Acta Palaeobot. 35 (1): 57–72, 1995

PECULIARITIES OF RECENT POLLEN SPECTRA OF LAKE SEDIMENTS IN THE CAUCASUS

ELISO V. KVAVADZE[1] and YURI V. EFREMOV[2]

[1]L. Sh. Davitashvili Institute of Palaeobiology of the Georgian Academy of Sciences, 4 Potochnaya St., Tbilisi 380004, Repubic of Georgia
[2]Krasnodar State University, Krasnodar, Russia

ABSTRACT. Pollen spectra have been analysed of recent bottom sediments in small lakes of high-mountain parts of the Caucasus. The lakes under study are of glacial origin. They are situated along the Greater Caucasian Watershed Range in the alpine meadow belt. The main peculiarity of the pollen spectra is availability of large amount of pollen transported from vegetation belts lying below. In the lakes above 2800–3000 m the pollen of local origin accounts for not more than 15–20% of the spectrum composition. Comparison of lake and soil spectra has revealed very interesting peculiarities of pollen spectra formation in high-mountain lakes.

KEY WORDS: pollen analysis, glacial lakes, transported pollen

INTRODUCTION

High-mountain landscapes of the Caucasus are distinguished by numerous lakes whose majority are concentrated in the high- alpine belt or just below the snow- line. In the literature there is a special term "lake belt" (Sevastianov 1985) by which a cluster of lakes is meant. Like vegetation belts, the lake belt can shift in either direction depending on many factors and, first of all, climatic ones. It seems necessary to reconstruct mountain lake belts of the past not only to determine palaeoclimates, but also to find out hydrological regime, to solve problems associated with evolution of glaciers as well as many other problems of high- mountain region palaeogeography. To solve the above mentioned problems palaeobotanical methods, and palynological method, in particular, are of paramount importance.

The main goal of the present investigation is to show:

1. how recent pollen spectra of lakes are formed in different regions of the Greater Caucasus along the transect running from the West to the East (Fig. 1);

2. what peculiarities characterize lake spectra at various altitudes (vertical transects). Nowadays it is impossible to correctly interpret fossil spectra of lakes in the mountains without studying the mentioned problems.

At present the majority of mountain lakes in the Caucasus are situated at altitudes from 2500 to 3000 m a.s.l. (Efremov 1980).

This is the lowest position compared to that in the mountains of the Pamirs and Tien-Shan (Fig. 2).

Genetic diversity of lakes in the mountains is considerably less than that in the valleys. The decisive role in lake formation here is played by glacier activity. All the scientists relate existence of glaciogenic lakes to recent and old glaciation. By the latter in this case only the last glaciation of the Late Pleistocene is implied which degraded in the course of the Holocene and whose remnants can be seen in recent mountain glaciers (Sevastianov 1985).

The traces of this glaciation are, in particular, troughs, moraines and lakes at the bottom of the troughs.

MATERIAL AND METHOD

The factual material was being collected from 1984 to 1992 during annual field expeditions in July-August. Lake samples were taken from 5 sites in the high mountains of Abkhazia, Caucasian Biosphere Reservation, Arkhyz, Qeli Volcanic Highland and Lagodekhi

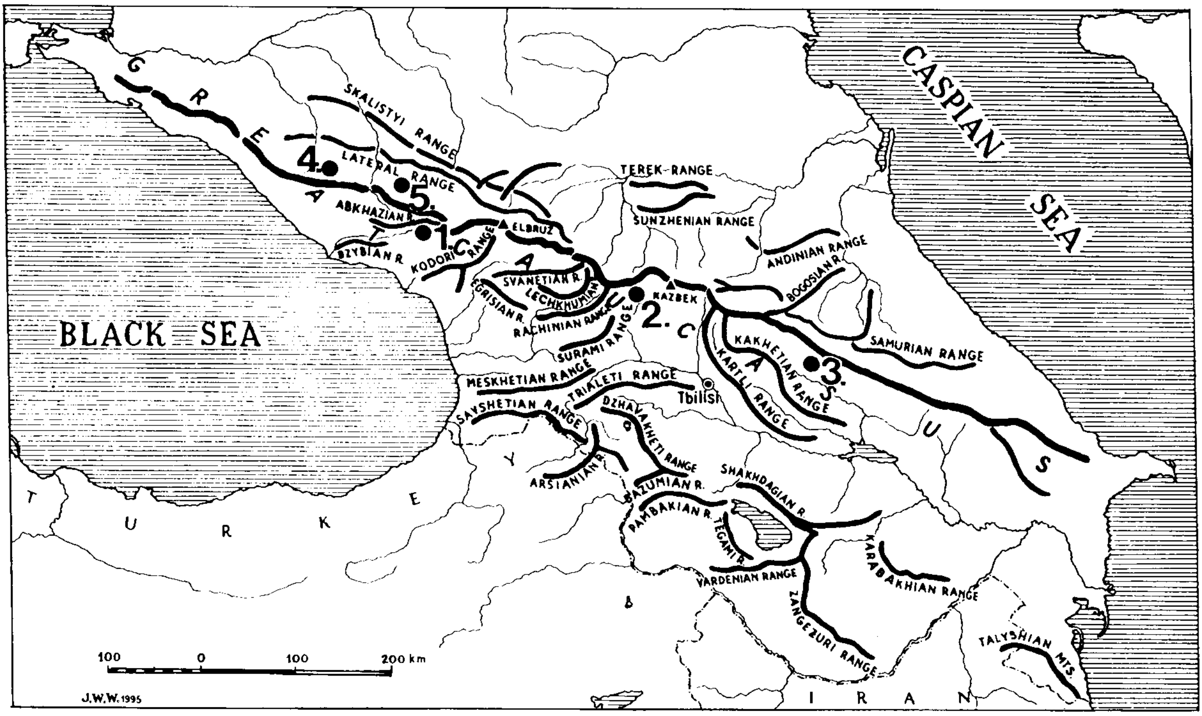

Fig. 1. Orographic scheme of the Caucasus and location of the sites under study: 1 – Lake region in Abkhazia 2 – Qeli Volcanic Highland 3 – Lagodekhi lake region 4 – Caucasian Biosphere Reservation 5 – Arkhyz lake region

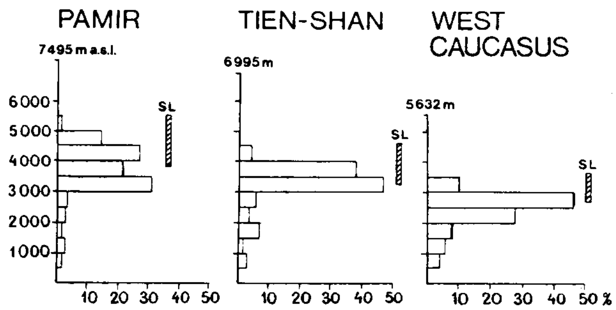

Fig. 2. Distribution of mountain lakes by altitudes (in percent from the total number): the Pamir, the Tien-Shan, West Caucasus; SL – altitudinal interval of the climatic snow line position; 7495 m, 6995 m, 5632 m – the highest summits of the mentioned mountain systems (taken from Sevastianov 1985)

Reservation (Fig. 1). All the mentioned sites are running along the Main Watershed Range. Sites 2 and 3 are on its northern offshoots, while the rest ones – on the southern offshoots. Altogether 24 high- mountain lakes have been studied. In addition to sampling, during the expeditions a botanical description of vegetation was made and morphometry of the lakes themselves was carried out. On the lake coasts in many cases soil samples were taken for spore-pollen analysis.

The material for the pollen analysis was first treated by the alkaline (KOH) method followed by acetolysis. From each sample up to 500–700 sporomorphs were counted on the average. The pollen and spore percentage was determined separately for trees, shrubs, herbs and sporiferous plants. Similarly, spore-pollen diagrams were prepared.

The studied preparations are saved at L. Sh. Davitashvili Institute of Palaeobiology of the Georgian Academy of Sciences.

RESULTS OF INVESTIGATIONS

POLLEN SPECTRA OF PERIGLACIAL LAKES OF ABKHAZIA

In the high-mountain part of Abkhazia, the spectra of bottom sediments of spring floods of three lakes have been studied. The lakes are situated at altitudes from 2200 to 2800 m a.s.l. (Fig. 3) on the southern offshoots of the Chkhaltini and Kodori Ranges. These are headwaters of the rivers Sibista (samples 1, 2), Adange (samples 3, 4) which belong to the basin of the rivers Kodori and Khodzhal (samples 5, 6) – a tribute of the Galidzga. The lakes are of glacial origin. They are small, their depth not exceeding 1.5–2.0 m. In the vicinity of the river Sibista (H:2200 m) there are alpine herb meadows with thickets of *Rhododendron caucasica*. The composition of alpine vegetation at the headwaters of the Adange (H:2800 m) and Khodzal (H:2650 m) becomes

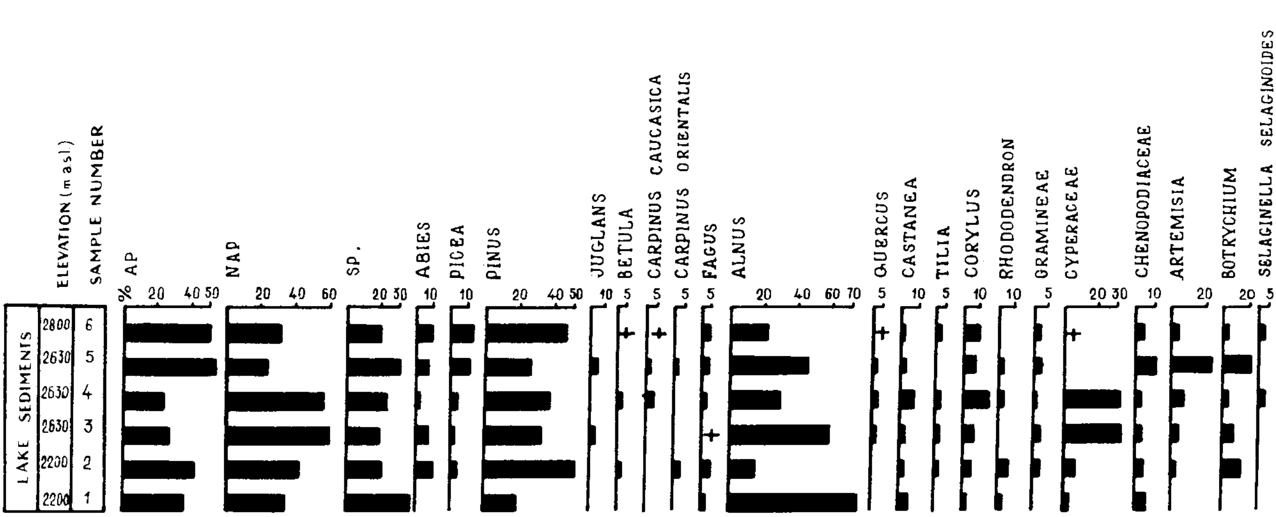

Fig. 3. Spore-pollen diagram of bottom sediments of the lakes in the Abkhazian region

scarce. It includes mostly short-grass formations. The upper forest-line in the regions under study runs at an altitude of 1700–1800 m a.s.l. The spore-pollen spectra of the lake samples (2, 4, 6) are characterized by exceeding saturation with microphytofossils. However, almost a half of each spectrum is represented by long-distance transported pollen and spores. On the whole, the amount of autochtonous pollen does not exceed 40%. The role of the long-distance transport rises with increasing altitude. This regularity is especially clearly seen in the content of coniferous pollen.

In the AP group the pollen of *Alnus* and *Pinus* is prevalent. It is worth noting that the latter dominates in bottom deposits of spring floods (samples 2, 4, 6), while in lake-bog formations near the coast (samples 1, 3, 5), on the contrary, the former becomes much more prevalent. Among broad-leaved species, *Fagus* and *Castanea* are always present, but their amount does not exceed 3–6%. The pollen of *Carpinus, Tilia, Quercus, Juglans* is found in smaller quantities and there is little pollen of *Betula* and *Ulmus*.

Among shrubs, the pollen of *Corylus* is prevalent. This pollen as well as that of arboreal plants is long-distance transported. However, the *Rhododendron* pollen is of local origin and the pollen quantity amounts to 5%. *Hedera, Vaccinium, Rhus, Lonicera* are found in the form of single grains.

In the NAP group the following situation is observed.

Compositae, Umbelliferae, Ranunculaceae, Polygonaceae, Caryophyllaceae, Cyperaceae are prevalent. *Artemisia*, Plumbaginaceae, Chenopodiaceae, Onagraceae, Gramineae belong to less important components of the spectra. Dipsacaceae, Labiatae, Cruciferae, Cerealia, *Cirsium, Valeriana, Campanula*, Primulaceae, Plantaginaceae, *Sparganium* are found as single grains. Among sporiferous plants, monolete spores of ferns are predominant which have been transported from the lower vegetation belts. The spores of *Botrychium lunaria, Lycopodium alpinum, Selaginella selaginoides* are of local origin, while those of *Pteris cretica, Pteridium aquilinum, Athyrium* sp. *Polypodium vulgare, Cryptogramma crispa* have been transported from the forest belts of mountainous Abkhazia.

As one can see, the lake spectra reflect not only the local alpine vegetation, but also all the components of high- and middle- mountain forests. These are dark coniferous forests consisting of *Picea* and *Abies* with admixture of *Fagus*. The latter at the same time forms the forest-line (beech elfin woodland). Middle mountains of Abkhazia are covered by mixed broad-leaved forests consisting of *Castanea, Carpinus, Quercus, Fagus, Tilia, Ulmus*. At the same time lowland forests are poorly reflected in the pollen spectra of high mountains. For example, no pollen of *Pterocarya pterocarpa, Ilex colchica, Buxus colchica* can be found in them.

The comparison of pollen spectra of the high-mountain lakes of Abkhazia with those of lowland lakes in open landscapes (Fig. 4) shows a number of both common and distinguishing features. In both cases in the AP

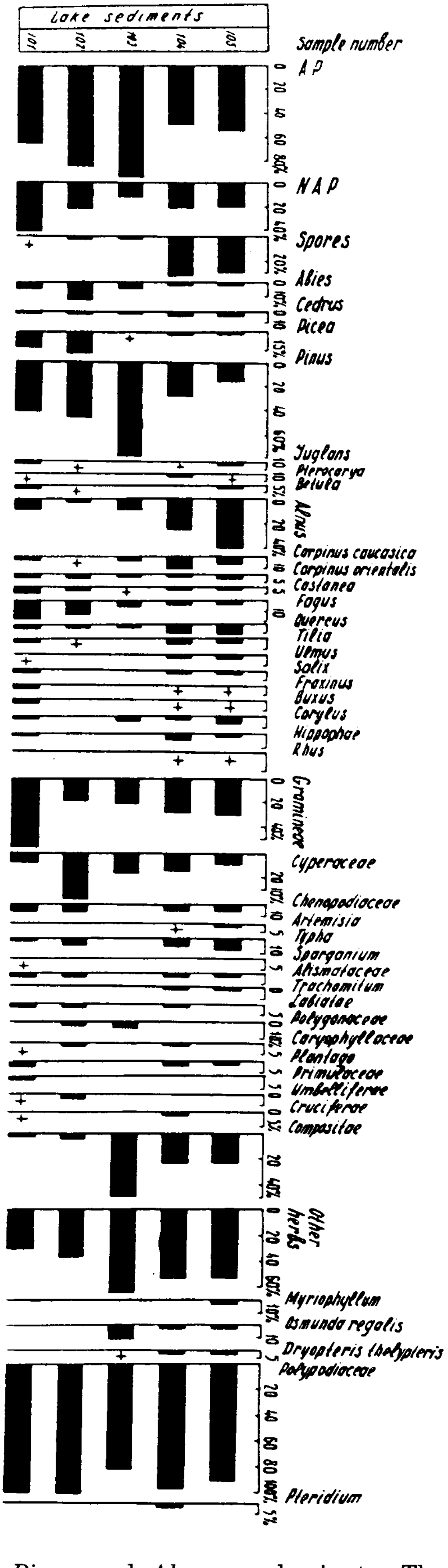

Fig. 4. Spore-pollen diagram of bottom sediments of lake Innit

group *Pinus* and *Alnus* predominate. There are a lot of dark coniferous plants. Among broad-leaved trees, the pollen of *Fagus* is prevalent. In the lowland one can permanently observe the pollen of *Carpinus, Castanea, Quercus, Tilia, Ulmus*. The pollen of *Betula, Juglans* is found in less quantities. However, here there is pollen of *Pterocarya, Fraxinus, Buxus, Salix*. Substantial differences can be observed in the herbaceous plants spectra in which Gramineae, Cyperaceae, Compositae are predominant. A lot of aquatic and semiaqueous plants are reflected in the spectra, such as *Typha*, Alismataceae, *Myriophyllum, Sparganium*. Almost all sporiferous plants are represented by monolete spores of ferns. There are few spores of *Pteridium aquilinum* and *Osmunda regalis*. Spores of elements of alpine meadows and high- and middle-mountain forest belts are completely absent.

POLLEN SPECTRA OF THE BOTTOM LAKE SEDIMENTS IN THE QELI VOLCANIC HIGHLAND

The Qeli Volcanic Highland is situated in the central part of the Greater Caucasus to the south-west of Mount Kazbegi. Here there are headwaters of the rivers Liakhvi, Ksani and Aragvi. The main peculiarity of the Qeli Highland landscape is volcanic complexes with swelling cones of extinct volcanos and enormous frozen lava flows as well as open spaces with numerous lakes of various size. Most of them are dykes, i.e. dammed volcanic cones and lava flows. Some of the lakes occurred in depressions of the lava flows. Here there are nival lakes, which formed as a result of erosion activity of snow, and thermokarst lakes formed as a result of melting of stagnant ice.

The lakes of the Qeli Highland represent various stages of evolution. However, due to filling-in of their basin with allochtonous material, they permanently degrade (Kvavadze & Efremov 1990).

The spore-pollen analysis was applied to study seven samples of lake sediments which were taken at various hypsometric levels from lakes Grdzelitba (H:2775 m), Aragvistavi (H:2886 m) and Archvebistba (H:3078 m). The average depth of the lakes is 3–4 m.

The material is highly saturated with pollen and spores. Sporomorph preservation is extremely good.

The spore-pollen spectra of the bottom samples from Grdzelitba lake (samples 1, 2 – Fig. 5) situated among alpine meadows are characterized by a maximum NAP content (up to 71–

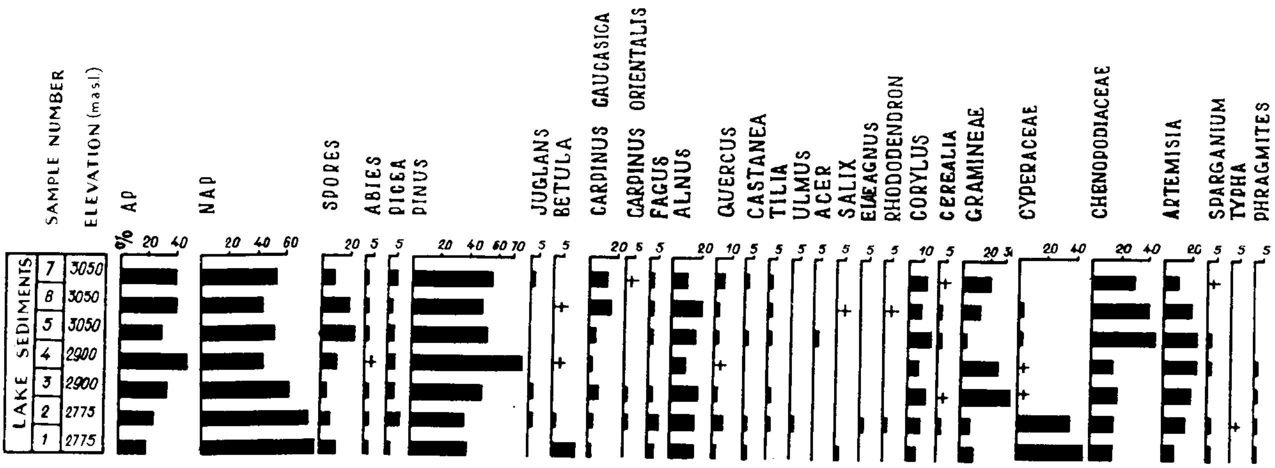

Fig. 5. Spore-pollen diagram of bottom sediments of the lakes in the Qeli Volcanic Highland

80%). A considerable part of it accounts for the pollen of coastal aquatic vegetation which reflects the actual picture quite adequately. At present the lake is marked by intensive filling-up with vegetation. The content of the *Carex* pollen in the sample spectra amounts to 45%. One can observe the pollen of *Sparganium, Typha, Phragmites*. The three components represent the formation of semiaquatic vegetation which is usually the main background of coasal thickets. The pollen of aquatic plants was not found by us either in lake Grdzelitba or in samples from any other lakes. The NAP group in the pollen spectra is represented by Gramineae among which there are also Cerealia transported here from agricultural regions of the lower mountain belts. There is a lot of pollen of Chenopodiaceae, *Artemisia,* Umbelliferae. It seems that this pollen cannot be attributed to the local one. The pollen grains of *Plantago, Taraxacum,* Saxifragaceae, Cruciferae, *Campanula,* Geraniaceae, Dipsacaceae, Labiatae, Polygonaceae, Ranunculaceae, Boraginaceae, etc. are found in small quantities.

The AP spectra are characterized by the the following peculiarities. The pollen of *Pinus, Alnus* and *Betula,* i.e. the components of high-mountain and flood plain forests, are predominant. In the valleys of the adjacent rivers (Aragvi, Ksani), *Betula* and *Pinus* form the upper forest-line at an altitude of 2000–2200 m a.s.l. *Alnus* grows much lower and its participation in the spectrum is the result of long-distance transportation. The pollen of *Abies* and *Picea* (up to 4–8%) has been transported from still more distant region of the Major and Minor Liakhvi basins. Broad-leaved plants play an important role in the spectra: *Fagus* up to 7%, *Quercus* up to 6%. The pollen of *Carpinus, Castanea, Tilia, Carpinus orientalis, Juglans, Salix* is observed in equal amounts. There is little pollen of *Rhododendron* and *Elaeagnus*, at the same time there is much pollen of *Corylus*. The content of monolete spores of ferns brought by the wind from the forest belt is not significant. *Athyrium* is determined at the level of genus.

The pollen spectra of samples 3 and 4 from lake Aragvistavi are marked by NAP reduction (compared to lake Grdzelitba spectra): their content lowers down to 42–62%. Participation of AP pollen increases up to 47%. There is small amount of sporiferous plants which are represented by monolete spores of ferns. Among the NAP group the following plants predominate: Gramineae (up to 33%), *Artemisia* (up to 22%), and Chenopodiaceae (up to 16%). The pollen of Umbelliferae, Labiatae, *Plantago, Ranunculus,* Geraniaceae, *Taraxacum,* Polygonaceae are represented in smaller amounts. Cruciferae, Caryophyllaceae, Compositae, Leguminosae, *Cirsium,* Scabiosae, Boraginaceae, *Carex,* Cerealia, *Cichorium,* Plumbaginaceae, Onagraceae, *Phragmites, Campanula* are found in the form of single pollen grains.

In the AP spectra, the pollen of *Pinus* and *Alnus* are prevalent amounting up to 69% and 18%, respectively. The amount of *Picea, Abies, Fagus, Carpinus, Quercus* and *Tilia* pollen is smaller. *Juglans, Betula, Carpinus orientalis* are represented by single pollen grains. Among shrubs, the content of *Corylus* pollen is rather large.

The spore-pollen spectra of samples 5–7 from the bottom of Archvebistba lake show an increase in the amount of the AP pollen; the role of sporiferous plants also rises. As in the previous spectra, among the AP group, *Pinus* and *Alnus* predominate. Besides, the role of *Picea, Carpinus, Quercus, Tilia* increases. The amount of the *Abies, Fagus* and *Castanea* pollen is rather small. *Betula, Juglans, Carpinus orientalis, Rhododendron* are found in the form of single pollen grains. Among shrubs, the pollen of *Corylus* predominates.

Considerable differences are mentioned in the NAP group. Here the pollen of Chenopodiaceae prevails (up to 44%). Also there is much pollen of *Artemisia* (up to 21%) and Gramineae (up to 17%). Compositae, *Plantago*, Polygonaceae, Ranunculaceae, Umbelliferae, Labiatae are represented in smaller pollen amounts. The pollen of Cerealia, Cruciferae, *Taraxacum, Veronica,* Saxifragaceae, *Draba,* Caryophyllaceae, *Carex, Sparganium,* etc. is found in the form of single grains.

Among sporiferous plants, monolete spores of ferns prevail. *Polypodium vulgare* is determined at the level of species. In sample 5 there are spores of *Pteridium aquilinum.* In all the three samples the spores of *Botrychium lunaria* are found.

Thus, the comparison of the composition of the obtained spore-pollen spectra with actually existing vegetation makes it evident that the bottom sediment spectra have completely reflected the character of the vegetation of the Qeli Volcanic Highland (see Tab. 1). However, it should be noted that the spectra reflected the transported pollen as well, whose amount increases with altitude. This, probably, can be explained not only by vegetation thinning, but also by wind power, whose average velocity and duration here reach very high values (Maruashvili 1971). That is why the cases of long-distance transport are not surprising. Here the transport of the pollen grains of *Castanea* is implied which grows to the west of the Qeli Plateau at a distance of at least 80–100 km.

The comparison of the obtained pollen spectra of the Qeli Highland from the alpine belt with those of the lakes in the subalpine belt of the same region at an altitude of 1950 m a.s.l. shows some very interesting peculiarities (Fig. 6). The role of the pollen transported from other belts here is negligibly small. In the spectra the pollen of *Fagus* predominates (37–40%), which corresponds to the actual situation. The forest ends in crooked beech woodland. The spectra also reflect such elements of high-mountain forest as *Acer, Sorbus, Salix, Rhododendron.*

There is small percentage of transported pollen of the NAP group: Cerealia, *Artemisia,* Chenopodiaceae. And there are very few spores of of monolete forest ferns.

The composition of subalpine meadows as well as that of coastal vegetation of the lake is reflected rather adequately.

POLLEN SPECTRA OF PERIGLACIAL LAKES OF THE LAGODEKHI RESERVATION

In the very north-east of Georgia, in the mountains of the Lagodekhi Reservation, the spectra of bottom sediments of four lakes have been studied. All of them are of glacial origin. They are situated at different hypsometric levels. In a pass water gap at the axis of the Main Watershed Range (H:2783 m), lake Khala-Khol was investigated. On the southern slopes of the range, lakes Ieroglif (H:2750 m), Mutnoe (H:2920 m), and Verkhnee (H:3043 m) were studied. The area of each lake does not exceed 5000–6000 sq. m. and their maximum depth is 3–4 m. Here is the region of alpine vegetation. The forest- line runs at an altitude 1900–2000 m a.s.l. The high-mountain forests of this region are characterized by lack of dark-coniferous elements. On the southern slopes *Pinus* is found rather seldom. However, on the northern slopes pine forests play an important role.

The pollen spectra of the bottom sediments of the lakes situated at lower altitudes (2750–2783 m a.s.l.) are marked by the following peculiarities (Fig. 7). In general, the NAP pollen prevails (up to 39–68%). Among the AP group, the pollen of *Pinus* (34–57%) and *Alnus* (7–33%) is predominant. The pollen of *Carpinus caucasica* amounts to 13–15%, that of *C. orientalis* – to 4%, and that of *Corylus* – to 8–10%. The pollen of broad-leaved plants such as *Fagus, Quercus, Tilia, Ulmus, Castanea* does not exceed 2–4%. The polen of *Picea, Juglans, Pterocarya, Acer* is found in the form of single grains. Among shrubs, there are small amounts of the *Rhododendron* and *Ephedra* pollen.

The NAP group is characterized by extraordinary abundance of pollen as well as taxa

Table 1. Percentage of local pollen in the spectra of lake sediments of the Qeli Volcanic Highland (calculation is made from the total sum of pollen and spores)

Sample No.	1	2	3	4	5	6	7
Absolute altitude in m a.s.l.	2775	2775	2900	2900	3050	3050	3050
1	2	3	4	5	6	7	8
Gramineae	4	5	21	10	0.5	5	5
Cyperaceae	35	25	0.5	0.5	0.5	1	–
Cichorium	2	0.5	1	4	1	0.5	3.5
Taraxacum	0.5	0.5	0.5	0.5	0.5	0.5	–
Cirsium	–	–	0.5	0.5	–	0.5	–
Campanula	–	0.5	0.5	–	–	–	–
Ranunculus	1	0.5	1	0.5	1	1	0.5
Plantago	1	2	1	0.5	1	0.5	1.5
Geraniaceae	0.5	0.5	1	–	–	–	–
Scabiosa	–	–	0.5	–	–	–	–
Knautia	–	0.5	0.5	–	0.5	–	–
Caryophyllaceae	–	1	0.5	0.5	0.5	–	0.5
Umbelliferae	4	3	3	3	1	1	0.5
Leguminosae	0.5	0.5	0.5	–	1	–	0.5
Brassicaceae	–	–	–	–	0.5	0.5	–
Labiatae	0.5	2	1	–	1	0.5	0.5
Plumbago	–	0.5	–	–	–	–	–
Aster	1	1	0.5	4	–	–	1.5
Saxifragaceae	0.5	0.5	0.5	–	–	0.5	–
Veronica	–	0.5	–	–	0.5	0.5	–
Onagraceae	–	0.5	–	–	–	–,	
Boraginaceae	–	1	1	–	1	0.5	–
Draba	–	–	–	–	0.5	–	–
Polygonaceae	0.5	0.5	1	0.5	1	1	–
Phragmites	0.5	1.5	–	–	–	–	–
Sparganium	0.5	0.5	–	0.5	0.5	–	0.5
Typha	–	0.5	–	–	–	–	–
Botrychium	–	–	–	–	0.5	0.5	0.5
Altogether	52%	48%	38%	25%	13%	14%	15%

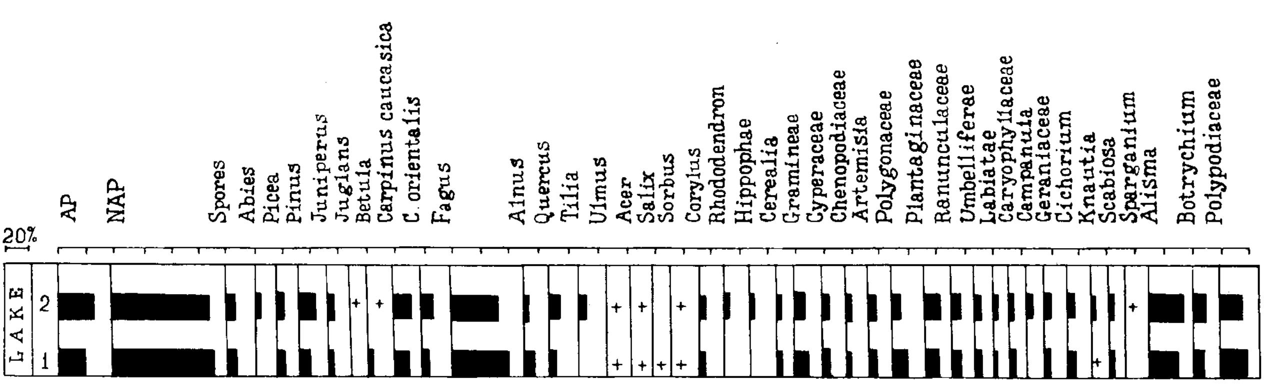

Fig. 6. Spore-pollen diagram of bottom sediments of the lake on Mt. Unagira

variability. There is a lot of pollen of Compositae, Leguminosae, Polygonaceae, Boraginaceae. The pollen of Gramineae, Labiatae, *Artemisia,* Chenopodiaceae, *Campanula* is represented by smaller amounts. Very few pollen grains were discovered of Geraniaceae, Dipsa-

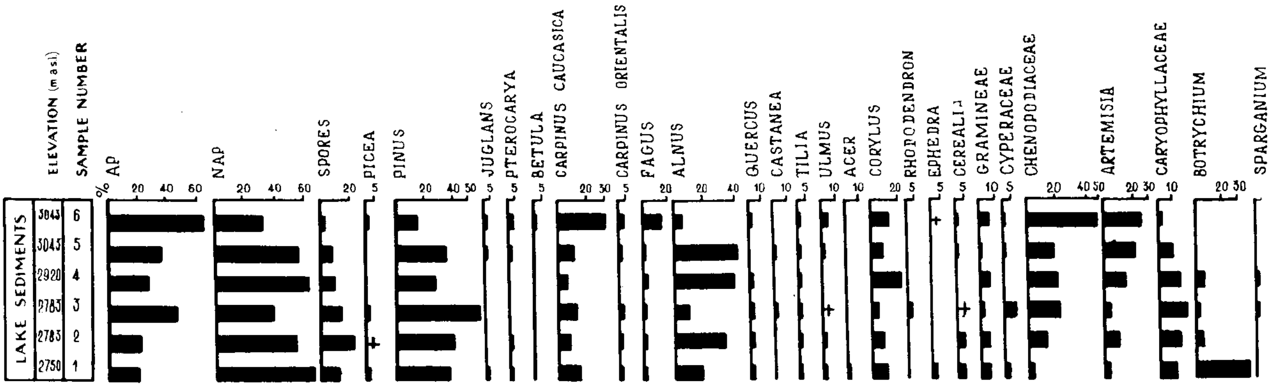

Fig. 7. Spore-pollen diagram of bottom sediments of the lakes in the Lagodekhi region

caceae, *Plantago,* Plumbaginaceae, Cruciferae. Among littoral-aquatic plants, only *Sparganium* pollen was found. It sould be noted that in the three samples, the pollen of cultivated crops of the *Triticum* type is mentioned in the form of single grains.

Among sporiferous plants, spores of monolete ferns and *Botrychium lunaria* are prevalent, the latter being abundant in sample 1 (up to 36%). *Polypodium vulgare* and *Pteridium aquilinum* are found sporadic.

Comparison of the spectra of these two lakes has shown that in Khola-Khol lake the amount of AP pollen, and especially long-distance transported pollen of *Pinus*, is prevalent, which is in agreement with the real situation, since, as was already mentioned, there grow a lot of pine trees on the northern slopes of the Caucasian Range. Among the NAP group, the amount of long-distance transported pollen of Chenopodiaceae and *Artemisia* increases up to 22% and 7%, respectively. The spectra of the lakes differ in sporiferous plants content. The role of *Botrychium lunaria* in Khola-Khol lake is negligibly small, while fern spores are prevalent.

When comparing the pollen spectra of lake sediments with those of soils, very interesting regularities can be observed (Figs 7, 8). On the whole, the amount of AP pollen in soils is smaller, while that of NAP pollen is larger. The content of sporiferous plants is, somewhat higher too. Among the AP group, the pollen of *Alnus* (34–44%) takes first place rather than that of *Pinus* (16–32%). Among other representatives of AP, the spectra mainly reflect *Tilia* (up to 18%). Besides, in the soil spectra there is no pollen of *Juglans, Pterocarya, Carpinus orientalis, Castanea. Fagus, Quercus, Picea, Ulmus, Acer* are reflected by small amounts of pollen. There are only few pollen grains of *Salix*, while in the lake sediments its pollen is not found at all.

There is rather substantial difference in the NAP spectra as well. The participation of Gramineae and *Carex* increases, while that of

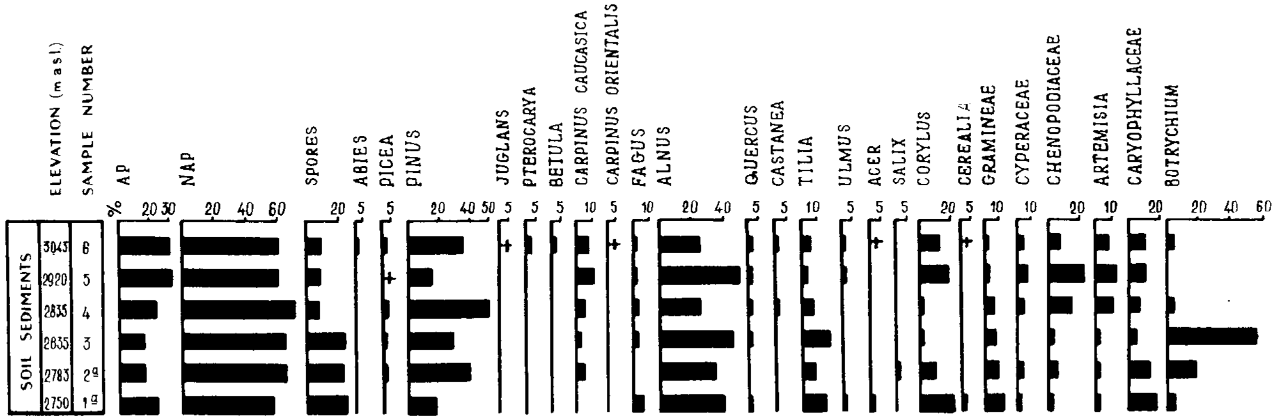

Fig. 8. Spore-pollen diagram of recent soils in the vicinity of the Lagodekhi region lakes

Chenopodiaceae, *Artemisia* as well as Cerealia decreases. The content of *Botrychium lunaria* spores in the soils near lake Khola-Khol increases (up to 16%), while in the lake sediments its percentage does not exceed 4%. A lot of *Botrychium lunaria* spores can be found in basins of former lakes (soil sample 3a) where they reach 70% (Fig. 8).

At the border between the high-alpine and subnival belts, at an altitude of 2920 and 3045 m a.s.l., the bottom sediments of lakes Mutnoe and Verkhnee were studied (samples 4, 5, 6).

The spore-pollen spectra are characterized by the following features. In general, the amount of AP pollen compared to the spectra of lower lakes (samples 1, 2, 3) increases, the content of herbaceous and sporiferous plants decreases. In the AP group, the pollen of *Alnus* predominates (40–41%). The pollen of *Pinus*, on the average equals 20–30%. Among broad-leaved trees, the pollen of *Carpinus* and *Fagus* predominates – 34% and up to 12%, respectively. There is a considerable amount of *Pterocarya* and *Ulmus* (up to 4% in both cases). The pollen of *Tilia, Carpinus orientalis* and *Juglans* amounts to 2% in each case. Only in some samples (4, 6), *Picea, Betula, Quercus, Ephedra* are represented by single pollen grains. Also, in sample 5 single pollen grains of *Castanea* are found. All the samples include a lot of pollen of *Corylus* (10–20%).

Among the NAP group, Chenopodiaceae and *Artemisia* predominate. There are considerable amounts of Gramineae, Compositae, Caryophyllaceae. Cerealia, *Plantago, Carex,* Polygonaceae, Geraniaceae, Ranunculaceae, Leguminosae, Dipsacaceae, Umbelliferae, Labiatae are less significant in the spectra. Among sporiferous plants, there are a lot of monolete spores of ferns. One can find single spores of *Botrychium lunaria, Polypodium vulgare* and *Pteridium aquilinum*.

The comparison of the pollen spectra of the two lakes allows us to conclude that the spectra of lake Verkhnee, situated higher than lake Mutnoe, better reflect the general regional character of vegetation: they register long-distance transported pollen components not only from forests, but also from steppes of East Georgia. A similar picture is observed when analysing the spectra of soil samples taken from the lakes under study (samples 5a, 6a). The AP composition of the pollen spectrum of sample 6a (near lake Verkhnee) is richer. It is only here that one can find the pollen of *Abies, Juglans, Pterocarya, Betula, Carpinus orientalis*. It should be noted that the amount of *Tilia* pollen in soils is larger than that in lake sample spectra. The NAP spectra are marked by the same peculiarities as those of bottom sediments. However, the NAP group in soil samples is richer and more diversified. There are few sporiferous plants, and, as in lake sediments, they are represented by monolete spores of ferns. *Pteridium aquilinum* and *Botrychium lunaria* are found in the form of single spores.

POLLEN SPECTRA OF PERIGLACIAL LAKES IN THE CAUCASIAN BIOSPHERE RESERVATION

The Caucasian Biosphere Reservation is situated in the far west of the Greater Caucasus. It is the largest Reservation in the region. Its area (263300 ha) covers both northern and southern slopes with rather diversified and even contrasting landscapes. The Reservation has been protected since the end of the last century. That is why natural structures here remained almost unviolated (Bannikov et al.1969, Akatov et al.1990).

In the alpine belts on the northern slopes of the Greater Caucasus at altitudes 2485–2812 m a.s.l., bottom sediments of 8 lakes have been studied. The lakes are situated at the headwaters of the rivers Zakan and Bezymianka, the tributes of the Major and Minor Laba. The Laba, in its turn, relates to the basin of the Kuban. Detailed information concerning each lake is presented in Table 2.

In the regions under a.s.l. investigation, the forest-line runs at an altitude 2000–2200 m. This is beech or birch crooked forest. 60% of the Reservation territory is covered with forests, 2/3 of which are occupied by fir forests consisting of *Abies nordmaniana* at altitudes from 1200 to 1900 m a.s.l. Below, between 1200–900 m a.s.l., beech forests spread consisting of *Fagus orientalis*.

The main distinguishing feature of the spore-pollen sediments of spring floods (Figs 9, 10) is extremely large content of transported pollen. At an altitude 2500–3000 m a.s.l. its percentage was 55–65%, while at higher altitudes it reached 80–90%. In the whole group either arbore plants and shrubs or sporiferous plants can be dominants.

Table 2. Characteristics of glacial lakes of the Caucasian Biosphere Reservation

Nos	Lake	Altitude m	Water plane area, sq. m.	Depth m	River basin
1.	George Bush	2812	85000	25	Zakan (the Major Laba tribute)
2.	Safronov	2711	41000	12	Zakan (the Major Laba tribute)
3.	Geografy	2710	5500	6	Zakan (the Major Laba tribute)
4.	Riviera	2650	5000	2	Zakan (the Major Laba tribute)
5.	Korgo	2548	2500	8	Bezymianka (the Minor Laba tribute)
6.	Chernoe	2534	44000	15	Zakan (the Major Laba tribute)
7.	Bezmolvie	2530	21000	18	Zakan (the Major Laba tribute)
8.	Bathing Chamois'	2485	3000	3	Bezymianka(the Minor Laba tribute)

Among the AP group, the pollen of *Alnus* and *Pinus* has reached the highest values: up to 50–60% and 35–45%, respectively.

The third dominant is usually *Abies*, though its amount seldom exceeds 8–12%. Among broad-leaved trees there are two dominants: *Tilia* (up to 3%) and *Carpinus caucasica* (up to 2.5%). Among shrubs, *Corylus* and *Rhododendron* are prevalent – up to 8–10% and 1.5–2.5%, respectively. *Sorbus caucasigena, Daphne caucasica, Salix caprea* are only found as single pollen grains.

The NAP composition is rather diversified (Tab. 2). The dominants of the spectrum change not only with increasing altitude but also horizontally. At lower altitudes the pollen of Caryophyllaceae is sometimes prevalent (headwaters of the Bezymianka), while sometimes it is that of Gramineae (lake Chernoe).

In the spectra of lake Bezmolvie, the first dominant is the pollen of Umbelliferae.

With increasing altitude one could clearly observe the rise of the amount of *Artemisia* and Chenopodiaceae pollen which has been transported from the steppes adjacent to the piedmonts of the North Caucasus. In the highlands of the West Caucasus these plants either do not grow or they can be found very seldom (Kolakovski 1980).

Among sporiferous plants, monolete spores of ferns are prevalent. In small amounts, though permanently, the spores of *Botrychium lunaria* can be found as well as single spores of various *Sphagnum*. *Selaginella selaginoides, Lycopodium alpinum, L. selago, Pteridium aquilinum* are found.

Comparison of the pollen spectra of lake sediments and soils has demonstrated great saturation of lake samples with microfossils. Besides, the latter have a richer taxonomic composition.

As is evident from the diagram (Fig. 10),

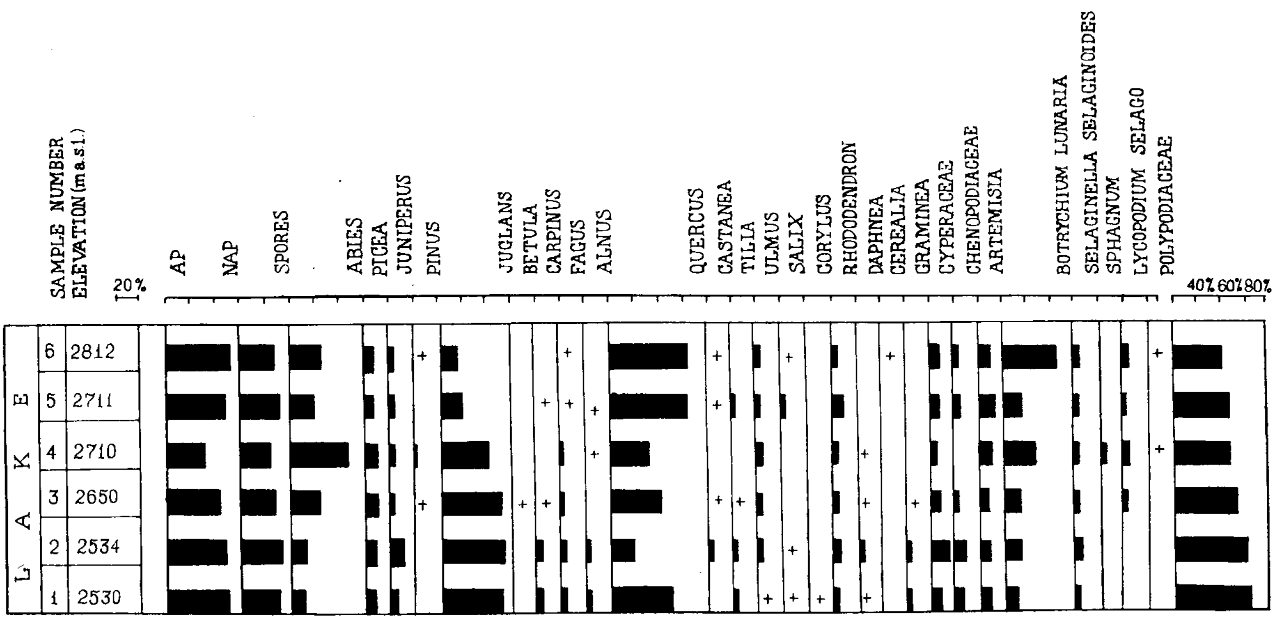

Fig. 9. Spore-pollen diagram of bottom sediments of the lakes in the Caucasian Biosphere Reservation

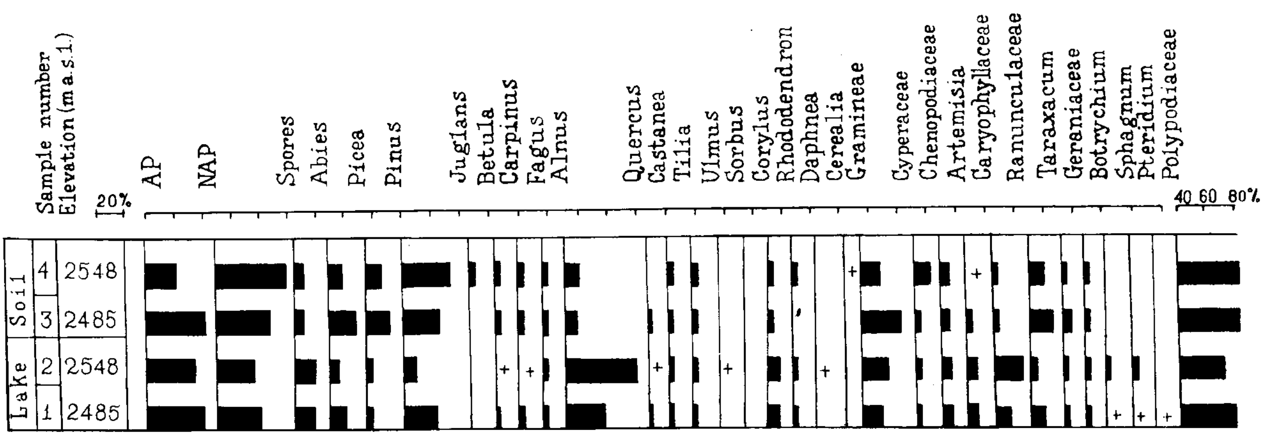

Fig. 10. Spore-pollen diagram of bottom sediments of Bathing Chamois' lake and Korgo lake (samples 3, 4) in the region of the Caucasian Biosphere Reservation

the soil and lake spectra have a number of common and distinguishing features. The role of transported AP pollen in the soil spectra is also significant. Though one and the same taxa are predominant, the first dominant in the soils is *Pinus* rather than *Alnus*. The role of other coniferous plants pollen in the soil samples is more essential. The NAP group shows the following regularities. The Gramineae pollen predominates. However, the amount of Caryophyllaceae decreases abruptly and, hence, this component in the soil spectra becomes subdominant. The second dominant, as could be expected, is Ranunculaceae. It should be emphasized an abrupt decrease of spore amount in soils. Their taxonomic composition is poor. Only monolete spores of fernes can be mentioned.

POLLEN SPECTRA OF PERIGLACIAL LAKES OF ARKHYZ

The Arkhyz site is situated to the east of the Caucasian Biosphere Reservation at the headwaters of the river Kiafar (a tribute of the Major Zelenchuk relating to the Kuban basin). On the northern slopes of the Abishir-Akhuba Range at altitudes from 2534 to 2884 m a.l.s. there are numerous small lakes of glacial origin.

Here the vegetation is alpine with prevalence of Cyperaceae, Gramineae, *Campanula*. The upper forest-line is at an altitude of 2000–2200 m a.s.l. In high-mountain forests, apart from dark-conferous plants, significant role is played by *Pinus hamata* (Polivanova 1990). The forest usually ends in croocked birch trees, The spore-pollen analysis was used to study the sediments of three lakes: Goluboe lake (H:2582 m) with an area of 77000 sq.m. and maximum depth 31 m; Perevalnoe lake (H:2761 m) with an area of 80000 sq.m. and depth 22 m; and the shallowest Bluzovoe lake (H: 2884 m) with total area not exceeding 5000 sq.m. and depth 4 m.

The pollen spectra are characterized by abundance of taxa both in quantitative and qualitative respects. The percentage of transported pollen and spores is also rather high.

In the whole AP and NAP group, the amount of pollen is almost the same (Fig. 11). The amount of spores is smaller. However, their role rises with increasing altitude. For instance, in the sediments of lakes Perevalnoe and Bluzovoe the spore content is as large as 28%, while in the bottom sediments of lake Goluboe it is as little as 8–9%.

In the AP group the pollen of *Pinus* and *Alnus* is prevalent, though with increasing altitude the role of the former increases. In the Caucasian Reservation inverse regularities are observed. Among dark-coniferous plants, *Abies* is much prevalent over *Picea*. There is little pollen of broad-leaved trees. At the lowest altitudes *Carpinus* and *Quercus* predominate. However, in the spectra of lakes situated at higher altitudes their role significantly decreases. There is little pollen of *Tilia, Ulmus, Castanea, Betula. Juglans, Quercus, Acer* are represented by single pollen grains. As to shrubs, all the samples have shown prevalence of the pollen of Corylus. The content of *Rhododendron* and *Ephedra* is lower.

In the NAP group the following situation is observed. At lower hypsometric levels the pollen of Gramineae predominates, while at

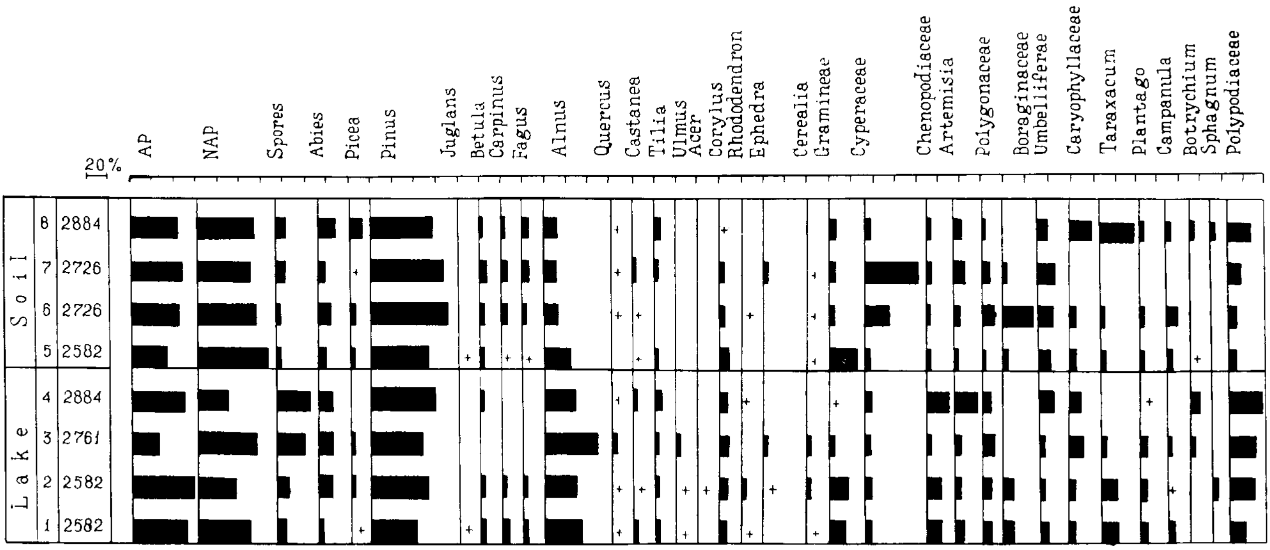

Fig. 11. Spore-pollen diagram of bottom sediments of the lakes in the Arkhyz region (samples 1–4); pollen spectra of soils on the lake coast (samples 5–8)

higher levels the pollen of *Artemisia* and Chenopodiaceae is prevalent. Each spectrum has different subdominants. These are *Carex,* Ranunculaceae, Compositae, Geraniaceae, Cruciferae. Umbelliferae, Polygonaceae, Boraginaceae, *Taraxacum* have smaller values. There is not much pollen of Plumbaginaceae, *Cirsium,* Dipsacaceae, *Campanula.* The pollen of *Plantago, Urtica,* Labiatae, *Viola,* Saxifragaceae, *Rumex,* Leguminosae, etc. is found in the form of single grains.

In the group of sporiferous plants, the ferns of the *Dryopteris* and *Athyrium* genera are obviously prevalent. There is also a certain amount of *Polystichum, Asplenium. Polypodium vulgare* is determined at the level of species. In addition the spores of *Sphagnum, Botrychium, Lycopodium, Equisetum* are mentioned in small amounts.

Comparison of the pollen spectra of the lakes with those of soils demonstrates the same regularities as in other sites. The taxonomic composition in the soils is not so rich as that in the lake sediments. The participation of coniferous plants here is very significant, while that of sporiferous plants, on the contrary, is considerably lower. The lake samples poorly reflect the pollen of Caryophyllaceae, *Taraxacum, Cirsium.* The microphytofossils preservation is also different. In lake sediments it is excellent.

DISCUSSION

Detailed analysis of the pollen spectra from 5 sites along the Main Caucasian Range has shown their very complicated character. The pollen spectra of the lakes could reflect not only the local vegetation, but also almost all the mountain belts existing in this region. Only in superhumid marine climate of Abkhazia where pollen dissipation through the air is rather restricted (Kvavadze 1993), the elements of lowland forests (*Pterocarya pterocarpa, Ilex colchica, Buxus colchica,* etc.) cannot be found in the spectra. As is known, to the east of the Black Sea the climate humidity decreases (Maruashvili 1970), and ability of pollen and spores to be transported through the air increases, i.e. the role of transported pollen increases. This is proved by the fact that in the spectra of the most high-mountain lakes of Abkhazia transported pollen accounts for not more than 60%, while in the lakes of the Qeli Volcanic Highland and Lagodekhi its percentage amounts up to 80–85%. That is why it is just in the eastern part of the Caucasus, unlike Abkhazia, the lake sediments reflect not only lowland forests consisting of *Pterocarya,* but also all the elements of the steppes adjacent to the forest belt: *Artemisia,* Chenopodiaceae, *Ephedra,* Cerealia (Figs 5, 7). The same can be mentioned for the spectra of the Arkhyz site where the climate is less humid than that in West Transcaucasia, and mountain forests in the lowlands are contiguous to steppe landscapes.

To more concretely characterize the spectra of the sites investigated, we shall separate palynozones for each of them, according to dominants, as is usually done for fossil pollen spectra (Tab. 3, 4). Such an approach is justified for two reasons. First, sediment accumulation in glacial lakes proceeds extremely slowly. That is why for accumulation of the uppermost layer of the spring flood deposit (even if its thickness is 0.5 cm) a few recent decades were required. Second, separation of palynozones in the recent spectra will facilitate their comparison with those of the Holocene.

Table 3. Pollen zones of lake deposits according to sites under study

Site No.	Site name	Dominating AP pollen	Dominating NAP pollen
1.	Abkhazia (West Transcaucasia)	*Alnus-Pinus-Abies*	Compositae-Polygonaceae-*Artemisia*
2.	Qeli Highland (East Transcaucasia)	*Pinus-Alnus-Carpinus*	Chenopodiaceae-*Artemisia*-Gramineae
3.	Lagodekhi (East Transcaucasia)	*Pinus-Alnus-Carpinus*	Chenopodiaceae-*Artemisia*-Caryophyllaceae
4.	Caucasian Biosphere Reservation (western part of the North Caucasus)	*Alnus-Pinus-Abies*	*Artemisia*-Compositae-Gramineae
5.	Arkhyz (western part of the North Caucasus)	*Pinus-Alnus-Abies*	*Artemisia*-Chenopodiaceae-Polygonaceae

Table 4. Pollen zones of soil samples according to the sites under study

Site No.	Site name	Dominating AP pollen	Dominaing NAP pollen
1.	Abkhazia(*) (West Transcaucasia)	*Pinus-Alnus-Abies*	Polygonacae-Umbelliferae-Compositae
2.	Qeli Highland (East Transcaucasia)	No data	No data
3.	Lagodekhi Reservation (East Transcaucasia)	*Alnus-Pinus-Tilia*	Chenopodiaceae-Caryophyllaceae-*Atemisia*
4.	Caucasian Biosphere Reservation (western part of the North Caucasus)	*Pinus-Abies-Alnus*	Gramineae-Ranunculaceae-*Taraxacum*
5.	Arkhyz (western part of the North Caucasus)	*Pinus-Alnus-Abies*	Ranunculaceae-Polygonaceae-Gramineae

(*) The data are taken from the paper by Kvavadze & Rukhadze 1989.

As is seen, the pollen zones of the West Caucasus are identical and differ from those of the East Caucasus, which are also similar as to sets of the AP pollen. At the same time, the common feature for all the studied sites is that the first two dominants are *Alnus* and *Pinus*. In some cases (the Arkhyz region) these two components simply interchange their places. As to the third dominant, it is different for the eastern and western parts, but within each of them it is the same. For the West Caucasus, it is *Abies*, while for the East Caucasus it is *Carpinus*. As to the NAP pollen, only *Artemisia* is common for all the regions. The rest components of the zones are different. For the humid western part, it is the pollen of Compositae, Polygonaceae, while for the more arid eastern part it is the pollen of Chenopodiaceae, Caryohyllaceae.

For general comparison of the lake and soil spectra, it is necessary to separate pollen zones in the latter as well.

Thus, in the soils along the whole Caucasian Range, the first dominant is the pollen of *Pinus*. However, *Alnus* is not always present as a second component. For instance, in the soils of the Caucasian Biosphere Reservation *Alnus* pollen gives way to *Abies* pollen, which is not observed in the lake spectra. In general, for the zones of the western part, the presence of three components (*Pinus, Alnus, Abies*) is invariable, which is not the case for the spectra of the eastern part. In high mountains of Lagodekhi the first dominant is *Tilia* pollen rather than that of *Carpinus* as was the case for the lakes.

In the NAP group there are more distinguishing features, than common ones. In the pollen zone of the western part, the pollen of *Artemisia* is not present at all. It is replaced by that of Umbelliferae, Ranunculaceae, *Taraxacum*. Here it should be noted that each concrete region of the West Caucasus is characterized by its own NAP dominants.

Going back to the peculiarities of the pollen spectra of lake sediments, the following should be added. The pollen spectra are marked by almost absolute absence of aquatic and coastal plants, which is probably explained by severe ecological conditions. Here lies the radical difference between these spectra and those of lowland lakes.

When answering the question how adequately the lake spectra have reflected the local (i.e. alpine) vegetation, we can claim that the spectra show almost all the components of alpine meadows rich in herbs (Figs 6, 11). Sporiferous plants of the alpine zone are also reflected very well. Among them there are *Selaginella selaginoides, Botrychium lunaria, Lycopodium alpinum, Sphagnum* which in the conditions of high mountains of the Caucasus grow along riversides, in humid bottoms of troughs and cirques (Bush & Bush 1936, Kolakovski 1980, Dolukhanov 1966, 1989).

The spectra of the lakes situated at the very border of the forest-line reflect local vegetation still more exactly (Fig. 6). The role of transported pollen here is quite insignificant. However, it should also be pointed out that in the alpine belt, the composition of transported pollen per se provides rather valuable information concerning the role of this or that component in the forests of the given region. This can be illustrated by the *Abies* pollen which prevails in the West Caucasus and is always the third dominant. Just in this part of the Caucasus the areal of *Abies nordmanniana* distribution is mainly concentrated (Fig. 12). *Alnus* trees in the western part are also widely spread (in low mountain region it is *Alnus barbata*, while in middle mountains it is *A. glutinosa*). The same holds for participation of *Pinus* pollen in the spectra. It is found in abundant amounts where *Pinus* grows in lower mountain belts (e.g. the Arkhyz site – Fig. 11).

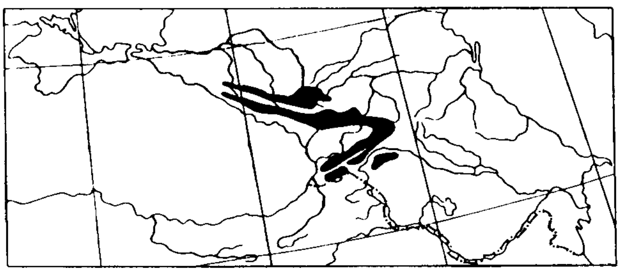

Fig. 12. The areal of *Abies nordmanniana* (taken from the book "Areals of arboreal and shrub of the USSR", vol.1: 68–100, Leningrad, 1977)

In the lake spectra of the East Caucasus the pollen of *Carpinus* prevails, which is also in agreement with the actual picture, since the area of hornbeam forests here is much larger than in the west (Dolukhanov 1989).

However, when considering the general picture of percentage of the dominants of the forest vegetation (Fig. 13), one can see that the role of *Carpinus orientalis* is essentially reduced in the spectra of high mountain lakes of the Caucasus. At present *Fagus* occupies more than a half of the forest area. This fact can be explained by poor volatility of beech pollen in the conditions of the Caucasus (Kvavadze 1988, Kvavadze & Efremov 1993). The *Betula* pollen, cannot be spread here over long distances too. Even where the forest-line consists of crooked birch forests (Qeli Highland), the amount of the *Betula* pollen in the lake spectra is very small.

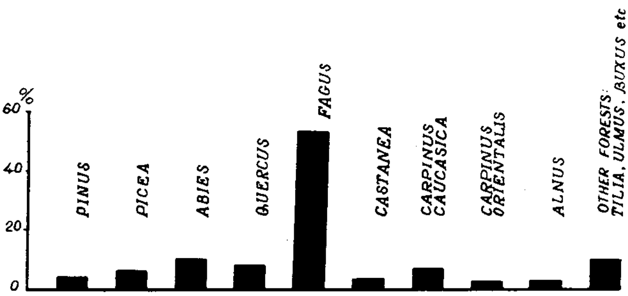

Fig. 13. Percentage of the area occupied by dominant forest vegetation of Georgia (the diagram was compiled on the basis of numerical indices presented in the "Atlas of the Georgian SSR", Tbilisi-Moscow, 1964)

As was already mentioned, the pollen spectra of the lakes throughout the Greater Caucasus have registered not only vegetation of mountain forests, but also that of adjacent steppes. This can be explained by ability of the pollen of *Artemisia*, Chenopodiaceae, Gramineae and *Ephedra* to be transported over long distances. Here, in the conditions of the Caucasus, their pollen can be transported over 200–300 km. However, in the literature there is a lot of evidence of these plants transportation over hundreds and even thousands of kilometers (Środoń 1960, Bortenschlager 1968, Pashkevich 1970, Manecki et al. 1978, Schneider 1984, Knaap 1987, Königsson 1992 and others).

CONCLUSION

The analysis of recent pollen spectra of lake sediments at various hypsometric levels of high mountains has shown the following.

1. The highest amount of local pollen is found at the lowest altitudes near the upper forest-line. With increasing altitude, the role of autochtonous pollen decreases, while that of transported pollen, on the contrary, increases. Long distant transport becomes of particular importance in lake sediments above 2800–3000 m where the amount of transported pollen increases every 100 m of elevation almost by 40–50% on the average. This is caused by ever thinning and scanty vegetation of mountain tundras, on the one hand, and by rise of speed and duration of winds carrying pollen, on the other hand.

This process shows up most prominently on summits and mountain ridges. Here transported pollen may account for up to 80–85%.

2. Apart from many methodical problems, the analysis of recent pollen spectra allows us to solve a number of problems relating to abilities of vegetation pollen and spores to be transported over long distances. It is established that in the conditions of the Caucasus, among the AP group the *Pinus* and *Alnus* pollen are characterized by the best volatility. Among shrubs, the pollen of *Corylus* is spread by air rather well. However, pollen grains of *Fagus, Betula, Acer, Salix, Rhododendron, Buxus* are badly spread by air. The pollen of other components of forest vegetation has moderate transportability. Apart from wind regime, the pollen transportation is effected by climate hiumidity. In more arid conditions of the eastern part of the Caucasus, pollen spreads by air much better than in overhumidified marine climate of Colchis.

3. Since during the Holocene lake belts as well as vegetation belts repeatedly shifted vertically in either direction, it is not sufficient to study spectra of recent lakes relating only to the alpine belt in order to correctly interpret fossil pollen spectra. It is necessary to study in detail recent lake sediments in all the existing belts and especially in high mountain forests. As to the alpine belt itself, our material shows (in spite of the fact that transported pollen plays an important part here) that their spectra in the past can be recognized without fail.

4. Comparison of the polen complex of lake sediments with those of soils has shown that besides similarity, there are rather substantial differences between them. Therefore, in reconstruction one should not compare lake sediment spectra with sediment spectra of another genesis (soils, moss pillows, etc.). Such drawbacks can be found in the present-day literature on the Caucasus (Margalitadze 1982, Serebriannyi et al. 1984) and they lead to serious mistakes.

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