The Potential of Optically Stimulated Luminescence for Dating Late Glacial and Holocene Dune Sands - A Case Study from Brandenburg, Germany

Alexandra HILGERS[1], Andrew S. MURRAY[2], Norbert SCHLAAK[3] and Ulrich RADTKE[1]

[1] Department of Geography, University of Cologne, Albertus-Magnus-Platz, D-50923 Cologne, Germany
[2] Nordic Laboratory for Luminescence Dating, Department of Earth Sciences, Aarhus University, Risø National Laboratory, DK-4000 Roskilde, Denmark
[3] Hochstrasse 13, D-16244 Altenhof, Germany

ABSTRACT. Here we present the results of a dating study using optically stimulated luminescence (OSL) of quartz for dating dune sand of four different dune sections in the Eberswalde ice-marginal valley in Brandenburg, north-eastern Germany. The luminescence ages, especially those obtained with the Single-Aliquot Regenerative-Dose Protocol (SAR), are in good agreement with independent age control. We conclude that luminescence dating provides a high potential for dating Holocene and late Pleistocene aeolian sediments. The luminescence ages, ideally in combination with radiocarbon dates, prove the alternation of dune mobilisation and stabilisation. The results obtained for the four dune sections in this study, especially when linked up with results of other investigated sections, give evidence for two main periods of very high aeolian activity: one at the transition from the Late Glacial to the Holocene, clearly extending into the Preboreal, and the other one beginning at the end of the Atlanticum period with its maximum in the last two thousand years. In addition, different phases of aeolian accumulation can be distinguished in the sediment sequences, probably due to changes in local environmental conditions.

KEY WORDS: luminescence dating, Holocene, Late Glacial, dunes, European Sand Belt.

Introduction

Aeolian sand deposits, notably inland and river dunes and cover sands, occupy an almost continuous area in the West and Central European Lowlands, the so-called 'European Sand Belt' that extends from Belgium and The Netherlands in the western part to the Baltic Region and Belarus in the East (Koster, 1988). Wind-blown sediments are valuable indicators of palaeoclimatic parameters, for example past wind regimes. A supraregional correlation of sediment sequences, and hence the information

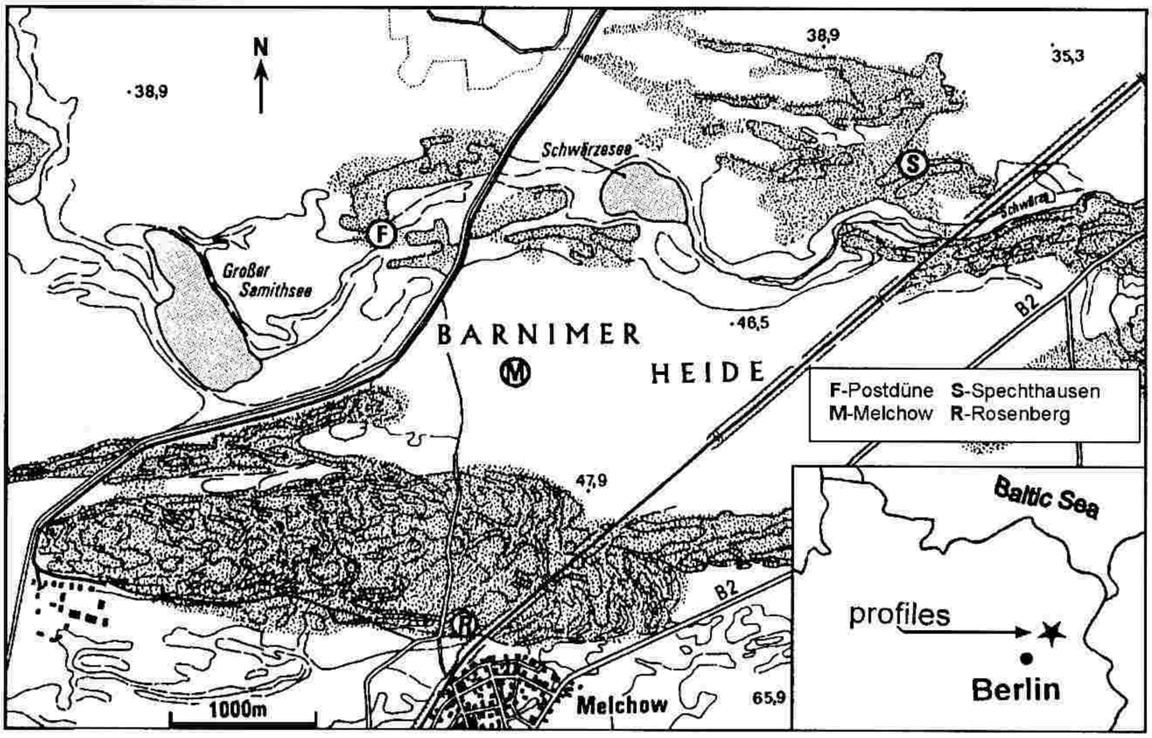

Fig. 1. Location of the four dune sections in the Eberswalde ice-marginal valley (coordinates of the section 'Postdüne' for guidance: 13°41'43"E; 52°48'36"N).

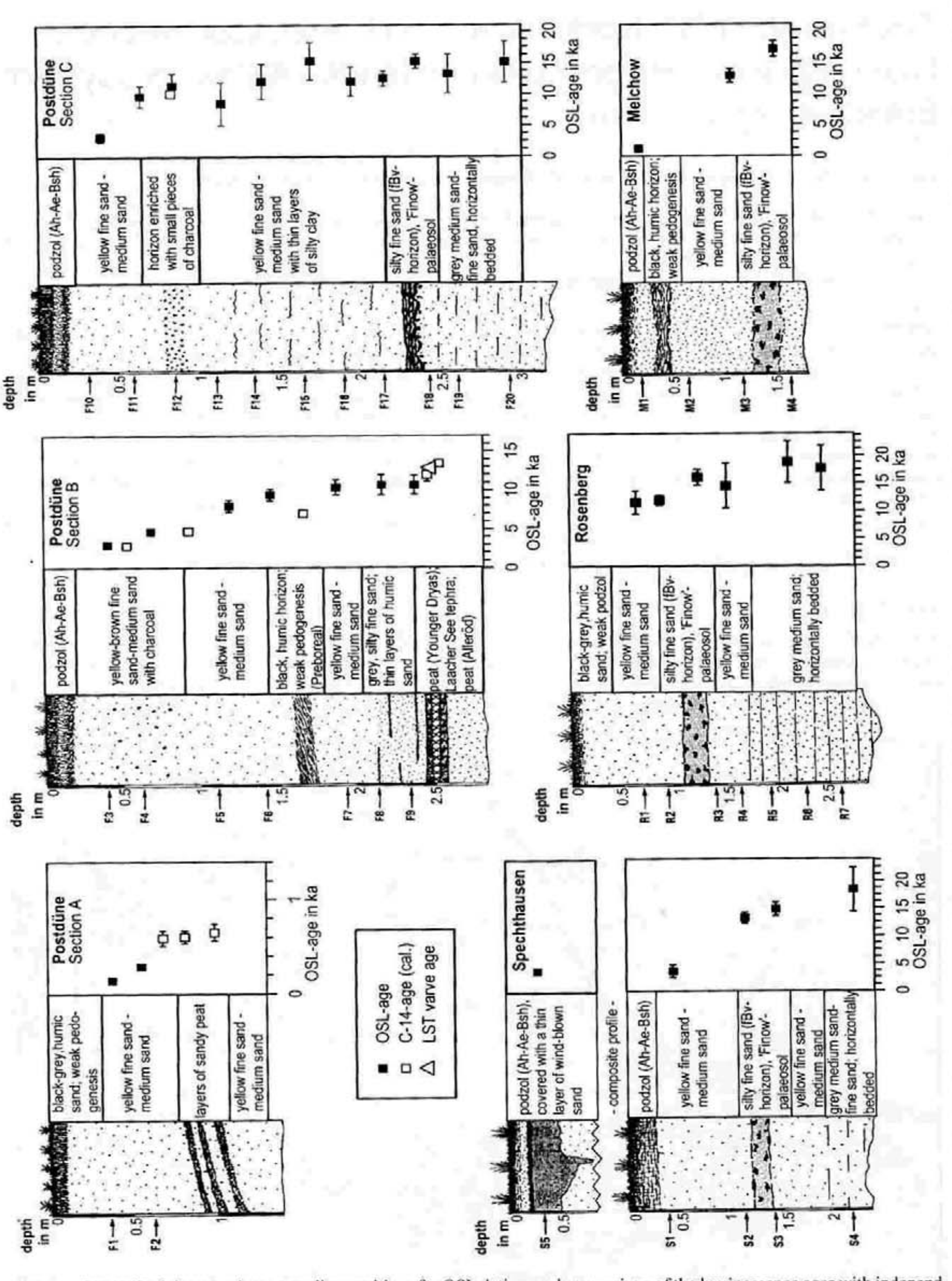

Fig. 2. Generalised dune sections, sampling positions for OSL dating, and comparison of the luminescence ages with independent age control of the Laacher See tephra (LST) and radiocarbon ages (^{14}C dates derived from Schlaak, 1999; calibrated using CALIB-4.1). At the 'Postdüne'-site three sections were examined with horizontal distances of several metres to each other (section A at the bottom of the dune slope, section B in the lower part, and section C in the upper part of the dune).

they provide, is possible by the age determination of the sediments. In the absence of organic material suitable for ^{14}C dating, luminescence techniques often provide the only method for dating these sediments. With thermoluminescence (TL) or optically stimulated luminescence (OSL) dating the last exposure of sediments to sunlight is determined (see for example Aitken, 1998). Here we present the results of a study using OSL for dating dune sand from four sections in Brandenburg, northeastern Germany. The examination of these profiles is part of a long-term project (see Radtke, 1998) dealing with Late Glacial and Holocene dune accumulation in Central Europe.

Methods and material studied

Description of the sites

Four different dune sections were sampled for luminescence dating (see Fig. 1). All sites are located within the Torun-Eberswalde ice-marginal valley, north of Berlin, which was a meltwater-outlet of the inland-ice during the remelting phases at the end of the Weichselian ice-age. To check the potential of luminescence techniques for dating late Pleistocene and Holocene aeolian sediments, it is useful and necessary to date sediment sequences with independent age control. Such a test study was carried out at the dune section 'Postdüne' (for details see Hilgers et al., 2000), because here chronological control is provided by ^{14}C ages and a layer of Laacher See tephra (12.88 ka varve years, Brauer et al., 1997). This tephra horizon is embedded in a peat horizon (see section B of the 'Postdüne' profile in Fig. 2). Palynological analyses prove the connection of the overlying and underlying peat with the Younger Dryas and the Allerød periods, respectively (Schlaak, 1993). In the upper, drier parts of this dune (see section C in Fig. 2), a fossil-Bv-horizon is exposed instead of the peat horizon. This fossil horizon was first described by Schlaak (1993) as a part of a palaeosol, the so-called 'Finowboden', which he suggested was developed during the Allerød interstadial with an age range of about 12.9–14 ka assumed from ice core-data from Greenland (Taylor et al., 1993). The 'Finowboden' is exposed in all four dune sections at Rosenberg, Melchow, Spechthausen and in the 'Postdüne' near Finow (see Fig. 2).

Sample preparation for luminescence measurements

Sample preparation was carried out in subdued red light. After dry sieving to extract the grain size fraction 100–200 μm, the samples were treated with HCl (10%), H_2O_2 (10%) and sodium oxalate (0.01 N) in order to remove carbonates, organic material and clay. Solutions of sodium polytungstate (2.62 and 2.7 g.cm^{-3}) were used to concentrate the quartz fraction. Etching in 40% HF for 40 min was carried out in order to remove the alpha-irradiated layer and to avoid contamination with any feldspars. After a further treatment with HCl to dissolve any acid-soluble fluorides the residual quartz grains were sieved again to provide the grain size fraction for dating (100–150 μm).

Method	MAA (Multiple-Aliquot Additive Dose Protocol)	MAR (Multiple-Aliquot Regenerative Dose Protocol)	SAR (Single-Aliquot Regenerative Dose Protocol)
Normalisation	0.1 s short shine stimulation	0.1 s short shine stimulation	---
Bleaching	---	several hours with sunlight	100 s with blue diodes
Irradiation	^{60}Co-γ-source	^{60}Co-γ-source	$^{90}Sr/^{90}Y$-β-source
Filterset for detection	HA3 & 3 · U340	HA3 & 3 · U340	HA3 & 3 · U340
Preheating	220 °C/300 s	220 °C/300 s	260 °C/10 s *
Stimulation	blue/green broad-band (420-550 nm)	blue/green broad-band (420-550 nm)	blue diodes (470±30 nm)
Aliquot temp. during stimulation	125 °C	125 °C	125 °C
Integral used for D_e calcul.	0–0.4 s	0–0.4 s	0–0.4 s
Background subtraction	90–100 s	90–100 s	90–100 s

*except samples F1 & F2 (preheating procedure used: 240 °C/10 s), for details see Hilgers et al. (submitted).

Tab. 1. Technical parameters used for luminescence measurements.

Analyses and results

Equivalent dose (D_e) estimation

All luminescence measurements were performed using automated Risø TL/OSL readers (type TL-DA-12). Equivalent doses (D_e) are estimated using the single-aliquot regenerative-dose (SAR) protocol (Murray and Wintle, 2000), the multiple-aliquot additive-dose (MAA) and the multiple-aliquot regenerative-dose (MAR) protocols (e.g. Aitken, 1998). The multiple-aliquot (MA) measurements were carried out at the laboratory in Cologne and the single-aliquot (SA) measurements at the Risø National Laboratory in Roskilde. Important details and differences between the measurement protocols employed are summarised in Table 1. All D_e estimates are presented in Table 2. The higher precision of the D_e values obtained with the SAR protocol in comparison to the MA values is clearly evident. (For

Sample	Uranium (ppm)	Thorium (ppm)	Potassium (%)	Dose rate (Gy ka^{-1})	Equivalent dose (Gy)	Method	Luminescence age (ka)
F1	0.47±0.05	2.24±0.11	0.92±0.05	1.36±0.08	0.193±0.006	SAR	0.143±0.013
F2	0.35±0.05	2.00±0.10	0.82±0.04	1.21±0.08	0.347±0.004	SAR	0.288±0.022
F3	0.38±0.05	1.54±0.08	0.85±0.04	1.22±0.08	3.74±0.08	SAR	3.09±0.26
F4	0.29±0.07	1.55±0.08	0.80±0.04	1.14±0.08	5.36±0.12	SAR	4.72±0.42
F5	0.38±0.05	1.20±0.06	0.87±0.04	1.18±0.08	9.4±0.3	SAR	8.02±0.78
F6	0.47±0.05	1.21±0.06	0.85±0.04	1.18±0.08	11.1±0.2	SAR	9.46±0.79
F7	0.31±0.05	1.82±0.09	1.00±0.05	1.32±0.08	13.7±0.4	SAR	10.4±1.0
F8	1.50±0.08	2.81±0.14	1.03±0.05	1.39±0.14	14.6±0.4	SAR	10.7±1.3
F9	1.52±0.08	3.08±0.15	1.07±0.05	1.43±0.14	15.1±0.2	SAR	10.7±1.2
F10	0.30±0.05	1.75±0.09	0.84±0.04	1.21±0.08	3.77±0.64	MAR	3.16±0.74
F11	0.37±0.06	1.76±0.09	0.78±0.04	1.16±0.08	11.1±1.2	MAR	9.7±1.7
F12	0.23±0.06	1.38±0.07	0.84±0.04	1.15±0.08	13.0±1.2	MAR	11.4±1.9
F13	0.61±0.05	1.76±0.09	0.85±0.04	1.26±0.08	10.4±3.6	MAR	8.5±3.4
F14	0.28±0.07	1.68±0.08	0.92±0.05	1.24±0.08	14.6±2.5	MAR	12.0±2.8
F15	0.57±0.06	2.26±0.11	0.88±0.04	1.31±0.08	19.8±2.7	MAR	15.3±3.0
F16	0.92±0.06	2.80±0.14	0.88±0.04	1.43±0.08	17.0±2.3	MAR	12.0±2.3
F17	0.72±0.18	3.90±0.20	0.97±0.05	1.49+0.11	18.5±0.4	SAR	12.5±1.2
F18	0.35±0.18	1.75±0.09	0.87±0.04	1.19±0.08	18.0±0.3	SAR	15.2±1.2
F19	0.53±0.06	3.07±0.15	1.09±0.05	1.54±0.09	20.0±3.5	MAR	13.2±3.1
F20	0.58±0.06	3.15±0.16	0.89±0.04	1.37±0.08	20.5±3.3	MAR	15.1±3.3
R1	0.35±0.18	1.71±0.09	0.90±0.05	1.26±0.08	14.3±1.7	MAA	11.5±2.1
R2	0.80±0.20	3.01±0.15	1.17±0.06	1.66±0.09	19.6±0.4	SAR	11.9±1.1
R3	0.35±0.18	1.62±0.08	0.82±0.04	1.15±0.08	18.4±0.4	SAR	16.1±1.4
R4	0.59±0.15	1.88±0.09	0.80±0.04	1.21±0.08	17.2±3.8	MAA	14.5±4.1
R5	0.35±0.18	1.77±0.09	0.78±0.04	1.11±0.08	NA	MAA	NA
R6	0.35±0.18	1.78±0.09	0.81±0.04	1.13±0.08	21.0±2.7	MAA	18.8±3.7
R7	0.35±0.18	1.41±0.07	0.72±0.04	1.01±0.07	17.6±2.9	MAA	17.7±4.1
S1	0.57±0.14	2.10±0.11	0.98±0.05	1.44±0.08	5.1±1.4	MAA	3.6±1.2
S2	0.35±0.18	1.81±0.09	0.98±0.05	1.33±0.08	17.5±0.3	SAR	13.2±1.0
S3	0.35±0.18	1.71±0.09	0.98±0.05	1.31±0.08	19.4±0.5	SAR	14.9±1.3
S4	0.35±0.18	1.42±0.07	0.99±0.05	1.28±0.08	23.3±3.7	MAA	18.4±4.0
S5	0.35±0.18	1.25±0.06	0.78±0.04	1.12±0.08	4.18±0.31	MAA	3.77±0.55
M1	0.64±0.16	1.96±0.10	0.92±0.05	1.38±0.08	1.59±0.42	MAA	1.17±0.37
M2	0.35±0.18	3.09±0.15	0.95±0.05	1.42±0.08	NA	MAA	NA
M3	0.99±0.25	2.92±0.15	0.98±0.05	1.56±0.09	19.9±0.5	SAR	12.8±1.1
M4	0.35±0.18	3.02±0.15	1.05±0.05	1.48±0.09	25.1±0.4	SAR	17.0±1.3

NA – not available.

Tab. 2. Summary of dose rates, equivalent doses, and resulting luminescence ages.

further details on the comparison of the different protocols and on measurement details see Hilgers et al., 2000.

Dose rate (D_0) determination

For all samples the radionuclide concentrations were determined by neutron activation analyses (NAA, undertaken at the Becquerel Laboratory, Sydney, Australia). Table 2 summarises these analyses. In a comparative study 11 samples of the section Postdüne were also examined with high-resolution gamma-ray spectrometry. The influence on the dose rate estimation and hence on age determination is reported and compared in Hilgers et al. (2000). The water content of the samples used for dose rate estimation was assumed from measured values (6 ± 2%, except for F8 and F9 30 ± 10%, and for F17 and R2 10 ± 5%). The cosmic ray contribution to the total dose rates was calculated according to the sampling depth following Prescott and Hutton (1994).

Resulting luminescence ages

A summary of all luminescence ages is presented in Table 2. In Fig. 2, the ages are compared with the ^{14}C ages, the Laacher See tephra and the 'Finow' palaeosol as chronometric markers. The comparison of OSL ages based on SAR with those based on MA measurements shows the broader error bars of ages obtained with multiple-aliquot protocols. The accuracy of the SAR ages is considered very satisfactory when tested against the independent chronological controls except the discrepancy between the ^{14}C age of the weak humic horizon and the OSL ages of the overlying and underlying luminescence samples F6 and F7. This horizon is described as Preboreal soil development based on analyses of pollen assemblages (Schlaak, 1993). Considering this age assumption the luminescence ages seem to provide more accurate age estimates than the ^{14}C age, which dates the humic horizon too young. In an earlier study Baray and Zöller (1994) dated the sediments above and below the Preboreal soil using TL of quartz and K-feldspars. They applied the MAR protocol and obtained luminescence ages similar to our results – overestimating the radiocarbon age of 6.13 ± 0.15 ka (Schlaak, 1999), e.g. for quartz 8.4 ± 1.2 ka, and 8.7 ± 1.7 ka for sediments from above and below the humic horizon, respectively.

The ages of the four samples underlying the 'Finow' palaeosol prove the accumulation of these sediments before the Allerød/Bølling-interstadial period (Fig. 2, Table 2), which is dated by Greenland ice-core records from about 12.9-14.9 ka (Taylor et al., 1993). The ages of the samples taken from the sediments immediately overlying the palaeosol concentrate on the Younger Dryas period (11.65–12.9 ka according to Taylor et al., 1993). Therefore, a phase of dune stabilisation and the possibility of soil development is limited clearly to the Allerød/Bølling-interstadial period in all four dune sections.

The youngest luminescence ages (F1, 143 ± 13 years and F2, 288 ± 22 years) are entirely consistent with the immediately underlying ^{14}C age of 590 ± 80 years (Fig. 2). From the homogeneous dose distribution in these two samples a sufficient resetting of the luminescence signal during transport is inferred indicating the presence of mobilisation processes many decades ago.

Discussion and conclusion

From the results presented here in context with other dating studies in Germany (e.g. Radtke, 1998, and ongoing work) two main phases of aeolian activity can be distinguished, and several other phases which seem to be related to regional conditions. Based on the luminescence ages we assume that a main period of high aeolian activity started during the second half of the Younger Dryas period. This onset of intensive aeolian accumulation terminated the Younger Dryas peat development at the 'Postdüne' site. The scenery is coincident with reconstructions of the palaeoclimate at the Late Glacial/Holocene transition proposing cold-wet climate at the beginning of the Younger Dryas, turning into slightly warmer but drier climate supporting aeolian processes during the second part (Isarin et al, 1998). These processes continued far into the Preboreal with high sedimentation rates especially at the 'Postdüne' section. The second main period of aeolian accumulation presumably started at the end of the Atlanticum period with a maximum extent in the last two thousand years most probably due to the increasing human impact on landscape, for example by extensive deforestation. The accumulation of the sediments at the top of the 'Postdüne' section, represented with samples F1 and F2, probably took place at the end of the Little Ice Age. Similar late Little Ice Age results have been reported by Murray and Clemmensen (2000) for aeolian sand in western Denmark.

We conclude that OSL dating of quartz is well suited for dating well-bleached dune sands over the entire age range from the present to the Late Weichselian. By using SA techniques in luminescence dating the chronological resolution of sediment sequences could be considerably improved. This is essential for the differentiation of Holocene and Late Glacial dune sections into phases of aeolian activity and dune stabilisation and, furthermore, for supraregional correlation of these phases. To ascertain the assumptions presented here it is necessary to examine numerous dune sections. In addition, a narrow sampling and hence numerous dates are necessary for a precise reconstruction of the chronometric history of a profile.

To improve the resolution for the whole sediment sequences of all four dune sites all samples will be dated using the SAR protocol. It is also intended to date samples derived from the bottom of the sections for determining the onset of aeolian mobilisation and dune development in this area.

Acknowledgements

This work was partly funded by the Deutsche Forschungsgemeinschaft (DFG, grant Ra 383/7-1). The visit of A.H. to Riso National Laboratory was financially supported by the 'Käthe-Hack' foundation (University of Cologne). Our thanks to Prof. Dr. G. Schmitt and Dipl.-Phys. B. Bannach for providing access to the ^{60}Co gamma source at the Department of Nuclear Medicine at the University of Düsseldorf for sample irradiation.

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Late Pleistocene Climatic Variations in Siberia Based on Loess-Palaeosol Records

Jiří CHLACHULA[1] and Rob A. KEMP[2]

[1] *Laboratory for Palaeoecology, Technical University FT VUT Brno, 762 72 Zlín, Czech Republic*
[2] *Department of Geography, Royal Holloway, University of London, Egham, Surrey, TW20 0EX, U.K.*

ABSTRACT. Loess-palaeosol records in Siberia represent a significant source of proxy data for reconstruction of past climates and climate change in the Northern Hemisphere. A series of high resolution loess sections recently studied in the Ob, Yenisei and Angara River basins within a 1500 km W-E continental transect shows patterned climatic variations and uniformity of natural environments across this territory during the Late Pleistocene. The key Late Quaternary Siberian record from Kurtak (Sections 29 and 33) in the Northern Minusinsk Basin provides evidence for a strongly fluctuating climatic change in the northern Eurasia during the Late Quaternary, with maximum deviation amplitudes between 130 and 10 ka BP. Magnetic susceptibility (low-frequency and FD%) records with other palaeoenvironmental proxy data (grain size, % Ca CO_3 and % organic carbon variations) show a globally diagnostic palaeoclimatic trend for the last glacial - interglacial cycle, and an environmental uniformity across southern Siberia.
The last interglacial (sensu lato) includes several relatively short warm as well as very cold intervals (correlated with OIS 5e-5a), with a strongly continental warm climate culminating around the peak of the last interglacial (OIS 5e) and a gradual shift to more humid and cooler conditions during the following interstadial stages (OIS 5c and 5a). Due to its pronounced continentality, the Siberian loess record provides an excellent source of high-resolution palaeoclimatic proxy data of regional as well as global significance.

KEY WORDS: loess-paleosol records, magnetic susceptibility, climatic change, Siberia, OIS 5.

Introduction

Palaeoclimatic loess records in Siberia, although still less known than those in Europe or China, have already provided important information on past climatic variations in this part of Eurasia (Chlachula et al., 1997, 1998; Chlachula, 1999; Zykina, 1999). Loess and loess-like deposits are widely distributed mainly in the southern part of the Siberian territory, covering a broad geographical area of about 800,000 km^2 between the Ob and Angara River basins north of the Altay and Sayan Mountains. They represent a continuation of the Eurasian loess belt spanning from Western Europe across the Russian Plains to the north-central China Loess Plateau. They range in thickness from a few metres in the Angara and Lake Baykal area in the eastern part of Siberia to maximum of 40 m in the Yenisei River valley and reaching up to 150 m on the Ob River (Priobie) loess plateau in the west. The loess is often locally intercalated with other aeolian, alluvial and colluvial deposits (sands, clays and silts) and it documents the complex nature of the Quaternary environments in this part of Asia. Following