CHAPTER 7

SOILS OF THE LAKE HÖVSGÖL AREA AND ITS WATERSHED

O. Batkhishig

Abstract

The soil cover of the Hövsgöl Lake area and its watershed is complicated because of its mountainous features, differences of exposure, the influence of permafrost, the taiga-forest and the soil forming rock sediments. Compared with the western part of the Lake area, in the east there are more sandy soils, and not as much high mountain soils. The Dark Kastanozem soil of the eastern Hövsgöl area is non-carbonated, and sandy-loamy. On the northern lower slopes cryomorphic meadow, cryomorphic peat and Chernozem soils are dominant. The larch forests are mainly dominated by Mountain taiga-derno soil, and in some lower areas there are Mountain taiga-cryomorphic soils. In the valley bottoms, cryomorphic peat, cryomorphic meadow and alluvial peat soils are common. In the western Hövsgöl area high calcium carbonated soils are wide spread, especially in the Horidil Saridag mountain areas.

Introduction

The cold-humid climate condition, wide-spread distribution of permafrost, the taiga forest and the peculiarities of the rock sediment has formed the specific soil cover of the Hövsgöl area, distinct from other parts of Mongolia. The Hövsgöl area is the most humid region of Mongolia. According to the natural zonations this is a mountain taiga zone representing the southern edge of the huge Sibirian taiga.

The soil cover of the Hövsgöl lake area is still not sufficiently studied. The beginning of geographical studies of Lake Hövsgöl dates to 1830, when N. S. Turchaninov and N. V. Kirillov visited this region and gave a first brief description. Until 1960s this region was never visited by soil scientists. the first time, in 1951, the Russian soil scientist N. D. Bespalov made a visit to the southern edge of the lake, at Hatgal. In the 1970s, the State University of Irkutsk and the National University of Mongolia began a joint investigation of the Hövsgöl region. This was a complex expedition, including all of the natural sciences, including soil scientists (Ivelsky, Martynov and Batjargal). The result of this expedition was issued in several scientific volumes, "Natural Conditions and Resources of the Hövsgöl Region", ended in 1989, and completed by publication of "The Lake Hövsgöl Atlas".

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In addition to this expedition, many Russian-Mongolian soil scientists (Ogorodnikov, Dorjgotov, Batkhishig) visited this region, but mainly at the southern edge of Hövsgöl lake and the Darhad depressions.

The general and specific peculiarities of this territory include the following: 1) this is the southern boundary of the Sibirian taiga forest 2) the area consists of undisturbed, pristine natural conditions and soil covers, 3) a short active biological period with a long period of negative temperatures in the soil, 4) the most humid region of Mongolia, and 5) the wide distribution of cryomorphic-peaty soils, etc. The specifics of soils of the Hövsgöl region are not only caused by the present soil forming conditions, but also some relict features inherited from the former period of the areas' historical development. For example: 1) cryoturbation features in the steppe soils, as an indicator of former cold humid climate conditions, 2) sandy sediment and sand accumulation in the eastern shoreline of Hövsgöl lake, eastern part of Darhad depression as evidence of a dry windy climate condition, 3) soils on moraine sediments – Ulaan taiga mountains, Horoo river valley, and the western Darhad depression (Fig. 7.1, 7.2).

This is the most humid part of Mongolia, characterized by continental climate conditions with a wide range of temperatures, from an absolute maximum air temperature of +35 °C, to a minimum of –50 °C. Precipitation averages 300-430 mm year^{-1} except in high mountainous zones where precipitation can be as high as 600 mm year^{-1}. This area is often under snow cover from the beginning of October to the end of April.

By the soil regionalization characterization, the study area belongs to the humid type of soil vertical zonations (Nogina, 1984). The cryomorphic taiga soils usually are surficially ferrimorphic, and include Derno-taiga deep freezing, Meadow-forest deep freezing, Chernozem without carbonate and meadow-boggy cryomorphic soils (Dorjgotov and Maximovich 1984).

The area surrounding Lake Hövsgöl is dominated by mountain soils. The upper part of mountains, above the forest line (2200 meter a.s.l. southern slopes, 2100 meter a.s.l. on northern slopes) are distributed Mountain tundra and Mountain meadow soils (Fig. 7.3. These soils are formed under dryad-lichen, kobresia-lichen-dryad and sedge-lichen plant associations, characterized by short stony profiles and the accumulation of decomposed plant residues and peats. There are very clear cryoturbation processes and cryogenic sorting of materials. Forest soils are distributed between 1800-2200 meter on southern slopes, 1900-2100 meter on northern slopes under larch (*Larix sibirica*) forests with moss and moss-bush associations. On southern slopes under forb-grass vegetation, Mountain Dark Kastanozem soils form. In eastern Hövsgöl areas non-carbonated Kastanozem soil are distributed on the sandy sediments. In northern lower slopes Chernozem or cryomorphic boggy soils occur. Valley bottoms have meadow and boggy cryomorphic soils.

The soil cover of the Western and Eastern parts of Hövsgöl lake areas differ (Fig. 7.3). In the Western parts, high mountain soils are more wide spread: Mountain tundra and Mountain meadow. Soils of this part especially of the Horidal Saridag mountain area is characterized by high carbonate content, resultinf from calcite, dolomite rocks. Even, forest soil has carbonate content.

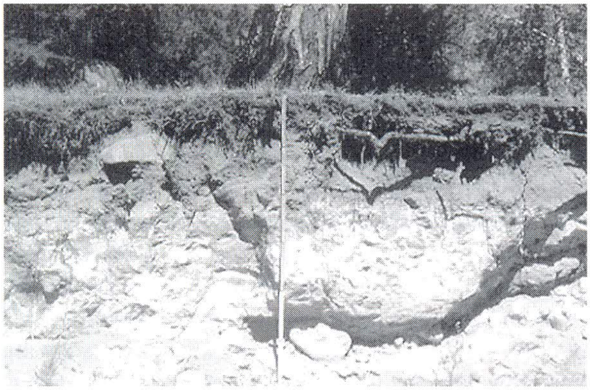


Fig. 7.1. Carbonated Mountain taiga-derno soil. Darhad depression – Western Hovsgol (June 2002).

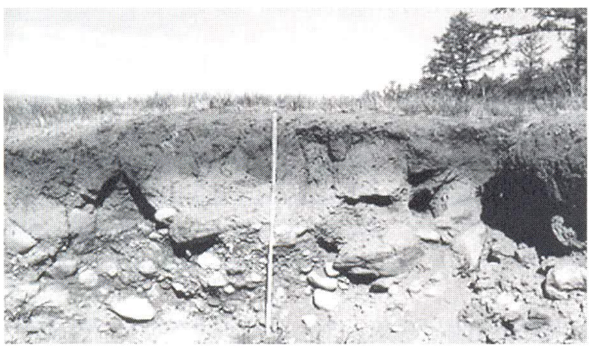


Fig. 7.2. Chernozem soil on the moraine sediment, Jarai river - Darhad depression.

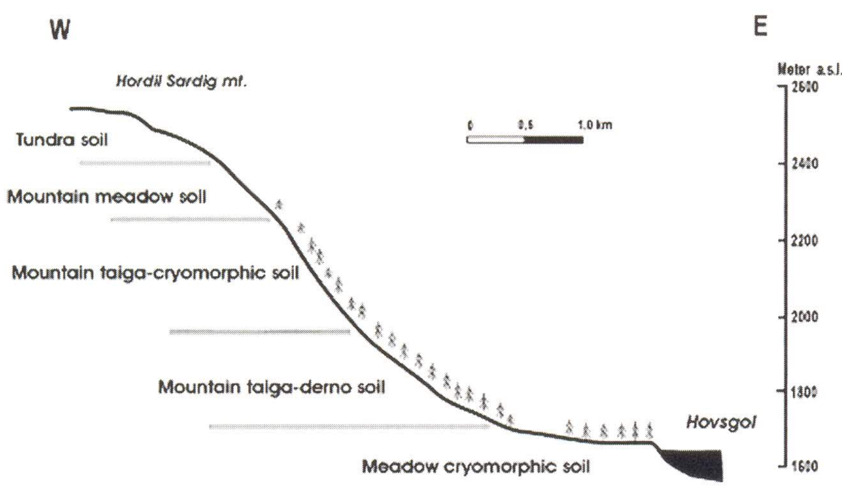


Fig. 7.3. Schematic soil transect of Western Hovsgol lake area.

Eastern Hövsgöl

The Eastern Hövsgöl lake area is dominated by Mountain taiga-cryomorphic, Mountain derno-taiga, Dark Kastanozem, Chernozem, Meadow–cryogenic and Boggy-cryomorphic soils. The eastern shoreline valleys (Sevsuul, Dalbay, Noyon valleys) of Hövsgöl lake have sandy soils, some parts with fixed or mobile sand dunes. In the eastern parts there is not much area covered by mountain tundra, Mountain meadow soils dominate the middle or low mountain slopes not exceeding 2000 – 2200 meter a.s.l. The topography of the eastern part of Hövsgöl lake is lower and less dissected than the western part; characterized by lower and moderate high mountains with relative elevations of 200-600 m. The highest point is Bulnain-Tsagaan uul 2367.9 m. a.s.l. in the upstream area of Borsog valley.

The eastern part of Hövsgöl lake is dominated mostly by Neogenic basalt, but in the northern part, in Turag river valley area, Rifein granodiorit or leikogranite are common (Chapter 1). In some parts of Dalbay, Borsog, Sevsuul valleys there occur Devonian granosienit. Valley riverbanks are covered by alluvial gravely-sandy material. The following soils are distributed in the eastern Hövsgöl areas:

South slopes	-	Non-carbonated Dark Kastanozem (*Mollisols*)
Floodplains of rivers	-	Alluvial meadow, Alluvial-derno, Alluvial-boggy cryomorphic (*Fluvisoils*)
North lower slopes	-	cryomorphic meadow, cryomorphic peat (*Histosols*), Chernozem,
North slope forest	-	Mountain taiga-cryomorphic, Mountain taiga-derno, Mountain forest dark colored

The soil of the eastern Hövsgöl lake area is characterized by sandy loamy texture, which is sensitive to erosion and degradation. By the study of Dalbay valley soils, we will introduce detailed soil characteristics of the eastern Hövsgöl lake area.

The soils of Dalbay valley

Nature geographical condition

Dalbay valley is located between 51° 05" - 50° 57" N, and 100° 43" - 100° 57" E (Fig. 7.4). By administrative division, the ILTER study site belongs to Turag bag of Hanh soum, Hövsgöl aimag. The valley is about 27 km long, occupies 161 square km. The lower part is up to 2 km wide and sandy, especially in its southern part. In the southern part of this down stream area, Ih Dalbay is joined by a small tributory, Baga Dalbay river valley, which occupies only 8 sq km area and continues for 6 km long. Dalbay valley territory belongs to the Hövsgöl National Park strictly protected zone.

The watershed is dominated by low mountains with relative elevations 100-200 meters high. Mountain tops are plain with small lakes. The valleys are asymmetrically shaped with a steep south facing slope, and a less steep forested north-facing slope. On the south part of the river floodplain there is a very clear 2-3 meter height terrace, that is not so clear on the

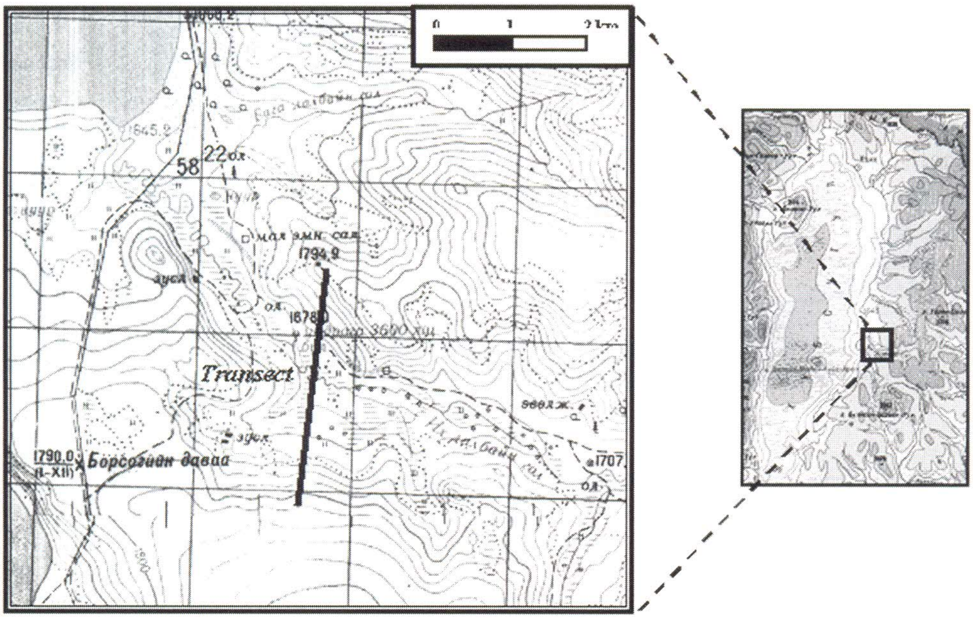


Fig. 7.4. Dalbay valley (June 2004).

northern-facing slope part of the floodplain. In the foot slopes of the forested north-facing slopes there is marked solifluction or a soil mass slow flow. Similar solifluction evidence also occurrs in other valleys; e.g., Borsog, Noyon etc.

Rock sediment

The Neogenic (Pliocene) basalt rock is widely distributed in Dalbay valleys. Some parts occurred Devonian granosyenite, for example in the south-facing slopes of our soil study transect (Fig. 7.5). Also, Rifien (Proterozoic) greenstones and slates are present. The main soil forming sediment of Dalbay valley is sand. Sandy sediment is distributed on the lower slopes up to the 1700 m a.s.l. on both slopes, the south and the north. In the floodplains sandy-gravel alluvium have accumulated. The alluvium is covered by 0.5-1.0 meter thick peat's.

Sand

In the eastern part of Hövsgöl lake territories sandy sediment is widely distributed. Especially along shorelines (Fig. 7.6). But the western shoreline of Hövsgöl lake is without any sand. The origin of the sand is still not clear. By the structural content, it is a well sorted medium sand, without layering. Layered sand usually accumulates by fluvial processes. Therefore, it is possible to say that this sand has an aeolian genesis. In the downstream of Dalbay, Anchigast, and Sevsuul valleys there are some big sand dunes up to 3-5 meter high.

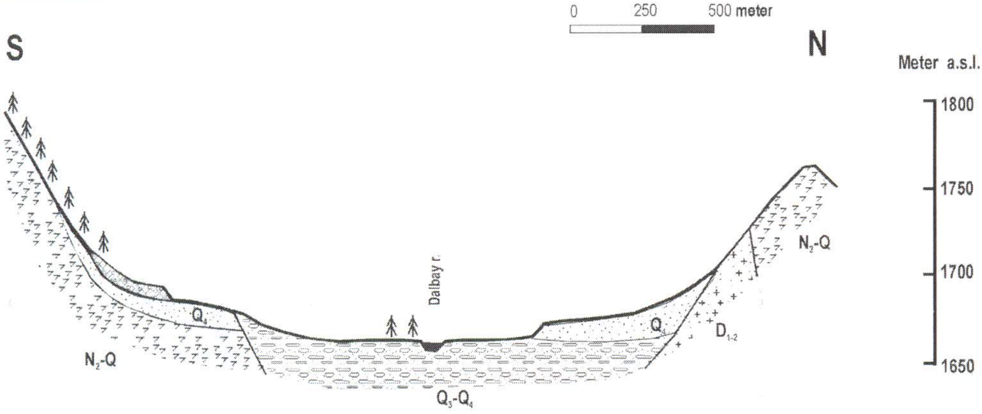


Fig. 7.5. Geomorphological transect of Dalbay river valley (June 2004).

Fig. 7.6. Sand massif in the Baga-Dalbay river valley.

These sand massifs accumulated under very dry, windy climate conditions. Probably at the end of the last glacial maximum time, when the climate was dominated by cold dry conditions. At the same time there were large sand massifs forming in western Mongolia.

For the investigation of the soil cover and soil characteristics of Dalbay valley, we made soil profiles along north-south directed transects in each valley, about 4 km south-east from Hövsgöl lake shorelines (Fig. 7.7). Ten soil profiles were established along a transect in Dalbay valley. Two soil profiles (DLB-01, DLB-10) were located in the steppe zones of

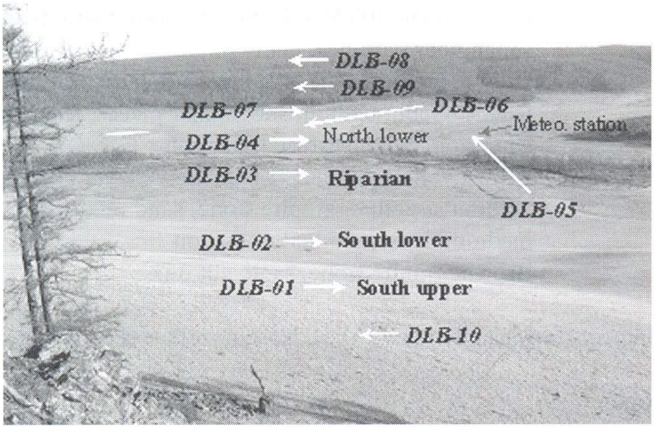


Fig. 7.7. Dalbay valley soil profiles.

south-facing upper slopes (SU), 1 soil profile (DLB-02) in the steppe zones of south-facing lower slopes (SL), 1 soil profiles (DLB-03) in the meadow-boggy floodplains of the riparian zone (R), 2 soil profiles (DLB-04, DLB-06) in the meadow-boggy zones of north-facing lower slopes (NL), one soil profile (DLB-05) nearby the meteorological station on the south part of the valley, one soil profile (DLB-07) in the forest edge of the north-facing slope, and two soil profiles (DLB-08, DLB-09) in the forest zone of the north-facing slope.

By the natural-geographical conditions Dalbay valley is typical of the eastern shore valleys. However, the soil cover is complicated by the mountainous features, exposition differences, the influence of permafrost, the presence of the taiga-forest and the hardrock geology. Compared with the western parts, the eastern part does not have high mountain soils. South facing slopes are not forested and are dominated by Dark Kastanozem soils. In the forested areas there are mainly Mountain taiga-derno soils, in depressions or upper parts of forest areas, Mountain taiga-cryomorphic soils are found. Valley bottoms are characterized by cryomorphic peat, cryomorphic Meadow and Alluvial peat gleye soils.

Morphological and chemical properties of soils

South upper slope

Dark Kastanozem soil is distributed on south-facing slopes under mountain forb-grass vegetation cover.

Profile DLB-01

Dalbay valley south-facing slope, upper steppe (inclination 25°)

N 51° 01' 52", E 100° 45' 27" ALT = 1724 m.

Eastern part of Hövsgöl lake. Lower part of Dalbay valley, upper part of south facing slope. *Kobresia-Fescue*-forb steppe. Canopy cover 60-70%. On the surface granite stone, sandy silty accumaltion berween grass. All soil profiles do not effervess with 10% HCl.

A 0-12 cm.	Dark brown (10YR 4/3), moist, sandy loam, friable, small subangular particles, many roots, gradual distuingish.
AB 12-24	Brown, granite stone, sand mixture (stone content 20-30%), friable small, medium subangular pieces, less roots than in the a horizon above, diffuse transition.
BC 24-35	Brown yellowish, darker than above layer (10 YR 4/4), without structure, granite stone, sand mixture, few roots, medium dense, gradual transition
C 35-60	Brown, granite stone, sand, silt mix

Soil: Non-carbonated, stony, sandy loamy Dark Kastanozem soil on granite sediments.

South lower slope

Profile DLB-02

N 51° 01' 26.1", E 100° 45' 49.3" ALT = 1686 m a.s.l.

The south-facing foot slope of Dalbay valley has an inclination of 10-12o. It is a *Fescue*-forb meadow-steppe with a canopy cover of 70-80%. There are no rocks on the surface of the soil. None of the soil profile horizons effervess with 10% HCl.

A	0-22 cm	Moist, dark brown (7.5 Y 3/2), sandy-loam, with many small roots, upper parts subangular blocky structures, gradual distintion by color
AB	22-35	Brown yellowish (7.5 YR 4/3), sandy-loam, stony, fragile medium subangular blocky, diffuse transition by color
BC	35-45	Yellowish brown (7.5 YR 4/6), fine sand, loam, granite stone (20-30%), clear distinction by texture content
C1	45-80	Moist, brown yellow, sand with cobble pebbles, friable
Cf	80 cm	Frozen soils

Soil: Non-carbonated sandy loamy Dark Kastanozem

In the south-facing steppe slopes there are Non-carbonated Dark Kastanozem soils. The Hövsgöl Atlas (Kozhova *et al.* 1989) indicates in the eastern Hövsgöl areas the distribution of Chernozem soils. But our results show that this is not Chernozem soil. By the humus content this soil belongs to the Dark Kastanozem soils (Dorjgotov 2003). Also, non-carbonated Dark Kastanozem soils are distributed on the south-facing slopes of other valleys. This soil is characterized by 24-35 cm thick humus horizons and 3.34-3.62% of humus content in top soils (Table 7.2). Downward, humus content gradually decreases. The upper slope is steeper, therefore the soil has more stones and is thinner (Profile DLB-01). The soil reaction is slightly acid, pH ranges from 6.29-6.72. It has been leached of its calcium carbonate, due to the high porosity associated within the largely sandy sediment and granite stone soil. The non-carbonated property of the Kastanozem soil of south facing steppe slopes is one of the specific characters of the eastern Hövsgöl region. The sum of exchangeable bases ranges between 10-20 meq/100 g. Calcium is dominant,

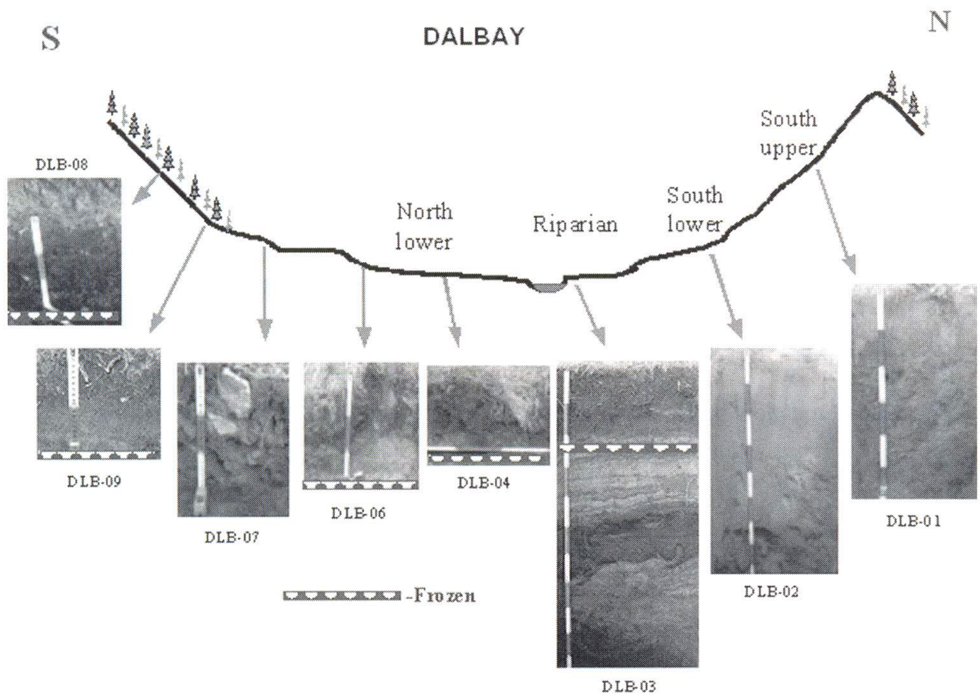


Fig. 7.8. Soil profiles in Dalbay valley (25 May 2004).

but in the C horizons or soil forming sediments of Profile No.DLB-01, Magnesium content (10.5 meq/100 g) is high, becoming nearly equal as Calcium (11.0 meq/100 g). This appears to be due to the chemical content of granosienite rocks. The main nutrient elements available are Potassium (16.0-5.0 mg/100 g) and Phosphorus (2.3-1.1 mg/100 g) content are low. Texture content is sandy loam, dominated by the sand fraction, up to 70-80% (Table 7.3). Sandy loam texture content is the main reason for the comparatively low fertility level and calcium carbonate leaching of the Dark Kastanozem soils.

Riparian zone

The Alluvial meadow-boggy (peat gleye)-cryomorphic soil formed under forb-sedge boggy meadows.

Profile DLB-03

N 51° 01' 09.8 E 100° 45' 34.6" ALT = 1665 m.

North floodplain of Dalbay river. two meters above the river water level. The surface plain, small micromounds. Forb-sedge-boggy-meadow. Canopy cover 90%.

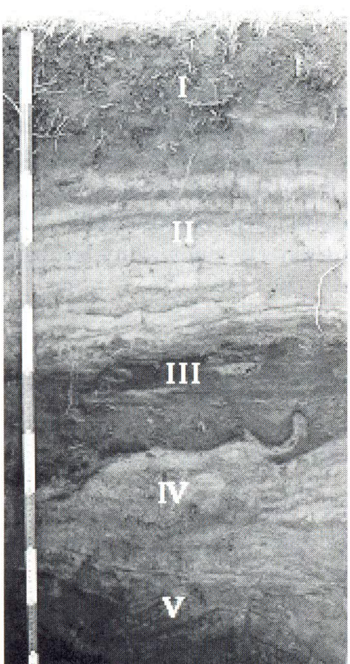
AT	0-6 cm	Moist. dark brown, root concentration and peat accumulation silt, clear transition by roots

A	6-25	Wet, dark brown, silt, many of roots, peat, small crumb structured, clear distinguish
Bg	25-45	Wet (frozen), mottled, yellowish-brown with yellow stains, layered, dark silt and yellow sandy layers, friable
ATb	45-65(70)	Dark brown, buried organic horizon, fine reddish mottles, medium angular blocky and platy structured, slightly firm, many of died roots, silt, abrupt transition
BC	65(70)-80	Reddish, course sand lense, cryoturbation featured
BC	80-100	Gray brown, mottled, with many yellow red mottles, friable platy, medium sand, cryoturbation featured
C	110 cm	Gravel sandy alluvium, granite graywakke

Soil: Alluvial meadow boggy (peat gleye) cryomorphic soil with buried peat soils

Table 7.1. Soil processes related by soil properties.

Alluvial soil



Period	Soil properties	Processes	Climate	**Estimated age**
I	Muck peat	Peat muck accumulation	Temperate cold	Recent
II	Sand silt layers	Fluvial silt deposition Aeolian sand accumulation	Cold dry	Little Ice Age
III	Buried peat soil	Peat accumulation Cryoturbation Redox concentration	Temperate wet	Holocene optimum
IV	Reddish (Iron oxide) course sand lens	Aeolian sand accumulation	Dry windy	Early Holocene
V	Reddish gray medium sand	Aeolian sand accumulation and Fluvial silt deposition	Dry	End of LGM
VI	Sandy gravel	Intensive fluvial activity, Gravel accumulation	Very wet cold	Last Glacial Maximum

Dalbay valley is characterized by a very wide floodplain 0.5-1.0 km. The floodplain soil cover is complicated, mainly dominated by alluvial meadow-boggy soil, in depressions usually soils of alluvial boggy-cryomorphic soils develop. Profile No. DLB-03 was established on the high places nearby river channels or riparian parts. Alluvial meadow-boggy (peat gleye) cryomorphic soil characterized by a 25 cm thick peat muck humus layer, down between 25-45 cm stratified silt and clay layers with gleyic properties. In the 45-65 cm depths occurred a buried soil horizon, more dark colored than the upper organic horizon. Reddish iron oxide sandy lens with cryoturbation features are layered at depths of 65-80 cm. From 110 cm and downward begins sandy gravel alluvium. By the morphological features of this profile it is possible to distinguish different stages of soil development related to climate conditions or precipitation regimes (Table 7.1). the age of the buried peat soils is estimated as a Mid-Holocene time, with soil-forming processes dominating. Radiocarbon dating of the presumably middle parts of these layers showed them to be of Middle Holocene age (Borsog Gol - 4510 +/- 40 BP) Krivonogov 2004).

There is high organic content in top soils up to 13.79%, but it decreases downward. As a result of the high organic content, exchangeable Calcium is very high (39.4 meq/100 g), Magnesium is not as high, Potassium and Phosphorus are comparatively high only in the top soils (Table 7.2). The soil reaction is neutral (pH = 6.67-7.04). Very clear gleyic properties especially below 25 cm, an abundance of reddish iron oxides in mid and lower parts of profiles is evidence of water saturation.

North-lower slope

Cryomorphic peat (Histosol) soil formed under moss-sedge meadow-boggy vegetation.

Profile DLB-04

N 51° 00' 52.5" E 100° 45' 34.5" ALT = 1676 m a.s.l..

North-facing slope profile was established 500-600 meter north of the forest boundary, slo-pe inclination 2-3o, surface with cryomorphic micromounds. On the surface there is a 2 cm thick moss cover. Shrub-sedge-moss swamp.

0-2 cm	Moss cover
T 2-7 cm	Wet, Dark brown, peat, undecayed plant residues, transition clear by color
Tg 7-20	Wet, Gray brown with fine reddish mottling, root concentrated, undecayed plant residues, peat
Tf 20 cm	Frozen peat.

North -foot slope

Cryomorphic stony peat histosol soil.

Profile DLB-06

N 51° 00'35.5" E 100° 45' 33.25" ALT = 1691 m a.s.l..

The 200-300 meter north from forest, north lower slope 4-5° inclination, small mounds, shrub-sedge boggy meadow. Canopy cover 90%.

AO	0-6 cm	Moist. Black undecayed plant residues and moss.
AT	6-20	Wet. Black (10YR 2/1), root concentrated.
B	20-30	Wet. Clay yeollowish brown (10YR 5/3), sandy loam, rock fragments (stones 20-30%)
Bf	30 cm	Frozen soil (26 May, 2004)

Soils: Cryomorphic stony peat

In the North lower slopes there are cryomorphic peat soils (Profile DLB-04). Surface features have permafrost moss covered micro-mounds. Under the moss peat has accumulated, and at 20 cm depths soil is frozen (26 May of 2004). Peat soil has a high organic content 31.17% (Table 7.2), but not very much exchangeable base or nutrient elements. Water stagnation on the frozen layers allowed washing out of water soluble nutrient elements. A second profile (DLB-06) was established on the upper slopes. Slope inclination more than lower place, but still not very steep only 4-5°. Peat thickness 20 cm, high content of organics, up to 36.05%, soil reaction slightly acid (pH = 6.62-6.46), very high exchangeable Calcium and Magnesium up to 58.0 meq/100 g, available Potassium (38 mg/100 g) and Phosphorus (4.5 mg/100 g) also high (Table 7.2). From 20 cm and downward beginning sandy-silt stony layer, organic content and other elements very low. Soil forming sediment is angular fragmented rock not of alluvial origin, covered by sandy-loam. In the north lower slopes of other valleys (Borsog, Noyon, Shagnuul) cryomorphic peat soils also formed.

North-slope mound
Sandy meadow soil near the MILTER network meteorological stations in Dalbay valley.

Profile DLB-05 (station)

N 51° 00' 52.5" E 100° 45' 24.9" ALT = 1670 m a.s.l.

Lower part of small branch valley of Dalbay, near small meteorological station. Forb-sedge meadow. Canopy cover 80-90%. Dominated by following plant species: Leymus chinensis, *Carex* sp, *Rhanunculus* sp, *Potentillia anserina*, *Taraxacum*.

The meteorological station was established on the southern slope of Dalbay valley, near a small tributary, but on a mound with 1.0-1.5 meter relative elevations, and 200 x 400 meter area. According to its vegetation this is meadow that is different than the surrounding bog swamp. The topsoil is very shallow, only 6 cm thick muck humic horizons. Elevated mound relief does not allow soil accumulation processes. Organic content is high 20.2%, calcium, magnesium, phosphorus, potassium ranges are normal (Table 7.2). The soil forming sediment is sand with reddish iron oxides and gleyic features. Between sand and muck humus horizons there are very clear two stratified thin layers. The upper (6-7 cm) is reddish silt, the lower (7-8 cm) is dark sandy loam layers. The sand accumulating condition is abruptly changed to peat soil forming conditions that continued for a very short time period. This seems to have been a cold wet period. After this time a recent soil forming period began. Similar origin as the alluvial soils (Profile DLB-03) of the riparian zone.

Table 7.2. Dalbay valley Soil chemical properties.

Profile	Strata	Soil	Horizon	Depth cm	pH	Humus %	Exchangeable cations			Available	
							Ca^{2+}	Mg^{2+}	SUM	K_2O	P_2O_5
							meq/100g			mg/100g	
DLB-01	**South upper slope**	**Dark Kastanozem stony**	A	0-12	6.72	3.34	7.2	5.5	12.7	16	2.3
			AB	12-24	6.63	2.67	8.9	4.7	13.6	7	1.9
			BC	24-35	6.55	1.24	8.4	6.0	14.4	5	1.5
			C	35-55	6.29		11.0	10.5	21.5	1	0.9
DLB-02	**South lower slope**	**Dark Kastanozem non-carbonated**	A	0 -10	6.45	3.62	15.0	5.5	20.5	13	1.3
				10-22	6.40	1.55	7.9	3.0	10.9	5	1.1
			AB	22-35	6.41	0.72	6.1	3.7	9.8	7	1.4
			BC	35-45	6.75	0.52	6.2	3.8	10.0	5	1.7
			C1	45-80	7.18	0.17	5.2	1.8	7.0	5	2.3
DLB-03	**Riparian**	**Alluvial peat gleye**	ÀT	0-6	6.67	13.79	39.4	7.2	46.6	30	4.0
			À	6-25	6.98	7.53	23.8	9.0	32.8	7	1.8
			Bg	25-45	7.07	1.17	8.8	5.0	13.8	5	1.4
			ATb	45-70	7.04	7.24	26.2	10.8	37.0	1	1.7
			BCg^{Fe}	70-80	6.79	0.04	5.2	3.4	8.6	1	1.4
DLB-04	**North lower slope**	**Cryomorphic peat**	Bg	7-20	6.19	18.43	4.8	3.6	8.4	1	0.7
DLB-05 station	**North slope mound**	**Sandy Meadow**	AT	0-6	6.20	6.45	20.2	5.6	25.8	28	3.7
			BCg	8-30	6.63	0.56	6.8	3.0	9.8	3	2.8
DLB-06	**North foot slope**	**Cryomorphic peat**	AT	6-20	6.62	36.05[1]	47.4	10.6	58.0	38	4.5
			B	20-30	6.46	0.80	5.6	3.0	8.6	3	1.7
DLB-07	**North slope solifluction**	**Sandy stony Meadow**	AO	0-8	6.37	15.15[1]	18.2	7.4	25.6	26	3.8
			B^{Fe}	8-30	6.23	1.13	7.6	2.4	10.0	3	2.3
DLB-09	**Forest north slope**	**Mountain taiga-derno**	O	4-8	5.20	18.44[1]	11.8	6.8	18.6	11	3.4
			AO	8-14	5.09	4.36	7.4	5.2	12.6	28	5.0
			B	14-20	5.59	3.73	7.0	5.4	12.4	9	2.2
			BC	25-35	5.84	1.14	4.6	2.2	6.8	5	1.8

[1] - Loss of ignition

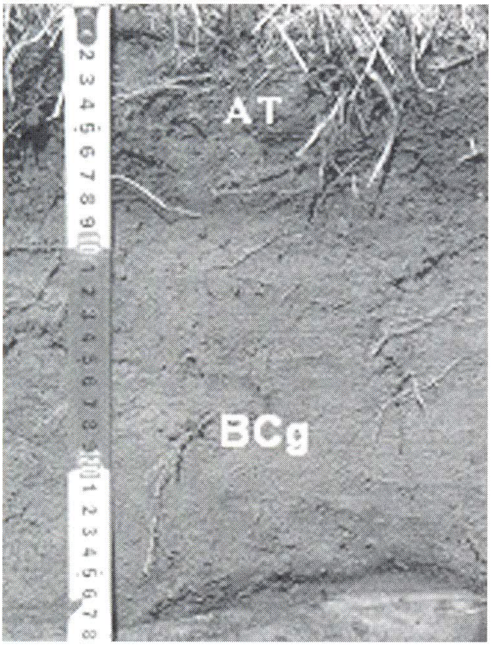


Fig. 7.9. Shallow, sandy meadow soil nearby meteorological station of Dalbay valley.

North slope area with solifluction

On the lower boundary of forests occurred solifluction flow, created 1.0-1.5 meter heights 100-200 meter widths terraces. This is down slope movement of a saturated soil mass, usually activated during very wet rainy periods. Soil (Profile DLB-07) very stony rock fragmented, more drained, therefore soil thawing is deepest in northern slopes. Within 0.5 meter depth no frozen soil on north slope, 26 May of 2004. Between rock stones sand silt mixed materials. Rock fragments consist of granite and basalts rocks. Solifluction flows are very common on the north lower forested slopes of eastern Hövsgöl lake valleys.

Profile DLB-07

N 51° 00' 31.2" E 100° 45' 33.2" ALT = 1695 m.

Solifluction terrace. 170 meter from lower forest boundary. On the surface some stones are moss covered. Forb-sedge meadow. The canopy cover is 70%.

AO	0-8 cm	Moist. Black, slity loam, rock fragments 40-50%.
B^{Fe}	8-30	Moist. Brown yeollow snady loam with reddish mottles, stone 50-60%.
BC	30-50	Granite stone, some bazalts, sand silt mixed.

Soil: Shallow, sandy and stony, iron oxide mottled meadow soil

Forest on north slopes

On the north slopes larch forest dominates with a moss covered floor. Under the forest distributed Mountain taiga-derno, Mountain taiga-cryomorphic soils. Mostly dominated Mountain taiga-derno soil, in depressions usually developed Mountain taiga-cryomorphic soil. Forest dark coloured and Podzoloic soils did not occur.

<u>Profile DLB-08</u>

N 51° 00' 11.7" E 100° 45' 33.6" ALT = 1768 m.

North upper slope, Larch forest, 8-9° inclination. *Rhododendron, Vaccinium* –soil is moss covered. Nearby site No. 4, 24 meter from banner No. 24.

	0-3 cm	Moss cover.
O	3-10	Decomposed plant residues.
AO	10-13	Slightly decomposed plant residues, root.
ABf	13-18	Frozen (26 May 2004). Dark (7.5YR 2.5/1) silt.

<u>Profile DLB-09</u>

N 51° 00'18.7" E 100° 45'36.2" ALT = 1736 m.

North lower slope Larch forest. *Vaccinium* sp., *Uliginosium*, inclination 15°.

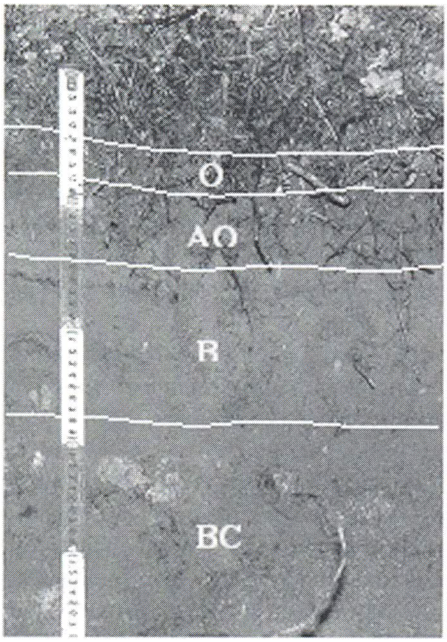


Fig. 7.10. Mountain taiga-derno soil.

The morphological features of the forest soils in the upper north slope and lower north slope are similar. On the surface moss, underneath 4-6 cm thick decomposed plant residues of larch tree needles. The organic-muck humus accumulation horizon has a 6-10 cm thickness. Underneath there is a fine sandy sediment. Soil humus content is high 18.44% but downward decreasing (Table 7.2). Soil reaction is acid (pH = 5.09-5.84), exchangeable Calcium and Magnesium low, ranges 18.6-12.4 meq/100 g. Available Potassium low between 5-28 mg/100 g, in the AO horizons increasing up to 28 mg/100g, phosphorus comparatively high, this is associateded with high organic content. Soil texture is silt-loam in top soils and downward becoming sandy loam, with the sand fraction dominant (Table 7.3). Within 0.5 meters there were no stones. By the end of May (25 May 2004) the forest soil had thawed only 15 cm.

The Mountain taiga-derno soil of Eastern-Hövsgöl soil is characterized by shallow organic-humus horizons with 10 cm thickness, acidic reaction, low nutrient elements and sandy-loam texture content. Sandy soil forming sediment is main factor of low fertility, wash out of nutrient elements from soils. The long cold season and permafrost does not allow organic residues to decompose so that humus accumulates. Soil organic content and fertile elements concentrated upper 15 cm. Tree roots also concentrate in the upper parts. Therefore, trees growing in these soils are not stable and easily fall during strong winds.

Water-physical properties

The cold climate condition and mountainous surface has a large influence on soil temperature and moisture of the eastern Hövsgöl lake area.

Temperature differences between south slope topsoil and riparian part or north lower slopes topsoil reaches 8-10o C (Fig. 7.11). By the 25-th of May, 2004, the riparian part or north lower slopes soils had thawed down to 25 cm, south lower slope soil thawed 1.0 meter, and south upper slope soils were not frozen at all. Soil temperature and moisture content have a very close inverse relationship (r2 = –0.68).

Soil moisture differences were also very big along the transects. The lowest soil moisture occurred in the south upper slopes, 8.50-10.30% of Volumetric Water Content (VWC), highest in the riparian and northern lower slopes, up to 41-71% of VWC. Permafrost in depressions forms an impermeable layer for soil water, and has an increasing peaty soil moisture content.

The south facing slope exposition, sandy loam texture content of soil, slope inclination all have a complex influence for the comparatively low soil moisture content of Dark Kastanozem soils of south lower slopes. Additional specific properties of soils of Eastern Hövsgöl lake area is, sandy sediment, which has a high water penetration property. The soil moisture of sandy loam soils is relatively evenly distributed down to profile, that indicates soil water percolation down to the profile. Probably, during summer heavy rains the full penetration of rainwater occurs through the soil profile. It is possible to conclude that a sandy loam soil texture allows a moderate water permeability regime in the Dark Kastanozem soils of the Eastern-Hövsgöl area. Moderate water penetration washes out soil Calcium Carbonate. Usually in the steppe Kastanozem soils, carbonate accumulates.

Table 7.3. Dalbay valley Soil texture content and particle density.

Profile	Soil	Horizon	Depth cm	Particle %, size mm.							Particle density g/cm³
				Sand		Silt			Clay	Physical clay	
				Coarse	Fine	Coarse	Medium	Fine			
				2-0.25	0.25-0.05	0.05-0.01	0.01-0.005	0.005-0.001	<0.001	<0.01	
DLB-01	**Dark kastanozem non-carbonated, stony**	À	0 - 12	32.7	36.9	14.7	3.9	5.6	6.2	15.7	2.65
		ÀB	12 - 24	38.1	35.2	13.4	3.4	5.2	4.7	13.3	2.68
		BC	24 - 35	32.3	41.7	14.5	2.7	3.1	5.7	11.5	2.70
		C	35 - 55	41.4	41.3	9.4	2.3	3.1	2.5	7.9	2.65
DLB-02	**Dark kastanozem non-carbonated**	À	0 -10	31.3	49.1	5.6	3.9	4.3	5.8	14.0	2.66
			10 - 22	39.0	40.4	7.8	4.6	2.5	5.7	12.8	2.64
		ÀB	22 - 35	42.3	38.8	7.5	1.9	3.2	6.3	11.4	2.62
		BC	35 - 45	31.5	52.0	6.2	3.1	1.1	6.1	10.3	2.72
		C1	45 - 80	41.1	45.1	7.3	0.6	1.4	4.5	6.5	2.73
DLB-03	**Alluvial peat gleye**	ÀT	0 - 6	3.3	31.7	36.8	5.8	10.1	12.3	28.2	1.96
		À	6 - 25	5.9	42.8	26.8	6.6	2.7	15.2	24.5	2.41
		Bg	25 - 45	17.3	65.0	8.7	0.2	0.8	8.0	9.0	2.16
DLB-04	**Cryomorphic peat (Histosol)**	Bg	7 - 20	42.4	46.3	5.6	0.3	0.8	4.6	5.7	2.64
DLB-05 station	**Meadow sandy**	AT	0 - 6	14.5	48.5	13.1	8.5	7.1	8.3	23.9	2.38
		BCg	8 - 30	20.1	60.6	10.3	2.9	0.7	5.4	9.0	2.69
DLB-06	**Meadow cryomorphic**	AT	6 - 20	19.4	23.9	23.7	9.7	8.8	14.5	33.0	1.88
		B	20 - 30	35.8	44.1	9.7	3.2	2.6	4.6	10.4	2.64
DLB-07	**Sandy stony Meadow**	AO	0 - 8	29.9	34.2	16.7	3.7	7.2	8.3	19.2	2.34
		B^{Fe}	8—30	34.3	39.5	10.0	3.6	5.4	7.2	16.2	2.75
DLB-09	**Mountain taiga-derno**	ÀO	8 - 14	24.3	32.5	19.7	5.8	8.5	9.2	23.5	2.57
		B	14 - 20	20.5	34.6	19.8	10.0	4.9	10.2	25.1	2.52
		BC	25 - 35	25.1	34.2	21.0	8.3	4.6	6.8	19.7	2.67

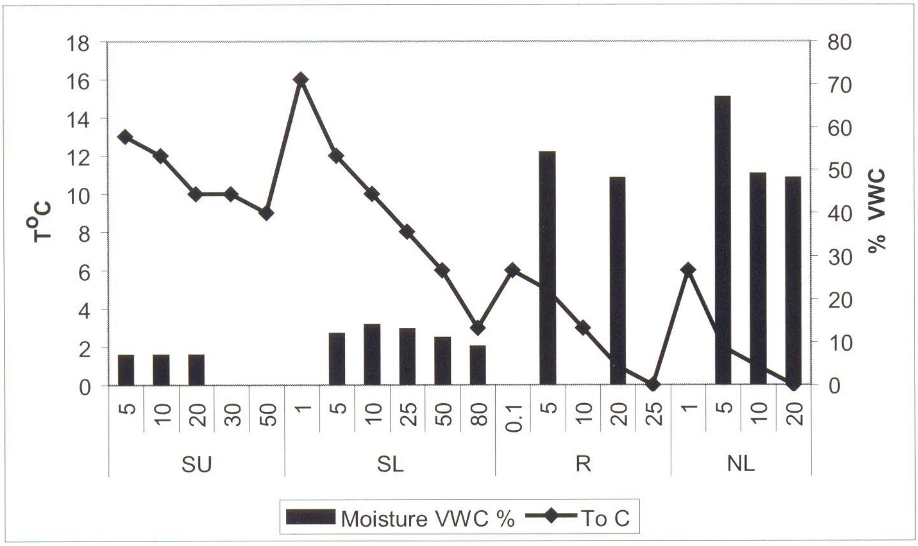


Fig. 7.11. Dalbay valley soil temperature and moisture (25 May 2004).

Soil bulk density ranges 0.27-1.55 g/cc. High organic content of Alluvial and Boggy cryomorphic soils caused low bulk density (0.47-0.27 g/cc). In the peaty soils bulk density very low 0.27 g/cc. The bulk density of the Dark Kastanozem soil of south facing slopes is 1.26-1.14 g/cc. Lower mineral horizons of south slope soils has the highest bulk density 1.45-1.55 g/cc. Particle density of south slope soils ranges from 2.70 to 2.62 g/cc; in the peaty soils it is low ranging from 1.80-2.64 g/cc (Table 7.4).

Soil porosity is relatively high (62.6-84.2%) in peaty soils, and lower (42.5-57.2%) in Dark Kastanozem soils. Water Holding Capacity (WHC) ranges from 50.24-79.29% of Volumetric Water Content. In the low mineralized, peaty soils of the riparian zone and north-facing lower slopes marked high level of Porosity (82.2-85.0%) and WHC (67.3-75.8%). Sandy textured south-facing slopes Dark Kastanozem soils have low values of soil moisture and WHC. Soil moisture content of Alluvial meadow-boggy and cryomorphic peaty soils is nearly the same as the WHC, in other words this soil is saturated by water. Permafrost and the lower position of this soil is a main factor in the stagnation of waters on top soils.

Conclusions

The area surrounding Lake Hövsgöl is dominated by mountain soils. The top part of the mountains, above the forest line (2200 meter a.s.l. south-facing slopes, 2100 meter a.s.l. in north-facing slopes) are distributed Mountain tundra and Mountain meadow soils. These soils formed under dryad-lichen, kobresia-lichen-dryad and sedge-lichen associations. Characterized by stony short profiles, accumulation of decomposed plant residues and

Table 7.4. Dalbay valley Soil physical properties.

Profile	Strata	Horizon	Depth cm	Particle density g/cm³	Bulk density g/cm³	Porosity %	Water holding (WHC) %	Soil moisture (VWC) %	T °C
								25/May, 2004	
DLB-01	**SU**	A	0-12	2.65	1.26	52.3	41.6	8.6	12
		AB	12-24	2.68	1.41	47.3	30.5	9.0	10
		BC	24-35	2.70	1.55	42.5	27.5	10.3	10
DLB-02	**SL**	A	0-10	2.66	1.14	57.2	40.2	9.0	15
			10-22	2.64	1.43	45.8	35.5	12.2	10
		AB	22-35	2.62	1.45	44.8	33.9	12.7	8
		BC	35-45	-	-	-	-	11.0	6
		C1	45-80	-	-	-	-	9.0	3
DLB-03(a)	**R**	AT	0-6	2.65	0.47	82.2	67.3	42.1	5
		A	6-25	2.76	1.02	63.0	49.2	41.7	1
DLB-04	**NL**	T (h)	0-8	1.80	0.27	85.0	75.8	71.8	4
		Bg	10-20	2.64	1.48	44.0	41.2	41.4	0

peat's. There are very clear cryoturbation processes and cryogenic sorting of materials. Forest soils are distributed between 1800-2200 meters on south slopes, 1900-2100 meter on north slopes under larch (*Larix sibirica*) forests with moss and moss-bush associations. In south slopes under forb-grass vegetations formed Mountain Dark Kastanozem soil. In eastern Hövsgöl areas non-carbonated Kastanozem soil are distributed on the sandy sediments. In north lower slopes Chernozem or Cryomorphic boggy soils occur. Valley bottoms have Meadow and Boggy cryomorphic soils.

The soil cover of the Western and Eastern shore areas of Hövsgöl lake are different. In Western parts more wide spread out high mountain soils: Mountain tundra and Mountain meadow. Soils of this part especially Horidil Saridag mountain areas characterized by high carbonate contents result of calcite, dolomite rocks. Even, forest soil has carbonate content. Soil cover of Eastern part of Hövsgöl lake area complicated due of mountainous feature, exposition differences, permafrost influence, taiga-forest and rock sediments. Comparing with Western parts in Eastern parts not very much High mountain soils, due of domination of low mountains. Soils of eastern parts of Hövsgöl lake characterized by loamy-sandy texture content due of wide distribution of sandy sediment. Light texture content defined soils, more fragile or sensitive for erosion and deflation.

The Dark Kastanozem soils of the eastern Hövsgöl area are characterized by medium fertility level: thickness of humus layer ranges from 25-35 cm (average 30 cm), with humus content 1.5-3.5% (average 2.3%), exchangeable Ca 7.2-15.0 meq/100 g, Mg 3.0-10.5 meq/100 g, available phosphorus 1.1-2.3 mg/100 g, and potassium 5.0-16.0/100 g.

The texture content is sandy loam, dominated sand fraction up to 70-80%. Sandy loam texture content is the main reason of comparatively low fertility level and calcium carbonate leaching of Dark Kastanozem soils.

The floodplain (Riparian zone) soil cover is complicated, mainly dominated by Alluvial meadow-boggy (peat gleye) soil, in depressions usually developed Alluvial boggy-cryomorphic soil. Alluvial meadow-boggy (peat gleye) cryomorphic soil is characterized by 25 cm thick peat muck humus layers, downward stratified gleyic silt, clay layers, buried peat soil and sandy-gravel alluvium. The high organic content in topsoils is up to 13.79%, soil nutrient elements are also high, very clear gleyic properties, redox accumulation in mid and low parts of profile.

In the North lower slopes are distributed cryomorphic peat soils. Under moss cover accumulated 20-40 cm thick peat with high organic contents up to 31.17-36.05%. Long cold season and permafrost does not allow more thick peat accumulations. In the north lower slopes other valleys (Borsog, Noyon, Shagnuul) also formed cryomorphic peat soils.

Temperature differences between south-facing slope topsoil and riparian part or north-facing lower slope's topsoil reach 8-10 °C (25 May 2004); the riparian part or north-facing lower slopes soil is thawed down to 25 cm; whereas, the south-facing lower slope soil is thawed 1.0 meter, and the south-facing upper slope soil is without permafrost. The soil temperature and moisture have a very close inverse relationship ($r^2 = -0.68$). The soil bulk density ranges from 0.27-1.55 g/cc. High organic content of Alluvial and Boggy cryomorphic soils is associated with low bulk density (0.47-0.27 g/cc). Dark Kastanozem soils of south-facing slopes bulk density is 1.26-1.14 g/cc. Soil porosity relatively high (62.6-84.2%) in peaty soils, and lower (42.5-57.2%) in Dark Kastanozem soils. Water Holding Capacity (WHC) ranges 50.24-79.29% of VWC (Volumetric Water Content), high in peaty soils of

Riparian zone and North lower slopes. Soil moisture content of alluvial meadow-boggy and cryomorphic peaty soils nearly same as WHC; in other words, this soil is saturated by water. The presence of permafrost and the lower position of this soil is a main factor of stagnation of waters in topsoils.

References

Batjargal B., 1976. "Soils of Huvsgul mountain" Autoreferat dissertation. Irkutsk.

Batkhishig O., 2001. Reports of Hovsgol expedition, 2001. [manuscript in Mongolian]

Batkhishig O., 2004. Soil Chemistry. 2004 ANNUAL REPORT. 'The Dynamics of Biodiversity Loss and Permafrost Thaw in Lake HÖVSGÖL National Park, Mongolia (GEF-MSP Grant No.TF028988) A Project of the Geoecology Institute, Mongolian Academy of Sciences., in Goulden, C.E. (Edit.), 2004. Ulaanbaatar, Mongolia. pp. 363-375.

Bespalov N.D., 1951. The Soils of Mongolian Peoples Republic. Moscow. [in Russian]

Brady, Nyle C. & Ray R. Well., 2002. The Nature and Properties of Soils. 13th Edition, New Jersey, USA

Dorjgotov, D, 2003. "Soils of Mongolia" UB 2003. [In Mongolian]

Dorjgotov D. & D. Batbayar, 1986. "Soil Classification of Mongolia" UB. [In Mongolian]

Dorjgotov D.S., V. Maximovich 1984. Vertical belt type of zonation territory. *In: The Soil cover and Soil of Mongolia*. Edited by Gerasimov I.P, Nogina N.A. Nauka. M., p 79. [In Russian]

Kozhova O.M., O. Shagdarsuren, A. Dashdorj & N. Sodnom (eds). 1989. Atlas of Lake Hövsgöl. Cartographic Ministry of USSR, Moscow, 118 pp. [In Russian].

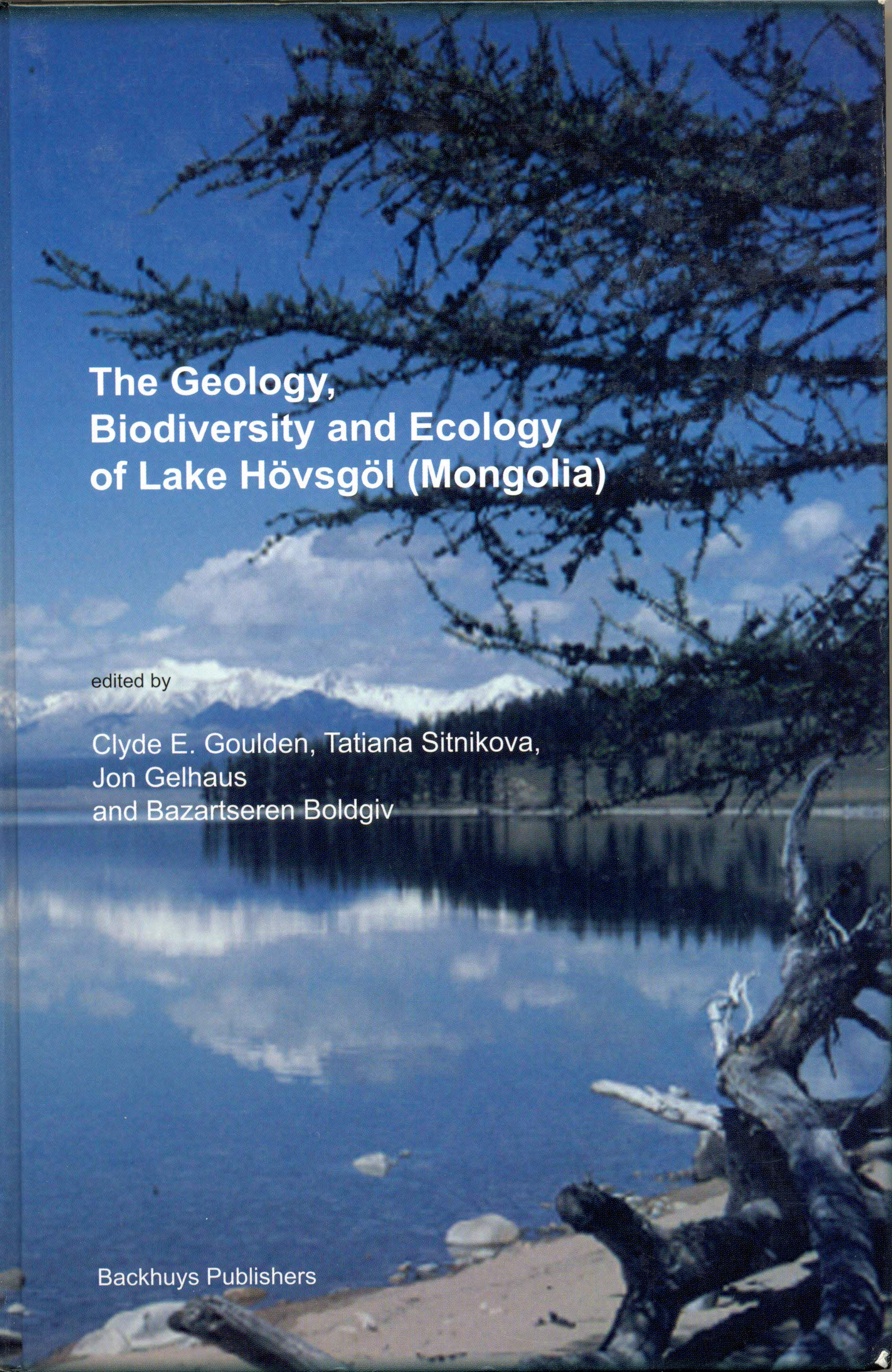
Krivonogov & Sergey K. 2003. Levels of the Baikal and Hövsgöl Lakes in Holocene and pre-Holocene time. *United Institute of Geology, Geophysics and Mineralogy SB RAS, Novosibirsk, RUSSIA*.

Martynov, V.P., P.K. Ivelsky, B. Batjargal & A.S. Martynova 1973. Soil cover of Hövsgöl mountain region, p 83, *In*: "Natural Conditions and resources of the Hövsgöl Region." Trudy of Soviet-Mongolian complex Expedition., Irkutsk – Ulan Bator.

Nogina N.A. & Dorjgotov D., General characteristics of soil-bioclimatical regions. *In: Soil cover and soil of Mongolia*. Edited by Gerasimov I.P., Nogina N.A., Nauka. M., 1984. p 64-66. [In Russian]

Ogorodnicov A.V., 1984. Mountain forest soils of Mongolia. Novosibirsk. *In: Soil cover and soil of Mongolia*, Nauka. 1984

Spaargaren O.C. (Edit.), 1994. World Reference Base for Soil Resources. Wageningen/Rome, 1994.



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