Postglacial tectonics of the Baikal rift

K. G. Levi[1], V. D. Mats[2], Yu. S. Kusner[3], P. G. Kirillov[1], A. M. Alakshin[4], S. V. Tolstov[3], E. Yu. Osipov[2], I. M. Efimova[2], S. Bak[5]

[1]Institute of the Earth's Crust, Siberian Division, Russian Academy of Sciences,
[2]Institute of Limnology, Siberian Division, Russian Academy of Sciences,
[3]Institute of Geochemistry, Siberian Division, Russian Academy of Sciences,
[4]GGP "Irkutskgeofizika",
[5]University of Potsdam, Germany

Introduction

Many phenomena related to sedimentary basins and adjoining mountainous areas of the Baikal rift zone have not been adequately interpreted, as yet. These are widespread occurrence of continental sands in rifting basins of the Baikal region, (their formation was traditionally associated with the maximum glaciation in the middle Pleistocene, but now it is considered as a stratigraphic element encompassing the whole Pleistocene and including deposits of various genetic types and various climatic phases [*Bazarov et al.,* 1982; *Logachev et al.,* 1974; *Mats,* 1987; *Olyunin,* 1961]); moraines that occur at depths of 300–400 m below the water level the Lake Baikal on its Barguzin slope, which may imply a lower lake level existing at that time [*Galkin,* 1975]; terraces on the Ushkan'i Islands, much more numerous as compared with four terraces on the lake bank [*Lamakin,* 1968] (the origin of the "superfluous" ones need be explained, but the number of shore terraces may also exceed ten, in which case they should be correlated with the terrace levels of the Bol'shoi Ushkanii Island [*Eskin et al.,* 1959]); and the unexplained presence of exotic boulders on the Olkhon and Ushkan'i Islands [*Bukharov and Fialkov,* 1996], as well as in certain eastern coastal areas of North Baikal. Also surprising are abnormally high velocities of recent vertical movements (RVM) of the Earth's surface in areas of a Pleistocene ice field [*Logachev et al.,* 1974], tectonic fractures in glacier structures, and other phenomena. On the whole, these phenomena suggest that the North Baikal region may have experienced glacioisostatic movements similar to those presently observed in Fennoscandia and on the Canadian shield. We will discuss recent geological constraints on the Baikal glaciations and neotectonic deformations consistent with glacioisostatic movements and present a numerical model of the lithosphere at the postglacial stage of its evolution in the Baikal region.

Paper No. TJE98004.

Online version of this paper was published on July 20 1998.
URL: http://eos.wdcb.rssi.ru/tjes/TJE98004/TJE98004.htm

Pleistocene Glaciation

The problem of glaciation in the Baikal region has been debated beginning from the works by V. D. Cherskii, P. N. Kropotkin, and others. *Obruchev* [1953] noted the presence of glacier structures in the Baikal region. Afterwards the presence of glaciers in the past was proven, and their dimensions and stages of their development have been established. More detailed data on these natural phenomena are reported in a number of works [*Baikal Atlas,* 1993; *Bazarov,* 1986; *Bazarov et al.,* 1982; *Kulchitskii,* 1967; *Lamakin,* 1968; *Logachev et al.,* 1974; *Salop,* 1964]. Geological and geomorphological studies revealed the existence of four glaciations, the most intense and oldest of which is the Samarovo Glaciation [*Kulchitskii,* 1967].

The maximum glaciation (300-250 ka) covered a vast territory in the Baikal region [*Logachev et al.,* 1974], but a more or less monolithic ice cap that covered the northern Baikal basin and adjacent ranges (Figures 1 and 2) is most pertinent to the purposes of our paper. The ice field was not continuous.

The underlying surface was comparatively smooth. Fragments of the end moraine belt indicate the glacier to cover an area of more than 100 000 km^2. Ice tongues descended from mountains outward, toward the areas surrounding the Baikal rift zone, and inward the North Baikal depression.

Maximum glaciation moraines existed on the western and eastern flanks of the North Baikal basin (Figure 3), and their radiocarbon ages are presented in Table 1.

On the western North Baikal coast, a buried 90-m thick moraine was drilled through at depths of 17 to 106 m below the present level of Lake Baikal [*Kulchitskii,* 1967]. To the east, the Samarovo moraines, extending into the lake water area for more than 7 km, have been traced to depths of 350–400 m. They are supposed to have formed under subaerial conditions [*Galkin,* 1975], because morphologically expressed moraines of recent

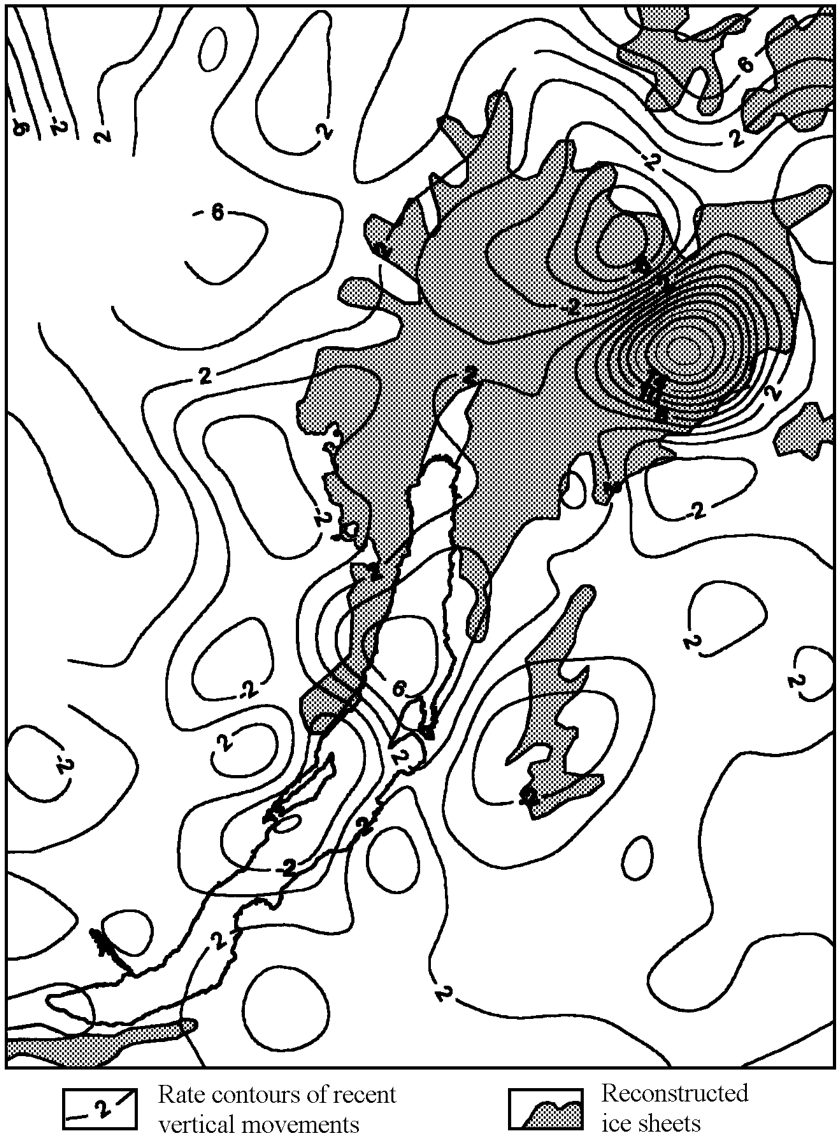

Figure 1. Map showing the rates of recent vertical movements of the Earth's surface and the reconstructed field of maximum glaciation in the Baikal region.

glaciation, developed under subaqueous conditions, are unknown. Then, the lake level considerably dropped some 300 ka.

Younger glacier structures include those of the late mid-Pleistocene (Taz stage) and early Late Pleistocene (early Ermakov stage, 80 ka and later) and have similar relationships with Baikal terraces. At greater distances from the shore zone, they form surfaces that preserve specific features of the glacier relief. In the near-shore zone, their surfaces experienced abrasion and show the plane relief of Baikal terraces. The latter are developed at levels of 150, 80, and 35–50 m. As is observed in the Tyya Promontory, in bank bluffs from the Kurla Head to Tyya River mouth, at both heads of the Frolikh Cove, in the left-hand divide area of the Biramya River near its mouth, and at several other places, intricate facial relationships characterize deposits that compose the terraces: lacustrine, glacial-lacustrine, and glacial boulder loams are overlain by lacustrine deposits and covering loam with relict lake pebble. Overall, this group of glacial deposits is characterized by close association with lake deposits. The latter include widespread frost involutions and clastic material with clasts as large as gigantic blocks (bearing obvious traces of glacial abrasion).

Thus, general synchronism has been established between glacial structures and Lake Baikal deposits (occasionally including endemic diatoms), and the moraine

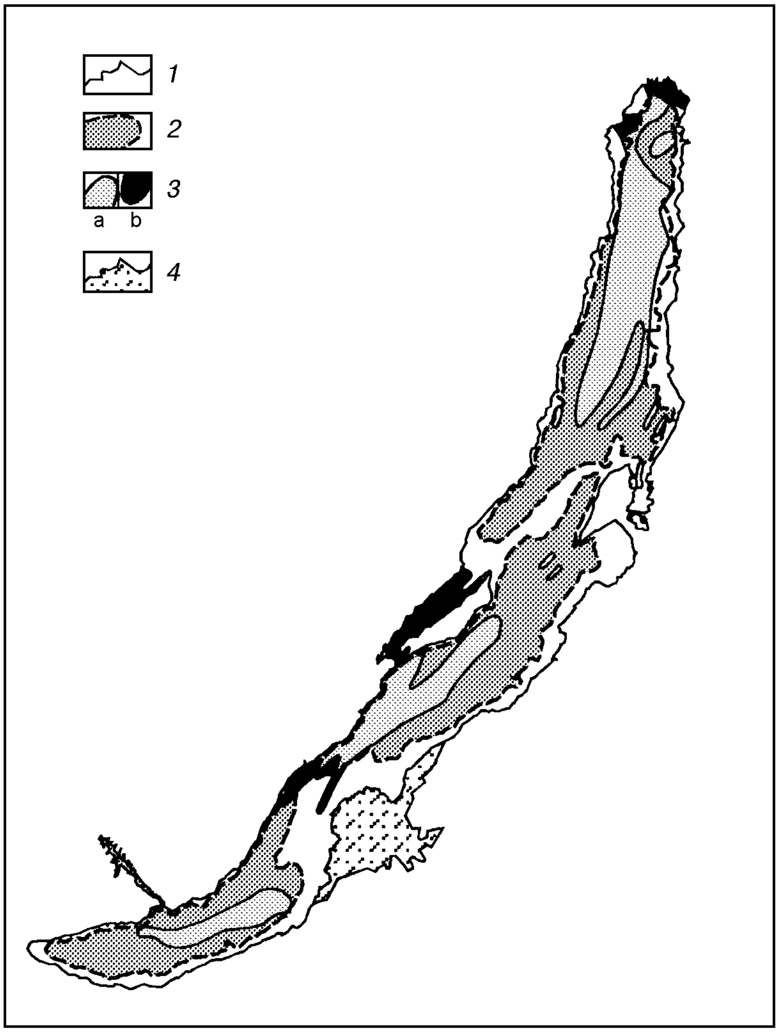

Figure 2. Schematic map showing pre-Baikal sand deposits and reconstructed lake depressions (with the use of the scheme constructed by G. S. Goldyrev in 1982): 1 - outline of the contemporary Lake Baikal basin; 2 - paleobasin outline; 3 - sand deposits comparable with the Middle Pleistocene Krivoi Yar sands (a) within and (b) outside the paleobasin contour; 4 - delta deposits of the Selenga River.

relief in the shore contact zone of Lake Baikal has been reworked as a result of abrasion. The penetration of lake Baikal facies into glacial ones appears to reflect specific relationships between the lake water and glacier tongues during the deglaciation period. The age of these formations is determined from geological and geomorphological evidence, findings of remnants of large mammal species specific to the middle Pleistocene in the section of a 80-m terrace [*Bazarov,* 1986], and radiocarbon datings ($\geq$ 57 ka) of 40-m terrace deposits, Tyya Promontory (Table 1).

Younger moraines are widely developed on the shores of North Baikal (Figure 3). Their characteristic feature is a well-preserved ensemble of bottom, side, and end moraines and fluvioglacial boulder-pebble and lake plains behind and ahead of the front of end moraines. They are evidently younger than the glacial structures associated with 30–50-m terraces; river and Baikal terraces as high as 20–25 m are leaned against or occasionally inset in the latter. The above glacial features may include two age groups: late Markov, as old as 50 ka (moraines of the Tampuda, Shegnanda, Kichera, and other rivers; a few dates are presented in Figure 3 and Table 1) and Sartan, younger than 25.88 $\pm$ 0.35 ka. The Sartan structures are mainly represented by cirque glaciers that only occasionally advanced into the Baikal shore zone.

As seen from the above data, the most important characteristic of glacial structures of the maximum glaciation is its discontinuous occurrence, weak (by far weaker

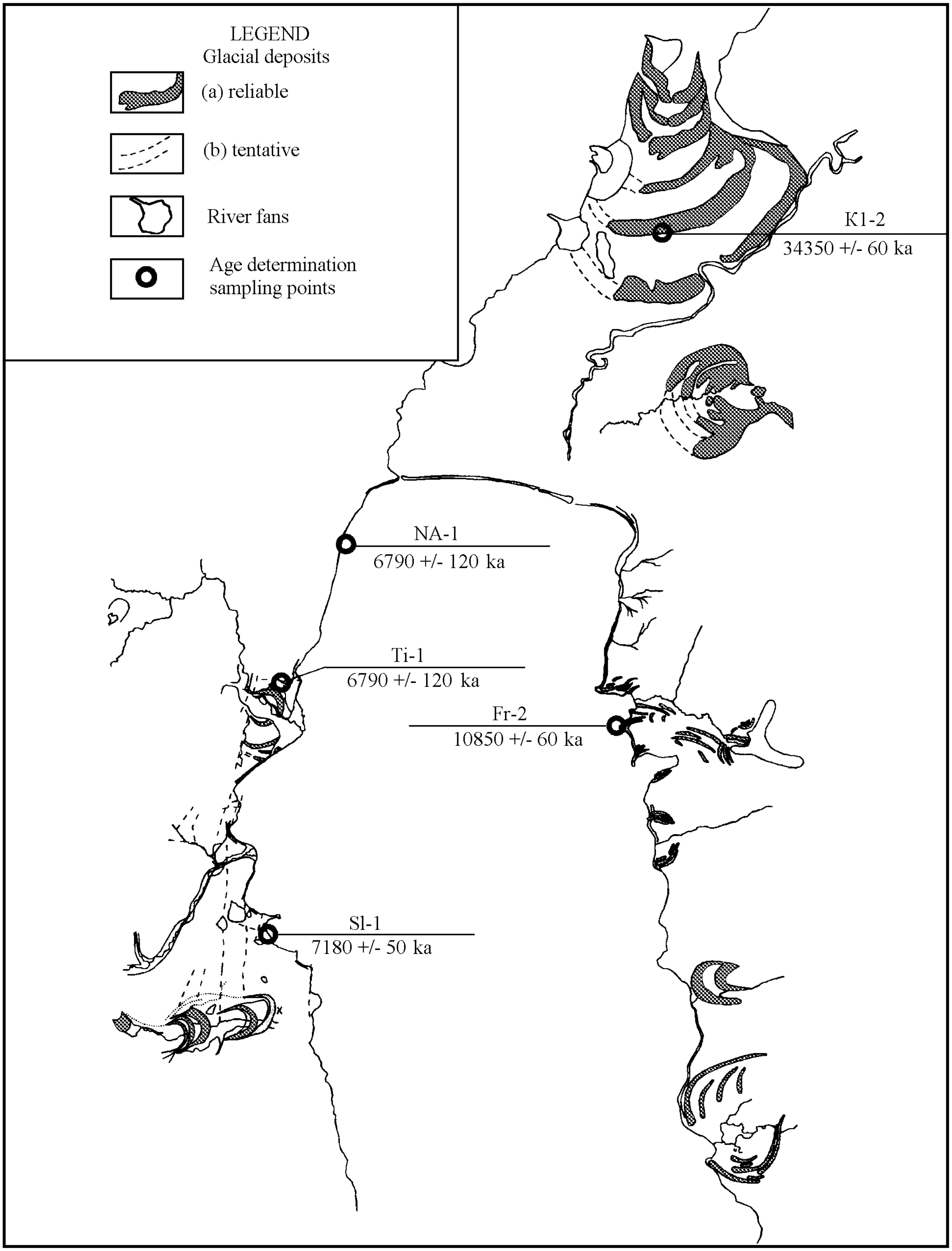

Figure 3. Schematic map showing glacier features of northern Baikal and related ages determined during the field works of 1996 and 1997.

Table 1. Radiocarbon datings of glacial and postglacial formations

Nos.	Ages	Locations and references
1	6790±120	Paleofan of the Molokon River, northern Baikal (BA 29/07 NA1) [this work]
2	7180±50	Rel-Slyudyanskoe constructional field, northern Baikal (turf overlying an ice lens; BA 05/08 SL1) [this work]
3	10850±60	Frolikh Bay, northern Baikal (BA Fr-2) [this work]
4	25880±350	A rhinoceros bone from a submoraine surface, Rel River (SOAN-289) [Mats, 1987]
5	34350±60	Moraine in the Kichera River valley, northern Baikal (BA Ki-2) [this work]
6	39240±1780	Tompinskaya moraine, Omogachan Promontory, Baikal (SOAN-1626) [Popova et al., 1989]

*BA - Beta Analitic Inc. Germany

*SOAN, Analytical laboratory, OIGGiM, Siberian Division of the Russian Academy of Sciences.

than at the postglacial stage) differentiation of the underlying surface, and occurrence of the Baikal basin moraines below the present level of the lake. The latter is difficult to explain without the assumption on a lower position of the lake water level at the Samarovo time. However, the drilling results from deep sea holes on the submarine Akademicheskii Ridge [*Kuz'min et al.,* 1997] show that this drop in the lake level may have been insufficient in order that the ridge area including the BDP-96 drillhole site at sea depths of 300-350 m emerged above sea level. The level drop was accompanied by tectonic subsidence of the lake bottom and uplift of its shores [*Dem'yanovich et al.,* 1988; *Logachev et al.,* 1974; *Obruchev,* 1953; *Salop,* 1964]. Post-maximum glacial features in upland cis-Baikal areas occur in deep (to 1000 m) valleys cutting the exaration surface of maximum glaciation, which implies a considerable tectonic uplift postdating the maximum. Study of the whole complex of glacial and lake deposits yields evidence of considerable post-glacial reworking of the relief.

Deformations of Late Pleistocene and Holocene Deposits

Morphological variability of active faults and their spatial relationship with sedimentary sequences and relief forms, varying in age and including those of the glacial and postglacial origin, suggest their classification into three age groups [*Dem'yanovich et al.,* 1988].

The first group includes deformations of relief elements related to faults; activation of these faults is dated at the beginning of the Late Pleistocene-Holocene stage. They are most clearly expressed as offsets in end moraine fronts marking a maximum advance of glaciers into the Baikal shore zone (Tyya Promontory) and in glacial deposits of the 80-m terrace [*Dem'yanovich et al.,* 1988]. Because of limited occurrence of mid-Quaternary forms in the contemporaneous relief, recognition of such faults encounters considerable difficulties. Faults active since the late Pleistocene have been discovered in the delta area of the Verkhnyaya Angara River, near the Verkhnyaya Zaimka settlement, and within the Rel-Slyudyanskaya constructional plain. Moreover, echo-sounding survey showed that end-moraine amphitheaters occur at considerable depths all along the Barguzin shore and extend into the lake water area for more than 7 km, implying high activity of tectonic movements in the late Pleistocene [*Sizikov and Levi,* 1987]. Repeated reworking of existing benches by later movements explains the fact that relief forms associated with the faults of first group have been poorly preserved.

The second age group includes faults that deform terraces of the first Late Pleistocene glaciation; these terraces are widespread along the Baikal shore. Deformations of this group are observed in mouths of the Muzhinai and Molokon Rivers, in the mid-course of the Kichera River, in the Tompuda River mouth, along the southeastern boundaries of the Bolsherechensko-Davshinskaya and Sosnovsko-Tarkulikskaya depressions, in the Snezhnaya River mouth, and so on. The activation of fault motions in the Baikal shore zone was accompanied by reconfiguration of the shoreline and lake transgression that has left signatures in the second (6–8 m) Baikal terrace. Along shores of the Tyya-Goremykskoe plateau and Barguzinskii Range, the back suture of the terrace obliquely cuts the end-moraine amphitheaters and higher levels of fluvioglacial, alluvial, and lacustrine aggradation. At the foot of the Primorskii and Baikalskii Ranges, fault scarps of this age are overlain by piedmont alluvial fans. This age group may also include movements that offset deposits of the Karginsky-Sartan age (50–12 ka), including those dated by the radiocarbon method.

The third age group of discontinuous deformations includes "fresh" ruptures on the northwestern lake shore (Kurla Head), associated with the epoch of the late Zyryanka (Sartan, 24–12 ka) glaciation dated from archaeological evidence [*Endrikhinskii,* 1982]. Existence of these movements is debatable in the topography of eastern shore zones, but they did take place in the Selenga River mouth, where a fault-line scarp bounding the contemporaneous river delta on the south began to form at that time. On the whole, the shoreline configuration changed insignificantly, and transgression features of the first (2–4 m) Baikal terrace formed in the Holocene are less pronounced than in terraces of higher levels. An exception is lowland aggradation banks in large river mouths, where active permafrost degradation was in progress at the Pleistocene-Holocene boundary time and large areas of Sartan (24–12 ka) terraces may have been completely reworked by thermal abrasion processes. Probably, some of the thermal abrasion and thermal erosion benches trace fault zones that are thermal water sources. Such a formation mechanism of benches that bound boggy basins may be responsible for the topography features observed at large piedmont promontories of the Baikal Range, in some delta areas of the Verkhnyaya Angara River between the Lake Baikal and Verkhnyaya Zaimka settlement, and on the isthmus of the Svyatoi Nos Peninsula.

The faults that were active in the Late Pleistocene-Holocene have significantly affected the lake shoreline configuration. The latter appears to be controlled by the relative orientation of fault zones and along-shore drift movement, particularly at places where loose Pleistocene deposits are involved in the shore formation process. Thus, Baikal and delta terraces in the Tyya and Slyudyanka mouths and in the Selenga delta are truncated by linear, NE trending benches of tectonic and abrasion origin. All this is evidence of rather intense tectonic processes at the Baikal deglaciation stage of the middle and late Pleistocene, and we cannot exclude the possibility that vertical tectonic movements were affected by the glaciation.

Estimation of the Barguzin Glacier Parameters

In the light of the aforesaid, the thickness of the Barguzin half-covering glacier, which existed in the northern part of the Lake Baikal, is of particular interest. The knowledge of contemporary glaciers provides means for estimating this thickness. As shown below, it is convenient to consider ice as a viscous solid body which flows under the action of gravity [*Landau and Lifshits,* 1965] but rather strictly preserves the relation between its area dimensions and thickness; under this approximation, contemporary glaciers are described by equations of the type

$$H_g = 96.9 S_g^{0.17} \tag{1}$$

where S_g is the glacier area (in km^2) and H_g is the ice shield thickness (in km), with the correlation coefficient being $r^2 = 0.625$ at the sample size $n = 70$. Substituting an approximate value of the glacier area (in our case, determined from the end moraine belt of maximum glaciation) into equation (1), we obtain an approximate ice sheet thickness of about 700 m. This value is not much divergent from a geological-geomorphological estimate of about 400 m, obtained from the height of trough valleys [*Logachev et al.,* 1974].

For comparison, we present the estimated sizes of present continental ice covers of Antarctic and Greenland [*Dolgushin and Osipova,* 1989]. The general area S_g of the Antarctic ice sheet is 13 589 000 km^2, and its average thickness H_g is = 2450 m, with a maximum of 4700 m. For the Greenland ice sheet, the respective values are 1 726 400 km^2, 1790 m, and 3416 m. Note that if these ice caps were removed from the Earth's surface, the internal sea at the place of Antarctic would have a depth of about 1500 m, and in the case of Greenland the depth would be about 800 m. Although the North Baikal glacier is not so large, it could ignificantly affect the underlying surface.

In our case there is enough evidence to suppose that, during the maximum glaciation period, the Lake Baikal level was lower by 300–400 m. This hypothesis is illustrated in Figure 1a. As seen from the figure, the Lake Baikal consisted of three connected or even isolated reservoirs at a time of 300–400 ka. Then, the water circulation in these reservoirs and therefore landscape environment essentially differed from those presently observed. A lower lake water level in the glaciation epoch is additionally supported by the fact that certain archaeological monuments (e.g. Ulan-Khada) have been destroyed as a result of their slow submersion below the lake level.

Large dimensions and total mass of the ice cover suggest the existence of glacioisostatic movements in the Baikal region. However, in order to verify the postglacial Baikal rift uplift, one should exclude the possible influence of gravity effects on the RVM rates of the Earth's surface. Below, we briefly consider the spatial pattern of both gravity and RVM velocity anomalies, based on geodetic data.

RVM Velocity Anomalies as Constrained by Geodetic Data

The RVM in situ measurements performed in the early 1990s provided a basis for constructing an RVM scheme on the territory of the Baikal rift zone. A rather complicated pattern of RVM anomalies is observed in the area where the ice half-sheet lay. However, to a first approximation, two NE-trending bands of anomalies are recognizable; the anomalous RVM are positive in one of the bands and negative in the other. The first extends from the Svyatoi Nos Peninsula to the Verkhnyaya Angara basin, and the second extends from the Olkhon Island to northern slopes of the Verkhneangarskii Range and bounds the first band to the west. The first, positive-anomaly band is separated into several anomalies. Of those, three anomalies are most pronounced: the northwestern, most intense one is observed above the Verkhneangarskii basin and adjacent mountains of the Delyun-Uranskii and Severo-Muiskii Ranges (maximum rates are +27.4 mm/yr in the Verkhnyaya Angara head area and +16.3 mm/yr at the Yanchuya River source); central anomaly above the Kichera basin (+8.9 mm/yr in the Kichera River head area); and southwestern anomaly above the Barguzin Range, Svyatoi Nos Peninsula, and southern Baikal Range (rates range from +0.2 to +8.8 mm/yr). Interestingly, the above maximums are confined to the most conspicuous traces of glaciation. The second band of negative anomalies is divided into at least four anomalies the largest of which trends northeast and is contiguous to the largest positive anomaly. This negative anomaly is observed above the eastern Verkhne-Angarskii Range, and its downward velocities reach 14.6 mm/yr in the Konkudera River head area. The rest of the anomalies, bending round the group of positive anomalies on the west, extends southwest through the Synnyr and Yngdar Ranges, crosses the axis of the Predbaikalskii basin, and ends at the Olkhon Island. Here, mean velocities of downward movements amount to −2 mm/yr. Obviously, these anomalies cannot be attributed to glacioisostatic movements, but they imply the presence of a complex mechanism in which both gravity-density inhomogeneities of the lithosphere and tectonic differences between various morphostructural elements may be main disturbing factors.

Many of the gravity anomalies spatially correlate with the anomalies of RVM velocities, and this correlation is either positive or negative. Undoubtedly some of the anomalies coincide with areas of isostatic adjustment, so that postglacial vertical movements are likely to occur in the Baikal region, but their intensity is by far smaller as compared with Fennoscandia and other regions with a similar Pleistocene history of development.

Deep Structure of the Crust and Upper Mantle Under the Baikal Rift

In order to estimate physical properties of the material on which the ice shield lay and which was involved (probably is still involved) in glacioisostatic movements, one should roughly assess the depth at which the ice load removal was accommodated. The accommodation depths of the crust and upper mantle are likely to have been associated with lower strength characteristics and higher ductility. Seismic soundings of the crust and upper mantle in the Baikal region yield evidence of at least three lower-strength layers that change seismic velocities [*Artyushkov,* 1993]. The shallowest inhomogeneity occurs at depths of 12 to 20 km and nearly coincides with the concentration area of seismic sources in the Baikal region; the next one is observed at depths of 35 to 50 km; and the deepest is the asthenosphere, whose roof occurs, according to various estimates, at depths ranging from 50 to 90 km. Another important fact is that earthquake sources in the Barguzinskii Range area are recorded down to depths of 55 km, whereas their usual depths in Baikal rift crust are as large as 35 km. Which of the inhomogeneities could have accommodated the ice load?

The answer to this question is not trivial, because the linear dimensions and mass of the Barguzin glacier are too small. The presence of abnormally deep (to 55 km) earthquake sources in the area where the ice thickness was highest and where abnormally high RVM rates are presently observed indicates that the subcrustal inhomogeneity was undoubtedly involved in the ice load adjustment process, because otherwise relatively ductile rocks at these depths would have inhibited the growth of seismogenic faults. However, from the standpoint of formal logic, the involvement of the intracrustal inhomogeneity in accommodation of the ice load also raises no doubts.

Thus, in our opinion, the available information is adequate for estimating the following important characteristics:

- minimum linear dimensions and mass of a glacier which can give rise to noticeable glacioisostatic movements;
- possible limiting dimensions of ice sheets of the Earth at given mean values of its physical parameters;
- possible amplitude of postglacial movements in the Baikal region;
- and viscous properties of those zones of the Baikal crust and mantle that are responsible for the glacioisostatic adjustment.

Model Estimates of Physical Parameters

In order to construct models of the postglacial uplift, one should estimate its characteristic linear dimensions L and height H. For this purpose, we represent the model postglacial uplift as a rectangular parallelepiped whose base area $S_g = L^2$ and height H are such that $L \gg H$. According to empirical relation (1), this inequality is valid for all of the presently existing glaciers to a large degree of reliability.

To construct such a model, we consider the lithosphere as a very viscous fluid, and the process itself of the postglacial uplift, as a hydrodynamic attenuation of a strongly elongated disturbance of the length L on a plane boundary of an incompressible fluid of high viscosity η. Then, we obtain the equation

$$\eta = \frac{\rho g L}{2\pi}\tau, \tag{2}$$

where ρ is the mean crustal density within the uplift area, g is gravity, and τ is the postglacial uplift time in the area considered. In our case we have $\rho = 3.03$ g/cm^2, $L = 320$ km $= 3.2 \times 10^7$ cm, and $\tau = 30000$ years $= 9.5 \times 10^{11}$ s. The substitution of these values into (2) gives $\eta = 1.3 \times 10^{20}$ poise, which is somewhat smaller than the estimates for Fennoscandia and Canadian shield [*Artyushkov,* 1993], but consistent with previous estimates for the Baikal region [*Levi and Sherman,* 1995].

However, formula (2) is not advantageous for estimating the dimensions of the postglacial uplift area L, since it relates two poorly defined quantities which are L and η. Therefore, we try to derive an equation relating L to easily estimated physical characteristics of the lithosphere; for this purpose, the latter will be considered as a high-viscosity solid [*Landau and Lifshits,* 1965]. Then, the stress tensor of such a body is defined by a general formula

$$\sigma = GU_{ik} + \eta\frac{dU_{ik}}{dt}, \tag{3}$$

where G is the elastic modulus of the lithosphere, and $U_{ik} \approx dL/L$ are strain components. For our estimates, it is sufficient to consider the simplest case of a homogeneous isotropic lithosphere and to replace the hydrodynamic derivative in (3) by the estimate

$$\frac{dU_{ik}}{dt} \cong \frac{U}{t} \approx \frac{U}{L/\nu}, \tag{4}$$

where we have $\tau \approx L/\nu$ for the "hydrodynamic" time and ν is the characteristic rate of uplift. Then, equation (3) for an isotropic stress assumes an essentially simpler form:

$$\sigma = (G + \frac{\nu}{\tau})U, \tag{5}$$

In order that the viscosity and elasticity of the body in question might be values of the same order, the following condition must be satisfied:

$$\eta = G\tau \tag{6}$$

Returning to the model adopted for the uplift area, the main condition $L \gg H$ gives

$$\frac{dL}{L} = \frac{2H}{L} \tag{7}$$

and hence the stress tensor can be written as

$$\sigma = \frac{\text{weight}}{\text{base area}} = \\ = \frac{\rho g H L^2}{L^2} = \rho g H = G\frac{dL}{L} = G\frac{2H}{L}, \tag{8}$$

Then, the required dimensions of the uplift area can be estimated from the formula

$$L = \frac{2G}{\rho g} \tag{9}$$

Equation (9) is self-consistent, because formula (2) can be readily obtained through eliminating G from (5) and (6). Adopting $G \approx 2.8 \times 10^{11}$ dyne/cm^2 and $\rho \approx 3.03$ g/cm^3 for rocks composing the lithosphere in the Baikal region, we obtain $L \approx 220$ 220 km, which agrees with observations. The same equations give an estimate of the characteristic minimum size of a glacier capable of producing glacioisostatic movements. Its characteristic size cannot be smaller than 25 km. On the other hand, the thickness of a very large glacier cannot exceed, on average, 3.5 km, because otherwise it would crush its own base.

To estimate the possible postglacial uplift amplitude, one should know the ice density ρg, density of the underlying substrate ρ, and thickness of the ice shield H_g, which we assume, for simplicity, to be 1000 m. This is a reasonable estimate, because equation (1) gives only an average value of H_g. Then, the equation

$$H = \frac{\rho g}{\rho}H_g \approx 0.25H_g, \tag{10}$$

gives an uplift height of 200–300 m, which agrees reasonably well with the amplitude estimates of Late Quaternary tectonic movements from North Baikal morphometric data based on the river system incision depth and sedimentation rates [*Levi et al.,* 1981]. The uplift rate may be estimated from the equation

$$V = H/\tau. \tag{11}$$

Deglaciation Rates of the Sartan Ice Sheets and Some Problems of Human Paleogeoecology

Presently, the deglaciation history of the Baikal region cannot be determined due to poor preservation of end moraine ramparts of maximum glaciation, which prevents the delineation of glaciation geographical boundaries. Based on the available geological and geophysical evidence, the time variation of deglaciation over the past 40 thousand of years can be, to an extent, reconstructed. Below, we shortly discuss this problem.

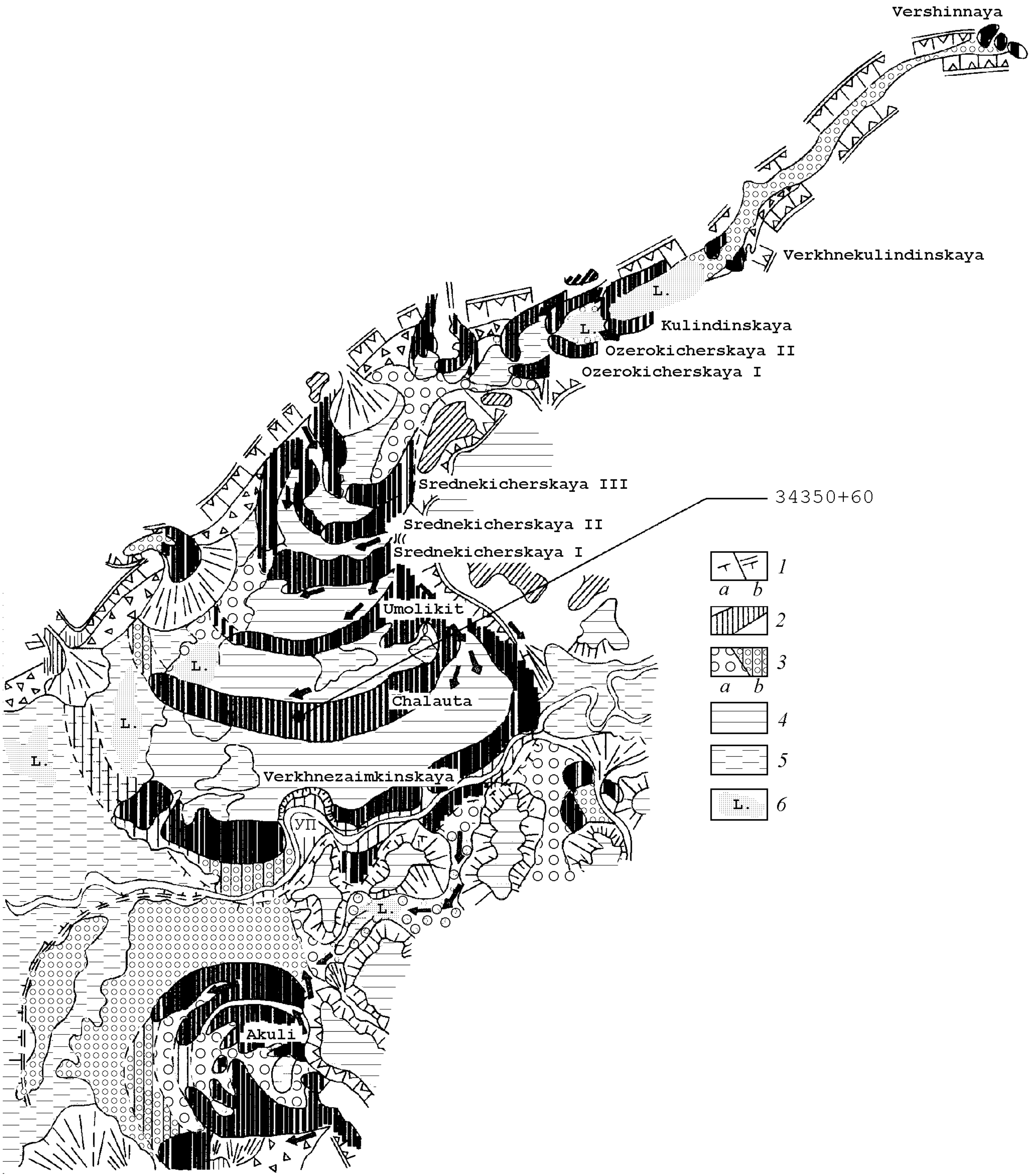

Figure 4. End moraine series in the Kichera River valley, northernmost Lake Baikal (after [*Osadchii,* 1989]): 1 – reliable (a) and tentative (b) boundaries of the maximum glaciation; 2 – stadial moraines preserved in the contemporary relief; 3 – alluvial-lacustrine plains in "flooded" (a) and eroded (b) areas of stadial moraines; 4, 5 – glacial-lacustrine plains: dry (4) and swampy (5); 6 – lakes.

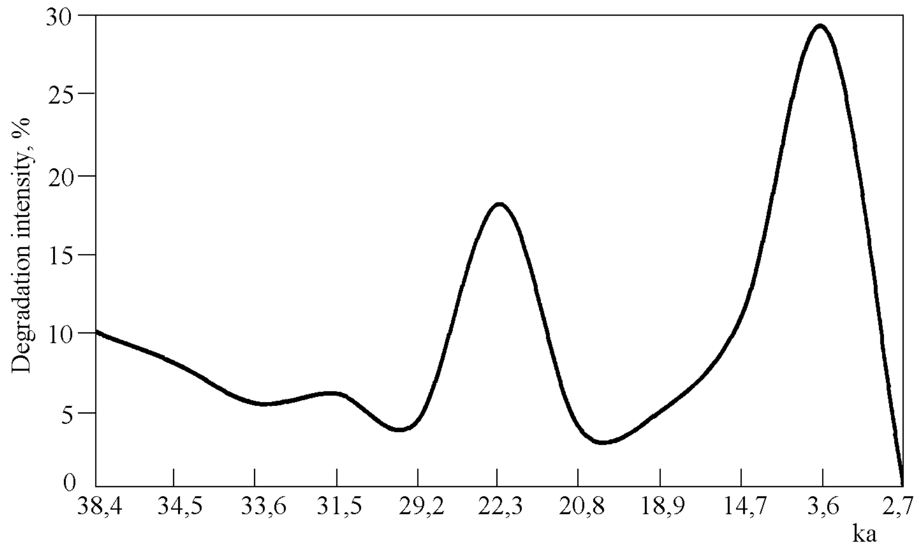

Figure 5. Degradation intensity of the Kichera glacier, northern Baikal.

Presently, the Kichera River valley (northernmost Lake Baikal area) is the only place where some ten ramparts of end moraines are well preserved. These ramparts are geomorphologically well expressed, and relative age determinations date them at the early to latest Pleistocene [*Bazarov,* 1986]. In 1989, S. S. Osadchii mapped the entire system of the end moraine ramparts in the Kichera River valley and established their number to be 11–13; he assumed that the lowermost moraine fixes the spatial position of the maximum glaciation boundary, the glaciation age being about 300 ka as mentioned above. In 1994 and 1995, P. G. Kirillov and S. Bak determined an age of 34350 ± 60 years from the Chalauta moraine (Table 1), which dramatically diverges from the relative geochronology data reported by previous researchers. The scheme of Figure 4 (constructed after *Osadchii* [1989]) clearly shows considerable variation in the spacing between the moraine ramparts, implying that the glacier retreat rate correlated with climatic variations in the air temperature. In order to estimate the relative age of each moraine rampart, one should admit that the temperature rose uniformly. Given the validity of this assumption, each moraine may be dated from spacings between moraine ramparts. These simple considerations showed that the deglaciation rate varied with time (Figure 5), indirectly reflecting the climatic variations in the air temperature.

Now we briefly consider the intensity of soil formation in East Siberia during the past 50 k.y. The plot shown in Figure 6 was constructed using a collection of ^{14}C datings (Appendix, Table 2). Furthermore, we assumed that, in the case of global development of a phenomenon, the number of datings that fall into a given "time window" is maximum, whereas it is minimum if the process is depressed. The time window was taken to be wider than the standard deviation of the ^{14}C determinations, and the windows overlapped, with a time step being 0.5. Simple calculations yielded a frequency curve, indirectly reflecting the climatic temperature variations in East Siberia; on the whole, this curve is consistent with the current geological notions (Figure 6).

Archaeological site datings in East Siberia (Appendix, Table 3) were processed in a similar way, and we obtained the site recurrence plot (which may show how often ancient peoples visited the Baikal region) illustrated in Figure 7.

Comparison between Figures 6 and 7 reveals an abnormally high recurrence of archaeological site datings during the Sartan glaciation in the Baikal region. The Holocene extremums may be explained by the general rise in temperature favorable for developing new lands by men. On the other hand, it is difficult to explain the frequent site occurrence during the Sartan time, when a rather cold climate dominated the Baikal region, and the ancient man was strongly dependent on environmental conditions. However, comparison of Figures 5 and 7 seems to resolve this contradiction. High deglaciation rates of the Sartan glaciers were characteristic of the time interval during which the Sartan archaeological sites were widespread. Thus, these facts, albeit indirect and somewhat insufficiently substantiated, yield

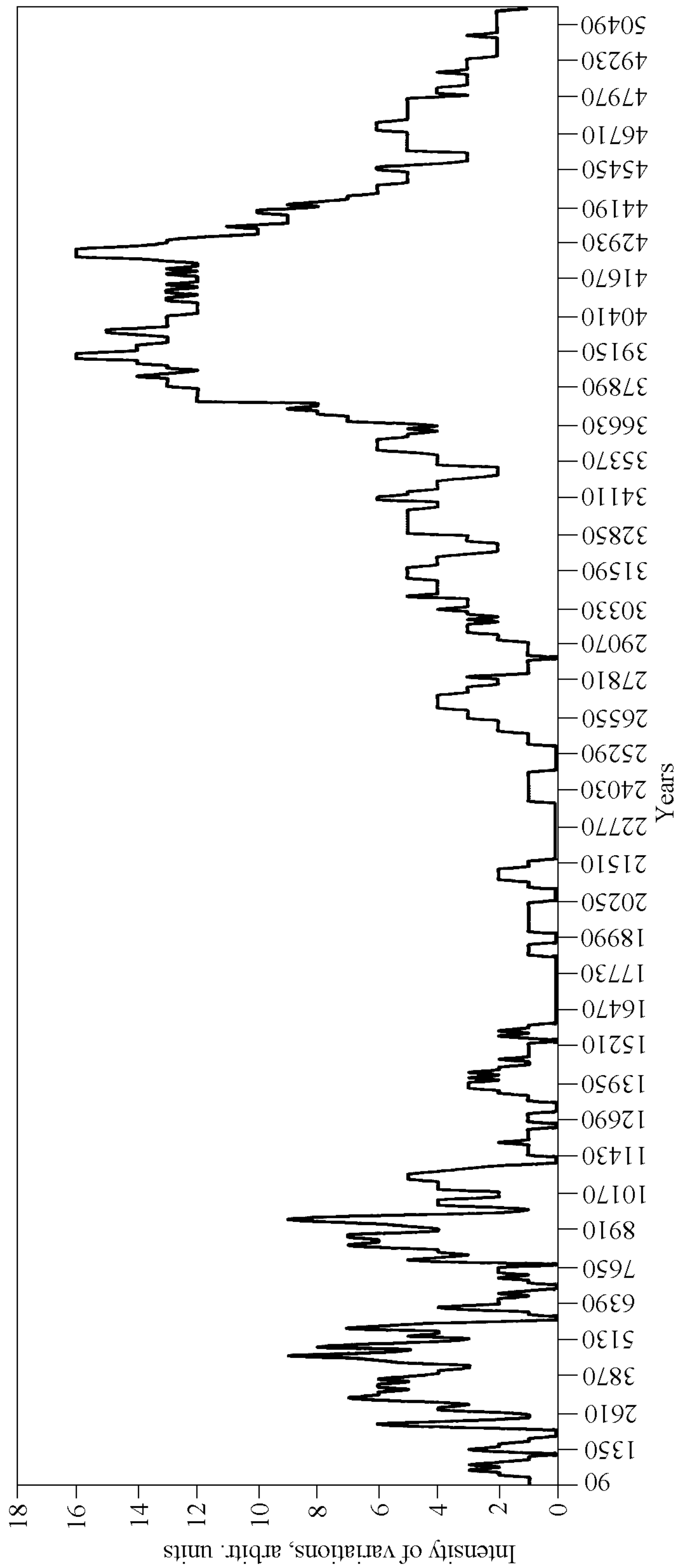

Figure 6. Soil formation variation in East Siberia over the past 50000 years.

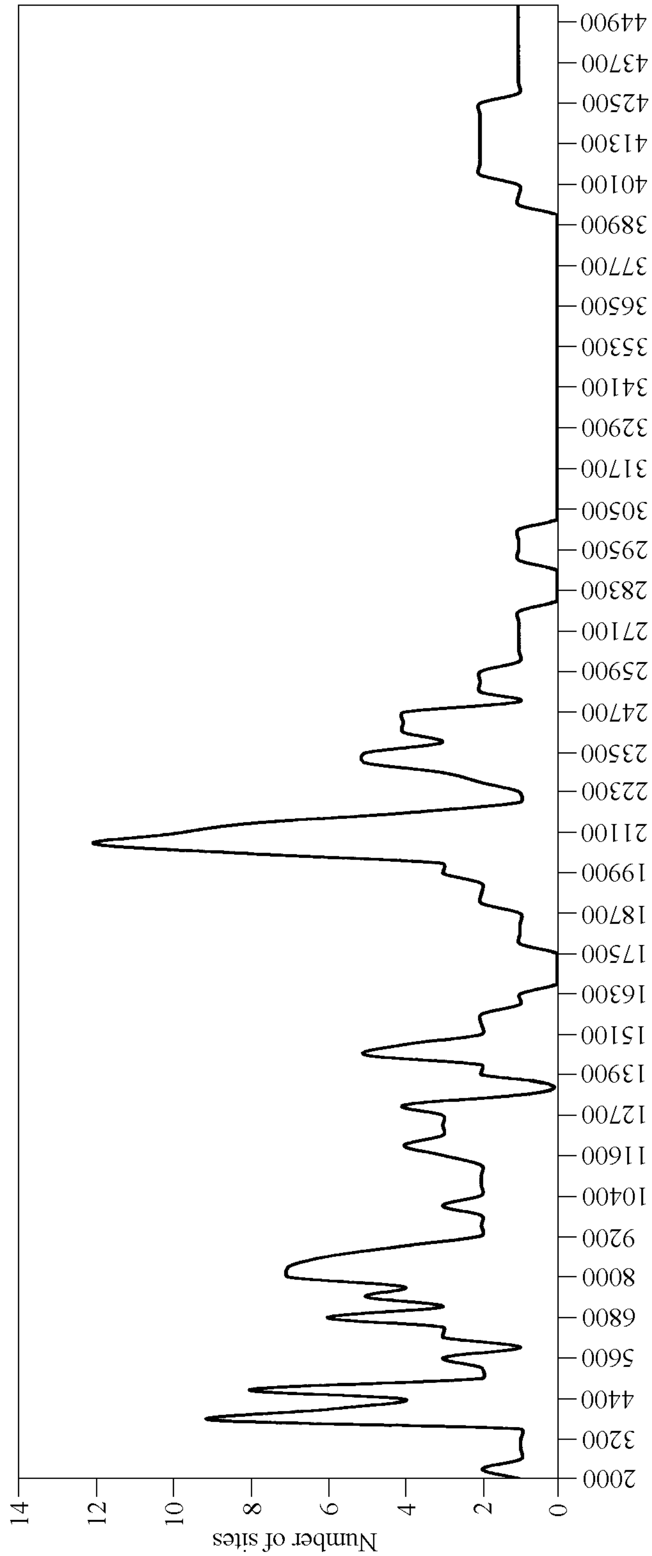

Figure 7. Recurrence of ancient people sites in East Siberia.

evidence of anomalous climatic conditions that existed in the Baikal region over the past 50 k.y. We hope that joint geological and geophysical studies that have been conducted since 1997 will provide final verification of these climatic features.

Future Development of the Postglacial Uplift Problem

The next stage in the elaboration of the problem of postglacial uplift in the Baikal rift zone consists in the intensity estimation of postglacial tectonic events as a function of the distance to the local center of the North Baikal glaciation. Deglaciation features in the region should correlate with stages of the Lake Baikal water level variation; thereby our knowledge of the mechanism responsible for the lake water discharge through the Angara River will be improved and many questions concerning the Pleistocene evolution of the region and regional climatic changes will be answered. Supposedly, the interpretation of terrace-like benches and terraces of the Ushkun'i Islands [*Lamakin,* 1952link13] can be beneficial to the solution of these and many other problems of the postglacial Baikal history.

Conclusion

Numerous traces of neotectonic movements and postglacial active tectonics have been reliably established in the Baikal rift zone. Substantial relief transformations postdating the maximum glaciation epoch are evidence of considerable tectonic uplift events with a highly probable postglacial component, which is additionally supported by relationships of the Bikal terraces of intermediate (35–50 and 80 m) and high (150 m) levels with glacial features. Subsynchronism of lake and glacial deposits and abrasion planation of the glacial relief at various levels can be most reasonably explained in terms of the glacier slide into the lake shore zone and, at the initial stage of deglaciation, abrasion truncation of the glacial relief which did not experience significant glacioisostatic uplift at that time. The glacioisostatic hypothesis is consistent with theoretical estimates obtained in this work.

Acknowledgements. We are grateful to Academician N. A. Logachev for a preliminary discussion and valuable comments. This work was supported by the International Science Foundation, grant No. RLG300; the International Association for the Promotion of Cooperation with Scientists from the Independent States of the Former Soviet Union, grant No. 93-014; the Russian Foundation for Basic Research, grant Nos. 95-05-14211, 96-05-64187, and 97-05-96529; and the Siberian Division of the Russian Academy of Sciences, grant No. IGSORAN-97-22.

References

Artyushkov, E. V., *Physical Tectonics,* Moscow, Nauka, 1993 (in Russian).

Atlas of the Baikal Region, Moscow, 1993 (in Russian).

Bazarov, D.-D. B., Budaev, R. Ts., and Kalmykov, N. P., On the age of Pleistocene terraces of the southwestern Lake Baikal shore, in *Late Pleistocene and Holocene of Southern East Siberia,* pp. 155–157, Novosibirsk, Nauka, 1982 (in Russian).

Bazarov, D.-D. B., *The Cenozoic of the Baikal Region and Western Zabaikal'e Area,* Novosibirsk, Nauka, 1986 (in Russian).

Bukharov, A. A. and Fialkov, V. A., *Geological Structure of the Lake Baikal Bottom: A Look from Paisis,* Novosibirsk, Nauka, 1996 (in Russian).

Dem'yanovich, Pulyavskii, G. M., Khaustov, A. P., et al., *Anthropogenic Impact on the Geological Medium,* Irkutsk, 1988 (in Russian).

Dolgushin, L. D. and Osipova, G. B., *Glaciers,* Moscow, Mysl, 1989 (in Russian).

Endrikhinskii, A. S., The sequence of main geological events in southern Siberia in the late Pleistocene and Holocene, in *Late Pleistocene and Holocene of Southern East Siberia,* pp. 6-35, Novosibirsk, Nauka, 1982 (in Russian).

Eskin, A. S., Palshin, G. B., Grechishchev, E. K., and Galazii, G. I., Geology and some problems of neotectonics of the Ushkan'i Islands, in *Proc. East Siberian Institute, Siberian Division of Russian Academy of Sciences. Ser. geol., vol. 2,* pp. 129–152, 1959 (in Russian).

Galkin, V. I., On the age of Lake Baikal terraces, in *Matter and Energy Fluxes in Lake Reservoirs,* vol. 2, p. 12, Novosibirsk, Nauka, 1975 (in Russian).

Kulchitskii, A. A., Maximum glaciation boundaries in the northern part of the West Baikal region, *Voprosy Geologii Pribaikal'ya i Zabaikal'ya,* 2(4), Chita, 298–301, 1967 (in Russian).

Kulchitskii, A. A., Deposits and paleogeography of the Baikal region during the maximum glaciation epoch, *Geol. Geofiz., 9,* 60–67 (in Russian).

Kuz'min, M. I., Grachev, M. A., Williams, et al., Continuous paleoclimatic record over the past 4.5 m.y. (preliminary report), *Geol. Geofiz.,* 38(5), 1021–1023, 1997 (in Russian).

Lamakin, V. V., *The Ushkan'i Islands and the Problem of the Lake Baikal Origin,* Moscow, Gos. izd. geogr. lit., 1952 (in Russian).

Lamakin, V. V., *Neotectonics of the Baikal Basin,* Moscow, Nauka, 1968 (in Russian).

Landau L. D., Lifshits E. M. *Theory of Elasticity,* M., Nauka, 1965, 203 pp.

Levi, K. G., Kulchitskii, A. A., and Zubarenkova, L. P., Holocene tectonic movements in the central Goremyko-Tyiskii Highland, in *Relief and Quaternary Deposits of the Stanovoe Upland,* pp. 138-144, Moscow, Nauka, 1981 (in Russian).

Levi, K. G. and Sherman, S. I., Applied Geodynamics Analysis, *Sciences Geologiques, 100,* Tervuren, Belgique, 1995.

Logachev, N. A., Antoshchenko-Olenev, I. V., Bazarov, D. B., et al., *Uplands in the Baikal Region,* Moscow, Nauka, 1974 (in Russian).

Mats, V. D., The Cenozoic of the Baikal Region, *Doctoral Dissertation,* Irkutsk, 1987 (in Russian).

Mats, V. D., Baikal: The origin and development of the lake depression, in *History of the Lakes Ladozhskoe, Onezhskoe, Pskovsko-Chudskoe, Baikal, and Khanka,* pp. 167–191, Leningrad, Nauka, 1990 (in Russian).

Obruchev, S. V., The Vostochno-Sayansko-Tuvinskoe Upland in the Quaternary, *Izv. VGO, 85* (5), 17–29, 1953 (in Russian).

Olyunin, V. N., On genetic types of Quaternary deposits in Buryatia, in *Papers of the All-Union Conference on the Quaternary,* pp. 271–276, Moscow, Izd. AN SSSR, 1961 (in Russian).

Salop, L.I., *Geology of the Baikal Mountainous Region: Vol. 1. Stratigraphy,* Moscow, Nedra, 1964 (in Russian).

Sizikov, A. M. and Levi, K. G., Possible implications of crustal glacioisostatic movements for the Late Pleistocene-Holocene tectonics of the Baikal basin, in *Cenozoic Geology of Southern East Siberia,* Irkutsk, 1987 (in Russian).

(Received May 15 1998.)

Appendix.

Table 2. The Holocene-Late Pleistocene age sequence of geological events in central Siberia

No.	Stage	Dating	Location and references
1	**Sub-**	210±170	(*Andreev*, 1992)
2	**Atlantic**	430±30	Fernau stage moraines, Altai (SOAN-1427) (*Endrikhinskii*, 1982)
3		440±50	Fernau stage moraines, Altai (SOAN-1618) (*Endrikhinskii*, 1982)
4		430±50	Fernau stage moraines, Altai (SOAN-1616) (*Endrikhinskii*, 1982)
5		430±30	Fernau stage moraines, Altai (SOAN-1426) (*Endrikhinskii*, 1982)
6		525±100	Kargapolovo village, Ob River (SOAN-71) (*Endrikhinskii*, 1982)
7		540±25	Peat bog, Dzhasator River, Altai (SOAN-1756) (*Ivanovskii et al.*, 1982)
8		550±30	Yana River, below Ust'-Kuiga (GIN-655) (*Kolpakov et al.*, 1980)
9		600±150	Megin-Kangalas district, Yakutia (Im-260) (*Kostyukevich*, 1980)
10		610±50	Fernau stage moraines, Altai (SOAN-1617) (*Endrikhinskii*, 1982)
11		715±140	Khara-Bugulunnyakh (Im-248) (*Kostyukevich*, 1980)
12		830±50	Peat bog, Dzhasator River, Altai (SOAN-1757) (*Ivanovskii et al.*, 1982)
13		870±60	Kirenga River (Vib-47) (*Endrikhinskii*, 1982)
14		910±120	(*Andreev et al.*, 1992)
15		1090±135	Kargopolovo settlement, Ob River (SOAN-72) (*Endrikhinskii*, 1982)
16		1140±30	Peat bog, Dzhasator River, Altai (SOAN-1758) (*Ivanovskii et al.*, 1982)
17		1220±70	Tuva Upland (Beta-107352) (*Arzhannikov*, this work)
18		1250±50	Pashino site (GIN-1742) (*Laukhin et al.*, 1980)
19		1350±150	Ust'-Aldan district, Yakutia (Im-370) (*Kostyukevich*, 1980)
20		1400±100	Megin-Kangalas district, Yakutia (Im-354) (*Kostyukevich*, 1980)
21		1515±60	Kargopolovo settlement, Ob River (SOAN-73) (*Endrikhinskii*, 1982)
22		1610±70	(*Andreev et al.*, 1992)
23		1670±65	Suzun River, Ob River tributary (SOAN-81) (*Endrikhinskii*, 1982)
24		2100±80	(*Andreev et al.*, 1992)
25		2110±70	(*Andreev et al.*, 1992)
26		2130±90	Suzun River, Ob River tributary (SOAN-28) (*Endrikhinskii*, 1982)
27		2170±60	(*Andreev et al.*, 1992)
28		2180±100	(*Andreev et al.*, 1992)
29		2230±100	Chadobets site, soil (KRIL-231) (*Laukhin et al.*, 1980)
30		2270±80	Pashino site (GIN-1743) (*Laukhin et al.*, 1980)
31		2300±10	Vitim River (Im-598) (*Endrikhinskii*, 1982)
32		2430±130	Selenga River delta, Dubrovino village (LG-142) (*Endrikhinskii*, 1982)
33	**Subbo-**	2520±80	(*Andreev et al.*, 1992)
34	**real**	2650±100	(*Andreev et al.*, 1992)
35		2680±60	Northern Middle Siberian Upland (GIN-498) (*Bardeeva et al.*, 1980)
36		2780±90	Bytantai River (GIN-559) (*Kolpakov et al.*, 1980)
37		2900±200	Ust'-Aldan district, Yakutia (Im-371) (*Kostyukevich*, 1980)
38		2970±40	Tumara, Kele, Tukulan, and Khandyga rivers (GIN-527) (*Kolpakov et al.*, 1980)
39		2990±120	Chadobets site, (KRIL-232) (*Laukhin et al.*, 1980)
40		3000±70	(*Andreev et al.*, 1992)
41		3060±70	Bytantai River (GIN-551) (*Kolpakov et al.*, 1980)
42		3160±100	(*Andreev et al.*, 1992)
43		3200±40	Northern Middle Siberian Upland (GIN-497) (*Bardeeva et al.*, 1980)
44		3200±100	Molodo River (GIN-1424) (*Shofman*, 1980)
45		3205±40	Peat bog, Dzhasator River, Altai (SOAN-1760g) (*Ivanovskii et al.*, 1982)
46		3215±20	Peat bog, Dzhasator River, Altai (SOAN-1759) (*Ivanovskii et al.*, 1982)
47		3250±70	(*Andreev et al.*, 1992)
48		3280±130	Severnaya Zemlya Archipelago, (LU-1125) (*Bolshiyanov et al.*,1995)
49		3320±170	Markha River (GIN-901) (*Shofman*, 1980)

No.	Stage	Dating	Location and references
50		3340±30	Bytantai River (GIN-550) (*Kolpakov et al.*, 1980)
51		3370±200	Tumara River (GIN-532) (*Kolpakov et al.*, 1980)
52		3390±30	Peat bog, Dzhasator River, Altai (SOAN-1760g) (*Ivanovskii et al.*, 1982)
53		3400±90	Severnaya Zemlya Archipelago (LU-1123)(*Bolshiyanov et al.*,1995)
54		3600±130	Markha River (GIN-902) (*Shofman*, 1980)
55		3600±200	Markha River (GIN-900) (*Shofman*, 1980)
56		3600±80	Omoloi River, (GIN-847) (*Kolpakov et al.*, 1980)
57		3610±100	(*Andreev et al.*, 1992)
58		3790±50	Taimyr Peninsula (GIN-1154) (*Nikolskaya et al.*, 1980)
59		3820±100	(*Andreev et al.*, 1992)
60		3880±120	Zakharova Rassokha River, Khatanga River tributary (GIN-1456) (*Andreeva*, 1980)
61		3900±500	Northern Middle Siberian Upland (GIN-1182) (*Bardeeva et al.*, 1980)
62		3910±100	Ust'-Aldan district, Yakutia (Im-362) (*Kostyukevich*, 1980)
63		4000±100	(*Andreev et al.*, 1992)
64		4080±130	Kazyra River, Yenisei River head area, (MGU-260) (*Endrikhinskii*, 1982)
65		4280±240	Ynakhsyt River (GIN-850) (*Kolpakov et al.*, 1980)
66		4410±200	Chadobets site, (KRIL-233) (*Laukhin et al.*, 1980)
67		4420±50	Taimyr Peninsula (GIN-681) (*Nikolskaya et al.*, 1980)
68		4460±50	(*Andreev et al.*, 1992)
69		4470±200	Megin-Kangalas district, Yakutia (Im-260) (*Kostyukevich*, 1980)
70	**Atla-**	4500±40	Yana River (GIN-553) (*Kolpakov et al.*, 1980)
71	**ntic**	4590±50	Molodo River (GIN-1432b) (*Shofman*, 1980)
72		4600±300	Megin-Kangalas district, Yakutia (Im-360) (*Kostyukevich*, 1980)
73		4620±50	(*Andreev et al.*, 1992)
74		4725±190	Ust'-Aldan district, Yakutia (Im-363) (*Kostyukevich*, 1980)
75		4790±60	Northern Middle Siberian Upland (GIN-499) (*Bardeeva et al.*, 1980)
76		4800±80	Molodo River (GIN-1428) (*Shofman*, 1980)
77		4800±60	Dulgalakh River (GIN-849) (*Kolpakov et al.*, 1980)
78		4870±80	Omoloi River, (GIN-711) (*Kolpakov et al.*, 1980)
79		4890±50	Yana River (GIN-554) (*Kolpakov et al.*, 1980)
80		4920±100	Dulgalakh River (GIN-699) (*Kolpakov et al.*, 1980)
81		4950±50	Molodo River (GIN-1432a) (*Shofman*, 1980)
82		5030±60	(*Andreev et al.*, 1992)
83		5110±80	(*Andreev et al.*, 1992)
84		5180	Taimyr Peninsula (IMSOAN-681) (*Nikolskaya et al.*, 1980)
85		5230±70	Molodo River (GIN-1425) (*Shofman*, 1980)
86		5300±250	Northern Middle Siberian Upland (GIN-1184) (*Bardeeva et al.*, 1980)
87		5320±100	Dulgalakh River (GIN-701) (*Kolpakov et al.*, 1980)
88		5330±50	Bytantai River (GIN-546) (*Kolpakov et al.*, 1980)
89		5480±70	(*Andreev et al.*, 1992)
90		5500±50	Bytantai River (GIN-548) (*Kolpakov et al.*, 1980)
91		5500±100	Taimyr Peninsula (GIN-979) (Nikolskaya et al., 1980)
92		5530±60	(*Andreev et al.*, 1992)
93		5550±70	(*Andreev et al.*, 1992)
94		5570±80	(*Andreev et al.*, 1992)
95		5570±30	Bytantai River (GIN-552) (*Kolpakov et al.*, 1980)
96		5730±200	Ishi River, Katun' River tributary (LG-62)(*Endrikhinskii*, 1982)
97		5990±50	Taimyr Peninsula (GIN-1460) (*Nikolskaya et al.*, 1980)
98		6120±70	Taimyr Peninsula (GIN-682) (*Nikolskaya et al.*, 1980)
99		6150±60	Taimyr Peninsula (GIN-1544) (*Nikolskaya et al.*, 1980)
100		6200±50	Undyulong, Begidzhyan, and Sobopol rivers (GIN-222) (*Kolpakov et al.*, 1980)
101		6290±100	Irtysh River, town of Semipalatinsk (LG-40) (*Endrikhinskii*, 1982)
102		6390±80	(*Andreev et al.*, 1992)

No.	Stage	Dating	Location and references
103		6400±200	Northern Middle Siberian Upland (GIN-1185) (*Bardeeva et al.*, 1980)
104		6670±40	Tumara River (GIN-536) (*Kolpakov et al.*, 1980)
105		6695±150	Gorelyi Les site, Belaya River (Ri-50) (*Endrikhinskii*, 1982)
106		7060±100	(*Andreev et al.*, 1992)
107		7210±?	Severnaya Zemlya Archipelago (*Bolshiyanov et al.*,1995)
108		7270±100	Bytantai River (GIN-547) (*Kolpakov et al.*, 1980)
109		7420±90	Bytantai River (GIN-549) (*Kolpakov et al.*, 1980)
110		7430±230	Shsihskino archaeological monument, Lena River (*Endrikhinskii*, 1982)
111		7440±40	Taimyr Peninsula (GIN-1457) (*Nikolskaya et al.*, 1980)
112		7740±70	(*Andreev et al.*, 1992)
113		7780±100	(*Andreev et al.*, 1992)
114		7810±150	Northern Middle Siberian Upland (GIN-500) (*Bardeeva et al.*, 1980)
115		7880±120	(*Andreev et al.*, 1992)
116		7950±50	(*Andreev et al.*, 1992)
117	**Boreal**	8000±700	Shsihskino archaeological monument, Lena River (*Endrikhinskii*, 1982)
118		8030	Taimyr Peninsula (*Nikolskaya et al.*, 1980)
119		8090	Taimyr Peninsula (*Nikolskaya et al.*, 1980)
120		8160±20	Molodo River (GIN-1435) (*Shofman*, 1980)
121		8200±80	Bukhuruk River (GIN-707) (*Kolpakov et al.*, 1980)
122		8220±120	Taimyr Peninsula (GIN-1198) (*Nikolskaya et al.*, 1980)
123		8270±150	Shsihskino archaeological monument, Lena River (*Endrikhinskii*, 1982)
124		8310±70	Taimyr Peninsula (GIN-774) (*Nikolskaya et al.*, 1980)
125		8340±100	Northern Middle Siberian Upland (GIN-1183) (*Bardeeva et al.*, 1980)
126		8340±80	Dulgalakh River (GIN-853) (*Kolpakov et al.*, 1980)
127		8370±400	(*Andreev et al.*, 1992)
128		8390±40	Molodo River (GIN-1426) (*Shofman*, 1980)
129		8400±600	Northern Middle Siberian Upland (GIN-522) (*Bardeeva et al.*, 1980)
130		8444±124	Gorelyi Les site, Belaya River (Ri-51) (*Endrikhinskii*, 1982)
131		8490±70	Molodo River (GIN-1431) (*Shofman*, 1980)
132		8580±50	Bukhuruk River (GIN-708) (*Kolpakov et al.*, 1980)
133		8600±70	Taimyr Peninsula (GIN-665) (*Nikolskaya et al.*, 1980)
134		8600±90	Molodo River (GIN-1430) (*Shofman*, 1980)
135		8600±100	Bytantai River (GIN-557) (*Kolpakov et al.*, 1980)
136		8650±200	Khara-Bulugunnyakh (Im-262) (*Kostyukevich*, 1980)
137		8650±235	Chik River, Altai (SOAN-414) (*Endrikhinskii*, 1982)
138		8730±50	Dulgalakh River (GIN-700) (*Kolpakov et al.*, 1980)
139		8800±130	Taimyr Peninsula (GIN-820) (*Nikolskaya et al.*, 1980)
140		8960±	Ust'-Belaya, Angara River (GIN-96) (*Endrikhinskii*, 1982)
141		9000±150	Taimyr Peninsula (GIN-680) (*Nikolskaya et al.*, 1980)
142		9100±100	Northern Middle Siberian Upland (GIN-1187) (*Bardeeva et al.*, 1980)
143		9120±200	Khara-Bulugunnyakh (Im-263) (*Kostyukevich*, 1980)
144		9130±70	(*Andreev et al.*, 1992)
145	**Prebo-**	9180±100	B. Balakhnya River, Taimyr Peninsula (GIN-791) (*Nikolskaya et al.*, 1980)
146	**real**	9200±40	Taimyr Peninsula (GIN-679) (*Nikolskaya et al.*, 1980)
147		9200±100	Tumara, Kele, Tukulan, and Khandyga rivers (GIN-528) (*Kolpakov et al.*, 1980)
148		9260±70	Tumara, Kele, Tukulan, and Khandyga rivers (GIN-528) (*Kolpakov et al.*, 1980)
149		9300±100	B. Rassokha River, Taimyr Peninsula (GIN-1322) (*Nikolskaya et al.*, 1980)
150		9460±400	Dulgalakh River (GIN-854) (*Kolpakov et al.*, 1980)
151		9700±100	Tabrata River, Yenisei River head area (MGU-199) (*Endrikhinskii*, 1982)
152		9730±50	(*Andreev et al.*, 1992)
153		9800±100	Bukhuruk River (GIN-706) (*Kolpakov et al.*, 1980)
154		9850±500	Ust'-Belaya, Angara River (GIN-483) (*Endrikhinskii*, 1982)
155		9990±100	(*Andreev et al.*, 1992)

No.	Stage	Dating	Location and references
156		10160±140	Torskaya depression, Irkut River (GIN-142) (*Endrikhinskii*, 1982)
157		10300±50	Ulakhan-Sakkyryk River (GIN-530) (*Kolpakov et al.*, 1980)
158	**Late**	10400±600	(*Andreev et al.*, 1992)
159	**Dryas**	10400±200	Markha River (GIN-912) (*Shofman*, 1980)
160		10480±250	B. Balakhnya River, Taimyr Peninsula (GIN-792)(*Nikolskaya et al.*, 1980)
161		10500±130	Lena River, below the Linda River mouth (GIN-852) (*Kolpakov et al.*, 1980)
162		10720±120	Northern Middle Siberian Upland (GIN-523) (*Bardeeva et al.*, 1980)
163		10800±250	Tumara, Kele, Tukulan, and Khandyga rivers (GIN-529) (*Kolpakov et al.*, 1980)
164	**Alle-**	10860±80	Boyarka River mouth, Taimyr Peninsula (GIN-674) (*Nikolskaya et al.*, 1980)
165	**ræd**	10900±500	Oshurkovo site, Selenga River (*Tseitlin*, 1979)
166		10995±400	Koira and Vitim interstream area (IM-97) (*Endrikhinskii*, 1982)
167		11250±180	Khamsara River, Yenisei River head (*Endrikhinskii*, 1982)
168		11400±500	Makarovo-2 archaeological monument, Lena River (GIN-480b) (*Endrikhinskii*, 1982)
169		11540±140	Markha River (GIN-899) (*Shofman*, 1980)
170		11800±70	Bukhuruk River (GIN-709) (*Kolpakov et al.*, 1980)
171		11860±280	Shsihskino archaeological monument, Lena River (GIN-480a) (*Endrikhinskii*, 1982)
172		11950±50	Makarovo-2 archaeological monument, Lena River (GIN-481) (*Endrikhinskii*, 1982)
173		12000±130	Berelekhskii occurrence site of mammoth bones (LU-149) (*Arslanov et al.*, 1980)
174		12180±120	Kokorevo-2 site, Yenisei River (LE-770) (*Endrikhinskii*, 1982)
175		12230±70	Berelekhskii occurrence site of mammoth bones (LU-149) (*Arslanov et al.*, 1980)
176		12600±150	Anui River, Altai (LG-39) (*Endrikhinskii*, 1982)
177		12700±150	Markha River (GIN-897) (*Shofman*, 1980)
178		12750±120	Eltsovka River, Altai (SOAN-575) (*Endrikhinskii*, 1982)
179		12750±120	Vitim River (GIN-1022) (*Endrikhinskii*, 1982)
180		12900±300	Oshurkovo site, Selenga River (*Endrikhinskii*, 1982)
181		12940±270	Kokorevo-2 site, Yenisei River (LE-526) (*Endrikhinskii*, 1982)
182		13300±50	Kokorevo-1 site, Yenisei River (GIN-91) (*Endrikhinskii*, 1982)
183		13300±	Kokorevo-2 site, Yenisei River (GIN-90) (*Endrikhinskii*, 1982)
184		13600±120	Anui River, Altai (SOAN-69) (*Endrikhinskii*, 1982)
185		13700±180	North Siberian Lowland (GIN-692) (*Isaeva et al.*, 1980)
186		13700±400	Berelekhskii occurrence site of mammoth bones (LU-149) (*Arslanov et al.*, 1980)
187		13750±70	Lebed' River, Turochak village, Altai (SOAN-576) (*Endrikhinskii*, 1982)
188		13890±200	Aya village, Katun' River (LG-92) (*Endrikhinskii*, 1982)
189		14100±350	North Siberian Lowland (GIN-1452) (*Isaeva et al.*, 1980)
190		14200±100	Yana River, Ust'-Kuiga (GIN-537) (*Kolpakov et al.*, 1980)
191		14320±330	Kokorevo-4 site, Yenisei River (LE-496) (*Endrikhinskii*, 1982)
192		14500±250	Linda River, below the Ynakhstakh River mouth (GIN-851) (*Kolpakov et al.*, 1980)
193		14540±365	Anui River, Altai (SOAN-16) (*Endrikhinskii*, 1982)

No.	Stage	Dating	Location and references
194		14700±150	Kokorevo-2 site, Yenisei River (GIN-262) (*Endrikhinskii*, 1982)
195		14750±120	Malta site, Angara River (GIN-97) (*Endrikhinskii*, 1982)
196		15000±300	North Siberian Lowland (GIN-1254) (*Isaeva et al.*, 1980)
197		15200±300	Vitim River (IM-236) (*Endrikhinskii*, 1982)
198		15460±320	Kokorevo-4 site, Yenisei River (LE-540) (*Endrikhinskii*, 1982)
199		15500±50	Yana River, Mus-Khaya (GIN-541) (*Kolpakov et al.*, 1980)
200		15630±80	North Siberian Lowland (GIN-938) (*Isaeva et al.*, 1980)
201		15800±60	Undyulong, Begidzhyan, and Sobopol rivers (GIN-333) (*Kolpakov et al.*, 1980)
202		15850±680	Isha River, Altai (LG-14) (*Endrikhinskii*, 1982)
203		17500±100	Isha River, Altai (SOAN-746) (*Endrikhinskii*, 1982)
204		17590±110	Shcherbakovo village, Ob River (SOAN-443) (*Endrikhinskii*, 1982)
205		18500±200	Tumara River (GIN-535) (*Kolpakov et al.*, 1980)
206		19600±500	Ust'-Aldan district, Yakutia (*Kostyukevich*, 1980)
207		20240±740	Isha River, Altai (LG-59) (*Endrikhinskii*, 1982)
208		20300±5000	Vilyui River (GIN-904) (*Shofman*, 1980)
209		20680±270	Ikonnikovo village, Katun' River (SOAN-441) (*Endrikhinskii*, 1982)
210		20790±260	Severnaya Zemlya Archipelago (LU-1069) (*Bolshiyanov et al.*,1995)
211		20900±300	Afontova Gora-2 site, Krasnoyarsk area (GIN-117) (*Endrikhinskii*, 1982)
212		21000±300	North Siberian Lowland (GIN-962) (*Andreeva*, 1980)
213		21260±310	Molodo River (LU-786) (*Shofman*, 1980)
214		23200±1800	Oshurkovo site, Selenga River (*Endrikhinskii*, 1982) **ionium dating**
215		23750±180	Shadrintsevo village, Ob River tributary (SOAN-435) (*Endrikhinskii*, 1982)
216		23800±190	B. Rechka River, Ob River tributary (SOAN-154) (*Endrikhinskii*, 1982)
217		24100±300	Yuskeevo village, Yenisei River (GIN-308) (*Endrikhinskii*, 1982)
218		24120±500	Irkineeva River (SOAN-127) (*Laukhin et al.*, 1980)
219		24240±2700	Kytmanovo village, Chumysh River, Ob River tributary (SOAN-31) (*Endrikhinskii*, 1982)
220		24300±220	Ulkan River (Vib-45) (*Endrikhinskii*, 1982)
221		24490±810	Severnaya Zemlya Archipelago (LU-665) (*Bolshiyanov et al.*,1995)
222		24500±320	Staroglinushka village, Ob River tributary (SOAN-430) (*Endrikhinskii*, 1982)
223		25300±600	Altai moraines (MGU-IOAN-65) (*Endrikhinskii*, 1982)
224		25800±140	Pavlovshchina village, Yenisei River (GIN-310) (*Endrikhinskii*, 1982)
225		25900±340	Biya River (SOAN-52) (*Endrikhinskii*, 1982)
226		25970±180	B. Rechka River, Ob River tributary (SOAN-1257) (*Endrikhinskii*, 1982)
227		26030±810	Severnaya Zemlya Archipelago (LU-1143) (*Bolshiyanov et al.*,1995)
228		26090±640	Severnaya Zemlya Archipelago (LU-1142) (*Bolshiyanov et al.*,1995)
229		26200±620	Biya River (SOAN-51) (*Endrikhinskii*, 1982)
230		26300±900	Novonazimovo village, Yenisei River (LG-19) (*Endrikhinskii*, 1982)
231		26600±1000	B. Balakhnya River, North Siberian Lowland (GIN-999) (*Andreeva*, 1980)
232		26700±210	Shadrintsevo village, Ob River tributary (SOAN-434) (*Endrikhinskii*, 1982)
233		26700±700	B. Balakhnya River, North Siberian Lowland (GIN-999) (*Andreeva*, 1980)
234		27000±700	Zakharova Rassokha River, Khatanga River tributary (GIN-1454) (*Andreeva*, 1980)
235		27100±200	Molodo River (GIN-1433) (*Shofman*, 1980)

No.	Stage	Dating	Location and references
236		27200±700	North Siberian Lowland (GIN-1454) (*Andreeva*, 1980)
237		28000±500	Tumara, Kele, Tukulan, and Khandyga rivers (GIN-533) (*Kolpakov et al.*, 1980)
238		28050±310	Pogorelka village, Ob River tributary (SOAN-1257) (*Endrikhinskii*, 1982)
239		28200±440	Vatutina Promontory Severnaya Zemlya Archipelago (LU-613) (*Bolshiyanov et al.*, 1995)
240		29500±250	Undyulong, Begidzhyan, and Sobopol rivers (GIN-345) (*Kolpakov et al.*, 1980)
241		29670±230	Irkineeva River (SOAN-128) (*Laukhin et al.*, 1980)
242		29700±1000	North Siberian Lowland (GIN-693) (*Andreeva*, 1980)
243		30100±150	Ust'-Kova, Angara River tributary (GIN-1741) (*Laukhin et al.*, 1980)
244		30400±300	Undyulong, Begidzhyan, and Sobopol rivers (GIN-224) (*Kolpakov et al.*, 1980)
245		30600±500	Varvarina Gora site (SO AN-850) (*Kind*, 1974)
246		31000±750	North Siberian Lowland (GIN-752b) (*Isaeva et al.*, 1980)
247		31450±440	Severnaya Zemlya Archipelago (LU-630) (*Bolshiyanov et al.*,1995)
248		31500±750	North Siberian Lowland (MGU-486) (*Isaeva et al.*, 1980)
249		31800±400	B. Balakhnya River, North Siberian Lowland (MGU-486) (*Andreeva*, 1980)
250		32700±2000	North Siberian Lowland (GIN-1550) (*Andreeva*, 1980)
251		32800±2000	B. Balakhnya River, North Siberian Lowland (GIN-1000) (*Andreeva*, 1980)
252		33300±400	North Siberian Lowland (GIN-752b) (*Isaeva et al.*, 1980)
253		33400±780	Irkineeva River (SOAN-129)(*Laukhin et al.*, 1980)
254		33450±550	Kargopolovo village, Ob River (SOAN-744) (*Endrikhinskii*, 1982)
255		33600±700	Undyulong, Begidzhyan, and Sobopol rivers (GIN-339) (*Kolpakov et al.*, 1980)
256		33950±400	Bobkovo village, Alei River, Ob River tributary (SOAN-446) (*Endrikhinskii*, 1982)
257		34015±1515	Severnaya Zemlya Archipelago (Upsala-1285) (*Bolshiyanov et al.*,1995)
258		34650±2100	B. Yeniseiskoe village (SOAN-161) (*Endrikhinskii*, 1982)
259		34860±2100	Tolbaga village, Khilok River (SOAN-1522) (*Endrikhinskii*, 1982)
260		35100±1000	Balakhnya River, North Siberian Lowland (GIN-1458) (*Andreeva*, 1980)
261		35110±1480	Severnaya Zemlya Archipelago (LU-1356) (*Bolshiyanov et al.*,1995)
262		35350±470	Malyshevo village, Ob River (SOAN-1633) (*Endrikhinskii*, 1982)
263		35400±700	Novosurtaevka village, Katun' River (SOAN-747) (*Endrikhinskii*, 1982)
264		35400±2500	Beloyarskoe village, Kan River (MGU-IOAN-158) (*Endrikhinskii*, 1982)
265		35530±2310	Severnaya Zemlya Archipelago (Upsala-1795) (*Bolshiyanov et al.*,1995)
266		35800±1700	Northern Middle Siberian Upland (GIN-493) (*Bardeeva et al.*, 1980)
267		35830±630	Terekhtyakh mammoth, Indigirka River basin (LU-504) (*Arslanov et al.*, 1980)
268		36000	Vilyui River (GIN-890) (*Shofman*, 1980)
269		36100±200	Molodo River (GIN-1427) (*Shofman*, 1980)
270		36200±1000	North Siberian Lowland (MGU-492) (*Isaeva et al.*, 1980)
271		36420±700	North Siberian Lowland (SOAN-1075) (*Andreeva*, 1980)
272		37300±1675	Severnaya Zemlya Archipelago (Upsala-1385) (*Bolshiyanov et al.*,1995)
273		37340±660	B. Rechka River, Ob River tributary (SOAN-1258) (*Endrikhinskii*, 1982)
274		37500±1000	North Siberian Lowland (SOAN-834) (*Andreeva*, 1980)
275		37600±800	Vilyui River (GIN-1103) (*Shofman*, 1980)
276		37900±700	Undyulong, Begidzhyan, and Sobopol rivers (GIN-343) (*Kolpakov et al.*, 1980)
277		37950±1150	Irkineeva River (KSM-10) (*Laukhin et al.*, 1980)
278		38000±?	Severnaya Zemlya Archipelago (*Bolshiyanov et al.*,1995)
279		38200±2500	Beloyarskoe village, Kan River (MGU-IOAN-153) (*Endrikhinskii*, 1982)
280		38400±800	Vilyui River (GIN-1104) (*Shofman*, 1980)
281		38400±800	Lena River, below the Aldan River mouth (GIN-545) (*Kolpakov et al.*, 1980)

No.	Stage	Dating	Location and references
282		38500±1000	Vilyui River (GIN-1100) (*Shofman*, 1980)
283		38590±1120	Selirikan horse, Balakhan River, Indigirka River basin (LU-506) (*Arslanov et al.*, 1980)
284		38590±770	Magadan young mammoth (LU-718V) (*Arslanov et al.*, 1980)
285		38800±?	Kargopolovo village, Ob River (SOAN-25) (*Endrikhinskii*, 1982)
286		38800±1600	Yana River, Mus-Khaya (GIN-500) (*Kolpakov et al.*, 1980)
287		38850±2200	Irkineeva River (SOAN-130) (*Laukhin et al.*, 1980)
288		39000±1000	Baty-Sala River, North Siberian Lowland (GIN-1441) (*Andreeva*, 1980)
289		39000±2000	Molodo River (GIN-1435) (*Shofman*, 1980)
290		39350±760	Shcherbakovo village, Ob River (SOAN-445)(*Endrikhinskii*, 1982)
291		39420±490	Severnaya Zemlya Archipelago (LU-558) (*Bolshiyanov et al.*, 1995)
292		39500±2000	Lake Taimyr, North Siberian Lowland (GIN-794) (*Andreeva*, 1980)
293		39500±500	Markha River (GIN-906) (*Shofman*, 1980)
294		39570±870	Magadan young mammoth (LU-718A) (*Arslanov et al.*, 1980)
295		39600±1200	Novosurtaevka village, Katun' River (SOAN-748) (*Endrikhinskii*, 1982)
296		39700±700	North Siberian Lowland (GIN-735) (*Isaeva et al.*, 1980)
297		39900±1500	North Siberian Lowland (GIN-784) (*Andreeva*, 1980)
298		40310±1230	Glacier-dammed features, Allakh-Yun' River, Priverkhoyan'e area (LU-602) (*Zamoruev*, 1979)
299		40350±880	Mammoth, Shandrin River, Yakutia (LU-595) (*Arslanov et al.*, 1980)
300		40450±1000	Malyshevo village, Ob River (SOAN-1632) (*Endrikhinskii*, 1982)
301		40600±800	North Siberian Lowland (GIN-1150) (*Isaeva et al.*, 1980)
302		40600±1900	Molodo River (GIN-1429) (*Shofman*, 1980)
303		40900±1000	Vilyui River (GIN-1101) (*Shofman*, 1980)
304		41200±3000	B. Yeniseiskoe village (SOAN-751) (*Endrikhinskii*, 1982)
305		41200±2000	North Siberian Lowland (GIN-1534) (*Isaeva et al.*, 1980)
306		41240±?	Severnaya Zemlya Archipelago (LU-1325) (*Bolshiyanov et al.*,1995)
307		41300±1500	Yana River, Mus-Khaya (GIN-538) (*Kolpakov et al.*, 1980)
308		41600±1300	Irkineeva River (KSM-11) (*Laukhin et al.*, 1980)
309		41750±1290	Mammoth, Shandrin River, Yakutia (LU-595) (*Arslanov et al.*, 1980)
310		42000±1500	Vilyui River (GIN-891) (*Shofman*, 1980)
311		42000±1500	Vilyui River (GIN-1106) (*Shofman*, 1980)
312		42600±1500	Boyarka River North Siberian Lowland (GIN-673) (*Andreeva*, 1980)
313		42800±1300	Malaya River, North Siberian Lowland (GIN-1530) (*Andreeva*, 1980)
314		42920±1240	Severnaya Zemlya Archipelago (LU-1672) (*Bolshiyanov et al.*,1995)
315		43000±1000	Severnaya Zemlya Archipelago (LU-592) (*Bolshiyanov et al.*,1995)
316		43100±1200	B. Romanikha River, North Siberian Lowland (GIN-1010) (*Andreeva*, 1980)
317		43100±1800	Markha River (GIN-896) (*Shofman*, 1980)
318		43100±1850	Vacha River (SOAN-406) (*Tishchenko*, 1982)
319		43200±1100	Tumara, Kele, Tukulan, and Khandyga rivers (GIN-525) (*Kolpakov et al.*, 1980)
320		43500±1000	Yana River, above Ust'-Kuiga (GIN-524) (*Kolpakov et al.*, 1980)
321		44000±1600	Vilyui River (GIN-1105) (*Shofman*, 1980)
322		44000±1500	Ulakhan-Sakkyryk River (GIN-704) (*Kolpakov et al.*, 1980)
323	**Karga**	44500±1000	Balakhnya River, North Siberian Lowland (GIN-1004) (*Andreeva*, 1980)
324		45500±1500	Tumara, Kele, Tukulan, and Khandyga rivers (*Kolpakov et al.*, 1980)
325		45560±1870	Severnaya Zemlya Archipelago (LU-1278) (*Bolshiyanov et al.*,1995)
326		45900±1570	Severnaya Zemlya Archipelago (LU-1121) (*Bolshiyanov et al.*,1995)
327		46100±?	Severnaya Zemlya Archipelago (LU-1075) (*Bolshiyanov et al.*,1995)

No.	Stage	Dating	Location and references
328		46200±2000	Bata-Sala River, North Siberian Lowland (GIN-1152) (*Andreeva*, 1980)
329		46550±1350	Severnaya Zemlya Archipelago (LU-1074) (*Bolshiyanov et al.*,1995)
330		46600±1200	Lake Taimyr, North Siberian Lowland (GIN-1324) (*Andreeva*, 1980)
331		47000±1000	Irkineeva River (KSM-41) (*Laukhin et al.*, 1980)
332		47600±1600	Aldan River (GIN-845) (*Kolpakov et al.*, 1980)
333		48150±3500	Vacha River (SOAN-405) (*Tishchenko*, 1982)
334		48700	Vilyui River (GIN-1102) (*Shofman*, 1980)
335		48800±2000	Ulakhan-Sakkyryk River (GIN-705) (*Kolpakov et al.*, 1980)
336		50000±2000	Markha River (GIN-893) (*Shofman*, 1980)
337		50000	Vilyui River (GIN-892) (*Shofman*, 1980)
338		51470±?	Severnaya Zemlya Archipelago (LU-1080) (*Bolshiyanov et al.*,1995)
339		51740±1500	Severnaya Zemlya Archipelago (LU-569) (*Bolshiyanov et al.*,1995)
340		52200±860	Severnaya Zemlya Archipelago (LU-570) (*Bolshiyanov et al.*,1995)
341		54040±?	Severnaya Zemlya Archipelago (LU-590) (*Bolshiyanov et al.*,1995)
342		54790±?	Severnaya Zemlya Archipelago (LU-593) (*Bolshiyanov et al.*,1995)
343		55230	Severnaya Zemlya Archipelago (LU-591) (*Bolshiyanov et al.*,1995)
344		55900±2200	Severnaya Zemlya Archipelago (LU-571) (*Bolshiyanov et al.*,1995)

Table 3. Occurrence calendar of ancient people sites in southern Siberia

No.	Pleistocene stages	Historical epochs	Dating	Location and references
1	**Late Holocene**		2130±145	Berloga site, Priolkhon'e Island (*Goryunova et al.*, 1996)
2		**Iron Age 3200–**	2230±100	Chadobets site, soil (KRIL-231) (*Laukhin et al.*, 1980)
3			2990±120	Chadobets site, soil (KRIL-232) (*Laukhin et al.*, 1980)
4			3440±20	Tyshkino site, Priolkhon'e Island (SOAN-2511) (*Goryunova et al.*, 1996)
5		**Bronze Age 3500–2500**	3525±25	Tyshkino site, Priolkhon'e Island (SOAN-2512) (*Goryunova et al.*, 1996)
6			3620±50	Ulan-Khada archaeological monument, Priolkhon'e Island (GIN-4875) (*Goryunova et al.*, 1996)
7			3660±60	Ulan-Khada archaeological monument, Priolkhon'e Island (LE-883) (*Goryunova et al.*, 1996)
8			3660±20	(«-2513) Tyshkino site, Priolkhon'e Island (SOAN-2513)(*Goryunova et al.*, 1996)
9			3710±100	Ulan-Khada archaeological monument, Priolkhon'e Island (LE-1279) (*Goryunova et al.*, 1996)
10			3780±40	Tyshkino site, Priolkhon'e Island (GIN-4880) (*Goryunova et al.*, 1996)
11			3800±100	Neolithic and Mesolithic paleosol cultural layer, Olkhon and Priolkhon'e Islands (LE-1277) (*Mats*, 1987)
12			4000±50	Ulan-Khada archaeological monument, Priolkhon'e Island (GIN-4876) (*Goryunova et al.*, 1996)
13			4030±115	Ulan-Khada archaeological monument, Priolkhon'e Island (SOAN-3335) (*Goryunova et al.*, 1996)
14			4060±80	Ulan-Khada archaeological monument, Priolkhon'e Island (GIN-4877) (*Goryunova et al.*, 1996)

No.	Pleistocene stages	Historical epochs	Dating	Location and references
		origin of cattle-breeding 5000 years ago		
15	**Late Middle Holocene**		4150±80	Ulan-Khada archaeological monument, Priolkhon'e (LE-1280) (*Goryunova et al.*, 1996)
16			4220±120	Neolithic and Mesolithic paleosol cultural layer, Olkhon and Priolkhon'e Islands (LE-1278) (*Mats*, 1987)
17			4410±200	Chadobets site, soil (KRIL-233) (*Laukhin et al.*, 1980)
18			4430±15	Ityrkhei-V, VI, archaeological monument, Priolkhon'e Island (*Vorob'eva et al.*, 1992)
19			4470±65	Neolithic culture on the surface of the 1st terrace, conclusion of the 1st terrace formation, Boguchanskaya Bay (SOAN-830) (*Mats*, 1987)
20			4485±45	Ityrkhei site, Priolkhon'e Island (SOAN-1585) (*Goryunova et al.*, 1996)
21			4500±100	Ulan-Khada archaeological monument, Priolkhon'e Island (*Vorob'eva et al.*, 1992)
22			4560±100	Neolithic and Mesolithic paleosol cultural layer, Olkhon and Priolkhon'e Islands (LE-1282) (*Mats*, 1987)
23			4600±60	Kazachka IV site (*Vorob'eva et al.*, 1992)
24			4740±155	Ityrkhei site, Priolkhon'e Island (SOAN-3342) (*Goryunova et al.*, 1996)
25		**Eneolithic** (Copper-Stone Age) **6000–5000**	5430±120	Gorelyi Les site (*Vorob'eva et al.*, 1992)
26	**Late Middle Holocene**		5495±125	Ulan-Khada archaeological monument, Priolkhon'e Island (SOAN-3336) (*Goryunova et al.*, 1996)
27		**Neolithic** in the Baikal region **6000–3200**	5680±60	Ityrkhei site, Priolkhon'e Island (SOAN-3341) (*Goryunova et al.*, 1996)
28			5700±200	Ityrkhei site, Priolkhon'e Island (GIN-4881) (*Goryunova et al.*, 1996)
29			6525±100	Berloga site, Priolkhon'e Island (SOAN-3169) (*Goryunova et al.*, 1996)
30			6650±200	Kazachka VI archaeological monument (*Vorob'eva et al.*, 1992)
31			6695±150	Gorelyi Les VI site (*Vorob'eva et al.*, 1992)
32	**Early Middle Holocene**		6850±210	Kazachka VIII archaeological monument (*Vorob'eva et al.*, 1992)
33			6996±150	Gorelyi Les VI archaeological monument (*Vorob'eva et al.*, 1992)
34			7300±290	Neolithic and Mesolithic paleosol cultural layer, Olkhon and Priolkhon'e Islands (IMSOAN-402) (*Mats*, 1987)
35			7430±230	Shishkino archaeological monument, Lena River (*Endrikhinskii*, 1982)
36			7620±900	Sagan-Nuge site, Priolkhon'e Island (SOAN-3056) (*Goryunova et al.*, 1996)
37			8000±150	Kazachka XII archaeological monument (*Vorob'eva et al.*, 1992)
38			8000±700	Shishkino site, Lena River, 1st above-floodplain terrace (Kind et al., cited in *Aksenov et al.*, 1975)

No.	Pleistocene stages	Historical epochs	Dating	Location and references
39			8010±100	Ityrkhei site, Priolkhon'e Island (GIN-4882) (*Goryunova et al.*, 1996)
40			8100±150	Kazachka XI archaeological monument (*Vorob'eva et al.*, 1992)
41			8270±150	Shishkino archaeological monument, Lena River (GIN-303) (*Endrikhinskii*, 1982)
42			8270±150	Berloga site, Priolkhon'e Island (SOAN-3340) (*Goryunova et al.*, 1996)
43			8300±250	Kazachka XI archaeological monument (*Aksenov et al.*, 1992)
44			8444±124	Mesolithic Gorelyi Les site, southern Angara area, elevated floodplain (*Medvedev et al.*, 1975)
45	**Early Holocene**	**Neolithic 10000--8000**	8720±210	Ityrkhei site, Priolkhon'e Island (SOAN-3171) (*Goryunova et al.*, 1996)
46			8855±300	Mesolithic Gorelyi Les site, southern Angara area, elevated floodplain (KRIL-234) (*Medvedev et al.*, 1975)
47			8960±60	1st above-floodplain terrace alluvium of the Angara River, Belaya River mouth area (GIN-96) (*Tseitlin*, 1975)
48			9105±70	Berloga site, Priolkhon'e Island (SOAN-3059) (*Goryunova et al.*, 1996)
49			9360±95	Sagan-Nuge site, Priolkhon'e Island (SOAN-3337) (*Goryunova et al.*, 1996)
50			9815±80	Sagan-Nuge site, Priolkhon'e Island (SOAN-3058) (*Goryunova et al.*, 1996)
51			9850±500	1st above-floodplain terrace alluvium of the Angara River, Belaya River mouth area (GIN-483) (*Tseitlin*, 1975)
52			10145±290	Berloga site, Priolkhon'e Island (SOAN-3060) (*Goryunova et al.*, 1996)
53			10290±40	Sagan-Nuge site, Priolkhon'e Island (SOAN-3057) (*Goryunova et al.*, 1996)
54			10900±500	Oshurkovo site, Selenga River (*Endrikhinskii*, 1982)
55	**Oldest Holocene**	**Mesolithic**	11400±500	Makarovo II archaeological monument, Lena River head area (GIN-480b) (Kind et al., 1972, cited in *Aksenov et al.*, 1975)
56		**12000--10000**	11860±200	Makarovo II archaeological monument, Lena River head area (GIN-480a) (Kind et al., 1972, cited in *Aksenov et al.*, 1975)
57			11930±230	Ust'-Belaya XIV archaeological monument (*Aksenov et al.*, 1992)
58			11950±50	Makarovo II archaeological monument, Lena River head area (GIN-481) (Kind et al., 1972, cited in *Aksenov et al.*, 1975)
59			12180±120	Kokorevo-2 site (LE-770), Yenisei River (*Endrikhinskii*, 1982)
60			12570±180	Mesolithic Verkholenskaya Gora site, alluvium of the 3rd above-floodplain terrace (MO-441) (*Medvedev et al.*, 1975)
61			12900±300	Oshurkovo site, Selenga River (*Endrikhinskii*, 1982)

No.	Pleistocene stages	Historical epochs	Dating	Location and references
62			12940±270	Kokorevo-2 site, Yenisei River (LE-526) (*Endrikhinskii*, 1982)
63			13300±50	Kokorevo-1 site, Yenisei River (GIN-91) (*Endrikhinskii*, 1982)
64			13300±?	Kokorevo-2 site, Yenisei River (GIN-90) (*Endrikhinskii*, 1982)
65			14320±330	Kokorevo-4 site, Yenisei River (LE-496) (*Endrikhinskii*, 1982)
66			14700±150	Kokorevo-2 site, Yenisei River (GIN-262) (*Endrikhinskii*, 1982)
67			14720±190	Malta archaeological monument (GIN-8476) (*Medvedev et al.*, 1996)
68			14750±120	Malta archaeological monument (GIN-97) (*Medvedev et al.*, 1996)
69			15200±1250	Kurla archaeological monument (SOAN-1396) (*Medvedev et al.*, 1990)
70			15460±320	Kokorevo-4 site, Yenisei River (LE-540) (*Medvedev et al.*, 1990)
71	**Late Pleistocene**		19100±100	Krasnyi Yar archaeological monument (GIN-5530) (*Medvedev et al.*, 1990)
72	**Samarovo Glaciation**		19900±800	Malta archaeological monument (GIN-7705) (*Medvedev et al.*, 1996)
73			20340±320	Malta archaeological monument (OkhA-6192) (*Medvedev et al.*, 1996)
74			20700±150	Malta archaeological monument (GIN-7709) (*Medvedev et al.*, 1996)
75			20800±140	Malta archaeological monument (GIN-7710) (*Medvedev et al.*, 1996)
76			20800±200	Malta archaeological monument (GIN-4367) (*Medvedev et al.*, 1996)
77			20900±300	Afontova Gora-2 archaeological monument, Krasnoyarsk area (GIN-117) (*Endrikhinskii*, 1982)
78			20900±200	Malta archaeological monument (GIN-4367) (*Medvedev et al.*, 1996)
79			21000±140	Malta archaeological monument (GIN-7706) (*Medvedev et al.*, 1996)
80			21100±110	Malta archaeological monument (GIN-7703) (*Medvedev et al.*, 1996)
81			21190±100	Buret' archaeological monument, Angara River (*Medvedev et al.*, 1990)
82			21260±240	Itegeiskii Log archaeological monument (LE-1590)(*Medvedev et al.*, 1990)
83			21300±110	Malta archaeological monument (GIN-7704) (*Medvedev et al.*, 1996)
84			21300±300	Malta archaeological monument (GIN-7702) (*Medvedev et al.*, 1996)
85			21340±340	Malta archaeological monument (OkhA-6193) (*Medvedev et al.*, 1996)
86			21600±170	Malta archaeological monument (GIN-8475) (*Medvedev et al.*, 1996)

No.	Pleistocene stages	Historical epochs	Dating	Location and references
87			21600±200	Malta archaeological monument (GIN-7708) (*Medvedev et al.*, 1996)
88			21700±160	Malta archaeological monument (OkhA-6191) (*Medvedev et al.*, 1996)
89		**Upper Paleolithic 12000--40000**	23000±5000	Malta archaeological monument, alluvium of the 3rd above-floodplain terrace, Belaya River, ionium dating (Cherdyntsev, 1961, cited in [*Tseitlin*, 1975; *Medvedev et al.*, 1990])
90			23200±1800	Oshurkovo site, Selenga River (*Endrikhinskii*, 1982)
91			23508±250	Igeteiskii Log archaeological monument (LE-1592) (*Medvedev et al.*, 1990)
92	**Late Pleistocene**		23700±100	Igetei archaeological monument (IM SOAN-405) (*Medvedev et al.*, 1990)
93	**Karginsky Inter-**		23760±1100	Upper Paleolithic Igeteiskii Log archaeological monument (IM SOAN-405) (*Medvedev et al.*, 1990)
94	**glacial**		23780±600	Igetei archaeological monument (SOAN-1681) (*Medvedev et al.*, 1990)
95			24060±570	Kurla archaeological monument, northern Baikal (SOAN-1397) *Medvedev et al.*, 1990)
96			24400±400	Itegeiskii Log archaeological monument (GIN-5327) (*Medvedev et al.*, 1990)
97			25760±260	Malta archaeological monument (OkhA-6190) (*Medvedev et al.*, 1996)
98			29700±500	Voennyi Gospital archaeological monument, spit between the Angara and Ushakovka Rivers (GIN-4440) (*Medvedev et al.*, 1990)
99			41100±1500	Malta archaeological monument (GIN-7707) (*Medvedev et al.*, 1996)
100			43100±2400	Malta archaeological monument (OkhA-6189) (*Medvedev et al.*, 1996)

53-36 ka, Kazantsevo time; 50-42 ka, early Karginsky time;
42-33 ka, Malokhetsky time; 33-24 ka, late Karginsky time;
17-10 ka, Sartan time

References

Aksenov, M.P., Lypsha, V.A., and Shun'kov, M.V., Complex of pre-Neolithic occurrences near the Kistenevo village, upper Lena River, in *Ancient History of Peoples in Southern East Siberia,* vol. 3, pp. 81–114, Irkutsk, 1975 (in Russian).

Andreev, A.A., Klimanov, V.A., and Sulerzhitskii, L.D., History of vegetation and climate in central Yakutia over the past 11000 years, in *Geochronology of the Quaternary,* pp. 113–117, Moscow, Nauka, 1992 (in Russian).

Andreeva, S.M., North Siberian lowland at the Karginsky time (50–24 ka). Paleogeography and radiocarbon chronology, in *Geochronology of the Quaternary,* pp. 183–191, Moscow, Nauka, 1992 (in Russian).

Arslanov, Kh.A., Vereshchagin, N.K., Lyadov, V.V., and Ukraintsev, V.V., On the chronology of the Karginsky Interglacial and reconstruction of Siberian landscapes from the study of mammoth corpses and their "satellites", in *Geochronology of the Quaternary,* pp. 208–209, Moscow, Nauka, 1992 (in Russian).

Bardeeva, M.A., Isaeva, L.L., Andreeva, S.M., et al., Stratigraphy, geochronology, and paleogeography of the Late Pleistocene and Holocene in the northern Central Siberian Upland, in *Geochronology of the Quaternary,* pp. 191–197, Moscow, Nauka, 1992 (in Russian).

Bezrukova, E.V., Vegetation and climate in the Baikal region at the postglacial and Holocene time, *and. Sc. Dissertation,* Novosibirsk, 1996 (in Russian).

Bolshiyanov, D.Yu. and Makeev, V.M., *Severnaya Zemlya Archipelago: Glaciation and the History of the Natural Environment,* Saint Petersburg, Gidrometeoizdat, 1995 (in Russian).

Chichagov, V.P., Radiocarbon constraints on natural and anthropogenic factors contributing to the acceleration of contemporary geodynamic processes, in *Geochronology of* *the Quaternary,* pp. 154–161, Moscow, Nauka, 1992 (in Russian).

Chipizubov, A.V. and Smekalin, O.P., Periodicity of seismic events on the Main Sayany fault from paleoseismological data, in *Abstr. All-Russia Confer. on Study of the Quaternary,* Moscow, 1994 (in Russian).

Dervits, A.L., Rasskazov, S.V., Polyakov, A.I., and Dobkina, E.I., Radiocarbon dating of young volcanoes of the Udokan Range, *Geokhimiya,* 8, 1250–1253, 1981, (in Russian).

Endrikhinskii, A.S., The sequence of main geological events in southern Siberia in the late Pleistocene and Holocene, in *Late Pleistocene and Holocene of Southern East Siberia,* pp. 6–35, Novosibirsk, Nauka, 1982 (in Russian).

Firsov, L.V., Kulchitskii, A.A., and Svinin, V.V., On the chronology of Holocene deposits and paleogeography of North Baikal, in *Ancient History of Peoples in Southern East Siberia,* vol. 3, pp. 142–149, Irkutsk, 1975 (in Russian).

Goryunova, O.I., Vorob'eva, G.A., and Orlova, L.A., New data on the chronology of multilayered settlements of the Priolkhon'e Island, in *Recent Archaeological and Ethnographic Discoveries in Siberia,* pp. 57–59, Novosibirsk, IAE SO RAN, 1996 (in Russian).

Isaeva, L.L., Kind, N.V., Andreeva, S.M., et al., Radiocarbon constraints on the geochronology and paleogeography of the Late Pleistocene of the North Siberian Lowland, in *Geochronology of the Quaternary,* pp. 191–197, Moscow, Nauka, 1992 (in Russian).

Ivanovskii, L.N., Panychev, V.A., and Orlova, L.A., Age of Altai end moraines of the "Aktru" and "Istoricheskaya" stages, in *Late Pleistocene and Holocene of the Southern East Siberia,* pp. 57–64, Novosibirsk, Nauka, 1982 (in Russian).

Kind, N.V., *Geochronology of the Late Anthropogene from Isotopic Data,* Moscow, Nauka, 1974 (in Russian).

Kolman, S.M., Kuptsov, V.M., Joyns, G.A., and Carter, S.J., Radiocarbon dating of Baikal sediments, *Geol. Geofiz.,* (10–11) 68–77, 1993 (in Russian).

Kolpakov, V.V. and Belova, A.P., Radiocarbon ages in the Verkhoyan'e glacial zone and adjacent areas, in *Geochronology of the Quaternary,* pp. 230–235, Moscow, Nauka, 1992 (in Russian).

Kostyukevich, V.V., Radiocarbon dating of alas deposits in central Yakutia, in *Geochronology of the Quaternary,* pp. 235–243, Moscow, Nauka, 1992 (in Russian).

Krivonogov, S.K. and Bezrukova, E.V., Development of sedimentation, vegetation, and climate in the Verkhnecharskii basin in the latest Pleistocene and Holocene, *Geol. Geofiz.,* (10–11), 226–237, 1993 (in Russian).

Kulchitskii, A.A. and Popova, S.M., Late Karginsky temperature rise in the western Baikal region, *Dokl. Ross. Akad. Nauk,* (in press), 1997 (in Russian).

Kulchitskii, A.A., Skovitina, T.M., and Ufimtsev, G.F., Rift bottom dammed lakes in East Siberia: Evidence from the past and prognosis for the future, *Geogr. Prirodn. Resursy,* 1, 61–65, 1997 (in Russian).

Laukhin, S.A., Drozdov, N.I., Starikov, A.V., et al., Radiocarbon datings of Holocene deposits in the E-W valley of the Angara River, in *Geochronology of the Quaternary,* pp. 213–223, Moscow, Nauka, 1992 (in Russian).

Makarov, S.A., Semenikhinskii landslide as a unique natural monument in the Baikal region, in *Conservation of Ecological Systems and Monitoring Problems of Protected Areas,* pp. 177–179, Irkutsk, IGU, 1996 (in Russian).

Makarov, S.A., Geomorphological processes in the Holocene of the Priolkhon'e Island, *Geogr. Prirodn. Resursy,* 1, 77–84, 1997.

Mats, V.D., The Cenozoic of the Baikal Basin, *Doct. Dissertation,* Irkutsk, 1987 (in Russian).

McCalpin, J.P. and Khromovskikh, V.S., Holocene paleoseismicity of the Tunka fault, Baikal rift, Russia, *Tectonics,* 14(3), 594–605, 1995.

Medvedev, G.I., Mikhnyuk, G.N., and Shmygun, P.E., Mesolithic in southern East Siberia, in *Ancient History of Peoples in Southern East Siberia,* vol. 3, pp. 74–80, Irkutsk, 1975 (in Russian).

Medvedev, G.I., Savel'ev, N.A., and Svinin, V.V., Eds., *Stratigraphy, Paleogeography, and Archaeology of Southern Central Siberia,* Irkutsk, IGU, 1990.

Medvedev, G.I., Cove, N., Vorob'eva, G., et al., *Malta Paleolithic Site,* Irkutsk-Brussels, 1996 (in Russian).

Nikolskaya, M.V., Kind, N.V., Sulerzhitskii, L.D., and Cherkasova, M.N., Geochronology and paleophytological characteristics of the Taimyr Holocene, in *Geochronology of the Quaternary,* pp. 176–183, Moscow, Nauka, 1992 (in Russian).

Popova, S.M., Mats, V.D., Chernyaeva, G.P., et al., *Paleolimnological Reconstructions (Baikal Rift Zone),* Novosibirsk, Nauka, 1989 (in Russian).

Ruzhitch, V.V. and Takeutchi, A., The assessment of seismic paleoearthquake areas in Pribaikalye, *Abstr. XIV INQUA Congress,* Berlin, 1995.

Savina, L.N., The development tendency of coastal landscapes of the Lake Baikal, in *Late Cenozoic Lake History,* Novosibirsk, Nauka, 1982 (in Russian).

Shofman, I.L., Geochronology and paleogeography of the late Anthropogene in the off-glaciation zone of the northeastern Siberian platform, in *Geochronology of the Quaternary,* pp. 223–230, Moscow, Nauka, 1992 (in Russian).

Sizikov, A.M., Upper Pleistocene-Holocene of the northern Baikal region, in *Ancient History of Peoples in Southern East Siberia,* vol. 3, pp. 115–120, Irkutsk, 1975 (in Russian).

Tishchenko, E.I., Some problems of the history of Quaternary sedimentation within the Baikalo-Patomskoe Upland, in *Late Pleistocene and Holocene of Southern East Siberia,* pp. 70–84, Novosibirsk, Nauka, 1982 (in Russian).

Tseitlin, S.M., Paleolithic Geology of the upper Angara region, in *Ancient History of Peoples in Southern East Siberia,* vol. 3, pp. 59–73, Irkutsk, 1975 (in Russian).

Tseitlin, S.M., *Geology of the North Eurasia Paleolithic,* Moscow, Nauka, 1979 (in Russian).

Vorob'eva, G.A., Goryunova, O.I., and Savel'ev, N.A., Chronology and paleogeography of the Holocene in the southern Central Siberia, in *Geochronology of the Quaternary,* pp. 174–181, Moscow, Nauka, 1992 (in Russian).

Zamoruev, V.V., Late Quaternary glacier-dammed lakes in southern Verkhoyan'e, in *History of Lakes in the USSR,* pp. 135–136, Irkutsk, VSF SO AN SSSR, 1979 (in Russian).