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Palaeogeography of the Pribaikal and Transbaikal Quaternary

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Abstract: Palaeogeographical conditions of the Quaternary Period are reconstructed on the basis of analyzing the development of the neotectonic structure of the Mongolo-Siberian mountain zone, the major morphological regions of Pribaikal and Transbaikal, and the sedimentation regimes in these regions, the palaeontological and palynological records and chronostratigraphical data. The role of neotectonic movements in forming repeated structural supports of water masses in the Baikal rift zone depressions and in forming sedimentary series of transgressive type on the background of climatic changes is discussed. Analysis of the taxonomical composition of the fossil fauna and reconstruction of the Quaternary ecosystems and peculiarities of the character of climatic fluctuations provide a summary view on the palaeoenvironmental evolution of the Baikal region during the Pleistocene.

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INTRODUCTION

An understanding of the Quaternary palaeogeography of the southeastern Siberian mountain regions requires the reconstruction of the sedimentary environment which is closely integrated with tectonics and development of the regional relief. The specific morphological character of the mountain topography, formed both in subplatform and subrifting tectonic regimes, the high-altitude zoning and the slope exposition, all indicate a wide variety of natural settings and landscapes throughout the Quaternary. The variety of palynological data provides evidence of strongly fluctuating climates. Over the last few decades, a number of new occurrences of the Late Cenozoic fauna (Fig. 1) has been discovered in the Pribaikal and Transbaikal sedimentary formations of various genetic types. They have provided the most complete information on the palaeoenvironmental abiotic factors which played a decisive role in the evolution of the Late Cenozoic ecosystems in this region.

The Cenozoic in the Pribaikal geological development is associated with the formation of the latest structure of the Mongolo-Siberian intercontinental mountain zone. Strengthening of the tectonic activity over the Paleocene and Eocene, and then again at the end of the Oligocene and Miocene, initiated formation of an united morphostructural geographical province, which includes the complex of conjugated structures associated with the Baikal arched uplift (Pribaikal), the Selengino-Vitim depression (West Transbaikal) and the Dauro-Stanovoy uplift (Central Transbaikal).

During the Late Miocene, the structural zones of the Darkhati, Tunka, South Baikal, Barguzin, Tsipa-Baunt and Chara depressions were formed as a result of prerifting neotectonic activity. The united system of palaeolakes began to spread apart within this zone (Rezanov 1988, 1994). A considerable increase in the tectonic activity at the beginning of Pliocene predetermined a relatively short, but extremely dynamic, Pliocene-Pleistocene phase of relief formation of the Sayano-Baikal Highland and the opening the Baikal rift zone. The total interrupted uplift of the Pribaikal and West Transbaikal territories caused downcutting of the entire drainage system to the level of buried floors of the present river valleys. By the end of the Late Pliocene, the drainage pattern was similar to the present; river valleys were quite deep and well developed.

EOPLEISTOCENE

The young tectonic movements at the onset of the Pleistocene accompanied by lowering of depressions and uplift of the surrounding ranges, caused accumulation of fluvial deposits and a gradual filling of the Pliocene rift zone. The transgressive type of sedimentation, resulting in thick alluvia accumulating in the valleys in both the Pribaikal and West Transbaikal areas, testifies to a morphostructural development of geological formations, and a temporary drainage cessation at the beginning of the Pleistocene owing to the uplift of the southwestern rim of the Baikal depression (Logachev 1974).

The great thickness (up to 130 m) and geological configuration of the buried sandy and coarse gravelly alluvia were primarily controlled by the Baikal level rise and differential tectonic movements. The most intensive uplifts of the antecedent floors of river valleys resulted in the formation of cut-aggradation terraces. The older, low series terraces are composed of Pliocene ochreous alluvium of a "normal" thickness.

During accumulation of alluvium, the sharpest differentation of the vegetation cover appeared on the south- and north-facing slopes, likely as a result of a seasonal strengthening of the warm temperate and humid continental climate. The earliest sediments contain arboreal spore and pollen spectra indicative of a forest-steppe landscape.

The forest vegetation was represented essentially by coniferous species among which *Pinus silvestris* and *P. sibirica* dominated, followed by *Abies* sp., and, more rarely, by *Pinus* sect. *strobus*. The relative proportion of *Artemisia* increased, but the composition of herbs, well represented by *Ericaceae* and various grasses remained more or less unchanged. Colonies of *Betula* forest with *Corylus* and *Filices* were spread in river valleys and mossy bogs on floodplains with *Salix* brushwood along the river beds.

By the end of the Early Eopleistocene, coarse--layered alluvia and proluvia were formed in accordance with an attenuation of the tectonic processes. In Southeast Pribaikal, the fauna of the second series of the Zasukhino locality on the right bank of the Itansi River, attributed to this period, is represented by *Ochotonoides* cf. *complicidens*, *Ochotona* sp., *Allophaiomys pliocaenicus*, *Villanyia* cf. *laguriformes*, *Mimomys* sp., *Mimomys* ex gr. *newton-pusillus*, *Marmota* cf. *sibirica*, *Coelodonta* cf. *tologoijensis*, *Spirocerus wongi* and *Capreolus* sp.

During the Upper Eopleistocene, the sedimentation dynamics was reduced and deposition of a light brown and a reddish pale-yellow rock debris-rich loam took place. The following fauna of mammals is associated with these formations at Zasukhino: *Ochotona tologoica*, *Ochotona* sp., *Villanyia* cf. *laguriformes*, *Mimomys* ex gr. *pusillus*, *Cricetinus* cf. *varians*, *Cricetinus* sp., *Citellus (Urocitellus)* sp., *Citellus* sp., *Prosiphneus* sp., *Castor* sp., *Microtus* sp., *Microtus* cf. *gregaloides*, *Marmota* sp., *Canis variabilis*, *Ursus* sp., *Hyaena breviostris* cf. *sinensis*, *Nyctereus* sp., *Homotherium* sp., *Xenocuon* sp., *Felis* sp., *Gulo* sp., *Archidiskodon* sp., *Equus* ex gr. *sanmeniensis*, *Equus (Hemionus)* sp., *Coelodonta tologoijensis*, *Capreolus* cf. *sussenbornensis*, *Cervus* sp., *Alces latifrons*, *Bison* sp., and *Spirocerus wongi* (Bazarov 1986, Rezanov 1988).

At the end the Eopleistocene, palaeoenvironmental data indicate a humid and warm temperate climate in Southeast Pribaikal where arboreal taxa dominated (88–98 %), with prevailance of *Pinus Diploxylon* (88 %) and only minor proportions of *Pinus sibirica* (10–25 %), *P. pumila*, *Picea*, *Tsuga* and *Betula*. A grassy vegetation is weakly represented (6–12 %). A spore and pollen spectrum from loam, filling the cavities of tubular bones, indicates a pine forest (94 %) dominated by *Pinus sibirica* (up to 27 %) and with a minor frequency of *P. pumila*, *Abies* and *Betula*.

In Western Transbaikal, the late Eopleistocene fauna fauna (*Canis* cf. *variabilis*, *Equus* ex gr. *sanmeniensis*, *Equus (Hemionus)* sp., *Coelodonta* cf. *tologoijensis*, *Cervus* cf. *elaphoides*, *Bison* sp. and *Spirocerus wongi*) comes from the key Ust-Obor locality (Kalmikov 1986).

PLEISTOCENE

The age and genesis of the Middle Pleistocene transgressive type sedimentary series, which have direct relevance for palaeogeographic and neotectonic reconstructions, are two of the most important problems in the Cenozoic history of the East Siberian region. The principal sedimentary formations are of a deltaic, fluviolacustrine and talus origin and of different ages. They consist either of sand or silt and are spread both in the river valleys of the Baikal run-off direction in West Baikal, and also in the Baikal rift zone depression. They are also known in the Ingoda Depression of Central Transbaikal which is drained by the river of the same name.

The spreading sedimentary series of this type in the Selenga River basin filled the river valleys and intermountain depressions. The Selenga lower terraces (25 m, 32 m and 40–50 m), as well as the 80 m high terrace, comprise fluvial and delta-lacustrine sands or sandy silts (Rezanov 1988, 1995).

Lower Pleistocene

The beginning of the Lower Pleistocene (ca. 80 ka BP) in the Pribaikal coincided with a new phase of tectonic movements that modified floors of the Baikal rift zone depressions by block shifts, and caused a build-up of the Baikal lake water mass and a gradual accumulation of 80 m of thick sandy strata. Occurrences of *Coelodonta* and *Spirocerus* are known from the sandy sequence at the bottom of a terrace near the Ust-Kyachta village. Spore and pollen spectra of the high terrace alluvia reflect mixed pine and birch forests with some *Picea* and *Abies*, in association with broad-leaved species (*Quercus*, *Fagus*, *Ulmus*, *Corylus*, *Pterocarya* and *Juglans*).

The Lower Pleistocene colluvial deposits are known from the upper part of the section on the Tology Mountain in West Transbaikal. The stratified sediments are represented there by pale-yellow mudstone with the admixture of a sandy and gravelly material. The fossil mammalian fauna from these deposits includes *Sorex* sp., *Ochotona daurica gureevi* (?), *Ochotona dodogolica*, *Citellus undulatus gromovi*, *Allactaga saltator transbaicalicus*, *Cricetus barabensis*, *Ellobius tencrei*, *Eolagurus siplicidedens simplicidens*, *Microtus fortis*,

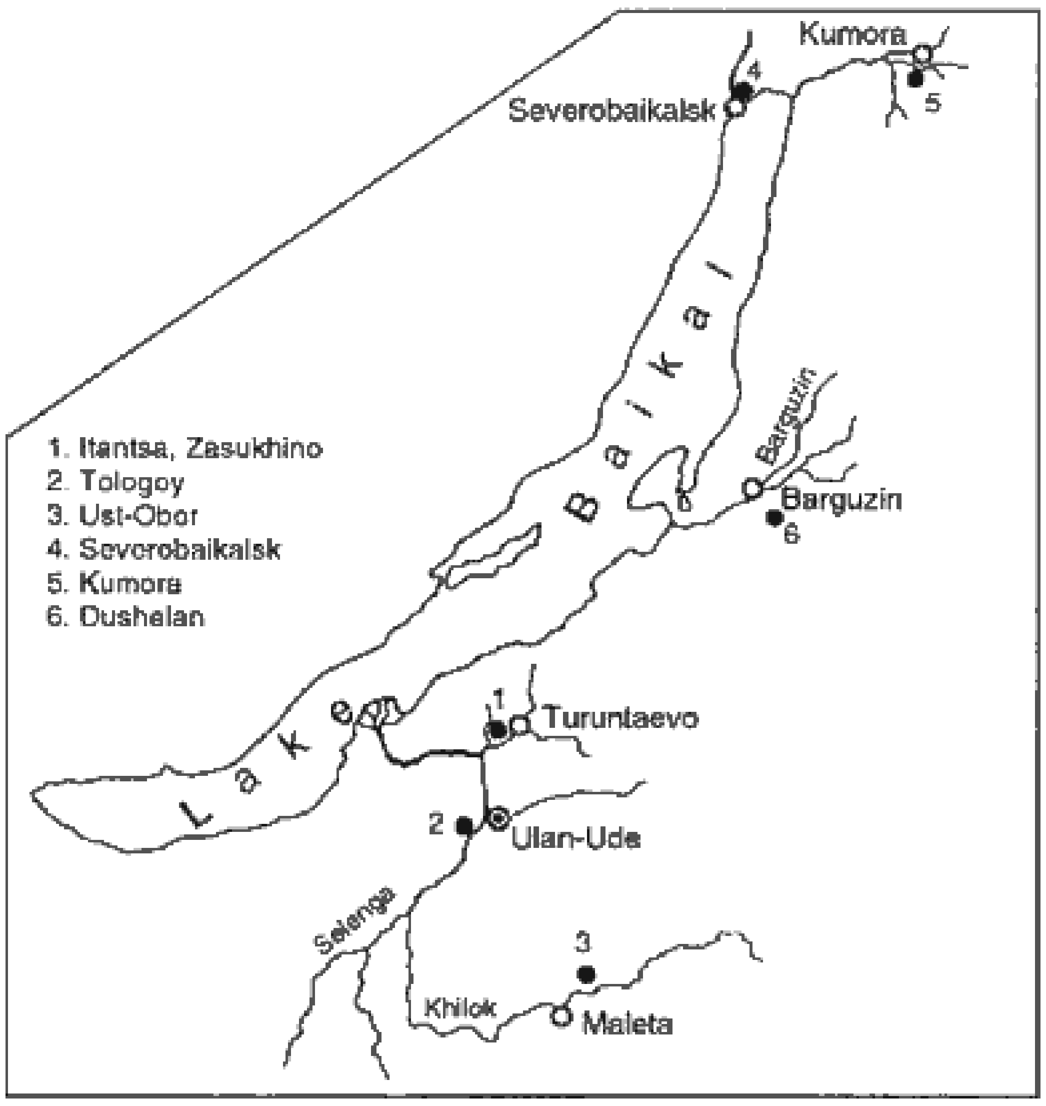

Fig. 1. Location of the main Pleistocene palaeontological localities in Pribaikalic and Transbaikalic areas.

M. brandti, Myospalax spalax wongi, Canidae gen. (?), *Archidiskodon* sp., *Equus sanmeniensis, Coelodonta tologoijensis, Cervus* ex gr. *elaphus, Bison* sp. and *Spirocerus peii*. Palynological data from the same formation testify to an emergence of open steppe areas in Transbaikal with some arboreal vegetation islands with *Pinus silvestris, Betula* sp., and *Tilia amurensis*. The composition of the spore and pollen spectrum indicates an accumulation of sediments under a warm temperate and semiarid climate in the period of the Tologoy faunal complex (RAVSKY 1972).

Middle Pleistocene

A reactivation of the neotectonic activity characterized the initial stage of the Middle Pleistocene in Pribaikal, resulting in the rise of the regional base level. This caused a Baikal water ingression into West Transbaikal as well as further support of the Angara water head (REZANOV 1988, 1995). The Pribaikal and West Transbaikal Middle Pleistocene deposits are mainly represented by sandy, gravelly-sandy and pebbly-sandy transgressive series of lake-alluvial, lake-deltaic, alluvial-proluvial and aeolian-deluvial sediments. They form river and lake terraces and submontane trains conjugated with them. The "Krivoyarsk" sandy strata, about 40–50 m above the present Selenga River, accumulated during the Tobol (Mindel/Riss, Holstein) interglacial and continued to form to the end of the Samarovo (Riss) period after previous fluvial downcutting into the older sandy strata.

The large fossil fauna from sands at the base of the Krivoyarsk series in West Transbaikal include *Mammuthus chosaricus, Bison priscus* (a large form), *Camelus knoblochi, Poephagus* cf. *baikalensis* and *Equus caballus* (a large form).

In general, the palaeoenvironmental data, characterized by a spore and pollen complex of the lower part of the Krivoyarsk sands, idicate a 50 % increase in precipitation compared to the present and an expansion of broad leaved arboreal species and *Tsuga* within the pine-birch forests (REZANOV 1988).

A climatic cooling took place by the time of the end of the sandy strata accumulation, correlated with establishment of a forest-steppe with pine-larch wood and an incipient glaciation in the Pribaikal Highlands due to the cold temperate and humid local climate of the Samarovo period. Terminal moraines are traced along the foothills of the Baikal, Barguzin, Angarsk and South Muisk mountain ridges. At this early stage of temperature decline, the Middle Pleistocene glaciers extended down to 1000–1300 m a.s.l. In the final part of the Middle Pleistocene when Baikal lake levels stopped rising, starting with the Shirta period (ca. 200 ka BP), a new phase of the fluvial downcutting took place. In Northern Pribaikal, in 50 m thick fluvio-deltaic and lacustrine sediments composed of coarse gravel (the Severobaikalsk Formation), the following mammals have been found: *Mammuthus primigenius, Equus* aff. *beijingensis, Coelodonta* cf. *antiquitatis; Cervus* sp. and *Bison priscus* (KALMIKOV 1990). In Western Transbaikal, this is correlated with malakofauna and the small mammalian fauna from layer 5 of the Zasukhino Formation, which includes *Pupilla (P.) asiatica* and *P. (P.) lindstromi*, and small mammals of *Ochotona* cf. *daurica, Citellus (Urocitellus)* sp., *Lasiopodomys* cf. *brandti, Cricetulus barabensis, Microtus* ex gr. *gregalis* (KALMIKOV 1990).

Upper Pleistocene

At the start of the Upper Pleistocene, tectonic activity of the Baikal rift zone and its mountain frame revitalized again. As a result of this, sandy strata were formed in the basins of the Selenga, Upper Angara, as well as Vitim, Muya and other rivers of Pribaikal and Transbaikal.

The peculiarities of spreading of the great thickness of sediments composing the fluvial terraces and their specific texture and mechanical properties, testify to a regressive accumulation in conditions of rising of base level of erosion. In the Baikal coastal part, the lake-deltaic series accumulated. Two platforms of different age are observed at the 32 m level accumulation terrace on the left bank of the Selenga River in the Ust-Selenginsk depression. A lower terrace, about 20 m in thickness, formed in the Kazantsevo (Riss-Würm, Eemian) period (ESR dates 135 000–103 000 ± 10 000 yr. BP) and a platform up to 10 m thick, composed of fluvial sand, dates to the Karginsk interval. This alluvial series can be traced along the Selenga River and in other river valleys of the Baikal run-off direction. It is composed of lacustrine and fluvial sandy silty sediments alternating with rock debris of colluvial facies. The grain size of sediments gradually decreases from the upper reaches down to the Baikal Lake.

The sandy series of different levels are characteristic not only of the Baikal Basin rivers, but they have also been deposited in the Tunka, Chara and Muya depressions of the Baikal rift system. Such a spatial confiness of the sandy series indicates that the lacustrine regime was spreading here both in connection and contrary to the Baikal water-level fluctuations. This could have been caused by a general uplift of the southern part of the Siberian platform.

The Pribaikal Kazantsevo (last interglacial) deposits generated in conditions favouring the development of authigenic minerogenesis. A warm temperate climatic regime supported expansion of a pine-birch forest with some rare elements of a broad-leaved flora (*Tsuga* and *Corylus*) on mountain sides and on the Baikal coast a growth of coniferous woods dominated by *Abies* and *Tsuga* and some broad-leaved forms.

By the middle of the Kazantsevo interglacial the humid temperate climate gradually became arid in both the Pribaikal and Western Transbaikal. The northwestern direction of prevalent winds stimulated a wide development of drifting sandy surfaces on the Early- and Middle Pleistocene terraces and the formation of sand trains on windward sides of lower foothills. Simultaneously, portions of the aeolian dust accumulated on lee sides, forming loess-like series.

The Zyriansk (Lower Würm/Weichselian, OIS 4) glacial stage started with an interval of relatively high humidity. Simultaneously, the Baikal Lake supports in the Angara River head and in the Tunka and Muya depressions of the Baikal rift zone were eliminated due to the fluvial transit of the downcutting rivers. Because of a gradual cooling, a dróp of snow-line and formation of mountain glaciers took place, marking the second glaciation in the Pribaikal Highlands and the formation of altiplanation terraces from 1000 m to higher elevations. Palynological data testify to establishment of a cold and rather humid climate in the extraglacial zone with invasion of a sparse pine-birch vegetation dominated by grasses.

During the following Karginsk (Middle Würm/ Weichselian, OIS 3) interstadial, a new stage of tectonic activity brought considerable changes into the Baikal Lake hydrological regime and accelerated the process of the sandy alluvia accumulation on the top of the 20 m Kazantsevo terrace (ESR 30 700 ± 4070 yr. BP). The total thickness of the Karginsk sandy series reached up to 32 m by the end of this accumulation. A subsequent erosion reduced the level to 23 m near slopes. The age of the earliest strata is TL dated to 51 000 ± 10 000 yr. BP.

In the process of the Baikal Lake transgression, due to the water level rise, estuarine deltas were formed at the mouths of lake tributaries.

A cultural layer of the Upper Palaeolithic initial phase (ESR 34 600 ± 3400 yr. BP) are found in the middle part of the Karginsk sandy strata. In general, the Karginsk interval was more arid than the Kazantsevo interglacial, contributing to the expansion of a parkland steppe with pine-birch trees and rich grass cover. Nevertheless, some thermophilous taxa of broad-leaved species like *Quercus, Fagus, Ulmus, Juglans* and *Corylus* existed as well.

During the Sartan (Upper Würm/Weichselian, OIS 2) glacial stage, palaeogeographic conditions were broadly similar to those of the Zyriansk stage. The Karginsk sandy series were followed by deposition of a 4–5 m thick alluvium. The earliest alluvium (ESR 18 638 ± 2400 to 16 000 ± 3200 yr. BP), overlaping the 23 m high terace III, reflects the end of the first downcutting stage. The completion of the following phase (ESR 13 500 ± 2100 yr. BP) is fixed by the terrace II, 12 m above the recent river level near its mouth. The latest erosional phase preceeded the aggradation of terrace I (6–7 m high). The final Palaeolithic occurrence near the Oshurkovo site, dated by ^{14}C to 10 400 ± 500 yr. BP, is associated with the uppermost deposits of terrace I. During the last glacial maximum (LGM), the Pribaikal Highlands experienced the most extensive glaciation with montane glaciers advancing far down from the mountains into the valleys. Altiplanation terraces formed and rock-stream slope movements became active. Deluvial-solifluction trains appeared on low mountain slopes. In the northern Baikal region, the Severobaikalsk series of light fine-grained calcareous sand (layer 5) provided fossil remains of *Equus* cf. *lenensis, Coelodonta antiquititatis* and *Bison priscus occidentalis*. This record chronologically corresponds to Late Pleistocene biological communities in the northern Pribaikal localities of Kumora and Dushelan. In the Southeastern Pribaikalie, a pale-yellow and grey loams of Zasukhino layer 6 with a rich ornithofauna, including *Crex crex* and *Anas crecca*, and some rodents, such as *Lasiopodomys brandti, Citellus (Urocitellus)* sp. and *Microtus* cf. *gregalis*, are correlated with the same period.

At that time, cold steppe covered the southern slopes of the Transbaikal river valleys, whereas a shrubby vegetation spread along the rivers. Large mammals, including *Equus* sp., *E. (Hemionus)* sp., *Coelodonta antiquititatis, Bison* sp., *Cervus* sp. and *Capreolus* sp. from the colluvial deposits, reflect a forest-steppe habitat. Water saturation of the upper horizons of the sandy series owing to intensification of the perenial frost resulted in appearance of allasic sinks, swelling hummocks and tetragonal ice veins on the surface of the alluvial valleys. The palaeogeographical conditions of the Selenga River delta suggest a higher water level in the Baikal Lake. The run-off was directed to the lower part of the Ust-Selenginsk Depression with boggy settings and lagoon relics of a bay shoreline preserved along the valley margins.

HOLOCENE

The Pribaikal and Transbaikal Holocene formations are not so widely developed as the Pleistocene ones, and have also a much reduced thickness. During the Early Holocene, floodplain deposits and related alluvial-proluvial and proluvial-deluvial sediments were formed. The Early Holocene alluvia of large tributaries are no more than 6 m thick. Several buried soil horizons are enclosed within the aeolian sediments, overlapping the Kazantsevo strata and deluvial loess-like slope formations up to 2.5 m thick. A Neolithic burial (^{14}C date 7490 ± 120 yr. BP, MAMONOVA - SULERZHITSKY 1989) was found in the latter. At that time, a wood vegetation dominated by *Pinus silvestris, P. sibirica, P. pumila, Abies, Picea* and *Betula* was established in the area.

To the Late Holocene are attributed alluvial sediments (up to 5 m thick), lacustrine and palustrine deposits 2 m) in the river valleys and proluvial-mudflow and mountain- mudflow formations, peat bogs, aeolian sand of young dunes and hummocks, solifluction deposits and ground sinters in mountain slopes with northern aspect above 1200 m a.s.l.

Quaternary ecosystems

Among other lines of the palaeoenvironmental data, fossil mammalian remains represent the most informative evidence for studying regularities of the Quaternary evolution process in the Baikal palaeoecosystem. Investigations of the character of evolutionary faunal transformations allow the establishment of a particular chronological sequence of events in the Pleistocene fauna community development, a reconstruction the appearance of new species and genera, and periods of mass dispersals and mammalian fauna extinctions.

New genera of mammals unknown in the Late Pleistocene can be attributed to the original ecosystems during the Early Pleistocene (Fig. 2). It is assumed that the first representatives of the genera *Equus, Itanzatherium, Coelodonta, Bison* and *Spirocerus* appeared at the beginning of the Pleistocene and experienced several flourishing epochs with the exception of the *Itanzatherium* genus. While examining the transitional Pliocene/Pleistocene faunal complex as a composite part of biological communities, it is necessary to note that the greater part of this complex further expanded in the Pleistocene, mainly the genera *Equus, Coelodonta, Bison* and *Spirocerus.*

Evolutionary transformations in the course of the Pliocene/Pleistocene transition within the families of *Elephantidae*, *Equidae*, *Rhinocerotidae*, *Cervidae* and *Bovidae* make an impression of an original "information" burst which resulted in an intensive production and formation of a great number of new and diverse biological communities.

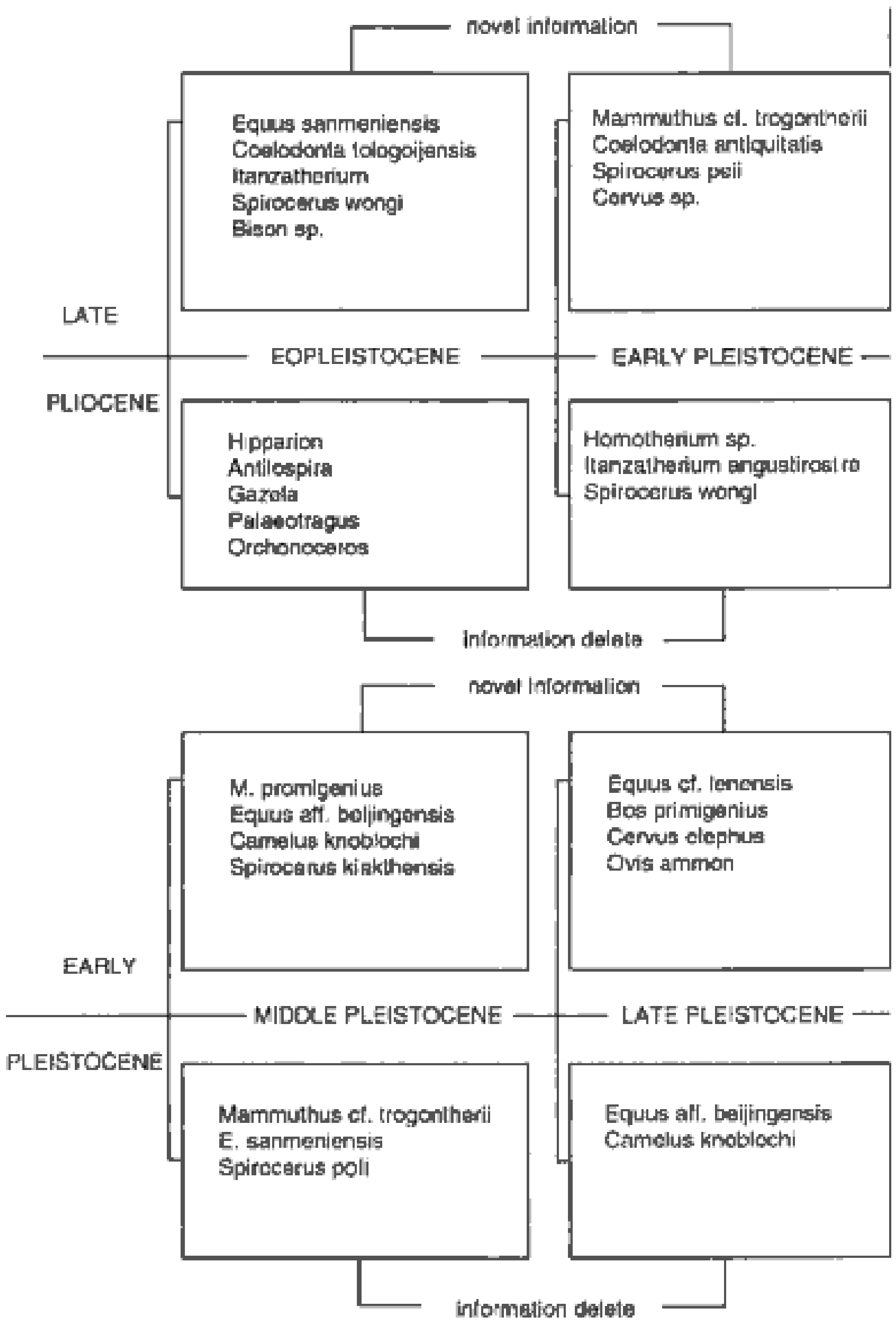

Fig. 2. Evolution of the Quaternary ecosystems of the Pribaikalic and Transbaikalic areas.

Analysis of the Pleistocene development of the Pribaikal and Transbaikal fauna shows that all the subsequent transformations in biota occurred at the expense of combining species and formerly developed biotic communities, eventually resulting in the taxonomical simplification of the Late Pleistocene ecosystems.

The evolutional development of the mammalian fauna of the Quaternary in our region may be correlated with the Middle and Late Pleistocene stages in other parts of Northern Eurasia. The peculiarity of the development is evidenced by the fact that the last two stages did not contribute any significantly new information to the mammal community. Changes in composition of faunal complexes occurred at the expense of the single taxons regrouping, accompanied with an immigration of some new species. As a consequence of the limited information capacity of the existing ecosystems, the evolution process of the Pribaikal and Transbaikal mammals over the Pleistocene Period represents a chain of repeated combinations of one and the same forms.

The process of repeated manifestation of a structural information has been widely developed over the evolution of the ecosystem biotic structure. An information break is accompanied by extinction of some species in the process of the ecosystem's transformation. The biotic diversity during the Pliocene and Pleistocene transition was controlled by the interaction of old and new ecosystems. The biotic structural information appered rather quickly relative to the scales of the geological time. The great diversity of the ecosystem structure of this transitional period subsequently became sharply reduced, leding to a relative taxonomic simplicity of the Pleistocene. The information "oversaturation" of the ecosystem structure probably occurred at the expense of filling different ecological niches which could became free as a result of extinction, owing to the change of climatic factors and new and progressive adaptation patterns of some species.

The taxonomical composition of the Middle and Late Pleistocene faunal assemblages does not show any sharp climatic fluctuations (glacial/interglacials) characteristic of the northern regions of Eurasia. The climatic changes did not result in sharp fluctuations of moisture- and solar radiation affecting the Pribaikal and Transbaikal ecosystems. This is also suggested by the relative uniformity of the Middle and Upper Pleistocene deposits, which show significant differences in their genesis and sedimentation conditions. Finally, the evolution of the Pleistocene ecosystems was not accompanied by sharp restructuring of their existing biological formations; nevertheless, shifts toward a new climatic optimum brought a new diversification of adaptive patterns, an increase of species variety and a narrowing of previously broadly exploited ecological niches.

Recommended for print by T. Czudek

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