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Geochemistry of loess-paleosol sediments of Kashmir Valley, India: Provenance and weathering

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ABSTRACT

Middle to Late Pleistocene loess-paleosol sediments of Kashmir Valley, India, were analyzed for major, trace and REE elements in order to determine their chemical composition, provenance and intensity of palaeo-weathering of the source rocks. These sediments are generally enriched with Fe_2O_3, MgO, MnO, TiO_2, Y, Ni, Cu, Zn, Th, U, Sc, V and Co while contents of SiO_2, K_2O, Na_2O, P_2O_5, Sr, Nb and Hf are lower than the UCC. Chondrite normalized REE patterns are characterized by moderate enrichment of LREEs, relatively flat HREE pattern (Gd_{CN}/Yb_{CN} = 1.93–2.31) and lack of prominent negative Eu anomaly (Eu/Eu* = 0.73–1.01, average = 0.81). PAAS normalized REE are characterized by slightly higher LREE, depleted HREE and positive Eu anomaly. Various provenance discrimination diagrams reveal that the Kashmir Loess-Paleosol sediments are derived from the mixed source rocks suggesting large provenance with variable geological settings, which apparently have undergone weak to moderate recycling processes. Weathering indices such as CIA, CIW and PIA values (71.87, 83.83 and 80.57 respectively) and A-CN-K diagram imply weak to moderate weathering of the source material.

1. Introduction

Loess blanket about 10% portion of the globe (Pye, 1987). The loess deposits are usually found very close to desert margins, to the mountainous areas, in flood plains of large rivers, on shallow marine shelves emerged during the last glacial periods and in the periglacial environment. Almost all the known loess deposits are essentially of Quaternary age, but little ancient loess with age as old as Late Precambrian has been recognized (e.g., Edwards, 1979). In the last two decades, loess deposits have attracted increasing attention of the Earth Scientists mainly because of their potential preservation of the past climatic records. Their aeolian origin was established more than a hundred years ago by the pioneering work of Von Richthofen (1882) on the Chinese Loess deposits. At present, an aeolian origin is generally accepted but the detailed processes of the loess formation with increasing complexity are also recognized (Smalley and Smalley, 1983). For example, a significant part of the loess deposits has been reworked and subsequently redeposited.

The chemical composition of loessic sediments is closely related to the mineral composition of the dust sources, post-depositional weathering and transportation of sediments from source region to depocenter. The bulk chemistry of these sediments preserves the near-original signature of the provenance. Consequently, loess differs in chemical composition from one region to another and even from one stratigraphic unit to another (Pye and Johnson, 1988; Taylor et al., 1983). These sediments also more faithfully reveal paleoweathering conditions (e.g., Yang and Ding, 2004; Yang et al., 2006; Ujvari et al., 2008; Muhs et al., 2001, 2008). Like other clastic sedimentary rocks, these loessic sediments also subjected to various degrees of chemical weathering and leaching. As loess weathers, elements that are soluble under surficial weathering conditions (e.g., Ca^{2+}, Na^+, K^+) can be readily leached out relative to stable residual constituents (Al^{3+}, Ti^{4+}) during weathering (Nesbitt and Young, 1982). If weathering is strong and persistent, silica is released, residual sesquioxides can be concentrated, and even some new sesquioxides can be formed. While low degree of weathering of sedimentary rocks indicates the absence or weak chemical alteration of the sediments. Thus, the fluctuation in chemical weathering intensity reflects the systematic variations of element abundances. The relative variations of various elements have been used to ascertain the degree of chemical weathering (Nesbitt and Young, 1982; Price and Velbel, 2003; Jin et al., 2006; Yang et al., 2006; Ceryan, 2008). Numerous investigations corroborate the above aspects pertaining to provenances and weathering of loessic sediments based on geochemical signatures of loess-paleosol sediments (e.g., Jahn et al., 2001; Sun et al., 2007; Muhs and Budahn, 2006; Liang et al., 2009).

In Kashmir, loess deposits are distributed throughout the valley and covering an area of 500 sq. km. However, these sediments show great variation in their thickness. The maximum thickness is found on the southwestern part of the Kashmir Valley where these are about 22 m thick. The thickness decrease toward the northeastern part of the valley and is measured about 4 m. These

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sediments lie within the Brunhes normal magnetic epoch (Kusumgar et al., 1980). The loess deposits along northeastern part of the Kashmir Valley are younger than 85 ka years. However, along the southwestern part of the valley entire loess sequence spans at least ~300 ka (Singhvi et al., 1987). On the basis of micromorphological investigation, Pant et al. (1985) and Bronger and Pant (1985) proposed a stratigraphic comparison between two loess-paleosol sequences both along the Himalayan and Pir Panjal flanks. They concluded that along the northeastern part of the Kashmir Valley, the older loess-paleosol sequence is missing and in their places, fluvio-lacustrine sediments of the Upper Karewa exist. Lot of work has been carried out by various workers (e.g., Agrawal et al., 1979, 1988, 1989; Kusumgar et al., 1980, 1986; Krishnamurthy et al., 1982, 1985; Bronger and Pant, 1985; Pant and Dilli, 1986; Bronger et al., 1987; Gardner, 1989) to establish the lithostratigraphy of these sediments. However, very little data based geological work has carried out on these loessic sediments. With the exception of work of Lodha et al. (1985) and Lodha (1987) no attempt has made to carry out the geochemical study of these loess-paleosol sediments. The present study examines the detailed geochemistry of Kashmir Loess-Paleosol sediments and attempts to constrain their chemical weathering and provenance. Two representative loess-paleosol containing sequences at Dilpur (33°56′N and 74°47′E) and Karapur (33°50′N and 74°57′E) village sections along the southwestern part of the Kashmir Valley have been selected for the present research work (Fig. 1). These sections represent the most complete and best records of the terrestrial sedimentation in Kashmir Valley.

2. Regional tectonic and geological setup of Kashmir Valley

Kashmir Valley comprises a very important place in the geotectonic of Kashmir Himalaya. The general strike of the Kashmir Valley is from NW to SE, running parallel to the Great Himalayan Mountain range in the north and Pir-Panjal Mountain range in the south. The valley takes the form of graben bounded by NW-SE trending parallel Panjal Thrust and Zanskar Thrust. Wadia (1931) described the thrust-bounded basin, as 'Kashmir Nappe Zone' comprising the rocks of Paleozoic–Mesozoic marine sediments, with Precambrian basement thrusted along a regional tectonic plane viz., Panjal Thrust over the younger rocks of the autochthones belt. The 'Kashmir Nappe' forms two major axes of orogenic upheaval along the Pir-Panjal and the Great Himalayan ranges. The valley posses almost complete stratigraphic record of rocks of all ages ranging from Archean to Recent (Fig. 2).

However, Panjal Volcanic Complex and the Triassic Limestone form the two main geological formations, underlain by the Archean metasedimentary rocks (Salkhala Formation) (Fig. 2). Salkhala Formation constitutes carbonaceous slates, graphitic phyllite and schist associated with carbonaceous grey or white limestone, marble, calcareous slate and calcareous schist. It also comprises sericitic phyllites and schists, garentiferous schists and flaggy quartzite. The outcrops of these oldest rocks are found around the northwestern extremity of the Kashmir Valley and portions of the Pir-Panjal range. Exposures of Triassic sequence comprise alternate thick dark grey limestone, micaceous shale and shally-arenaceous impure limestone (Datta, 1983). These rocks are also associated with granites and gneisses. The other rocks of lesser distribution include Dogra Slates, Cambro-Silurian, Zewan Formation and Muth-Quartzite (Bhat, 1982). Dogra Slates constitute dark grey shale/slate with quartzite; Cambro-Silurian rocks consist of limestone, siltstone, shale, quartzite, greenish-grey sandstone and dolomite with stromatolite (Bhat, 1982).

The Panjal Volcanic Complex is divisible into two well-marked horizons, the lower Agglomeratic Slate and the upper Panjal Lava flows (Bhat and Zainuddin, 1978). The Panjal traps includes all the coeval flows found throughout Ladakh, North Zanskar (Singh et al., 1976), Suru area (Fig. 1c; Honegger et al., 1982; Papritz

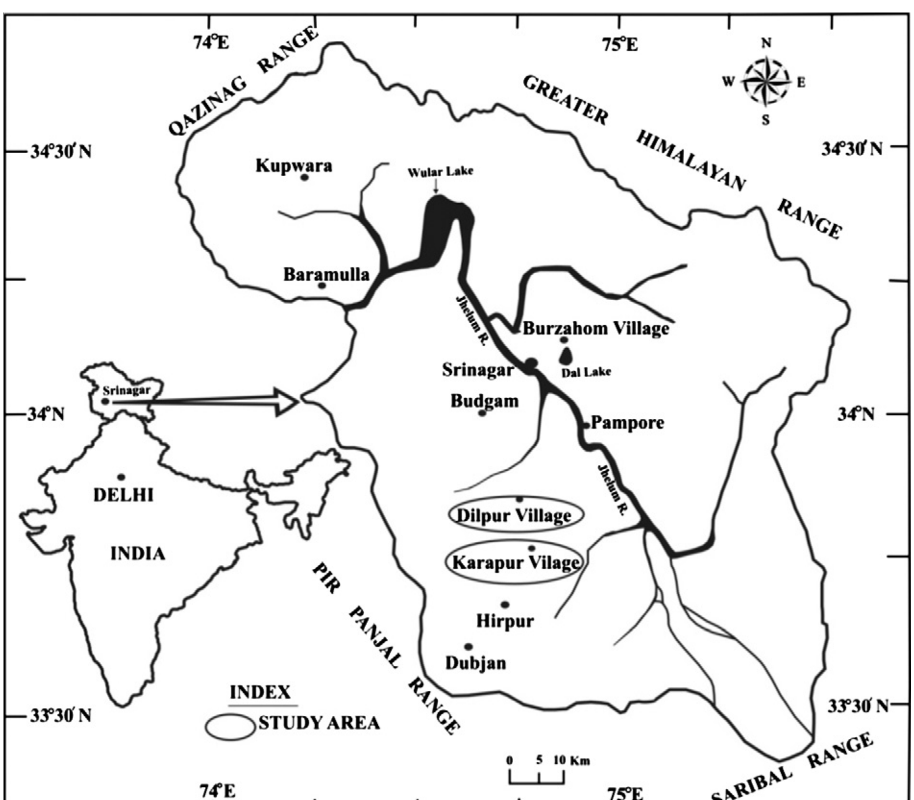

Fig. 1. Map showing the locations of the study area.