THE NEW POLLEN DATA ABOUT LATE QUATERNARY VEGITATION IN NORTHEAST SIBERIA

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ABSTRACT

Detailed palinological investigations of sediments of lakes lokated in different phytogeographic zones ofnortheast Siberia, South Chukotka (Patricia's lake), Upper Kolyma, Annachag Ranges (Figurnoe and Elgennya lakes), northern coast of the Sea of Okhotsk (Glukhoye lake) testify to the synchronous character of climatic changes in Western Beringia at the end of Quaternary period. In Late Pleistocene (Sartanian, Late Visconcene) absinthecerial tundra prevailed on the most parts of the region. About 12,5 thousand years ago these tundras were replaced by birch shurb ones changing by large shurb and deciduous forests due to the rise of temperature. 8 thousand years ago *Pinus plumila* to play an important role in vegitation cover. *Pinus pumila* formed the independent plantation above the boundary of deciduous forest in mountains. In the south of Chukotka, large shurb cedar tundra was widely spread. The peculiarities of the vegitation cover development of Western Beringia are analyzed in comparison with the eastern part of Beringia (Alaska)

Vegetation history and the response of past ecosystems to fluctuations in climate and sea levels associated with changing glacial and interglacial conditions have always been central themes of late Quaternary research in Beringia (the Kolyma drainage of northeast Russia eastward to northwestern most Canada; Hopkins, 1967; Shilo et al., 1987; Kontrimavichus, 1984). As the earliest scientists gathered data from the then poorly known region, they developed paleoenvironmental reconstructions that viewed: 1) the late Pleistocene vegetation as similar throughout Beringia; 2) the post-glacial vegetation shifts as synchronous across most, if not all, of this broad subcontinent; and 3) the post-glacial vegetation change as reflecting a simple south-to-north migration from glacial refugia of intact communities whose composition was similar to modern (e.g., Matthews, 1976; Guthrie, 1968; Colinvaux, 1964; Livingstone, 1955). Implicit in all of these ideas is either a similarity of climate across Beringia or a strong north-south zonal pattern with no significant east-west variations.

The hypothesis that the full-glacial vegetation was a uniform grassland or steppe was the first of these issues to be seriously challenged by paleoecologists who proposed a more complex vegetational mosaic, involving both altitudinal (e.g., Schweger and Habgood, 1976; Schweger, 1982; Guthrie, 1982) and regional (Anderson, 1988; Barnosky et al., 1987) gradients. As additional late- and post-glacial pollen records became available, the strong individualistic responses of the major plant taxa to post-glacial climatic amelioration and the time-transgressive nature of the major vegetational changes also became evident (Anderson and Brubaker, 1994; Anderson and Brubaker, 1993; Barnosky et al., 1987; Ritchie 1984). Finally, the development of atmospheric general circulation computer models revised ideas of late Quaternary climates. These simulations suggested that areas respond in a more complex and individualistic manner to shifts in global climate controls (COHMAP, 1984; Wright et al., 1993). Furthermore, the model results for Beringia indicated that no single uniform climate dominated this region over the last 18,000 years and that important east-west variations in climate might be expected (Barnosky et al., 1987).

The newer interpretations were based primarily on evidence from eastern Beringia (Alaska and adjacent northwestern Canada). However, palynological data from western Beringia (northeastern Siberia) also imply that significant differences in vegetation and climate history probably characterized each side of the Bering Strait, at least over the last 10,000 to 12,000 years (Lozhkin, 1993; Lozhkin et al., 1993). These paleobotanical data were obtained from peats or organic-rich alluvial deposits that often had poor dating control (Shilo et al., 1987). Therefore, comparisons to the eastern Beringian records, obtained primarily from lake cores, were difficult because of problems in interpreting pollen assemblages from different sampling media (i.e., lake vs. peat) and questions of timing of the observed vegetational changes. Consequently, a cooperative Russian- American coring project was begun in 1989 to retrieve late Quaternary lacustrine pollen records from western Beringia as a means to improve our understanding of the spatial and temporal variability in vegetation and climates of Beringia. We present preliminary findings from select sites. Although these cores currently lack radiocarbon dates, they are adequate to discuss the emerging paleoenvironmental patterns in late Quaternary Beringia.

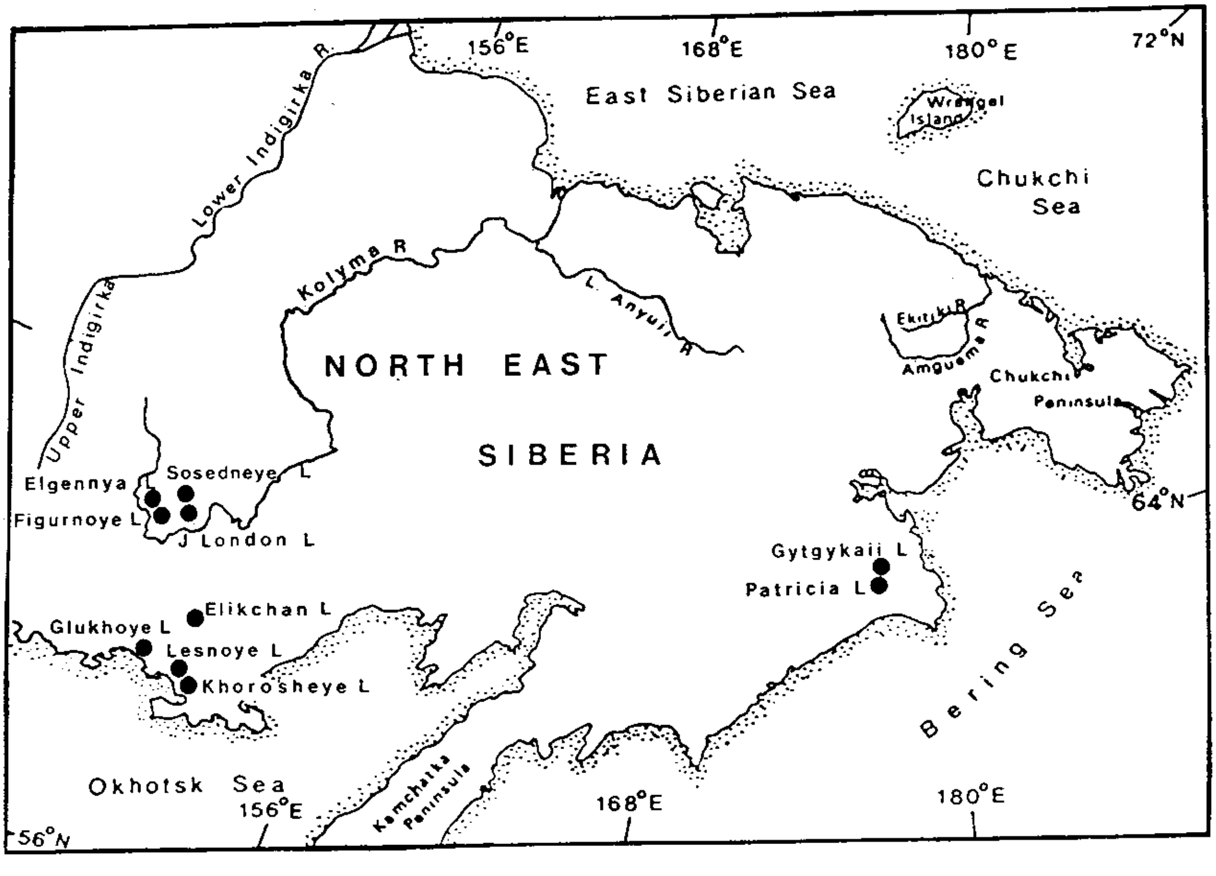

Fig. 1. Map showing locations of coring sites.

Patricia Lake (informal name) is located in the northern foothills of the Kankaren Range (Fig. 1). The lake consists of a single basin with a maximum depth of ca. 11 m. It is of glacial origin and surrounded by moraines of Sartan age (late Wisconsinan equivalent in North America; Shilo, 1961). We raised a 512 cm core which consisted of organic-rich silts (0-428 cm) and silts with 1 to 5 cm thick sand layers (428 to 512 cm). Today the region is characterized by a unique high shrub tundra dominated by *Pinus pumila* and *Alnus fruticosa*. These shrubs often grow to heights of 2 m or more. Other members of this community include *Betula exilis*, Ericales (e.g., *Ledum decumbens, Empetrum nigrum, Vaccinium vitis idaea*), *Salix spp.*, Cyperaceae, Poaceae, *Potentilla*, and *Spiraea*. Small outlying populations of Populus sauveolens, reaching heights of ca.7 m, occur occasionally along streams ca. 18 km from Patricia Lake.

The Patricia Lake pollen diagram has been divided into five zones (Fig. 2). The basal zone (***PA1***) is dominated by Cyperaceae, Poaceae, and *Artemisia* pollen and *Selaginella rupestris* spores. Percentages of *Artemisia* and Poaceae pollen and *Selaginella rupestris* spores increase with greater antiquity in the zone, whereas *Salix* pollen percentages increase from trace amounts to ca. 20% near the top of the zone. Pollen from other shrubby species occurs in trace amounts only. The minor pollen taxa (e.g., Polygonaceae, Rumex, Chenopodiaceae, Caryophyllaceae, Ranunculaceae, *Thalictrum*, Brassicaceae, Saxifragaceae, Rosaceae, Leguminosae, Schrophulariaceae, Plantaginaceae, *Valeriana*, Asteraceae, and Cichoriaceae) indicate that a variety of ecological settings were present. Pollen assemblages of Sartan age are characterized by high percentages of graminoid (Cyperaceae and Poaceae) and *Artemisia* pollen, moderate amounts of *Salix* pollen, and a great diversity of minor herb taxa. Although no radiocarbon dates are available, the similarity of the zone ***PA1*** spectra to herb zone assemblages from other dated sites indicates a full-glacial age. These data suggest that the southern Chukotkan vegetation was a mosaic of tundra communities, ranging from dry stony slopes supporting a discontinuous vegetation to Cyperaceae-true moss associations with prostrate *Salix* shrubs. The abundance of *Selaginella* *rupestris* spores implies that much of the landscape was poorly vegetated. *Betula* and *Alnus* shrubs were most likely absent or, if present, they were extremely rare. Climates were significantly cooler and drier than present.

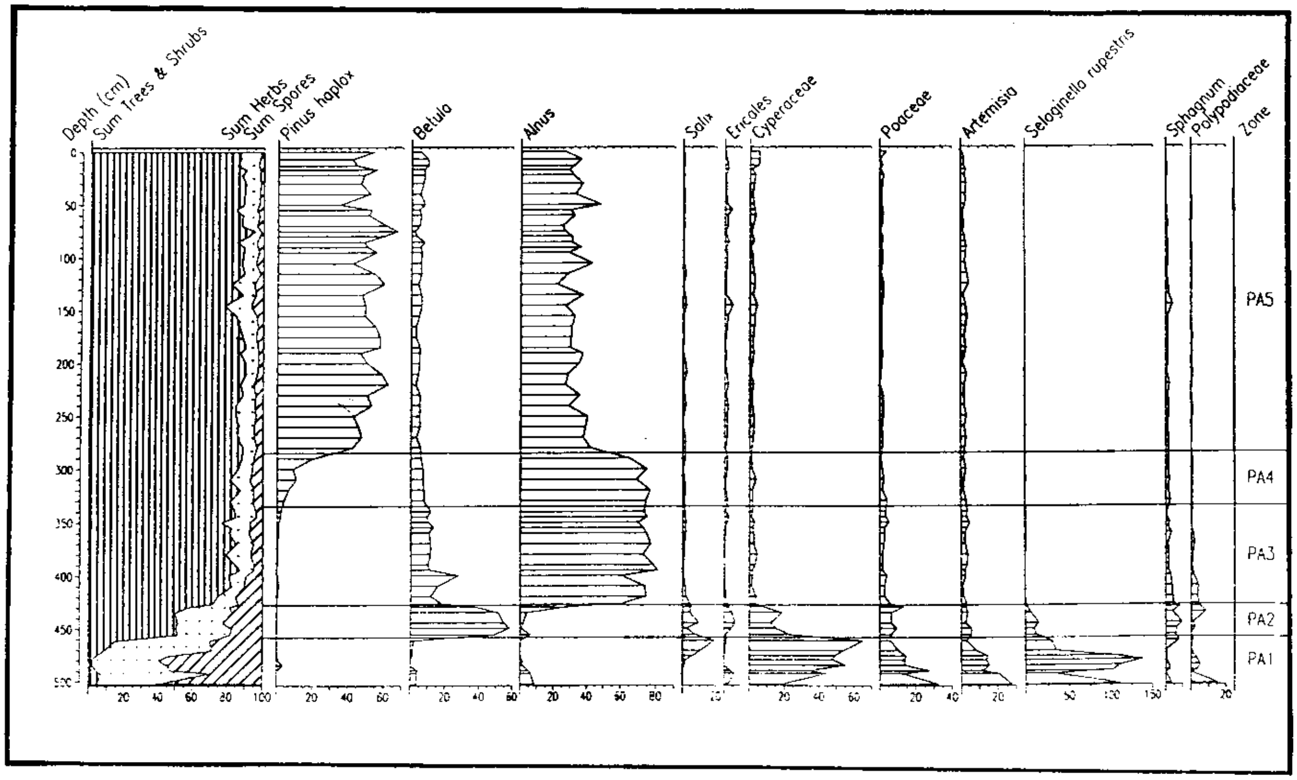

Fig. 2. Percentage diagram of major taxa from Patricia Lake.
The subsum curves on the left hand side of the diagram are based on a sum of trees, shrubs, herbs and spores (Russian method). Curves for the individual taxa are based on a sum of all tree, shrub, and herb pollen (American method).

Betula pollen rises dramatically in zone PA2, and pollen of Cyperaceae, Poaceae, *Artemisia*, and *Salix* continue to be important in the assemblage, although less so than in zone ***PA1***. Ericaceous pollen is also greater in this zone. *Selaginella rupestris* spores decrease, whereas spores of Polypodiaceae and *Sphagnum* increase. Changes in the zone ***PA2*** pollen assemblage reflect the first influences of post-glacial climatic amelioration and mark the replacement of the herb-*Salix* communities with a *Betula* shrub tundra. A greater abundance of mesic sites is suggested by the increase in *Sphagnum* spores. This shift from herb to *Betula* tundra is documented throughout northeastern Siberia and consistently dates to ca. 12,000 to 12,500 B.P. (Lozhkin and Fedorova, 1989; Lozhkin, 1991; Lozhkin, 1993; Lozhkin et al., 1993).

Zone ***PA3*** is dominated by *Alnus* pollen and indicates the establishment of an *Alnus-Betula* shrub tundra. The appearance of *Betula* sect. Costate pollen suggests that trees grew at or near the site. Because *Betula* pollen can be blown for long distances, the presence of *Betula* trees (likely *Betula ermanii* and/or *Betula lanata*) needs to be confirmed with macrofossils. However, if true, the data indicate a ca. 200 km range extension for the species. Although Populus groves are found near Patricia Lake today there is no indication of expanded populations during zone ***PA3***.

Pinus pollen percentages first rise in zone ***PA4***, with a slight decline in *Betula* pollen. Although a few *Pinus pumila* shrubs may have been present, the major population establishment did not occur until zone ***PA5***, which shows a dominance of *Pinus* Haploxylon pollen. The modern vegetation was likely established at this time.

Elgennya Lake is located between the Malyii and Bolshoi Annachag Ranges of the Upper Kolyma drainage (Fig. 1) and was formed by a terminal moraine from a late Pleistocene valley glacier. The lake is large and deep (maximum depth of ca. 40 m), with a complex basin morphology. A ca 4.5 m core was raised from a 14 m deep basin in the southwestern area of the lake. This core is dominated by organic-rich silts in the upper 300 cm, whereas the lower 150 cm are primarily silts or sandy silts. A thin tephra layer occurs at 307 cm. We believe this to be the Elikchan tephra which has been dated to ca. 8,300 B.P. (Lozhkin et al., 1993). The Upper Kolyma region supports a *Larix dahurica* forest at low to mid-elevations. *Populus sauveolens* and *Chosenia arbutifolia* form gallery forests along the major streams. *Pinus pumila, Betula exilis*, and Ericales are important members of the understory. *Pinus pumila* also forms a zone of high shrub tundra in areas immediately beyond altitudinal treeline. Shrub *Salix spp.* and *Alnus fruticosa* are present near streamsides. The latter also occurs in mountain draws and at mid-elevations.

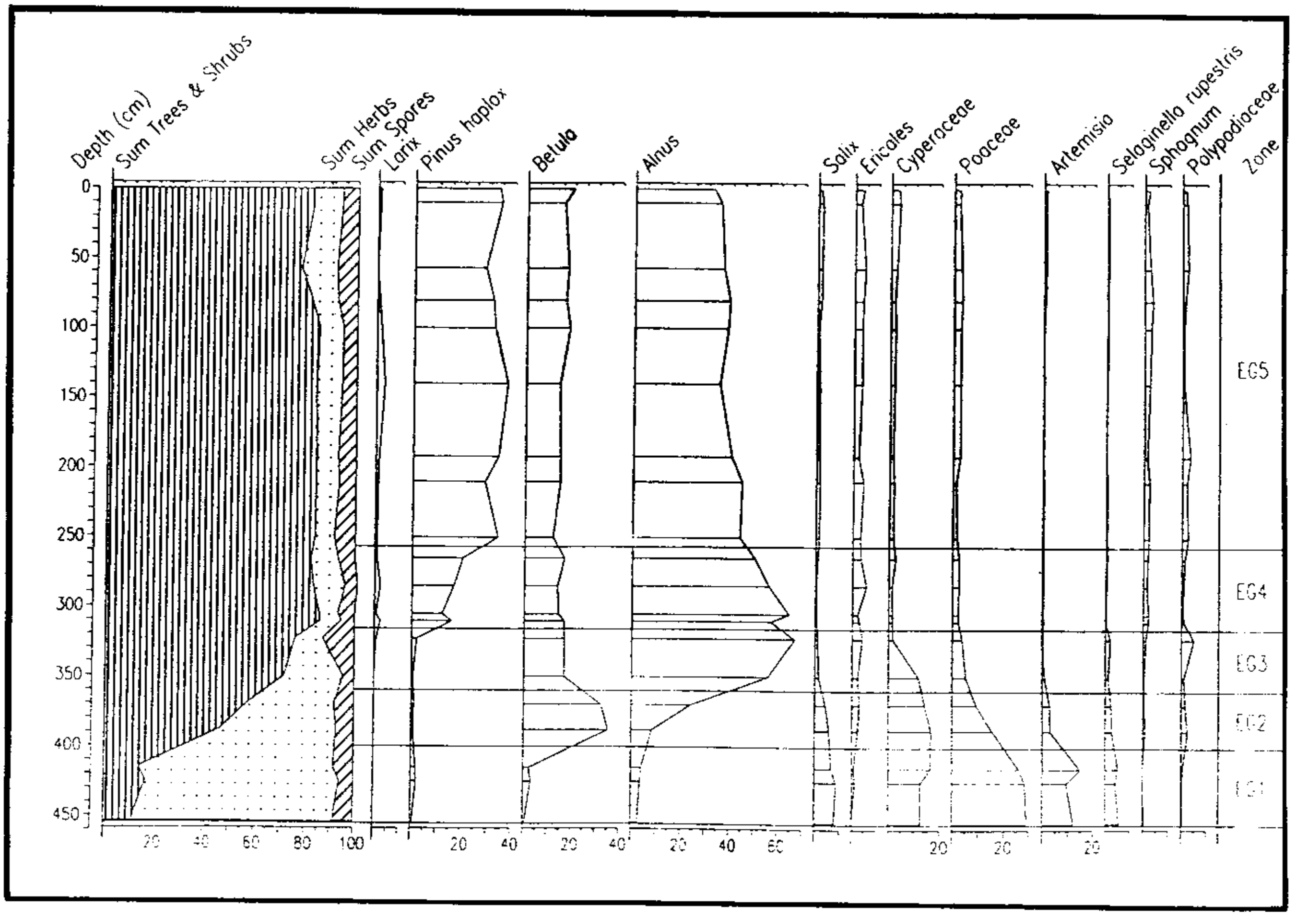

Fig. 3A. Percentage diagram of major pollen and spore taxa from Elgennya Lake.

Like the Patricia Lake diagram, the oldest zone in the Elgennya record (zone ***EG1***; Fig. 3A) is presumably of Sartan age and is dominated by Cyperaceae, Poaceae, *Artemisia* and *Salix* pollen with a great diversity of minor herb taxa (e.g., Ranunculaceae, *Thalictrum*, Rosaceae, Saxifragaceae, Asteraceae, Scrophulariaceae, *Pedicularis*, Caryophyllaceae, and Brassicaceae). Although *Selaginella rupestris* spores are present, they occur at only a fraction of the values recorded in the Patricia Lake herb zone. This assemblage indicates the presence of an herb-dominated tundra associated with cool, dry climates. *Salix* and perhaps some Ericaceous species are the only shrubs present at this time.

As conditions ameliorated, the vegetation abruptly changed to a *Betula* shrub tundra (zone ***EG2***) that probably was quickly invaded by Alnus shrubs (zone ***EG3***). The arrival of *Betula* and *Alnus* have been dated to ca. 12,500 and 12,000 B.P., respectively, at Sosednee Lake located to the east of the Bolshoi Annachag Range (Lozhkin et al., 1993).

The appearance of minor amounts of *Larix* pollen in zone ***EG4*** marks the first establishment of the post-glacial coniferous forests. *Pinus pumila* pollen, although significant in zone ***EG4***, does not achieve maximum percentages until zone ***EG5***. Possibly the shrub was present in small numbers and restricted to the most favorable lowland habitats during zone ***EG4*** times. Pinus populations were probably not extensive until zone ***EG5*** when they expanded to form a major component of the forest understory and a mid-elevational belt of high shrub tundra. The arrivals of *Larix* and *Pinus pumila* in the Sosednee core have been dated to ca. 11,500 and 9,000 B.P., respectively. The occurrence of the Elikchan tephra at 307 cm in the Elgennya core implies that the arrival of *Pinus pumila* was probably closer to 8,000 B.P., an age slightly later than to the east of the Bolshoi Annachag Range.

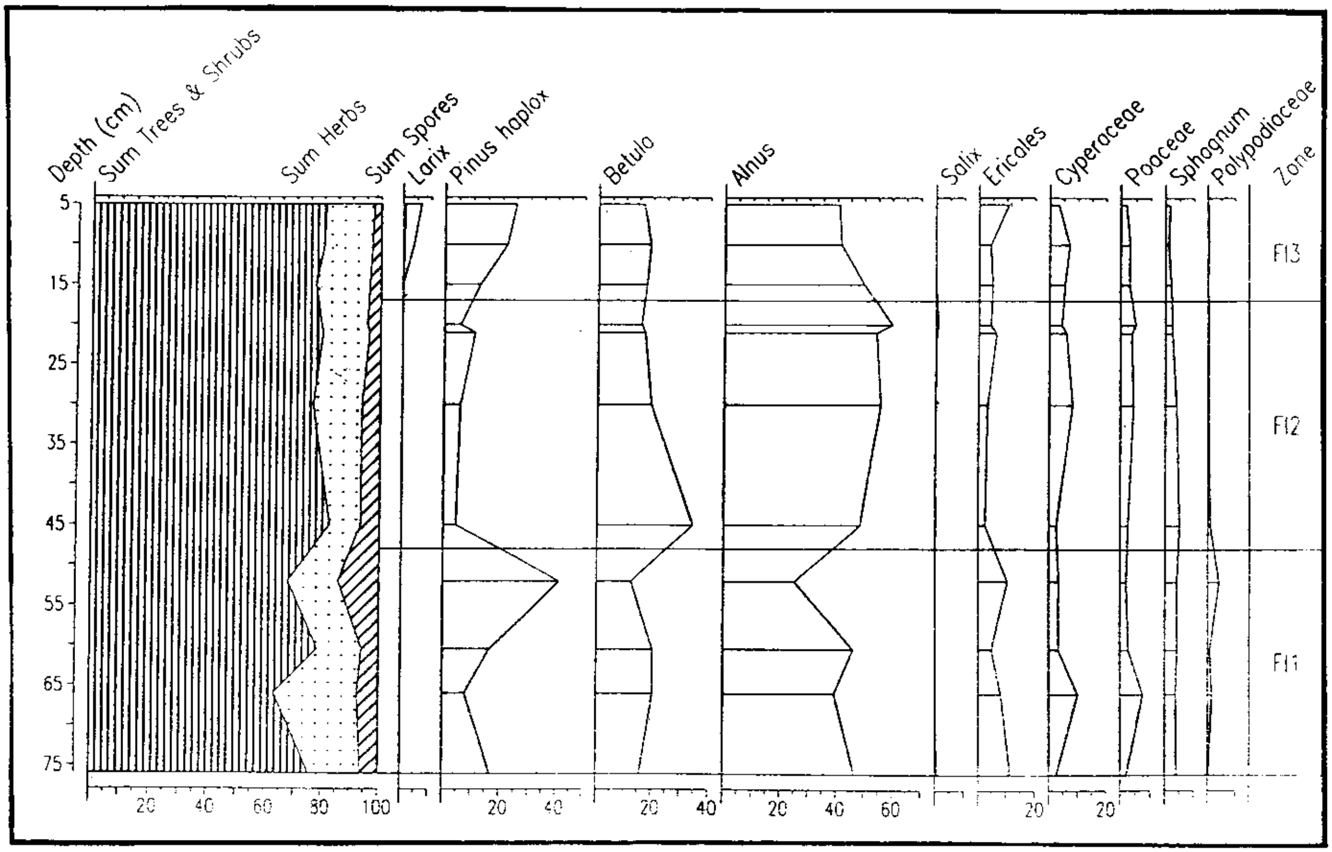

Fig. 3B. Percentage diagram of major pollen and spore taxa from Figurnoye Lake. The Larix curve is shown with a 10X exaggeration.

Slight variations in percentages of *Pinus pumila* and *Larix* pollen in zone ***EG5*** are suggested in the uppermost portions of the Elgennya diagram, but the sampling interval is too coarse to make any definitive conclusions. However, fluctuations in *Pinus* pollen are more clearly recorded at Figurnoye Lake (Fig. 3B), a kettle located ca. 0.5 km to the west of Elgennya Lake. Here we retrieved a 220 cm core in 11.6 m of water. Only the results from the upper 75 cm, which correlate to the upper portion of zone ***EG5***, are illustrated. In contrast to the Elgennya record where *Pinus* percentages are typically 30% to 40%, percentages in the Figurnoye diagram usually are below 25%, with minimum values of ca. 5%. Although differences in lake size and basin history can result in some inter-site variations in the pollen percentages, such great differences would not be expected as a simple function of depositional processes. A more likely explanation for these data is that significant fluctuations in *Pinus* populations occurred during the Holocene. *Larix* pollen is absent in the Figurnoye diagram except for the most recent samples (zone ***FI3***). A late Holocene *Larix* decline is also suggested at Elgennya Lake, although again the number of analyzed samples is insufficient to confirm this pattern. In addition, the absence of *Larix* pollen must be interpreted carefully, because this taxon is extremely under-represented in pollen records. Both *Pinus pumila* and *Larix dahurica* share similar summer temperature requirements (minimum of 12 C; Andreev, 1980). Parallel changes in their populations as inferred from these preliminary pollen data probably reflect a period of cool, late Holocene summers.

Glukhoye Lake (Fig. 1) at one time may have been an embayment of the Okhotsk Sea, but today the site lies ca. 1.5 km from the beach (Lozhkin et al., 1990). A ca. 170 cm core was obtained in ca. 2 m of water from the central area of the lake. The sediments are 0 to 13 cm organic-rich silt, 13 to 73 cm silt, 73 to 169 cm sandy silt, and gravels at the base. Like the interior, the coastal vegetation is predominantly a *Larix-Pinus pumila* forest, with *Populus suaveolens* and *Chosenia arbutifolia* forming streamside forests, and *Betula platyphylla* growing on the rocky mountain slopes. The coastal areas are characterized by a series of tectonic depressions that often support a *Salix*-Ericales tundra.

As with the other diagrams, the Glukhoye record begins with an herb-dominated pollen assemblage with a variety of minor taxa (Ranunculaceae, *Thalictrum*, Leguminosae, *Polygonum bistorta*, Rosaceae, Saxifragaceae, Umbelliferae, Lamiaceae, Caryophyllaceae, Campanulaceae, Cichoriaceae, and Valerianaceae; zone ***GK1***; Fig. 4). However, unlike the other records, these spectra are dominated by Poaceae; Cyperaceae is virtually absent. *Artemisia* pollen is abundant in the lowermost samples of zone *GK1*, although it decreases to minor amounts in the upper portion of the zone. *Betula* and Asteraceae pollen are more common than in other herb zones. This assemblage is unique to Beringia and contrasts greatly to other full-glacial records. At first, we thought this zone reflected some unusual and local aspect of vegetation development near Glukhoye Lake, perhaps relating to the basin initially being connected to the sea. However, recent preliminary results from Lesnoye Lake (Fig. 1), a coastal site 50 km to the east of Magadan, display similar characteristics. Interpretation of full-glacial pollen spectra from Beringia are difficult because of the poor quality or lack of modern analogs during the late Pleistocene (Anderson et al., 1989). However, the dominance of Poaceae pollen may indicate the presence of meadows in the lowlands with *Artemisia*-Poaceae-herb communities on the mountain slopes or disturbed areas (e.g., along stream channels).

Post-glacial climatic amelioration is registered in the Glukhoye core in a similar manner as the other lakes; i.e., a rapid transition to a *Betula* (zone ***GK2A***) and then a *Betula-Alnus* (zone ***GK2B***) shrub tundra. Ericales pollen at Glukhoye Lake is high as compared to other western Beringian sites, probably indicating a greater importance of these shrubs on the landscape. An increase in *Sphagnum* spores indicates mesic settings were more common than during the full-glacial.

In contrast to the records from the Upper Kolyma region, *Pinus pumila* appears to establish prior to *Larix* (zone ***GK3***). However, the Glukhoye diagram includes middle to late Holocene fluctuations in *Pinus pumila* percentages. Two *Pinus maxima* were also observed in a peat exposure located 500 m to the west of the lake, with the more recent peak dating between 2,630 +/- 100 B.P. (MAG-1076) and 3,940 +/- 120 B.P. (MAG-1074; Lozhkin et al., 1990). The other peak apparently predates 5,530 +/- 2000 B.P. (MAG-1978). These percentage variations are much clearer than at Figurnoye or Elgennya Lakes, thereby suggesting that the patterns from the interior reflect actual vegetational changes and are not an artifact of pollen depositional processes. A late Holocene decline in *Larix*, postulated from the interior diagrams, does not seem to occur at the coast. Although *Larix* and *Pinus pumila* have similar summer temperature requirements, they need different winter conditions. *Larix* survives the severe winters by shedding its leaves to protect itself from winter desiccation. *Pinus pumila* retains its leaves, but prior to snow fall its branches become decumbant. In this way the shrub is covered by the autumn snows which act as an insulator from the extreme winter conditions. Thus variations in *Pinus pumila* populations, as inferred from changes in the pollen percentages, likely reflect changing winter/fall snow conditions.

Although all of the above diagrams require more analysis and radiocarbon dating, some preliminary conclusions can be made about spatial and temporal variations in past environments of western Beringia during the late Pleistocene and Holocene.

1. The full-glacial vegetation of Beringia was not uniform, but significant variation existed within western Beringia and between eastern and western Beringia. Both regional and elevational variations have been described for eastern Beringia based on relatively slight variations in percentages of Cyperaceae, Poaceae, and *Artemisia* and select minor herb taxa (e.g., *Thalictrum*, Cruciferae, Asteraceae; Anderson and Brubaker, 1994). Regional variations also seem to characterize western Beringia, but the paleovegetational differences may be even greater than those documented to the east. The Glukhoye diagram provides the first major deviation from the usual Cyperaceae-Poaceae-*Artemisia* spectra and indicates the presence of a vastly different vegetation type along the northern Okhotsk Sea coast. Although the full-glacial assemblage from Patricia Lake is similar to those from eastern Beringia, the high percentages of *Selaginella rupestris* spores suggest a landscape that likely had a greater abundance of dry, stony sites. Such variations in these herb-dominated vegetation types imply that, although the Sartan climate was cooler and drier than present, important temperature and effective moisture gradients occurred in Beringia during the full-glacial.

2. Unlike eastern Beringia (Anderson et al.,1988), the post-glacial transition from tundra to coniferous forest in Western Beringia apparently lacks a period of *Populus* dominance (ca. 9,000 to 11,000 B.P.). The appearance of tree Betula pollen at Patricia Lake suggests that a broadleaf deciduous woodland may have been present in southern Chukotka at or near this time, but available data suggest that this vegetation type was not as extensive as in eastern Beringia. The establishment of a *Populus* forest in eastern Beringia may imply that summer conditions were warmer and/or drier to the east of Bering Strait during the Holocene-late Pleistocene transition.

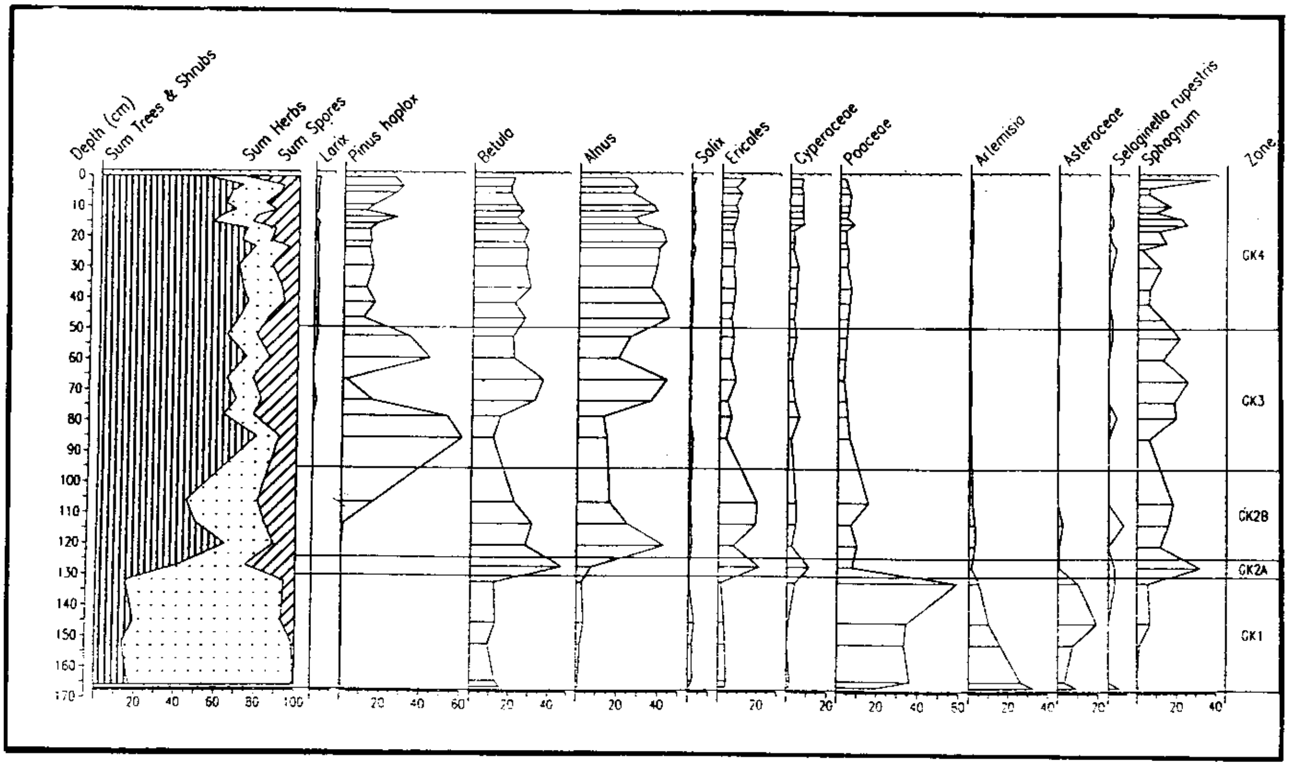

Fig. 4. Percentage diagram of major pollen and spore taxa from Glukhoye Lake. The Larix and Selaginella rupestris curves are shown with a 10X exaggeration.

3. Although the northward extension of *Betula* and *Larix* treeline during the early Holocene is well documented in northern Chukotka (Lozhkin, 1993; Glushkova et al., this volume), an eastward expansion of *Larix*3 apparently did not occur in southern Chukotka. The distribution of *Betula* is less certain, but, as stated above, the trees may have not been abundant in areas beyond their current range limits. The different behaviors between latitudinal and longitudinal treeline probably reflect the importance of sea surface temperatures and reorganizing circulation patterns (e.g., southerly winds blowing off the cool north Pacific Ocean and opening Bering Sea would counteract the effects ofincreased insolation to depress summer temperatures in southern Chukotka).

4. *Larix* and *Pinus pumila*, the two major tree/shrub taxa in Western Beringia, responded individualistically to post-glacial climatic amelioration. This is evidenced by the establishment of *Larix* prior to *Pinus pumila* in interior regions, whereas *Pinus pumila* establishment preceded *Larix* on the coast. Such behavior implies that either the two species have greatly different migration rates or that the vegetation communities within glacial refugia were dissimilar than modern.

5. The major tree and shrub species at northern high latitudes are typically limited by summer conditions. However, *Pinus pumila* is equally dependent on snow depth, thereby providing a means to examine winter climates. Fluctuations of *Pinus pumila* percentages suggest significant variations in the shrub's population and therefore winter precipitation during the middle and late Holocene.

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