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A vertic paleosol at the Archean-Proterozoic contact from the Singhbhum-Orissa craton, eastern India

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ABSTRACT

We report on an inferred Paleoproterozoic soil horizon from the Singhbhum-Orissa craton near Keonjhargarh, Orissa, eastern India, which preserves vertic (Vertisol-like) features. The ~2–10 m thick, white shale consists of quartz–muscovite–pyrophyllite interpreted as a paleosol, overlies ~3.32 Ga granite and is covered by pre-2.0 Ga sandstones (Kolhan Group) deposited in marginal marine environments. The paleosol passes downwards through a partly altered granite (saprolith) zone to fresh granite. Abundant pedogenic slickensides, ped structures, gilgai topography, reddish stain on ped surfaces, and sepic-plasmic microfabric in the paleosol were probably related to shrink and swell processes driven by marked seasonal precipitation in a well-drained landscape. An observed decrease of alkali elements and an increase of silica, alumina and CIA values from granite to paleosol, together with relatively constant Ti/Al ratios suggest *in situ* weathering of granite protolith. However, a paleo-Vertisol necessitates a mafic parent rock, either directly (igneous) or reworked through alluvium. The c. 2.25 Ga Malangtoli-Jagannathpur basaltic rocks are relatively widespread and close to the inferred paleosol occurrences, and provide a logical solution. Geochemistry of the highly depleted paleosol, in contrast, particularly when applying the isochon method, strongly supports a granitic parent. The apparent conundrum can possibly be solved through repeated alluvial reworking of both granitic and mafic detritus and accumulation of weathered material with varying proportions of these two components, yet enough smectitic clays (~30%) to form a paleo-Vertisol. This pre-2.0 Ga weathering event in the Singhbhum craton is consistent with a global scenario of Paleoproterozoic weathering which followed an extended global glaciation, and thus has the potential to contribute to understanding of pre-2.0 Ga amalgamation of regional and global cratonic blocks.

1. Introduction

The study of Precambrian paleosols is always a difficult task because such paleosols are generally either partly or almost completely eroded away, commonly preserve only the lower saprolitic (C horizon) zone (Gall, 1999) or are severely altered during later metamorphic and deformation events. Hence Precambrian paleosols are chiefly recognized on the basis of geochemical variations and mineralogical changes (Schau and Henderson, 1983; Grandstaff et al., 1986; Kimberley and Grandstaff, 1986; Reimer, 1986; Zbinden et al., 1988; Golani, 1989; Macfarlane et al., 1994; Panahi et al., 2000; Rye and Holland, 2000; Sreenivas et al., 2001; Yang and Holland, 2003; Pandit et al., 2008), nevertheless a few studies have recognized diagnostic physical soil features and relatively complete soil profiles from Precambrian paleosols (Retallack, 1986; Retallack and Mindszenty, 1994; Driese et al., 1995; Banerjee, 1996; Mitchell and Sheldon, 2009). This study documents a pre-2.0 Ga inferred paleosol from Keonjhargarh, eastern India, which apparently developed on Archean granite but with mafic-sourced alluvium admixed, retains chemical signatures similar to modern *in situ* weathering profiles and also preserves vertic features analogous to modern Vertisols (Dudal and Eswaran, 1988; Coulombe et al., 1996) and Paleozoic vertic paleosols (Driese et al., 1992; Driese and Foreman, 1992; Joeckel, 1994; Caudill et al., 1996; Miller et al., 1996; Driese and Ober, 2005). The latter physical soil features, although not common in the Precambrian paleosol record, have been documented previously (e.g., Retallack, 1986; Driese, 2004).

Our primary objectives are to characterize the vertic features, describe the overlying sandstone and the partial protolith granite based on several stratigraphic profiles, and to establish the pedogenic origin of the inferred paleosol and its possible mafic source materials. The geochemical evidence in favour of a granitic parent rock contrasts with strong physical evidence for a vertic soil, necessitating a mafic progenitor (e.g., Driese, 2004 and references

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therein); the possibility of mixing of alluvium from these two parent rocks is discussed here. Alumina-rich rocks are considered to be an important indicator of paleosols (Reimer, 1986). The Al-rich white shale around Keonjhargarh has long been quarried for pyrophyllite and has also been interpreted tentatively as a paleosol developed on eroded Singhbhum granite by Saha (1994). Despite this, it has never been studied in any detail nor included in paleosol reviews or references to Indian occurrences (Sreenivas and Srinivasan, 1994; Gall, 1999; Pandit et al., 2008). The Keonjhargarh paleosol is unique because it demarcates a pedostratigraphic horizon associated with an Archean-Proterozoic unconformity, appears to be related to a subsequent transgression, and preserves vertic features comparable to modern Vertisols. Although it is our prime concern to characterise a previously undocumented paleosol from eastern India and to interpret the dominant pedogenic processes and parent rocks, we will also attempt to relate the inferred paleosol to Precambrian weathering environments, as well as possible correlation of pre-2.0 Ga Indian cratonic blocks based on paleosol occurrences.

2. Geological setting

The paleoweathering profile in areas around Keonjhargarh is apparently developed on Archean granitoids dated at 3328 ± 7 Ma (Mishra et al., 1999) and is overlain by marginal marine sandstones of the pre-2.0 Ga Kolhan Group (Fig. 1A and B). The Archean granitoids with enclaves of older metamorphic tonalitic gneiss (OMG) constitute the Singhbhum-Orissa craton, flanked to the east, north and west by deformed and metamorphosed, late Archean Iron Ore Group (volcanics, tuffs, and banded iron formation) and Paleoproterozoic volcano-sedimentary successions, deposited in varied tectonic, climatic, magmatic and paleogeographic regimes (Eriksson et al., 1999; Mukhopadhyay, 2001; Mazumder, 2005). The craton on its western and southern margins experienced extrusion of the Jagannathpur/Malangtoli basaltic lavas (Alvi and Raza, 1991, 1992) at ~2.25 Ga (Bose, 2009) followed by deposition of sediments of the Kolhan Group. The latter is estimated to be of pre-2.0 Ga age, based on 1531 and 1468 Ma Rb/Sr ages for weakly metamorphosed shale forming the top-most stratigraphic unit of the Kolhan Group and on a maximum 2.0 Ga age of dykes intruded into the Kolhan sedimentary rocks (Krishnan, 1968; Saha, 1994; Misra, 2006).

In the study area, the Kolhan Group comprises 5–50 m thick deposits of intercalated conglomerates-sandstones, sheet sandstones and sandstone-siltstone alternations, formed in braided stream, beach and wave-dominated shelf settings (Ghosh and Chatterjee, 1994). The sandstones are mostly quartzarenite with a few subarkoses. The basement rocks around Keonjhargarh are medium- to coarse-grained, crystalline, leucocratic, and non-schistose granite and granodiorite, forming predominantly flat topography interspersed with small hills. The latter have a maximum relief of ~150 m and provide spectacular views of quarries of white massive rock overlain by horizontal beds of sandstone (Fig. 2A).

3. Methodology

Representative whole rock samples of fresh granite protolith, altered granite saprolith, quartz-pyrophyllite-bearing white shale, and the Kolhan sandstone from the weathering profile at the Amjor

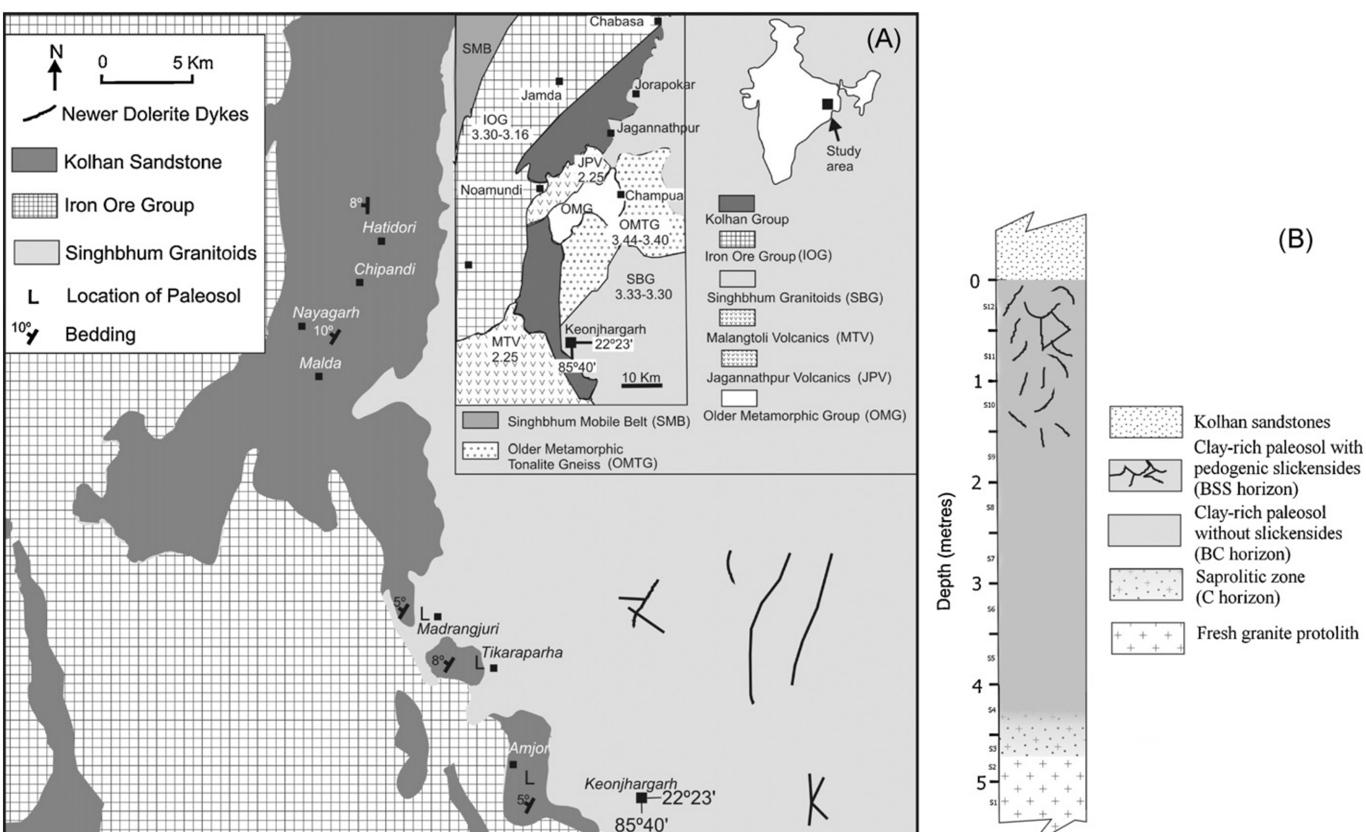

Fig. 1. (A) Geological map (part of quadrangle geological map (73 G) of the Geological Survey of India) of the region around Keonjhargarh, showing narrow outcrops of the Kolhan Group flanked on the east by the Singhbhum granite and on the west by the Iron Ore Group. Inset map shows the location of the Kolhan basins within the Singhbhum-Orissa craton. (B) Stratigraphic profile through the Keonjhargarh paleosol. Samples S1–S12 (Table 1) are shown according to depths within the granite-saprolith-paleosol succession.