ISSN 0031-0301, Paleontological Journal, 2006, Vol. 40, Suppl. 5, pp. S558–S566. © Pleiades Publishing, Inc., 2006.

The Fossil Palynoflora, Geological Age, and Climatostratigraphy of the Earliest Deposits of the Karama Site (Early Paleolithic, Altai Mountains)

N. S. Bolikhovskaya[a], A. P. Derevyanko[b], and M. V. Shun'kov[b]

[a]*Geographical Faculty, Moscow State University, Vorob'evy Gory, Moscow GSP-3, 119992 Russia*
e-mail: nbolikh@geogr.msu.ru

[b]*Institute of Archeology and Ethnography, Siberian Division, Russian Academy of Sciences, pr. Akademika Lavrent'eva 17, Novosibirsk, 630090 Russia*
e-mail: derev@archaeology.nsc.ru; Shunkov@paleo.archaeology.nsc.ru

Received February 10, 2006

Abstract—The results of palynological analysis of the Early Paleolithic Karama site (northeastern Altai Mountains) are presented. The Karama site is among the most unique and ancient archeological sites of Eurasia. Detailed palynological study has refined the geological age of the sediments that enclose pebble industry artifacts. The landscape and climatic conditions of Early Paleolithic man are reconstructed. A detailed characterization of the changes in the flora and vegetation that occurred during the most ancient Neo-Pleistocene interglacials and glacials is provided.

DOI: 10.1134/S0031030106110025

Key words: palynology, archeology, Early Paleolithic, Altai Mountains, landscape and climate reconstructions.

INTRODUCTION

The reliability of stratigraphic reconstructions based on palynological data depends on the completeness of paleogeographic records in the studied sections of Late Cenozoic sediments and the representativeness of the analytical materials obtained. The available paleobotanical information for the mountain regions of southern Siberia and all of northern Asia is still insufficient for a positive identification of heterochronous interglacials of the Lower and Middle Neo-Pleistocene. In northern Asia, some interglacial events that can be correlated with interglacial horizons of European stratigraphic charts still remain undiscovered. For example, Bolikhovskaya (1995, 2004) reconstructed by detailed palynological analysis of the most complete Neo-Pleistocene sections of central and southern Russian Platform seven interglacials in the period that corresponds to the Middle Pleistocene of the European scale, whereas the East Siberian stratigraphic scale of this interval contains no more than five interglacial horizons (Arkhipov and Volkova, 1994; Dobretsov et al., 2003).

It should be noted that palynological studies have contributed significantly to the elucidation of this problem in the Altai Mountains.

The Late Cenozoic sediments of the Altai Mountains have been palynologically analyzed from the mid-20th century. In the 1950s–1970s, Matveeva (1960), Chernysheva (1971, 1984), and Boyarskaya (1978) studied sections of the eastern Altai Mountains; valleys of the Katun' and Chuya rivers, Chuya mountainous basin, and Lake Teletsky basin. The vegetation of two interglacials and three cooling periods of the Pleistocene was characterized by palynological spectra. It was revealed that during the interglacials, mountain-taiga, forest-steppe, and steppe communities prevailed in these regions, whereas periglacial steppes, forest-steppes, and tundra-steppes dominated during the glacials.

In the western Altai Mountains, comprehensive palynological investigations of recent sediments began in the 1990s. A large body of paleobotanical data was obtained by E.M. Malaeva, who was a member of the scientific team performing interdisciplinary studies of Paleolithic sites of this region (led by academician A.P. Derevyanko). The palynological analysis of the Chernyi Anui, Nizhnii Karakol, Ust'-Karakol-1, Denisova Cave, and Anui-2 sections allowed Malaeva (1995) and Derevyanko et al. (1993, 1998a, 1998b, 2000, 2003) to reconstruct the vegetation and climatic changes in the Anui River valley during the Late and Middle Neo-Pleistocene: Sartan Glacial, Karga Mega-interstadial, Ermakovo Cold Stage, Kazantsevo Cold Stage, Taz Glacial, Shirta Interglacial, Samarovo Glacial, and Tobol Interglacial. Two warm (forest-steppe) stages with prevailing forest communities were also revealed in the Early Neo-Pleistocene (Derevyanko et al., 1992). In total, over 120 taxa were determined in the pollen spectra of the sediments studied. It was shown that the humidity increased during the cooling periods, and the dark coniferous forests (spruce and Siberian pine), which previously occupied the upper tiers of the mountain slopes, considerably expanded their range. During interglacials, relatively dry climatic conditions existed; forests and forest-steppes were widely developed. Birch and pine-birch forests prevailed; the contribution of broad-leaved elements was significant.

The data of the above-mentioned studies and those of the paleobotanical studies of Late Cenozoic sequences of adjacent territories (Giterman et al., 1968; Volkova, 1977; Makhova, 1978; Shilova, 1981; Grichuk, 1982; Golubeva and Karaulova, 1983; Belova, 1985; Arkhipov and Volkova, 1994), as well as spatiotemporal patterns of the vegetation and climate development in the southern regions of North Eurasia (Bolikhovskaya, 1995, 2004, 2005), were used as the paleofloristic and paleophytocenological basis for the climatic-stratigraphic subdivision of the sediments of the Early Paleolithic Karama site and for determining their geological age.

THE REGION AND SUBJECT OF STUDY

The Location and Environmental Conditions of the Region

The region under study is situated in the northwestern Altai Mountains. The Early Paleolithic Karama site is located on the left bank of the Anui River, 3 km upstream from the mouth of its right-bank tributary, the Karama River. The geographic coordinates are 51°28′02″ N and 84°33′55″ E. The site is situated on the mid-slope that is formed by terrace scarp at elevations of 30 to 60 m above the present-day river channel (about 600–630 m above sea level).

The territory is characterized by temperate continental climate. In the Karama Region, the average annual temperature is 0–1°C, the average January temperature is –17°C, the average July temperature is +17.8°C, and the average annual rainfall is 624 mm.

Nowadays, associations of four altitudinal belts occur in the northwestern Altai Mountains: mountain steppe, mountain forest-steppe, mountain taiga, and mountainous (alpine meadows and mountain-tundra) vegetation (Ogureeva, 1980). There are no broad-leaved and coniferous–broad-leaved forests in the plant cover of the Altai Mountains. Of all broad-leaved elements of the fossil Pleistocene dendroflora of the Anui River valley, only *Tilia sibirica* Bayer grows in the modern Altai. This relict occurs in the northeastern Altai Mountains.

The map of the plant cover of the Altai Mountains (Ogureeva, 1980) and the structure of phytocenoses in the vicinity of the Karama site indicate that the region under study is situated in a transitional zone between the mountain forest-steppe and mountain-forest belts.

Fig. 1. Excavation no. 2 of the Karama site, Anui River valley.

The Site under Study

The present paper describes the results of the palynological analysis of sediments more than 8-m-thick that were uncovered by excavation no. 2 of the Karama site (Fig. 1).

The composite section of the Pleistocene sediment of excavation no. 2 (Fig. 2) consists of three sequences and has significant hiatuses of sedimentation judging from the bedding pattern, sediment structure, and the dynamics of the palynospectra (Derevyanko et al., 2004). The lower alluvial sequence (layers 9–13), formed with participation of proluvial process, is filled with channel (layers 13–11), floodplain (layer 10), and oxbow (layer 9) facies. Hydromorphic soil that in places divides into two initial soils is observed in the floodplain sediments. This soil was earlier assigned to the family of compacted soils (Zykin et al., 2005). Montmorillonite and hydromica prevail in its mineralogical content. The middle diluvial-proluvial sequence (layers 7, 8) is composed of bouldery-blocky sediments

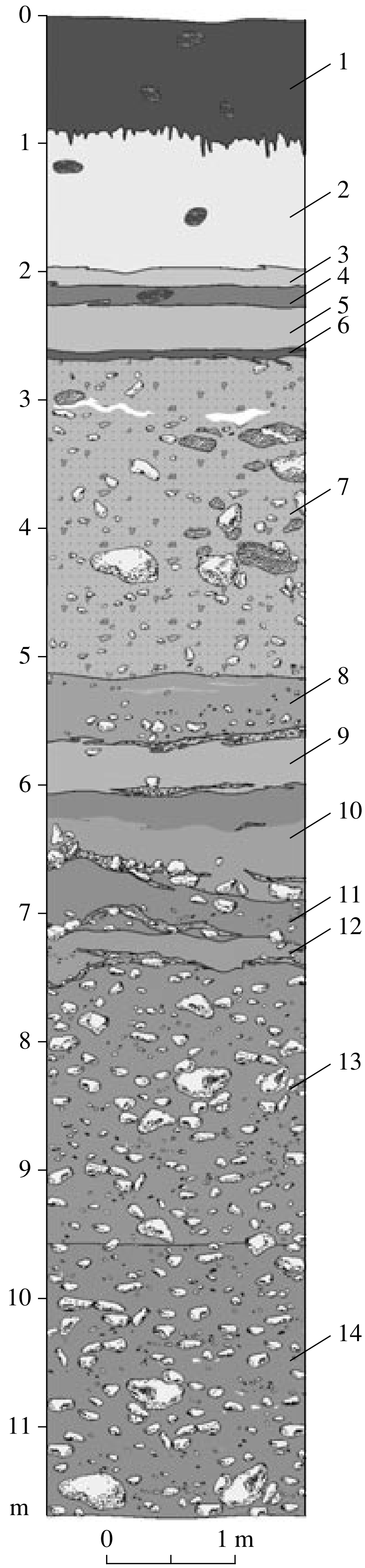

Fig. 2. Composite section of the sediments uncovered by excavation no. 2 of the Karama site: depth scale is to the left, and numbers of layers are to the right.

with loamy-sandy filler of reddish-brown colors. The upper sequence (layers 1–6) includes subaerial deposits of loessial soil.

In the most ancient sediments of the section (within layers 7, 8, 11, and 12), four levels with archaic Early Paleolithic finds have been discovered, showing that the multilayered Karama site is one of the most ancient Paleolithic sites of Central and North Asia. The cultural horizons of the Karama site with stone artifacts of pebble industry show that the low- and mid-mountain Altai was settled by ancient man, who came from Africa during the first wave of migration (Derevyanko et al., 2005).

METHODS

When determining the zonal affinity and structure of paleovegetation in the Pleistocene intervals under reconstruction, we took into account that our paleogeographic interpretation was based on palynological data from mountain regions. The subfossil analogues of the fossil palynological spectra studied, and their plant communities-producers were compared. A thorough ecological analysis of the taxa of the fossil dendroflora from the Karama section was made (Bolikhovskaya and Shun'kov, 2005).

Pollen assemblages obtained from modern sediments in the piedmont and mountain regions of the Altai (Matveeva, 1960; Boyarskaya and Chernysheva, 1973; Derevyanko et al., 2003) and additional data collected by Bolikhovskaya et al. (2005) from northwestern and eastern Altai have shown that subfossil palynological spectra adequately reflect zonal and local characteristics of mountainous (alpine meadows and mountain-tundras) and mountain-taiga vegetation of the studied region. The situation is different in the case of the subfossil spectra of mountain-steppe and forest-steppe zones: the proportion of pollen grains of trees is often much more significant in the subfossil spectra than is the role of the trees in relevant plant communities. The formation of such spectra, their characteristic composition, and the composition of phytocenoses that produced them are analyzed to facilitate correct paleogeographic reconstructions.

Particular attention is paid to the subfossil palynological spectra of from heterogeneous facial samples from the Kan and Kurai steppe depressions, as well as to forest-steppe communities of the Ursul River valley. The comparison between the fossil spectra of the Pleistocene periglacial vegetation of the East European and West Siberian Plains, Altai, and other regions of North Eurasia (Giterman et al., 1968; Volkova, 1977; Bolikhovskaya, 1995; Derevyanko et al., 2003) and subfossil spectra of mid-mountain and mountainous steppes shows that these modern steppes are refugia of periglacial phytocenoses of Pleistocene glacial epochs.

Steppe and forest-steppe palynological spectra of hypsithermal intervals of the earliest interglacials, reconstructed by the study of the Karama section, differ from subfossil palynological spectra of modern mountain steppes and forest-steppes of Altai in the relatively high abundance and diversity of thermophilic and exotic elements of the dendroflora. The generic (and, in part, specific) composition of the dendroflora reflected in these spectra is comparable to that of subfossil palynospectra of the southern Russian Plain, northern Ciscaucasia (Klopotovskaya, 1973; Bolikhovskaya, 1976), and the forest-steppe Lake Khanka lowland in southern Primorye Region (Aleshinskaya and Shumova, 1978; Korotkii, 2002).

RESULTS OF PALYNOLOGICAL ANALYSIS

The Composition of the Palynoflora and the Geological Age of the Sediments

The results of palynological study of the sediments of the site are shown in the palynological diagram (Fig. 3). Most taxa determined at the specific level were united and shown at the generic and familial levels for the sake of convenience.

In total, more than 130 taxa of various ranks were determined in the autochthonous palynoflora of the studied sediments of the Karama site. Pollen grains of trees and shrubs belong to no less than 45 taxa: *Abies* sp., *Picea* sect. *Eupicea, P. obovata* Ledeb., *P.* sect. *Omorica, Pinus* subgenus *Haploxylon*, *P.* sect. *Strobus*, *P.* cf. *koraiensis* Siebold et Zucc., *P. sibirica* Du Tour, *P. sylvestris* L., *Larix* sp., *Betula* sect. *Costatae, B.* sect. *Albae, B. pendula* Roth, *B. pubescens* Ehrh., *B. sect. Fruticosae, B. fruticosa* Pall., *B. sect. Nanae, B. rotundifolia* Spach, *Alnaster fruticosus* (Rupr.) Ledeb., *Alnus* sp., *Alnus glutinosa* (L.) Gaertn., *A. incana* (L.) Moench, *Corylus* sp., *Corylus avellana* L., *Juglans mandshurica* Maxim., *Carpinus betulus* L., *C. cordata* Blume, *C. orientalis* Mill., *Ostrya* sp., *Quercu*s sp., *Q. robur* L., *Tilia cordata* Mill., *T. amurensis* Rupr., *T. mandshurica* Rupr., *T. sibirica, Ulmus pumila* L., *Morus* sp., *Euonymus* sp., *Viburnum* sp., *Sambucus* sp., *Grossularia* sp., *Ribes* sp., *Salix* spp., *Juniperus* sp., *Humulus lupulus* L., and others.

Among pollen grains of herbs and subshrubs, 56 taxa (species, genera, and families) were determined: *Cannabis* sp., Ericales, Poaceae, Cyperaceae, *Ephedra* sp., *Artemisia* subgenus *Euartemisia, A.* subgenus *Dracunculus, A.* subgenus *Seriphidium, Chenopodiaceae* (including *Salsola* sp., *Chenopodium album* L., *C. aristatum* L., *Corispermum mongolicum* Iljin, and others), Rosaceae, *Chamaemorus* sp., Apiaceae, Rubiaceae, Solanaceae, Frankeniaceae, Brassicaceae, Plantaginaceae, *Plantago* sp., *Plantago lanceolata* L., *P. maritime* L., *P. major* L., Polygonaceae, *Rumex* sp., Boraginaceae, Brassicaceae, Gentianaceae, Onagraceae, Primulaceae, Ranunculaceae, *Ranunculus* sp., *Thalictrum* sp., Polemoniaceae, Rubiaceae, Campanulaceae, Lamiaceae, Valerianaceae, Violaceae, Caryophyllaceae, Fabaceae, Liliaceae, Iridaceae, *Urtica* sp., Zygophillaceae, Convolvulaceae, Plumbaginaceae, Asteraceae, *Xanthium* sp., *Arctium* sp., Cichoriaceae, *Myriophyllum* sp., *Potamogeton* sp., *Typha* sp., and others.

Microfossils of higher spore-bearing plants (bryophytes, ferns, lycophytes, and others) are less numerous and include 30 taxa: Polypodiaceae, *Polypodium vulgare* L., *P. virginianum* L., *Dryopteris* sp., *Dryopteris filix-mas* (L.) Schott, *D. spinulosa* (Müll.) Ktze, *D. thelypteris* (L.) A. Gray, *D.* cf. *austriaca, Athyrium filix-femina* (L.) Roth., *Pteridium aquilinum* (L.) Kuhn ex Decken, *Cryptogramma crispa* (L.) R. Br., *Lycopodium* sp., *Lycopodium annotinum* L., *L. clavatum* L., *L. dubium (pungens)* Zoega, *L. selago* L., *L. appressum* (Desv.) Petr., *Diphazium alpinum* (L.) Rothm., *D. complanatum* (L.) Rothm., *Equisetum* sp., *Botrychium* sp., *Botrychium boreale* (Fr.) Milde, *B. multifidium* (S. G. Gmel.) Rupr., *B. simplex* E. Hitchc., *B. lunaria* (L.) Sw., *B. lanceolatum* Angstr., *B. matricariifolium* A. Br. ex Koch, and *Ophioglossum* sp.

The palynological data obtained clearly show (Fig. 3) that a long hiatus existed between the time of alluvial and diluvial-proluvial sedimentation of the lower and middle sequences (layers 13–7) and the formation of the upper subaerial sediments (layers 6–1). The horizons that fit this period (or its significant portion) were uncovered upslope, in excavation no. 3. Unfortunately, the concentration of pollen and spores is low; therefore, the analysis is still far from complete.

Judging from the structure of the section and the composition of fossil palynospectra, the upper loess-soil sequence is dated to the Late Pleistocene and Holocene. Fossil soil at a depth of 2.0–2.6 m (layers 6–4) was formed during the Karga Interstadial, which is correlated to marine oxygen isotope stage 3 (MIS 3). In that period, dense spruce forest grew in the area of the site. The sedimentation of loess loams and lower part of the loams that constitute the modern soil-forming rock (layers 3 and 2 and the lower part of layer 1) occurred under the severe conditions of the cold Sartan time (MIS 2), when forest areas diminished considerably. Tundra and steppe cenoses became dominant. During the Early Sartan time (depth 1.3–2.0 m), thin pine-larch-spruce forests prevailed. Cryophytic shrubs (*Betula* sect. *Nanae*) and steppe and meadow communities occupied relatively large areas. During the Late Sartan time (depth 0.6–1.3 m), the intensified cryoarid climate caused the domination of tundra-steppes and the abundance of cryophytes (*Alnaster fruticosus, Betula* sect. *Nanae* and *Fruticosae*, and *Diphazium alpinum*) and xerophytes (*Artemisia* subgenus *Dracunculus* and *Seriphidium* and others) in the vegetation cover. Small areas of the forests were covered by *Pinus sylvestris* and *P. sibirica.* The palynological spectra of the upper part of the modern chernozem-like soil (up to 0.6 m depth) characterize the Holocene forest and forest-steppe communities (MIS 1).

In contrast to the spectra of the Upper Pleistocene sediments, the palynological spectra of layers 7, 8, and

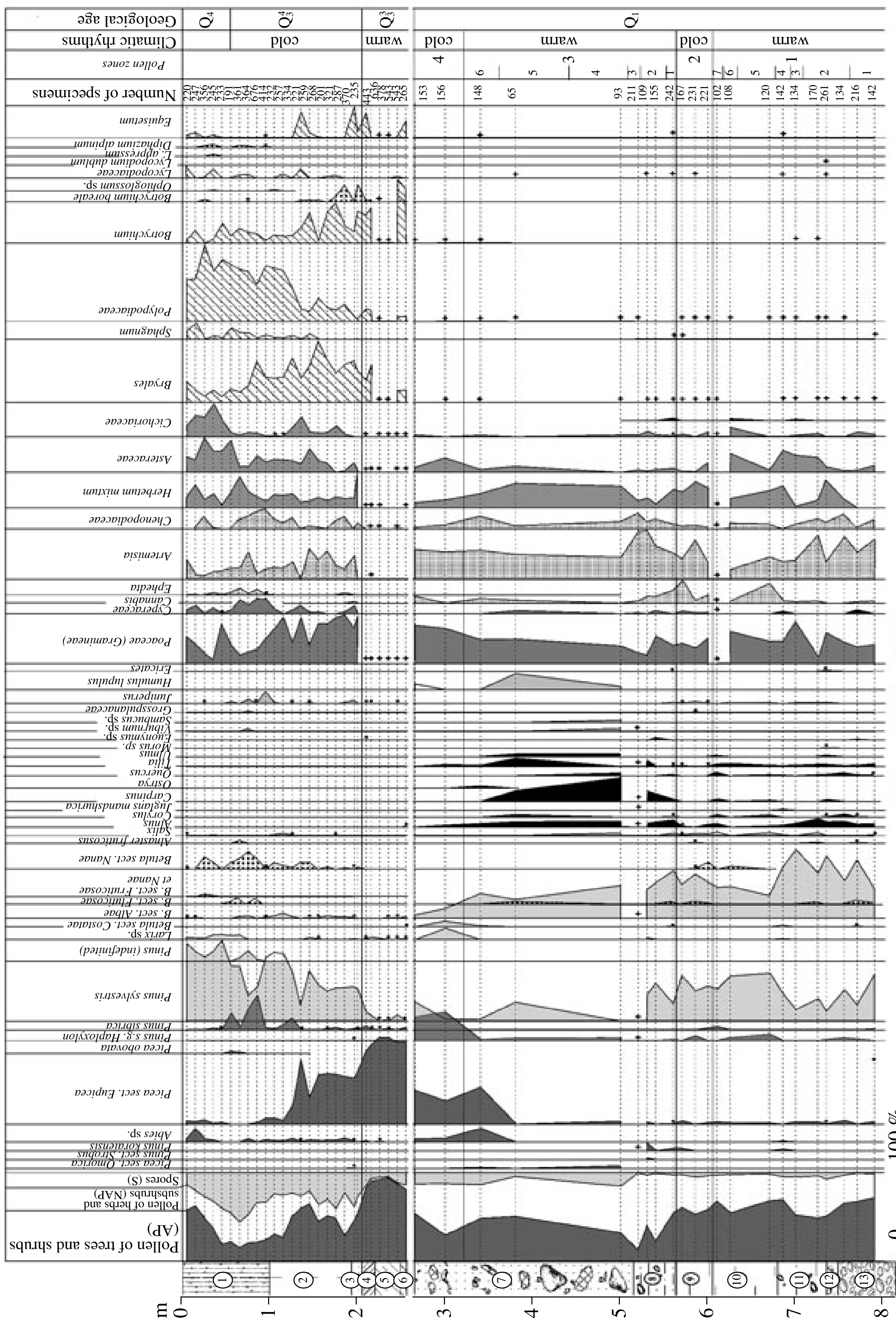

Fig. 3. Palynological diagram of the sediments uncovered by excavation no. 2 of the Karama site: (*1*) lithological layer; (*2*) the proportion of pollen is less than 1%; (*3*) the presence of spores in a scant group (proportion was not counted).

10–13 contain a significant number of exotic elements (for the modern dendroflora). These include both boreal taxa (*Picea* sect. *Omorica, Pinus* sect. *Strobus, Pinus* cf. *koraiensis*, and *Betula* sect. *Costatae*) and nemoral European, Far Eastern, and other taxa (*Alnus glutinosa, A. incana, Corylus avellana, Juglans mandshurica, Carpinus betulus, C. cordata, C. orientalis, Ostrya* sp., *Quercus robur, Tilia cordata, T. amurensis, T. mandshurica, Ulmus pumila, Morus* sp., and others). Some of these taxa have not previously been recorded in the Middle–Early Neo-Pleistocene sediments of the Anui River valley.

The presence of *Pinus* sect. *Strobus, Carpinus cordata, C. orientalis, Ostrya* sp., *Quercus robur, Tilia cordata, T. amurensis, T. mandshurica, Alnus glutinosa, A. incana, Corylus avellana, Juglans mandshurica, Carpinus betulus, C. cordata, C. orientalis, Quercus robur, Ulmus pumila, Morus* sp., and others in the palynological flora of layers 7, 8, and 10–13, as well as the ecological peculiarities of the exotic elements found, and the analysis of geographical groups of genera of trees, allow us to infer that the age of layers 7–13 is no younger than the Early Neo-Pleistocene.

It is pertinent to note that more precise dating of the most ancient sediments of the Karama site can currently be based on geomorphological, lithological, paleopedological, paleomagnetic, and palynological data. In spite of an extensive search, no faunal remains have so far been found.

Paleomagnetic data indicate normal polarity in all horizons uncovered in excavation no. 2. Taking this into account, the relative antiquity of the palynoflora, and the fact that compacted soils were only found in Pliocene sediments of western and central Siberia, Zykin et al. (2005) concluded that along with the Early Neo-Pleistocene date of layers 7–13, the alternative correlation with Barnaul layers of the Eopleistocene and the Olduvai episode (1.95–1.77 Ma) cannot be excluded.

Bolikhovskaya and Shun'kov (2005) previously pointed out that the palynological data do not substantiate the Eopleistocene date of the layers of the Karama site containing Early Paleolithic archaic artifacts. The floras studied differ significantly from the Eopleistocene floras of the eastern Altai Mountains and southwestern Siberia. The palynological spectra of layers 7–13 do not contain pollen grains of subtropical broad-leaved elements (*Pterocarya, Carya, Zelkova, Celtis, Ilex*, and others), *Tsuga* and other members of the Pinaceae, which are characteristic of thermophilic Eopleistocene floras of these and adjacent regions of North Eurasia. Below we will show that the interglacials reconstructed on the basis of palynological study of the Karama site also differ remarkably in their floristic, phytocenotic, and paleoclimatic characteristics from the period of formation of Barnaul layers of southwestern Siberia (*History* …, 1970). According to Volkova and Kul'kova (*Climatic* …, 1999, text-fig. 46), the sediments containing Barnaul flora with pollen of *Tsuga* were accumulated in forest-steppes and steppes under nearly modern climatic conditions. Interglacial floras of the Karama site existed under much warmer climatic conditions than the modern climate of Altai.

The comparative analysis showed that the palynoflora of layers 7, 8, and 10–13 is richer than the floras of the Early Neo-Pleistocene sections of the Anui River valley that have been studied earlier. The generic and specific composition of the dendroflora and the structure of paleophytocenoses bring the reconstructed ancient interglacials of the Karama site closer to the sediments of the Chernyi Anui and Nizhnii Karakol sections, which are dated to the Early Neo-Pleistocene (Derevyanko et al., 2003).

The Chernyi Anui and Nizhnii Karakol sections are situated upstream in the Anui River valley, in modern mountain-forest belt (740–750 m above sea level). Derevyanko et al. (1992) provided palynological data on these sections characterizing the vegetation of two Early Neo-Pleistocene warm epochs, when the dendroflora contained not only the modern forest builders, but also exotic elements like *Betula* sect. *Costatae, Alnus, Corylus avellana, Ulmus* cf. *laevis, Tilia sibirica, Acer, Quercus, Carpinus betulus*, and *Juglans* cf. *mandshurica*. During the previous interglacial, forest-steppes developed in which birch forests dominated in the area of the Chernyi Anui site with participation of coniferous elements, *Pinus sylvestris*, and *P. sibirica.* Later, the cooling and increased humidity led to the domination of forest communities with *Pinus sylvestris, Abies, Picea*, and *Pinus sibirica.* The next interglacial is reflected by the palynological spectra of the Nizhnii Karakol section. During this epoch, forests prevailed initially, then forest-steppes became dominant, and finally the significance of forest communities increased again. Similarly to the first warming episode, birch forests with broad-leaved and coniferous elements dominated during hypsithermal intervals.

Considering all the points above and the correlation with the most complete and well-characterized (in terms of paleogeography) sections of southern regions of North Eurasia, we conclude that the sediments of the Karama site under discussion are of Early Neo-Pleistocene age.

The Neo-Pleistocene Vegetation and Climatic Reconstructions

Significant changes in the composition and proportions of taxa in the palynological spectra of the studied Early Neo-Pleistocene sediments testify to repeated alternations of zonal types of vegetation in the Anui River valley and rearrangements of plant communities in the vicinity of the site (Fig. 3), which were caused by global climatic changes of two interglacial and two glacial epochs of the Early Neo-Pleistocene.

1. During the most ancient interglacial, alluvial sediments accumulated (layers 13–10). We correlate this epoch to marine isotope stage 19 (MIS 19) and the Gremyachie Interglacial of the Russian Plain, which is dated by correlative estimations as 787–760 ka (Bolikhovskaya, 2005). The climate of the epoch was warmer than the modern one, and forest-steppes and steppes dominated on the territory studied. We reconstructed seven phases of transformations of the communities that constituted these landscapes: steppe areas, broad-leaved forests (*Tilia cordata* and *T. sibirica, Quercus robur, Q. mongolica* Fisch. ex Ledeb., *Carpinus cordata, Juglans mandshurica, Ulmus, Morus*, and others), and birch and conifer forests.

Phase 1 (palynological zone 1.1) is characterized by dominating pine-birch and birch-pine forests of *Betula pendula, B. pubescens, Pinus sylvestris*, with the participation of spruce, *Betula* sect. *Costatae*, oak, *Tilia cordata, T. sibirica*, and with *Corylus avellana* in the undergrowth. Pollen grains of thermophilic elements constitute in total 3.5–7.9%.

Phase 2 (palynological zone 1.2) is dominated by forest-steppes. The proportion of pollen of nemoral species of the dendroflora increased up to 9.2%. Under the conditions of warming climate, the total area of forests diminished, but the contribution of broad-leaved elements increased: *Carpinus cordata, Quercus robur, Tilia cordata, T. sibirica, Ulmus pumila, Morus*, and others. The steppe biotopes were first dominated by cereals and mixed grasses and later by *Chenopodium-Artemisia* and *Aster-Artemisia* communities.

Phase 3 (palynological zone 1.3) corresponds to endothermic (interglacial) cooling, during which forest-steppes still dominated. The cooling is indicated by a sharp decrease (to 1.4%) in the contribution of broad-leaved elements, which are represented there only by *Tilia sibirica.* The Poaceae, Asteraceae, and *Artemisia* became dominants of steppe communities.

Phase 4 (palynological zone 1.4) reflects the increased humidity and the prevailing forest landscapes (the proportion of pollen of trees increased to 70%). Pine-birch forests dominated. Due to the relative warming and increased humidity, *Abies, Pinus* cf. *koraiensis, Betula* sect. *Costatae, Juglans mandshurica*, and *Quercus* appeared in the forests.

Phase 5 (palynological zone 1.5) was dominated by forests with *P. sibirica* and *Pinus sylvestris* and by birch-oak-linden-hornbeam forests.

Phase 6 (palynological zone 1.6) characterizes the further transformation of forest vegetation during the marked decrease in warmth and humidity during the second endothermal. The contribution of broad-leaved elements became less prominent, hornbeam and oak disappeared. Birch-pine forests with spruce, *Pinus* cf. *koraiensis*, *Tilia cordata*, and *T. sibirica* prevailed. Shrubby birch appeared in the understory.

Phase 7 (palynological zone 1.7) corresponds to the thermohygrotic maximum of the interglacial. The proportion of thermophilic elements of the dendroflora reached 14%. Broad-leaved forests of *Quercus* sp., *Carpinus cordata, Tilia cordata, T. sibirica*, and *Ulmus* sp. (with the participation of *Alnus glutinosa*) dominated. Coniferous-birch forests with spruce, *Pinus sylvestris, Pinus* cf. *koraiensis*, and birch were also present.

2. The gully facies of layer 9 (palynological zone 2) were formed during a cooling episode that is correlated to MIS 18 and the Devitsa Glacial of the Russian Plain (approximately 760–712 ka). The region studied was occupied by periglacial landscapes. Birch-pine forests, shrub communities (*Betula* sect. *Fruticosae, B. fruticosa, B.* sect. *Nanae, Alnaster fruticosus, Juniperus*, and others), and meadow and meadow-swamp cenoses dominated.

3. Diluvial-proluvial sediments of layer 8 and the most part of layer 7 were accumulated during the next interglacial (palynological zones 3.1–3.6), which is correlated to MIS 17 and the Semiluki Interglacial of the Russian Plain (approximately 712–659 ka). The climate was warmer and dryer than during the previous interglacial. Six phases have been reconstructed in the development of the steppes and forest-steppes that dominated during this warm epoch.

The first phase (palynological zone 3.1) was dominated by forest-steppes that combined areas of mixed-grass steppes, broad-leaved forests (of *Carpinus betulus, C. cordata, Quercus* sp., *Tilia mandshurica,* and others), pine-birch forests, and alder forests (*Alnus glutinosa* and *A. incana*). During the second phase (palynological zone 3.2) steppes dominated, although the areas of broad-leaved forests expanded. The forest areas were first dominated by hornbeam (*Carpinus cordata* and *C. orientalis*) and pine-birch communities. Later, the climate became more humid, and the role of *Carpinus cordata, Tilia mandshurica, T. sibirica*, and dark coniferous elements increased. *Pinus* sect. *Strobus* and *P.* cf. *koraiensis* appeared. During the third phase (palynological zone 3.3) steppes with mixed-grass and *Artemisia* communities prevailed, as well as hornbeam forests of *Carpinus cordata* and *C. orientalis,* with participation of *Juglans mandshurica, Tilia mandshurica*, and *Alnus glutinosa.*

During the second half of the interglacial, the most prominent expansion of thermophilic elements of dendroflora took place: the proportion of their pollen in the relevant palynological spectra is 27–33%. During the forth phase (palynological zone 3.4) forest-steppes dominated, most areas were occupied by mixed-grass steppes and very open hornbeam forests of *Carpinus betulus, C. cordata,* and *C. orientalis*, with participation of oak, elm, and alder. Birch stands were rare. A distinctive feature of the forest-steppes of the fifth phase (palynological zone 3.5) is the prevalence of linden-hornbeam communities of *Carpinus cordata, Tilia cordata*, and *T. mandshurica* among other broad-leaved forests. In the forest-steppes of the sixth phase (palynological zone 3.6) the composition of the forests changed considerably: hornbeam and some species of *Tilia* disappeared; most areas were occupied by broad-leaved-fir-spruce forests with participation of *Tilia mandshurica* and *Ostrya* sp. and the occurrence of alders and birches (*Betula* sect. *Costatae, B. pendula*, and *B. pubescens*).

4. During the next cooling epoch (palynological zone 4) that is correlated to MIS 16 and the Don Glacial of the Russian Plain (approximately 659–610 ka) proluvial-diluvial sediments of the upper part of layer 7 were accumulated. Periglacial steppes dominated with small patches of coniferous open woodland of larch, *Pinus sylvestris, Pinus* cf. *koraiensis*, and spruce. Among herbs and subshrubs, cereals prevailed, as well as mixed grasses, *Artemisia*, and meadow grape-fern (with *Botrychium simplex* and *B. lanceolatum*) communities.

CONCLUSIONS

The palynological data (as well as other paleogeographic data) show that the Karama site is one of the most ancient archeological sites in Siberia and Eurasia.

(1) According to the correlations achieved, the absolute age of the period when the Early Neo-Pleistocene sediments were accumulated is within the interval of 790–610 ka. The vegetation changes were determined by the alternation of two interglacials and two cooling epochs.

(2) During the hypsithermal intervals of the reconstructed Early Neo-Pleistocene interglacials, northwestern Altai was part of the transcontinental zone of nemoral forests and forest-steppes, which occupied in these periods the southern regions of North Eurasia.

(3) A characteristic feature of Altai nemoral Early Neo-Pleistocene forests that grew in the Anui River valley was the association of arboreal elements that nowadays occur in very distant centers of nemoral flora; the southern Far East of Russia, eastern Europe, Caucasus Mountains, and the Crimean Peninsula. The absence of counterparts of such phytocenoses among modern forest communities of North Eurasia unequivocally testifies to the considerable antiquity of the sediments enclosing fossil pollen of these plants.

(4) Another important feature of the Early Neo-Pleistocene forests of the Anui River valley is the composition of the forest builders. The main builders of the Early Neo-Pleistocene forests under description were *Juglans mandshurica*, European and Manchurian species of hornbeam (*Carpinus betulus, C. cordata*, and *C. orientalis*), and linden (*Tilia cordata, T. amurensis, T. mandshurica*, and *T. sibirica*). In contrast to these forests, the builders of the modern European and Russian Far Eastern broad-leaved and coniferous–broad-leaved forests are various species of oak (*Quercus robur, Q. petraea* Liebl., *Q. pubescens* Willd., *Q. macranthera* Fisch. et May. ex Hohen, and others in eastern Europe, Caucasus, and Crimea, and *Quercus mongolica, Q. dentata* Thunb., and *Q. crispula* Blume in the southern Far East of Russia).

ACKNOWLEDGMENTS

We are grateful to A. V. Abdul'manova for her help in preparation of the illustrations. The study was supported by the Programs of the Presidium of the Russian Academy of Sciences "The Origin and Evolution of the Biosphere" and "Adaptation of Peoples and Cultures to Environmental Changes and Social and Technological Transformations", and by the Russian Foundation for the Humanities, project no. 04-01-00537.

REFERENCES

1. Z. V. Aleshinskaya and G. M. Shumova, *Subfossil Spore–Pollen Spectra of the Lake Khanka Lowland* (Dal'nevost. Nauchn. Tsentr Akad. Nauk SSSR, Vladivostok, 1978) [in Russian].
2. S. A. Arkhipov and V. S. Volkova, *The Pleistocene of Western Siberia: Geological History, Landscapes, and Climates* (Nauka, Novosibirsk, 1994) [in Russian].
3. V. A. Belova, *The Late Cenozoic of the Southern Part of Eastern Siberia: Vegetation and Climate* (Nauka, Novosibirsk, 1985) [in Russian].
4. N. S. Bolikhovskaya, "Palynology of Loesses and Buried Soils of the Russian Plain," in *Problems in General Physical Geography and Paleogeography* (Mosk. Gos. Univ., Moscow, 1976), pp. 257–277 [in Russian].
5. N. S. Bolikhovskaya, *Evolution of the Loess-Soil Formation in Northern Eurasia* (Mosk. Gos. Univ., Moscow, 1995) [in Russian].
6. N. S. Bolikhovskaya, "Main Stages in the Development of Vegetation and Climate in the Pleistocene," in *Geography, Society, and Environment*, Vol. 1: *Structure, Dynamics, and Evolution of Natural Geosystems* (GEOS, Moscow, 2004), pp. 561–582 [in Russian].
7. N. S. Bolikhovskaya, "Main Patterns in the Development of Vegetation and Climate on the East European Plain throughout the Past 900000 Years," in *Horizons of Geography: Contribution to the 100th Anniversary of the Birth of K.K. Markov* (Geogr. Fak. Mosk. Gos. Univ., Moscow, 2005), pp. 159–181 [in Russian].
8. N. S. Bolikhovskaya and M. V. Shun'kov, "Climatostratigraphic Subdivision of the Oldest Deposits of the Early Paleolithic Site Karama," Arkheol., Etnogr. Antropol. Evrazii, No. 3, 34–51 (2005).
9. N. S. Bolikhovskaya, G. N. Ogureeva, and N. A. Rudaya, "Distinctive Features of the Subfossil Palynological Spectra of the Steppe and Forest-Steppe Phytocenoses of the Altai," in *Proc. 11th All-Russia Palynological Conf. on Palynology: Theory and Practice* (Paleontol. Inst. Ross. Akad. Nauk, Moscow, 2005), pp. 32–33 [in Russian].
10. T. D. Boyarskaya, "On the Vegetation of the Gornyi Altai in the Late Pliocene–Pleistocene," in *The Section of the Recent Deposits of the Altai* (Mosk. Gos. Univ., Moscow, 1978), pp. 173–176 [in Russian].

11. T. D. Boyarskaya and M. B. Chernysheva, "On the Procedure of the Spore–Pollen Analysis of Deposits from the Piedmont and Mountain Regions of the Southeastern Altai," Vestn. Mosk. Gos. Univ., Ser. Geogr., No. 1, 93–97 (1973).

12. *Changes in Climate and Landscapes throughout the Past 65 Million Years (Cenozoic: From the Paleocene to the Holocene)*, Ed. by A. A. Velichko (GEOS, Moscow, 1999) [in Russian].

13. M. B. Chernysheva, "Palynological Characterization of the Anthropogene Deposits of the Gornyi Altai," Vestn. Mosk. Univ., Ser. Geol., No. 2, 81–86 (1971).

14. M. B. Chernysheva, "The History of the Development of Vegetation in the Gornyi Altai in the Pleistocene," in *Paleogeographic Boundaries and Methods of Their Study* (Dal'nevost. Nauchn. Tsentr Akad. Nauk SSSR, Vladivostok, 1984), pp. 88–94 [in Russian].

15. A. P. Derevyanko, S. A. Laukhin, E. M. Malaeva, et al., "The Lower Pleistocene in the Northwestern Gornyi Altai," Dokl. Akad. Nauk SSSR **323** (3), 509–513 (1992).

16. A. P. Derevyanko, S. A. Laukhin, E. M. Malaeva, et al., "The Problem of the Existence of Broad-Leaved Varieties in the Late Würm of the Altai," Dokl. Akad. Nauk SSSR **330** (6), 736–739 (1993).

17. A. P. Derevyanko, E. M. Malaeva, and M. V. Shun'kov, "The Dynamics of Changes in the Paleoclimate of the Northwestern Altai in the Late Pleistocene," in *Problems in the Reconstruction of the Climate and Natural Environment of the Holocene and Pleistocene of Siberia* (Inst. Arkheol. Etnogr. Sib. Otd. Ross. Akad. Nauk, Novosibirsk, 1998a), pp. 120–126 [in Russian].

18. A. P. Derevyanko, E. M. Malaeva, M. V. Shun'kov, et al., "Formational Conditions, Palynology, and Age of Unconsolidated Sediments of the Anui River Valley in the Denisova Cave Region," in *Problems in Paleoecology, Geology, and Archaeology of the Paleolithic of the Altai* (Inst. Arkheol. Etnogr. Sib. Otd. Ross. Akad. Nauk, Novosibirsk, 1998b), pp. 14–26 [in Russian].

19. A. P. Derevyanko, E. M. Malaeva, and M. V. Shun'kov, "The Development of Vegetation in the Low-Mountain Region of the Altai in the Pleistocene," in *Problems in the Reconstruction of the Climate and Natural Environment of the Holocene and Pleistocene of Siberia* (Inst. Arkheol. Etnogr. Sib. Otd. Ross. Akad. Nauk, Novosibirsk, 2000), Issue 2, pp. 162–174 [in Russian].

20. A. P. Derevyanko, M. V. Shun'kov, A. K. Agadzhanyan, et al., *Man and the Natural Environment in the Paleolithic of the Gornyi Altai* (Inst. Arkheol. Etnogr. Sib. Otd. Ross. Akad. Nauk, Novosibirsk, 2003) [in Russian].

21. A. P. Derevyanko, M. V. Shun'kov, N. S. Bolikhovskaya, et al., "The First Results of the Integrated Studies of the Early Paleolithic Site Karama in the Altai," in *Problems in the Archaeology, Ethnography, and Anthropology of Siberia and Adjacent Areas* (Inst. Arkheol. Etnogr. Sib. Otd. Ross. Akad. Nauk, Novosibirsk, 2004), Vol. 10, Part 1, pp. 96–100 [in Russian].

22. A. P. Derevyanko, M. V. Shun'kov, N. S. Bolikhovskaya, et al., *The Early Paleolithic Site Karama in the Altai* (Inst. Arkheol. Etnogr. Sib. Otd. Ross. Akad. Nauk, Novosibirsk, 2005) [in Russian].

23. N. L. Dobretsov, V. S. Zykin, and V. S. Zykina, "Structure of the Pleistocene Loess-Soil Sequence of Western Siberia and Its Correlation with the Baikalian and Global Records of Climatic Changes," Dokl. Akad. Nauk **391** (6) 821–824 (2003) [Dokl. Earth Sciences **391** (6), 921–924 (2003)].

24. R. E. Giterman, L. V. Golubeva, E. D. Zaklinskaya, et al., "Main Stages in the Development of Vegetation in the Anthropogene of Northern Asia," Tr. Geol. Inst. Akad. Nauk SSSR, No. 177, 1–269 (1968).

25. L. V. Golubeva and L. P. Karaulova, "The Vegetation and Climatostratigraphy of the Pleistocene and Holocene in the Southern Part of the Soviet Far East," Tr. Geol. Inst. Akad. Nauk SSSR, No. 366, 1–143 (1983).

26. V. P. Grichuk, "Flora and Vegetation," in *Stratigraphy of the USSR: The Quaternary System* (Nedra, Moscow, 1982), Half-Vol. 1, pp. 337–373 [in Russian].

27. N. B. Klopotovskaya, *Main Patterns in the Formation of Spore–Pollen Spectra in the Mountain Regions of the Caucasus* (Matsniereba, Tbilisi, 1973) [in Russian].

28. A. M. Korotkii, *Geographical Aspects of the Formation of Subfossil Spore–Pollen Assemblages (Southern Part of the Russian Far East)* (Dal'nauka, Vladivostok, 2002) [in Russian].

29. Yu. V. Makhova, "The Formation of Dark Taiga in the Upper Reaches of the Amur River (Based on Palynological Data)," in *Palynological Studies in the Soviet Far East* (Dal'nevost. Nauchn. Tsentr Akad. Nauk SSSR, Vladivostok, 1978), pp. 101–109 [in Russian].

30. E. M. Malaeva, "The History of the Vegetation of Mongolia in the Pleistocene and Holocene and Paleoindicative Characters of Fossil Pollen Floras," in *The Late Cenozoic of Mongolia* (Nauka, Moscow, 1989), pp. 158–177 [in Russian].

31. E. M. Malaeva, "On the Variations in the Climatic Regime of the Gornyi Altai in the Late Pleistocene and on Paleoglaciological Reconstructions," Geomorfologiya, No. 1, 51–60 (1995).

32. O. V. Matveeva, "Spore–Pollen Spectra of the Quaternary Deposits of the Piedmont Areas of the Altai and Mountain Regions of the Eastern Altai and Western Tuva," Tr. Geol. Inst. Akad. Nauk SSSR, No. 31, 85–112 (1960).

33. G. N. Ogureeva, *Botanical Geography of the Altai Region* (Nauka, Moscow, 1980) [in Russian].

34. G. N. Shilova, "Palynological Characterization of Sediments and the History of the Development of Late Cenozoic Vegetation in the Mongolian People's Republic," Extended Abstract of Candidate's Dissertation in Geology and Mineralogy (Moscow, 1981).

35. *The History of the Development of Vegetation in the Nonglacial Zone of the West Siberian Plain in the Late Pliocene and Quaternary Time* (Nauka, Moscow, 1970) [in Russian].

36. V. S. Volkova, *The Vegetation of Western Siberia in the Late Cenozoic: Stratigraphy and Developmental History* (Nauka, Moscow, 1977) [in Russian].

37. V. S. Zykin, V. S. Zykina, K. A. Chirkin, and L. G. Smolyaninova, "The Geologic Structure and Stratigraphy of the Upper Cenozoic Deposits in the Region of the Early Paleolithic Site Karama in the Upper Anui River Valley (Northwestern Altai)," Arkheol., Etnogr. Antropol. Evrasii, No. 3, 2–20 (2005).