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Current status of Quaternary research in Siberia

Jiří Chlachula[1] - Rob A. Kemp[2]

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

Studies of past climates and palaeoenvironments have witnessed considerable developments during the last twenty years, mainly because of the increased awareness of the value of reconstructing geological and natural histories in order to understand present-day ecosystems and predict the extent and consequences of future climatic changes. Many natural sciences, including climatology, evolutionary biology, terrestrial and marine palaeontology, soil science, glacial and sedimentary geology have been applied and involved in a series of projects aimed at investigating the pathways and rate of palaeoclimatic change on local, regional, as well as global scales. Computerised simulations of past environments in specific geographical areas over different time periods have been introduced to assess the effects of orbital variations on seasonal and latitudinal distribution of solar radiation and atmospheric circulation patterns, and the consequential changes in regional temperatures, precipitation and moisture balance. Postulated long-term models, though theoretical and unverifiable in essence, are believed to provide some means of prediction for future climatic evolution in the context of the overall climate history of the Earth, and to assess the potential global environmental impact of the human factor.

Most palaeoclimate studies focus on the Quaternary Period, i.e. the time span of the last 2.5 Ma. Due to the complex nature of the problems, Quaternary studies have become increasingly interdisciplinary, integrating Quaternary geology, glaciology, sedimentology, palaeogeography, palaeopedology, palaeontology, palaeobotany, Palaeolithic archaeology, and many other fields. Recent developments in dating methods, improving their reliability and accuracy (e.g. the AMS, ESR dating, amino-acid racemisation, thermoluminescence, optical luminescence, fission-track, isotopes studies and magnetostratigraphy) have significantly contributed to establishment of more detailed chronostratigraphic frameworks and to the refinement of existing palaeoclimatic sequences.

Siberia, possibly because of its vast area of about 14 million km^2 and geographical isolation, remains one of the least known regions of the Northern Hemisphere, and the world in general (Fig. 1). Administratively, the territory includes the Tyumen, Omsk, Tomsk and Novosibirsk Oblasť (region) in the west, the Krasnoyarsk Oblasť in the central part; the Altai Kray (district), the Kemerovo Oblasť, and the Altai, Khakassia and Tuva Republics in the south; the Buryatia Republic and the Irkutsk Oblasť in the east; and the Sakha Republic (Yakutia) in the north. Altogether, Siberia, comprising the northern half of Asia, covers about 60 % of the existing Russian Federation. It is characterised by a highly diverse topographic relief with vast lowlands extending in the eastern and north-central regions, and broad highlands and high mountain ranges in the south (the Altai and the Sayan Mountains) and the east (the Yablonovyy Khrebet, the Stanovoy, the Verkhoyansk, the Dzhugduzuhur and the Koryak Mountains).

Climatically, Siberia is known for extreme seasonal climatic fluctuations with the lowest temperatures measured on Earth in central Yakutia (below (below –80 °C), and hot dry summers in the southern steppes with temperatures over 40 °C. Current atmospheric conditions are controlled by the intensity of the Siberian Anticyclone moving cold, dry arctic air (the Arctic Front) during winter, and moderating regional air-mass temperature increases during summer. Precipitation brought by the western cyclone circulation (the warm Atlantic Stream), as well as the eastern air masses from the Pacific coast are considerably weakened by mountain ranges and increasing distance from the oceans. Seasonality is very pronounced with a short and windy spring and autumn. Active permafrost underlies most of the territory, especially in the northern areas, where it reaches up to several hundred metres in thickness. Mountain glaciers are present at higher elevations in the Altai and the Eastern Sayan Mountains (above 3000 m). The west-east/northwest-southeast oriented southern Siberian mountain ranges (highest peak being Belukha Mt. at 4506 m) form a natural barrier between the northern subarctic uplands and arctic lowlands, and the southern steppes and deserts in Mongolia and northwestern China. Many of the world's largest rivers (Ob, Yenisey, Angara and Lena) flow through the Siberian territory with a south-north-oriented drainage pattern emptying into the Arctic Ocean across all vegetation zones from the mountains in the south through semideserts, steppes, southern taiga, boreal forests, forest-tundra, subarctic steppe-tundra and arctic periglacial tundra in the north.

Geologically, the principal physiogeographical features of Siberia (the Siberian Plateau, the Northern and Southern Siberian Lowlands, the Taimyr and Sayan-Altai Mountains) were formed during the Eocene and Oligocene by the break up of the Palaeogene Siberian Platform. Palaeogene and Neogene deposits are widely distributed in the main sedimentary basins above Cambrian, Jurassic and Cretaceous formations. The early neotectonic activity continued during the Miocene. Orogenic processes became increasingly active during the Pliocene (after ca. 3.5 Ma BP), initiating the Baikal Rift System (currently 1620 m below the Baikal Lake level), and uplifting the Baikal Range (2588 m) and the Eastern Sayan Mountains (3491 m).

Formation of the southern Siberian mountains had a direct impact on atmospheric circulation. Free passage of warm and humid air masses from the southeast became increasingly obstructed by the rising orographic barrier, so cold arctic streams became dominant. In the process, the present strongly continental climatic regime was established. The topographical changes occurred during the Pleistocene, particularly the later stages, when intensive denudation processes modified the uplifted areas, and thick deposits released from the orogenically-active margins filled the deepening depressions within large sedimentary basins. Extensive aeolian (sandy and silty) sediments subsequently accumulated in the main valley depressions and within the transitional zone between the southern Siberian mountains and the northern lowlands. The Siberian Quaternary geological formations, especially in the southern areas, provide excellent sources of high-resolution proxy data for palaeoclimatic studies of regional and global significance, because of their specific zonal distribution coupled with the pronounced climatic continentality of the territory.

The southern Siberian territory is of a particular significance for Quaternary studies as it lies in the transitional subarctic continental zone between the north Siberian lowlands, south of the Arctic Ocean, and the southern Siberian mountain system north of the Gobi Desert (Fig. 1). Long and almost continuous Pleistocene stratigraphic records have been obtained from within major river valleys (Ob, Yenisey, Angara and Lena Rivers), which have been exposed after intensive slope erosion triggered by constructions of large river dams. Other, equally significant sources of Quaternary (geological, palaeontological and archaeological) data come from large-scale coal-mining operations in southern Siberia, particularly the Kuznetsk Basin.

Among continental deposits, loess (i.e. a silty aeolian sediment in its primary context) has attracted most attention because of its high environmental susceptibility and long-term stratigraphic sequences. Although more discontinuous and less extensively distributed than the loess in the Russian Plain farther west, or on the north-central China Plateau to the southeast, the loess and related subaerial deposits in southern Siberia reach up to 150 m in thickness (the Ob Plateau), and represent the most significant climatic record for this part of northern Asia, with a complete chronostratigraphic coverage extending back to at least the Middle Pleistocene (ZYKINA et al.; this volume). Moreover, because of its geographical location between the major Central Asian (Himalayan) mountain systems and the Arctic Ocean, ensuring a strong continentality to the area, the Siberian loess provides more detailed information on high-resolution climatic shifts which may not be detected in thick, but more uniform, loess-palaeosol sequences from other parts of Eurasia. A particular research focus has been on the last interglacial-glacial cycle, i.e. 127–10 ka BP, for which there is a continuous geological proxy record (CHLACHULA; this volume). The Siberian loess record is also of major importance for the establishment of a palaeoclimatic correlation framework with the European, the Central Asian, and the Chinese loess provinces. In addition to its palaeoclimatic importance, the local loess deposits have proved to be rich in fossil micro- and macro-fauna, and early cultural remains.

The geographical location of the Siberia has particular significance for mapping changes of the arctic air-mass circulation above eastern Eurasia during the Pleistocene Epoch, as reflected in the textural and compositional patterns of aeolian deposits, and for assessing the influence of the tectonic uplift of the Himalaya Range on the continentality of the north-central Asian climatic regime between the Tibetan Plateau and the Arctic Ocean. Recorded past climatic shifts, in terms of chronostratigraphy, periodicity, intensity and possible impact on the terrestrial ecology, can be incorporated eventually into a general framework of global Pleistocene climatic and environmental evolution in the Northern Hemisphere. Palaeoecological implications have a direct bearing for modelling adaptive patterns and responses in past biotic communities, and the main preconditions for early human occupation in the northern part of the Asian continent. Most of the projects entail an interdisciplinary approach because of the nature of proxy data.

Although not as intensively supported as under the former Soviet Union economic system, which largely focused on the mapping and exploitation of the Siberian

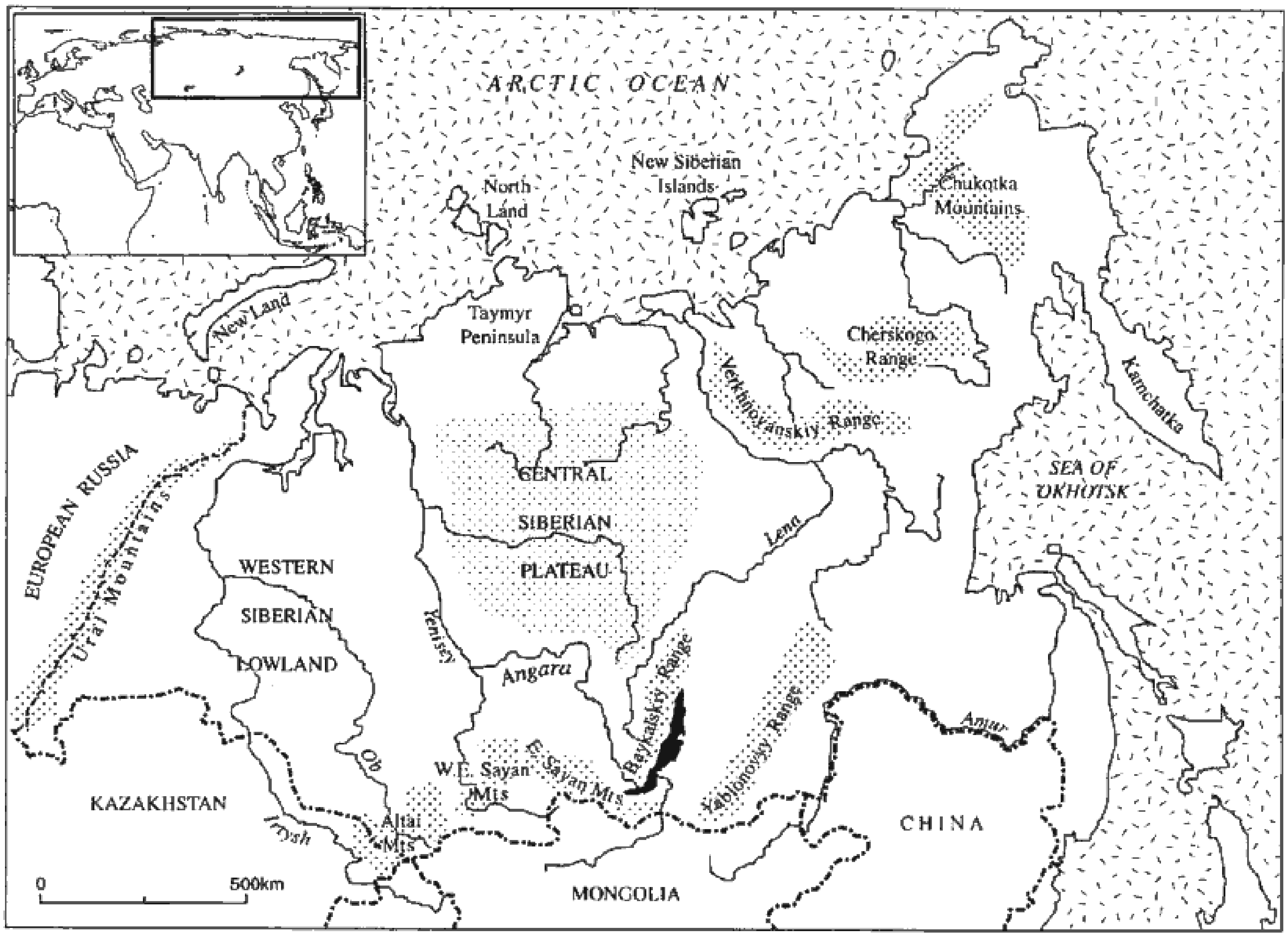

Fig. 1. Geography and physiography of Siberia.

natural resources, Russian geological investigations continue to bring new information on the remote as well as more recent geological history of the territory. These particularly concern detailed morphostructural and chronostratigraphic studies, and palaeogeographical reconstructions (e.g. Rezanov - Kalmikov, Nemchinov et al., Sukhorukova; this volume). In addition to the southern regions, particular progress has been achieved in the arctic and subarctic areas. For instance, Quaternary studies in Chukotka suggest that the earliest glaciations occurred as early as 3.5–2.4 Ma BP, followed by warm interglacials with temperatures well above the present values (Laukhin et al.; this volume). Recent palaeogeographical data from north-western Siberia indicate sharply contrasting conditions in sea palaeobasins between interglacial and glacial stages, which can be correlated with global climatic fluctuations reflected by the oxygen-isotope deep-sea records. Recent studies on the dynamics of interglacial environments suggest that specific transgressive marine sedimentary conditions and biogeocenoses were controlled by the geoplanetary circulation, as well as the local glacioisostatics and neotectonics of the northern lowlands (Vasilev et al.; this volume). Geological data from this part of Siberia also provide evidence of large-scale catastrophic events around the Pleistocene stratigraphic boundaries, which seem to have had direct links to global atmospheric and climatic factors (Zolnikov; this volume). Finally, Quaternary geology studies here, traditionally more closely linked with archaeological investigations than anywhere else, have also provided complex analyses of palaeoenvironmental changes affecting early human settings and the Pleistocene adaptation within broader geographical areas (Arkhipov, Baryshnikov - Maloletko; this volume).

Recent information provided by Palaeolithic archaeologists has fundamentally challenged traditional views about the early human occupation of this part of Eurasia. Until a few years ago, the earliest cultural records from Siberia, and northern Asia in general, were believed to be at most 40 000 years old. Systematic field rescue investigations, following large-scale surface cover disturbances along the major river reservoirs and extensive industrial field operations in the southern coal-mine areas since the late 1980s, have revealed a large number of Pleistocene-age occupation sites, some of them (e.g. Diring-Yuriakh, Mokhovo, Kurtak) of very high antiquity and an exceptional contextual completeness. Some (e.g. the Usť-Izhuľ site in the upper Yenisey River basin), with rich palaeotological remains and abundant evidence of early human activities, are unparalleled in other parts of Asia (Drozdov et al.; this volume). Although largely represented by stone (pebble tool) industries, the stratigraphically-fixed archaeological localities clearly demonstrate that prehistoric people colonised the northern latitudes as early as the Middle Pleistocene. Evidence from the southern Siberian river basins surrounded by high mountain ranges indicates that these served as ecological refugia for faunal communities, including the Palaeolithic people, even during the cold glacial stages.

Another area of intensive geoarchaeological investigations relates to the Middle and Upper Palaeolithic cave settlement in the Altai foothills (Derevianko - Markin, Deverianko et al.; this volume) suggesting a parallel culture-biological evolution as documented in Europe and in the Near East. The recent finds clearly show that this area was inhabited by the Neanderthals by the early Late Pleistocene with a typical Mousterian tradition which survived into later transitional stages already dominated by *Homo sapiens sapiens*. A progressive Upper Palaeolithic development in the early last glacial stage is also recorded in other parts of southern Siberia (e.g. the Usť-Koba Site on the Yenisey River, the Maľta Site in the Belaya River basin and the Kamenka Site in the southern Baikal area), showing a successful adaptation of early prehistoric people to local periglacial climatic conditions (Zolnikov, Lbova; this volume). The associated contextual geoarchaeological and palaeoenvironmental studies have a crucial relevance for reconstruction of the timing and conditions of the Pleistocene colonisation of Siberia and may help in the elucidation of the process of peopling of the New World.

Most of the palaeontological discoveries with rich faunal assemblages also come from the thick Quaternary deposits in the southern Siberian river valleys and inter-mountain basins. The Kuznetsk Basin, with up to 150 m thick sections, represents an exceptionally prolific fossiliferous area, from which have been derived more than 60 species of large Pleistocene fauna (Foronova; this volume). In particular, the unique fossil materials showing the morphostructural adaptation and biostratigraphic distribution of *Elephantidae*, *Equidae* and *Bovidae* provide new insights into the evolutionary history and adaptation of the faunal communities in a broader Eurasia (Foronova - Zudin; this volume). Pleistocene microfaunal complexes from the upper Yenisey Basin and the southern Baikal area further allow a more detailed chronostratigraphic subdivision of local subaerial deposits within a broader regional Quaternary palaeoecological framework (Krukover - Chekha, Khenzykhenova; this volume). As with early cultural records, the fossil faunal remains provide a significant source of proxy data for chronostratigraphic reconstruction of Quaternary environments and a spatial-temporal correlation of palaeoclimatic change. Equally significant as the terrestrial macro- and micro-fauna are data on foraminiferal complexes from the Arctic Ocean which monitor marine palaeotemperature fluctuations and coastal transgression changes, and represent means of palaeooceanic reconstructions along the north Siberian shelf since the Middle Pleistocene (Gusskov - Levchuk; this volume). The detailed studies of key chronostratigraphic sections presented and reviewed in this volume have contributed significantly over the past few years to better understanding of regional and global climatic changes during the Quaternary Period. They have also provided new sets of data on locally diverse natural environments which, coupled with the recent palaeontological and archaeological discoveries, have allowed a more complete chronological and ecological reconstruction of the early human colonisation of this part of the northern Hemisphere. Continuation of these multidisciplinary field investigations will undoubtedly broaden our knowledge of past environmental processes and fundamentally contribute to our understanding of the Pleistocene history of the world.

This special publication reflects the current state of Quaternary research in Siberia, and summarises some of the former achievements as well as the most recent results of long-term Russian investigations in this vast territory. The papers present a general overview of the palaeoclimatic evolution and the related palaeoenvironmental changes in this part of Eurasia during the Quaternary. As most of the previous work was published in the Russian language, it also provides a considerable amount of previously inaccessible information available to western readers.