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Multidisciplinary approach for paleoenvironmental reconstruction in loess-paleosol studies of the Darai Kalon section, Southern Tajikistan

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Abstract

The available data on the loess-paleosol formation in South Tajikistan illustrate the completeness of climatostratigraphic records. However, studies with a multidisciplinary approach have not been practically used for paleoenvironmental reconstructions. This study partially corrects the lack of data on paleolandscape evolution in the loess area of Pamir and Tien Shan piedmonts. Darai Kalon serves as a key section embracing the upper part of the Matuyama Chron and the entire Brunhes Chron. High resolution magnetic susceptibility record shows that during the Brunhes epoch the climate cycles reflected by the Central Asian loess-paleosol succession can be correlated to the deep-sea oxygen isotope curve. The combination of pedological and palynological material is particularly useful for mutual interpretation. Lithological and mineralogical data essentially extend our understanding of pedogenetic and paleoclimatic dynamics. The tendency of soil and paleoenvironmental evolution recorded in the Darai Kalon section can be associated with subtropical semi-humid forest and forest-steppe landscapes. The variation of paleoclimatic parameters and paleovegetation type are characteristic of the contemporary vertical zone of Cinnamon Soils.

1. Introduction

For the last decades it became obvious that thin dispersed loess sediments serve as a valuable archive for paleoenvironmental reconstructions during the Quaternary. Loess-paleosol key sections in Southern Tajikistan, Central Asia, have been studied by international groups, producing evidence of very complete stratigraphical records in this area (Bronger et al., 1993, 1998; Forster and Heller, 1994; Dodonov and Baiguzina, 1995; Shackleton et al., 1995; Frechen and Dodonov, 1998; Schäfer et al., 1998; Dodonov et al., 1999; Mestdagh et al., 1999; Ding et al., 2002) (Fig. 1).

Regional phases of tectonic uplift of the Central Asian mountains resulted in aridisation of intermountain depressions where loess-paleosol formation is widespread. The loess-paleosol sequence demonstrates the short-period paleoclimatic oscillations with specific features for different cycles from Lower to Upper Pleistocene. Many archaeological localities in fossil soils of Southern Tajikistan provided data on ancient human paleoecology and essentially supplement paleogeographic records (Dodonov, 1995; Ranov, 1995).

The Darai Kalon, one of the reference sections of loess-paleosols in Southern Tajikistan, has been studied with a multidisciplinary approach using grain size and mineralogical analyses, paleosol macro- and micromorphology, palynological and biomorphic methods, as well as magnetic susceptibility measurements. This approach provides comprehensive data needed for paleoenvironmental reconstruction.

2. Geologic setting and stratigraphic context

The Darai Kalon section is situated on the watershed with a altitude of 2000 m, in northeast of the Tadjik Depression. This section exhibits 18 horizons of paleosol/pedocomplexes with a total thickness of 176 m. In the piedmont, hypsometrically below 2500 m, loess and loess-like deposits predominate on watersheds and ridge slopes,

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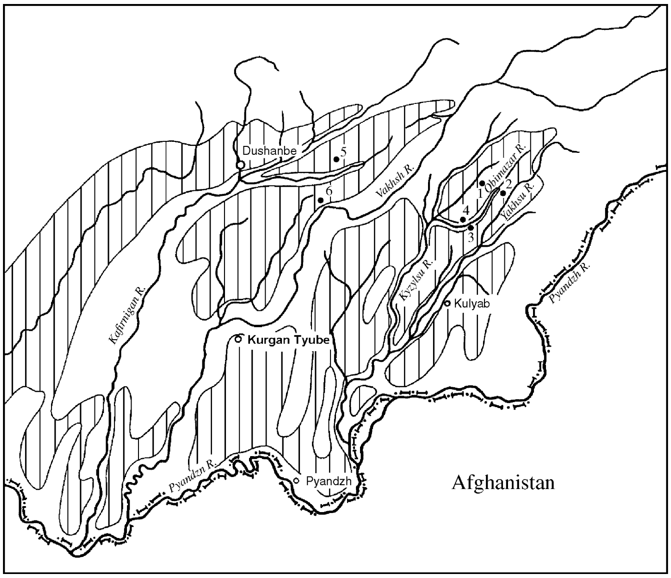

Fig. 1. Loess distribution (area with vertical lines) and key sections in Southern Tajikistan, Central Asia. 1. Darai Kalon, Chashmanigar; 2. Khonako; 3. Tagidjar; 4. Lakhuti; 5. Karamaidan; 6. Karatau.

whereas alluvial and proluvial deposits are represented along valleys with constant and temporal water flows. Loess sediments are facially related to alluvial and proluvial deposits consisted of gravel, sand, silt, and debris. The thickness of loess strata in Southern Tajikistan reaches 100–200 m on watersheds.

According to paleomagnetic data, provided by Pen'kov, the position of the Matuyama/Brunhes boundary (M/B) was found in many loess-paleosol sections in Southern Tajikistan between the pedocomplexes PC9 and PC10 (Pen'kov et al., 1976). The Jaramillo Subchron was recognized at the level of two paleosol horizons, PC16 and PC15. The same position, between PC9 and PC10, for the M/B boundary was confirmed in the Karamaidan section by Forster and Heller (1994) and in the Tagidjar section by J. Hus (Mestdagh et al., 1999). Detailed measurements provided by V.M. Trubikhin showed that the M/B boundary falls at the lower part of PC9 in the Darai Kalon section or at the transition between PC9 and loess horizon L10 in the Khonako section. The oldest loess-paleosol succession corresponds to the lower part of the Matuyama Chron below the Olduvai Subchron, which was established in the Karamaidan section.

The loess-paleosol series and its magnetic susceptibility signature (see below) allow us to compile a relative climatostratigraphic succession correlated with oxygen isotope records of deep-sea sediments. For the upper part of the loess section, the correlation is controlled by TL dates on PC1, obtained in Cambridge University and Cologne University (Zhou et al., 1995; Frechen and Dodonov, 1998). According to the TL measurements the age of PC1 is from ± 120 to ± 70 ka, and it can be correlated to stage 5, δ^{18}O. The PC1 is a very important marker at the top of the section, being a key point in the geochronological calibration of the loess-paleosol sequence. Relying on the markers in the loess sequence represented by PC1, M/B boundary and Jaramillo Subchron, the geochronological calibration of loess-paleosol succession was carried out using the δ^{18}O curve of ODP 677 (Fig. 2). The magnetic susceptibility signal of the loess-paleosol series provides a good correlative control for the age calibration.

Most pedocomplexes in the Brunhes Chron are composed of two or three paleosol horizons, illustrating different characters of soil-forming processes (Fig. 3). Macromorphologically, the PC1 consists of three paleosols: the lowest is the most developed and leached. PC2 has a two-member structure, where the lower member ($PC2_2$) is more decalcified. PC3 consists of two well-developed and leached brown soils; the lower is reddish-brown with extended profile and high clay content. PC4 is characterized by a compact profile displaying signs of clay illuviation at the Bt horizon. The latter is represented by a reddish-brown loam showing prismatic structure and ferrous–manganese films along the joints. The most developed part of the profile of PC5 is very similar to PC4, though the signs of clay illuviation are less distinct in PC5 than in PC4. The PC6 consists of two soils. The illuvial-carbonate horizon of the upper soil overlaps the lower one. The PC7 is relatively simple in structure, and its profile is well developed and leached. PC8 and PC9 are light brown and not leached, and both paleosols have a illuvial-carbonate horizon.

Eight paleosols (11–18) were recognized in the Darai Kalon section below PC 10, at the upper part of the Matuyama Chron. Paleosols 11, 13, 14, and 17 are composed of massive brown, slightly calcareous loams lacking any signs of clay illuviation. Paleosols 12 and 15 are similar to the above listed units, but are more leached. High clay content, decalcification, a well developed prismatic structure and red color are characteristic features of B horizons in paleosols 16 and 18.

3. Methods and analytical data

3.1. Lithological and mineralogical features

Generalized lithological characteristic of loess-paleosol series in Darai Kalon can be represented as follows. Loess horizons consist of well-sorted grayish-pale-yellow clay-aleurite with carbonate content of 15–25%. Abundance of root-like calcite forms, amorphous concentrations of pelitic calcite, and sparse carbonate algae including Chrysophyta are characteristic. The coarse silt fraction (0.05–0.01 mm) is dominant, ranging from 35% to 45% of the total and nearly 40% on average. The clay matter in the loess horizons has been weakly subjected to secondary processes of transformation, although in some intervals, for example in L1, L6 and L8, there are signs of destruction and dissolution of clay minerals. The well developed paleosols have an essentially clayey composition, to 20–30% of the clay fraction (<0.001 mm). Carbonate content varies from