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PALYNOLOGICAL STUDIES ON LATE PLIOCENE/EARLY PLEISTOCENE SEDIMENTS FROM LAKE BAIKAL (SIBERIA)

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ABSTRACT. Palynological analysis of sediment samples from the BDP-96-1 drilling (Lake Baikal, Academician Ridge) was performed focussing on the time interval 3.6 to 2.2 Ma B.P. (million years before present). Pollen and spore data revealed the vegetation development from conifer forests with associated broadleaved trees to forests with declining participation of hemlock firs (*Tsuga*). Spread of fir, shrub alders and juniper as well as of steppe vegetation (*Artemisia*) reflect climatic changes (dry, cold) in the Baikal region, which are related in time to the intensification of northern hemisphere glaciations.

KEY WORDS: Lake Baikal, late Pliocene, pollen analysis, vegetation history, palaeoclimate

INTRODUCTION

With increasing knowledge about Cenozoic environmental changes in the northern hemisphere, the time interval of 3.5–2 Ma B.P. (million years before present) is of special interest for the elucidation of past global climatic processes. North Pacific sediments show a distinct increase in the deposition of ice-rafted debris after 2.75 Ma related to a major cooling step with intensification of northern hemisphere glaciation (Maslin *et al*. 1995), while fluvio-lacustrine deposits in central China give also information about climatic deterioration (Han *et al*. 1997). The position of Lake Baikal provides the opportunity for reconstructing the Pliocene-Pleistocene vegetation history in the continental interior of northeastern Eurasia with regard to shifts in adjacent floristic regions and vegetation zones including northern boreal taiga forests and the southern mongolian steppes and forest steppes.

MATERIAL AND METHODS

The BDP-96-1 drilling (Baikal Drilling Project) was located on the submersed Academician Ridge (water depth 321 m) dividing the northern from the central basin of Lake Baikal. The recovered sediments are composed of clay and diatomic ooze in changing relative quantities, with silt, sand and gravel in smaller, varying amounts. The age model is based on linear interpolation between palaeogeomagnetic reversals documented by inclination data (BDP Members 1997, 1998, Williams *et al*. 1997).

Laboratory preparation of the sediment samples included treatment with hydrochloric and hydrofluoric acid, followed by micro-sieving. Acetolysed *Lycopodium clavatum* spores were added to the samples in order to calculate absolute pollen concentrations. The material was mounted in glycerine jelly with a paraffin sealing. For calculation of percentages a basic sum of at least 300 grains (arboreal and non-arboreal pollen, AP+NAP) was counted, in case of very low concentrations a minimum sum of 100 grains. Pollen of aquatics and spores were excluded from the basic sum.

POLLEN AND SPORE DATA

Pollen concentrations vary strongly (order of size 100–100 000 grains per ccm), with a tendency to lower maximum values in the upper part. About 150 different pollen and spore types were noticed. Percentage sums of non-arboreal pollen vary considerably, with peak values present in the lower section (3.6–2.7 Ma) and a maximum in the upper section.The preliminary zonation comprises five pollen zones and two subzones (Fig. 1). The arboreal pollen are dominated by bisaccate grains of coniferous trees, mainly pine (*Pinus*) and spruce (*Picea*). Pollen grains of *Tsuga* are frequent to abundant in the lower zones, also pollen of *Quercus* and *Ulmus/Zelkova*, while types of other important arboreal taxa (*Acer, Tilia, Juglans, Pterocarya*) are infrequent. *Betula* and *Alnus* are present throughout the investigated section.

In pollen zone I grains of *Quercus* are abundant, those of *Ulmus*, *Corylus* and *Tsuga* frequent. Occurrences of *Tilia* pollen are confined to this zone. Zone II is characterized by high percentages of *Tsuga* pollen, with slightly increasing values of *Abies*. *Quercus* and *Ulmus/Zelkova*

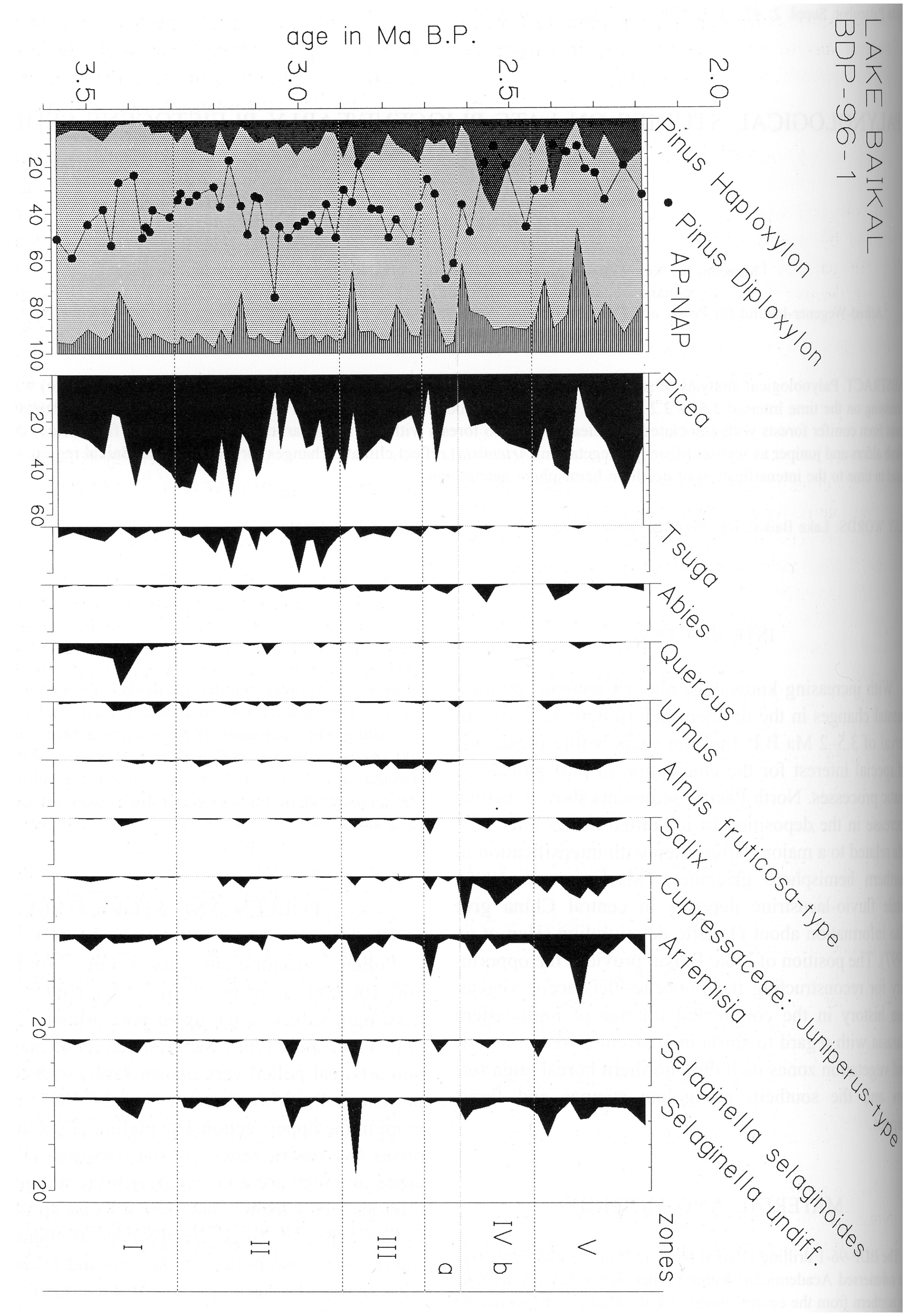

Fig. 1. Strongly simplified percentage pollen and spore diagram for the BDP-96-1 drilling with a preliminary zonation for the time interval 2.2–3.6 Ma B.P.

are less frequent than in the previous zone, but grains of other important broadleaved taxa are still present. After the strong decline of *Tsuga* pollen in zone III and after a first distinct maximum of *Artemisia*, pollen of *Abies* and *Alnus fruticosa*-type become more frequent. The associated broadleaved taxa are no longer present. Zone IV is characterized by low percentages and disappearance of *Tsuga*, *Quercus* and *Ulmus/Zelkova* pollen, while the records of *Artemisia* (lower boundary of subzone IV a) and Cupressaceae (*Juniperus*-type) pollen (subzone IV

b) show a distinct increase. In zone V grains of *Corylus*, *Ulmus* and *Quercus* are more frequent again and percentages of *Artemisia* increase considerably.

VEGETATION HISTORY

Generally, the landscape around Lake Baikal was dominated by mixed conifer forests including pines (*Pinus* subgen. *Diploxylon* and subgen. *Haploxylon, Pinus cembra*-type), spruce (including *Picea* sect. *Omorica*), but also firs (*Abies*) and, up to 2.6 Ma, hemlock firs (*Tsuga*). Important associated arboreal taxa of the forests included broadleaved trees like *Acer, Tilia, Juglans, Quercus* and *Ulmus* (pollen zones I and II).

An expansion of oak trees (*Quercus*) around 3.4 Ma (within pollen zone I) and a decrease in *Tsuga* trees may reflect a dry climatic phase in the Baikal region. At the same time marine records from North Pacific sediments show a minor increase in the accumulation of ice-rafted detritus (IRD) as inferred from data on magnetic susceptibility (Maslin *et al*. 1995).

Between 3.3 and 2.9 Ma (pollen zone II) changes in the montane *Tsuga-Picea-Abies* forests of higher elevations took place, with the hemlock firs attaining more importance. Since 3.0 Ma the importance of *Abies* increased, while in lower elevations associated broadleaved taxa like *Quercus* and *Ulmus* were still present.

The decline of hemlock firs around 2.9 Ma (pollen zone III) was followed by a spread of shrub alders (*Alnus fruticosa*-type) and willows (*Salix*). Steppe elements expanded in open places, as indicated by a first maximum in the *Artemisia* curve.

Open vegetation (*Artemisia*, Chenopodiaceae, Gramineae) became more important from 2.7 to 2.45 Ma (pollen zone IV), when the diversity of forests was further reduced. After 2.6 Ma (boundary of subzones IV a and b) *Tsuga* possibly disappeared in the northern Baikal region, while juniper could spread in drier forest types. Based on the pollen record distinct climatic deterioration is reflected as dryness after 2.7 Ma. Intensification of northern hemisphere glaciations around 2.75–2.55 Ma resulted in a dramatic increase of ice-rafted debris in North Pacific sediments.

During 2.45 to 2.2 Ma (pollen zone V) communities with *Artemisia* penetrated into the open landscape. Reappearance of broadleaved taxa like *Quercus* and *Ulmus* suggest a slight warming, which is also indicated by lowered IRD values in the Pacific. At the same time dry conditions favoured the establishment of steppes in the Baikal region.

The outlined development (decline of *Tsuga*, spread of *Artemisia*) reflects long-term variations in vegetation and climate. A comparison of arboreal taxa indicative for relatively warm versus cool growing conditions points to more favourable climatic conditions prior to ca. 2.9 Ma and to a distinct late Pliocene cooling trend between 2.9 and 2.5 Ma. Increasing openness of the vegetation, as shown by the NAP/AP ratio, corresponded to a spread of forest types growing under drier conditions. Indicators of cliff (*Selaginella* undiff.) and steppe (*Artemisia*) vegetation on exposed sites strongly reacted to climatic cool/dry signals and peak percentages of their pollen and spore types suggest a retreat of the forest.

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