УДК 551.583.7(571.65)

VEGETATION RESPONSE TO CLIMATE CHANGE DURING THE MIDDLE CALABRIAN IN ARCTIC CHUKOTKA

A. V. Lozhkin[1], P. M. Anderson[2]

[1]*North-East Interdisciplinary Scientific Research Institute n. a. N. A. Shilo, FEB RAS, Magadan*
[2]*Quaternary Research Center, University of Washington, Seattle WA, USA*
E-mail: lozhkin@neisri.ru, pata@uw.edu

A palynological record obtained from El'gygytgyn Lake sediments, which spans the 1.244–1.304 million years (Ma) interval of the Calabrian Stage, shows repeated changes in the plant communities of Arctic Chukotka. These variations in the vegetation further suggest a dominance of interstadial and interglacial climates. Eight pollen zones were distinguished within this interval. According to the working age model for the composite El'gygytgyn core, these pollen zones correspond to marine oxygen isotope stages (MIS) 40, 39, and 38. The upper boundary of MIS 38 coincides with magnetic event the Cobb Mountain (1.240 Ma), which is one of the main chronological landmarks used in creating the core's chronology. The features of modern pollen-spore spectra obtained from the water-sediment interface within the lake aided in reconstructing both the local and regional paleovegetation. The consistent presence of *Larix* pollen throughout the 1.244–1.304 Ma interval indicates that even under the severest climatic conditions *Larix* forest-tundra persisted on the Anadyr Plateau and near El'gygytgyn Lake. This pattern differs sharply from that seen in the Middle and Late Pleistocene when herb-dominated tundra characterized the glacial intervals in the Arctic. The spore-pollen spectra further show that the warmest climatic conditions occurred during MIS 39. The data from the 1.244–1.304 Ma interval represent the last step in completing the Quaternary vegetation history from this unique site in Arctic Siberia.

***Keywords*: isotope stage, pollen zone, spore-pollen spectra, changes in plant communities, forest-tundra, interstade, interglaciation.**

DOI: 10.34078/1814-0998-2022-3-63-72

A continuous palynological record obtained from sediments of El'gygytgyn Lake documents changes in vegetation in Arctic Chukotka throughout the Quaternary and into the latest Pliocene (Piacenzian Age). The lake lies within a meteor impact crater, which formed *c*. 3.58 million years (Ma) ago (Layer, 2000). The crater is located beyond the Arctic Circle at 67º30' N, 172º05' E (Fig. 1*a*) with an elevation of 492 m above sea level. The maximum diameter of the crater is 18 km. The circular shaped lake varies in width between 12 and 14 km and has a water depth of 176 m in the central part of the basin (Fig. 1*b*). The peaks of the Anadyr Plateau, which surround the lake, rise to 600–1000 m above sea level. The full 317-meter thickness of the El'gygytgyn Lake sediments, represented by silt with a mix of fine-grained sand, was recovered at coring site 5011-1 by the "El'gygytgyn Drilling Project" in 2009. Previous analyses of younger sediment cores (Melles et al., 2012; Nowaczyk et al., 2013; Lozhkin et al., 2020; Lozhkin, Anderson, 2020) described the plant communities associated with various glaciations and interglaciations of the last 2.588 Ma. The data presented herein span the interval between 1.244 and 1.304 Ma and represent the latest step in the completion of the Quaternary vegetation history from this unique site in Arctic Siberia.

A working chronology for a composite sediment core from El'gygytgyn Lake was determined by comparing its magnetic characteristics to patterns described in the Global Chronostratigraphic Correlation Table (Fig. 2). This chronology was refined further by aligning sediment characteristics (e. g., Si/Ti ratios, biogenic silica, total organic carbon) with the marine isotope stack LR04 (Lisiecki, Raymo, 2005) and with the summer insolation curve for 65º N (see Nowaczyk et al., 2013 for more details). The timing of the meteorite impact has been $^{40}Ar/^{39}Ar$ dated to 3.58 Ma and provides a basal age for the composite core. Thus, all sediment samples from the El'gygytgyn core have been assigned ages based on the established age model. According to this chronology, the results presented in this paper fall within the interval 1.244–1.304 Ma, which en-

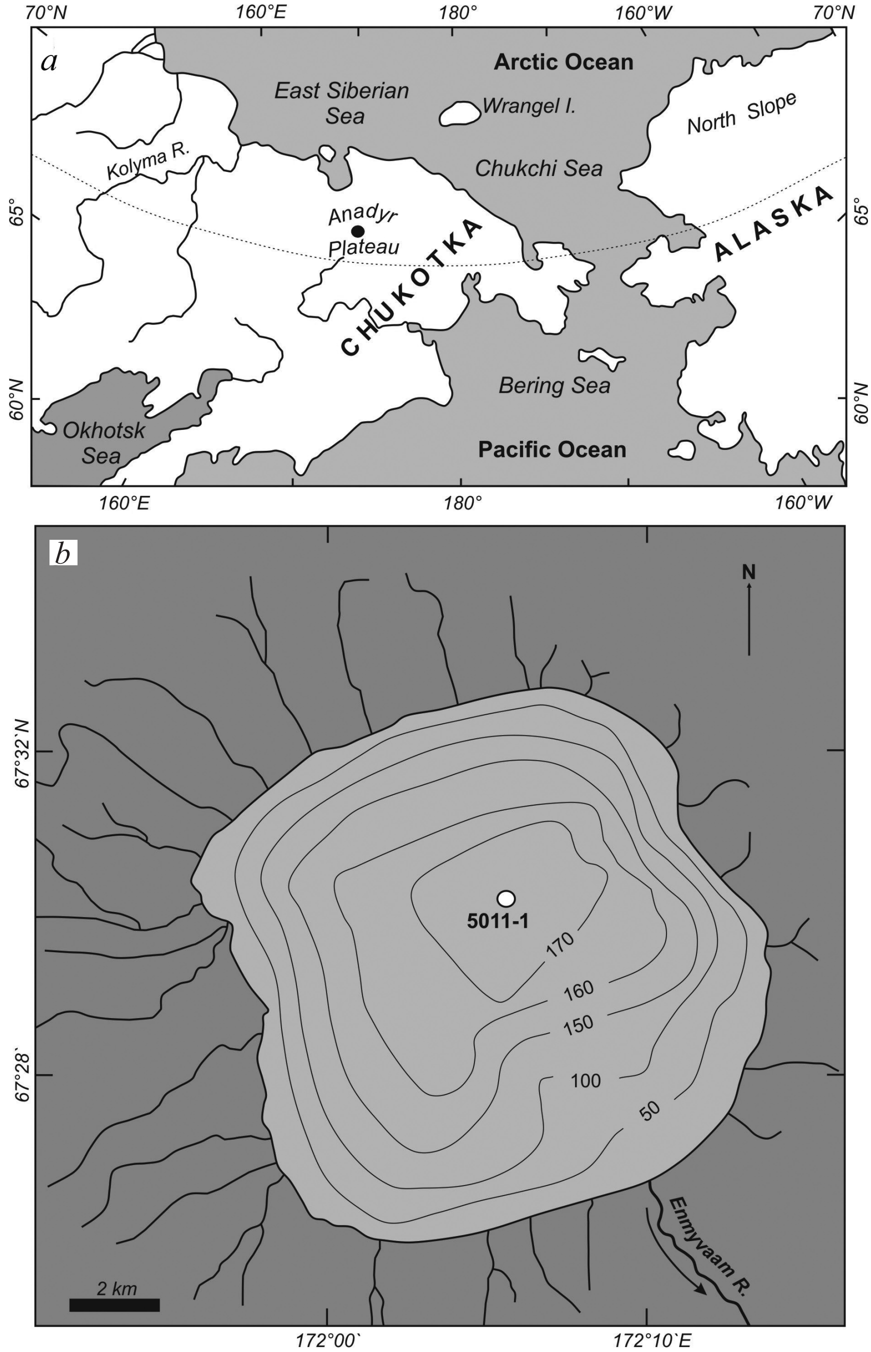

Fig. 1. Maps showing: (*a*) the location of El'gygytgyn Lake (dark circle) within Beringia; the dotted line represents the Arctic Circle; and (*b*) the bathymetry of El'gygytgyn Lake (water depths in meters), the location of the coring site (white circle), and the El'gygytgyn catchment including the Enmyvaam River (lake outlet)

Рис. 1. Карта-схема (*а*), показывающая нахождение оз. Эльгыгытгын (темный кружок) в пределах Берингии; пунктирная линия представляет полярный круг. Карта-схема (*b*), показывающая батиметрию оз. Эльгыгытгын (глубины озера даны в метрах), место отбора керна озерных осадков (белый кружок), ручьи, впадающие в озеро, и вытекающая из озера р. Энмываам

compasses marine isotope stages (MIS) 38–40. The upper boundary of MIS 38 approximates magnetic event the Cobb Mountain (1.240 Ma), thereby acting as a strong chronological "landmark" for determining the upper age of the results presented here.

The 1.244–1.304 Ma interval falls within the Calabrian Stage. Its upper limit is determined by the boundary of the Brunhes-Matuyama paleomagnetic zone, which has been dated to 781 thousand years ago. The lower Calabrian boundary corresponds to the upper limit of the Gelasian Stage. The Quaternary Subcommittee of the International Commission on Stratigraphy (ICS) determined this boundary to be 1.806 Ma. In 2011, the Executive Committee of the International Union of Geological Sciences (IUGS) approved the ICS application for the global strato-

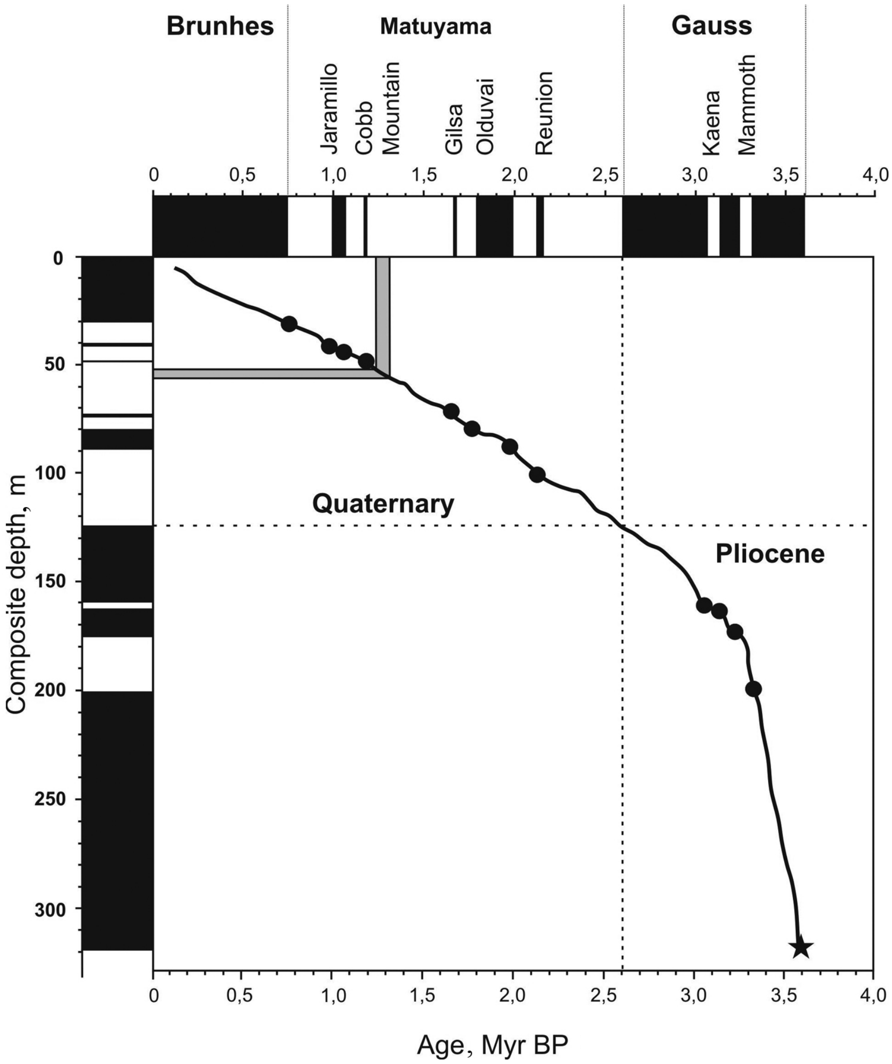

Fig. 2. Paleomagnetic events and the Lake El'gygytgyn age model. The horizontal scale at the top of the figure corresponds to the global paleomagnetic chronology. The vertical column reflects the magnetic characteristics of the El'gygytgyn sediments. The black line indicates the age-depth model used in the El'gygytgyn core. The black dots mark the ages of the magnetic events, and the star denotes the age of the meteorite impact as determined by $^{40}Ar/^{39}Ar$ dating. The gray bar highlights the interval discussed in this paper (1.244–1.304 Ma). See Nowaczyk et al. (2013) for more details

Рис. 2. Палеомагнитные события и возрастная модель оз. Эльгыгытгын. Вертикальный столбец в левой части рисунка отражает магнитные характеристики отложений оз. Эльгыгытгын. Горизонтальная шкала вверху рисунка соответствует глобальной палеомагнитной шкале. Границы магнитных событий отмечены черными точками. Падение метеорита 3.58 млн лет назад ($^{40}Ar/^{39}Ar$) отмечено звездочкой. Изогнутая линия указывает на модель, используемую для определения возраста озерных отложений. Серая полоса – рассматриваемый интервал (1.244–1.304 млн лет назад). См. Nowaczyk et al. (2013) для более подробной информации

type of the Calabrian-Gelasian boundary (GSSP) based on the Vrica section in southern Italy (Cita et al., 2012). The boundary is located at the top of sapropel "e" in the upper part of the Olduvai subchron (1.77–1.95 Ma). It is also approximates the boundary between MIS 65 and MIS 64 (Lisiecki, Raymo, 2005).

The preparation for palynological analysis of samples taken between 1.244 and 1.304 Ma followed the same methods as used for other core intervals from El'gygytgyn Lake. This technique is one that is standard for the study of materials from organic-poor Arctic lakes (PALE, 1994). At least 300 pollen grains from terrestrial arboreal and nonarboreal plants were counted in each sample. The spore-pollen diagram (Fig. 3) shows the percentages of vegetation groups (referred to as subsums) on the left side of the diagram (i. e., pollen from trees and shrubs, from herbaceous plants, and from spores) followed by the percentages of the main individual pollen and spore taxa. A separate diagram (Fig. 4) illustrates minor pollen and spore types. Percentages of individual taxa are based on a pollen sum that includes all arboreal and nonarboreal taxa (excepting aquatics).

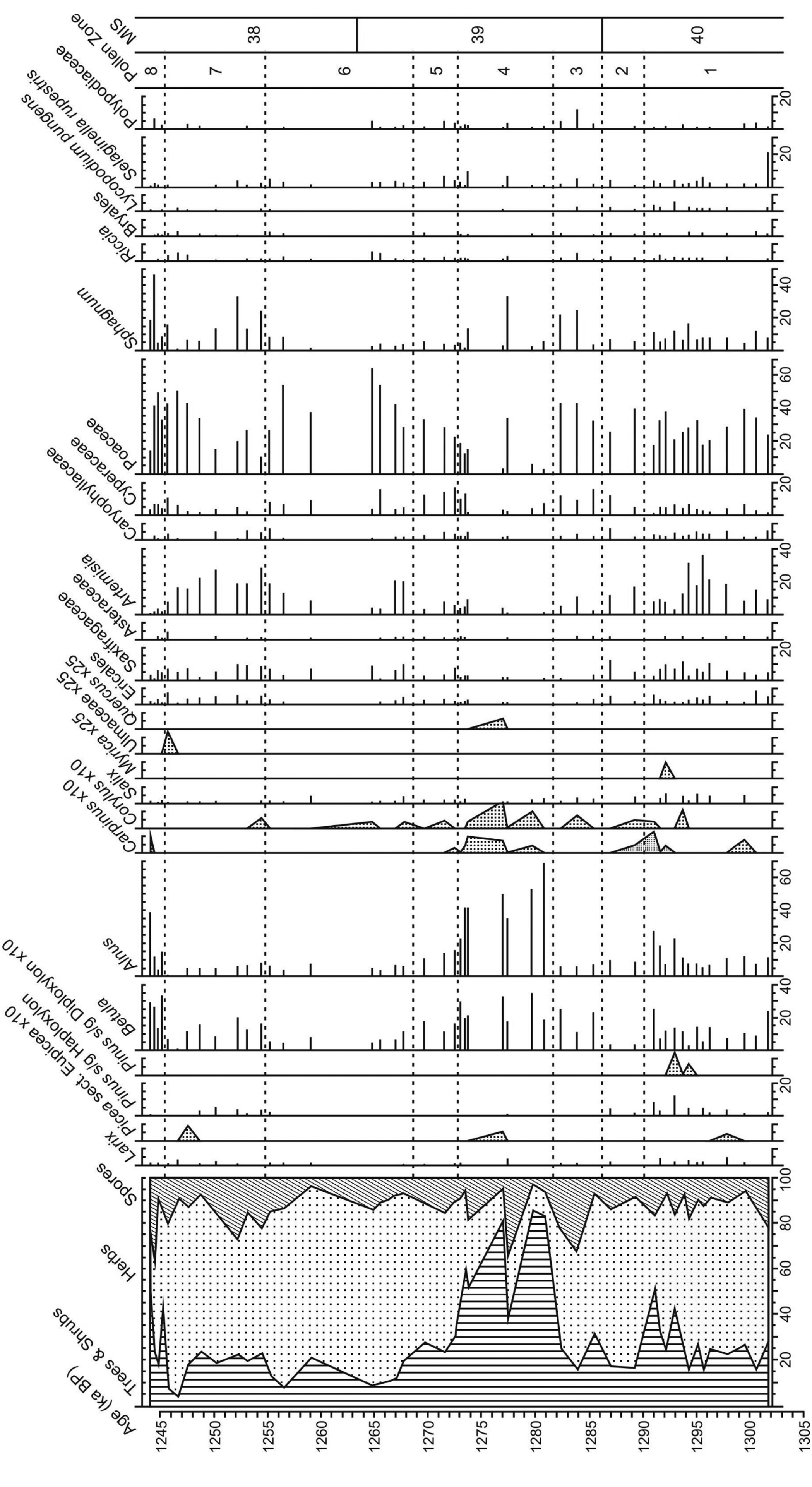

Fig. 3. Percentages of major pollen and spore taxa, including vegetation groups, from marine isotope stages 40, 39, and 38, El'gygytgyn Lake

Рис. 3. Процентные соотношения групп растительности, основных пыльцевых и споровых таксонов в спектрах осадков оз. Эльгыгытгын (изотопные стадии 40, 39 и 38)

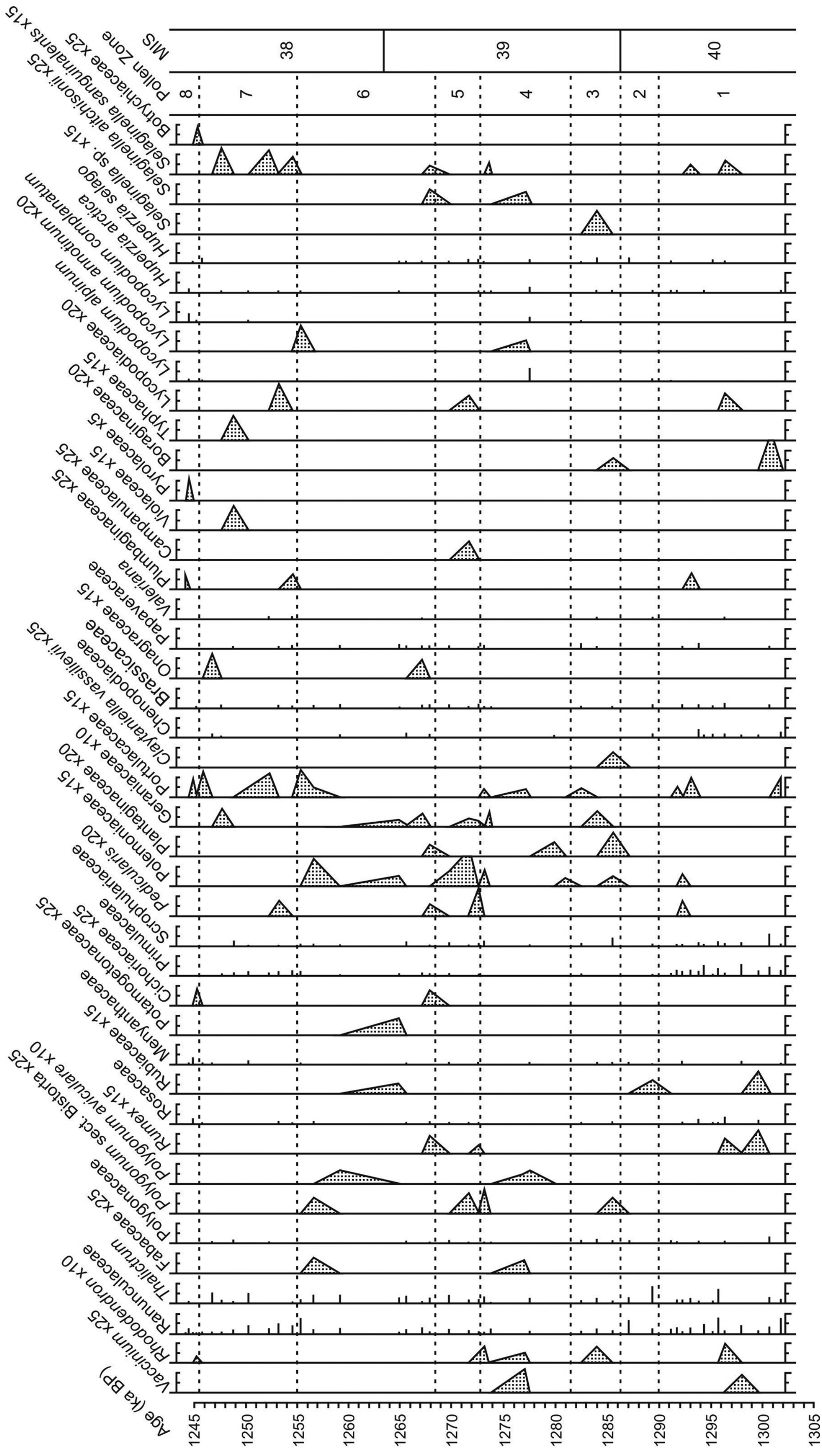

Fig. 4. Percentages of minor pollen and spore taxa from marine isotope stages 40, 39, and 38, El'gygytgyn Lake

Рис. 4. Участие второстепенных таксонов пыльцы и спор в спектрах осадков морских изотопных стадий 40, 39 и 38, оз. Эльгыгытгын

Spores are calculated as a percentage of the pollen sum. Percentages for these subsum groups are based on a sum of all nonaquatic terrestrial pollen and spores.

Low concentration of pollen in sediment samples, especially those deposited during cold stages, can affect the completeness of the pollen record. Pollen and spores are usually abundant in samples taken from interstadial or interglacial sediments, but they are fewer in sediments deposited under glacial conditions. Such differences in pollen concentrations are often found in other lake cores from North East Siberia, whose records include one or more glacial cycles. In the case of El'gygytgyn Lake, some samples between 1.244 and 1.304 Ma had pollen concentrations that were so low that a reliable pollen sum could not be obtained. New samples were then prepared adjacent to the problematic levels to obtain reliable counts.

One of the best tools for reconstructing the paleovegetation near El'gygytgyn Lake is the comparison of the fossil spore-pollen spectra to samples obtained from the lake's sediment-water interface. Such spore-pollen spectra reflect the composition of the modern plant communities (Lozhkin et al., 2020). Today the vegetation near the lake is dominated by lichens, interspersed with graminoid (Poaceae-Cyperaceae)-forb meadows. A discontinuous plant cover characterizes the crater uplands. Low shrubs of *Salix krylovii* E. Wolf and *S. alaxensis* Cov. occupy protected areas within the open mountain valleys and along the valley floor of the Enmyvaam River. *Betula exilis* Sukacz. is limited both regionally and locally to areas where organic matter has accumulated (e. g., along terraces in river valleys and mountain saddles). A mosaic of low shrub and graminoid tundra, which include small populations of *Pinus pumila* (Pall.) Regel and *Duschekia fruticosa* (Rupr.) Pouzar, are present across the Anadyr Plateau.

Pollen and spores are deposited into lakes by air currents and by overland water flow. Wind-blown pollen represents both regional and local vegetation, whereas pollen carried by ground runoff and streams primarily reflects the local vegetation. In the case of El'gygytgyn Lake, the modern pollen samples are comprised of up to 35 % *Alnus* (note: by convention the pollen of *Duschekia fruticosa* is classified as *Alnus*), ~ 20 % *Betula*, and ~ 15 % *Pinus pumila*. The total amount of shrub pollen can be up to 45%. Thus, the spectra obtained from the bottom sediments of El'gygytgyn Lake are more indicative of the regional vegetation of northern Chukotka, rather than the plant communities in the vicinity of the lake. This difference in representation reflects the low pollen productivity of the relatively sparse vegetation cover near the lake and the greater pollen productivity from the more continuous vegetation of the surrounding Anadyr Plateau.

Eight pollen zones were defined for the 1.244–1.304 Ma interval of the El'gygytgyn record based on changes in the percentages of the main pollen and spore taxa and in the vegetation group subsums (Fig. 3). Variations in the paleovegetation are most directly related to the influences of cold and warm climatic conditions, which in turn can be linked to alternating stadial/glacial and interstadial/interglacial conditions as delimited in the oxygen isotope curve. As mentioned above, pollen zones have been correlated with the MIS based on ages defined by Lisiecki and Raymo (2005) and the age model developed for the El'gygytgyn record (Nowaczyk et al., 2013). In only one case does the pollen zone and MIS boundaries coincide: the upper boundary of pollen zone 2 and the MIS 40 – MIS 39 boundary. In contrast, MIS 39 encompasses pollen zones 3, 4, 5, and the lower part of pollen zone 6. MIS 38 includes the upper part of pollen zone 6 and all of zones 7 and 8. These discrepancies indicate that the El'gygytgyn age model needs adjusting to better align the pollen zones and isotope stages. A more likely correlation of the pollen and isotope records are: zone 1 with either MIS 41 or with a warming reversal in the MIS 41 – MIS 40 transition; zone 2 with MIS 40; zones 3 and 4 with MIS 39; zone 5 with the MIS 39 – MIS 38 transition; zone 6 with MIS 38; zones 7 and 8 with MIS 37 or possibly with a warming reversal within MIS 38. Such correlations are only suggestions, and more definitive age assignments must wait for a future reevaluation of the entire Quaternary record from El'gygytgyn Lake.

One of the most noteworthy features of the 1.244–1.304 Ma spore-pollen record is the persistent presence of *Larix* pollen. *Larix* pollen can reach 4–5 % in the El'gygytgyn pollen zones belonging to both relatively warm and cool isotope stages. Although not possible to differentiate species based on the pollen morphology, it is likely that the species represented in the El'gygytgyn record is one that is similar to the modern Siberian species *Larix sibirica* Ldb. and not *Larix cajanderi* Mayr, the latter being the only coniferous tree that is found in the modern forests in North East Siberia. Additional support for this assumption is the fact that the pollen of *Larix cajanderi*, in contrast to *Larix sibirica*, is extremely poorly preserved even in modern spore-pollen assemblages. The consistent occurrence of *Larix* pollen in these fossil spectra clearly indicates that even under the severest climatic conditions during this part of the Calabrian, *Larix* forest-tundra was present both near the lake and on the Anadyr Plateau, a distribution that differs sharply from the herb-dominated tundra, which characterized most glacial intervals in the Arctic during the Middle and Late Pleistocene.

In contrast to *Larix*, pollen from *Pinus pumila*, the other main conifer in the present-day vegetation, occurs in trace amounts in all but pollen zones 1 and 7. In the records from the Holocene and Late Pleistocene, such low percentages are found only during glacial times, whereas warm intervals have percentages that can exceed 30 %. As *Pinus pumila* and *Larix* share similar summer temperature requirements, the apparent rarity of the shrub on the landscape suggests a snow cover that was insufficient to protect its evergreen leaves from the cold winter temperatures.

Betula and *Alnus*, while having variable percentages, are persistent components in the 1.244–1.304 Ma pollen spectra. These taxa typically are dominant in pollen assemblages from North East Siberia that are indicative of warm conditions. However, in this portion of the El'gygytgyn record, these taxa occur in significant amounts (up to 25 %) in what may be considered as transitional climatic intervals (pollen zones 1, 3, and 7). The percentages of *Betula* and *Alnus* pollen are markedly reduced in pollen zones where the inferred vegetation indicates a sharp cooling of the climate (pollen zones 2 and 6). Like *Larix*, *Betula* species are not distinguishable by the pollen morphology. In the case of *Betula*, the pollen could represent either shrub or tree growth forms. Both types are found today in northern Chukotka. Shrub tundra with *Betula* thickets (yernik) is common. While much rarer in the regional vegetation, tree *Betula* occurrs in small stands in protected areas such as along river valleys. *Alnus* pollen can also represent either shrubs or trees. *Alnus* (*Duschekia*) in the modern vegetation is restricted to shrubs, but it is not unreasonable that tree *Alnus* was established during warm times both in the crater and on the surrounding uplands.

Salix, another taxon that represents both shrubs and trees, is represented consistently throughout pollen zones 1–9. During cool climates, the pollen source would be from shrub species. Although possible that tree *Salix* established this far north during the warmest interglaciations, shrub *Salix* probably was more common, especially along stream valleys.

Single pollen grains of *Picea* sect. Eupicea are most likely the result of long-distance transport from more southern and western regions. The same is true for the trace amounts of pollen from the moderately thermophilus broad-leaved taxa of *Carpinus*, *Corylus*, and *Quercus*.

Poaceae pollen dominates the herb taxa in all zones, although its percentages are greatly reduced in pollen zone 4. Cyperaceae also appears consistently throughout this part of the record, although in much lower percentages as compared to Poaceae. These results emphasize the importance of graminoid communities on the landscape, both within the crater and in the surrounding uplands. *Artemisia* is another key herb type, with the largest pollen percentages occurring in zones 1 and 7 (up to 35 % and 29 %, respectively). High pollen percentages of this taxon are associated with the development of dry tundra under glacial climates. However, *Artemisia* is also indicative of xeric substrates and/or disturbed soils. Modest percentages of *Selaginella rupestris* spores add further support for the presence of rocky and/or south-facing slopes with disturbed soils. In contrast, the relatively high percentages of *Sphagnum* spores in pollen zones 1, 3, 4, 7, and 8 suggest soils with a rather high moisture content.

The results of the palynological analysis from El'gygytgyn Lake trace the successive changes of plant communities between 1.244 and 1.304 Ma. Pollen zone 1 indicates the regional and local establishment of *Larix* forest-tundra or perhaps even the existence of open *Larix* forests with an undergrowth of shrub *Betula*, *Alnus*, and *Pinus pumila*. Open, graminoid-forb meadows with shrub *Salix* were present near the lake. Mesic substrates are suggested by the relatively high percentages of *Sphagnum* spores. However, the abundance of *Artemisia* pollen and *Selaginella rupestris* spores also indicate the presence of well-drained, stony slopes and areas of disturbed soils. Climatic conditions were more favorable than modern and were likely characterized by mean July temperatures that were no lower than 12–13 ºC. The comparative warmth of the zone 1 assemblage suggests conditions that were more like a moderately warm interstade than a full interglaciation. Such an interpretation is consistent with zone 1 being more appropriately assigned to a warming reversal in the MIS 41 – MIS 40 transition, a conclusion that is consistent with oxygen isotope patterns where isotope levels are similar between the MIS 41 – MIS 40 climatic reversal and the MIS 3 interstade (Lisiecki, Raymo, 2005).

If pollen zone 1 reflects the development of plant communities corresponding to an interstadial climate, then the spectra of pollen zone 2 characterize vegetation indicative of climatic cooling associated with MIS 40. This change in climate led to the spread of tundra communities. The dominance of Poaceae pollen in the spectra of zone 2 emphasizes the wide distribution of graminoid-forb communities both locally and regionally. The continued importance of *Artemisia* pollen indicates areas of well-drained substrate and/or disturbed ground. The role of *Betula* and *Alnus* shrub communities in the vegetation was noticeably reduced as compared to zone 1. At the same time, the presence of *Larix* in the pollen spectra shows that some areas supported *Larix* forest-tundra. Mean July temperatures apparently did not fall below 10 ºC.

Pollen zone 3 is characterized by an increase in *Betula* percentages, which indicates a major restructuring of the vegetation. It also marks the onset of warming associated with the MIS 39 interglaciation. The low but consistently occurring percentages of *Larix* pollen suggest the regional presence of forest-tundra communities, possibly ones that included tree *Betula* or high growth forms of shrub *Betula*. Arboreal *Betula* and its shrub species also may have been found as isolated stands on the crater slopes or on the surrounding highlands. With the initial warming associated with MIS 39, *Larix* forests likely established in the most favorable areas such as within protected river valleys. *Alnus* shrubs, while not abundant, were probably present in the valleys of the lake's inflowing streams and along the Enmyvaam River. In addition to the stream valleys, a mosaic of habitats developed within the interfluves and on nearby slopes. Graminoid communities probably dominated the vegetation within the crater. The occurrence of other microsites, such as well-drained, disturbed soils and scree slopes, are indicated by *Artemisia* and other xeric pollen taxa and by *Selaginella rupestris* spores. The presence of forest-tundra and meadows indicate higher effective moisture than in zone 2. Mean July temperatures likely exceeded 12 ºC.

With continued warming, a major and abrupt change in the vegetation is reflected in pollen zone 4. During this period, *Larix* forests became more widespread. These forests had a dense shrub understory of *Alnus*, *Betula*, and *Salix*. The forest may also have included tree *Betula* or *Betula* shrubs of tree height. The abundance of *Betula* and *Alnus* pollen in the spectra indicates a predominance of *Betula* – *Alnus* communities in the vegetation, either within the forest or as shrub tundra communities found beyond tree line or along stream and lake sides. A noted addition to the landscape may have been *Corylus* and, possibly the broad-leaved trees *Carpinus* and *Quercus*. However, if present these moderately thermophilus taxa were minor components of the forest communities. Alternatively, the trace amounts of pollen represent long-distance transport that reflects the northward movement of a more temperate forest as climates warmed. Gallery forests of *Larix*, *Alnus hirsuta*, *Populus* (probably *Populus suaveolens*, *P. tremula*), and *Chosenia arbutifolia* established in the river valleys. The extent of Cyperaceae-Poaceae meadows declined noticeably in the vicinity of El'gygytgyn Lake. The trace amounts of *Pinus* and *Picea* pollen or, more often, the absence in the zone 4 assemblage indicates that conifers, including *Pinus pumila*, were not characteristic of the vegetation of northern Chukotka during MIS 39. In this respect, the zone 4 assemblage is most reminiscent of pollen spectra that characterized the transitional period from the Pleistocene to the Early Holocene rather than to the thermal maxima seen in the most recent interglaciations (Late…, 2002). Nonetheless, the spore-pollen spectra of zone 4 mark the warmest climatic conditions in this interval of the Calabrian. Mean July temperatures during the MIS 39 interglaciation probably exceeded 16 ºC. Although summers were warm enough to support the presence of *Pinus pumila*, the lack of *Pinus* pollen possibly indicates an insufficient snow cover to protect the evergreen leaves from low winter temperatures. Alternatively, the forest may have been sufficiently dense to prevent the establishment of *Pinus pumila*, which requires an open canopy.

The spectra of zone 5 indicate the expansion of shrub *Betula* – *Alnus* communities in the El'gygytgyn area. This change probably reflects a retreat of regional tree line and/or an opening of the *Larix* forest. *Pinus pumila* apparently remained absent on either regional or local landscapes, suggesting that climate rather than forest density was the limiting factor on the shrub's distribution. As in pollen zone 3, *Larix* forest-tundra was still an important component of the local and regional vegetation. Areas of graminoid-forb meadow expanded near El'gygytgyn Lake with the continued occurrence of more xeric communities on sites with well-drained soils and on scree slopes. The low percentages of *Sphagnum* spores in zone 5, as compared to zone 3, suggest that local sites were dominated by well drained substrates. As in pollen zone 3, the plant communities represented in the spectra of zone 5 developed under transitional climates. Mean July temperatures probably were ~ 12–13 ºC.

The pollen zone 6 assemblage reflects climatic cooling associated with MIS 38. These spore-pollen spectra are similar to those found in pollen zone 2. *Betula* and *Alnus* shrub communities were markedly reduced on the landscape. The dominance of Poaceae pollen (peaks of up to 62 %) emphasizes the wide distribution of graminoid-forb meadows near the lake. High percentages of *Artemisia* pollen and *Selaginella rupestris* spores indicate the presence of well-drained and/or disturbed substrates. The cool conditions inferred from the zone 6 spectra are indicative of the expansion of relatively xeric, shrub and herb dominated tundra. However, trace amounts of *Larix* pollen in the assemblage suggests a limited presence of *Larix* forest-tundra, which in turn implies that mean July temperatures did not fall below 10 ºC.

Pollen zone 7 reflects another restructuring of the regional vegetation following climatic amelioration associated with either a warming reversal during MIS 38 or the onset of the MIS 37 interglaciation. *Betula* pollen percentages increase from those in zone 6, which indicates an expansion of shrub tundra and/or a greater abundance of *Betula* shrub thickets (yernik). *Larix* pollen (up to 4 %) also increases as compared to zone 6, indicating a regional expansion of *Larix* forest-tundra. These communities possibly included tree *Betula* or *Betula* shrubs of tree height. *Alnus* pollen percentages remain low, suggesting that the shrubs had a restricted distribution (e. g., along the valley lowlands of the Enmyvaam River and the streams flowing into the lake). Graminoid dominated communities, which also included Caryophyllaceae, Saxifragaceae, *Sphagnum*, and *Lycopodium pungens*, characterized the El'gygytgyn shoreline. Such associations suggest mesic to water-logged substrates. The high percentages of *Artemisia* pollen (up to 27 %), however, indicates the continuation of well-drained microhabitats and stony slopes in the crater. Comparatively high percentages of *Sphagnum* spores and Ericales pollen show that mesic, heath communities were common locally. Moderate percentages of *Pinus* suggest that the evergreen shrub was present albeit not as a common element on the landscape. The paleovegetation reconstruction suggests that mean July temperatures were no lower than 12–13 ºC, and that patterns in seasonal precipitation limited the distribution of *Pinus pumila*. The data also support an interpretation that pollen zone 7 most likely reflects either a warming reversal during the otherwise cooling trend of MIS 38 or the onset of interglacial warming associated with MIS 37.

The increases in *Betula* and *Alnus* pollen in pollen zone 8 document the greater importance of these shrubs in both the local and regional vegetation. These spectra also reflect the continued presence of *Larix* forest-tundra, which had established in zone 7. Tree *Betula* probably was present in the forest. It may also have formed isolated stands on the crater slopes or spread across the Anadyr Plateau. As throughout this part of the Calabrian, graminoid communities were an important part of the landscape. Mesic to wet substrates were associated with the forest-tundra and with areas occupied by meadows. A characteristic of both pollen zones 7 and 8 is the notable variability in percentages of such taxa as *Betula*, *Alnus*, and Poaceae. Such changes may reflect the relatively rapid change of plant communities from, for example, forest-tundra to open *Larix* forests. Such variability in the spore-pollen spectra is characteristic of MIS 3 in North East Siberia (Anderson, Lozhkin, 2002). Such similarity suggests that the climate of pollen zone 8 may have been more like an interstade than a interglaciation, which in turn suggests that the zone may in fact represent a warming reversal during MIS 38 rather than full interglacial conditions associated with MIS 37. In either case, the zone 8 data suggest mean July temperatures that are ~ 12 ºC.

We express our gratitude to Yu. A. Korzun, L. N. Kotova, E. Yu. Nedorubova, and T. B. Solomatkina for help in article preparation.

Received 06.07.2022

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РЕАКЦИЯ РАСТИТЕЛЬНОСТИ АРКТИЧЕСКОЙ ЧУКОТКИ НА ИЗМЕНЕНИЕ КЛИМАТА В СРЕДНЕМ КАЛАБРИИ

А. В. Ложкин[1], П. М. Андерсон[2]

[1]ФГБУН Северо-Восточный комплексный научно-исследовательский институт им. Н. А. Шило ДВО РАН, г. Магадан
[2]Вашингтонский университет, Центр четвертичных исследований, г. Сиэтл, США

Палинологическая летопись осадков оз. Эльгыгытгын в интервале 1.244–1.304 млн лет назад показывает неоднократные изменения растительных сообществ в арктической Чукотке, отвечающие смене относительно холодных, интерстадиальных и межледниковых климатических условий. По соотношению групп растительности, основных пыльцевых и споровых таксонов на пыльцевой диаграмме осадков оз. Эльгыгытгын в интервале 1.244–1.304 млн лет назад выделяется 8 пыльцевых зон. Пыльцевые зоны сопоставляются с морскими кислородно-изотопными стадиями 40, 39, 38. Верхняя граница изотопной стадии 38 совпадает с магнитным событием Mountain (1.240 млн лет назад), которое можно рассматривать как хронологический ориентир. При реконструкции палеорастительности по данным спорово-пыльцевых спектров осадков оз. Эльгыгытгын учитывались особенности современных пыльцевых спектров в донных осадках озера на границе вода – осадок. Постоянное участие пыльцы *Larix* в спектрах пыльцевых зон, характеризующих растительные сообщества интервала 1.244–1.304 млн лет назад, свидетельствует, что даже в крайне суровых климатических условиях, проявлявшихся в калабрии, в районах Анадырского плоскогорья и оз. Эльгыгытгын сохранялась лиственничная лесотундра, резко отличающаяся от травянистой тундры, характеризовавшей многие ледниковые интервалы в Арктике во время среднего и позднего плейстоцена. Спорово-пыльцевые спектры показывают, что в изотопную стадию 39 проявились наиболее теплые климатические условия в интервале 1.244–1.304 млн лет назад, отвечавшие одному из межледниковий калабрия. Приведенные данные, охватывающие интервал между 1.244–1.304 млн лет назад, представляют собой последний шаг в завершении четвертичной истории растительности уникального района в арктической Сибири.

***Ключевые слова*: изотопная стадия, пыльцевая зона, спорово-пыльцевые спектры, смена растительных сообществ, лесотундра, интерстадиал, межледниковье.**

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