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Paleoclimatic significance of a loess-paleosol sequences from Tian-Shan, Central Asia

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Introduction

Global warming and impending sea-level rise have attracted increasing interest in regional climate changes in the Pleistocene and Holocene. The soil cover of the extensive territory of Tian-Shan (Kyrgystan) is represented by mono- and polygenetic Holocene soils and by buried in loess soil horizons of Late Pleistocene and Holocene age. Specific features of all these soils are due to the action of elementary present-day and relic soil processes of different age and intensity, that could either coincide or alternate under the influence of glacier movements and climatic fluctuations. Thus, the analysis of soil properties could help to elucidate conditions of soil formation during at least the Late Pleistocene and Holocene.

Study sites

A soil chronoseqence was studied in the central part of Kirgizskiy Range (at the longitude of the city Bishkek) at elevations between 1800 and 3400 m above sea level (interfluve of the rivers Alamedin and Ala-Archa). The studied interfluve is highest part of the Kirgizskiy Range with maximum of the glaciation – Shopokov Glacier. The studied valley contains typical glacial features. These include U-shaped cross-sections, cirques, moraine termini and glaciofluvial sediments. Bedrock is comprised of limestone, diorite, porphirite and metamorphic rocks.

All examined soils (40 profiles), representing the change of soil types from the foothill to the top of slope in the Tatyr, Chon-Kurchak, Kurchak-Tor valleys, were groped into three genetically similar units in accordance with soil profile morphology. . The older members of the chronosequence developed on the lowest frontal moraines

(Last Glacial Maximum (LGM), as established by Maksimov (1980)) at altitudes of 1900-2100 m, represented by the monogenetic full-Holocene mountain Chernozem (Calcic Chernozem according to FAO) with a profile as A-AB-B-BC1-C1-Bb_1-C2-C3-Bb_2-C4-Bb_3 under sweetbrier-herbage-estragon meadow-steppe. These soils have several buried in loess horizons (Bb_1, Bb_2, Bb_3). Upvalley, moraines are present at 2100, 2350, 2450 and 2600 m above sea level. These moraines characterize Late Glacial ice advances. The soils of Late Glacial age are classified as Chernozem-like soils or Faiozem by FAO with A-Ab-AB-B-Bt-C1-B_{b1}-C2-B_{b2}-C3 profiles under a prairie-grass-herbage meadow steppe and dry subalpine meadows. Some of these full-Holocene polygenetic soils have buried A and B horizons. Monogenetic incomplete Holocene soils in the initial stages of their formation at altitudes of 3100 m were described under cobresia meadow, represented by the alpine-meadow soil-rankers (Umbric Leptosoil according FAO), having a profile A-AC-C. These soils are developed on the frontal moraines with large porphyrite and granite-diorite boulders.

Methods

The focus of this paper is on soil morphological description combined with chemical properties of humus and radiocarbon dating. The ^{14}C analyses of the extractable humic acids were carried out (Kovaleva, Evdokimova, 1997). We also used radiocarbon data, obtained by Maksimov (1980) and Pomortsev (1980) for soils studied.

The $^{13}C/^{12}C$ ($\delta^{13}C$) ratio was measured at Soil Scince Institute of Bayreuth University (BRD). Interpretation of organic carbon stable isotope ratio ($\delta^{13}C$) values is based on model of Francey and Farquhar (1982), using the correlation between $\delta^{13}C$ values in humus and CO_2 concentrations in atmosphere, and the model of Ryskov et al., (1996), using the distribution of theoretical and experimental values of $\delta^{13}C$ for carbonates under the different temperature. In addition, macro-, meso- and micromorfological descriptions were made for all studied profiles.

Results and Discussion

The $^{13}C/^{12}C$ ratio in carbonates and humus has been under examination for loess and soils in order to clarify the type of vegetation and conditions promoting carbonates formation. Based on the radiocarbon chronology and $\delta^{13}C$ data of the burial soils the following major climatic events can be reconstructed:

- $\delta^{13}C$ value –4 – -5‰ in the C2 and C3 horizons of the mountain Chernozem (on the LGM moraine) characterized the glacial climate with the temperature about – 25^0C according Ryskov's et al. model (1996). Unfortunately, no organic material was found for radiocarbon dating. We can assume, based on the works of Zech (2000), that the age is greater than 24-25 kyr BP.

- Based on the δ^{13}C data, –8 - -10‰, the cold and dry climatic period with temperature about 0^0C, with little alpine desert vegetation and highly weathered soils like Brjansk soil of Eastern Europe can be reconstructed. This period likely corresponds to the North Atlantic 2 Heinrich event (Williams et al, 1998). A similar horizon is described by Zech in Western Tian-Shan (2000) (24300±1160 years BP), as well as by Yan et al. in Tibet (25910±400 years BP).
- According to δ^{13}C in the B_{1b} horizon (-24.41 ‰) of a Chernozem-like soil, the warm period is reconstructed at about 14030±880 years BP (the date by Pomortsev (1980)) with C-4 type of vegetation. It conforms to the 1 North Atlantic Heinrich event. Similar findings were reported from Western Tian-Shan (Zech, 2000) and Yan et al. in China (1999).
- Cold and dry climate with temperatures about 0^0C and SAM-type of photosynthesis (δ^{13}C in the C1 horizon –7 - -10 ‰) predominanted, probably in the Early Holocene at about 10100± 564 and 9130±640 years BP (data by Pomortsev, 1980).
- At the 8-6 kyr BP, we reconstructed the warm and dry period with temperature about + 15^0C, when peats spread out in the piedmonts and lowlands due to glacial melting, the C-3 type of plants commenced to develop (δ^{13}C values range from –19 to –29 ‰), composed mainly of meadows. The age of B horizon at the altitude 2350 and 2450 m in studied valley is 7130 and 6440 years BP respective (data by Maksimov, 1980).
- The Holocene optimum events with a warm and dry climate, air temperatures greater than at the present, a C-3 type of vegetation on the Chernozem soils in the valleys can be reconstructed at 6-4 kyr BP. The age of the Ab horizon, as described above, is 5560 ±90 years BP.
- Modern subalpine and alpine vegetation and Chernozem-like soils below the 3000 m, and subalpine soils at the altitude above 3000 m began to develop at 4-3 kyr BP, and a trend towards increasing humidity has taken place ever since (δ^{13}C=-28 ‰). The age of the present-day A horizon in Chernozem-like soils is 3010±90 years BP and in alpine soil – 109±47 years BP. Similar findings were reported by Savoscul and Solomina (1996) from Western Tian-Shan (2850±110 B.P. and 910±40 B.P.).

Thus, climatic changes in the Holocene in the mountain regions of Tian-Shan (Kyrgystan) seem to coincide in Tibet, Eastern Europe, Northwestern Caucasus and correspond to the global climate changes. But, these changes in Central Asia were probably less intensive than it in the other regions.

Conclusions

1. Since soil evolution is determined by a trend in the landscape development, soils studied indicate the cold and dry climate of Late Pleistocene and Early Holocene, the automorphic conditions of soil formation in the Middle Holocene, and the Late-Holocene moderate climate.

2. Climatic changes in the Holocene in the Northern Tian-Shan seem to coincide in Western and Innen Tian-Shan, Tibet, Eastern Europe, Northwestern Caucasus and correspond to the global climate changes, but have lower intensity.

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