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PEDOSEQUENCES IN NORTHERN TIEN SHAN MOUNTAIN BELT (KAZAKHSTAN-KIRGIZSTAN)

ABSTRACT: PREVITALI F., ASSI I. & ŠEFRNA L., *Pedosequences in Northern Tien Shan mountain belt (Kazakhstan-Kirgizstan).* (IT ISSN 0391-9838, 1997).

Some selected soil profiles and environmental conditions of a sector of the Tien Shan mountain belt, between Kazakhstan and Kirgizstan, were investigated. Main target of the research was to give information about soil classification and distribution, and about changes in chemical, biochemical and physical properties with elevation, lithology, vegetation, and climate.

The survey and the analyses confirmed the lack of podzolization marks, also under conifers cover. We verified an important altimetric raising of the vegetation stages, compared to alpine environments, in clear relation to moderate rainfall.

Moreover, we recognized the non usual presence of a probable aeolian cover on a valley bottom, at about 3,000 m a.s.l. It seems that such occurrence favoured the development of Phaeozems (Borolls), soils that are more common on dryer and warmer grasslands at lower altitudes.

Finally, on the basis of the geochemical analyses carried out on soil samples, it could be said that the Tien Shan spruce forest plays an important role as trap of the atmospheric trace elements, compared to other local vegetation types. Also its release capacity to the soil could be faster.

KEY WORDS: Soils, Vegetation, Tien Shan (Kazakhstan-Kirgizstan).

RIASSUNTO: PREVITALI F., ASSI I. & ŠEFRNA L., *Pedosequenze nella catena del Tien Shan settentrionale (Kazakhstan-Kirgizstan).* (IT ISSN 0391-9838, 1997).

Sono stati studiati e analizzati alcuni profili di suoli, scelti fra i più rappresentativi, inquadrati nelle rispettive condizioni ambientali, in un settore della catena del Tien Shan, situato fra il Kazakhstan e il Kirgizstan. Scopo fondamentale della ricerca era quello di fornire una classificazione e di verificare la zonalità dei suoli, attraverso lo studio delle variazioni di caratteri chimici, biochimici e fisici in rapporto a quota, litologia, vegetazione e clima.

Il rilevamento a terra e le analisi di laboratorio hanno accertato l'assenza di fenomeni di podzolizzazione, anche sotto copertura di conifere, nonostante numerosi caratteri ambientali sembrerebbero poterne favorire la comparsa. È stato verificato un significativo innalzamento altimetrico delle fasce di vegetazione, rispetto agli analoghi ambienti alpini, in evidente rapporto con le moderate precipitazioni.

Inoltre, è stata riconosciuta la presenza non usuale di una probabile copertura eolica in un fondovalle, a circa 3.000 m s.l.m. Tale materiale sembrerebbe aver favorito la formazione dei Phaeozems (Borolls), tipici suoli di praterie, più aride e più calde, a minori altitudini .

Infine, sulla base delle analisi geochimiche effettuate su campioni di suolo, sembra potersi ipotizzare che la foresta di abete del Tien Shan svolga un più significativo ruolo di trappola degli elementi in traccia di provenienza atmosferica, rispetto ad altri tipi di vegetazione, però con capacità di rilascio più rapida rispetto a questi.

TERMINI CHIAVE: Suoli, Vegetazione, Tien Shan (Kazakhstan-Kirgizstan).

INTRODUCTION

The study is based on a sequence of soils lying on the northern and southern slopes of the Hrebet Zailijskij Alatau (Trans-Ili Alatau) range and the northern slopes of the Hrebet Kungai Alatau, on the border between the Kazakhstan and the Kirgizstan. Zailijskij Alatau and Kungai Alatau, about 400 km long, are two northern chains of Tien Shan. They are surrounded by the valley of the river Tcharin on the East and the river Tchu on the West. The Mt.Talgar, in the middle of Zailijskij Alatau, reaches 5,017 m a.s.l.

The involved sites are in the catchment basins of Chong Kemin and Levj Talgar rivers. The soils occuring in this region have previously been studied mainly by Assing (1986), Nasyrov & Sokolov (1988), and Nasyrov & *alii* (1991). The relationships between spruce forest and soil formation have particularly been investigated by Samusenko & Kozhekov (1982), while the biological activity of soils has been the object of a study of Tazabekov & *alii* (1986).

The fringes of the investigated area, located between the town of Alma-Ata and the lake of Issyk-Kul (fig. 1), are bounded by latitudes 43°10'N and 42°54'N, and by longitudes 76°52'E and 77°10'E. The altitudes of the studied soil profiles are between 2,000 and 3,500 m a.s.l. Among the many examined soil profiles, we chosed 4 of them presented in this work, as we believe they represent the observed characteristics at best.

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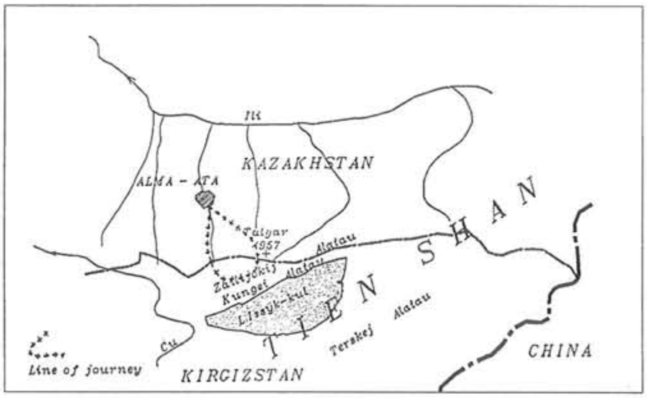

FIG. 1 - Location of the investigated area in the Tien Shan mountain belt.

SOIL ENVIRONMENT

Geology and Geomorphology

The Tien Shan mountain belt stretches out from West (the Syrdarja River basin) to East (the Gobi desert) for about 2,500 km, and is about 600 km wide, from the northern Kazakh shield to the southern Tarim block. This range is marked by several roughly parallel mountain systems, oriented E-W, with elevations frequently exceeding 5,000 m. The ridges are separated by depressions at 2,000-3,000 m in height, covered by late Pleistocene-Holocene glacial and fluvioglacial deposits, and by Quaternary alluvial beds. The old denudated Caledonian shield has been later affected by slight Quaternary uplift and faulting (Visloguzova & *alii,* 1991; Tibaldi & *alii*, 1997).

A belt of hills (Prilavky, 900-1,800 m a.s.l.) runs along the northern fringe of the high Zailijskij Alatau mountains. The hills developed on glaciofluvial sediments which, in their turn, are the result of the erosion of the adjoining mountain ranges. They are covered by aeolian deposits thick 20-30 m. The chernozems developed on such deposits.

On the basis of the relative morainic deposits, three Pleistocene glaciation phases have been distinguished. The first of them, which dates back to the early Pleistocene, was the most intense. In that period, glaciers sloped down to 1,500-1,600 m a.s.l. At present time, in the Zailijskij Alatau area there are 393 glaciers, covering 496 km^2, that are slowly retreating, especially on the Kungai Alatau chain (Visloguzova & *alii,* 1991).

In the investigated area, a sharp lithological change occurs across the boundary between Kazakhstan and Kirgizstan. In fact, the Devonian granites and Ordovician granodiorites and gabbros (Abdulin & *alii,* 1984) prevalently outcrop in the Levy Talgar and Prahodnaia stream catchments. On the contrary, metamorphic rocks (phyllites, slates, greenschists, amphibolites), and sedimentary ones (mainly sandstones and conglomerates) dominate in the upper part of the Chong-Kemin river basin.

All the investigated area is characterized by a high energy relief. Besides, some environmental conditions are frequently fulfilled (Mitchell, 1991): 1) abundant morainic and detrital materials, relatively porous by being both unconsolidated and composed by a mix of particle size; 2) unstable poised position; 3) absence of binding vegetation, above the treeline; 4) sudden snow and ice melting, together with torrential rains; 5) presence of a discontinuous permafrost. In addition, in all the area frequent earthquakes are triggered. All these conditions, together with the deep torrential carving (boulders up to 8 m^3 transported) and the heap of morainic and detrital materials, are favouring the periodical occurrence of *mures* (russian, *sel;* english, *debris flow*), earthflows and debris avalanches, causing disasters along the river valleys and even downhill up to the Alma-Ata town. By means of the construction of stream barrages and meteorological monitoring, experts are trying to contain these effects.

Vegetation

The upper limit of soil cover and fragmentary vegetation is 3,300-3,400 m a.s.l. (Nasyrov & Sokolov, 1988), reaching locally also 3,600 m. Above, there are bare rocks, detrital deposits and fans, moraines, and glaciers. The line of the perennial snows is at 4,000-5,000 m a.s.l., depending on slope orientations.

Above Medeo, the upper limit of the arboreal vegetation (*Picea schrenkiana*) is at about 2,700 m. Above this limit we find a Juniperus belt, changing then, at upper heights, into bare rock, fragmental stones, snow fields and glaciers. The vegetation vertical zonality is expressed in a clear way. The slope orientation plays an important role, resulting in a strong development of xerophile species (mountain steppe) on south facing slopes. We can distinguish:

1 - Stage of the alpine meadow, under the perennial snow line (fig. 2), were the Poaceae and *Carex* sp. prevail; on southern slopes, at an altitude of 3,600-2,900 (3,100) m a.s.l., the main species are the xerophile ones, such as *Avenastrum* sp., *Festuca* sp. and *Stipa* sp.

2 - Subalpine stage, represented by meadow with *Alchemilla* sp. and *Geranium* sp. At the foot of the meadow (at 3,100/2,900-2,800 m a.s.l.), we can notice *Juniperus sibirica* and *Juniperus seravschanica* (*Artcha association*).

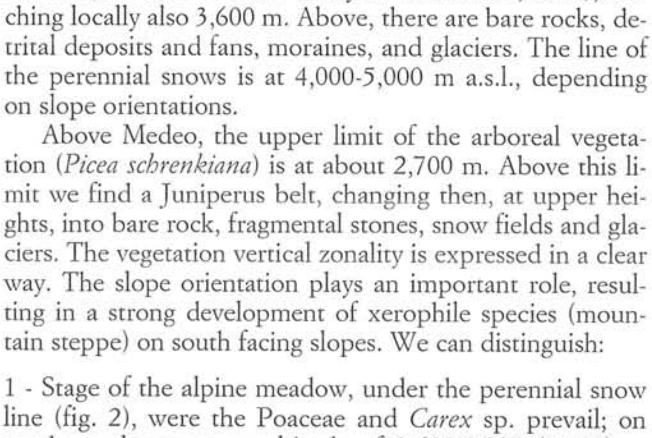

FIG. 2 - The Chong-Kemin river Valley (Kirgizstan): U-shaped glacial trough and alluvial deposits, covered by alpine meadow.

FIG. 3 - The lower limit of the Tien Shan spruce forest, fluctuating, above Medeo (Alma-Ata), at about 1,700-1,800 m a.s.l.

3 - Forest stage, with Tien Shan spruce (*Picea schrenkiana)* and many varieties of broadleaved shrubs: Lonicera, Rosa, Spirea, Crataegus, etc. The xerophile shrub-meadow develops on southern slopes (fig. 3).

At lower altitudes (Prilavky), we find broadleaf open forests (wild orchards), with *Malus sinensis*, *Prunus abricote,* dry cherry, etc.

Climate

The air mean annual temperatures are as follows (Nasyrov & *alii*, 1991):
– −2.6°C (with mean monthly temperature of 7.0°C in August and −11.9°C in January) at the station of Myn-Dzilkj (3,017 m a.s.l.);
– +0.7°C (with mean monthly temperature of 10.5°C in August and −9.7°C in January) at the station of Alma-Atjnskoe Ozero (2,511 m a.s.l.);
– +6.7°C (with mean monthly temperature of 18.0°C in July and −4.3°C in January) near Medeo (1,713 m a.s.l.);
– +7.7°C (with mean monthly temperature of 21.3°C in July and −7.1) at Talgar (1,015 m a.s.l.).

Excluding the last station, which is exposed to the climatic influence of the northern deserts, we find an average environmental temperature lapse rate of 6.4÷7.4 °C. 1,000 m^{-1} of ascent, not far from the usual average values of earth's atmosphere (Strahler & Strahler, 1992).

The average annual precipitations (partially or prevalently snowy, in relation with the heights) are the followings:
– 774 mm (Myn-Dzilkj station), with a monthly absolute maximum in May with 152 mm, and two minima in January and February with 17 mm respectively;
– 720 mm (Alma-Atjnskoe Ozero), with a monthly absolute maximum in May with 142 mm, and a minimum in January with 17 mm;
– 872 mm (Medeo station), with a monthly absolute maximum in May with 183 mm, and a minimum in January with 28 mm;
– 606 mm (Talgar station), with a monthly absolute maximum in May with 115 mm, and a minimum in January with 20 mm.

Over about 2,000 m of altitude, the most rainy months are May, June and July; beneath, the most abundant precipitations are slightly in advance and are distinctive of April, May and June.

Soil moisture and temperature regimes

Precipitations temporal distribution, characterized by high concentrations during the vegetative period and associated to the generally regular drainage of soils, makes the water storage plus rainfall equal or exceeding the amount of evapotranspiration; so, the soil moisture regimes are of *udic* type (Soil Survey Staff, 1994).

Over 2,200÷2,500 m a.s.l., the soil temperature regimes seem to be of *pergelic* type, with periods of dry frost, while, under those elevations, they seem to belong to *cryic* type.

SOIL TYPES AND DISTRIBUTION

DESCRIPTION OF PROFILES

Soils have been classified according to:

1) Fao-Unesco-Isric (1990), then briefly called Fao;

2) Keys to Soil Taxonomy (Soil Survey Staff, 1994), then simply called Usda;

3) Soil Map of the Kazakh SSR (Gugk, 1976), then named Gugk;

4) Référentiel Pédologique (Afes, 1995), then called RP.

5) World Reference Base for Soil Resources (Fao, Isric & Isss, 1994), then named Wrbsr.

We thought it better to quote also the taxonomic references to the Chinese Soil Taxonomic Classification (Gong, 1994), stated by the acronym Cstc, considering the existing pedological affinities between the soils of the study region and those of the Chinese part of the Tien Shan belt.

SITE No. 1

Location:
Jugo-Zapadnoj Talgar stream (Kirgizstan), 42°56'N, 77°08'E (figs. 4 and 5).

Altitude, slope aspect, and inclination:
3,530 m a.s.l.; south-east facing; 5% (local inclination).

Drainage:
Regular.

Vegetation:
Subnival-rocky stage of alpine prairie, with *Carex melanostachya* Bieb. ex Will, *Primula nivalis* Pall., *Ranunculus rubrocalyx* Regal. ex Kom., *Callianthemum alatavi-*

FIG. 4 - Soil profile at the Site No.1 (3,530 m a.s.l.), under alpine prairie of the subnival-rocky stage.

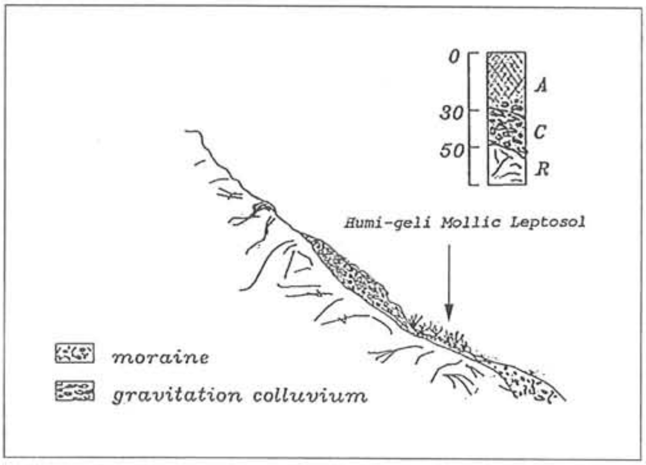

FIG. 5 - Schematic transect across the right side of the Jugo-Zapadnoj stream Valley. The arrow points at the pedological site No. 1.

cum Freyn., *Papaver tianschanicum* M. Pop. that is the prevailing species, together with *Callianthemum* ssp.

Landform and geomorphology:
Detrital and morainic slope deposit.

Parent material:
Morainic sandy loam with boulders and cobbles of greenschists, amphibolites, mylonites, basalts, lying on crystalline schists.

Soil profile

0-30 cm. A horizon (Sample: K1A). Dark yellowish brown 10YR3/4 (moist), light olive brown 2.5Y5/3 (dry); loamy; weak, fine granular structure; friable; few medium pebbles; common fine roots; clear wavy boundary.

30-50 cm. C horizon. Light olive brown 2.5Y5/3 (moist), light yellowish brown 2.5Y6/3 (dry). Sandy loam; structureless; friable; few coarse pebbles; no roots; abrupt wavy boundary.

50-80+ cm. R horizon. Morainic pebbles and boulders, lying on crystalline schists.

Classification

Humi-geli Mollic Leptosol (Fao); Pergelic Cryorthent (Usda); High Mountain Meadow Alpine Soil (Gugk); Cryosol Minéral lithique, à pergélisol sec discontinu, de haute altitude (Rp); Cryic Leptosol (Wrbsr). In the Cstc system: Order of Primarosols, Suborder of Lithic Primarosols, Group of Umbribumic Leptisols.

SITE No. 2

Location:
Ak-Su stream (left tributary of the Chong-Kemin River, Kirgizstan); 42°53'N, 77°05'E (figs.6 and 7).

Altitude, slope aspect, and inclination:
3,140 m; eastern facing; 3-4%.

Drainage:
Well drained.

Vegetation:
Mountain, xerophile, steppe-like meadow stage, with *Festuca kryloviana* Reverd, *F. valesiaca* Gaudin, *Helictotrichon tianschanicum* (Roshev) Henrard, *Androsace sericea* Ovcz., A. *lactiflora (septentrionalis* L.*), Geranium saxatile* Kar. et Kir., *Gentiana karelinii* Griseb.

Landform and geomorphology:
Edge of an old alluvial terrace of the Ak-Su stream.

Parent material:
Glacial drift of loam, boulders, and pebbles of phyllites and crystalline schists.

Landuse:
Former pastureland.

Soil profile

0-10 cm. A horizon (Sample: K2A). Very dark brown 10YR2/2 (moist), dark greyish brown 10YR4/2 (dry); silty loam; moderate, fine granular structure; few small stones; common fine roots; clear wavy boundary.

FIG. 6 - Soil profile at the Site No. 2 (3,140 m a.s.l.), under mountain, xerophile, steppe-like meadow.

10-40 cm. BA horizon (Sample: K2BA). Dark brown 10YR3/3 (moist), brown/yellowish brown 10YR5/3.5 (dry); silty loam; weak, fine granular structure; few small stones; few fine roots; clear wavy boundary.

40-50⁺ cm. C/R horizon. Coarse fragments of schists.

Classification

Humi-haplic Phaeozem (Fao); Pergelic Cryoboroll (Usda); Mountain Meadow Alpine Soil (Gugk); Cryosol Minéral régosolique, à pergélisol sec sporadique (Rp); Geli-eutric Regosol (Wrbsr). According to the Cstc, this pedon could be tentatively classified as an intergrade between the Frost-sod soils of the Altocryic Isohumisols and the Umbrihumic Leptisols of the Lithic Primarosols.

SITE No. 3

Location:
Left bank of the Chong-Kemin River (Kirgizstan); 42°54 N, 77°03'E (figs.8 and 9).

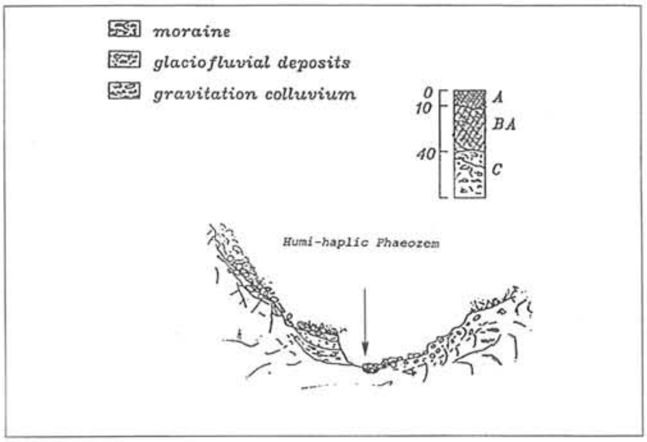

FIG. 7 - Schematic transect across the Ak-Su stream Valley. The arrow points at the soil profile of site No. 2.

Altitude, slope aspect, and inclination:
2,980 m; nearly level.

Drainage:
Somewhat excessively drained.

Vegetation:
Alpine-subalpine subxerophile meadow, with *Alchemilla sibirica* Zamm., *Dracocephalum grandiflorum* L., *Festuca kryloviana* Reverd., *Aconitum rotundifolium* Kar. et Kir., *Carex* sp. Phytocoenose degraded by grazing.

Landform and geomorphology:
Alluvial deposit with probable aeolian cover, overlying a bottom moraine.

Parent material:
Silty loam overlying morainic pebbles and boulders.

Landuse:
Summer pastureland.

FIG. 8 - Soil profile at the Site No. 3 (2,980 m a.s.l.), developed over alluvial deposits with aeolian cover, and under alpine-subalpine, subxerophile meadow.

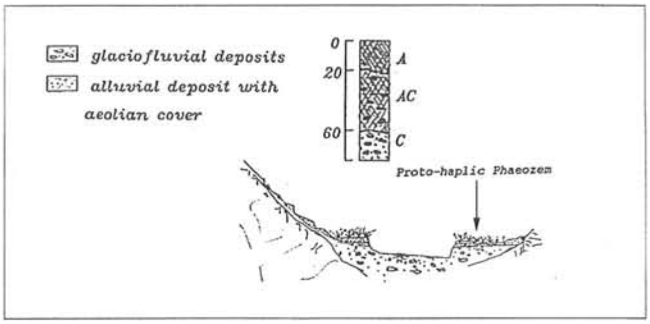

FIG. 9 - Schematic transect across the Chong-Kemin river Valley. The arrow points at the pedological site No. 3.

Soil Profile

0-20 cm. A horizon (Sample: K3A). Very dark greyish brown 10YR3/2 (moist), brown 10YR4.5/3 (dry); silty loam; strong medium prismatic structure; common fine roots; gradual wavy boundary.

20-60 cm. AC horizon (Sample: K3AC). Dark brown 10YR3/3 (moist), light yellowish brown/light olive brown 2.5Y5.5/3 (dry); silty loam; moderate medium prismatic structure; few fine roots; abrupt smooth boundary.

60-80+ cm. 2c horizon. Alluvial bed of pebble and stones.

Classification

Proto-haplic Phaeozem (Fao); Pergelic Cryoboroll (Usda); Mountain Meadow Alpine (Subalpine) Soil (Gugk); Quasi-Phaeosol Haplique, mésosaturé, alluvial, subalpin (Rp); Haplic Phaeozem (Wrbsr). According to the Cstc, this soil could be considered as an intergrade between the Cryo-black (meadow-steppe vegetation stage) and the Cryo-sod (subalpine meadow vegetation stage) soils of the Altocryic Isohumisols.

SITE No. 4

Location:
Left side of the Prahodnaia stream, tributary of the Almaatinka stream (Kazakhstan); 43°03'N, 76°55'E (figs. 10 and 11).

Altitude, slope aspect, and inclination:
2,160 m; western facing; 80÷100%.

Drainage:
Well drained.

Vegetation:
Upper limit of the Tien Shan spruce (*Picea schrenkiana* Fisch. et C.A. Meg.), with *Geranium pratense* L., *Aconitum leucostomum* Worosch, *A. soongaricum* Stapf., *Lonicera karelinii* Bunge ex P.Kir.

Landform and geomorphology:
Steep slope of glaciated valley, covered by mass wasting and moraines.

FIG. 10 - Soil profile of the Site No. 4 (2,160 m a.s.l.), located at the upper limit of Tien Shan spruce forest.

Parent material:
Slope clasts of weathered granites, granodiorites and gabbros, mixed with morainic materials.

Soil profile

5-0 cm. Oe horizon. Black 10YR2/1 partially decomposed organic matter; many fine roots; abrupt smooth wavy boundary.

0-10/15 cm. A horizon (Sample: K4A). Very dark greyish brown 10YR 3/2 (moist), brown/yellowish brown 10YR5/3.5 (dry); loamy; moderate, fine granular structure; many fine and medium roots; few medium and coarse pebbles; gradual smooth boundary.

10/15-25/30 cm. BA horizon (Sample: K4BA). Dark brown 10YR3/3 (moist), yellowish brown 10YR5/4 (dry); sandy loam; weak, medium prismatic structure; few, fine roots; few, medium weathered pebbles; abrupt wavy boundary.

25/30-50+ cm. C horizon. Medium and fine rock fragments, grain-by-grain highly weathered.

Classification

Molli-eutric Cambisol (Fao); Typic Cryoboroll (Usda);

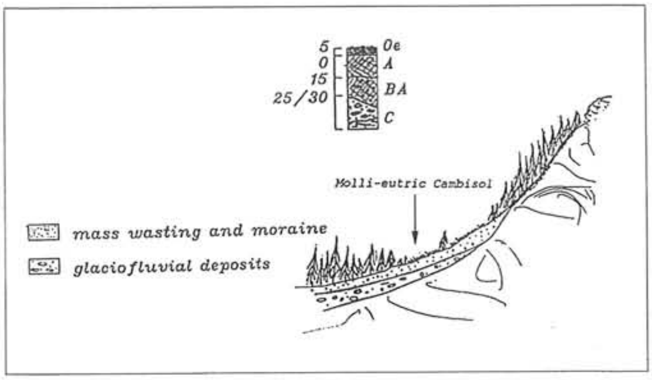

FIG. 11 - Site No. 4: schematic transect along the left side of Prahodnaia stream Valley. The arrow points at the described soil profile.

Mountain Forest Dark Coloured Soil (Gugk); Brunisol Mésosaturé, humifère (Rp); Eutric Cambisol (Wrbsr).
This pedon, tentatively classified according to Cstc, could be considered as an intergrade between the Cryo-black soils (Order of Isohumisols, Suborder of Altocryic Isohumisols) and the Cryo-brown soils (Order of Siallisols, Suborder of Udic Siallisols).

LABORATORY METHODS

Organic components

Organic carbon was determined by Springler-Klee method. Organic matter was eliminated by treatments with H_2O_2 and then the samples were treated with Dcb (Mehra & Jackson, 1960).

Na-pyrophosphate plus NaOH were used to obtain total extractable carbon (TEC); humic acids (HA) were separated from fulvic acids (FA) with H_2SO_4. FA were purified by polyvinylpyrrolidone.

Mineral components

Soil reaction was potentiometrically measured in a 1:2.5 soil-water or soil-KCl suspension. Cation exchange capacity, exchangeable cations and extractable acidity were obtained by $BaCl_2$-triethanolamine pH 8.2 method. Particle size distribution was determined by the pipette method after dispersion with $(NaPO_3)_6$ with total removal of cementing agents. Total iron (Fe_t) was obtained by aqua regia attack; dithionite-soluble iron (Fe_d) and aluminium (Al_d) by Mehra & Jackson (1960) methods; oxalate-extractable iron (Fe_o) and aluminium (Al_o) by Schwertmann (1964) method; pyrophosphate-extractable iron (Fe_p) and aluminium (Al_p) by Mckeague & Schuppli (1982) methods.

PROPERTIES OF SOIL HORIZONS

Textural properties

A rough examination of the soil textural classes (tab. 1) shows that the silt loam textures are, in a certain way, the most frequent, with shiftings towards the loamy class in the two epipedons of sites No. 1 and No. 4, and towards the coarse sandy loam in the BA horizon of site No. 4.

The argillification index (%clay/%silt+sand) is higher in the A horizons of sites No. 1 and No. 3, where it reaches the value of 0.32. But in the first profile this seems to be due to a former abundance of clay in the morainic material, while in the second one it is probable that the loess-like parent material had actually suffered a higher weathering.

The clay traslocation within the profiles seems to be everywhere absent or negligible, but, maybe, in profile No. 2. The sum of very fine sand plus coarse and fine silt reaches the highest values in the whole profile No. 3 (71.80% and 75.40%), upholding a probable aeolian contribution.

TABLE 1 - Particle size distribution

Horizon	Soil dispersed texture (%)					
	Sand			Silt		Clay
	2.0-0.2	0.2-0.1	0.1-0.05 (mm)	0.05-0.02	0.02-0.002	<0.002
K1A	12.3	3.2	10.7	9.2	40.4	24.2
K2A	18.8	8.2	1.2	27.4	35.2	9.2
K2BA	13.1	2.6	5.2	24.2	40.5	14.4
K3A	3.1	1.0	14.9	15.2	41.7	24.1
K3AC	4.7	5.0	15.9	18.3	41.2	14.9
K4A	30.0	11.6	5.3	12.4	25.5	15.2
K4BA	39.5	18.2	12.1	9.5	12.5	8.2

Chemical properties

The soil reactions (tab. 2) range between strongly acid, with $pH(H_2O) = 5.2$ (Profile 1), and slightly acid-neutral, with $pH(H_2O) = 6.6$, in the deepest horizon of Profile 2. There are not great changes among the values of such parameter on the surface and into the depths. Even the values of $\Delta pH(H_2O\text{-}KCl)$ are not very high, as they are between 0.3 and 1.4, in clear connection with the very low exchangeable acidities. Such soil reactions do not encourage the release of free Al-cations, so it was not possible to detect them within the exchange complex. Then, the acidity of those soils is just potential and, although it can be found also in the profile with a neutral reaction, it produces only a base saturation lowering. Moreover, such acidity, is probably due to the abundant organic matter, responsible for the largest quantity of the colloidal variable charges, available only at a particular pH.

The high organic matter content is, notoriously, the main cause of the measured high cation exchange capacity. Also the remarkable clay and fine silt percentages exert, of course, their influence on such chemical parameter. In fact, where the fine particles content lowers, as in Profile 4, also the CEC decreases.

TABLE 2 - Chemical characteristics of the soils

Horizon	Reaction pH		Exchange complex (cmol (+)/kg soil)							Base saturation (%)
			Exchangeable Bases				C.E.C. *	Exchangeable Acidity **	Acidity *	
	(H_2O)	(KCl)	Ca	Mg	K	Na				
K1A	5.2	4.8	20.64	2.73	0.53	0.13	44.4	0.5	25.64	54
K2A	6.5	6.1	27.55	1.92	0.11	0.04	37.8	0.1	13.34	78
K2BA	6.6	6.0	22.51	3.25	1.21	0.50	35.6	0.1	11.92	77
K3A	6.0	5.2	24.33	3.46	1.57	0.73	47.0	0.2	22.60	64
K3AC	6.4	5.0	22.02	3.23	0.65	0.10	39.1	0.3	19.99	66
K4A	5.7	5.4	15.47	1.80	0.47	0.14	27.8	0.3	10.64	64
K4BA	5.9	5.0	5.27	0.78	0.27	0.02	9.1	0.1	4.74	70

* By $BaCl_2$
** By KCl 1N

FORMS AND DISTRIBUTION OF MINERAL ELEMENTS

Iron and aluminium

The total iron content is rather variable, ranging from a minimum of 3.5% to a maximum of 7.0% (tab. 3). The weak increasing with the depth of profiles 2 and 3 could be indicating a loss of this element from the upper horizons.

The weathering indexes (Fe_d/Fe_t) indicate in all the profiles a low weathering degree, and mainly in the Profile 4, situated at the lowest altitude. Anyway, this index is constantly higher in the surface horizons, where also the organic matter content, well-known as a strong agent of mineral weathering (Robert & *alii,* 1987) is higher. In addition, the ratio of the oxalate-extractable Fe to the dithionite-citrate-extractable Fe, the so-called active iron ratio (Fe_o/Fe_d), follows the same trend, being around values of 50% (44-61%). This denotes a certain balance between the amorphous and the crystalline Fe forms, but with a slight supremacy of the latters in the deepest horizons. Also the ratios between the analogous Al forms show similar trends.

TABLE 3 - Iron and aluminium fractionation (%)

Horizon	Fe_t	Fe_d (1)	Fe_o (2)	Fe_p (3)	Fe_d/Fe_t x 100	Fe_o/Fe_d x 100	Al_d (1)	Al_o (2)	Al_p (3)
		(1)	(2)	(3)			(1)	(2)	(3)
K1A	4.57	0.91	0.46	0.22	19.9	50.5	0.44	0.21	0.13
K2A	4.92	1.17	0.59	0.22	23.8	50.4	0.62	0.32	0.17
K2BA	5.42	1.22	0.57	0.28	22.5	46.7	0.93	0.43	0.24
K3A	6.40	1.50	0.70	0.31	23.4	46.7	0.64	0.40	0.20
K3AC	7.02	1.20	0.53	0.16	17.1	44.2	0.47	0.36	0.10
K4A	3.70	0.57	0.35	0.15	15.4	61.4	0.37	0.16	0.06
K4BA	3.52	0.38	0.19	0.08	10.8	50.0	0.20	0.11	0.04

(1) DCB extractable (Na-dithionite-citrate-bicarbonate)
(2) NH_3-oxalate extractable
(3) Na-pyrophosphate extractable

Checking the existence of any podzolization process, in the different examined soils, led us to conclude that the B horizons do not meet any of the requirements the Fao Revised Legend (1990) considers as typical of the spodic B horizon. More in particular, the ratio of Fe_p+Al_p/clay is not 0.2 or more and the ratio Fe_p+Al_p/Fe_d+Al_d is not 0.5 or more.

Silicate and clay minerals

The results of the clay minerals qualitative analysis, performed by Rtg difrattometry, are listed in tab. 4.

TABLE 4 - Silicate and clay minerals

Horizon	Main components	Subordinate components	Minor components
K1A	Quartz Chlorite Muscovite Plagioclase	Amphibole	Orthoclase? Pyroxene?
K2A	Quartz Chlorite Muscovite Plagioclase	Amphibole	Orthoclase? Pyroxene?
K2BA	Quartz Chlorite Muscovite Plagioclase	Smectite	Amphibole Orthoclase? Pyroxene?
K3A	Quartz Smectite Chlorite Plagioclase	Muscovite Amphibole	Orthoclase? Pyroxene?
K3AC	Quartz Smectite Plagioclase Chlorite	Muscovite Amphibole	Pyroxene?
K4A	Quartz Chlorite Muscovite Plagioclase	Amphibole	Smectite? Orthoclase?
K4BA	Quartz Chlorite Muscovite Amphibole Plagioclase	—	Smectite? Orthoclase?

Quartz, plagioclase and chlorite are ubiquitous and abundant in all the samples. Micas are only represented by *muscovite,* abundant in the samples K1, K2A, K2BA, K4A and K4BA. The K3A and K3AC samples show a high content of smectite, probably correlable with an aeolian covering of the alluvial material. There are variable quantities of amphibole in all the samples. *Pyroxene,* although only dubitatively found, seems to be absent in the samples of the site No. 4 profile; this means there is a different lithological environment of soil formation. *Orthoclase,* in small quantities, seems to be present in all the samples.

Trace elements

Interpreting the geochemical data shown in tab. 5, we have to considere the lithological, pedological and vegetational diversities existing among the study sites.

First of all, the soil profiles of sites No. 1 and 2 are of noncumulative type (Birkeland, 1984), as they formed on glacial material covering metamorphic rocks. The profile of the site No. 3 is probably of cumulative type, extending through aeolian, alluvial, and glacial layers. The profile of site No. 4 was formed on igneous rocks, partially covered by slope detrital materials.

Besides, the three first profiles are developing under alpine meadows, while the last one is under spruce woodland, with different uptakes and releases.

In order to judge the geochemical content of each individual sample, we need to refer to the average values in trace elements related in literature (Allaway, 1968; Kabata-Pendias & Pendias, 1984). It can be noticed, then, how As is quite abundant compared to the average values in soils, more in particular, in samples K2A and K2BA. Cd is found in standard amount, with a slight excess in the two latter samples, while Cr is everywhere abundant, especially in K3A and K3AC. Cu and Mo are everywhere standard, while Zn is slightly in excess but only in K2A and K2BA, where also Pb, that generally is standard, reaches high values. Ni reaches very high values in K3A and K3AC, and, together with Cr, confirms a probable genetic diversity of the parent materials of this soil. Mn, that, after Ti, is normally the most abundant trace element, confirms itself as predominant in the examined samples as well, keeping, anyway, the standard amounts. Also the Co percentages have not abnormal values, although quite high. Be content is low only in K3A and K3AC, where, on the contrary, V is more abundant than elsewhere, but, anyway, in standard amount. In short, according to geochemical content, the profile of site No. 3 seems to stand out from the others, showing higher contens in Cr, Cu, Ni, Mn, Co, and V.

As far as the leaching of the trace elements through the soil profile, that in cool and humid climate should be intense, is concerned, we can notice how in sites No. 2 and 3 the concentrations in the deepest horizons prevail, while in site No. 4 almost all the upper horizons are richer.

Although without drawing any final remarks, from a limited whole of data, it seems we can suppose a higher atmospheric input and a more intensive release of trace elements to the soil under the Tien Shan spruce forest. The spruce, in other words, seems to play a role as trap, of atmospheric pollutants, more intense than the one played by meadows and alpine prairies. On the other hand, the spruce seems to release the atmospheric trace elements more rapidly on the ground than the other vegetation kind of this environment. But we have to take into account that, on the northern slopes of the investigated area, it is possible that the orographic rainfall increases the atmospheric input.

The tab. 6 shows the order of abundance of the trace elements in topsoil of world soils and it is compared with the one found in individual horizons of the examined profiles.

TABLE 6 - Abundance order of the trace elements in individual horizons of the examined profiles and in topsoil of the world soils (Kabata-Pendias & Pendias, 1984)

	Trace elements
Topsoil of the world soils	Mn > V > Cr,Zn > Pb > Cu > Ni > Co > As > Mo > Be > Cd
Sampled soil horizons	
K1A	Mn > V > Cr > Zn > Cu > Ni > Pb > As > Co > Be > Mo > Cd
K2A	Mn > Zn > V > Pb > Cr > As > Ni > Cu > Co > Be > Mo > Cd
K2BA	Mn > Zn,V > Cr > Pb > As > Cu > Ni > Co > Be > Mo > Cd
K3A	Mn > Cr > V > Ni > Zn > Cu > Co > Pb > As > Mo > Be > Cd
K3AC	Mn > Cr > V > Ni > Zn > Cu > Co > Pb > As > Be > Mo > Cd
K4A	Mn > V > Zn > Cr > Ni > Cu > Pb > As > Co > Be > Mo > Cd
K4BA	Mn > V > Zn > Cr > Ni > Cu > As > Co > Pb > Be > Mo > Cd

It can be noticed how Mn is always the most abundant among all the considered trace elements. V is everywhere the second or third element according to abundance. Zn is

TABLE 5 - Trace elements in soil profiles (mg/kg)

Horizon	As	Cd	Cr	Cu	Mo	Zn	Pb	Ni	Mn	Co	Be	V
K1A	19.5	0.05	101	39.0	1.8	93.5	28.3	33.9	435.0	11.6	4.66	129.0
K2A	43.8	0.28	96	32.0	1.6	138.0	113.0	37.2	895.0	15.4	4.23	134.0
K2BA	38.0	0.31	100	37.6	1.5	152.0	65.1	37.5	972.0	17.1	4.09	152.0
K3A	19.0	0.06	351	48.6	1.2	95.8	19.6	167.0	915.0	30.4	0.91	178.0
K3AC	19.6	0.09	210	55.2	1.1	111.0	25.1	118.0	981.0	25.6	1.95	146.0
K4A	14.4	0.22	74.5	22.2	1.5	85.8	14.9	29.0	709.0	12.2	3.87	111.0
K4BA	14.0	0.09	68.9	18.9	1.2	73.2	8.7	26.7	684.0	11.8	2.81	121.0

regularly third or fourth, except in K2A and K2BA, where it is particularly abundant, and in K3A and K3AC where, on the contrary, it recedes in fifth position, because of the high quantity of Ni (together with Cr, Cu and Co) here contained, in comparison with all the other samples. Cu occupies standard positions. Pb, usually seventh, is very advanced in K2A and K2BA, where also As is more abundant than elsewhere. The last elements occupy almost normal positions.

ORGANIC COMPONENTS

In all the A horizons (tab. 7) the organic matter content (TOCx1.72) varies from 6.6% (K3A) to 11.3% (K2A). In the subsurface horizons, the organic matter ranges between 1.2% (K4BA) and 4.9% (K2BA). So, these soils, both under meadow and under spruce forest, are very humic.

The fractioning of the organic matter points out the existence of a generally low-active environment, also from a microbiological point of view, as the humified carbon represents everywhere a very low percentage of the total amount. In fact, only a part, which is constantly under 30%, of the total Na-pyrophosphate plus NaOH soluble carbon, is actually humified. The remaining 70% is constituted by the nonhumic fraction, mainly represented by the polysaccharides. The scarce humified fraction is, however, rather steady, as the humic acids are prevailing over the fulvic ones.

The C/N ratio increases from 8.5 to 12.4 in A horizons, and to a maximum of 12.8 in the K3AC. In the A horizons, the C/N ratio does not considerably change with the type of vegetation cover, it is as low under conifers as under alpine meadows. Such a small ratio might indicate an accumulation of organic nitrogen related to the amount of organic matter and amorphous aluminium and iron compounds preventing mineralization (Righi & Lorphelin, 1987).

TABLE 7 - Organic carbon fractionation

			Corg.					N	C/N
Horizon	TOC (1)	TEC (2)	HA (3)	FA (4)	NH (5)	DH (6)	HR (7)	mg. g^{-1}	
			mg. g^{-1}			%	%		
K1A	61.51	21.47	4.47	1.71	15.29	28.8	10.0	5.03	12.2
K2A	65.63	22.07	4.62	1.83	15.62	29.2	9.8	7.70	8.5
K2BA	28.29	9.53	1.59	1.00	6.94	27.2	9.2	2.48	11.4
K3A	38.35	14.12	2.29	1.35	10.48	25.8	9.5	3.57	10.7
K3AC	11.64	2.35	0.35	0.18	1.82	22.6	4.6	0.91	12.8
K4A	48.18	17.06	3.35	1.53	12.18	28.6	10.1	4.00	12.4
K4BA	7.20	3.77	0.69	0.49	2.59	31.3	16.4	0.68	10.6

(1) Total Organic Carbon
(2) Total Extracted Carbon (NaOH + total Na-pyrophosphate soluble carbon)
(3) Humic Acids (NaOH + Na-pyrophosphate soluble and H_2SO_4 undissolvable carbon)
(4) Fulvic Acids (NaOH + Na-pyrophosphate and H_2SO_4 soluble carbon.Cleansed by polyvinylpyrrolidone)
(5) Non-Humic fraction
(6) Degree of Humification (HA+FA/TEC)
(7) Humification Rate (HA+FA/TOC)

CONCLUSIONS

The soil survey and the laboratory analyses pointed out a complete absence of podzolization features, even though the altitudes, the temperatures and the rainfall, the vegetation, and the acidic mother rocks, lead us suppose that such soil forming process could be active. Such conclusions agree with the hypothesis already expressed by Samusenko & Kozhekov (1982). On the contrary, we have to point out the presence of chernozem-like soils at very high altitudes. This occurrence seems to be in connection with a steppic climate influence and a loess-like aeolian input, with a consequent soil melanization.

The orographic position and the slope elevation seem to exert the strongest influence, prevailing on the other soil forming factors. In short, the analyses pointed out a higher atmospheric input and a more intensive release of trace elements to the soil under the Tien Shan spruce woodland. It seems likely to think about an uptake by soils under forest, which would behave as a trap for atmospheric pollutants.

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