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Thin-section analysis of lithified paleosols from Dagshai Formation of the Himalayan Foreland: Identification of paleopedogenic features and diagenetic overprinting and implications for paleoenvironmental reconstruction☆

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ABSTRACT

In the present study we report micromorphology of diagenetically altered paleosols (~31 Ma old) from Dagshai Formation, Himalayan Foreland. The fluvial sequence exposed along the Koshaliya River, NW Himalaya, contains four types of paleosols with decreasing abundance of well-developed paleosols from basal to upper part of the Dagshai Formation. Burial diagenesis (at ~7.5 km depth) caused compaction (54–78% current thickness compared to pre-burial thickness) and cementation of the paleosols, accompanied by internal reorganization of groundmass within peds, staining of ped walls with iron oxide, plugging of voids, disruption of textural pedofeatures, fracturing of large mineral grains and nodules, coarsening of pedogenic calcite crystals, redoximorphic features, and mineralization of root channels. Despite diagenetic alteration, evidence of paleopedogenic processes is still well-preserved in these fossil soils in the form of microstructures, b-fabrics, pedogenic calcite, bioturbation, and textural pedofeatures. Thin-section analysis helped to distinguish pedogenic and diagenetic features of lithified paleosols and to infer the paleoenvironment of the Dagshai paleosols. The paleopedological characteristics of the fossil soils suggest humid to sub-humid conditions during their formation in early Oligocene. The paleoclimate inferred here is consistent with prevalence of tropical paleovegetation (cf. *Ficus* L.) reported from Dagshai sediments.

1. Introduction

Pre-Quaternary paleosols that are found in thick sedimentary sequences require a cautious approach to unravel the ancient soil-forming processes because of overprinting caused by burial diagenesis (Lander et al., 1991; Nesbitt and Young, 1989; Nordt et al., 2012; Retallack, 1991; Sheldon and Retallack, 2001). Major controlling factors during diagenetic alteration of the paleosols include interaction of ground water with weathered profile and changes in temperature and pressure (Nesbitt and Young, 1989). Burial diagenesis results in compaction, cementation, and disequilibrium between minerals formed during pedogenesis and conditions after burial (Nesbitt and Young, 1989). Diagenetic overprinting may make it difficult to recognize and properly interpret the paleosols (Bronger and Catt, 1989; Johnson and Watson-Stegner, 1987; McCarthy et al., 1998, 1999; Nordt et al., 2012; Retallack, 1991). However, micromorphological investigation of such paleosols can resolve the complexity caused by diagenetic overprinting by detailed description of pedogenic and diagenetic features and at the same time enable organizing them into a sequential order of pedogenic and geological events (Bronger and Heinkele, 1989; Fedoroff et al., 2010; McCarthy et al., 1998).

In view of the potential of micromorphological analysis for identifying soil-forming processes, we have undertaken a detailed micromorphological study of the fossil soils of the Dagshai Formation (31.6 ± 3.9 Ma to 30.3 ± 3.9 Ma) representing the period immediately after transition from marine (Subathu Formation) to continental (Dagshai Formation) sedimentation in the Himalayan Foreland. The goal of the present study is to reconstruct the paleopedogenesis of the fossil soils of the Dagshai Formation that could provide valuable additional knowledge on tectonics, paleoclimate, sedimentology, geochronology, and paleoecology of this fluvial record from the Himalayan Foreland (Bera et al., 2008; Bhatia, 2000; Kumar et al., 2008; Najman et al., 2004; Raiverman et al, 1983; Ravikant et al., 2011; Sahini et al., 1983).

2. Geological setting

The outer part of the Himalayan range in the south is marked by an active foreland basin that resulted from thrust loading and subsidence with synorogenic sedimentation from the hinterland (Burbank et al., 1996; Raiverman et al., 1983). It is bounded by the Main Boundary Thrust in the north and the vast Indo-Gangetic Plains in the south (Burbank et al., 1996; Parkash et al., 1980; Raiverman et al., 1983).

☆ This paper is dedicated to the late Nicolas Fedoroff, an exceptional micromorphologist and palaeopedologist and a great person.

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The terrestrial sedimentary record preserved in the foreland is related to hinterland tectonics, mirroring the exhumation history of the hinterland, southward propagation of the thrust sheets, and progressive shift of the provenance (Ravikant et al., 2011). The synorogenic sediments in the marine Subathu sub-basin representing the basal part of the foreland sedimentary sequence were sourced from mixed Tethyan and Lesser Himalayan rocks in the North and Cratonic rock of the Indian shield from the South (Ravikant et al., 2011). The overlying continental Dagshai Formation consisting of red mudstone and white/gray sandstone deposited by meandering rivers indicates drastic changes in depositional environment and progressive shift of the provenance (Bera et al., 2008; Bhatia and Bhargava, 2006; Najman, 2006; Ravikant et al., 2011). A recent study of detrital zircon (U–Pb age and Hf isotopy) from the Himalayan Foreland demonstrated that the sediments of the Dagshai Formation were derived from exhumed Tethyan Himalaya and are marked by very low-grade metamorphic detritus (Ravikant et al., 2011).

The Subathu successions (Fig. 1) in the Himalayan Foreland represent the last phase of marine sedimentation during Paleocene–Eocene (Bera et al., 2008, 2010a; DeCelles and Giles, 1996; Najman, 2006; Ravikant et al., 2011). It is overlain by fluvial sediments of the Dagshai and Kasauli Formations with a hiatus of possibly considerable duration (Bhatia and Bhargava, 2006; Najman, 2007; Najman et al., 1993, 1994, 2004). Based on benthic foraminifera providing a continuous biochronological record across the Subathu and Dagshai formations, the Subathu-Dagshai transition was assigned to an age of 44 Ma (Bhatia and Bhargava, 2006; Mathur, 1978). The hiatus

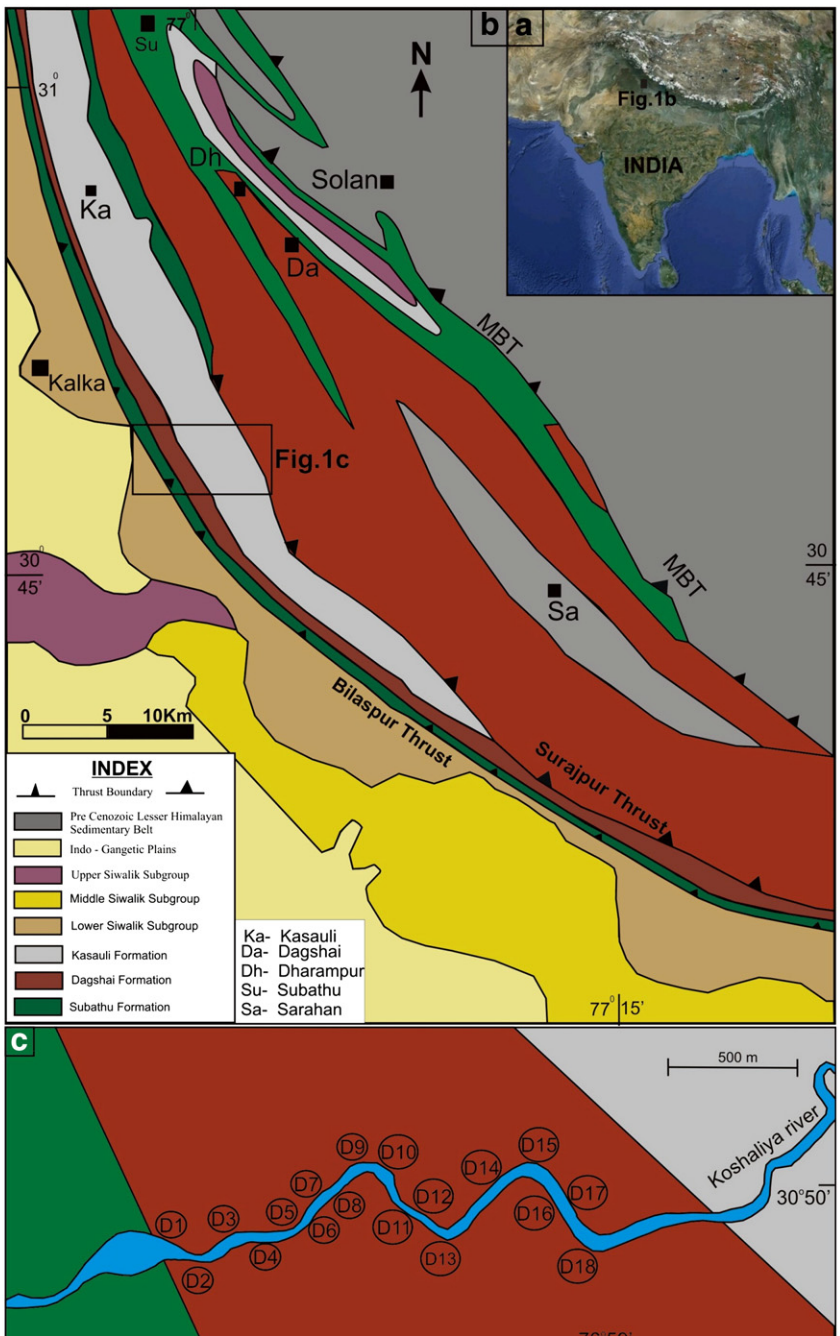

Fig. 1. (a) Location of Dagshai basin in the Himalayan Foreland, (b) geological map of the Dagshai basin (after Raiverman, 1979 and Raiverman et al., 1983), and location of the 18 logged sections (D1 to D18) along the Koshaliya River in the Dagshai Formation (c).