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PAST GLOBAL CLIMATE CHANGE: A HIGH RESOLUTION EVIDENCE FROM SW SIBERIA

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The southern Siberian loess, being a continuation of the Eurasian loess-belt, has provided one of the most complete terrestrial proxy records on the global past climate development. New high-resolution loess-paleosol sections from the Priobie Loess Plateau (Iskitim) and the Altay Plains (Biysk, Bystrianka and Krasnogorskoe), SW Siberia, recently studied as a part of the 2000 km W-E Siberian paleoclimatic transect, provide new detailed information on the Late Pleistocene climate evolution and landscape development in the parkland-steppe zone of southern Siberia. The complete stratigraphic records documented by magnetic susceptibility, grain-size, % $CaCO_3$ and % organic carbon as proxy climatic data, and supplemented by thin-section studies, show cyclic climatic variations within the last interglacial-glacial cycle. A strongly continental warm climate culminated around the peak of the last interglacial (sensu stricto OIS 5e) and cooler conditions occurred during the following interstadial stages (OIS 5c and 5a), corresponding to shifts in palaeolandscape development with gradual replacement of parkland-steppe and mixed southern taiga by boreal forest, transformed into a cold arid periglacial tundra-steppe during the stadial stages (OIS 5d and 5b). A similar trend with short warm and very cold intervals can be observed in the mid-last glacial interglacial interval (OIS 3) in accordance with the evidence from other Siberian key high-resolution loess sections from the Yenisei and Angara region, separated by the early and late last glacial loess beds (OIS 4 and 2, respectively). The pedosedimentary record, reflecting the effects of syndepositional pedogenic processes, attests to a dynamic global climate pulsation during the Late Quaternary in north-central Asia.

Key words: *loess, climate, SW Siberia*.

ОДНО ИЗ ГЛОБАЛЬНЫХ КЛИМАТИЧЕСКИХ ИЗМЕНЕНИЙ ПРОШЛОГО: ХОРОШО ОБОСНОВАННЫЕ ДОКАЗАТЕЛЬСТВА ПО ЮГО-ЗАПАДНОЙ СИБИРИ

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Южносибирский лесс, будучи продолжением Евро-Азиатского лессового пояса, дает одни из самых полных и достоверных сведений по глобальному климатическому развитию в прошлом. Новые детальные лессово-палеопочвенные разрезы из Приобского лессового плато (Искитим) и Алтайских равнин (Бийск, Быстрянка и Красногорске), недавно изученные как часть палеоклиматического широтного разреза Сибири протяженностью в 2000 км, обеспечивают новой детальной информацией по позднеплейстоценовой климатической эволюции и развитию ландшафта в лесостепной зоне Южной Сибири. Полные стратиграфические сведения, задокументированные с использованием магнитной восприимчивости, гранулометрического анализа, процентного содержания $CaCO_3$ и органического углерода как достоверного климатического показателя, дополненные исследованиями шлифов, указывают на цикличные климатические колебания во время последнего межледникового-ледникового периода. Резко континентальный, теплый климат достиг кульминации в пике самого последнего межледникового периода, (sensu

stricto OIS 5e), а более холодные условия имели место в последующих межстадиальных периодах (OIS 5c и 5a), соответственно смещениям в развитии палеоландшафта с постепенным замещением лесостепи и смешанной южной тайги северной лесной зоной, трансформировавшейся в холодную аридную межледниковую тундру, во время стадиальных периодов (OIS 5d и 5b). Схожую тенденцию с короткими теплыми и очень холодными интервалами можно наблюдать в средне-позднем межледниковом периоде (OIS 3), согласно данным из других Сибирских ключевых лессовых разрезов Енисейского и Ангарского регионов, разделенных ранними и самыми поздними лессовыми пластами (OIS 4 и 2, соответственно). Педоосадочные данные, отражающие эффекты синхронных процессов почвообразования свидетельствуют о динамичной глобальной пульсации климата во время позднего четвертичного периода на севере Центральной Азии.

Ключевые слова: *лесс, климат, юго-западная Сибирь*.

Introduction

Quaternary paleoclimates and paleoenvironments have become the focus of detailed multidisciplinary studies aimed at understanding past climate changes, but also their implications for future global climate development. Among the terrestrial sediments used as climatically significant paleoarchives, loess has attracted most attention because of its environmental sensitivity and long-term stratigraphic records.

The southern Siberian loess region (latitude 50°-60° N and longitude 66°-104° E) is important for reconstruction of past climate changes, as it lies in the transitional sub-arctic continental zone between the northern Siberian lowlands and the southern mountain system of central Asia. The loess and loess-like deposits east of the Ural Mountains represent a continuation of the Eurasian loess belt extending from Western Europe across the Russian Plains to the north-central China Loess Plateau. Opposite to the previous studies on thick, but chronologically discontinuous Quaternary loess sections, recent investigations have focussed on high-resolution climatic records and related paleoenvironmental evolution of landscape and biota using multiproxy data [Chlachula et al., 1997; Chlachula, Kemp, 2000; Evans et al., 2003] and refinement of the loess/paleosol chronostratigraphy, particularly for the last 130 ka.

This contribution details some of the results from an ongoing project concerned with the reconstruction of the climatic and landscape history along a 2000 km west-east transect between the Ob and the Angara river basins during the Late Quaternary for a time interval of the last 150 ka [Chlachula, 2003]. Temporal correlation and paleoclimatic interpretation of the principal high-resolution section is based on pedogenic macromorphological and micromorphological characteristics, magnetic susceptibility, grain size, organic carbon and calcium carbonate records.

Study area

The southern Siberian loess belt is a zone c. 1500 km wide in the central part of southern Siberia, north of eastern Kazakhstan and Mongolia (fig. 1). Physiographically, the broad area is bordered by the Western Siberian Lowland on the NW, by the Altai and Sayan Mountains on the south and the east Siberian mountain ranges on the east. The present climate is strongly continental with cold and dry winters with little snow cover, and warm to hot summers; mean annual temperature ranges from -0,5 to -2°C. Most of the area is covered by open parkland-steppe characterised by typical chernozemic soils with well-developed humic horizons disturbed by active frost wedges as a result of low winter temperatures and reduced snow cover. Gleyed brown forest soils developed under mixed taiga prevail in the mountains.

The distribution of loess reflects the dominant western wind direction and the geomorphic setting, with extensive open lowlands in the west and depressions in the central and eastern parts of the territory. Most of the aeolian sediments we-

Fig. 1. Loess distribution in southern Siberia and location of the key stratigraphic sections.

re derived from south ice-marginal areas of the northern continental ice-sheet, large alluvial floodplains and the floors and margins of (glacio-) lacustrine basins. The periodically glaciated southern and eastern mountain areas (the Altay and Sayan Mountains) were also a significant source of the aeolian silty sediments in the adjacent river basins.

Thickness of the aeolian deposits ranges from a few metres in the Angara river valley and the lake Baikal area in the eastern part of Central Siberia to maxima of 40 m in the Yenisei river valley and 150 m on the Ob river (Priobie) loess plateau in the west. The loess is locally intercalated with other aeolian, alluvial and colluvial deposits (sands, silts and clays), and with variably developed paleosols, together documenting a complex sequence of Pleistocene environmental changes. The most complete sections on the Ob Loess Plateau, the Altay Plain and the Northern Minusinsk Basin (Kurtak) cover about the last two glacial and interglacial cycles (OIS 7-1) [Chlachula et al., 1997; Evans et al., 2003; Rutter et al., 2003].

Site description

The principal and most complete section at Iskitim, which is the eponymous reference site for the mid-last glacial (OIS 3) pedocomplex in SW Siberia [Volkov, Zykina, 1984], is located in the NE part of the Ob (Priobie) Loess Plateau, which is an extensive (about 300 × 200 km) area of loess, up to 150 m thick, along the upper reaches of the Ob river, south of Novosibirsk. The plateau, a parkland-steppe with elevations of 190-240 m asl, is bordered to the north by the Western Siberian Lowland (100-200 m asl) and to the south by the Altay Mountain foothills (500-2000 m asl). The site, with Late Quaternary loess-paleosol sections, lies on the right bank of the Ob river (55,0° N, 82,2° E; 200 m asl) in the steppe zone.

The Late Quaternary pedostratigraphic record at Iskitim includes a late Middle Pleistocene (OIS 7?) pedocomplex with chernozemic and grey luvisolic parkland soils separated from the overlying Berdsk (OIS 5) pedocomplex by 3-4 m of colluvial loess deposits. The latter comprises a series of three chernozems separated by two loess units, 20-40 cm and 70-100 cm thick. The upper part of the sequence consists of about 5 m of early last glacial (OIS 4) loess underlying the mid-last glacial (OIS 3) pedocomplex, which includes two cryogenically-altered chernozemic soils with ^{14}C dates of 33,1-29,0 ka BP and 26,3-24,5 ka BP. The pedocomplex is overlain by 4-6 m of loess with incipient paleosols of the late last glacial (OIS 2) topped by the present chernozem.

Methods

The investigated loess-paleosol section at Iskitim (19,2 m) was mapped in detail and samples (for magnetic susceptibility, grain size, calcium carbonate and total organic carbon analyses) collected in 8 cm^3 plastic boxes at 2,5 cm intervals taken for analysis. Larger block samples were taken from each of the main loess and paleosol horizons for thin-section analysis and for OSL dating. Low-frequency magnetic susceptibility (MS) was determined in all bulk

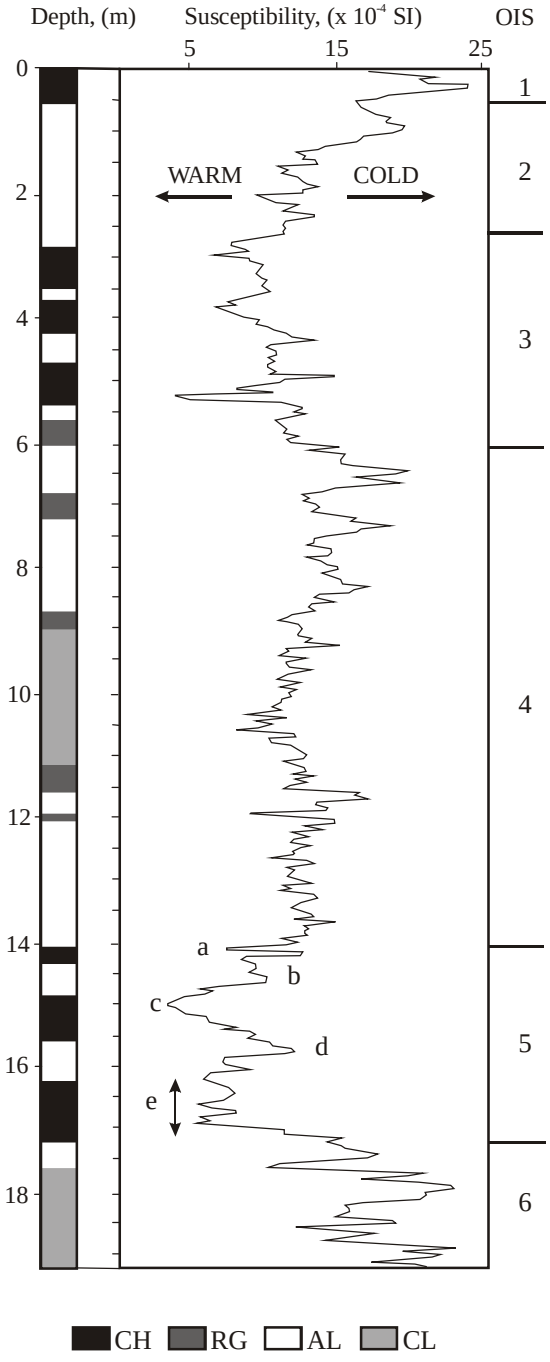

Fig. 2. Magnetic susceptibility (LF) record from Iskitim corresponding to OIS 6-1.

sediment and paleosol samples (385 spaced by 5 cm intervals) by a Kappabridge.

Results

Bulk analytical data

Magnetic susceptibility (MS) records show clear distinctions between the principal paleosol units and intercalated loess beds (fig. 2). The overall intensity of the MS signal is less reduced at Iskitim in comparison with the principal section at Kurtak (the Yenisei area), with the lowest values of 15-40 × 10^{-8} m^3kg^{-1} in chernozemic palaeosols and the highest values of 50-280 × 10^{-8} m^3kg^{-1} in loess. The Kurtak loess has susceptibility values generally >250 × 10^{-8} m^3kg^{-1}, whereas the Iskitim loess is <100 × 10^{-8} m^3kg^{-1}. The MS differences between the interglacial soils are less pronounced, with values for the OIS 5e and OIS 5c steppe chernozems of 15-50 × 10^{-8} m^3kg^{-1} at Iskitim but 30-100 × 10^{-8} m^3kg^{-1} at Kurtak. This confirms the site-specific character of the climate-dependent MS variations in Siberian loess-palaeosol sections.

Other proxy climate date (organic carbon record, calcium carbonate variations and grain size) show a consistent trend with the MS record (fig. 3). The bulk analytical data from the Iskitim section indicate a pattern of climate development consistent with that from Kurtak.

Chronology

The chronology of the studied Iskitim section is in agreement with the regionally established chronostratigraphy of the OIS 5 pedocomplex in the southern Siberian loess region, with the OIS 5e chernozem as the key chronostratigraphic marker. The new OSL results provide, for the first time, an absolute dating for the specific loess/paleosol units. The OSL date of 57790±5407 yr BP (RH 99004) from the gleyed regosol in the OIS 4 loess matches the OSL date of 58437±4502 yr BP (RH99006) from the same stratigraphic position in the Kurtak section [Chlachula et al., 2004]. The new OSL date of 102641±9 769 (RH 99005) from the basal part of the second well-developed paleosol above the OIS 5e chernozem (IRSL-dated at Kurtak to 125±5 ka BP) corresponds to OIS 5c.

The Late Pleistocene climate evolution in southern Siberia

The investigated loess-paleosol section at Iskitim shows, in congruence with the other high-resolution loess records from the Altay Plains, the uniformity of the climatic change and the

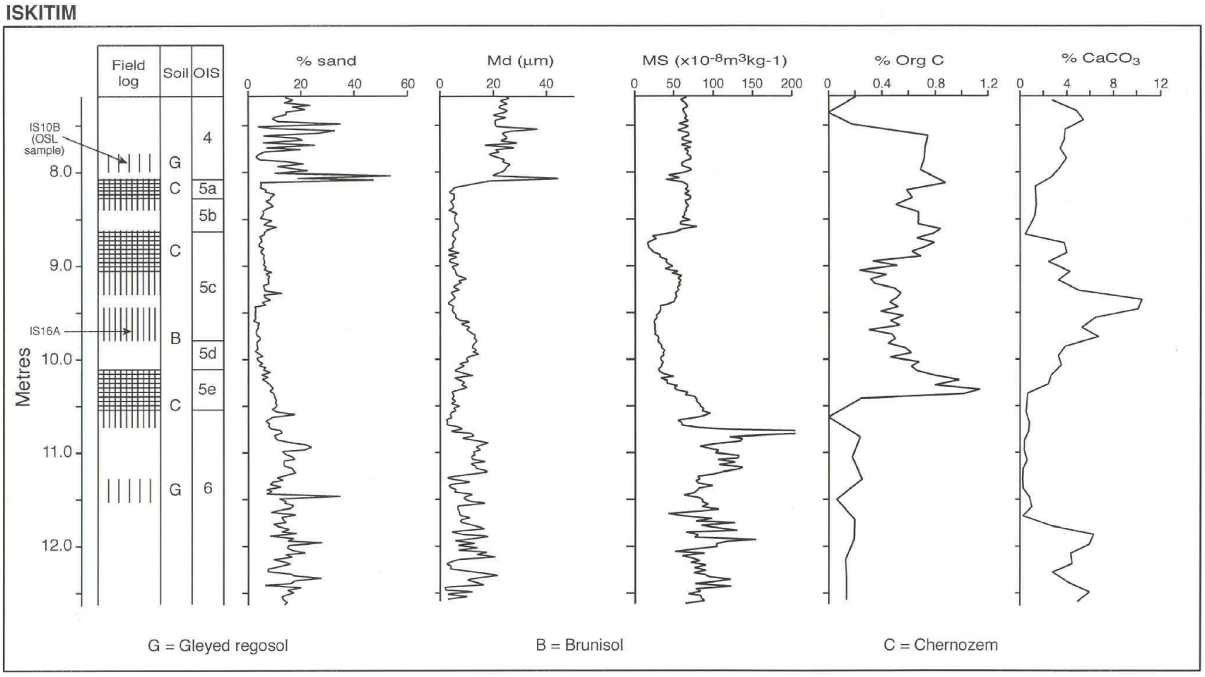

Fig. 3. Iskitim section. Pedostratigraphy and paleoclimate proxy data of the last interglacial (OIS 5)

corresponding landscape and biotic development in the parkland-steppe zone of north-central Asia. The stratigraphic sequences attest to enhanced loess deposition during dry and cold stages, and soil formation during warm intervals with surface stabilisation and subsequent cryogenic distortion by frost and colluviation with renewed climatic cooling.

Loess accumulation in the periglacial tundra-steppe zone along the northern mountain foothills correlated with the penultimate glacial (OIS 6, 170-130 ka BP) followed a major Pleistocene glaciation of the Altay and Sayan mountains. Fluctuating cold and humid conditions, with surface saturation, leading to intense colluviation of the loessic sediments at the later stage of OIS 6, are indicated across southern Siberia by 2-5 m thick packages of interstratified (0,2-1 cm thick) silt to silt loam layers distorted by minor (0,5-2 cm) frost wedge casts and involutions characteristic of cyclic loess sedimentation and snow melt.

The landscape stabilisation during the last interglacial (OIS 5, 130-74 ka BP) is indicated by formation of distinct soil horizons separated by thin loess units. The warm climatic sub-stages (OIS 5e, 5c and 5a) resulted in formation of chernozemic paleosols, which were disrupted by periglacial surface deformations covered by loess during the intervening colder sub-stages 5d and 5b and OIS 4. The initial interglacial warming, promoting boreal forest expansion, resulted in aggradational soil development under warmer and more humid conditions, leading to formation of the OIS 5e parkland-steppe chernozem under a more continental climate around 125 ka BP. This climatic amelioration is regionally traced by a sharp decrease of MS. Deep frost-wedge cast distorting the OIS 5e chernozem indicate a dramatic cooling during the last interglacial correlated with OIS 5d in support of the limnological record from lake Baikal [Karabanov et al., 2000].

Reactivated loess deposition above the last interglacial pedocomplex marked the onset of the early last glacial stage (OIS 4; 74-59 ka BP) with a climatic trend increasing aridity and cooling. A sharp decrease in temperature and humidity, indicated by the increased MS values of unweathered silty sediment, culminated in several cold and hyperarid stadials. These were interrupted by intervals of climatic amelioration, resulting in formation of gleyed periglacial tundra soils, which indicate cool conditions with ground water saturation resulting from degradation of perennial permafrost. The cooling during OIS 4, culminating in a major Late Pleistocene glacia-

tion in Siberia, triggered intensive wind erosion and transfer of large amounts of aeolian sediment from the areas along the continental ice-sheet in the north.

A new period of warm climatic variations (with corresponding MS and other proxy data signal) represents mid-last glacial interstadial interval (OIS 3) represented by the Iskitim Pedocomplex radiocarbon-dated to ca. 33-26 ka BP. This is overlain by a new massive layer of loess of the last glacial (OIS 2) topped by the present chernozem.

The recently investigated high-resolution loess-paleosol records from the Altay Plains corroborate the evidence from the Priobie Loess Plateau. The principal profiles at Biysk and Bystrianka display the globally diagnostic oxygen isotope chronology and the ice-berg Heinrich events (H1 to H6) seen in marine cores from the North Atlantic [Evans et al., 2003].

Conclusions

The new multi-proxy data from the southern Siberian loess region indicate pronounced and globally triggered climatic changes during the early Late Pleistocene in north-central Asia. The series of paleosols separated by loess beds provide evidence for a strongly fluctuating climate and landscape development across the broad territory. The principal loess-paleosol section at Iskitim on the Ob Loess Plateau, together with the recently studied loess sections on the Altay Plains (unpublished data) and in the Yenisei region, provide one of the most complete, high-resolution paleo-climate records for the time span of the last 150 ka.

References

Chlachula J. The Siberian loess record and its significance for reconstruction of the Pleistocene climate change in north-central Asia // Dust Indicators and Records of Terrestrial and Marine Palaeoenvironments (DIRTMAP). Quaternary Sci. Rev. 2003. № 22 (18-19). P. 1879-1906.

Chlachula J., Kemp R.A. Late Pleistocene climatic variations in Siberia based on loess-paleosol records // Upper Pleistocene and Holocene Climatic Variations. Proc. Intern. conf. on Past Global Changes. Prague, 2000. P. 83-85.

Chlachula J., Kemp R.A., Jessen C.A. et al. Landscape development in response to climate change during the Oxygen Isotope Stage 5 in the southern Siberian loess region // Boreas. 2004. № 33. P. 164-180.

Chlachula J., Rutter N.W., Evans M.E. A late Quaternary loess-palaeosol record at Kurtak, southern Siberia // Can. J. Earth Sci. 1997. № 34. P. 679-686.

Evans M.E., Rutter N.W., Catto N.R. et al. Magnetoclimatology: teleconnection between the Siberian loess record and North Atlantic Heinrich events // Geology. 2003. V. 31. № 6. P. 537-540.

Karabanov E.B., Prokopenko A.A., Williams D.F., Khursevich G.K. Evidence for mid-Eemian cooling in continental climatic record from Lake Baikal // J. Paleolimnology. 2000. № 23. P. 365-371.

Rutter N.W., Rokosh C.D., Evans M.E. et al. Correlation and interpretation of paleosols and loess across European Russia and Asia over the last interglacial cycle // Quaternary Research. 2003. V. 60. № 1. P. 101-109.

Volkov I.A., Zykina V.S. Loess stratigraphy in Southwestern Siberia. // Late Quaternary Environments of the Soviet Union. Minneapolis: University of Minnesota Press, 1984. P. 119-124.

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