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PALYNOLOGICAL STUDIES OF LAKE AND LAKE-SWAMP SEDIMENTS OF THE HOLOCENE IN THE HIGH MOUNTAINS OF ARKHYZ (WESTERN CAUCASUS)

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ABSTRACT. On the basis of palynological studies of lake, lake-swamp and soil sediments located in the alpine and subnival belts of the northern part of the Western Caucasus (Arkhyz, Russia), the character of the evolution of vegetation, climate and lake levels during the last 5–6 millenia has been established. During the period 4300–4200 BP the landscape of the Arkhyz high mountains underwent radical changes when, as a result of intense cooling, the alpine belts descended several hundred metres. The lakes that had existed on the site under investigation throughout the Atlantic period began to disappear. Alpine meadows were replaced by the sparse vegetation of the subnival belt. The deterioration of the SB climate was rather prolonged and was interrupted by one significant warming. However, the SA coolings were marked by their short duration and greater frequency. The most important were the climatic deteriorations from 1300–1200 BP and 400–350 BP.

KEY WORDS: Holocene pollen spectra, glacial lakes, pollen transport, sedimentation-accumulation intensity

INTRODUCTION

The lake and lake-swamp Holocene sediments of the high-mountain part of the Greater Caucasus have not been studied adequately so far. For the profiles situated above 2700–2800 m, practically at the border with the subnival belt, accounts of palynological analysis appear in only a few works (Kartashova et al. 1988, Kvavadze & Efremov 1990)

This paper contains the results of investigations carried out in the western part of the Northern Caucasus in the Karachaevo-Cherkessian Autonomous Region (Russia). Here, on the northern slopes of the Abishara-Akhuba range, at an altitude of 2156–2884 m, by the headwaters of the Kiafar river, a tributary of the Bolshoi Zelenchuk, there are many lakes of glacial origin (Fig. 1). The present day data on the sediments of these lakes have been studied by us using the spore-pollen analysis method (Efremov & Kvavadze 1994). Additionally, a series of the Holocene lake and swamp sediments was studied. The thickest of them occurs in rock near Lake Rybnoe at an altitude of 2156 m with its thickness measuring as much as 257 cm. The layer of sediments opened up near the Kvartsevoe (2156 m) and Bluzovoe lakes (2884 m) situated much higher than Lake Rybnoe, are only 45–50 cm thick.

Orographically, the region under investigation is characterized by high-mountain erosion-structured relief with a wide development of old glacial forms. The highest point of the Abishara-Akhuba range (Mount Rechepsta) is 3214 m. The range itself runs mostly along the main watershed.

Recent glaciation here is not significant. The main peculiarity of the geological structure is the presence of various sedimentary and metamorphic mountain rocks of the Palaeozoic period (Geograficheskii Atlas 1969).

The climate is cold. At an altitude of 2000 m the mean annual temperafure is about zero, and at 2600–2800 m it is –1.9° C to –1° C (Davidovich & Tareeva 1980). With altitude, the strength of the winds which blow here steadily increases. West winds prevail althought south and south-west winds are significant (Savelieva 1967). The summer is short with the temperature above 5° C for only 2–3 months. The snow cover lasts for a long time, about 3/4 of

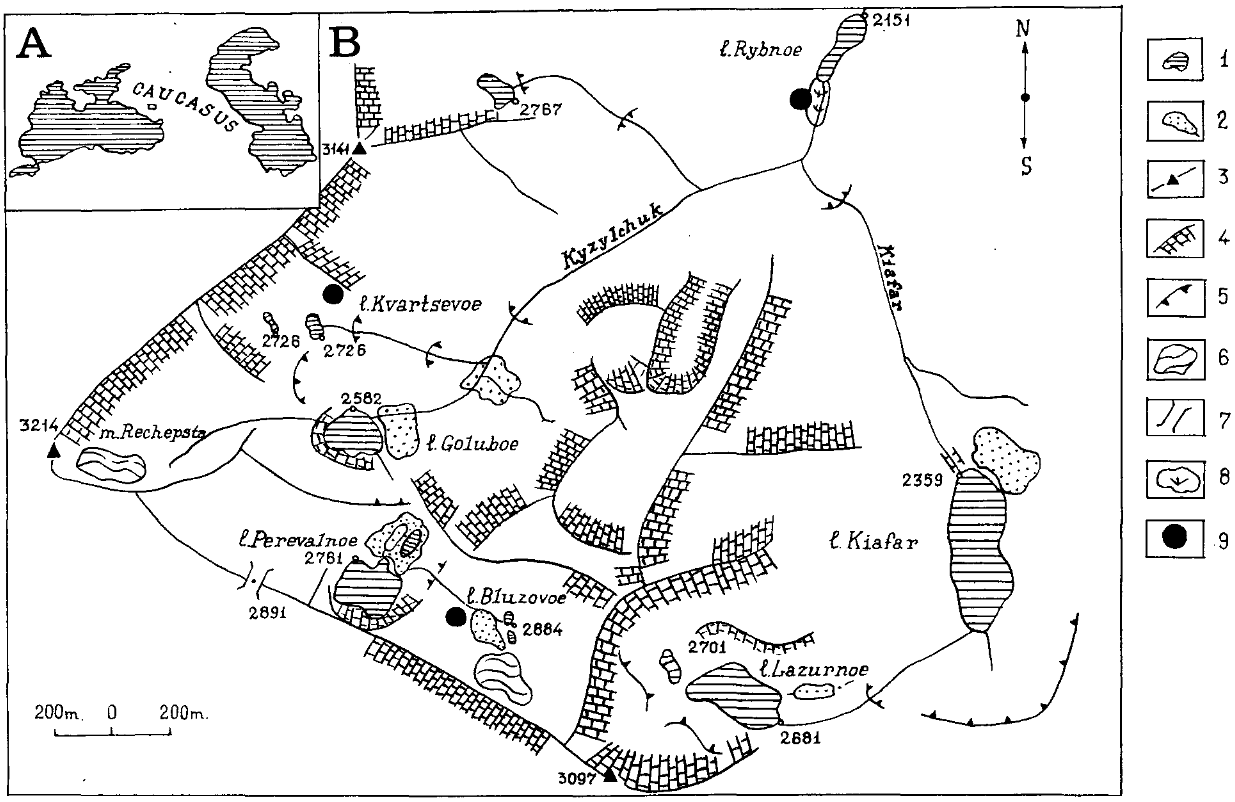

Fig. 1. A – Location of the region under stude; B – schematic map of the lakes situated by the headwaters of the Kiafar river. 1 – lakes, 2 – moraine, 3 – ranges, single summits, 4 – rock walls, 5 – rock bars, 6 – glaciers, 7 – mountain passes, 8 – bogs, 9 – location of the profile under study

the year. In general precipitation is heavy, but less in the alpine belt, than in the subalpine one.

With altitude the vegetation of Arkhyz changes. From 2000–2400 m, short grassy alpine meadows occur with a predominance of various species of Cyperaceae, *Festuca, Briza, Primula, Gentiana, Campanula* and others. On saddles and near lakes grow *Carex dacica* and *C. stellulata.* With increasing altitude, the floristic composition of the meadows becomes poorer. On loose screes occur plants with quickly growing and well developed root systems such as *Delphinium caucasicum, Pseudovesicaria digitata, Viola minuta* and *Jurinea depressa.* On fixed screes they are replaced by species of *Minuartia, Saxifraga* and *Alchemilla.* The description of the vegetation is given according to Shiffers (1953). On rocks one can find alpine species of *Draba, Potentilla, Senecio,* etc.

In the subnival belt there is no continuous alpine cover (Fig. 2). Some group of plants can only be found in clefts on leeward slopes near stones. Only isolated individuals of *Carex tristis, Elyna capillifolia, Alopecurus glacialis* and some others grow high up.

The tree line in the region under study runs at an altitude of 1800 m and is formed by open crook-stem birch forest (*Betula litwinowii*) with clumps of *Pinus hamata. Rhododendron caucasica* occurs occasionally.

In the upper forest belt of Arkhyz pine forests play an important role because of the dry climate compared with the more western regions (Fig. 3). Forests, mainly of beech, grow on the river terraces and on the slopes above them. *Picea, Abies, Betula, Acer* and *Sorbus* grow here as admixtures.

The lower forest belt reaches at an altitude of 1300 m. It consists mainly of remnants of oak (*Quercus robur, Q. hartwissiana, Q. petraea*) and oak-hornbeam (*Carpinus caucasica*) forest.

Piedmont steppificated meadows and meadow-steppes (to be more precise, forest-steppes) that are mostly ploughed, adjoin the lower forest belt. At lower levels they give way to herb-bunchgrass steppes that traverse the whole Krasnodar territory and Stavropol highland in a wide band.

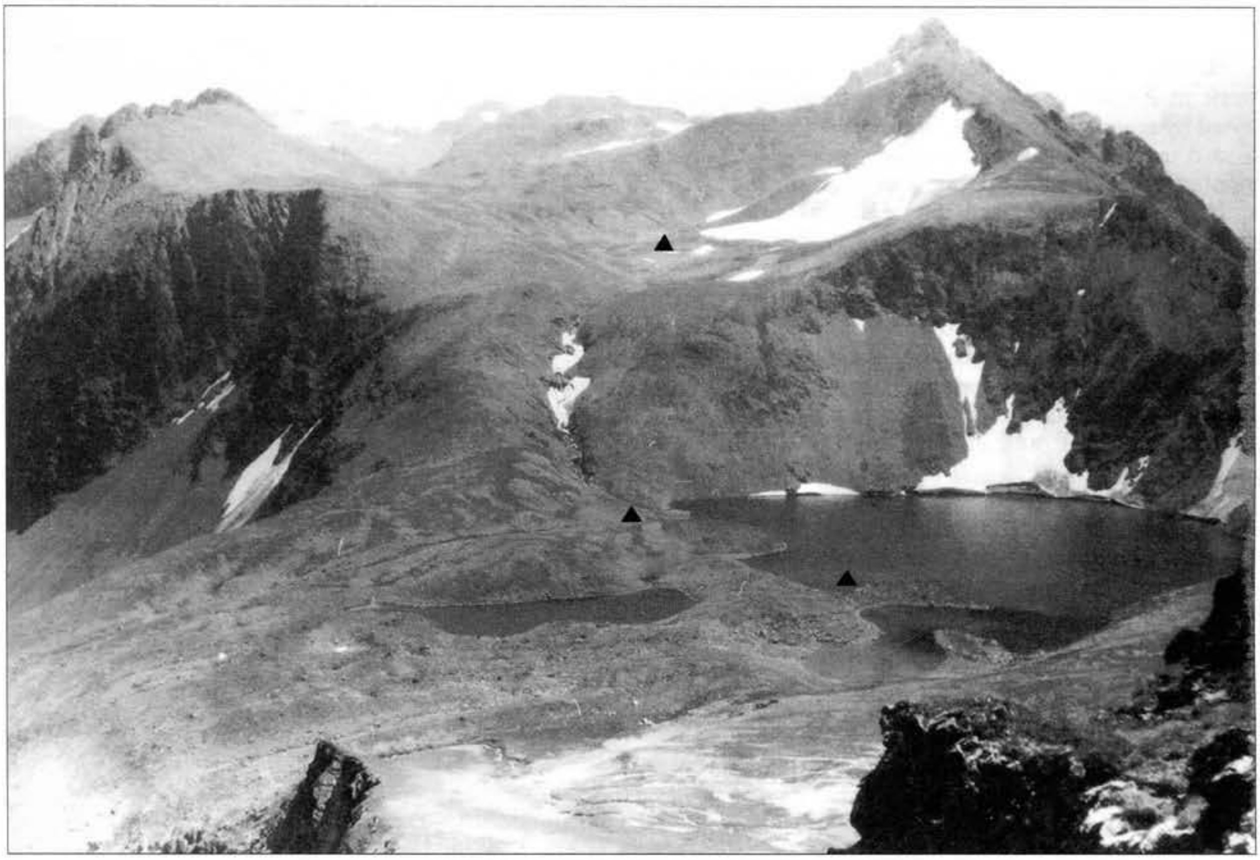

Fig. 2. Upper-alpine landscapes by the headwaters of the Kiafar river (photo Yu. V. Efremov)

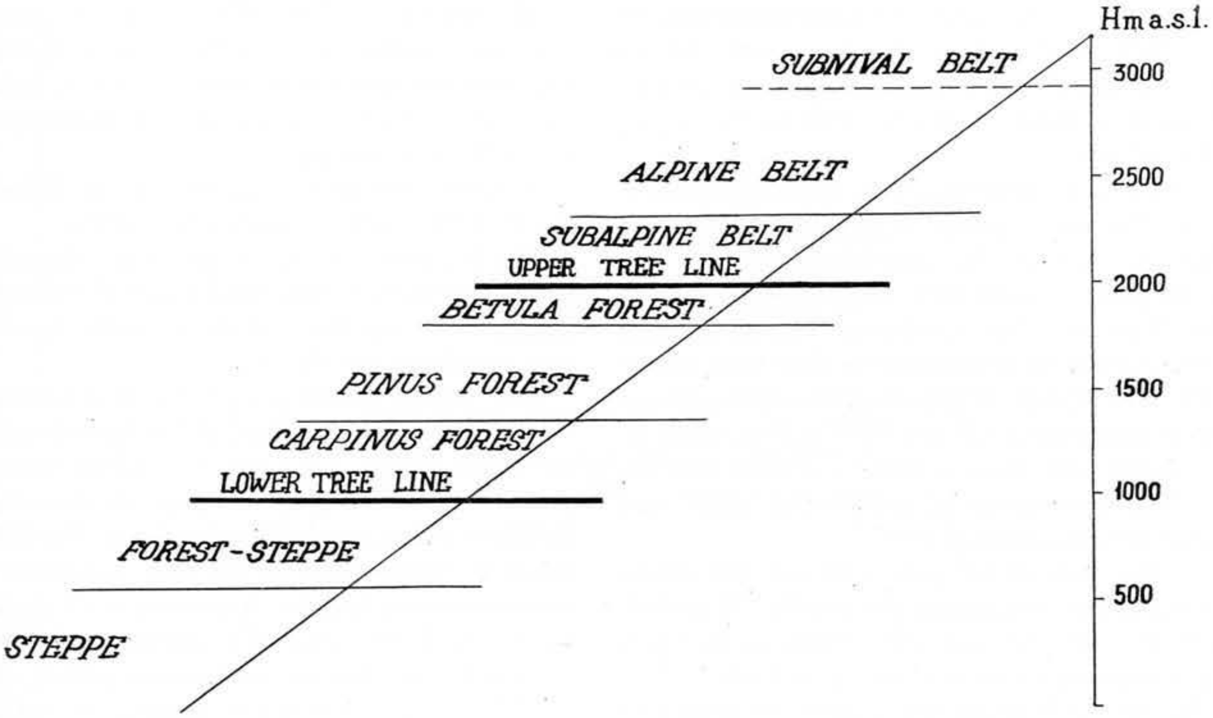

Fig. 3. Altitudinal zonality of vegetation in the valleys of the Kiafar and Bolshoi Zelenchuk rivers

MATERIAL AND METHODS

Material for spore-pollen analysis was taken during work in August of 1992. Holocene deposits were exposed by means of trenches. Samples were taken every 5 to 8 cm on average. The absolute age of the sediments was determined using the ^{14}C method.

The material analysed was notable for an abundance of pollen and spores in a very good state of preservation. Altogether 49 pollen spectra of the Holocene and 8 spectra of recent sediments were studied. The material was treated first by the alkaline (KOH) and then by the acetolysis methods. From each sample, on average, up to 500–600 sporomorphs were determined. The percentages of pollen and spores was calculated separately for AP and shrubs, NAP and sporiferous groups.

Spore-pollen diagrams were drawn up similarly.

The preparations studied are kept in the L. Sh. Davitashvili Institute of Palaeobiology of the Georgian Academy of Sciences.

PALYNOLOGICAL CHARACTERIZATION OF THE SEDIMENTS OF LAKE RYBNOE

The profile is located among the headwaters of the Kiafar river at an altitude of 2156 m. Here, near where the river enters Lake Rybnoe, on the bank of a silted up river, a trench was dug exposing a 257 cm thick sedimentary rock mass composed of lake swamp formations (Fig. 4). According to ^{14}C, the age of the peat from a depth of 52–54 cm is 343±67 BP (VUE-1407), while that from 102–104 cm is 1261±65 BP (VUE-1403). Interlayers of lake clays occur twice at depths of 46 to 50 cm and 60 to 67 cm.

29 samples were taken for spore-pollen analysis. The spore-pollen diagrams obtained are characterized by the prevalence of AP and shrub pollen (up to 50%) in the lowest part of the diagram. The sporiferous plant content also reaches its maximum in this part (up to 23%). The middle of the diagram shows almost equal amounts of AP and NAP pollen, while in the upper part there is clearly of more the latter. The percentage of sporiferous plant material here is minimal (5%).

In the case of AP pollen, *Pinus* and *Alnus* predominate throughout the profile (40 to 60% and 10 to 36% respectively). *Fagus* is the third most important component (up to 18%).

In the NAP group the pollen of *Carex* and Gramineae prevail, with the role of the latter increasing in the upper part of the profile and the amount of *Carex* pollen decreasing. This inverse relation occurs throughout the whole profile.

Fig. 4. View of Lake Rybnoe (photo Yu. V. Efremov)

The pollen of Umbelliferae and Polygonaceae are subdominants of the spectra. Sporiferous species are mainly represented by ferns. There is a considerable number of spores of *Selaginella* and *Ophioglossum*.

A peculiarity of the spectra of the Rybnoe profile is the lack of redeposited pollen.

The features mentioned above are the most common but each individual layer of the eight which make up the complete profile has its own peculiarities (Fig. 5).

The pollen complexes of the first (lowest) layer (depth 257 to 145 cm) differ from those of the upper layers in the minimal pollen content of *Betula* and *Fagus*. Among shrubs, only *Ephedra* pollen appears in this layer. The NAP group is represented by the first minimum of the Gramineae and the maximum of Chenopodiaceae and *Artemisia*. The presence of *Carex* is significant. Among sporiferous plants, the percentage of *Botrychium lunaria* is rather high and *Selaginella selaginoides* is characterized by its first maximum.

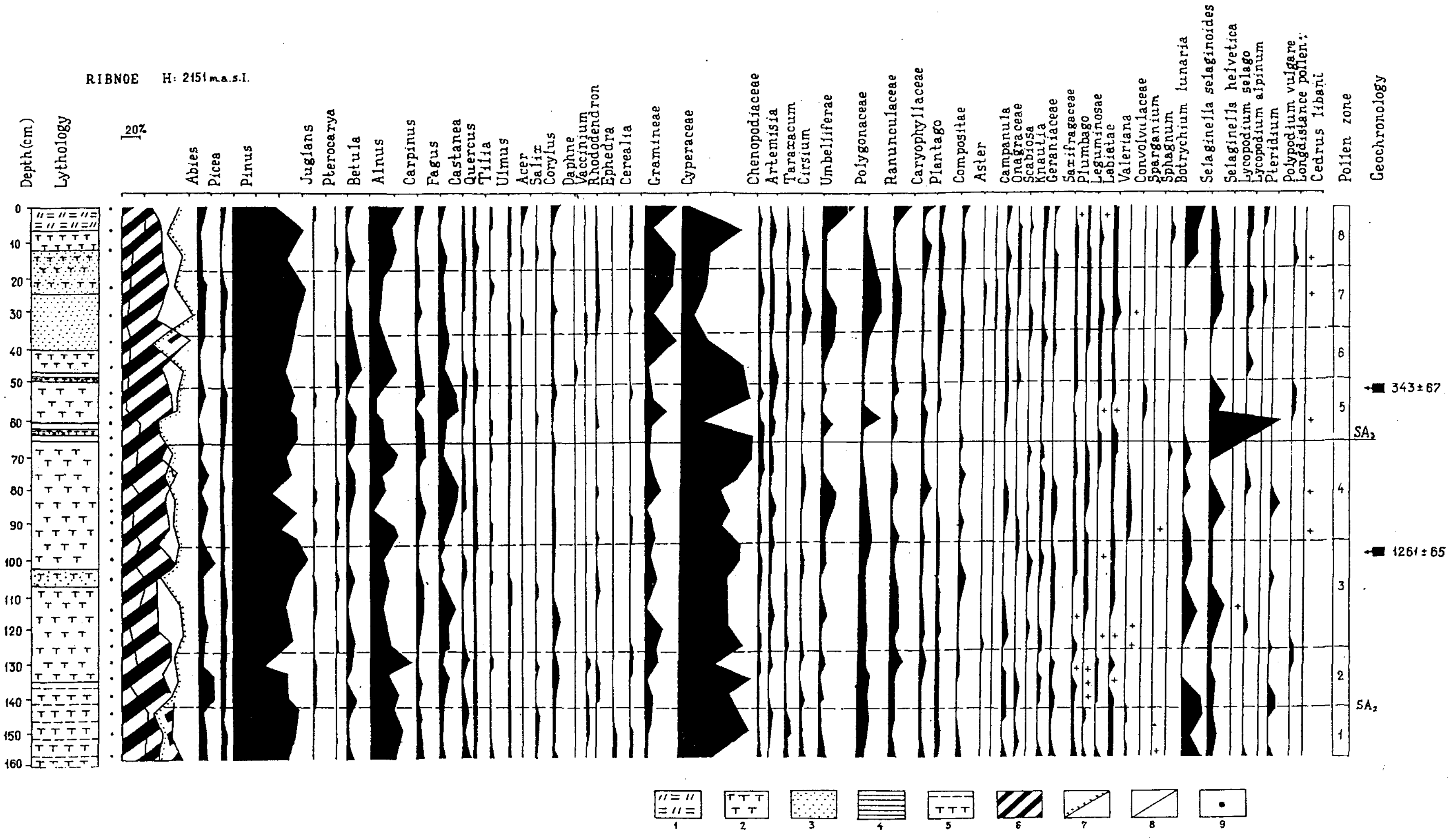

Fig. 5. Spore-pollen spectra of the Rybnoe profile. 1-soil, 2-peat, 3-sand, 4-lake clays, 5-clay with peat, 6-AP, 7-NAP, 8-spores, 9-sampling site (6, 7, 8, 9 valid also for Figs 7 and 9)

The pollen spectra of the second layer (depth 145 to 128 cm) indicate a decrease of the AP pollen role and an increase of that of the NAP. The amount of material of sporiferous plants is also reduced. Among the AP group, viz. conifers, the *Abies* content increases significantly (up to 10%) and the *Pinus* content becomes smaller in comparison with the lowest layer. However, the amount of *Alnus* pollen increases as does that of *Betula* and *Fagus*. At the same time, the roles of *Carpinus* and *Castanea*, by contrast, decrease. For the first time *Juglans* pollen appears. Among shrubs, *Corylus, Rhododendron* and *Vaccinium* become considerably more important, while *Ephedra* pollen disappears. In the NAP group the pollen contents of *Carex*, *Artemisia* and Chenopodiaceae all decrease. The amount of pollen of the Gramineae increases, including that of cultivated species (Fig. 5). The role of Ranunculaceae, *Campanula*, Caryophyllaceae, Geraniaceae, Leguminosae and Boraginaceae becomes more significant. Among sporiferous plants, the proportion of *Botrychium lunaria* present reduces sharply and then disappears. The number of spores of *Selaginella selaginoides* also decreases, but that of *Pteridium* increases.

The pollen spectra of the third layer (depth 128 to 97 cm) are characterized by an increase in the amount of AP pollen. The proportion of sporiferous plants grows fairly significantly. In the AP group the content of *Pinus* pollen increases greatly, while that of *Alnus*, by contrast, decreases. The proportion of *Abies* pollen present declines. Among broad-leaved species, *Fagus* and *Carpinus* are dominant while there is little pollen of *Castanea, Ulmus, Quercus* and *Juglans*. *Tilia* and *Pterocarya* pollen are presented by single grains. The latter makes its first appearance in this layer. Among the NAP groups, the role of *Carex* becomes more important. The quantity of pollen of *Artemisia,* Chenopodiaceae, Umbelliferae and Polygonaceae is somewhat larger. Among sporiferous species, the proportion of *Botrychium* and *Selaginella* increases.

The pollen spectra of the fourth layer (depth 97 to 66 cm) are marked by a decrease in the content of *Pinus* and an increase of all the other components of AP pollen. The *Fagus* content reaches its maximum (up to 18%) but *Salix* and *Ulmus* pollen disappear. In the shrub group *Corylus* and *Rhododendron* show a decline. NAP does not show any radical changes here.

The percentages of Cruciferae, *Campanula*, Geraniaceae, *Valeriana* and Leguminosae increase somewhat. Sporiferous species are characterized by a smaller proportion of *Botrychium* and *Selaginella* while the content of *Lycopodium* and *Pteridium* increases.

The spore-pollen spectra of the fifth layer (depth 66 to 53 cm) are distinguished by the first maximum of *Picea* and the first minimum of *Abies* pollen, while the amount of *Pinus* increases. Among other AP there is less *Alnus* pollen and the amount of *Fagus, Betula, Juglans* and *Pterocarya* is somewhat smaller. The proportion of *Ulmus* and *Salix* increases. Among shrubs, the *Corylus* and *Rhododendron* pollen content rises. In the NAP group a number of significant changes take place. *Carex* pollen reaches its first minimum. Its percentage drops from 69% to 16% at 60 cm depth where in the interlayer of lake clays occurs (Fig. 5). The reduction of *Carex* pollen is accompanied by an increase in the content of Gramineae, Umbelliferae, Polygonaceae and Cruciferae. In the sporiferous group, *Selaginella selaginoides* (up to 60%) becomes the dominant of the spectrum.

The pollen spectra of the sixth layer (depth 53 to 36 cm) are also rather peculiar. At this depth AP pollen markedly dominates over NAP and reaches 62%. The content of conifers, including *Pinus*, is lower, but that of some foliate species, on the contrary, rises. *Alnus* and *Betula* reach their maximum values, 20% and 11%, respectively. The percentage of broad-leaved species is reduced and *Juglans* and *Tilia* pollen vanish. Among shrubs, *Daphne* is a new element, though in the uppermost part of this layer its amount decreases. The content of *Artemisia* becomes higher in comparison with lower layers, while that of Chenopodiaceae, by contrast, is reduced. In the sporiferous group *Selaginella* disappears altogether and *Botrychium* is only found in the form of single spores. The amount of *Lycopodium* is increased and fern spores become dominants.

The pollen spectra of the seventh layer (depth 36 to 18 cm) show a reduction in AP content to 31%. The NAP group percentage reaches 61%. The amount of conifer pollen as a whole increases, while that of broad-leaved plants, in contrast, decreases fairly significantly. Here one can find *Acer* pollen with an increased presence of *Corylus* and *Rhododendron* the latter reaching its maximum value. Among the NAP, the content of Gramineae, Umbelliferae and Polygonaceae increases markedly and there is much pollen of *Cirsium, Taraxacum* and *Plantago*. In the group of sporiferous species, appears *Selaginella selaginoides* and for the first time one can see spores of *Lycopodium alpinum*.

The pollen spectra of the uppermost, eighth, layer (depth 18 to 0 cm) are characterized by an increase in sporiferous species AP pollen is dominated by that of the NAP. Among the AP, *Pinus* predominates, but compared with the lower layers its pollen content decreases in line with those of *Picea* and *Abies*. The proportion of *Pinus* does increase somewhat. As to the other AP species, their content either does not change at all or decreases slightly. Among shrubs, *Rhododendron* and *Corylus* are permanent elements of the spectra. The NAP group is characterized by an increase in cultivated Gramineae (mainly *Triticum*-type) pollen. In the group of sporiferous species the proportion of *Selaginella* gradually decreases, while that of *Botrychium*, in contrast increases. Spores of *Lycopodium alpinum* and *L. selago* are permanently present but *Polypodium vulgare* is represented by single spores. At the same time monolete spores of ferns are abundant.

It is worth noting that both in the eighth and lower layers one can find pollen grains of *Cedrus libani* whose presence is a result of long-distance transport from the Taurian mountains of Turkey where *Cedrus libani* still forms rather large stands. The ability of *Cedrus* pollen to spread via the air for hundreds of kilometres, not only in the Caucasus but in other mountain regions, has been repeatedly mentioned in the literature (Van Zeist et al. 1975, Beug 1987, Kvavadze 1991, Reille 1991, Reille & Lowe 1993).

Thus, having considered the character of the pollen spectra from the Lake Rybnoe profile sediments, we can now consider vegetation and climate descriptions. From these we will attempt to deduce the evolution of the lakes of the region. Proceeding from the data on the absolute age, as well as the results of climatic stratigraphy of neighbouring regions, we can claim that the sediment mass under study was accumulating during the Middle and Late Subatlantic (SA_2 and SA_3) over the last 1600 to 1800 years. Throughout this period both climate and vegetation underwent repeated changes. This is indicated by qualitative and quantitative characteristics of the pollen spectra in the region under study (Efremov & Kvavadze 1994, Kvavadze & Efremov 1995).

The lowest part of the peat layers interbedded with loam formed when the climate was rather cool, that is much more severe than nowadays. The indicators of cooling in the pollen spectrum for the region under investigation are the combination of a high content of spores of *Botrychium, Selaginella* and Polypodiaceae, a maximum percentage of *Ephedra*, Chenopodiaceae and *Artemisia* pollen and a large amount of *Pinus* pollen. Indicators of warming are different: the combination of maximum values of *Alnus, Abies* and *Betula* pollen with a minimal content of *Pinus* and Cyperaceae pollen as well as the presence of *Botrychium* and *Selaginella* spores.

Around the headwaters of the Kiafar river where the present-day lower alpine belt occurs, there grew sparse upper-alpine vegetation which nowadays is characteristic for landscapes at altitudes of 2000 to 2700 m. This conclusion is based on the fact that the spectra of the lowest layers of the profile are similar to recent sediments in the vicinity of Lakes Goluboe and Kvartsevoe located 450 to 550 m above Lake Rybnoe (Fig. 6). The tree line, too, was lower than now, but the difference probably did not exceed 300 to 400 m. A lowering of the tree line of such intensity took place in the Western Caucasus 1600–1800 BP (Kvavadze et al. 1992). The mentioned increase of warmth, which was replaced by the cooling referred to above, lasted throughout the second half of the SA. However, the warming was interrupted by one intense cooling and a number of lesser climatic deteriorations.

During this Subatlantic warming, layers 2 and 4 were formed. Upper alpine vegetation was gradually replaced by that of the middle alpine with a more varied composition of meadow formations.

Rhododendron thickets appeared and the area of bogs was somewhat reduced. The pollen spectra demonstrate very well the movement of forest vegetation boundaries. However, this process of the vertical upward displacement of the mountain forest belts was stopped by a new period of cooling (spectra of layer 3). This cooling was much less intense than the previous one (layer 1).

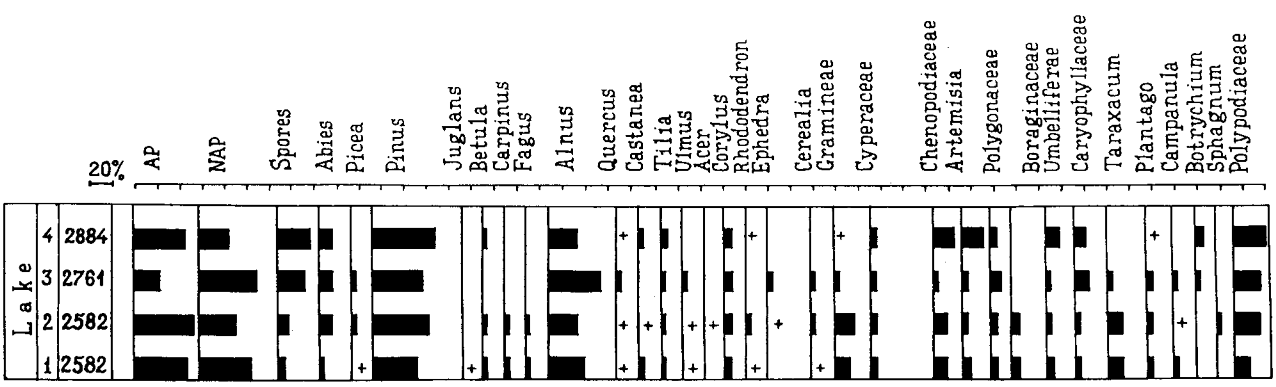

Fig. 6. Recent spore-pollen spectra of the bottom sediments of Arkhyz

Layer 4 of peat was accumulated under the conditions of a very warm climate. On the site of the Rybnoe profile there grew alpine meadows which were very much like current ones. However, the climate seemed to be much more humid and the bog area more extensive. The warm superhumid climate stimulated the appearance of a lake on the site of the profile under study.

At the next stage of climatic evolution, a major cooling occurred. It was the first phase of the Minor Glacial Period 600 to 700 BP and was much more intense than that which had taken place from 343±67 BP. The upward migration of the vegetation belts stopped. However, during a regular warming after the Minor Glacial Period, the upper limit of the forest consisting of open crook-stem birch trees reached the region under study. This was the optimum period during which the lake reappeared.

The second part of the SA is characterized by one cooling (layer 7) and one warming (layer 8). The tree line gradually descended. In this case, however, apart from climate, the anthropogenic effect seems to have played an important part. The lake existed for several decades and then again was transformed into a bog.

Having analysed the dynamics of the lake, vegetation and climatic evolution around the headwaters of the Kiafar river, one can conclude that they agree well with those based on similar data from the profile of the Lugansk bog (Fig. 7). During the second half of the Subatlantic, lakes twice appeared there for a short time. Their origins coincided with a warm and humid climate. The disappearance of lakes is associated with climatic cooling.

POLYNOLOGICAL CHARACTERISTICS OF LAKE KVARTSEVOE PROFILE SEDIMENTS

Near the headwaters of a right hand tributary of the Kiafar river at an altitude of 2726 m, not far from Lake Kvartsevoe, a 50 cm thick mass of sedimentary rock, consisting of bog and lake-bog formations was exposed by means of a trench. Geomorphologically, the locality is an old silted up lake. The peat age at a depth of 26 cm is 4370±175 BP (VUE 1408). From 29 to 40 cm there is a layer of lake clays with plant remains. 11 samples were taken for spore-pollen analysis. The spore-pollen diagram obtained has unique peculiarities which are probably explained by the high position of the profile above sea level resulting in a very slow rate of sediment accumulation. The curve trace for almost all elements of the spectrum is smoother, than in other diagrams for the studied region. This regularity occurs both for AP and NAP (Fig. 8). The dominants are almost the same throughout the whole profile. Nevertheless, detailed analysis of the spectra makes if possible to divide the studied sediments into a number of horizons. For the lower part of the diagram (at a depth of from 31 to 50 cm) the predominance of AP over NAP pollen is typical. The dominant of the spectrum is *Pinus*, though its pollen is present in somewhat smaller amounts than in the upper layers. Among conifers more pollen of *Abies* occurs than *Picea*. There is a considerable amount of *Alnus*, especially in the upper part of the layer. Pollen of *Betula* is ever present. Broad-leaved species, represented by *Tilia, Fagus, Carpinus* and *Quercus*, occurs as single pollen grains. Pollen of low mountain forest

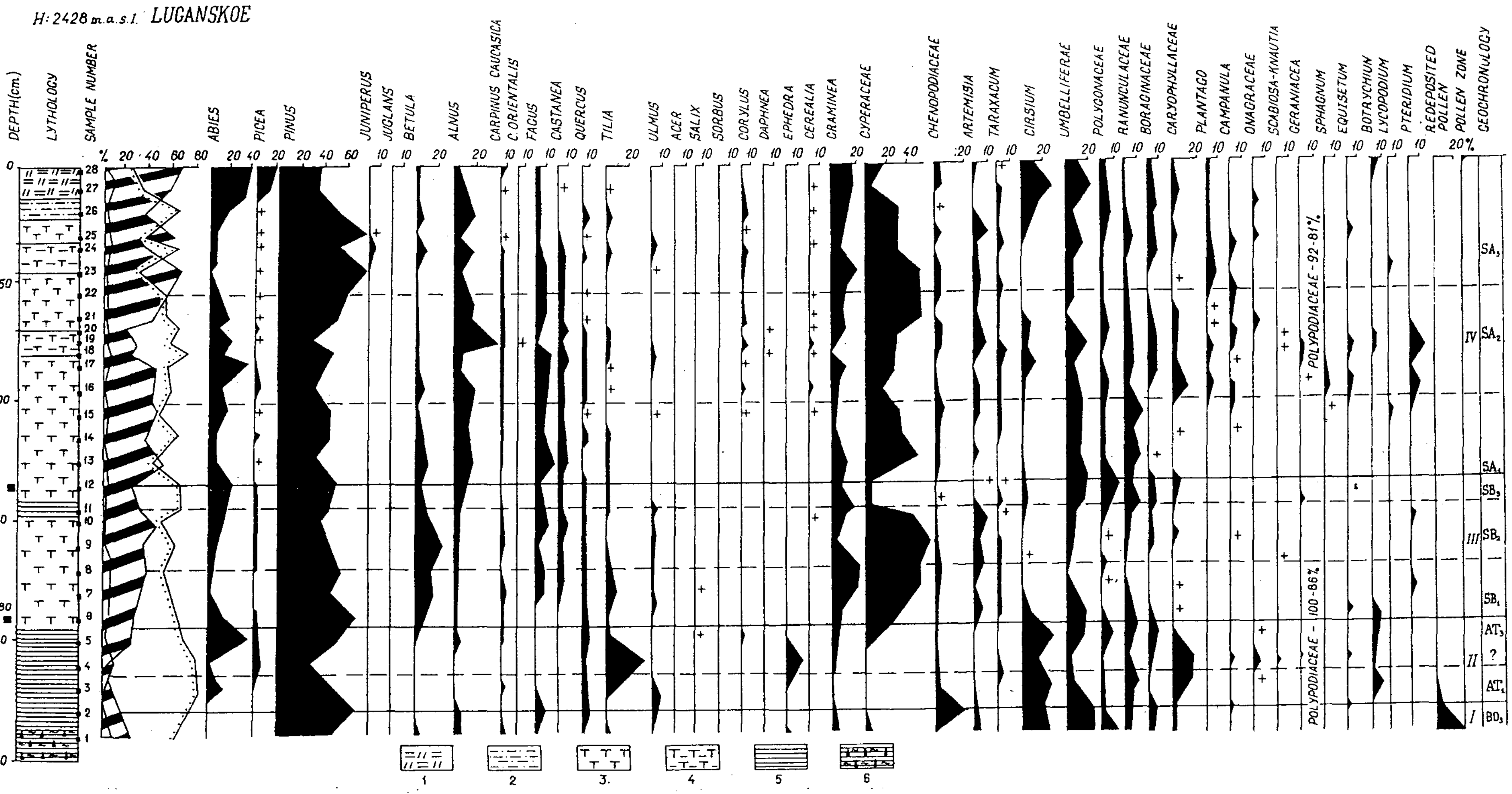

Fig. 7. Spore-pollen spectra of the Luganskoe profile. 1-soil, 2-clay with sand, 3-peat, 4-clay with peat, 5-lake clays, 6-clay with moraine

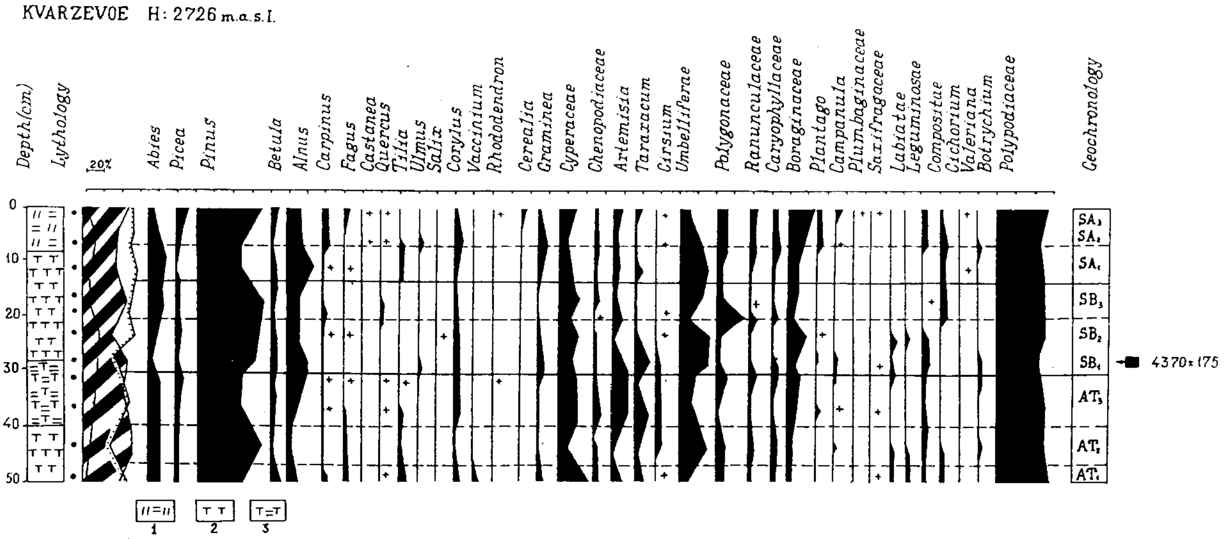

Fig. 8. Spore-pollen spectra of the Kvartsevoe profile. 1-soil, 2-peat, 3-clay with peat

elements, such as *Juglans, Pterocarya, Castanea,* etc. is totally absent. *Corylus* solely represents shrubs while *Vaccinium* and *Rhododendron* are represented by single grains. Among NAP *Carex* prevails. The Umbelliferae, *Artemisia* and Boraginaceae are present in considerable quantities. Sporiferous species are represented almost entirely by the monolete spores of ferns while *Botrychium lunaria* is found as single spores.

The spectra of the middle layer (31 to 12 cm) are distinguished by a greater quantity of NAP pollen. The sporiferous content rises as well. Among the AP species, the amount of *Pinus* pollen increases to 70% . The percentage of *Picea* and *Abies,* by contrast, decreases and there is a smaller amount of *Betula* and *Alnus* pollen. *Fagus, Carpinus* and *Quercus* are represented only by single grains and there is no pollen of *Tilia* at all. However, in this layer we see for the first time pollen of *Ulmus* and *Salix.* Among the NAP species, Umbelliferae and Polygonaceae dominate. The amount of *Carex, Artemisia* and Chenopodiaceae decreases while among sporiferous species, the number of *Botrychium lunaria* spores shows an increase.

The spore-pollen spectra of the uppermost layer (12.0 to 0.0 cm) are distinguished by an increase in the proportion of AP pollen, with *Pinus* and *Alnus* predominant. However, the *Pinus* content decreases, while that of *Alnus* increases. The amount of pollen of *Abies, Betula, Carpinus* and *Fagus* also rises and *Tilia* reappears. For the first time one can see pollen grains of *Castanea* but there is little pollen of *Ulmus* and *Quercus.* Among shrubs, the percentage of *Corylus* increases and *Rhododendron* is found as single pollen grains. As to NAP pollen, the content of Gramineae increases. For the first time cereals are present of the *Triticum*-type. The amount of *Carex, Artemisia* and Chenopodiaceae becomes smaller while that of Ranunculaceae, Caryophyllaceae, Boraginaceae and *Plantago* increases. Sporiferous plants are almost always represented by monolete spores of ferns. *Botrychium* is found as single spores.

Thus, analysis of the pollen spectra of the Kvartsevoe profile sediments makes it possible to conclude that its lower part was accumulated during the warm period of the Atlantic. The local alpine vegetation was richer in species content than it was subsequently. During the second half of the Atlantic, when the climate was at its warmest and most humid, a lake was formed which existed, not only at the end of the AT, but also at the beginning of the SB. However, climatic cooling and reduced rainfall deprived this water body of supply, and it began to dry up. The warming of the Subatlantic at such altitudes was insufficient for this lake to reappear.

PALYNOLOGICAL CHARACTERICTICS OF THE LAKE BLIUZOVOE SEDIMENTS

At an altitude of 2884 m in the vicinity of Lake Bliuzovoe a soil profile 35 cm thick has

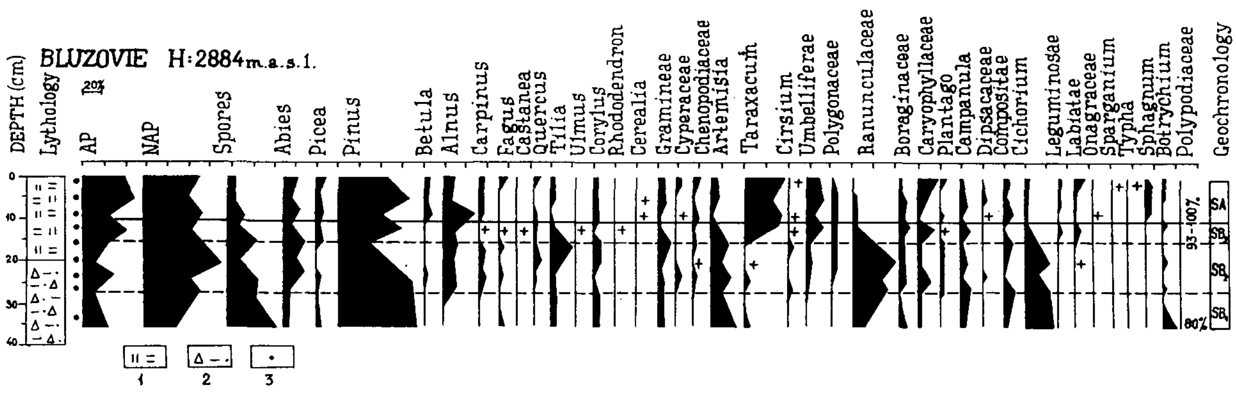

Fig. 9. Spore-pollen spectra of the Bluzovoe profile. 1-soil, 2-loam, 3-sampling site

been studied. 9 samples were taken for spore-pollen analysis. Their pollen spectra (Fig. 9) appeared to be not only almost saturated, but extremely interesting. The pollen diagrams have much in common with those of the uppermost part of the Kvarsevoe profile. The percentage of *Pinus* pollen is almost 4 to 5 times that of *Alnus*. In both cases the third dominant is *Abies*. In the lowest part of the layer, sporiferous species reach their maximum. This similarity of the pollen spectra allows us to date the lower part of the Bluizovoe profile as early as the beginning of the Subboreal. The layer is at the depth 35 to 26 cm. Its spectra are distinguished by *Pinus* pollen (up to 67%) and a small amount of *Picea* and *Abies*. There is no pollen of *Betula, Alnus, Carpinus, Quercus* and *Ulmus* at all. Among broad-leaved species, the pollen grains of *Tilia* are present, as well as single grains of *Fagus*. Among the NAP pollen, *Artemisia*, Ranunculaceae and *Cichorium* prevail. Among the sporiferous plants, *Botrychium lunaria* is characterized by its first maximum.

The pollen spectra of the next layer (26 to 15 cm) are distinguished by a marked increase in the NAP pollen content. The pollen of AP and sporiferous plants reaches its first minimum. Among the AP the content of *Pinus* is considerably reduced and *Picea* disappears. However, by contrast the content of *Abies* increases significantly. The content of foliate species becomes larger, the dominants being *Alnus* and *Tilia*. There is little pollen of *Quercus, Carpinus, Fagus* and *Betula*. As in the lowest layer, shrubs are represented here by *Corylus* pollen. In the NAP group Ranunculaceae and *Cichorium* prevail. The proportion of Caryophyllaceae, Gramineae and *Campanula* increases while the amount of *Botrychium* spores reduces. There are many spores of ferns.

The spectra of the layer at a depth of 15 to 10 cm are rather odd. The NAP pollen content decreases, while that of AP and sporiferous species increases. Among the AP, the *Pinus* pollen amount rises again, but that of other species is reduced. There is no pollen of *Betula, Carpinus, Fagus*, while *Castanea* and *Ulmus* are represented by single pollen grains. In this layer *Rhododendron* occurs for the first time. Among the NAP, *Taraxacum* pollen becomes the apparent dominant. There is much pollen of Umbelliferae, Caryophyllaceae and Gramineae. Ferns are the only representatives of sporiferous species and *Botrychium* occurs as single spores.

The pollen spectra at a depth of 10 to 0 cm are characterized by a significant decrease in the sporiferous species content and almost equal proportions of AP and NAP with the latter slightly in excess. Among the AP, the amount of *Alnus* pollen again attains maximum values. The content of *Betula, Carpinus, Quercus, Tilia* and *Fagus* increases. Shrubs are represented by *Corylus*. In the NAP group, *Cirsium* and Caryophyllaceae are predominant with much pollen of Umbelliferae, Labiatae, Polygonaceae, *Campanula* etc. present. Among sporiferous species *Sphagnum* appears for the first time and small quantities of *Botrychium* spores occur. Spores of ferns are predominant.

Thus, the character of the pollen spectra considered makes it possible to describe the climate and vegetation during the last 4000 years which underwent repeated changes. The coldest conditions occured during the formation of lowest layer. The local vegetation was very sparce and was represented only by communities which nowadays are typical for the subnival zone. Later on, during the warming of the climate in the middle of the Subboreal and in the Subatlantic, the territory emerged from beneath glaciers and the first pioneering associations occurred, eventually becoming transformed into short grassy upper alpine meadows.

CONCLUSION

Analysis of the three profiles located at different sites in the same region has shown that each has its own specyfic pollen spectra. Though in the highlands 80% of the spectra represent transported pollen, many features of the evolution of the local vegetation are revealed. Unlike the forest belt, replacement of formations in the alpine zone occurs relatively rapidly. For example, during the last 1600–1800 years at an altitude of 2151 m, one can distinguish eight stages in the evolution of the vegetation. The character of these changes during this period allows us to single out 4 cooling and 4 warming periods of the climate. However, at very high altitudes where the severe subarctic climate retards the sedimentation intensity samples every 5 to 8 cm are not sufficient. That is why we could not trace in detail all the phases in the evolution of the vegetation, not only for the Subatlantic, but also for other periods. In this case it is absolutely necessary to take samples every 1 or 0.5 cm. It should be noted that in the high mountains of the Greater Caucasus, sediments of mountain tundras located above 2700 to 2800 m remain almost uninvestigated. At these altitudes there are no absolute datings, according to ^{14}C. In this connection, we were surprised at first by the data obtained on the Kvartsevoe profile where, during the last 4375 years, the thickness of the peat layer formed is only 20 cm and that of the soil 6 cm, 26 cm altogether! We even doubted whether the dating analysis was correct. However, having familiarized ourselves with the works on the stratigraphy and palynology of the Holocene arctic tundras of the Spitsbergen mountains and subantarctic tundras of Antarctica, we made sure that such a retarded rate of sedimentation of both organic and mineral formations under such conditions is quite possible (Birkenmajer et al. 1985, Knaap van der 1989b, Knaap van der and Leenwen van 1993).

It is also very important that the presence of large amounts of transported pollen from the lower mountain belts in the spectra of high-mountain lakes and bogs makes it possible for us to describe the vegetation of each individual belt, establish migration rates, not only of the upper tree line, but, in our case, of the lower one as well. In the region under study during climate cooling, the forest belt narrowed, since alpine vegetation approached it from above and steppe vegetation from below. This approach of the steppe belt is very clearly shown in the spectra during the intense coolings of the Holocene by the maxima of *Ephedra*, Chenopodiaceae and *Artemisia* pollen which was carried from below by winds which intensified during cold periods. None of the above mentioned plants grows in the alpine humid belt of the Western Caucasus nowadays, and neither could they grow in the Holocene.

The pollen spectra of the Rybnoe profile provide information about events that took place not only in the Northern Caucasus, but also in the Western Transcaucasus. An increase of humidity in the second half of the Subatlantic resulted in an expansion of waterlogged forest consisting of *Pterocarya pterocarpa* (Kvavadze & Rukhadze 1989). *Pterocarya* pollen, as well as that of other plants was transported to the Arkhyz mountains by south and south-west winds which most probably prevailed at that time. Pollen of *Cedrus libani* was transported here from Turkey by the same winds. It is not impossible that in the Late Holocene the area of *Cedrus libani* forest expanded in its native land. As evidence we may cite the increase in transported *Cedrus* pollen to the east of its area as well, viz. in the Late Holocene sediments of Lake Van (Van Zeist & Woldking 1978).

Therefore, as one can see, the palynological material in the high-mountain sediments of the Greater Caucasus provides incredibly extensive and varied information on both the vegetation and climate of the region under study and on many issues related to air currents, the evolution of lakes, stratigraphy, erosion effects of glaciers, anthropogenic effects on landscapes, etc. This may be due to the fact that the primary vegetation in the mountains of the Caucasus was not completely destroyed in the Subatlantic nor even recently and on steep and high ranges, where, as a rule, there are no roads, it has been preserved in its primeval natural state.

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