Late Pleistocence and Holocence environmental changes recorded in the terrestrial sediments and landforms of Eastern Siberia and North Mongolia

Proceedings: International Symposium of the Kanazawa University 21st-Century COE Program Vol. 1 (2003)
Edited by Naoto KAMATA

Late Pleistocene and Holocene environmental changes recorded in the terrestrial sediments and landforms of Eastern Siberia and Northern Mongolia.

Sergey K. KRIVONOGOV
United Institute of Geology, Geophysics and Mineralogy SB RAS, Academician Koptug Avenue, 3, 630090, Novosibirsk, RUSSIA
Hikaru TAKAHARA
Graduate school of Agriculture, Kyoto Prefectural University, Kyoto 606-8522, JAPAN

Abstract. Environmental changes of the Late Pleistocene and the Holocene are well-recorded in the terrestrial sediments, accumulated in the depressions of the Baikal rift zone. This article briefly describes peculiarities of their geological structure and shows the most general regularities, important for the reconstructions of environments.

I. Introduction

The Baikal rift depressions (Fig. 1) have the most complete sequences of the Late Pleistocene and the Holocene sediments in Eastern Siberia and Northern Mongolia. Long sequences of lacustrine sediments were accumulated in the deep permanent lakes (Baikal and Hovsgol), and shorter ones were deposited in the temporarily dammed lakes of the Darhad, Muya, and Chara depressions. Different types of terrestrial deposits occur in the non-lacustrine depressions (Upper Angara, Barguzin, and Tunka), and around the Baikal and Hovsgol. Steady sinking of all the depression bottoms caused the big thickness of the sediments, and their fast bury. This fact is very important for us: surface sediments and accumulative landforms of non-lacustrine basins are of the Late Pleistocene and the Holocene age, with few exceptions.

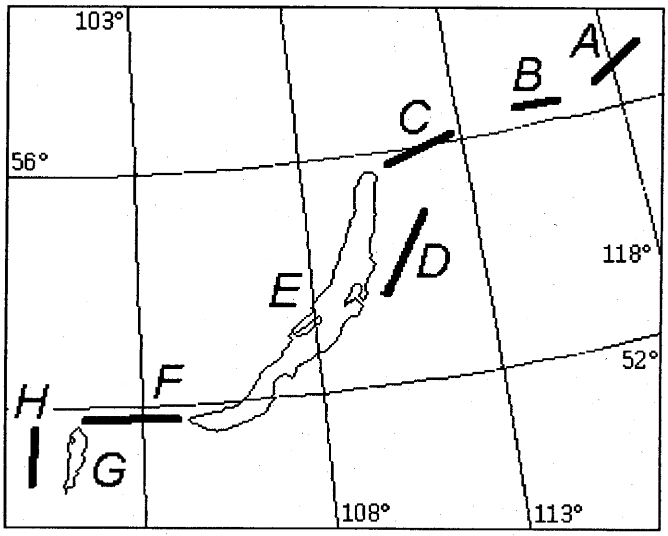

Fig. 1. Depressions of the Baikal rift zone. *A-* Chara, *B-* Muya-Kuanda, *C-* Upper Angara, *D-* Barguzin, *E-* Lake Baikal, *F-* Tunka valley, *G-* Lake Hovsgol, *H-* Darhad.

The considering time limit (last 50-70 Ka BP) correspond to single tectonic phase. There were no dramatic rebuilds of tectonic structures (except the neotectonic ones) which could noticeably change the drainage network or the sedimentation pattern.

Surface sediments are well-exposed in those depressions. Good correlation between the sediments and the landforms allows us to estimate their origin more confidently, and this is one more advantage of the geological study of the area.

This territory presents a wide range of paleoenvironments, from glacial to desert ones, and their changes are well-recorded in the sediments and relief. The territory extends more than one thousand km from the north to the south, and crosses a big range of climatic zones. Zonation had influence on the sedimentation processes and spatial differences of paleoenvironments, and this is also geologically recorded.

In this article we briefly describe the most important peculiarities of geological structure of these depressions in order to find some general regularities, and to show their environmental contents.

II. Geological features

A. Chara depression

This northernmost part of the area under investigation is characterized by wide distribution of the glacial sediment complex (Fig. 2). Well-preserved moraines up to 200 m high situate in front of the large trough valleys of the main tributaries of the Chara River. The rest of the depression bottom is occupied by fluvioglacial sediments of merged cones (fans) and outwash plains. This glacial complex has the Sartan age estimated by geomorphologic correlations and by radiometric dates. The radiocarbon date of 38,270+/-870 BP (LU-997) was obtained at the depth of 54 m [1] from the sediments underlying moraine. Unfortunately, date of 34,700+_150 BP (IM-803) [2] has no correlation with the moraines.

Varve sediments of the ice-dammed lake correspond to the maximum of the Sartan glaciation; they are buried in the northern and central parts of the Chara depression [3]. Sandy outwash occupies the lowermost northern part of the Chara valley and corresponds to the final stages of the deglaciation within the Sartan time interval.

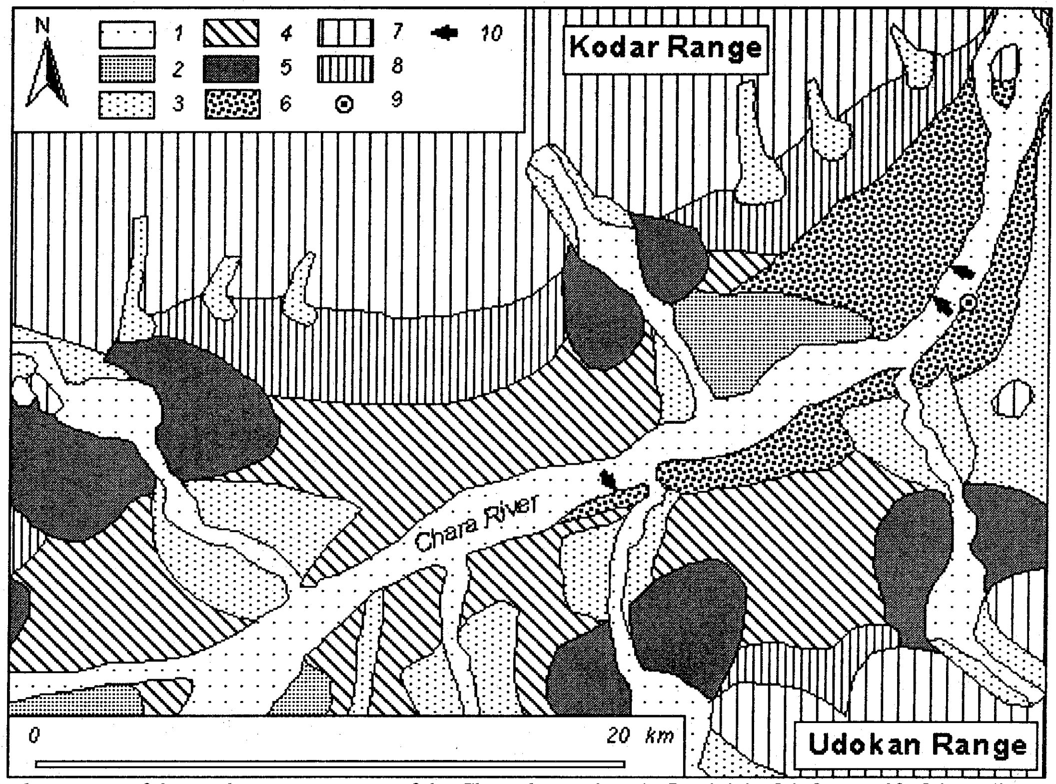

Fig. 2. Geological structure of the northern-eastern part of the Chara depression. 1- floodplain Q4; 2- massif of the eolian sands Q3/4; 3- Late Glacial fluvial terraces and cones Q3/4; 4- sloped plains, composed from merged pebble-and-boulder fans of the Sartan glaciation maximum Q3/4; 5- end moraines of the Sartan glaciation Q3/4; 6- sandy outwash of the deglaciation stage Q3/4' 7- Kodar and Udokan Ranges, and blocks of rocks in the bottom of the depression; 8- colluvial piedmonts Q; 9- Chapo-Ologo Village; 10 – outcrops with radiocarbon dates.

Several radiocarbon dates indicate the stop of fluvioglacial activity in the outwash field, and appearance of forest vegetation and soils [4], [5]: 12,390+/-75 BP (SOAN-2830); 11,990+/-40 BP (SOAN-2829); and 10,625+/-45 BP (SOAN-2828).

Four vast eolian massifs occupy the central part of the depression. The largest one, named "Sands", has dimension of 15 km, and the maximum sediment thickness is about 200 m. This massif has a 'living' central part where parabolic dunes (barchans) are being developing. Origin of these massifs has relation to the wind erosion of the fluvioglacial plains, and processes of dune formation and fluvioglacial sedimentation were simultaneous. Fluvioglacial plains were re-worked by the wind until the vegetation formation in the Holocene. However, in the Chara depression these sands have no radiometric dates.

The Holocene is presented by a wide range of sedimentation environments: rivers, stone-runs, linear dunes, bogs, and thermokarst lakes. Abundance of organic is a characteristic feature of the Holocene sedimentation in this depression, and yields good possibility for vegetation and climate reconstructions [4].

B. Muya-Kuanda depression

Glacial fans and outwashes are distributed in the western and eastern periphery of this depression. Central part is occupied by a huge sand massif, cut in the center by the Vitim River. The geology of this massif, with sediment thickness of at least 200-300 m, is not well-studied, and probably it can contain layers of different origin. Sediments of the central and northern parts of this massif, exposed along the Vitim, Kuanda, and Muya Rivers, were accumulated in the lake environment. According to [5], this was a huge lake appeared as a result of ice damming of the Vitim valley near the Oron lake. Two stages of the lake activity, recorded in the outcrop on the Muya River, are separated by non-lacustrine phase: paleosoil dated to the Karginian interstadial (40,500+/-930 BP, SOAN-2893; and 38,320+/-755 BP, SOAN-2823).

The Holocene is mainly represented by vast floodplains of the Muya, Vitim, and Kuanda Rivers. The last two are extremely swampy, probably due to the sinking of the central part of the depression.

C. Upper Angara depression

Glacial features also are not typical here; the largest moraines are distributed in the biggest tributaries of the Upper Angara River (Churo, Yanchui, and Kotera), and the smaller ones occupy slopes of the Upper Angara Range.

A big sandy massif, situated in the central part of the depression, is not well-exposed. Probably, this is a very big outwash of the Sartan age, re-worked by the wind in the Late Glacial and the Holocene. The radiocarbon dates, determining the age of the underlying strata as Karginian (27,421+/-540 BP, Ri-S_2; 30,450+/-570 BP, Ri-S_1, and 33,200+/-430 BP, Ri-S_3), were obtained in the boring hole from the depth of 100-200 m [6].

The lowermost part of the depression is occupied by extremely wide floodplain of the Upper Angara River, which can be explained by sinking of its bottom.

D. Barguzin depression

There are no traces of glacial events in the Barguzin depression, except restrictedly distributed fans with pebbles and boulders, carried from the glaciers situated higher in the mountains. Glaciers of strongly glaciated Barguzin Range, due to its asymmetry, discharged mainly to the direction of the Baikal.

Two geological features compose the bottom of the Barguzin depression: extensive floodplain and grandiose massif of eolian sands, cut by the rivers into three parts (Fig. 3). Height of this massif exceeds 150 m above the drainage basis, and the total sand thickness is even larger. Radiocarbon date of 17,400+/-1200 BP (AA-37087) was obtained from the roots in the weak soil situated approximately in the middle part of this sand layer. This date indicates the age of the main stage of the sand massifs accumulation in the Baikal region.

E. Baikal depression

A narrow stripe of the Baikal shore has an environmentally valuable geological data in the valleys and in some fault plains, such as the Tanhoi Plain in the south, and the Rel-Sludjanka Plain in the north. The Late Pleistocene and the Holocene sediments form thin cover there, contra to the situation in the non-lacustrine depressions.

End moraines locate in the mouths of the trough valleys at the different distance from the lake shore depends on shore wideness and the power of glacier. We have only indirect estimates of their age. Thus, in the north the flowtill of the Tompuda moraine ridge has the date of 39,240+/-1780 BP (SOAN-1626) [7]. The Duliha moraine in the south is older than the buried peat layer, dated to 30-46 Ka BP according to [8] and recent results. We correlate these moraines with the oldest Late Pleistocene glaciation, the Ermakovian. Traces of younger glaciers are deeper in the mountains. One of the youngest interstadials is dated in the Sneznaya River basin, the Khamar-Daban Range, to 11,200+/-100 BP (LG-77) [9].

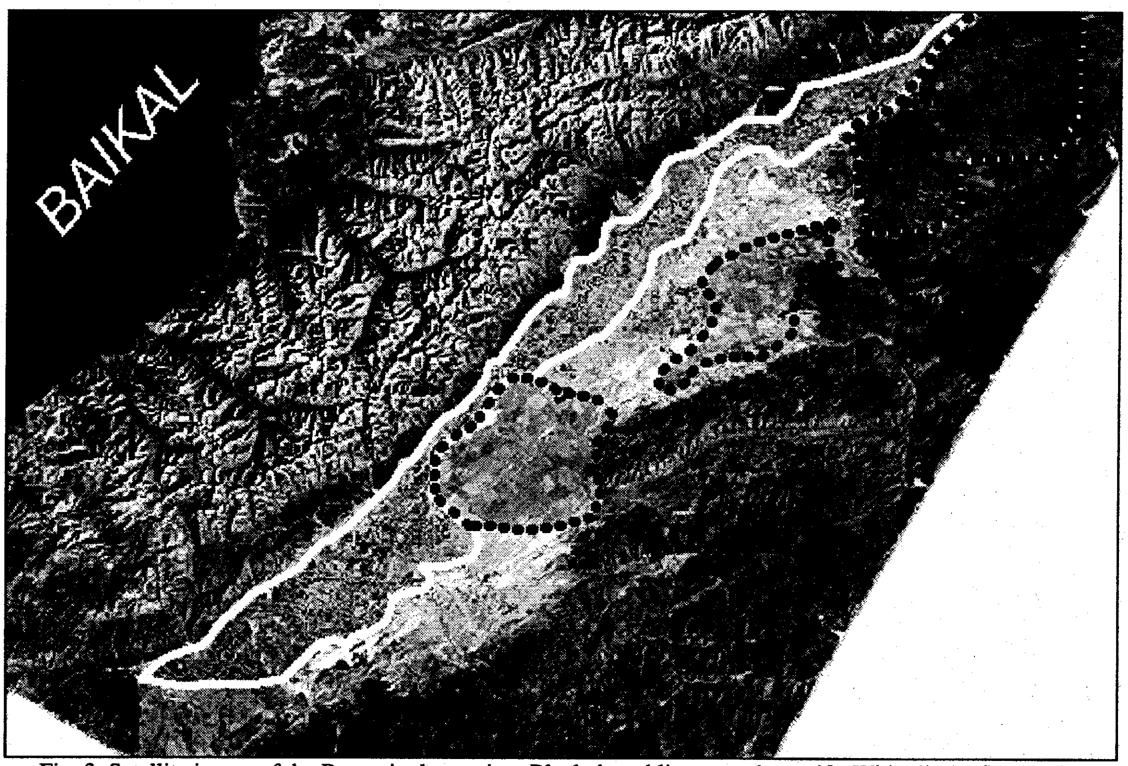

Fig. 3. Satellite image of the Barguzin depression. Black dotted line – sand massifs; White line – floodplain.

Coastal fluvial sediments of the glacial part of Late Pleistocene can be separated to older fluvioglacial cones, and younger terraces incise those cones.
We did not find lacustrine terraces of the Late Pleistocene and Holocene age around the Baikal, except the modern one. The apparent reason, discuss by the author in another article of this book, is the control of the Baikal level by the threshold of the Angara River spillway, which has been tectonically stable during at least the last 50-60 Ka BP [7], [10].

The Holocene terrestrial sediments (river, eolian, slope, and bog) have minor part in the environment of the Baikal. Nevertheless, the bogs were found as very important sources of the paleoenvironmental information [8], [11], [12], [13].

F. Tunka valley

A chain of smaller depressions along the Irkut River (Tory, Tunka, Turan, Khoitogol, and Mondy) has general name the Tunka valley. Separately they have their own peculiarities of geological structure, and here we indicate the common ones.

The valley is almost free of moraines. Only the uppermost Mondy depression is a container of the large destructed end moraine complex of the Ermakovian age. Fresher moraine occupies partially the Khoitogol depression, and their age can be correlated with the Sartan glaciation. Fans correspond to these moraines extend downstream from their fronts. Remnants of the ancient fluvioglacial forms situate in the downstream of the Big and Small Zangisan Rivers, as well as in the northern part of the Tunka depression. However, their age is not determined. The younger fans locate at the valleys near their exit from the Tunka Goltsy and Khamar-Daban Ranges.

One of the most important peculiarities of this area is the abundance of sand sediments. Sand coats dams between the depressions and forms 100-200 m high massifs in different places of the valley. Sand massifs obviously crossed the Tunka valley in two places: So-called Badary massif has his continuation near the Kyren Village, and previously it was the single massif now separated. The next massif, famous due to the Bely Yar I and II outcrops in the lower part of the Tunka depression, can be combined with the massifs at the right bank of the Irkut River. According to the dates from underlying sediments at the Bely Yar II: > 51,000 BP (LG-169), 39,500+/-1000 BP (GIN-736b), and 37,000+/-500 BP (GIN-736c) [14], [15] considered as of indefinite age, these sands were formed during the second part of the Late Pleistocene and even before that. RTL dates of 31,500+/-2300 BP (near the Kyren Village) and 50,400+/-3000 (in the lower Tunka) [16] confirm this suggestion. Structure of these sands indicates their accumulation by the wind and slope processes, accompany by the soil and permafrost ones, i. e. in the severe conditions of the Last Glacial epoch. The drainage by the Irkut River was strongly reduced at this time.

River beds of the Late Pleistocene age are preserved in some places of the valley. Some of them have age beyond the radiocarbon dating limit, like the Bely Yar II and the Tibelti River [7]. Other ones have Late Glacial age, like the Shimki outcrop: 11,040+/-70 BP (SOAN-3543). Older river terraces were washed out in the Holocene. Wide modern floodplain occupies a valuable part of the depressions, especially in the Tunka and the Tory.

G. Hovsgol depression

The Hovsgol Lake had much smaller dimensions at the Late Pleistocene then now [17], [18]. The drainage was reduced; slope and eolian processes predominated in its surrounds. Glaciers were distributed in the north and north-east in the high mountains. Only one large glacier of Ih Horoo River moved far in the depression; its end moraine is partly covered by the Hovsgol water now.

Similarly to the Irkut valley situated not so far northward over the Munku-Sardyk Range, moraines of the Hovsgol correspond to two glaciations. The larger ones are Ermakovian, and smaller ones correlate to the Sartan age.

Rivers of non-glaciated zone are very small. Slope sediments and floodplain form their valleys. Hanh Gol, the largest stream of non-glaciated area, has older fluvial deposits, buried under the covers. Their age is Karginian according to the palynological and 14C data: > 45,000 BP (SOAN-4303) and 28,070±965 BP (SOAN-4743).

Lake transgressions occurred in the warmer periods of the Late Pleistocene, and in the Holocene. Buried traces (Late Pleistocene) and the surface ones (Holocene) locate in the shores of modern bays, and in the mouths of the rivers in the eastern banks of the lake. Changes of the Hovsgol level is discussed in the author's article in this book. Transgressions, also controlled by the spillway of Egiin Gol in the southern end of the lake, could not be higher than 6 m.

H. Darhad depression

This is currently non-lacustrine depression, the satellite of the Hovsgol. The Shishhig Gol (headwaters of Yenisei River) drains this depression. A huge dammed lake with depth of about 190 m occupied this depression probably during the whole glacial part of the Late Pleistocene. The dam resulted from the fan activity of the Tengissiin Gol, the tributary of Shishhid Gol River, decreased stepwise which is presented now by the 'terraces' of embedded fans, and in the tens of paleoshoreline strips on the mountain slopes surrounding the depression (Fig. 4).

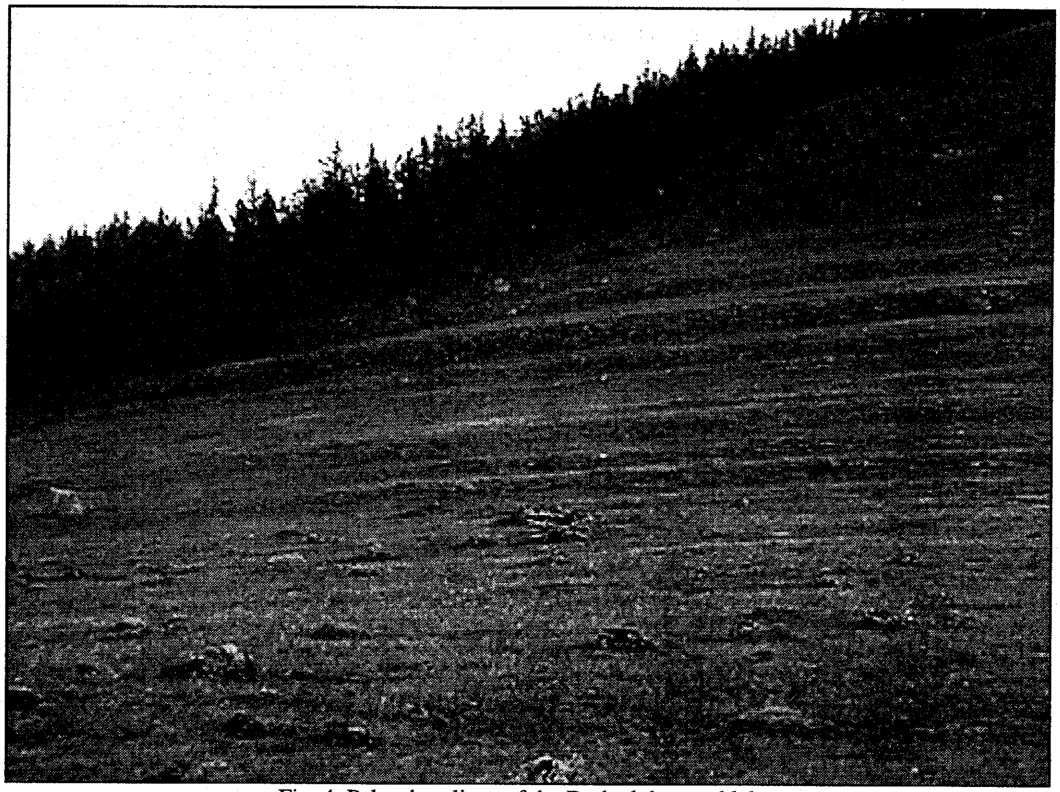

Fig. 4. Paleoshorelines of the Darhad dammed lake.

III. Regularities

Problems of definition and spatial distribution of the geological objects discuss in this section, as well as environmental change regularities.

A. Glacial and fluvioglacial features

Two glaciations have been recorded in the sediments and landforms of this region. The older glaciation had larger extents then the younger one. However, there are no radiometric determinations except two TL dates of 70,000+/-11,000 BP and 72,000+/-9000 BP, obtained from the Mondy moraine in the Tunka valley [16].

Position of these two moraines varies from the north to the south. In the Chara depression, the moraines are visible in modern relief, and they are of the Sartan age. Larger Ermakovian morains are buried underneath the Sartan ones [3]. Both the Mondy and the Hovsgol depressions have two moraines, and their relation shows a very big difference in the size and energy between two glaciations (Fig. 5). The most problematic issue is the age of moraines around the Baikal. The latest results, shown above, convince us about their Ermakovian age.

Both Ermakovian and Sartan glaciations naturally change their parameters, such as the amount of ice, the snowline position, and elevation of moraines, from the north to the south in accordance with the climatic model.

Fluvioglacial features, corresponding to moraines, have similar patterns. The amount of water, carried off from the glaciers, decreased from the north to the south. This regularity is well-seen in the distribution of the outwash deposits typical for the northern depressions.

B. Eolian and slope features

Huge eolian massifs are very characteristic features of the Baikal rift zone depressions. The big thickness of the sand deposits is a result of the wind structure in the glaciated areas, and the abundance of sand produced by the glaciers and frost weathering. Probably, these massifs appeared in some places with specific wind interference, and in other places protected from erosion. The amount of sand in the depressions with drier environment (Barguzin and Tunka) is larger than in those with more water resources. Nevertheless, the northernmost part of the Chara depression also has huge sand massifs, which obviously is the result of abundance of sand in the deposits of the fluvioglacial plains.

Formation of these massifs occurred during the Last Glaciation in the northern part of the region, and they could be accumulated even in the previous glaciation in the southern part.

Fig. 5. Reconstructed extents of the Late Pleistocene glaciers in the southern slope of the Munku-Sardyk Range. 1- Ermakovian, and 2- Sartan glaciers; 3- Hovsgol Lake in its current position; 4- rivers.

Eolian massifs are not typical for depressions occupied by lakes, both permanent and temporary, because of assimilation of the sand material by the lakes, whereas smaller dune fields exist there. Eolian activity of smaller scale was typical for all of these depressions in the Late Glacial time, and throughout the Holocene. The rule of their formation is presence of the sand sources.

Slope sediments of northern and southern territories have different grain patterns, due to amount of precipitation. In the north, silt component of depositing slope covers was actively carried out by the surface waters, and in the south its content in the sediments is larger due to lesser water activity. Nevertheless, toward the south we can see an increase of the eolian sand in the slope sediments. Thus, in the Tunka valley slope sand covers of eolian genesis are more typical then the covers of slope wash origin. Mixed slope-and-eolian covers are usual in the southern depressions. The Bely Yar site in the Tunka valley is the best example of such complex sediments.

C. Lacustrine features

Damming of the depressions in their lower gates caused appearance of the lakes, sometimes of very large scale. Such lakes appeared only under certain geomorphologic position. Several natural agents could cause the damming: glaciers of the tributary valleys (Chara and Muya-Kuanda), or fan sediments (Darhad). We did not see evidences of the tectonic dams, discussed previously [19]. Dammed lakes directly correspond to the glaciations.

On-shore lacustrine forms of the Baikal and the Hovsgol are of limited distribution, caused by the spillway control of their level.

D. Fluvial activity

River versa fluvioglacial: usually, this is a questionable definition of the stream sediments and terraces. We recognize the floodplain deposits as the indicator of the river beds. They have a limited distribution in the Baikal rift zone depressions, except in the floodplains. In the northern depressions we found that hyperactivity of the fluvioglacial processes did not allow the rise of the river regime. In the other places we can see a strong re-working of the older parts of the valley by the river activity, took part in the Holocene. The typical place is the Tunka valley, where we found only fragments of the Late Pleistocene terraces, 'shadowed' from the wash-out by the mountain borders between the depressions.

Wide modern floodplain, full of ox-bow lakes and bogs, is typical for the lowermost parts of the depressions, sinking or damming by the tectonic processes.

E. Holocene biogenic formation

Vegetation and soil processes were activated by the Late Glacial warming followed by the reduction of the glacial water discharge in the depressions [5]. Lakes and bogs, appeared in this period, gradually filled the depressions by organic sediments. These sediments reflect the vegetation and climatic changes since approximately 13 Ka BP [8], [11], [12], [13]. Long-living bogs are typical for the Chara and the Kuanda depressions in the north, and the best places found around the Baikal. Mongolia is free of bogs; nevertheless, the boggy soils are widely distributed in the valleys around the Hovsgol.

Acknowledgements

Author investigates this territory within the research program of the Siberian Branch of Russian Academy of Sciences since 1988. Special support by SB RAS and RFBR occurred in the last years. Close collaboration with Prof. Hikaru Takahara (Kyoto Prefectural University, Japan) and Prof. Frank Riedel (EDCA, Free University of Berlin, Germany) allowed us to obtain new geological information. Radiocarbon dating was kindly provided by Dr. Lyubov A. Orlova (Institute of Geology, Novosibirsk, Russia), Prof. Hikaru Takahara, Dr. Yaroslav V. Kuzmin (Pacific Institute of Geography, Vladivostok, Russia), and Dr. A. J. Timothy Jull (University of Arizona, Tucson, AZ, USA).

References

[1] F. I. Enikeev, T. I. Dudetskaya, "Report on the hydrogeological survey of 1:200,000 scale by the 'Valley' party on the territory of the BAR in 1975-1985," unpublished.

[2] V. V. Kostukevich, G. P. Degtyareva, I. E. Ivanov, S. A. Nesterenko, "Radiocarbon dates of the Permafrost Institute of SB AN USSR," *Bulletin of the Commission on the Quaternary period investigation,* No. 47, pp. 145-152, 1977.

[3] F. I. Enikeev, "Sedimentation environment of the Chara depression in the Late Pleistocene, the Holocene," *Questions of geology and metallogeny of the Chita region,* Moscow, Ministry of geology of RSFSR, pp. 37-43, 1986.

[4] S. K. Krivonogov, E. V. Bezrukova, "On the history of sedimentation, vegetation and climate of Upper Chara depression in the end of Late Pleistocene and the Holocene," *Geology and geophysics,* No. 10-11, pp. 226-238, 1993.

[5] S. K. Krivonogov, "Remains of buried forests in the Late Pleistocene sediments of Siberia," *News of paleontology and stratigraphy*, Vol. 4, (appendix for Russian geology and geophysics, 42), pp. 143-152, 2001.

[6] A. A. Kulchitsky, N. V. Kulagina, A. G. Trofimov, G. P. Chernyaeva, "Yanchui group of the Upper Pleistocene in the Northern Pribaikalie," *Geology and minerals of Eastern Siberia,* Irkutsk University, pp. 61-62, 1993.

[7] V. D. Mats, G. F. Ufimtsev, and M. M. Mandelbaum, *The Baikal basin in the Cenozoic: structure and geologic history,* Novosibirsk, SB RAS Press, Branch "GEO", 2001.

[8] E. V. Bezrukova, S. K. Krivonogov, H. Takahara, K. E. Vershinin, N. Miyoshi, T. Nakamura, A. A. Abzaeva, Y. Morita, K. Kavamuro, Y. Shinomiya, S. M. Krapivina, "Record of the Late Pleistocene and Holocene history of south-east bank of the Baikal lake by data of the Dulikha bore hole," *Problems of reconstruction of climate and environments in the Holocene and the Pleistocene of Siberia,* Novosibirsk, Edition of SB RAS, pp. 36-47, 2000.

[9] V. P. Badinova, V. A. Zubakov, E. M. Itsikson, Yu. P. Rudnev, "Radiocarbon dates of the VSEGEI laboratory (LG)," *Bulletin of the Commission on the Quaternary period investigation,* No. 45, pp. 154-167, 1976.

[10] V. D. Mats, S. Fujii, K. Mashiko, E. Yu. Osipov, I. M. Efimova, A. V. Klimansky, "Changes in the Lake Baikal levels and runoff direction in the Quaternary period," *Lake Baikal. A mirror in time and space for understanding Global Change Processes.* Elsevier, pp. 108-118, 2000.

[11] H. Takahara, S. K. Krivonogov, E. V. Bezrukova, N. Miyoshi, Y. Morita, T. Nakamura, Y. Hase, Y. Shinomiya, K. Kawamuro, "Vegetation history of the southeastern and eastern coasts of Lake Baikal from bog sediments since the last interstade," *Lake Baikal. A mirror in time and space for understanding Global Change Processes.* Elsevier, pp. 108-118, 2000.

[12] E. V. Bezrukova, S. K. Krivonogov, H. Takahara, N. Miyoshi, Y. Morita, A. Takehara, X. Noi, T. Shinomiya, "Changes of the environments, vegetation and climate in the Transbaikalia during the Late Pleistocene and the Holocene," Problems of reconstruction of climate and environments in the Holocene and the Pleistocene of Siberia, Novosibirsk, Edition of SB RAS, pp. 46-50, 1998.

[13] E. V. Bezrukova, S. K. Krivonogov, H. Takahara, A. A. Abzaeva, K. E. Vershinin, N. Miyoshi, T. Nakamura, Y. Morita, K. Kavamuro, Y. Shinomiya, S. M. Krapivina, "Reconstruction of the landscape and climate conditions of the eastern shore of the Baikal in the Holocene resulted from the complex investigation of the "Arangatui" bore hole," *Main regularities of global and regional changes of climate and environments in the Late Cenozoic of Siberia,* Novosibirsk, Edition of SB RAS, pp. 36-47, 2002.

[14] N. V. Kind, L. D. Sulerjitsky, S. N. Vinogradiva, A. L. Ryabinin, V. S. Forova, "Radiocarbon dates of GIN AN USSR. Report VIII," *Bulletin of the Commission on the Quaternary period investigation,* No. 46, pp. 169-185, 1976.

[15] V. P. Badinova, V. A. Zubakov, E. M. Itsikson, E. V. Cherepanov, "Radiocarbon dates of the VSEGEI laboratory (Index LG). List IV," *Bulletin of the Commission on the Quaternary period investigation,* No. 48, pp. 208-212, 1978.

[16] A. A. Shchetnikov, *Structure of relief and neotectonics of the Tunka rift*, Abstracts of PhD thesis, Irkutsk, 2001.

[17] A. Fedotov, E. Chapron, T. Pouls, K. De Rycker, R. Hus, M. Grachev, M. De Batist, "The first reflection seismic profiles from Lake Khubsugul: preliminary results," *2001 International workshop for the Baikal & Hovsgol drilling project in Ulaanbaata,. Abstracts,* Ulaanbaatar, Mongolia, pp. 10-11, 2001.

[18] S. K. Krivonogov, E. V. Bezrukova, H. Takahara, F. Riedel, "Late Pleistocene and Holocene of the Lake Hovsgol: state and perspectives of investigation," *2001 International workshop for the Baikal & Hovsgol drilling project in Ulaanbaata,. Abstracts,* Ulaanbaatar, Mongolia, pp. 16-17, 2001.

[19] T. M. Skovitina, *Neotectonics and dammed lakes of the Baikal rift zone,* Abstracts of PhD thesis, Irkutsk, 2002.