シベリア南東部バイカル地域の第四期最終期における古植生・古気候の変遷（英文）

Palaeovegetational and Palaeoclimatic Changes during the Latest Quaternary in Baikal Area, Southeastern Siberia[1)]

Norio FUJI[2)]

Abstract

Автор настоящей статьи анализировал с точки зрения палинологического исследования девятнацать образцов грунтовых кернов ок. 5-метрового керна, который отобрали с сегодняшнего дна озера Байкал, и может на время сделать следующие выводы согласно рис.

(1) Накопления пылец в образцах грунтовых кернов подразделяются в две пыльцевые зоны, т.е. зона А и зона Б, а также в десять пыльцевых субзон, т.е. субзоны А1 до А4 и субзоны Б1 до Б6.

(2) В пыльцевой зоне А преобладают *Abies, Larix,* тип *Pinus Haplxylon* и *Picea* с обыкновенной или редкой *Betula, Lepidobalanus, Salix, Alnus* и лиственные растения, которые сегодня часто встречаются в Тайге, и/или лиственный смешанный лес, который сегодня встречается в Бассейне Байкала и вокруг его в юго-восточной Сибири.

(3) Пыльцевая зона А хронологически совпадает с голоценом, а пыльцевая зона Б совпадает с последним периодом плейстоцена.

(4) В пыльцевой зоне А пыльцевая субзона А4 связана с концом бореального периода, А3 с атлантическим, А2 с суббореальным и А1 с субатлантическим периодом.

(5) На основании абсолютного количества пыльцевых зерн, спор и накоплений пылец можно связывать пыльцевую зону Б с последним ледниковым периодом.

The present writer analyzed from the view point of a palynological investigation nineteen samples from about 5 m core obtained in the present bottom of Lake Baikal, and can conclude tentatively as follows.

(1) The pollen assemblages of core samples are divided into two pollen zones as Zone A and Zone B, and also ten pollen-subzones as Subzones A-1 to A-4 and Subzones B-1 to B-6. respectivelly.

(2) The pollen Zone A is characterized by predominate *Abies*, *Larix*, *Pinus Haploxylon*-type, and *Picea* with common or rare *Betula*, *Lepidobalanus*, *Salix*, *Alnus* and forbs, which have been

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2) : Department of Science for Natural Environment, Division of Physical Sciences, Graduate School of Natural Science and Technology, Kanazawa University ; Kakuma-cho, Kknazawa 920-11, Japan.

grown widely in the present-day taiga and/or broad-leaved mixed forest in and around the Baikal Basin, southeastern Siberia.

(3) The Pollen Zone A may have been chronologically correlated with the Holocene period, and the Pollen Zone B with the latest Pleistocene period.

(4) In the Pollen Zone A, the Pollen Subzone A-4 may be correlated with the end of Boreal, A-3 with the Atlantic, A-2 with Subboreal and A-1 with Subatlantic period respectivelly.

(5) From view points of an absolute number of pollen grains and spores and pollen assemblages, the Pollen Zone B may be correlated with the Last Glacial period.

Der Verfasser dieses Artikels analysierte vom Standpunkt einer palynologischen Untersuchung neunzehn Proben von ca. 5m Bohrkern, welcher dem derzeitigen Grund des Baikalsees entnommen wurden, und kann vorläufig gemäß add. wie folgt schließen :

(1) Die Pollenansammlungen der Kernproben teilen sich in zwei Pollenzonen, Zone A und Zone B, sowie in zehn Pollenunterzonen, nämlich Unterzone A-1 bis A-4 und Unterzone B-1 bis B-6, auf.

(2) Pollenzone A zeichnet sich durch ein Vorherrschen von *Abies*, *Larix*, des *Pinus Haploxylon*-Typs und *Picea* mit gewöhnlicher oder seltener *Betula*, *Lepidobalanus*, *Salix*, *Alnus* und Blattpflanzen, welche in der heutigen Taiga weitverbreitet sind, und/oder Laubmischwald aus, der im und um das Baikalbecken in Südostsibirien anzutreffen ist.

(3) Pollenzone A kann chronologisch mit dem Holozän, Pollenzone B mit dem letzten abschnitt des Pleistonzäns korreliert werden.

(4) In Pollenzone A kann Pollenunterzone A-4 mit dem Ende der borealen, A-3 mit der atlantischen, A-2 mit der subborealen und A-1 mit der subatlantischen Periode korreliert werden.

(5) Vom Standpunkt der absoluten Anzahl von Pollenkörnern und Sporen und Pollenansammlungen kann Pollenzone B mit der letzten Eiszeit korreliert werden.

L'auteur de ce document procédera, d'un point de vue palynologique, à une analyse de 19 échantillons obentus à partir d'une carotte de 5 m prélévée au fond du lac Baîkal et il en tirera les conclusions suivantes qui seront également illustrées au fig.

(1) Les assemblages de pollen des échantillons sont divisés en deux zones de pollen, zone A et zone B, et en 10 subzones de pollen, respectivement en les sub-zones A-1 à A-4 et les sub-zones B-1 à B-6.

(2) La zone de pollen A est caractérisée par une prédominance de *Abies*, *Larix*, *Pinus Haploxylon*, *Picea*, *Betula*, *Lepidobalanus*, *Salix*, *Alnus* et des graminees, qui poussent largement dans la taîga et/ou dans les forêts mixtes à larges feuilles dans et autour du bassin de Baîkal, dans la Sibérie sud-est.

(3) Du point de vue chronologique la zone de pollen A pourra correspondre avec le Holocène, la zone de pollen B avec la dernière période du Pleistocène.

(4) Dans la zone de pollen A, la sub-zone de pollen A-4 pourra correspondre avec la fin du

Boréal, A-3 avec l'Atlantique, A-2 avec le Subboréal et A-1 avec la période subatlantique.
(5) Du point de vue du nombre absolu de grains de pollen, de spores et des assemblages de pollen, la zone de pollen B pourra correspondre á la dernière période glaciaire.

L'autore di questo articolo ha analizzato dal punto di vista di un esame palinologico diciannove provini da una carota di circa 5 metri, la quale è stata prelevata dal fondo attuale del Lago Baikal, ed è in grado per il momento, come da fig. di concludere quanto segue:

(1) Gli accumuli di polline dei provini si suddividono in due zone di polline, zona A e zona B, oltre che in dieci sottozone di polline, vale a dire sottozona da A-1 a A-4 e sottozona da B-1 a B-6.
(2) La zona di polline A si distingue per il prevalere di *Abies*, *Larix*, del tipo *Pinus Haploxylon* e di *Picea* con *Betula* comune o rara, *Lepidobalanus*, *Salix*, *Alnus* ed erbaccie, le quali sono diffuse nella Taiga odierna, e/o foresta mista di latifoglie, come la si può incontrare nel bacino del Baikal e intorno ad esso, in Sideria sudorientale.
(3) La zona di polline A può essere messa in correlazione cronologica con l'epoca dell'Olocene, la zona di polline B con l'ultimo periodo del Pleistocene.
(4) Nella zona di polline A la sottozona di polline A-4 può essere messa in correlazione con la fine dell'epoca boreale, la A-3 con l'epoca atlantica, la A-2 con l'epoca subboreale e la A -1 con l'epoca subatlantica.
(5) Dal punto di vista del numero assoluto di grani di polline e di spore e degli accumuli di polline, la zona di polline B può essere messa in correlazione con l'ultima era glaciale.

(Fuji, 1992)

1. Introduction

In an old sedimentary basin, deposits during long ages since old geological time have been preserved on bottom of its basin. Such old sedimentary basin is divided generally into types such as ocean and ancient lake. As the deposits of the former show generally a small sedimentation rate, the deposits are unfil for detailed analysis of palaeoenvironment as palaeovegetation and palaeoclimate during short times. On the other hand, the deposits of the latter show generally a large sedimentation rate and also include many fossils derived from lands such as many land-plant fossils. The deposits, therefore, are suitable for detailed analysis of palaeoenvironment during short times.

Lake Baikal is a representative lake throughout the ancient lakes above-mentioned. The lake located in the southeastern part of Siberia is one of the large lake throughout the world. The lake sediment, therefore, is expected to preserve the records of both activities of lake organisms and terrestrial palaeoenvironment, and is very important for considering climatic history since the Neogene period on continental area because of having long history and pelagic environment.

Lake Baikal is an especially promising site for investigations such as palaeoclimate, palaeoenvironmental sciences, palaeovegetation, palaeomagnetism, palaeontology, and others. Its high-latitude location (52° to 56°N) makes it particularly sensitive to changes in solar insolation due to long-period variations in the earth's orbital parameters. These variations are widely believed to be the main forcing functions of climate change in the Quaternary (Hays *et al.*, 1976). The extreme continentality of the climate in the southeastern Siberia makes Baikal an ideal location to study temporal changes in seasonality. Baikal is also one of the few high-latitude lakes that has not been glaciated during the last two million years (Grossward, 1980), although a record of glaciation in its drainage basin is preserved in the lake sediments.

Lake Baikal is the largest (23,000 km^3), deepest (ca. 1,640 m), and one of the oldest exact lake systems in the world. Accordingly, the sedimentary section in the Baikal depression is more than 5 km thick and probably spans more than 15 million years (Hutchinson et al., in press). Therefore, Lake Baikal sediments represent one of the longest and most complete continental climate records available anywhere in the world.

Lake Baikal is also palaeoclimatically important because the vast central Asian continent is a critical component of the global climate system, controlling, among other things, the atmospheric circulation pattern responsible for the Indian and Southeast Asia monsoons (Lamb, 1972). The central Asian deserts are the source area for the extensive Chinese loess deposits (Kukla, 1987). Long palaeoclimatic records from central Asia should contain a history of the uplift of the Himalayas and the Tibetan Plateau (Molner and Enland, 1990).

Baikal sediments contain a variety of climatically sensitive properties, despite the fact that biogenic carbonate is poorly preserved. These well-known properties include sediment grain size, biogenic silica, the amounts and isotopic composition of organic carbon, and the biostratigraphy of diatoms and pollen grains.

A proposal describing the concept of a Baikal Drilling Preject (BDP) was prepared at the University of South Carolina in May 1989 and presented to representatives of the Ministry of Geology and Academy of Sciences of the USSR in Moscow by Dr. P.P. Hearn, and Jr. Deputy of Chief For Soviet Programs, Office of International Geology in the United States Geological Survey. An Ad Hol Baical Committee had been formed in June 1989 to priority the scientific goals of a BDP prior to the IGC meeting held in USA in July 1989. The meeting concluded the first joint agreement on the scientific goals plans for a BDP (Williams, 1992). Japanese scientists who had been jointed the Russian-American BDP effort became a member of a Russian-American-Japanese BDP effort.

The Lake Baikal Palaeoclimate Project had been begun firsly as a Joint Russian-American Cooperative Project in 1990, and surveyed many problems such as sensitive perameters at the Pleistocene-Holocene boundary, grain size, magnetic susceptibility, organic carbon, changes in microfossil assemblages, and changes in ^{13}C and lignin oxidation etc. for sedimentary records of past climates in the central Asia.

Fortunately, we had a chance to observe the piston core sample of this lake. This piston core sample : No. 323-PC1 was collected by by USGS and the Russian Academy (Colman *et al.*, 1992) at the site of 710 m deep of 55°32.08′ N, 109° 31.28′ E in the lake. After lithological observation, operators collected samples for pollen analysis, planktonic remain analysis, inorganic chemistry, organic chemistry, grain components and grain size analyses.

In this paper, the writer states about palaeoenvironment in and around Lake Baikal, especially palaeovegetation and palaeoclimate changes, on the basis of palynological investigation of about twenty samples from about five-meter core obtained from Lake Baikal.

2. The Modern Flora of the Southeastern Siberia

In the northern part of Siberia tundra area is distributed as a belt from Obi Bay to Bering Sea along the Arctic Ocean. As climate at the present-day has been cold in the tundra area, although trees have not been grown, moss and lichenosa (Lichenophyta) have been distributed in this belt.

In the southward of the tundra area, forest tundra area has been narrowly spread, and changed gradually to taiga area, which has been distributed in the wide areas, about 4000 km in east-west trend and about 1000 km in north-south trend. The taiga area is composed mainly of conifer such as *Abies*, *Larix*, *Pinus* and *Picea* at the present-day.

In the southward of the taiga area, forest and steppe areas have been mixed, and changed gradually to forest-steppe area which has been zonally distributed a few hundred km in wide (north-south trend). The forest-steppe area has been spread intermittently by a distribution of mountains in the eastern Siberia. As it has been dry in the southward of the forest-steppe area, trees decrease gradually and the area has been changed to a steppe area except river-sides.

Lake Baikal is located narrowly in north-south trend between the taiga area and mountain or forest-steppe area.

According to the previous palaeontological investigation (Zubarev, 1983) in the Baikal region, palynological investigation was carried out in the Lesser Hamar-Daban and Hamar-Daban ranges. The distribution of forest formations has been determined by the climatic peculiarity. The northwestern part of the region from the lake-side to the water divide has been covered with the mixed cedar pine (*Juniperus*)-fir (*Abies*) forests. In the southeastern part of the region common pine (*Pinus*) forests have been characteristic flora in the lower mountain area and cedar pine forest has been spreaded in the upper mountain area. In the southwestern part of the region, larch (*Larix*) forest has been predominate in the lower area of mountain, and cedra pine forest has been distributed in the upper mountain (Bezrukova *et al.*, 1992).

3. General Geology during the Late Quaternary in the Baikal Region, Southeastern Siberia

The upper Quaternary strata are characterized by abundant remains of a mammoth fauna, archaeological findings, spores and pollen grains, and in some cases, radiometric datings obtained by a c^{14} method. The lower half of the upper Quaternary succession consists usually of sedimentary beds of a Kazantsevo (Mikulino) horizon which build up the third and fourth terraces of the Angara and Selenga Rivers and their large tributaries. A pedocomplex of the Kazantsevo period consisting of two deformed soil horizons total 1.5 or 1.6 meters thick was identified at the bottom of the Igetei and Tarakhai sections in and around the Angara area. The lower bed exhibits features of leached chernozem, and the upper of saline chernozem. These features are indicative of a zerothermic climate with a sharp change to arid conditions in the middle Kazantsevo period.

Having analysed the lithology and structure of the third 16- to 20-meter terrace of the Angara River, Logachev came to a conclusion that a sharp climatic change occurred at the boundary of Kazantsevo and Zyrianski periods. It is concluded that multistage glaciation occurred in the Tunka, Hamar-Daban, Baikal, Barguzin and other mountain ranges after the formation of the fourth terrace and in rare cases of the third terrace of the large rivers. Glacial deposits of an early stage dated tentatively as the early Würm stage are scattered in isolated localities in the above-mentioned ranges. Of wider distribution are glacial deposits of the maximum glaciation stage recorded by many investigations in the Irkutsk, Snezhnaya, Kirenga, Barguzin and Upper Angara drainage basins. The late mammoth remains were found in the terraces of fluvioglacial and alluvial deposits, which are genetically related to the glacial drift of the most intensive glaciation stage.

Under severe conditions of cold paleoclimatic times, a thin soil cover of a poorly differentiated profile were formed on the frozen ground. In warm times, probably the Karginski

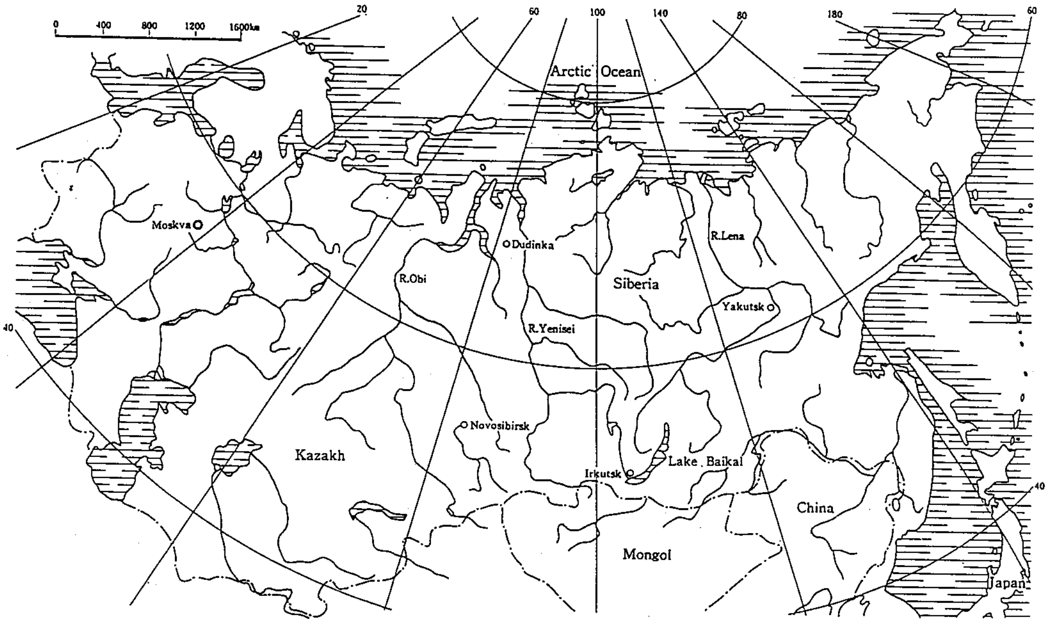

Fig. 1. Siberian map showing the surveyed area.

age, leached chernozem was formed in the Kuda river valley, and meadow-chernozem of meadow-forest soils were formed at the coast of Lake Baikal in the Malyi Goloustnyi area. Around the Angara area, fragments of the Karginski soils are found in the loose deposits at a depth of 1.5 to 2 m. The soils of this age are markedly zonal in a profile of the Igetei section, and their composition and structure suggest the climatic conditions being similar to ones of the present-day.

The Holocene deposits are divided into such three units as the lower Holocene, middle Holocene and upper Holocene deposits, dated by rediocarbon method. A series of datings

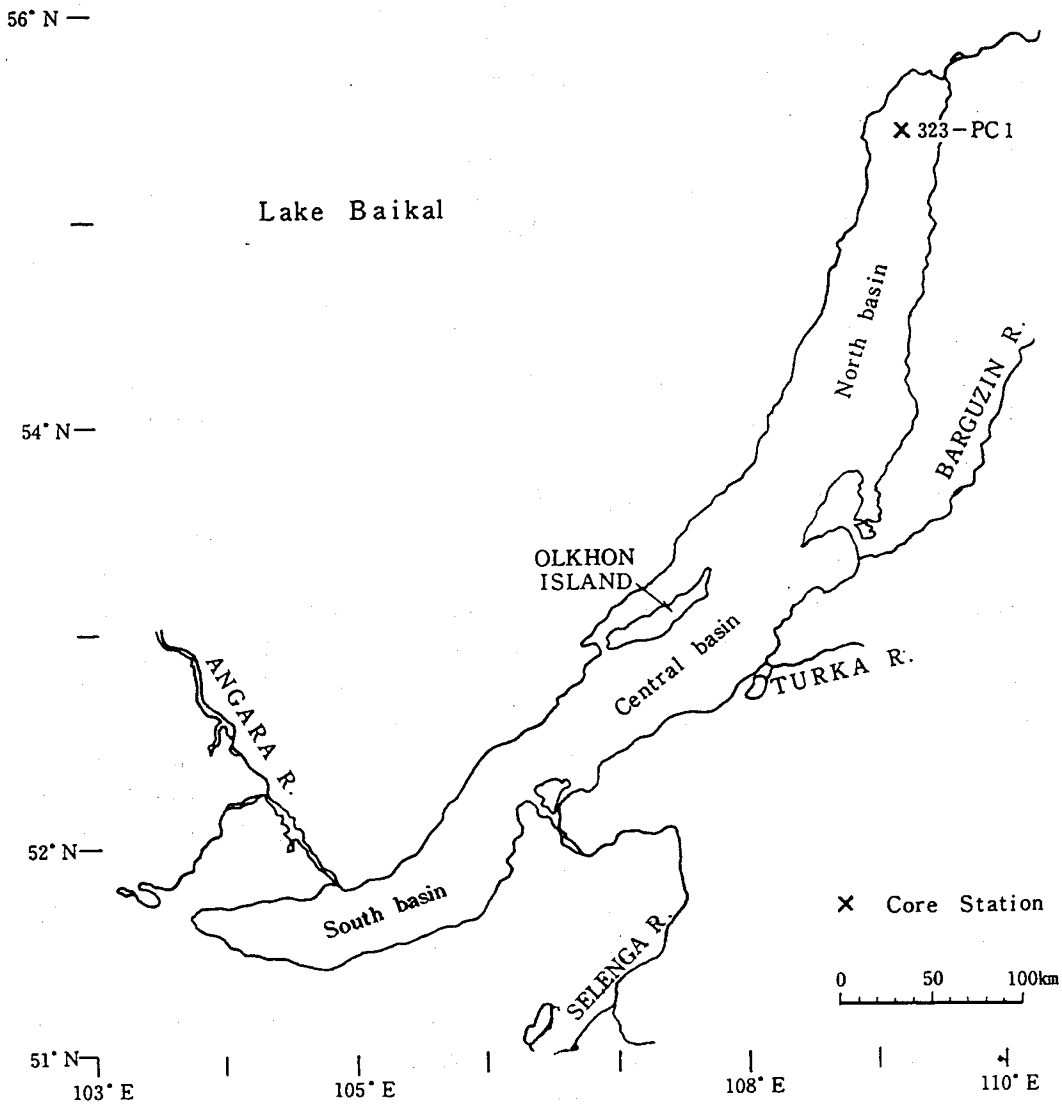

Fig. 2. Map of Lake Baikal showing the topography and the locality of a boring well.

obtained in the camps of Verkholenskaya Gora in the Angara Valley, Shishkino and Makarobo-II in the Lena upper reaches, Oshurkovo in the Selenga Valley, and in the Belaya Valley, indicate that the surficial deposits of the first terrace above the flood plain of the large rivers and of the second Baikal lake-coast terrace were formed in the early Holocene. Peat-boggy and podsolic boggy soils were developed in some localities of the second Baikal terrace. The age of peaty-boggy soils in the Izhimey Cape of the Olkhon Island was dated 10,325±85 years (SOAN-1433). In a time interval of 8 to 12 thousand years, glaciation was reduced in the nearBaikal mountains, and steppe landscapes were developed in the basins and river valleys. In an interval of 7 to 9 thousand years, the Ityrkhey, Berloga, Ulan-Hada, Tsar-Devitea and Lisikha Sites appeared, the archaeological findings in which represent the youngest chronological group, the final Mesolithic age (Perhaps the beginning of the Holocene Optimum age).

The middle Holocene period, 4 to 8 thousand years B.P., was marked by the activization of tectonic movements in some of the Pribaikalie and Zabaikalie areas. During this period scarps of first terrace were formed the flood plains of the large rivers, and the aggradation of flood plains began. The middle Holocene vegetation in the Baikal basin consisted of mountain-taiga coniferous forest with *Picea*, *Abies* and *Pinus sibirica*. At the time of a climatic optimum, 5 or 6 thousand years B.P., oak, elm and lime forests were growing in the large river valleys and intermontane areas.

A series of datings younger than 4000 years characterize the period of peat formation in the Baikal coast. A gradual fall of temperature during the late Holocene period caused the vanishment of oak. elm and limetrees from the mixed forest in the time interval of 2000 to 3000 years ago (Volpova and Belova, 1980). During the last 2000 years, two short phases of glaciation occurred in the Pribaikalie and Zabaikalie mountains, the remnants of which have been found in the Baikal, Barguzin and East Sayan Ranges, and in the Stanovoy Upland.

The examination of the Holocene buried and recent soils reveals a relative identity of their morphology and composition and a repeated rejuvenation of genetically similar processes of soil formation after the soil was covered by such loose deposits as mudflow, talus and debris. However, the appearance of saline chernozem in an alkaline chernozem succession found in the Maloe Goloustone section at the Baikal coast suggests a slight change of climate towards drying. Since no outcrops of Holocene soils exhibiting this phenomemon were found elsewhere, the climatic change can be considered as a local one (Galazy *et al.*, 1982 ; Logachev *et al.*, 1982).

4. Station of the Core

A Core 323-PC1 analysed for the present writer's palynological investigation was obtained from a bottom of 710 m in depth of Lake Baikal at 55° 32.08′N and 109°31.28′E of the southeastern Siberia. Total length of this core reaches to 461 cm.

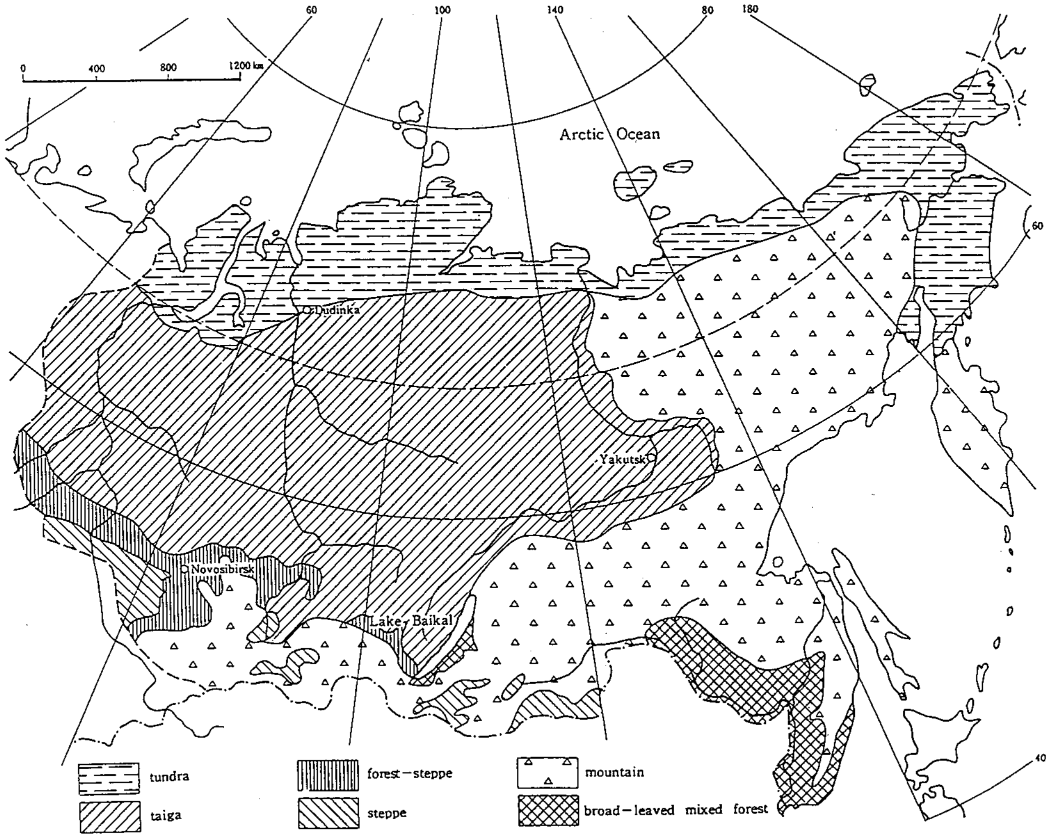

Fig. 3. Map showing the modern flora of Siberia.

5. Lithology of Core Samples

Core samples analysed for the present palynological investigation were taken for primary analyses at intervals of about 25 cm, and the samples taken from same horizons were used also for chemical grain-size and plankton analyses.

The core is composed mainly of soft homogeneous clay excepting thick, about 40 cm, silty deposit occupying at the uppermost horizon of the core including about ten sand bands which are about 5 to 15 cm thick and twenty-six very thin, a few mm, sandy layers. The clay is very homogeneous and roughly bluish grey or greyey blue in color. On the basis of lithologic observation, smear slide analysis and grain-size analysis (Takemura *et al.*, 1992), it is clear that the core samples are divided into two parts at the horizon of about 140-150 cm deep. The upper part than No. 7 sample horizon (about 150 cm) is composed mainly of grey silty clay and silt having yellowish grey color at some horizons, and characterized by very abundant diatom fossils. The lower part is composed mainly of bluish grey clay-silt and has bluish grey color.

Sandy size layer until 8 cm thick is intercalated in both parts. These sandy sediments had been transported intermittently in the continuous clay sedimentation. Few diatom fossils are included.

Samples for palynological analyses were obtained from nineteen horizons of the Core : 323 -PC1 as shown in Fig. 4. In some instances a wider or narrower intervals were necessary because of the intercalation of several sand bands and thirty sandy layers.

6. Palynological Investigation

(1) Main Zoning

Main zoning of this core is as a following description (Fuji, 1992). Pollen Zone B. depth: 130-460 cm, samples No. 7—No. 19. This pollen assemblage of the Zone B is characterized by scantiness of pollen grains and spores. Namely, absolute number of fossil pollen grains and spores are very rare on a comparison with the Pollen Zone A. And also, number of fossil non -arboreal pollen grains such as Gramineae, *Artemisia*, Cyperaceae and Chenopodiaceae is shown by frequency rarer than one of arboreal grains. Such phenomenum as frequency of arboreal and non-arboreal pollen grains is similar to phenomenum during the glacial period.

Pollen Zone A, depth: O-about 130 cm, Sample: No. 1-No. 6.

This pollen assemblage of the Zone A is shown by domination of *Abies* (about 25%)—*Larix* (about 15%)-*Pinus Haploxylon*-type (about 13%)-*Betula* (about 10%)-*Lepidobalanus* (deciduous *Quercus*, about 5%)-*Alnus* (a few percentages)-Cf. *Brasenus* (a few percentages)-Gramineae (about 5%). This zone is also divided into four subzones by conspicuous changes of pollen percentages, especially such as conifer as *Abies*, *Larix*, *Pinus*, *Picea,* and *Betula* etc. This zone is characterized by very high percentage of such conifer as above-mentioned.

Judging from the pollen assemblages of the Pollen Zone A and data from many references on the modern flora around Lake Baikal, *Abies*, *Larix*, *Pinus Haploxylon*-type, *Picea* and *Betula* have been thriuved in the present-day very wide taiga area of the eastern Siberia, being main plants in the modern flora around Lake Baikal. And, it is estimated that such fossil plants as *Abies*, *Larix*, *Pinus Haploxylon*-type, *Picea*, *Betula* and *Salix* had been derived from the taiga area in the ancient age, perhaps since during the Holocene.

If this assumption is true, on the basis of the morphology of the modern pollen grains from the modern taiga area near Irkutsk and Lake Baikal, eastern Siberia, it may be assumed that fossil *Abies* is determined to *Abies sibirica*, fossil *Larix* to *Larix dahurica*, fossil *Pinus Haploxylon*-type to *Pinus sibirica* or *P. sylvestris* of *P. pumila*, fossil *Picea* to *Picea obovata*, and fossil *Betula* to *Betula exilis*.

(2) Detailed Zoning

Datailed zoning of this core is as afollowing description (Fuji, 1992).

(a) Subzone B-6, depth: about 390-about 460 cm, Sample: No. 17—No. 19.

The character of the pollen assemblage of Subzone B-6 is similar to one of Subzone B-1 and B-3. Frequency of the Subzone B-6 is very rare.

The pollen assemblage of Sample No. 19 is shown such as rare Gramineae-*Juniperus* -Cyperaceae>very rare *Abies-Pinus Haploxylon*-type>very very rare *Larix*-Compositae -*Inapertipollenites-Juglans*.

The pollen assemblage of Sample No. 18 is shown as very rare Gramineae-Chenopodiaceae - other forbs>very rare *Pinus Haploxylon*-type-*Larix-Inapertipollenites*.

The pollen assemblage of Sample No. 17 is characterized by very rare Gramineae -Chenopodiaceae>very very rare *Abies-Pinus Haploxylon*-type-*Betula*.

These fossil pollen grains found out from this subzone might have been transported fundamentally by wind forests in the sourthern part of Siberia.

(b) Subzone B-5, depth: about 370-about 390 cm, Sample: No. 16.

The pollen grains and spores are not found from Sample No. 16.

(c) Subzone B-4, depth: about 340-about 370 cm, Sample: No. 15.

The character of the Subzone B-4 is shown by more or less increase of absolute number of arboreal pollen grains. And, the peculiarity of Sample No. 15 is summarized by such pollen assemblage as fewly common Gramineae-Chenopodiaceae-*Juniperus*≫very rare *Larix-Abies* -Cyperaceae. Pollen frequency of this subzone is common, being more than one of Subzone B -1 and B-3, and also similar to Subzone B-2.

(d) Subzone B-3, depth: about 260-about 340 cm, Sample: No. 12—No. 14.

The character of the pollen assemblage of Subzone B-3 is similar to one of Subzone B-1. Frequency of this subzone is very rare.

The palynological character of Sample No. 14 is summarized by such pollenflora as rare Gramineae-*Pinus Haploxylon*-type-*Dicellaesporites*>very rare *Ulmus-Lepidobalanus*.

The pollen assemblage of Sample No. 13 is shown by rare Gramineae-Cyperaceae-other forbs>very very rare *Larix-Inapertipollenites-Abies*.

The pollen assemblage of Sample No. 12 is characterized by very rare Gramineae-forbs> very very rare *Larix*>*Abies-Pinus Haploxylon*-type-*Artemisia*.

The fossil pollen grains found from this subzone might have been transported fundamentally by wind from the southern part of Siberia.

(e) Subzone B-2, depth: about 230-about 260 cm, Sample: No. 11.

The character of the Subzone B-2 is shown by a slightly increase of absolute number of arboreal pollen grains such as *Abies* and *Larix*.

The peculiarity of pollen assemblage from Sample No. 11 is shown by such pollen-flora as common Gramineae-Chenopodiaceae>very rare *Abies-Larix-Inapertipollenites*.

Pollen frequency of this subzone is common, and more than one of Subzones B-1 and B-3.

(f) Subzone B-1, depth : about 130-about 230 cm, Samples: No. 7—10.

The character of this zone is shown by the drastic decrease of absolute number on comparison to Zone A, that is, frequency of this subzone is very rare or very very rare. These fossil pollen grains and spores included in the samkles No. 7-No. 10 might have been transported fundamentally by wind and/or stream.

The pollen assemblage of Sample No. 10 is shown by very rare Gramineae-Cyperaceae -Chenopodiaceae>very very rare *Abies-Larix-Inapertipollenites*.

The main element of the pollen assemblage of Sample No. 9 is very rare Gramineae -Cyperaceae-Chenopodiaceae>very very rare *Pinus Haploxylon*-type-*Abies-Larix*. The frequency of non-arboreal pollen grains is more than one of arboreal pollen grains, and the peculiarity of pollen assemblage from this sample is similar to Sample No. 7 and No. 8.

The pollen assemblage of Sample No. 8 is shown by very rare Gramineae-Cyperaceae -Chenopodiaceae>very very rare *Abies-Larix-Inapertipollenites*, being similar to an assemblage of Sample No. 7. In this sample an absolute number of arboreal pollen grains are very rare.

The pollen assemblage of Sample No. 7 is characterized by very rare Gramineae-Cyperaceae-Chenopodiaceae>very very rare *Inapertipollenites-Abies-Pinus Haploxylon*-type. From the view point of statistical research, as absolute number of fossil arboreal pollen grains from the Sample No. 7 is less than one thousand specimens at the total, the relative frequency of pollen assemblage from this sample is not shown by percentage.

(g) Subzone A-4, depth: about 100—about 130 cm, Samples: No. 5—No.6.

Pollen assemblage of Sample No. 6 is characterized by *Abies* (21%)>*Betula* (14%)-*Pinus Haploxylon*-type (13%)-Larix (12%)-*Salix* (10%)-*Lepidobalanus* (7%)-Gramineae-forbs. Especially, dominate *Lepidobalanus* and *Salix* are one of the peculiarity of pollen assemblage in this sample.

Pollen assemblage of Sample No. 5 is shown by *Abies* (19%)-*Pinus Haploxylon*-type (13%)>*Betula* (10%)-*Larix* (10%)-*Corylus* (10%)-Gramineae-forbs-spores.

(h) Subzone A-3, depth: about 75—about 100 cm, Sample: No. 4.

The character of Subzone A-3 is summarized by a drastic increases of *Abies* (frequency: 37%) and *Betula* (frequency: 20%) on a comparison with Subzones A-2 and A-4. The peculiarity of pollen assemblage for Sample No. 4 is shown by very high frequency (about 40%) of *Abies*. Pollen assemblage of this subzone is *Abies* (37%)>*Betula* (20%)>*Larix* (14%)-*Pinus Haploxylon*-type (12%)>Cf. *Brasenia*-type (10%)-*Corylus* (7%)-Inapertipollenites-forbs.

(i) Subzone A-2, depth: about 55—about 75 cm, Sample; No. 3.

Pollen assemblage of Sample No. 3 is *Larix* (21%)-*Abies* (20%)-*Pinus Haploxylon*-type (15%)>Cf. *Braesenia*-type (10%)-*Inapertipollenites* (10%)-*Inapertisporites* (10%)-forbs -Gramineae. *Larix* and *Abies* are predominate pollen grains, and *Pinus Haploxylon*-type is dominated one.

From the view point of absolute number of pollen grains, although the Subzone A-1 is very abundant, the Subzone A-2 is common.

(j) Subzone A-1, depth: 0—about 55 cm, Samples: No. 1—No. 2.

Assemblage of Sample No. 2 is shown by *Abies* (32%)-*Larix* (20%)-*Pinus Haploxylon*-type (18%)>*Betula* (5%) -*Picea* (4%)-Cf. *Braesnia*-type (4%)-Gramineae (4%).

Pollen assemblage of Sample No. 1 is shown by *Abies* (20%)-*Larix* (15%)>*Pinus Haploxylon*-type (8%)-*Betula* (8%)-*Juniperus* (6%)-NAP (dominate forbs-Gramineae, common

Nympaeaceae-*Inapertipollenites Inapertisporites-Dicellaesporites-Multicellaesporites*).

As above-mentioned, in the Subzone A-1 *Abies*, *Larix* and *Pinus Haploxylon*-type are predominates, *Picea*, *Betula*, *Juniperus* and forbs are common.

(3) Interpretation of Palaeovegetation and Palaeoclimatic History

(a) Vegetation of the Baikal Region during the Latest Quaternary

On the basis of the recently palynological investigation and radiocarbon data, the changes of forest formations beginning with the end of the Boreal period have been summarized as following description.

Boreal : Birch (*Betula*) forests with cedra pine (*Juniperus*) and fir (*Abies*) were widespread on the Baikal coasts. Wide areas were covered with thickets of shrubby birch and forbs. Alpine tundra occupied the mountain slopes up to water divides. Slightly forested landscapes with shrubby birch, alder (*Alnus*) forests and willow (*Salix*) predominated in the southeast.

Atlantic : An intense afforestation of the region occurred. In its northwestern part of the Baikal basin the Baikal coast was covered with firbirch forests, the mountain slopes were occupied by cedar pine-birch forests, the mountain slopes were occupied by cedar pine. The bog forests, the mountain slopes were occupied by cedra pine. The bog formation began in topographic depressions. Cedar pine-birch forests were formed in the valleys of large rivers. In the southeast the slightly forested landscapes were replaced by forests of spruce, larch, and fir. In upper mountain belts the main species was cedra pine. In the southwest, cedra pine descended to the lower zones alng the shady slopes, and the sunny slopes were occupied by larch.

Subboreal : The climate between somewhat drier and more continental, and birch forests on the coast increased, whereas spruce and fir were preserved only in overmoistened habitats. Pine appeared on sunny slopes of river valleyes and became dominant in the southwestern part of the region. Large intermontane basins, where cold air messes accumulated, were occupied by larchcedra pine light forests with thickets of shrubby birch and associations of forbs. In the lower parts of mountains larch was replaced by pine.

Subatlantic : The vegetatin changes in the Subatlantic seemed to occur under the ingluence of the short cooling of the little Ice Age. In the southwestern part, essential changes occurred at the boundary areas between forest belt and in intermontane basins. The areas of larch forests were considerably increased, and the part of pine diminished. In the upper parts of mountains the larch-cedra pine forests were replaced by shrub tundra. The vegetation of the southeastern and northwestern margins of the region was not essentially changed. By the end of this period, the forests had a modern appearance (Zubarev, 1983).

(b) Change of Palaeovegetation and Its Interpretation

The pollen assemblages are generally a basis for a reconstruction and an interpretation of the changes of palaeovegetation and palaeoclimate during the latest Quaternary, especially "Holocene" and the "Last Pleistocene". It also allows comparison with diagrams from other regions. The zone system has the advantage in it which allows interregional comparison.

The zone and/or subzone boundaries, however, are in most cases defined on climatological criteria which influence the vegetation. On the other hand, a local zone system permits a detailed discussion of the vegetational development. However, many local zone systems may show confusing if used alone. This disadvantage can be avoided by using both regional and local zone systems, the local tending to be a subdivision of the regional one.

The present pollen spectra of Lake Baikal have been subdivided into two zones and ten subzones as already mentioned on the basis of conspicuous changes in pollen percentages.

As shown in the pollen diagram, there is a remarkable difference between the Pollen Zones A and B. Accordingly, the Zone A is characterized by very high percentage of such conifer *Abies*, *Larix*, *Pinus Haploxylon*-type, *Picea* with common or rare *Betula*, *Lepidobalanus*, *Salix*, *Alnus* and forbs. Such flora is fundamentally similar to forest of the present taiga and/or mixed forests by conifer and broad-leaved trees distributed around Lake Baikal in the present-day eastern Siberia.

On the basis of the present writer's palynological research and the previous studies by the Russian scientists (Belova *et al*., 1982 ; Zubarev, 1983), Subzone A-4 may have been correlated preliminaly with the end of the Boreal period, Subzone A-3 with Atlantic, Subzone A-2 with Subboreal, and Subzone A-1 with Subatlantic respectivelly. A detailed comparison from the view points of climate and vegetation may be analized by many core samples obtained from the bottom of Lake Baikal in the nearest future.

On the other hand, the Pollen Zone B is characterized by scantiness of pollen grains and spores. An absolute number of such fossil nonarboreal pollen grains as Gramineae, *Artemisia*, Cyperaceae and Chenopodiaceae is very rare. Such pollen-flora is similar to pollen assemblage from flora as the present-day tundra distributed in the northeastern Siberia around the Arctic Ocean. Therefore, it seems to be indicated that such flora might have been thrived under the cold climatic condition during the Last Glacial period (Fig. 4, 5).

A detailed global comparison for such six subzones as Subzones B-1 to B-6 from the view points of palaeoclimate and chronology may have been studied in the nearest future.

7. Conclusion

The present writer can analize from the view point of a palynological investigation about twenty samples from about 5 meters core obtained in the present bottom of Lake Baikal, and got tentatively a few conclusions as follows :

(1) The pollen assemblages of nineteen core samples are shown.

(2) These assemblages are divided into two pollen-zone A and B, and also the pollen -subzones as Subzones A-1 to A-4 and Subzones B-1 to B-6 respectivelly.

(3) The Pollen Zone A is characterized by predominate *Abies*, *Larix*, *Pinus Haploxylon*-type and *Picea* with common or rare *Betula*, *Lepidobalanus*, *Salix*, *Alnus*, which have been grown widely in the present-day taiga and/or broadleaved mixed forest in and around the Baikal Basin, southeastern Siberia.

(4) The Pollen Zone A may have been chronologically correlated with the Holocene period, and the Pollen Zone B with the latest Pleistocene period.

(5) In the Pollen Zone A, the Pollen Subzone A-4 may be correlated with the end of Boreal, A-3 with the Atlantic, A-2 with Subboreal and A-1 with the Subatlantic period respectivelly.

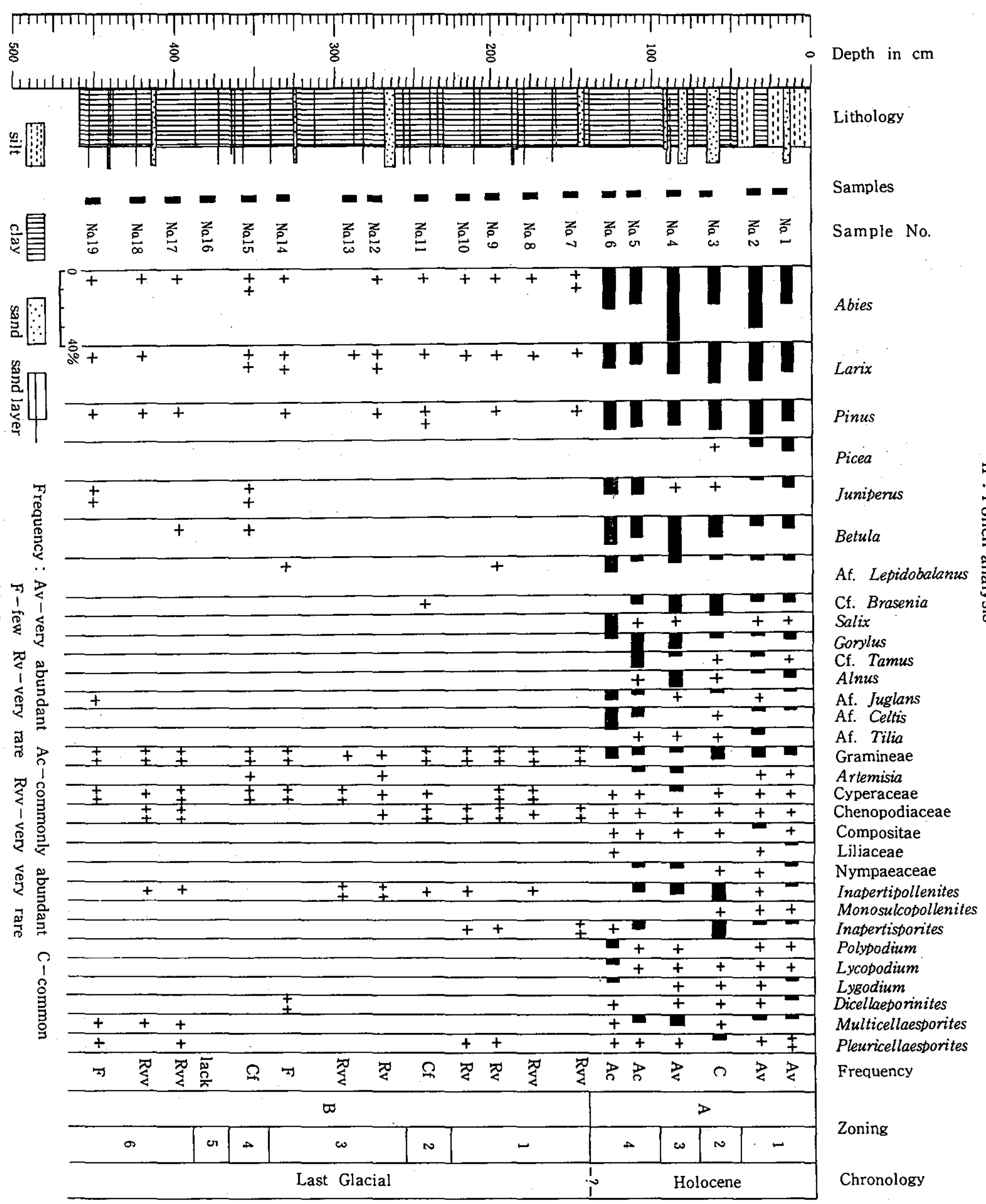

Fig. 4. Pollen diagram of core-sample: 323-PC1 obtained from Lake Baikal. (Fuji, 1992)

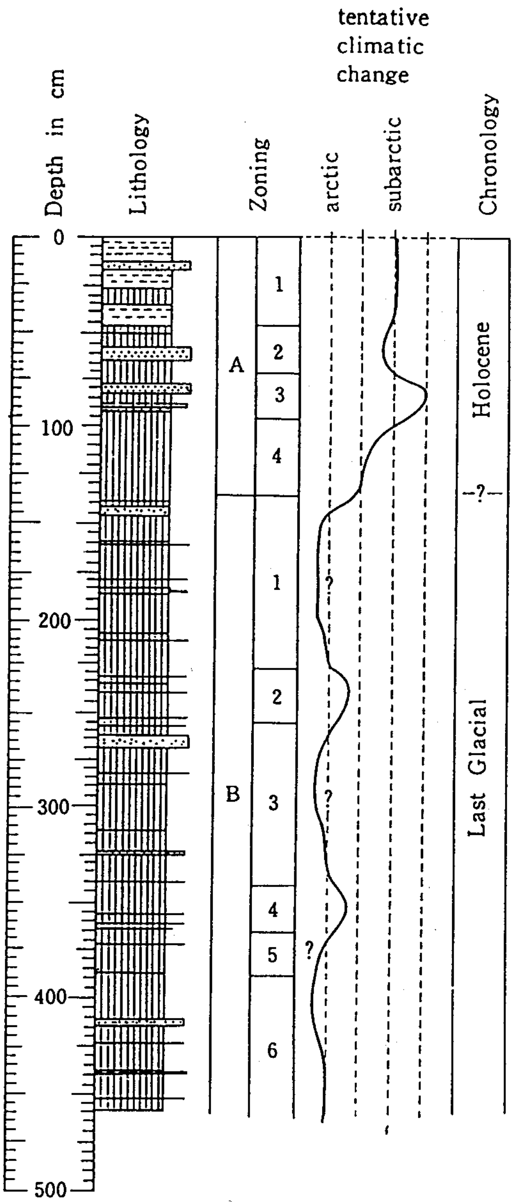

Fig. 5. Tentative palaeoclimatic change in the Baikal area, Siberia based on the palynological analyses (Fuji, 1992).

(6) From the view points of an absolute number of pollen grains and spores and pollen assemblages, the Pollen Zone B may be correlated with the Last Glacial period.

(7) The detailed changes of palaeovegetation and palaeoclimate based upon the palynological investigation shall be analysed by many core samples obtained from deeper holes drilled in the near future.

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