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Vegetation and climate dynamics during the Holocene and Eemian interglacials derived from Lake Baikal pollen records

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Abstract

The last interglacial (LI) and Holocene changes in annual precipitation (P_{ann}), the mean temperature of the warmest (T_w) and coldest (T_c) month and the moisture index (α) were reconstructed from continuous pollen records from Lake Baikal. The Holocene core (52°31′N, 106°09′E) presented in this study was recovered from a depth of 355 m in the 25-km wide underwater Buguldeika saddle separating the southern sub-basin of Lake Baikal from its central sub-basin. The biome reconstruction shows that tundra and steppe biomes have highest scores during ca. 15,000–13,300 cal. years B.P. and that taiga becomes a dominant vegetation type after ca. 13,300 cal. years B.P. Our quantitative reconstruction indicates an onset of relatively warm and wet conditions soon after ca. 10,000 cal. years B.P. The warmest and wettest climate with $T_w \sim 16$ °C, $P_{ann} \sim 480$ mm and $\alpha \sim 0.9$–1 has been reconstructed for ca. 9000–7000 cal. years B.P. In the Lake Baikal region this interval is characterized by the appearance and spread of hunter communities (Kitoi culture). Consistently a hiatus in the regional archaeological record (4900–4200 years B.C. or 6850–6150 cal. years B.P.) coincides with the interval of a major climate deterioration which followed the 'climatic optimum'. An attempt to find a relationship between the archaeological record and a spread of steppe and meadow communities in the Lake Baikal region demonstrates that despite a long habitation of the area the human impact on vegetation was local rather than regional and likely did not affect the pollen record from Lake Baikal. The reconstructed peaks in the steppe biome scores during the last 9000 years are consistent with short (one to five hundred year) episodes of weak Pacific (summer) monsoon supporting our interpretation that the Holocene vegetation changes around Lake Baikal are associated with large-scale circulation processes controlling regional water balance rather than with human activities. Thus, our study proves the suitability of Lake Baikal pollen data for the reconstruction of natural vegetation and climate dynamics through the whole period from the onset of the LI to the present. Comparison of the recent and the last interglacial suggests that the Holocene 'climatic optimum' was less pronounced (e.g. lower summer and winter temperatures and annual precipitation sums) than that of the LI. On the other hand, pollen records demonstrate that the Holocene

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'forest phase' already lasts some thousand years longer than that of the LI. The interglacial vegetation dynamics derived from the Lake Baikal pollen records can be satisfactorily explained by reconstructed changes in summer and winter temperatures and in available moisture. The interglacial vegetation around Lake Baikal is dominated by the boreal forests, which are associated with a generally warm and wet climate. The high sea level associated with decreased ice volume appears to have had a greater impact on the Siberian environments during the last and the recent interglacial than the direct effect of lower-than-present winter insolation. Reconstructed changes in the winter temperature correlate well with changes in the sea level and global ice volume, while the summer temperatures derived from the Lake Baikal pollen records track changes in the summer insolation.

Keywords: Holocene; Last interglacial; Pollen record; Climate reconstruction; Human dynamics; Lake Baikal; South Siberia; Russia

1. Introduction

Objective reconstructions of the past climate and environment are among the priority tasks for the scientific community working in the field of past global changes and the Earth's system modeling (PAGES: http://www.pages.unibe.ch/). After pioneering works by Iversen (1944), Szafer (1946) and Grichuk (1969, 1984) pollen from the continental lacustrine sediments soon became a frequently used proxy to quantify late Quaternary climate changes at both a local and regional scale (e.g. Bartlein et al., 1984; Guiot et al., 1989; Seppä and Birks, 2001, 2002; Nakagawa et al., 2002; Seppä et al., 2005; Tarasov et al., 2005 and references therein).

Since the 1990s Lake Baikal – the world's largest, deepest and oldest freshwater reservoir – is in the focus of several large-scale national and international multidisciplinary projects (e.g. BDP-Members, 1997; Grachev et al., 1997; Williams et al., 1997; BDP-Members, 1998; Williams et al., 2001; Oberhänsli and Mackay, 2004; BDP-Members, 2005 and references therein). These projects aim at obtaining long, detailed and adequately dated palaeoenvironmetal records well preserved in the lake-bottom sediments and at using them for reconstructions of the regional climate and vegetation (e.g. Colman et al., 1996; Bezrukova, 1999; Horiuchi et al., 2000; Khursevich et al., 2001; Prokopenko and Williams, 2004; Bezrukova et al., 2005).

Lake Baikal (Fig. 1) is well suited for the collection of pollen and spores produced by the regional vegetation. The size of the basin reduces the effects of local or non-climatic factors on the composition of the pollen spectra, and mountain barriers surrounding the lake substantially minimize the role of long-distance pollen transport. Using these natural advantages the first quantitative reconstruction of the last interglacial (LI: ca. 130–115 kyr B.P.) climate for the Baikal Region was obtained, based on the detailed pollen record from the CON01-603-2 deep-water core from the Continent site (Fig. 1), northern Baikal (Granoszewski et al., 2005) and an extensive reference surface pollen data set from northern Eurasia (see Tarasov et al., 2005 for details). Working with the late Quaternary pollen records from western and central Europe Kühl and Litt (2003) stressed a predominant interest in comparison of the LI (Eemian) climate with the present (Holocene) warm interval. Particularly in the Baikal region such a comparison would contribute to a better understanding of natural climatic variability during the late Pleistocene–Holocene warm phases (Cheddadi et al., 2005) and provide an opportunity to examine the effects of orbital forcing and other climatic factors on regional climate and vegetation (Harrison et al., 1995; Kubatzki et al., 2000; Tarasov et al., 2005).

To date, there have been several attempts at palaeoclimatic interpretation of the late glacial and Holocene pollen records from the Lake Baikal region (see Demske et al., 2005 and references therein). However, the earlier reconstructions based on poorly-dated and low resolution pollen records were either solely qualitative (e.g. Khotinskii, 1984a; Bezrukova, 1999; Tarasov et al., 2002) or concerned with the 'mid-Holocene optimum' time slice (e.g. Frenzel et al., 1992; Tarasov et al., 1999). Demske et al. (2005) exploited a combination of several 'pollen indices' for the qualitative interpretation of changes in humidity and temperature at the three sites from Lake Baikal since the late glacial. However, the latter study also pointed out the need for an objective quantitative palaeoclimate reconstruction for the region.

Despite the fact that during the pre-industrial late glacial and Holocene time human impact on the Lake Baikal regional environments was minimal in comparison with that in Europe, the eastern Mediterranean and Central China, published archaeological material (e.g. Okladnikov, 1950, 1955, 1959; Weber, 1995; Vasil'ev et al., 2002; Parzinger, 2006 and references therein) suggests that the Baikal region has a long and intriguing habitation history. Extensive conventional and AMS-

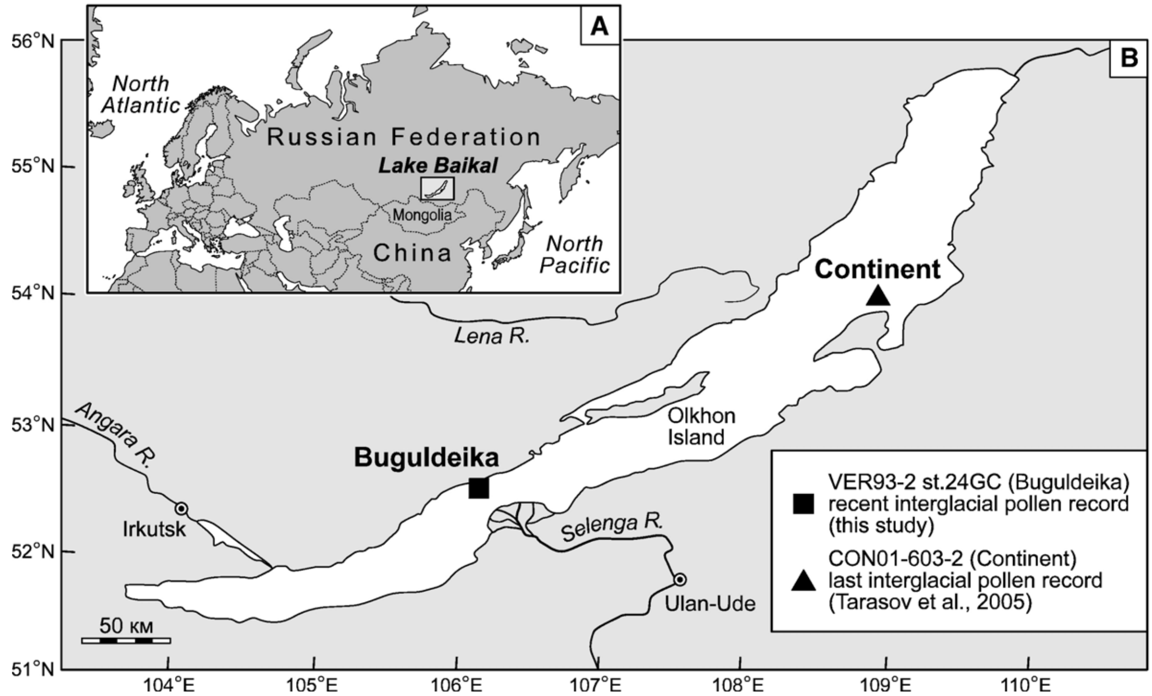

Fig. 1. Maps of Eurasia (A) and the Lake Baikal region (B) with locations of the pollen and palaeoclimate records discussed in the recent study.

radiocarbon dating of the Holocene archaeological material proves that hunter–gatherer groups lived around Lake Baikal from at least ca. 8800 cal. years B.P. (Weber, 1995; Weber et al., 2002). However, a gap in the archaeological record for the period ca. 6850–6150 cal. years B.P. was interpreted as a cultural hiatus (Weber et al., 2002). This hiatus separates Late Mesolithic and Early Neolithic cultures from Late Neolithic and Bronze Age cultures and is an interesting 'biocultural phenomenon' discussed in detail by Weber et al. (2002). Nevertheless the authors of the latter study were aware that they could not fully rely on the available oversimplified palaeoclimatic schemes for Siberia (e.g. Khotinskii, 1984a,b), but that a high-resolution reconstruction of the Holocene climate in the region would be indispensable for a better understanding of the habitation history of the area around Baikal and for a more accurate interpretation of the archaeological data.

In our paper we present the new detailed and adequately dated Holocene pollen record from the Buguldeika Saddle (Fig. 1) in Lake Baikal and the results of the quantitative climate reconstruction based on this record. We employed the same reconstruction method and reference data set as used in Tarasov et al. (2005) in order to facilitate a comparison between the last and current interglacial in the Baikal region. The high quality of the record as well as the following additional reasons proved the choice of the study site as most suitable. The core was recovered in the southern part of Lake Baikal and is representative for the region between Olkhon Island and the Angara River outflow where the majority of the archaeological sites analysed in Weber et al. (2002) are located. Moreover, the southern part of Lake Baikal where modern vegetation is represented by southern boreal forests and transitional forest–steppe communities should be most sensitive to the regional climate dynamics, particularly to the changes in summer and winter temperatures and moisture conditions (e.g. Khotinskii, 1984a,b; Tarasov et al., 2002).

The results of the quantitative reconstruction of the four bioclimatic variables – mean temperature of the coldest month (T_c), mean temperature of the warmest month (T_w), mean annual precipitation (P_{ann}) and moisture index (α), calculated as the ratio of actual to equilibrium evapotranspiration (Prentice et al., 1992) – derived from the Buguldeika pollen record are then compared with published archaeological and palaeoenvironmental data in order (i) to evaluate the possible role of climate in the mid-Holocene hunter–gatherer habitation discontinuity and culture change in the Lake Baikal region; (ii) to discuss anthropogenic and climatic controls of the Holocene vegetation dynamics; and (iii) to perform a comparison of the regional climate dynamics during the last and the recent interglacial.

2. Data and reconstruction methods

2.1. Study area

The modern climate around Lake Baikal (455 m a.s.l.) is continental with large seasonal variations in precipitation and temperature (e.g. Alpat'ev et al., 1976; Galaziy, 1993). January and July represent the coldest and warmest months respectively, and clearly show the annual range of temperature which can be taken as an indicator for the severity of seasonality in the region. In July temperatures in the intermountain depressions may reach 35 °C, dropping in January below −40 °C in the mountains. The surrounding Lake Baikal mountain ridges reach 1700 to 2500 m in elevation and annually receive over 700 mm of precipitation. The intermountain depressions and coastal plains (500–700 m a.s.l.) experience a drier climate with P_{ann} ~ 250–300 mm or even less (Galaziy, 1993). The effect of rather low precipitation on the forest vegetation at the lower elevations is compensated by low summer temperatures (~ 14–16 °C in July) and low evaporation (Tarasov et al., 2005). As a result moisture conditions are favorable to support a wide spread of taiga dominated by the boreal summer-green (e.g. larch — *Larix*, birch — *Betula*, poplar, aspen — *Populus*), evergreen (e.g. Siberian pine — *Pinus sibirica*, spruce — *Picea*, fir — *Abies*) and eurythermic (e.g. Scots pine — *Pinus sylvestris*) broadleaved and coniferous arboreal taxa. Steppe and forest–steppe vegetation communities become more important on Olkhon Island where P_{ann} is only 161 mm (Galaziy, 1993) and in the semiarid depressions along the Selenga River south of the Khamar–Daban Ridge. Shrubby sub-alpine associations represented by shrubby pine — *Pinus pumila*, alder — *Alnus fruticosa* (*Duschekia fruticosa*) and birch — *Betula middendorfii* cover the upper parts of the mountain slopes above 1800 m (Molozhnikov, 1986). Mountain tundra occupies large areas north and northeast of Lake Baikal (Galaziy, 1993). Until recent times human impact on the regional vegetation was minimal. In 1986, forest cover around the lake exceeded 80% and over 50% of the Lake Baikal region was practically uninhabited (Galaziy, 1993).

The core material used in this study was recovered from the underwater site VER93-2 st.24GC (Fig. 1) in the southern part of Lake Baikal. On the western coast of the lake north of the site, light open forests with Scots pine and larch dominate the vegetation at lower altitudes. At higher elevations Siberian pine becomes an important component. Northward along the coast steppe associations with grasses and *Artemisia* species are widely spread (Galaziy, 1993). The Buguldeika meteorological observatory (Fig. 1) located near the lake coast west of the coring site records T_w ~ 15 °C, T_c ~ −20 °C and P_{ann} ~ 300 mm.

The eastern coast of Lake Baikal zonal vegetation is mainly composed of Siberian pine and spruce forests and of secondary poplar–aspen–birch forests. Swampy associations composed of mosses, ferns, sedges and shrubs are common in the Selenga River delta. According to several low-elevated meteorological stations situated at the eastern coast of Lake Baikal, T_w varies from ~13.8 to 14.7 °C, while T_c is around −19 °C and decreases to below −26 °C with increasing elevation. The P_{ann} sums vary from ca. 300–400 mm in the coastal zone to above 500 mm in the upper elevation belt (Galaziy, 1993).

2.2. Core setting and chronology

In our study we used results of the pollen analysis and radiocarbon dating obtained from the Lake Baikal Drilling Project (BDP: http://www.geol.sc.edu/SIL/bdp.htm) for the upper part of the 472.5-cm long gravity core VER93-2 st.24GC (52°31′N, 106°09′E), hereafter referred to as the 'Buguldeika' (BDP-Members, 1997). The core was taken from a water depth of 355 m (Karabanov et al., 2004) from the 25-km wide underwater Buguldeika Saddle (also known as '*Bugul'deiskaya Peremychka*'), which separates the southern sub-basin of Lake Baikal from its central sub-basin (Fig. 1). The core consists of four sedimentary units, represented either by a diatom-rich olive or greenish-gray soft silty clay (0–152 cm and 216–249 cm from the core top) or by bluish-grey silty clay with a few or no diatoms (152–216 cm and below 249 cm from the core top). Further details on the core lithology, carbon, biogenic silica and diatom and other siliceous microfossils contents are presented in Karabanov et al. (2004).

A set of AMS ^{14}C dates on decalcified bulk sediments from the Buguldeika core was used to construct the uncalibrated ^{14}C age-depth model (Karabanov et al., 2004). All dates become progressively older with depth, supporting an undisturbed sedimentation in the studied core (Table 1 and Fig. 2). For the current study we first corrected the ^{14}C dates for a reservoir effect (Table 1) following Colman et al. (1996), who determined surface age correction for the BDP93/Buguldeika core site as 1160 years. The latter study presents a set of 146 AMS dates from Lake Baikal and adequately addresses chronological problems of the lake sediments. The corrected dates were then calibrated (Table 1) using the latest version of the CalPal — University of Cologne Radiocarbon Calibration Program Package (http://www.calpal.de). The resulting age-depth model representing a

Table 1
Radiocarbon ages for the VER93-2 st.24GC core from Lake Baikal used in this study

Core depth, cm from the core top	^{14}C ages with 1σ error (after Karabanov et al., 2004), years B.P.	^{14}C ages with 1σ error corrected on reservoir effect of 1160 years (Colman et al., 1996), years B.P.	Calibrated ^{14}C ages with 1σ error (http://www.calpal.de), cal. years B.P.	Laboratory number
4.5	1720±55	560±55	587±46	OS-25976
9.0	2650±35	1490±35	1375±30	OS-25977
30.0	3520±35	2360±35	2400±47	OS-25978
39.0	3800±35	2640±35	2767±16	OS-25979
61.5	4920±40	3760±40	4125±80	OS-25980
82.0	5680±40	4520±40	5181±93	OS-25981
98.5	6610±50	5450±50	6254±39	OS-25982
124.5	7860±60	6700±60	7568±50	OS-25983
149.5	9520±50	8360±50	9384±63	OS-25984
179.5	10,650±55	9490±55	10,848±161	OS-25985
194.5	12,420±70	11,260±70	13,165±107	OS-25986
228.0	13,210±65	12,050±65	14,067±244	OS-25987
266.5	15,770±80	14,610±80	17,857±231	OS-25988

regression line (Fig. 2) as suggested in Colman et al. (1996) was applied to the pollen record and used to date reconstructed changes in vegetation and climate discussed in the text.

2.3. Fossil pollen record

Sediments from the Buguldeika core sampled for pollen analysis comprised 1 cm^3 and were picked in 4-cm steps, providing a time resolution of about 250 years throughout the late glacial and Holocene period. Standard laboratory methods were used to extract pollen from the sediment samples, including HCl and KOH treatments, heavy-liquid separation and subsequent acetolysis (Berglund and Ralska-Jasiewiczowa, 1986). Pollen and spores mounted in glycerin were counted under the light microscope with ×400–1000 magnification. Identification and counting of the fossil pollen and spores was performed by Bezrukova with assistance from Letunova using regional pollen atlases (Kuprianova and Alyoshina, 1972, 1978; Bobrov et al., 1983) and the reference collection in the Limnological Institute (Irkutsk).

Samples from the upper part of the core (0–200 cm) were rich in pollen and counting 400 to 4000 pollen grains per sample was possible. However, the pollen content was substantially lower in the sediment layer between 200 and 236 cm, where the calculated sum of arboreal (AP) and non-arboreal pollen (NAP) reached only 9 to 195 grains per sample (Fig. 3). Pollen and spores were extremely rare in the lower clay unit and the counting results from this unit were not used in the further statistical treatment of the pollen data on the grounds of being non-representative. A simplified percentage diagram presented in Fig. 3 shows results of the pollen analysis from the upper 236-cm part of the Buguldeika core. Percentages for individual terrestrial pollen taxa at each level were conventionally calculated

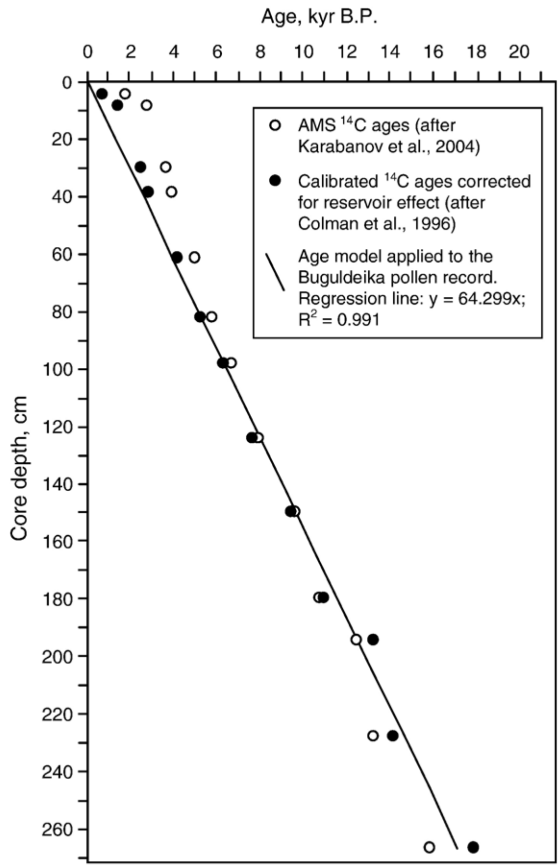

Fig. 2. Depth-age model applied to the Buguldeika (VER93-2 st.24GC) pollen record (this study).

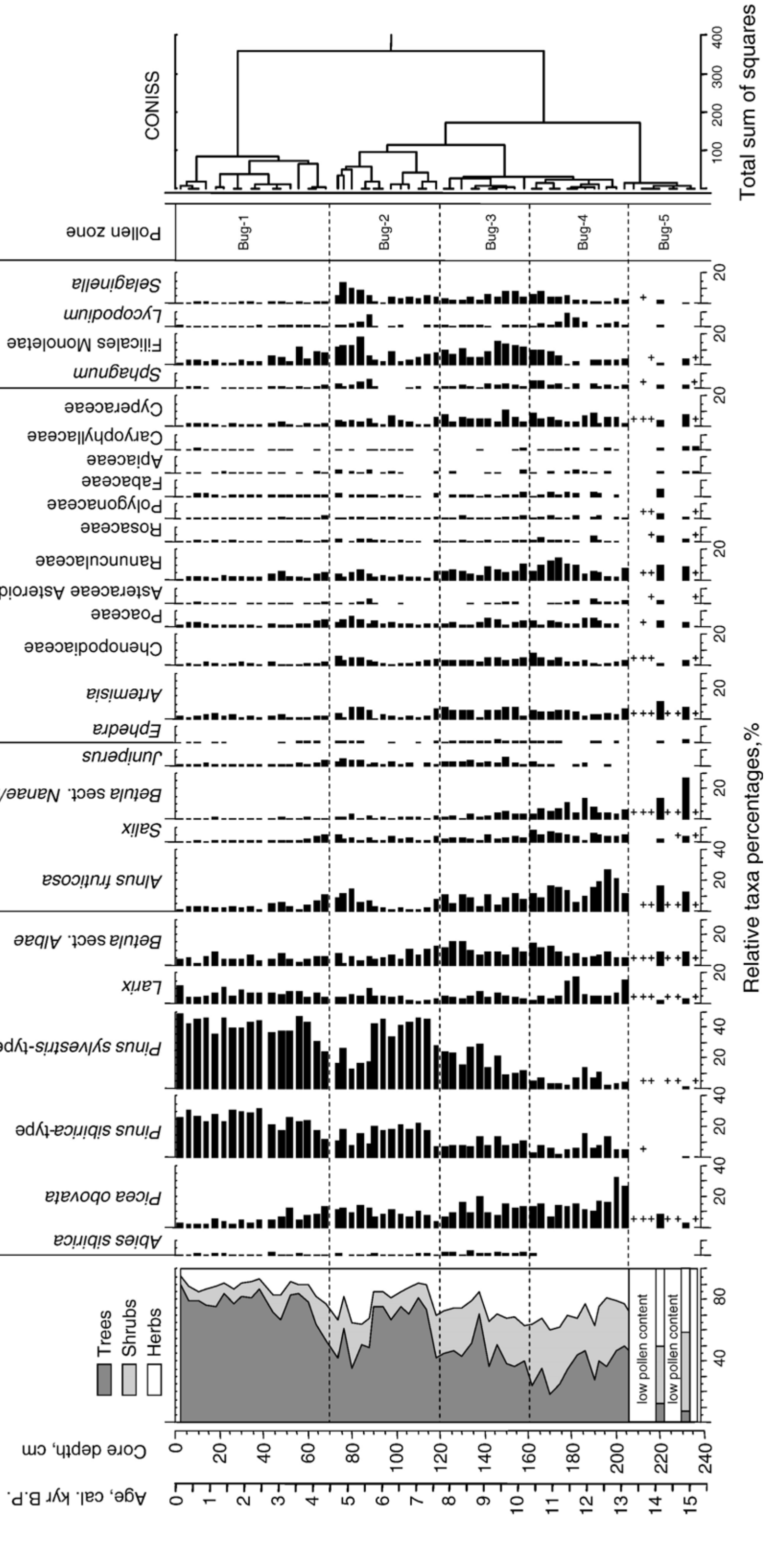

Fig. 3. Simplified pollen diagram from the Buguldeika (VER93-2 st.24GC) record.

from the total sum of AP and terrestrial NAP taken as 100%. Spore percentages for cryptogam plants (e.g. *Selaginella*, *Lycopodium*, Filicales Monoletae and *Sphagnum*) were calculated in relation to the total sum of counted pollen and spores. Among the spike-moss spores counted in the Buguldeika record ca. 90% were identified as *Selaginella rupestris* = *S. sibirica* — extremely frost-resistant species commonly found in the steppe, open larch and pine forests, and even in the grass–shrub tundra with shrubby pine (Molozhnikov, 1986). The remaining 10% were attributed to *S. sanguinolenta* — xerophytic species found in the steppe environments on Olkhon Island. In order to facilitate presentation and discussion of the pollen record, the pollen diagram was subdivided into local pollen assemblages zones (LPAZ) based on square-root-transformation of the percentage data and stratigraphically constrained cluster analysis by the method of incremental sum of squares (Grimm, 1987).

2.4. Biome and climate reconstruction methods

The potential of the biome reconstruction ('biomization') method (Prentice et al., 1996; Tarasov et al., 1998a,b) and the best modern analogue (BMA) approach (Guiot et al., 1989; Guiot, 1990) has been used for the quantitative interpretation of the LI pollen spectra from Lake Baikal (Tarasov et al., 2005). Both methods have their own set of assumptions and shortcomings. The biomization method provides only semi-quantitative and indirect climate information, but is "closer" to the actual vegetation and does not suffer as much from the no-analogue problem that more quantitative approaches do. The modern-analogue technique may suffer from that problem, but when good analogues exist, can provide robust climate reconstructions. The two methods thus complement one another allowing a more robust interpretation of the past changes in vegetation and climate (Tarasov et al., 2005).

In order to perform the 'biomization' all terrestrial pollen taxa identified in the Buguldeika record (Fig. 3) were attributed to appropriate biomes (Table 2) using the taxon–PFT–biome matrix already applied for the LI record from the Continent site (Tarasov et al., 2005). Table 2 shows a number of temperate deciduous taxa (*Acer*, *Carpinus*, *Fraxinus*, *Tilia* and a few others) currently absent in the Baikal flora. None of these taxa exceeds 0.5% in the pollen spectra, the universal threshold suggested by Prentice et al. (1996), who defined it in order to avoid possible problems related to long-distant pollen transport, re-deposition or incorrect identification of rare pollen types. These taxa were attributed to the cool mixed forest biome according to the applied biomization scheme (Table 2). However, their presence in the calculation matrix did not affect the reconstruction results. For the demonstration in Fig. 4 we kept only those biomes, which had the highest score at least for one analyzed spectrum.

Table 2
Terrestrial pollen taxa identified in the Buguldeika (*this study*) and in the Continent (Granoszewski et al., 2005) pollen record from Lake Baikal and used in the biome and climate reconstructions

Biome	Taxa included
Tundra	*Alnus* (shrub), *Betula* sect. *Nanae+Fruticosae*, Cyperaceae, Ericales, *Gentiana**, Poaceae, *Polemonium**, *Polygonum*, *Rubus chamaemorus**, *Rumex**, *Salix*, *Saxifraga*, Scrophulariaceae, *Valeriana*
Cold deciduous forest	*Alnus* (tree), *Betula* sect. *Albae*, Ericales, *Juniperus*, *Larix*, *Pinus* subgen. *Diploxylon*, *Pinus* subgen. *Haploxylon* (*pumila*-type), *Populus*, *Rubus chamaemorus**
Taiga	*Abies*, *Alnus* (tree), *Betula* sect. *Albae*, Ericales, *Juniperus*, *Larix*, *Picea*, *Pinus* subgen. *Diploxylon* (*sylvestris*-type), *Pinus* subgen. *Haploxylon* (*sibirica*-type), *Populus*, *Rubus chamaemorus**, *Sambucus**
Cool conifer forest	*Abies*, *Alnus* (tree), *Betula* sect. *Albae*, *Carpinus**, *Corylus*, Ericales, *Frangula**, *Juniperus*, *Larix*, *Picea*, *Pinus* subgen. *Diploxylon* (*sylvestris*-type), *Pinus* subgen. *Haploxylon* (*sibirica*-type), *Populus*, *Rubus chamaemorus**, *Sambucus**, *Tilia**, *Ulmus*
Cool mixed forest	*Abies*, *Acer**, *Alnus* (tree), *Betula* sect. *Albae* *Carpinus**, *Corylus*, Ericales, *Frangula**, *Fraxinus excelsior**, *Juniperus*, *Larix*, *Picea*, *Pinus* subgen. *Diploxylon* (*sylvestris*-type), *Pinus* subgen. *Haploxylon* (*sibirica*-type), *Populus*, *Quercus* (deciduous), *Sambucus**, *Tilia**, *Ulmus*
Steppe	Apiaceae, *Artemisia*, Asteraceae undif., Boraginaceae*, Brassicaceae, *Cannabis*, Cariophyllaceae, Chenopodiaceae, Fabaceae, Lamiaceae*, Liliaceae*, Onagraceae*, *Plantago**, Plumbaginaceae*, Poaceae, *Polygonum*, Ranunculaceae, Rosaceae, Rubiaceae, *Rumex**, Scrophulariaceae, *Thalictrum*, *Urtica*, *Valeriana**
Desert	*Artemisia*, Boraginaceae*, Chenopodiaceae, *Ephedra*, *Polygonum*

Taxa whose percentages in the pollen spectra do not exceed 0.5% and therefore do not influence results of biome reconstruction are indicated with an asterisk.

We selected T_c, T_w, P_{ann} and α, for the reconstruction using the BMA approach. All four climatic variables are important to explain the spatial distribution of the main vegetation types in northern Eurasia and are commonly derived from fossil records and simulated with climate models (e.g. Kutzbach et al., 1993; Kageyama et al., 2001; Battarbee et al., 2004). In the present study we used the reference data set of 1173 modern pollen spectra from the large area of the former Soviet Union

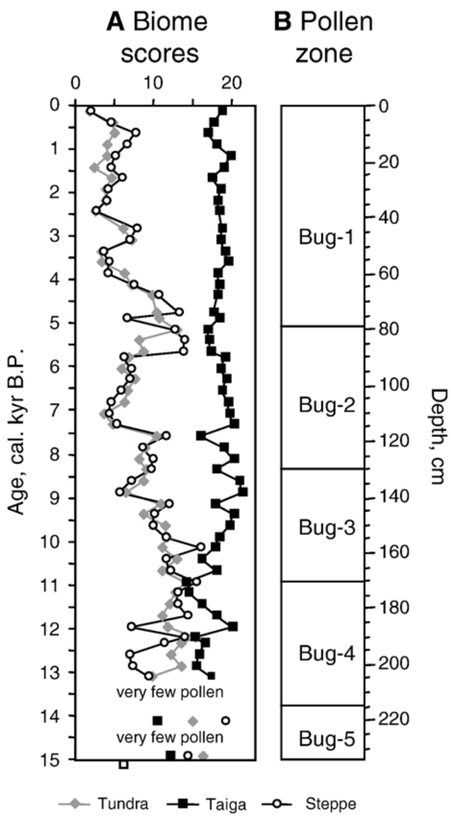

Fig. 4. Numerical biome scores reconstructed from the Buguldeika (VER93-2 st.24GC) pollen record (A). Time series of individual biome scores are discontinuous in the late glacial part of the record due to very low pollen content. Pollen zones (B).

and Mongolia with all main vegetation types of the region well represented (Tarasov et al., 2005). Surface pollen spectra from the Lake Baikal region included in the reference data set were analyzed by Bezrukova, Abzaeva and Kulagina. All terrestrial pollen taxa identified in the Buguldeika record also appear in the list of 81 taxa presented in the reference data set. Modern climate values at each of the 1173 modern pollen sampling sites have been calculated from the high-resolution global climatology database that provides the 30-year average (1961–1990) of the monthly means of principal meteorological parameters on a 10’ grid (New et al., 2002).

The BMA method uses a chord distance to determine the similarity between each fossil pollen spectrum and each spectrum in the reference modern data set (Guiot, 1990). In the present study, the 8 spectra that have the smallest chord distance are considered as the closest modern analogues of the analyzed fossil spectrum. The reconstructed value, which is treated as the most probable climate for each fossil sample, is then calculated as the weighted average of the climatic variables of the selected best analogues, with the inverse chord distance as weights (Nakagawa et al., 2002). In this study, the calculation and graphic presentation of the climate reconstruction results were effected using a non-commercial Polygon software package (http://dendro.naruto-u.ac.jp/~nakagawa/). The error bars for the reconstructed values are defined by the climatic variability in the set of best modern analogues and can be presented as 68.2% (1σ) and 95.4% (2σ) uncertainty ranges. These confidence limits include possible errors in the modern climate observations, the natural climatic variability for the given pollen assemblage and the effect of non-climatic factors (see Nakagawa et al., 2002 for details of the error calculation). Another critical point of the reconstructions using the BMA approach is the threshold value of squared chord distance (SCD) chosen to separate ‘reliable’ and ‘non-reliable’ analogues to be assigned to each fossil spectrum. In this study we accepted the analogues with an SCD value below 0.08. This definition is arbitrary; however, the value is small enough and comparable with those justified in regional studies on the boreal vegetation zone (e.g. Overpeck et al., 1985; Anderson et al., 1989).

3. Results and interpretations

3.1. The Buguldeika pollen record and reconstructed vegetation dynamics

A summary pollen diagram of the Buguldeika record (Fig. 3) shows distinct differences between the five local pollen assemblages zones (LPAZ). Pollen of shrubs and herbs dominates in the LPAZ Bug-5 (236–206 cm), suggesting an open landscape covered with shrub tundra and steppe plant communities during ca. 15,000–13,300 cal. years B.P. A rather drastic change in the pollen composition occurred in the LPAZ Bug-4 dated to ca. 13,000–10,400 cal. years B.P. Already at 204-cm level AP content exceeds 50%, reflecting a quick spread of boreal conifer and deciduous trees (mainly cold- and permafrost-tolerant larch, spruce and birch) out of their glacial refuges and a forestation of the most suitable habitats around Lake Baikal. Cold and dry environments less suitable for arboreal vegetation were still occupied by low shrubs and steppe forbs. Pollen spectra from the LPAZ Bug-3 (160–120 cm) reveal the appearance of *Abies* and a steady increase in the *Pinus sylvestris* pollen percentages accompanied by a decrease in the pollen percentages of shrub birches (*Betula* sect. *Nanae*/*Fruticosae*) and alder shrubs (*Alnus fruticosa*). The spread of fir and Scots pine suggests further climate amelioration and degradation of the permafrost layer in the region between ca. 10,400 and 7800 cal. years B.P. In the LPAZ Bug-2 (120–70 cm) AP content changes from 75–80% (ca. 7000–5500 cal. years B.P.) to 40–60% (ca. 5500–4500 cal. years B.P.). An observed decrease in AP occurs soon after 6000 cal. years B.P. in parallel with an increase in shrub pollen represented by *A. fruticosa* and *Salix* as well as in steppe forbs and grass pollen — mainly *Artemisia*, Chenopodiaceae and Poaceae species. *Pinus sylvestris* and *Pinus sibirica* pollen co-dominate in this pollen zone reaching modern values. This likely indicates that pine forests around the lake reached their present-day limits already in the mid-Holocene. In the uppermost LPAZ Bug-1 AP is 90% mainly due to high contents of pine and larch pollen. On the other hand, low *Abies* and *Picea* pollen percentages indicate a less important role in the vegetation cover during the last three millennia, likely reflecting an overall decrease in humidity and more pronounced climate seasonality.

3.2. Quantitative biome and climate reconstructions

The biome reconstruction results (Fig. 4) complement the qualitative interpretation of the Buguldeika pollen record. Tundra and steppe biomes have the highest scores in the LPAZ Bug-5. Taiga becomes a dominant vegetation type after 13,300 cal. years B.P. However, numerical scores of steppe and tundra are very close to that of taiga, suggesting that forests still occupied a limited area around Lake Baikal during the late glacial/early Holocene time. After ca. 10,000 cal. years B.P. the taiga biome scores are noticeably higher than the scores of non-arboreal biomes. However, relatively high scores of the steppe biome are reconstructed around ca. 7500, 5500, 3000 cal. years B.P. and between 1000–500 cal. years B.P. indicating that a short-term spread of steppe and meadow communities occurred several times during the Holocene.

The results of the quantitative climate reconstruction based on the Buguldeika pollen record are shown in Fig. 5. The uncertainty ranges for the reconstructed climatic variables expressed as 68.2% (1σ) probability distribution (Nakagawa et al., 2002) are rather large (e.g. ±75 mm for P_{ann}, ±2 °C for T_w, ±4 °C for T_c and ±0.1 for α), but likely provide adequate estimates of the potential of pollen-based climate reconstructions (Nakagawa et al., 2002; Kühl et al., 2002).

Pollen spectra from the bottom part of the record with low pollen content were excluded from the climate reconstruction as presumably non-representative and thus are not shown in Figs. 4 and 5. For the rest of the record the changes in the reconstructed climate variables can be summarized as follows. The reconstruction suggests that

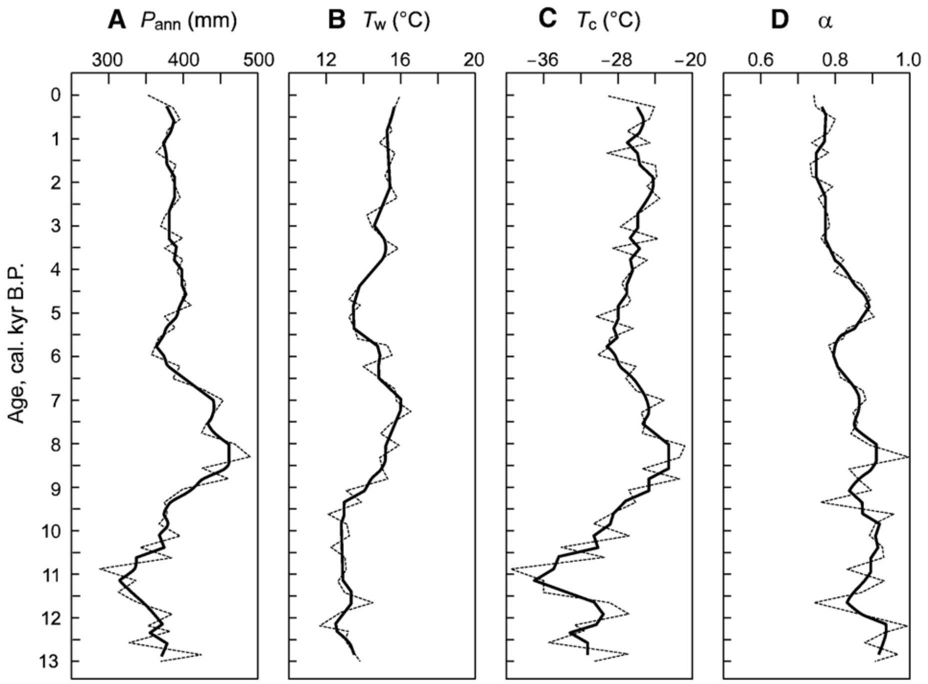

Fig. 5. The charts of the climate variables reconstructed from the Buguldeika (VER93-2 st.24GC) pollen record using the BMA approach: annual precipitation (A); the mean temperature of the warmest month (B); the mean temperature of the coldest month (C); and the moisture index (D). Each chart shows reconstructed most probable values (*dashed line*) based on the weighted average of the selected analogues and on the percentages of the sum of terrestrial pollen taxa as defined in Tarasov et al. (2005). Three-point moving averages (*solid line*) are shown for each reconstructed variable.

climate conditions at the late glacial/Holocene transition ca. 13,000–10,000 cal. years B.P. were rather unstable. The first major spread of the boreal taiga vegetation in the region at ca. 13,000 cal. years B.P. was associated with relatively warm and wet climate conditions ($T_w \sim 14$ °C, $T_c \sim -27$ °C, $P_{ann} \sim 420$ mm, $\alpha \sim 0.9$). However, already at ca. 12,500 cal. years B.P. (LPAZ Bug-3) the BMA reconstruction suggests a decrease in both July ($T_w \sim 11$ °C) and January ($T_c \sim -32$–35 °C) temperature and precipitation ($P_{ann} \sim 320$ mm). Despite a noticeably low precipitation, the moisture index reconstruction ($\alpha \sim 0.9$) suggests that the climate remained rather humid, due to relatively low evaporation losses (Tarasov et al., 2005). Our biome reconstruction (Fig. 4) supports such an interpretation. Scores of the steppe biome increase, reflecting an increased role of herbaceous vegetation (likely on the locally dry slopes of southern exposure). However, the scores of tundra and taiga biomes remained relatively high. After a short-term climate amelioration reconstructed at ca. 12,000 cal. years B.P. conditions became very harsh again between ca. 11,500 and 11,000 cal. years B.P.

The onset of a relatively warm and wet climate occurred soon after 10,000 cal. years B.P. The most favorable conditions with $T_w \sim 16$ °C, $T_c \sim -21$ °C, $P_{ann} \sim 480$ mm and $\alpha \sim 0.9$–1 are reconstructed for the 9000–7000 cal. years B.P. interval. During this time interval taiga started to be a dominant biome in the region and fir and spruce pollen reached their highest values throughout the late glacial/Holocene period.

After ca. 6500 cal. years B.P. the climate reconstruction shows a decrease in all reconstructed variables. The minima in T_c, P_{ann} and α values are reconstructed at ca. 6000 cal. years B.P. and a major decrease in T_w is dated to ca. 5500–5000 cal. years B.P. An interval between 6000 and 4000 cal. years B.P. is characterized by relatively high scores of the steppe biome with a short-term oscillation around 5000 cal. years B.P. corresponding to a short-term interval with a slight increase in precipitation and the moisture index.

The reconstruction demonstrates a more or less gradual increase in winter and summer temperatures and a decrease in precipitation and the moisture index from ca. 5000 to 2500 cal. years B.P. Taiga biome scores reached the maximum during the middle and late Holocene interval. However, the role of boreal evergreen conifers (fir and spruce) in the regional vegetation decreased, and eurythermic Scots pine became the most widely spread conifer tree species. The results of the quantitative climate reconstruction corroborate well with this change in the vegetation. The reconstruction for the uppermost pollen spectrum shows an oscillation towards a more severe climate. The age model suggests this sample is dated to 130±50 cal. years B.P., roughly representing the Little Ice Age environment.

4. Discussion

4.1. Hunter–gatherer habitation and the regional climate dynamics

The effect of past climate changes on human activities and eventual societal collapses has become a frequently discussed topic (e.g. Ingram et al., 1981; de Menocal, 2001; Berglund, 2003; Tarasov et al., 2006). Did climate changes in some way also influence the Holocene human dynamics in the Lake Baikal region? To discuss this question we consulted the archaeological records. They indicated that the area around Lake Baikal was settled by hunter–gatherer groups during Mesolithic and Neolithic time (Weber, 1995), but a habitation hiatus occurred during 6850–6150 cal. years B.P. (Weber et al., 2002). The authors of the latter study went to great lengths analyzing and discussing archaeological and environmental aspects of this hiatus separating Early Neolithic Kitoi culture from Late Neolithic and Bronze Age Serovo–Glazkovo cultures (Fig. 6A). Addressing the possible role of climate in the habitation discontinuity, Weber et al. (2002) assume that the disappearance of the Kitoi hunter–gatherers was likely caused by socio-cultural (i.e. internal) rather than by environmental–climatic (i.e. external) processes. Consistently, the re-habitation of the region seven hundred years later is also viewed as an “influx of small groups of hunter–gatherers over just a generation or two within a context of practically no environmental change” (Weber et al., 2002). This conclusion is mainly based on the much generalized model of the Holocene climate in South Siberia (Khotinskii, 1977, 1984a) which was constructed on the basis of a few poorly-dated pollen records. Adjusted to the West European Blytt–Sernander climate stratigraphy, this model places the climate shift in the Baikal region from the warmer and wetter Atlantic to the cooler and drier Subboreal about two millennia later than the end of the hiatus. However, recent publications of high-resolution sedimentary and pollen data from Lake Baikal (e.g. Horiuchi et al., 2000; Karabanov et al., 2000; Demske et al., 2005; Tarasov et al., 2005) demonstrate that the interglacial climate dynamics of the region differ from those in Europe. Our climate reconstruction (Fig. 5) suggests that the appearance of the Kitoi people in the Lake Baikal region about 9000 years ago (Weber, 1995) is synchronous with a distinct amelioration of the

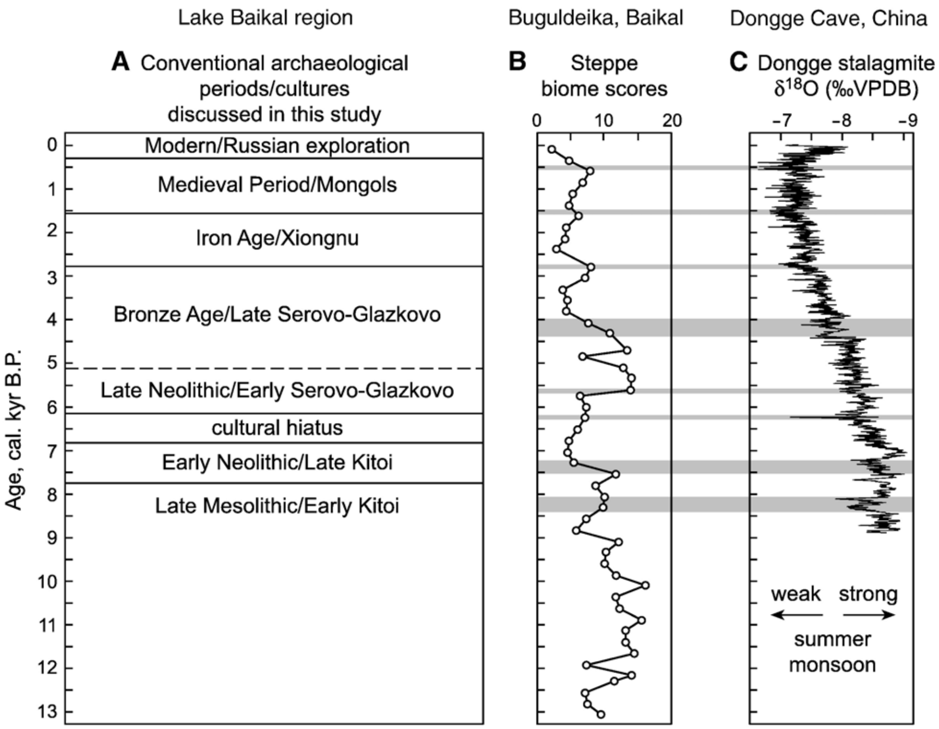

Fig. 6. Culture history model (A) used in this study (after Weber et al. (2002) with modifications), plotted together with steppe biome scores derived from the Buguldeika pollen record (B) and oxygen isotope data (C) from Dongge Cave (after Wang et al., 2005). Gray bars indicate weak summer monsoon episodes reported in Wang et al. (2005).

regional climate. According to our results a major change in the reconstructed climatic variables (Fig. 5) occurs between ca. 7200 and 6000 cal. years B.P. and the observed habitation hiatus falls in this time interval. These clear coincidences of environmental and habitation changes in the Lake Baikal region provide new arguments for discussion about causal links between climate and human dynamics and complement the archaeological interpretation of Weber et al. (2002). A relatively small population of Kitoi people lived in socially closed groups, maintained a relatively stable home basis, had a narrow diet (for example, did not hunt the Baikal seal — '*nerpa*'), distributed food in favor of the adult males, had a low number of females and children, and experienced demographic stagnation or even decline during the late phase of their history. The combined archaeological and climatic records suggest that the pre-hiatus Kitoi communities established their life under a more favorable climate, but had a less flexible subsistence strategy in comparison with the post-hiatus people. Keeping their traditional life-style, Kitoi people were not able to survive a period of severe deterioration of the regional climate likely associated with a more frequent occurrence of extreme weather events. In contrast, the new inhabitants of the region lived in smaller and very mobile groups, keeping contact with each other and making better use of the existing food resources (Weber et al., 2002). As a result they experienced population growth during the interval of climate amelioration ca. 5000–4000 cal. years B.P. (Fig. 5).

4.2. Factors controlling Holocene vegetation dynamics

Numerous examples from the ancient and recent past demonstrate that humans often played a more active role in the interactions with environments (e.g. Berglund, 2003; Diamond, 2005). Forest clearance for getting fuel, construction material, pastures and fields is among the most frequently reported human activities changing natural vegetation and modifying landscapes. In northern Europe, for example, pollen and archaeological records helped to reconstruct several major periods around 5900, 4500, 3800, 3000–2800 and 1100 cal. years B.P., which were characterized by expanding agriculture and deforestation (Berglund, 2003). Around Lake Baikal, destruction of the natural forest ecosystems by industrial wood cutting and wild fires became a serious ecological problem during recent decades. So far there are no comprehensive studies on past human impact in the region.

In the current work we are confronted with the problem of how to explain relatively high scores of the steppe biome around 7500, 5500, 3000, and 1000–500 cal. years B.P. (Fig. 4). The recent trend of accusing humans of having affected global climate for ca. 8000 years already (Ruddiman, 2003) provides a temptation to find a relationship between the cultural periods and the phases with a more pronounced role of the steppe and meadow communities also around Lake Baikal. Furthermore, a direct comparison of the archaeological (Fig. 6A) and biomization results (Fig. 6B) demonstrates a chronological match between the Early Neolithic, Late Neolithic, Bronze Age and Medieval cultures and reconstructed 'steppe' episodes. Therefore, this feature deserves more attention.

Radiocarbon-based chronology of the Paleolithic in Siberia indicates human presence in the region of Lake Baikal from about 43,000–39,000 years ago (Vasil'ev et al., 2002). There is no estimation of the size of the Paleolithic population. For the later period (ca. 9000–3000 cal. years B.P.) the archaeological evidence (e.g. Vorob'eva et al., 1992; Weber et al., 2002; Parzinger, 2006) shows that the regional population of hunters, fishers and gatherers was very sparse and continued a Mesolithic subsistence without agriculture. So far there is no proof that these cultures contributed to the clearing of the landscape to an extent that it became visible in the Lake Baikal pollen record (e.g. Fig. 6B). In the future the results of charcoal analysis could verify the occurrence and frequency of fires in the region.

About 2200 years ago the region south of Lake Baikal came under the control of the semi-nomadic Xiongnu tribes with their power center in modern Mongolia. The northernmost outpost of Xiongnu – Ivolginskoe Gorodishche – has been discovered near Ulan-Ude (Davydova, 1985; Parzinger, 2006). The results of the large-scale archaeological excavation performed at the site demonstrated that it was a permanent settlement (ca. 180 × 300 m) with four rings of defense walls separated from each other by water ditches (Davydova, 1985). Wood was intensively used as construction material and as fuel for heating, cooking, pottery making and bronze and iron casting. Agriculture was practiced, and millet (*Panicum* sp.), barley (*Hordeum vulgare*) and wheat (*Triticum compactum*, *T. aestivum*) were among the cultivated crops. The broad flood-plain of the Selenga River where the settlement was constructed provided enough easy accessible arable land and the surrounding hilly forest–steppe landscape was an ideal pasture for sheep and goats (26%), cows (17%) and horses (12%). A high proportion of pigs (15%) and dogs (29%) was also found. The excavation of the contemporary graveyard revealed the remains of 195 adults and 49 children (Davydova, 1985).

Summarizing all this archaeological evidence we would expect that the activities of the Xiongnu should have left traces of deforestation in the regional pollen records. Instead, the Buguldeika pollen diagram shows relatively high AP content and consequently low steppe biome scores during ca. 2400–1800 cal. years B.P. (Fig. 6B). There might be at least three reasons for that: a relatively short period of presence of the Xiongnu settlers in the region, a small population size and large distances between the known Xiongnu settlements and Lake Baikal.

Ivolginskoe existed less than two hundred years, was finally destroyed by fire around 2000 years ago and was never re-settled (Davydova, 1985). The population estimation using an equation from Wagner (2006) and data from the excavated cemetery suggests that the maximum number of the inhabitants of Ivolginskoe could hardly have exceeded 100–200 people. Last but not least, the settlement is situated ca. 80 km from the Baikal coast and is separated from the lake by the forested mountain ridges. The waterway to Baikal along the Selenga valley, moreover, is 150 km long. Two other Xiongnu settlements and a large number of burials dated to the same period are situated even further south, close to the present Russian–Mongolian border (Davydova, 1985).

During Medieval times the area south of Lake Baikal was home to different ethnic groups and tribes leading a nomadic life and paying tribute to semi-nomadic states which succeeded one another in the Mongolian and northern Chinese territories (e.g. Turkic Kaganat, Khitan (Liao) Empire, Jurchen of the Jin Dynasty, Mongol Empire and the Yuan dynasty). However, the permanent fortified settlements around Lake Baikal appeared again less than four centuries ago in 1646–1680 when the region became part of Russia (Galaziy, 1993). Since that time agricultural practices and forest clearance around these settlements took place on a more regular basis and the region experienced progressive population and economical growth. Surprisingly, the last 500-year interval in the Buguldeika pollen record again demonstrates an increase in AP and a decrease in the steppe biome scores, suggesting that until very recently human impact on the forests around Lake Baikal was rather local and not intensive enough to influence the regional vegetation development and to leave traces in the pollen assemblages. A similar trend can be seen in several other high-resolution Holocene pollen records from northern, central and southern Baikal (Demske et al., 2005).

Thus, we conclude that the reconstructed ‘steppe’ episodes in the Buguldeika record require a non-anthropogenic explanation. Searching for other reasons we concentrated on the regional rather than local records free from direct or indirect influence of past human activities. In the Lake Baikal region abrupt changes in precipitation during the LI (Tarasov et al., 2005) occurred synchronously with an onset and attenuation of the summer monsoon derived from the Chinese stalagmites (Yuan et al., 2004). Recently, decadal-scale changes in the summer monsoon precipitation over China during the past 9000 years were reconstructed using the 5-year resolution oxygen isotope data from Dongge Cave (Wang et al., 2005). The latter results show (Fig. 6C) a strong summer monsoon already at 9000 cal. years B.P., a drastic decrease in precipitation around 6000 cal. years B.P. and the most pronounced precipitation minimum occurring between 1000 and 500 cal. years B.P. These results are broadly coherent with the precipitation pattern reconstructed from the Buguldeika pollen record. Moreover, the record from Dongge Cave is punctuated by eight weak monsoon events lasting one to five centuries and centered at ca. 8300, 7200, 6300, 5500, 4400, 2700, 1600 and 500 cal. years B.P. (Wang et al., 2005). The reconstructed weak monsoon episodes show a pretty good temporal coherence with peaks in the steppe biome scores (Fig. 6B), supporting our interpretation that the Holocene vegetation changes in the Lake Baikal region were driven by natural forcing and likely were associated with large-scale circulation processes controlling the regional water balance rather than with human activities.

4.3. Interglacial climate dynamics in the Lake Baikal region

A quantitative reconstruction of the LI climate based on the century-resolution pollen record from the Continent underwater ridge (Fig. 1) provides a first opportunity to compare natural vegetation and climate dynamics in the region during the LI with the results of the recent study (Fig. 7). The Continent pollen record (Granoszewski et al., 2005) covers the complete LI corresponding to MIS 5e. For the pre-LI time ca. 130–128 kyr B.P. a severe late glacial climate with $T_c \sim -38$ to -35 °C and $T_w \sim 11$–13 °C, $P_{ann} \sim 300$ mm and $\alpha \sim 1$ is noticeable (Fig. 6A–D). The LI lasted from ca. 128 kyr B.P., when shrubby tundra was replaced by taiga, until ca. 117.4 kyr B.P., when boreal forest vegetation became largely replaced by cool grass–shrub communities (Fig. 6E). The most favorable climate conditions occurred during the first half of the LI. Soon after 128 kyr B.P. P_{ann} reached 500 mm and maximum values of $T_c \sim -20$ °C and $T_w \sim 16$–17 °C are reconstructed from about 126 kyr B.P. After ca. 121 kyr B.P. conditions became gradually cooler with a sharp turn towards a dry climate after ca. 118 kyr B.P. The early stage of the last glaciation (ca. 117.5–114.8 kyr B.P.) was cold ($T_c \sim -28$ to -30 °C, $T_w \sim 14$–15 °C) and dry ($P_{ann} \sim 250$ mm and $\alpha \sim 0.5$).

The described general pattern of changes in the vegetation and climate derived from the Continent record very much resembles the late glacial/Holocene vegetation and climate dynamics reconstructed from the Buguldeika record (Figs. 4, 5). However, Fig. 7 also shows some noticeable differences between the last and the recent interglacial in the Lake Baikal region. For example, the Holocene ‘forest phase’ already lasts some thousand years longer than that of the LI (Fig. 7B). Moreover, the recent studies on ‘how and when the present warm period would end’ point towards a long interglacial that may last another 50,000 years (Berger and Loutre, 2002). The reconstructed Holocene ‘climatic optimum’ occurs slightly later after the onset of the interglacial conditions and is characterized by slightly lower summer and winter temperatures and precipitation in comparison with the LI (Fig. 7A). The latter conclusion concurs with previous studies on the ‘climatic optima’ of the two interglacials (e.g. Frenzel et al., 1992; Velichko et al., 2002), but requires a better understanding of the underlying mechanisms.

Both the last and the recent interglacial in the Lake Baikal region are characterized by well-defined differences in the earth orbital parameters (Fig. 7C–D) from those of today (Berger, 1978; Berger and Loutre, 1991). A comparison of the pollen-based reconstructions of the interglacial vegetation and climate with model simulations testifying to the contribution of the orbital forcing to the climatic changes in the Northern Hemisphere in middle and high latitudes (e.g. Kutzbach et al., 1993; Harrison et al., 1995) shows that the reconstructed interglacial environments cannot always be satisfactorily explained by insolation changes alone (e.g. Texier et al., 1997; Kubatzki et al., 2000). The sensitivity experiments with the CCM1 model examining the effect of extreme orbitally-induced changes in insolation during the LI (Harrison et al., 1995) suggested, for example, that in the Lake Baikal region the simulated temperature anomalies reached +8 °C in summer and −1 °C in winter at 125 kyr B.P., causing a substantially drier than present climate and the resulting spread of steppe vegetation south of Lake Baikal. Attenuation of both summer and winter insolation anomalies towards the end of the LI (ca. 115 kyr B.P.) caused less pronounced temperature anomalies (e.g. −4 °C in summer and +1 °C

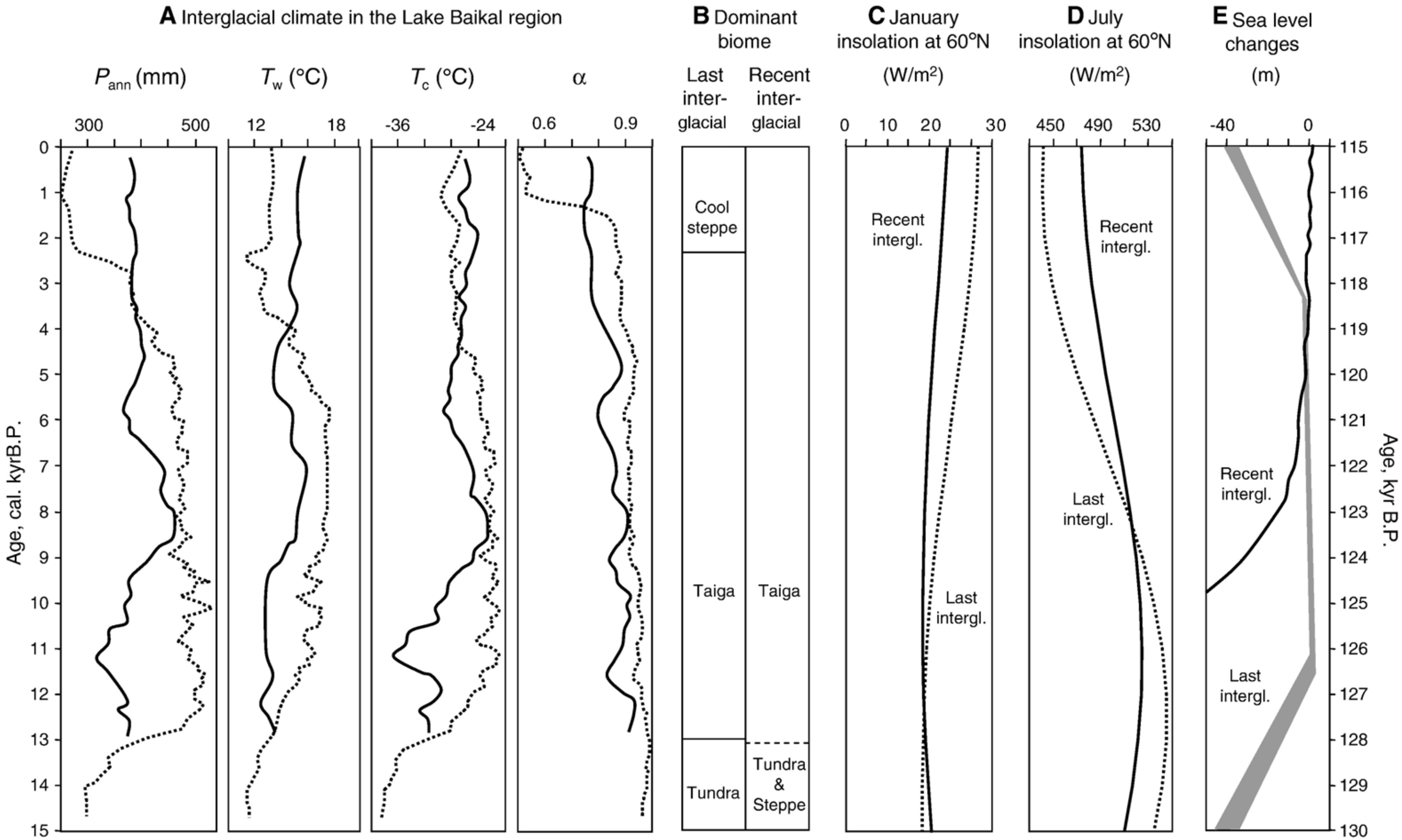

Fig. 7. Three-point moving averages of selected climate variables (A) of the recent (Holocene) interglacial (*solid line,* this study) and of the last (Eeemian) interglacial (*dotted line,* after Tarasov et al., 2005) and the dominant biomes (B) in the Lake Baikal region plotted against the respective time-scales. Temporal variations in January (C) and July (D) insolation (Berger, 1978; Berger and Loutre, 1991) and sea level changes (E) during the last (Lambeck and Chappell, 2001) and the recent (Behre, 2003) interglacial are shown for comparison.

in winter) and more favorable conditions for taiga and tundra communities around Lake Baikal. Both simulated scenarios contradict the regional pollen data, indicating the dominance of boreal forests in the vegetation cover during the LI and expansion of the herbaceous communities ca. 117–115 kyr B.P. (Frenzel et al., 1992; Granoszewski et al., 2005).

The interglacial records from Lake Baikal hint at a rather complex interaction of several driving forces, effecting regional vegetation and climate during the Holocene and LI. The changes in summer insolation (Fig. 7D) driving the northern hemisphere temperature change and influencing the strength of the summer monsoon adequately explain the reconstructed changes in T_w (Fig. 7A). However, a comparison of winter insolation (Fig. 7C) with the reconstructed T_c shows a rather negative correlation, suggesting that the summer insolation increase had long lasting cumulative effects also during the cold season. A relationship between precipitation changes in the Baikal region and the strengthening/weakening of the summer monsoon circulation can be seen in the LI and Holocene records from Lake Baikal. Similar patterns have been found in the Holocene pollen sequences from Buryatia and northwestern Mongolia (Tarasov et al., 2002). They are in line with meteorological observations in the region (Zhukov, 1965; Alpat'ev et al., 1976). The curves of the reconstructed sea level (equivalent to the global ice volume) show a different pattern of change during the last and the recent interglacial (Fig. 7E). The period with generally high sea level and low ice volume would imply a general decrease in continentality of the central Asian climate (Tarasov et al., 2005). In the Continent and Buguldeika records, this period corresponds to relatively high winter temperatures (Fig. 7A). Warmer-than-present winters in Siberia during the high sea level can be explained by the combined effects of warm currents, reduced sea ice, higher cyclonic activity along the Polar Front, a weakening of the Siberian Anticyclone and the increased warming effect of the Westerly flow (Tarasov et al., 2005). The cooling effect of the progressive lowering in sea level reflecting an increase in ice volume can be traced in the LI record from Lake Baikal (Fig. 7A). The reconstructed post-LI decrease in winter temperature is steadier compared to the steep geometry of the sea level curve. The reason for this might be the gradual increase in winter insolation (Fig. 7C).

5. Conclusions

This study presents a new pollen record from Lake Baikal spanning the past 15,000 years. Pollen-based reconstruction of four climatic variables and biome scores contribute to a better understanding of post-glacial vegetation and climate dynamics in South Siberia — a region with so far only few quantitative palaeoclimatic records.

The biome reconstruction shows that tundra and steppe biomes have the highest scores during ca. 15,000–13,300 cal. years B.P. and that taiga becomes a dominant vegetation type after ca. 13,300 cal. years B.P. The most favorable warm and wet climate (Holocene 'climatic optimum') with $T_w \sim 16$ °C, $P_{ann} \sim 480$ mm and $\alpha \sim 0.9$–1 has been reconstructed for ca. 9000–7000 cal. years B.P. In the Lake Baikal region this interval is characterized by the appearance and spread of hunter–gatherer communities (Kitoi culture). Consistently a hiatus in the regional archaeological record (6850–6150 cal. years B.P.) coincides with the interval of major climate deterioration which followed the 'climatic optimum'.

An attempt to find a relationship between the archaeological records and the phases with an expansion of steppe and meadows derived from the Buguldeika pollen record demonstrates that despite the long habitation of the area, man's impact on vegetation was local rather than regional and did not affect the pollen record from Lake Baikal. The reconstructed peaks in steppe biome scores during the last 9000 years are consistent with one to five hundred year long episodes of weak summer monsoon. This supports our interpretation that the Holocene vegetation changes around Lake Baikal are associated with large-scale circulation processes controlling regional water balance rather than with human activities. Our study proves once more the suitability of Lake Baikal pollen data for the reconstruction of natural vegetation and climate dynamics throughout the period from the onset of the LI to the present.

A comparison of the recent and the last interglacial contributes to the discussion on the similarity of vegetation and climate dynamics during interglacial periods. The Holocene 'climatic optimum' was less pronounced, e.g. with lower summer and winter temperatures and annual precipitation sums than that of the LI. On the other hand, pollen records demonstrate that the Holocene 'forest phase' in South Siberia already lasts some thousand years longer than that of the LI.

The interglacial vegetation dynamics derived from the Continent and Buguldeika pollen records can be satisfactorily explained by reconstructed changes in summer and winter temperatures and in available moisture. The interglacial vegetation around Lake Baikal is dominated by the boreal forests, which are associated with a generally warm and wet climate. The high sea level associated with decreased ice volume appears to have had a greater impact on the South Siberian vegetation and climate during the last and the recent interglacial than the direct effect of lower-than-present winter insolation. Reconstructed changes in the winter temperature correlate well with changes in the sea level and global ice volume, while the summer temperatures derived from the Lake Baikal pollen records reflect changes in the summer insolation.

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