarh) and not on an Archean-Proterozoic basement; it is overlain by fluvial volcaniclastic conglomeratic lithologies of the Sarnadih Sandstone. Had this sandstone belonged to the basal Lohardih Formation deposited in fan-deltas of an opening basin, as is currently believed, it would have been overlain by prodelta deposits including mature quartz arenites and floored by crystalline rocks. Formation-mapping, facies analysis, and petrologic considerations place the Sarnadih Sandstone, and thus the ~1000 Ma Sukhda Tuff, near the top of the sedimentary sequence of the Chhattisgarh basin. Consequently, rocks below the Sukhda Tuff must be pre-Neoproterozoic in age. Hence, rocks and tectonics of these Proterozoic basins are irrelevant to arguments about the Cryogenian or break-up of Rodinia, but are related more to the assembly of Rodinia and the break-up of Nuna. Metazoan and animal life forms, reported from the Chhattisgarh and equivalent basins, must also have originated and evolved in pre-Neoproterozoic time.

1. Introduction

Rhyolitic tuffs near Sukhda and Sapos villages (Mukherjee and Sahoo, 2003) in the Proterozoic Chhattisgarh (*var.* Chattisgarh) Basin (Fig. 1), in Janjgir District of Chhattisgarh State in central India, erupted ~1000 Ma ago as determined from U-Pb SHRIMP ages of magmatic zircons in the tuff (Patranabis-Deb et al., 2007). Mapping and stratigraphic considerations strongly suggest that the lithostratigraphic position of the tuff horizons (Sukhda Tuff for nomenclatural convenience) is near the top of the sedimentary succession of the Chhattisgarh Supergroup (Patranabis-Deb, 2001, 2004; Patranabis-Deb and Chaudhuri, in press). This implies that most of the Chhattisgarh Supergroup and its equivalents, such as the virtually unmetamorphosed sedimentary successions in the Vindhyan (Chakraborty and Paul, 2008; Malone et al., 2008), Kurnool (part of Cuddapah), Kaladgi–Badami–Bhima, Khariar, and Indravati basins in peninsular India (Kumar et al., 2005; Naqvi, 2005; Maheshwari et al., 2005), are also older than ~1000 Ma. Based on detrital zircon ages and paleomagnetic data, Malone et al. (2008) have shown that the maximum age of the top of the Vindhyan Supergroup is ~1000 Ma.

If so, inferences about the Neoproterozoic history of Earth, as deduced from sedimentary rocks found in peninsular India are rendered irrelevant. It is no puzzle that glacial deposits, such as those in the Cryogenian Snowball Earth, are absent in these basins (Williams and Schmidt, 1996; Chaudhuri et al., 1999; Kumar et al., 2005). The absolute age of the tuffs implies that these basins opened and closed before the complete assembly of Rodinia. Therefore, reconstructions of Rodinia with India in it (e.g., Dalziel, 1997) cannot draw from the sedimentary tectonics of these basins. In fact, there is a growing body of convincing evidence that India was not a part of Rodinia any way (Malone et al., 2008; Cawood et al., 2007; Kröner and Cordani, 2003; Meert and Torsvik, 2003; Torsvik et al., 2001). Hence, the impetus to put India in Rodinia based on the assumed

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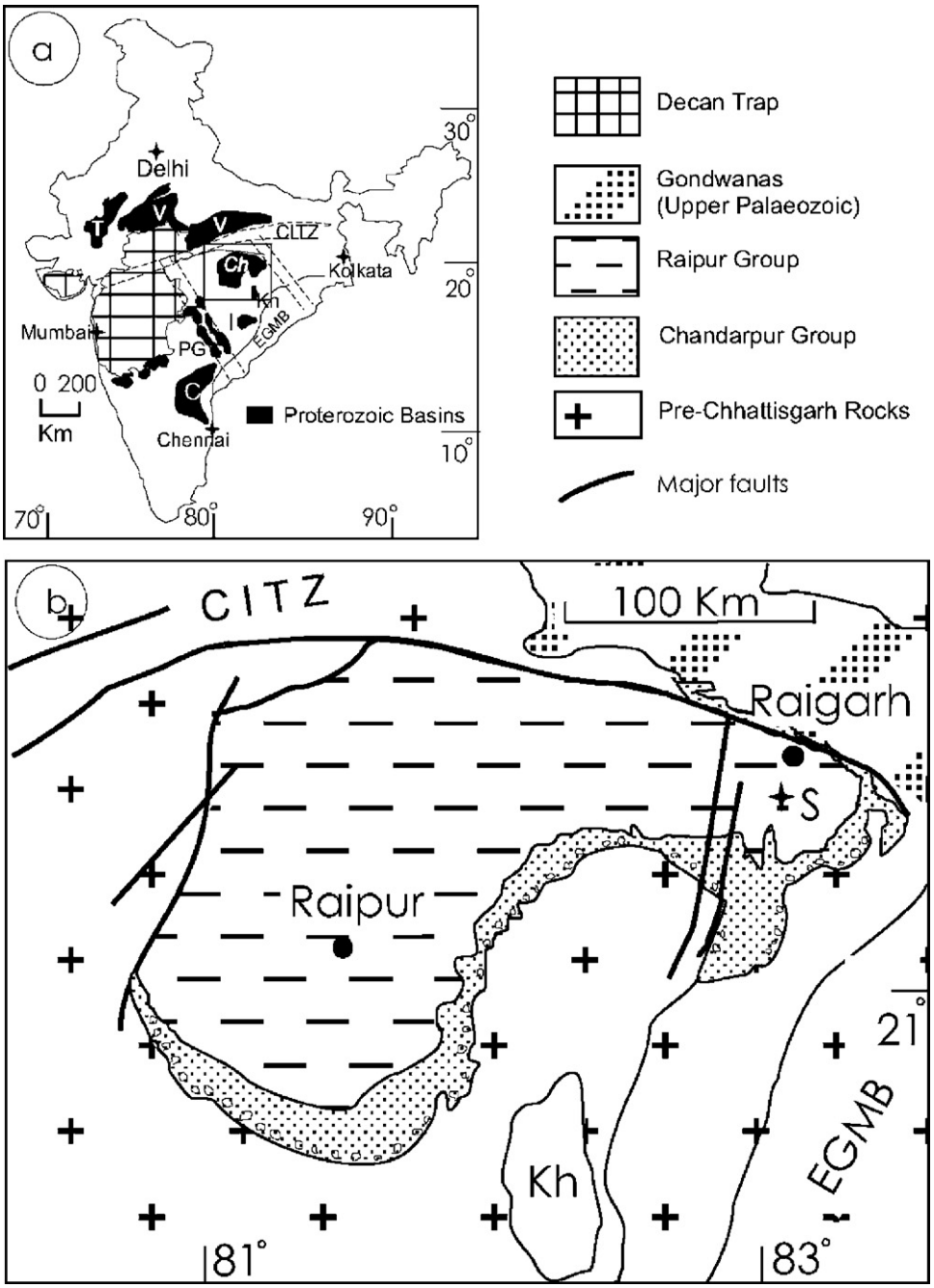

Fig. 1. (a) Distribution of major Proterozoic Basins in India. V = Vindhyan, T = Trans-Aravalli; Ch = Chhattisgarh; Kh = Khariar; C = Cuddapah; I = Indravati; PG = Pranhita-Godavari; CITZ = Central Indian Tectonic Zone; EGMB = Eastern Ghat Mobile Belt. (b) Simplified geological map of the Chhattisgarh Basin (modified from Chakraborty and Paul, 2005) showing Group boundaries, locations of Lohardih and Sarnadih sandstones, and Sukhda Tuff. S = Location of Sukhda Tuff and Sarnadih Sandstone.

Neoproterozic age of these basins is based on false assumptions. Finally, the new absolute ages also demand that the life forms, including metazoans and small shelly fossils (SSF) that have been reported from the strata in these basins are all much older. Because this implies that metazoan life started and evolved in deep time (Bengtson et al., 2007; Basu, 2008), the exact stratigraphic placement of these fossils needs to be verified through careful resampling of in-place material.

The Sukhda Tuff and its enclosing sedimentary package have been placed by some in the lower part of the Chhattisgarh Supergroup (Subba Rao et al., 2006; Mukherjee and Ray, 2008; GSI, 2005a,b). If so, there arises a 500 Ma problem in Indian Proterozoic stratigraphy. This is a matter of much verbal public discussion (e.g., International conferences at ISI, Kolkata, January, 2008, and, at IIT, Mumbai, December, 2007 and February, 2008; see also Mukherjee and Ray, 2008). The purpose of this short note is to present arguments from our formation-mapping, facies-mapping and petrologic observations (optical and SEM-BSE-CL) to show that the Sukhda Tuff (Fig. 2) indeed is located near the top of the Chhattisgarh Supergroup. This finding requires a bold re-assessment of the Proterozoic geology of peninsular India.

2. Lithostratigraphy

There is no dispute over gross lithologies and geographic locations of outcrops in the Chhattisgarh Basin, the eastern part of

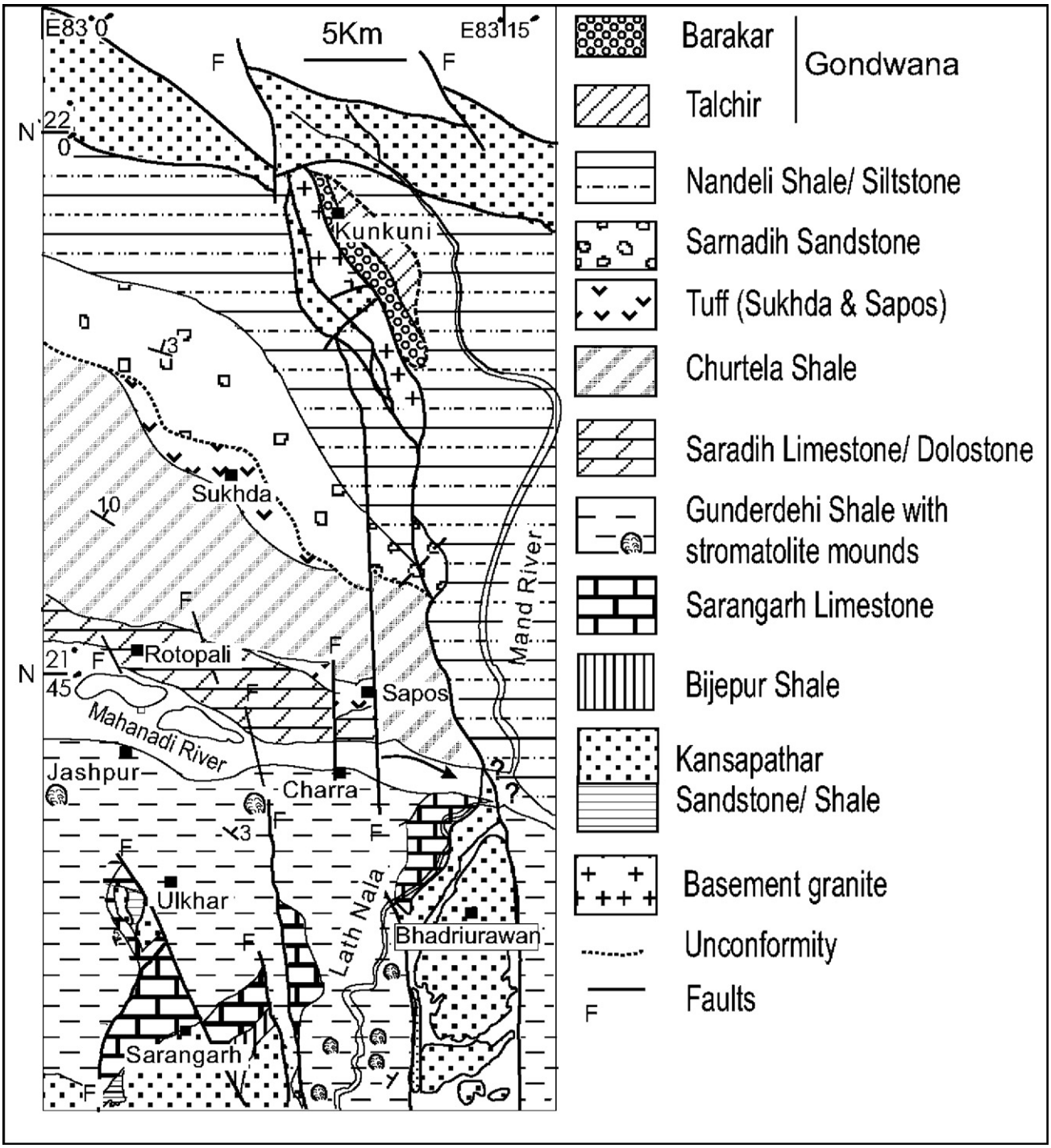

Fig. 2. Detailed geological map of the Sukhda area. The Sukhda Tuff dips towards NNE below the Sarnadih Sandstone above. At Sapos the tuff overlies the Saradih Limestone. Adapted from Patranabis-Deb and Chaudhuri (in press).

which is sliced by a number of faults. We, however, interpret the relative stratigraphic positions of these lithologies differently from what is depicted on currently available maps published by the Geological Survey of India, in which the sandstone outcrop NE of Sukhda is listed as *Lohardih* (GSI, 2005a, b). Traditionally, the Chhattisgarh Supergroup has been divided into a lower Chandarpur Group and an upper Raipur Group (Dutt, 1964). An even lower Singhora Group and an upper Kharsiya Group have been advocated more recently (Das et al., 1992; Chakraborti, 1997; GSI, 2005a; Patranabis-Deb and Chaudhuri, in press), but we include these units in the Chandarpur and Raipur Groups respectively in the interest of avoiding a stratigraphic debate that is not relevant to this paper. A simplified stratigraphic order of rock-types in the basin is given in Table 1 in which we list the names of nearly all formations and members used in the current literature (Dutt, 1964; Schnitzer, 1969; Murti, 1987; Das et al., 1992; Guhey and Wadhwa, 1993; Patranabis-Deb and Chaudhuri, in press). We have italicized the *Lohardih* and *Sarnadih* Formations because they are in dispute. Abbreviated petrographic descriptions of the four major sandstone units are given in Table 2.

Table 1
Simplified order of Proterozoic lithologies of Chhattisgarh Supergroup.

Principal lithologies	Depositional environments	Stratigraphic names (different authors)	Group
Late Paleozoic Shale and Sandstone (Gondwana)			
Unconformity			
Shale; gypsum	Lagoon?	Maniari	
Dolostone; gypsum	Sabkha; closed marine	Hirri; Kodwa	
Shale; limestone	Tidal flat; muddy shelf	Nandeli	
Conglomerate; volcaniclastic pebbly sandstone	Fluvial; shallow marine?	*Sarnadih*; *Lohardih*	
Unconformity			
Shale; rhyolitic tuff	Outer shelf	Sukhda; Churtela; Tarenga	Raipur (~1200 m)
Limestone- stromatolitic; dolostone	Platform; reef	Chandi; Saradih; Nandini; Bhatpara; Bamandihi; Khairagarh	
Shale	Muddy shelf	Gunderdehi; Karuid II	
Limestone	Platform	Charmuria; Sarangarh; Seorinarayan; Karuid I	
Shale	Shelf; lagoon	Bijepur	
?Unconformity?			
Sandstone	Shoreface bar	Kansapathar	Chandarpur (~900 m)
Mudstone; sandstone	Prodelta; tidal flat	Chaporadih; Gomarda	
Conglomerate; sandstone	Fan-delta	*Lohardih*	
Unconformity			
Archean-Proterozoic Granite, Gneiss, Schist and Greenstone Basement			

The reddish outcrop of the Sarnadih Sandstone is surrounded by upper units of the Raipur Group whereas the light grey Lohardih Sandstone outcrops at the periphery of the Chhattisgarh basin and is considered the basal unit of the Chandarpur Group (Fig. 1). This basal unit in one section in the southeastern edge of the basin, locally named Rehatikhol Formation that rests directly on an Archean granite-granodiorite basement, has a volcaniclastic sandstone member (Chakraborti, 1997). Our detailed geological map around Sukhda (Fig. 2) shows that the Sukhda Tuff, further south near Sapos, conformably overlies the Saradih Limestone. The observation is independently confirmed by a drill hole through the Sukhda Tuff, which encountered limestone (Mukherjee and Ray, 2008). If the Sukhda Tuff and the associated sandstone unit were to be a part of the Chandarpur Group and specifically of the basal Lohardih Formation (as per the maps of GSI, 2005a,b) or the Rehatikhol Formation by another name (Chakraborti, 1997), the drill hole should have encountered rocks of the Archean basement. Such is not the case.

Table 2
Characteristic mineral compositions of principal sandstone horizons.

Sandstone (see Table 1 for formation names)	Composition
Sarnadih	Volcaniclastic conglomeritic, pebbly sandstone (rock fragments ~10–70%; mostly volcanic; also, mud/ash? clasts); bright blue-luminescing zoned fracture-free quartz; no polycrystalline quartz; calcite and clay cement; sprinkling (~1%) of almandine garnet (Figs. 3 and 4).
Kansapathar	Mature quartz arenite; rounded quartz overgrowths; quartz cement; minor (<2%) sphene, zircon and tourmaline.
Gomarda	Mature quartz arenite; quartz cement; sprinkling of sphene and tourmaline (~1%). Subarkose with both plagioclase and microcline (feldspar ~5–15%); rare fragments of quartzite and schist; clayey cement.
Lohardih	Subarkose (feldspar ~10%); polycrystalline quartz common; detrital matrix <3%; quartz cement. Basal conglomeritic, pebbly, lithic arkose (feldspar ~30%; mostly microcline; rare plagioclase); large polycrystalline quartz (10–15%); rock fragments are predominantly granitic (~5–30%); dull blue-luminescing quartz with sets of cross-cutting subparallel fractures; clay and quartz cement (Fig. 3).

3. Discussion

The basal conglomeritic sandstone of the Chandarpur Group (~900 m), overlying Archean-Proterozoic granite, gneiss, schist and greenstones, named the *Lohardih* Formation virtually by all authors, is characterized by abundant rock fragments of granitic composition and occurs along the periphery of the basin (Fig. 1). The principal provenance of this sandstone is plutonic. Primary sedimentary structures and sedimentary architecture indicate that the sandstone was deposited in fan/braid-deltas in an opening basin (Patranabis-Deb, 2001, 2004; Chakraborty and Paul, 2005). This sandstone is followed upward by mudstones and subarkosic to quartz arenitic sandstones deposited in prodelta and tidal flats (Chaporadih or Gomarda Formations). Very mature quartz arenites containing recycled quartz grains with rounded overgrowths, which accumulated in shoreface bars (Kansapathar Formation), lie above this middle sandstone and are separated from overlying units by an unconformity or its correlative conformity to the west (Tables 1 and 2; Dutt, 1964; Schnitzer, 1969; Murti, 1987; Das et al., 1992; Chakraborty and Paul, 2008).

The lower part of the Raipur Group (~1200 m) consists mostly of shale, limestone and dolostone deposited in shelf and lagoonal environments. The topmost unit of this lower part is a monotonous appearing shale (Churtela Shale) that is interpreted as an outer shelf deposit. The upper 300 m of this shale unit is intercalated with tuff beds (Subba Rao et al., 2006; Patranabis-Deb et al., 2007). Almandine garnet phenocrysts that occur in this tuff unit are generally quite rare in rhyolitic tuffs and is a robust specific provenance indicator (Patranabis-Deb et al., in press). The upper part of the Raipur Group consists mostly of evaporites and carbonates (~150 m) that were deposited principally in sabkha and lagoonal environments and rest on fluvial and shallow marine conglomerates and pebbly and very coarse to fine grained sandstones (Sarnadih Sandstone). These sandstones contain abundant volcanic rock fragments that are identical to the Sukhda Tuff below. Many quartz grains are hexagonal-bipyramidal in shape, have embayments, and their SEM-cathodoluminescence is bright blue. They are of volcanic origin. Almandine garnets, optically identical to those in the Sukhda Tuff,

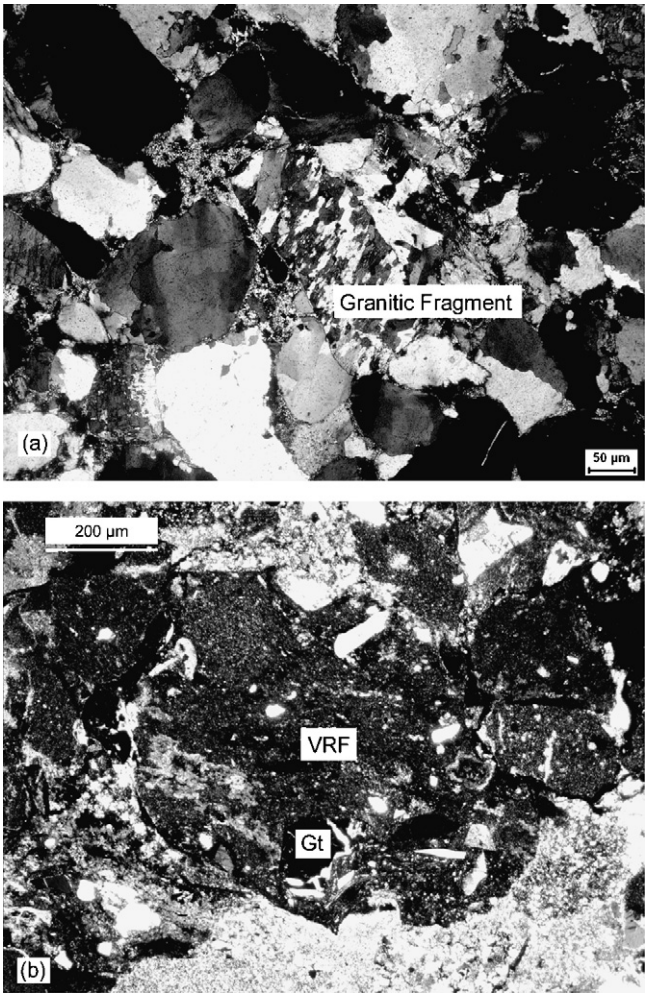

Fig. 3. Optical photomicrographs in cross-polarized light of typical very coarse sandstones of (a) Lohardih and (b) Sarnadih Formations. Note contrast in lithic clast types and especially the occurrence of garnet (Gt in lower center; in extinction) in a tuff fragment (VRF) in Sarnadih.

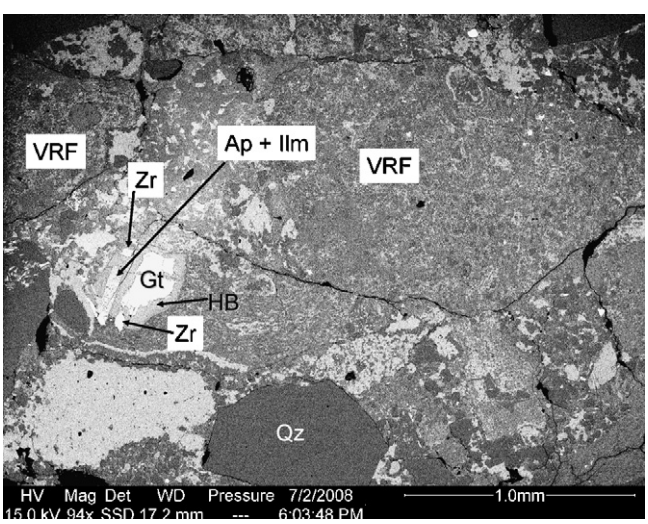

Fig. 4. Backscattered electron micrograph of a typical volcanic rock fragment (VRF) in the Sarnadih Formation. Note garnet (Gt) in lower left with apatite-ilmenite (Ap + Ilm) and hydro-biotite (HB), a characteristic association of garnet occurrences in the Sukhda Tuff (cf. Fig. 4f in Patranabis-Deb et al., in press). The image is optimized to show internal texture of VRF and not the differences in backscattering by zircon, ilmenite, and garnet.

are commonly observed in thin sections (Figs. 3 and 4). There are no obvious granitic or schistose clasts. We call this unit '*Sarnadih Sandstone*' (Fig. 2; Tables 1 and 2). However, the outcrop of this sandstone unit in the Janjgir District is nominally identified as *Lohardih* Formation in previous maps (e.g., GSI, 2005a). Because of its physical association and juxtaposition with the Sukhda Tuff, the erroneous stratigraphic assignment of this sandstone is at the heart of the current debate about the age of the Chhattisgarh Supergroup (e.g., Subba Rao et al., 2006; Mukherjee and Ray, 2008; personal communications).

4. Conclusion

The sandstones in the Sarnadih, Lohardih and Kansapathar Formations are petrographically distinct (Table 2). The Kansapathar sandstones are very mature quartz arenites that were deposited in shoreface bars. The Sarnadih and Lohardih sandstones are both immature and were deposited primarily in continental and near-shore environments respectively. The Sarnadih sandstone rests on the Sukhda Tuff and the Lohardih sandstone rests on the Archean-Proterozoic basement. The provenance of the Sarnadih (volcanic) is distinct from the provenance of the Lohardih (plutonic-metamorphic); they are easily distinguishable in thin sections of very coarse gritty sandstones. The depositional environments of the Sarnadih (primarily fluvial) and Lohardih (fan-delta) are also different, as are the depositional environments of adjacent formations (Table 1).

Evidence from mapping, facies analysis, and petrology indicates that the Sukhda Tuff (~1000 Ma) and the overlying Sarnadih Formation are near the top of the Chhattisgarh Supergroup. Because of the ~1000 Ma age of the Sukhda Tuff, most of the sedimentary rocks of the Chhattisgarh Supergroup must be Mesoproterozoic in age. This conclusion has enormous implications for the origin and evolution of Animalia, amalgamation and dismemberment of earliest supercontinents, and for reconstructions of Snowball Earth. At the least, the inference calls for impertinent re-thinking about the Proterozoic history of the Indian shield.

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