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ON THE INTERPRETATION OF SUBFOSSIL SPORE-POLLEN SPECTRA IN THE MOUNTAINS

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ABSTRACT. The results of the analysis of spore-pollen spectra of more than 600 surface samples taken from the mountain systems of the Caucasus, the Ukrainian Carpathians and the Khibini Mountains have been presented. It is established that in the upper mountain belt the wind regime and, in particular, its average velocity and duration, is the most important factor of spectrum formation which determined the amount of transferred pollen of arboreal plants fromed the alpine and subnival belts where pseudo-forest spectra can be fored. This process is most pronounced in the spectra of glacial lakes. It is also established that the pollen spread by air depends not only on the wind velocity, but, to a great extent, on air humidity. Of special interest is the fact that even within the Caucasus the same plants produce different quantities of pollen and spores.

KEY WORDS: subfossil pollen spectra, Caucasus, Carpathians

INTRODUCTION

The majority of pioneering investigations of mountain palynology have demonstrated particular complexity of the present-day spore-pollen spectra (SPS) interpretation which is due to diversity of landscape conditions peculiar to very dissected relief. Development of the actuopalynological trend made it possible to clarify a lot of details related to spectrum formation in each particular mountain region and to show radical difference between the pollen spectra taken from the mountains and lowland.

The analysis of enormous factual materials from the Caucasus, the Carpathians and the Khibini Mountains has shown that in the mountains the character of SPS considerably depends on the wind regime. In this case the pollen transfer from one vegetation belt to another is direcly related not only to wind's direction (as it was previously considered), but also to its velocity, duration and seasonal dynamics.

THE ROLE OF THE WIND REGIME AND AIR HUMIDITY IN FORMATION OF MOUNTAIN SPORE-POLLEN SPECTRA

As a hole, the mountains are characterized by rather complicated wind regime, since the disturbing action of underlying surface violates the general planetary transfer of air masses in the lower atmospheric strata. Here of special importance becomes occurrence of local thermal circulation due to nonuniform heating of the land and the sea, mountain ridges, plateaus and valleys. Sometimes the paths of air masses transfer determine the direction of the main ranges. Orographic conditions contribute to appearance of powerful atmospheric currents of foehn character. Depending on the ranges height and direction, the air masses can be subject to a secondary and sometimes tertiary ascent.

In Transcaucasia the land and sea temperature difference causes the development of breezes and currents of monsoon character. On the most part of the sea coast the extension of the effective range of breezes results from their superposition on the mountain-valley circulation. Vertical intensity of the sea breezes in the region of the Black Sea coast in Georgia amounts to 1.0–1.2 km (see Climate and Climatic Resources of Georgia 1971). As to the mountain-valley circulation, it covers not only the mountain regions, but also the valleys of large rivers and intermountain troughs. Such winds blow mostly in warm seasons, since they develop as a result of different warming up to the relief elements and are related to settled sunny weather.

The temperature contrast in high-mountain regions between glacier and snow patch zones and the areas which are free of them reaches maximum values and gives rise to the so called glacier breezes which are characterized by ferocity, long duration and high velocities. The higes average and extremal wind velocities are observed on isolated highly raised ridges and peaks (Barry 1981).

In this connection the pollen-spectra of high-mountain regions are to be reported as the most universal and at the same time the most complex, since due to strong and durable winds, they reflect not only local, but also regional vegetation as well as the characteristic for different regions. For exaple, in the spectra of lacusrine deposits of the Qeli volcanic highlands one can see the vegetation of all the belts of both East and West Georgia (Kvavadze & Efremov 1990) (Fig. 1). The spectra of the samples from the glacier and snow-patches of Mount Elbrus taken in altitudes of 3680–3700 m showed that pollen and spores had been transferred not only from the northern slopes of Caucasus, but from its southern slopes as well (Troshkina 1958, Troshkina & Makhova 1961). Similarly one can observe the vegetation of all the belts (from steps to hight-mountain forests) of North Caucasus and Transcaucasia in the subfossil SPS of water-gaps of the Main Caucasus Range (Kvavadze & Efremov 1991). It should be noted that the amount of transferred pollen increases with altitude (Figs 2, 3), i. e. this transfer depends on wind velocity and duration which in middle altitudes increases with mountain altitude (Barry 1984). The amount of transferred pollen in the highlands can rise up to 80% and more (Table 1).

Of special interest is also the fact that the pollen of the same plants can spread well only at a certain wind regime. Thus, in the Caucasus, where the average wind velocity

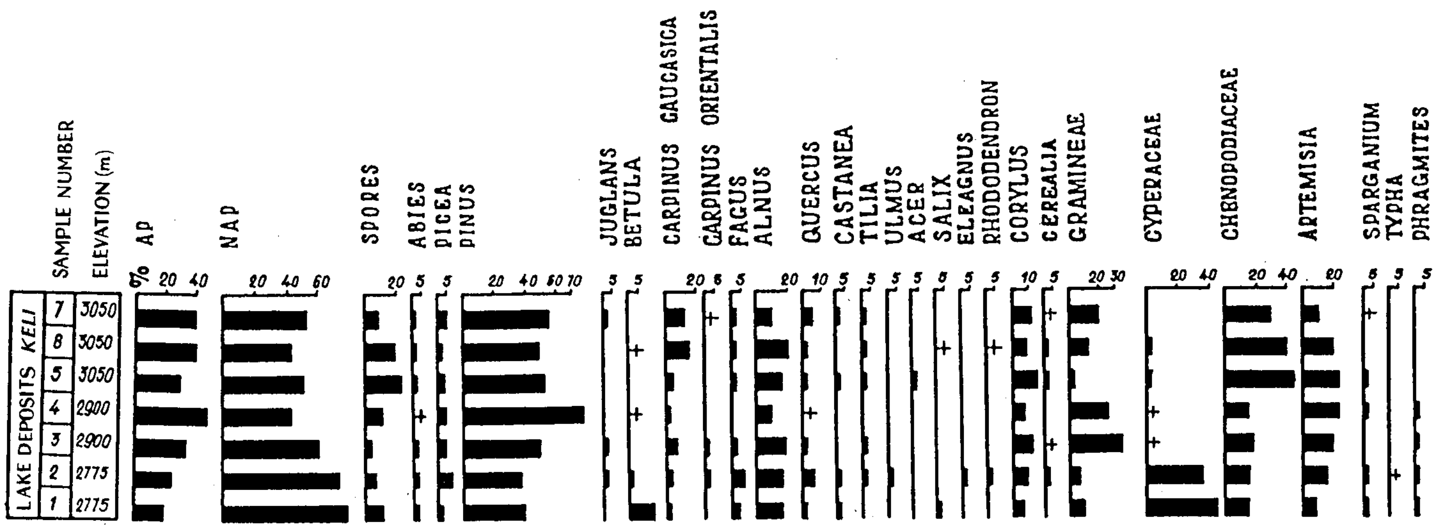

Fig. 1. Subfossil spore-pollen spectra of the lacustrine deposits of the Qeli volcanic highlands

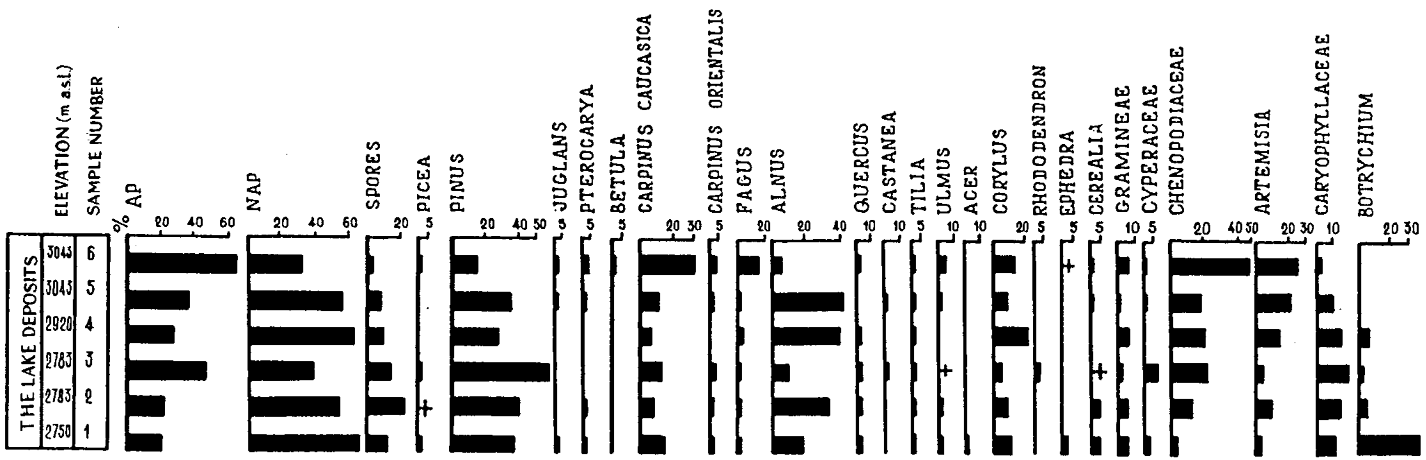

Fig. 2. Subfossil spore-pollen spectra of the lacustrine deposits of the highlands of Lagodekhi and Daghestan

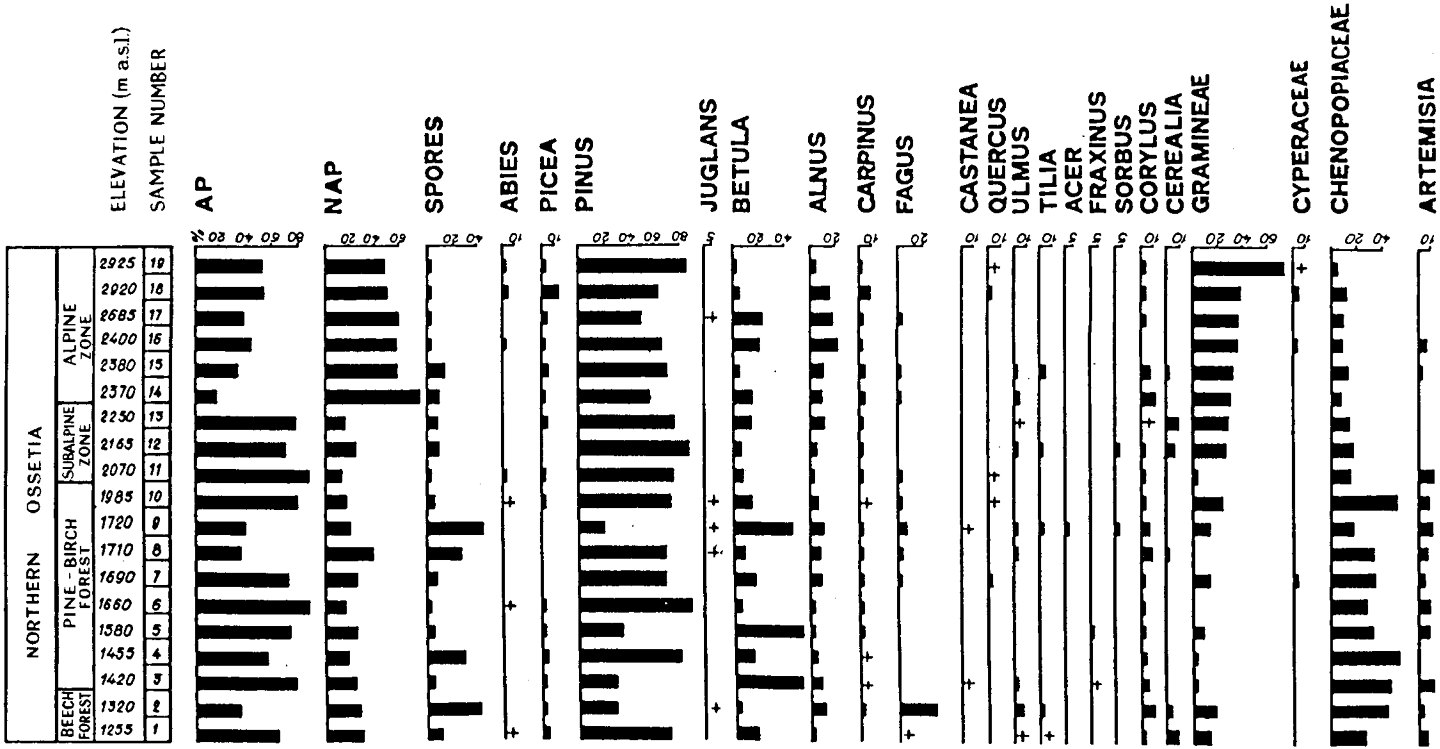

Fig. 3. Subfossil spore-pollen spectra of the soils in the mountains in North Ossetia

Table 1. Percentage of the local pollen content in the spectra of the lacustrine deposits of the Qeli volcanic highlands (the calculation is made from the total sum of the pollen and spores)

Sample No.	1	2	3	4	5	6	7
Absolute mark in m a. s. l	2775	2775	2900	2900	3050	3050	3050
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		1.5	
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
Total	52%	48%	38%	25%	13%	14%	15%

seldom exceeds 7–8 m/s, the pollen of *Fagus* is very rarely transferred for large distances (Fig. 4), while in the Carpathians (where the average wind velocity is up to 15 m/s) it is transferred to the alpine and subnival belts in enormous amounts (Figs 5, 6). This is also true for monolete spores of ferns. For example, Zaklinskaya (1948) indicates that they are not spread far from their producer, however, in the Caucasus the fern spores can be spread by air for rather long distances and in considerable amounts (Kvavadze 1990).

Seasonal wind dynamics also plays an impotrant role. The wind force usually rises in cold season, but in the mountains there are some places where air masses stagnate in winter, while in summer, vice versa, intensive circulation predominates, i. e. the maximum wind velocity and duration are characteristic for warm season (Svanidze et al. 1987). One of such regions is the Alazani valley with the adjoining mountain slopes where the pollen transfer from one belt to another is the largest due to summer winds. For example, in the alpine belt the pollen content of *Tilia*, *Pterocarya* and *Carpinus* as well as fern spores amount to very high values (up to 40–50%).

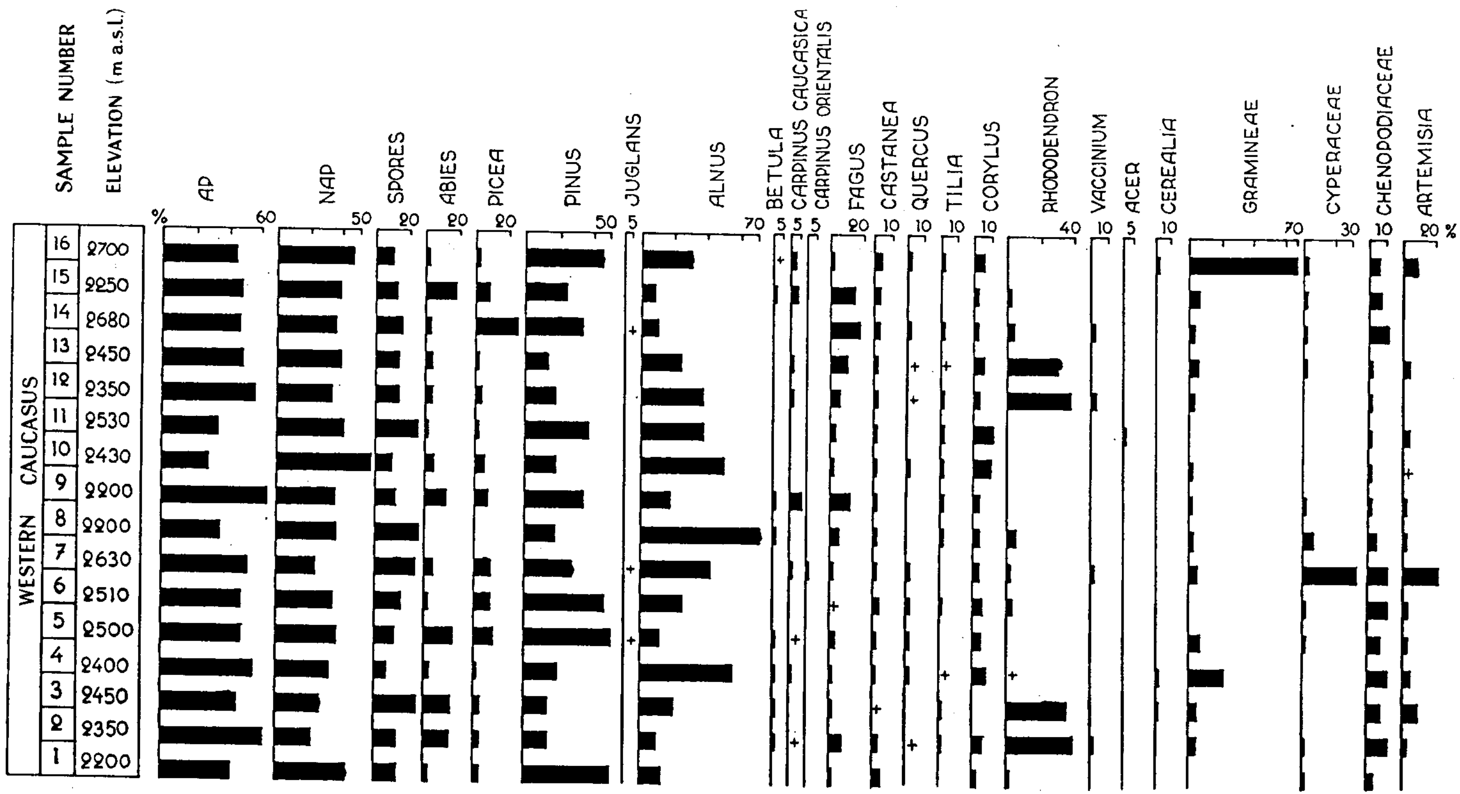

Fig. 4. Subfossil spore-pollen spectra of the alpine belt soils in Abkhasia

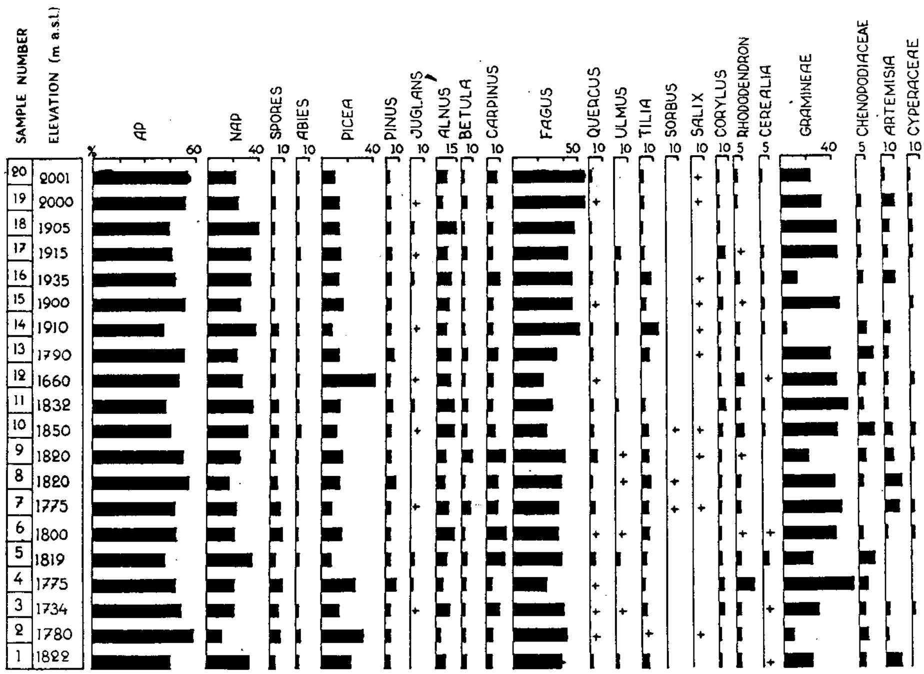

Fig. 5. Subfossil spore-pollen spectra of the alpine belt soils in the Ukrainian Carpathians

From the comparison of the pollen spectra of recent deposits from different regions of Transcaucasia one can see that the pollen spread is strongly affected by air humidity. In the arid climate of the eastern part of the region the pollen of both arboreal and herbaceous plants is spread much better than in the humid marine climate of Colchis. The same conclusion on spread of the pollen of conifers was drawn by Nekrasova (1983). This can be explained by the fact that in humid climate pollen grains either sticks to each other or absorb moisture, them swell, become heavy and are deposited faster. Besides, the spread of pollen by air is also prevented from permanent rains.

Therefore, mountain spectra formation proceeds in a complicated way and differently in different vertical belts and that is why we cannot agree with those who try to simplify this process. For example, Abramova (1989) excludes pollen transfer by air from the upper to lower belts, particularly, to littoral areas. It is underestimation of the role of pollen transfer from one belt to another that it is reason for a number of mistakes made at vegetation reconstruction in high-mountain regions of the Central Caucasus during glacial stages of the Holocene (Serebryannyi et al. 1984). This authors explain the discrepancy between the glacio-climatic and paleobotanic reconstructions by disadvantages of the palynological method. The reason for this, however, consists in incorrect deciphering of fossil spectra. As was mentioned above, climate cooling in the highlands involves an increase in forse and duration of the wind carrying a very large amount of

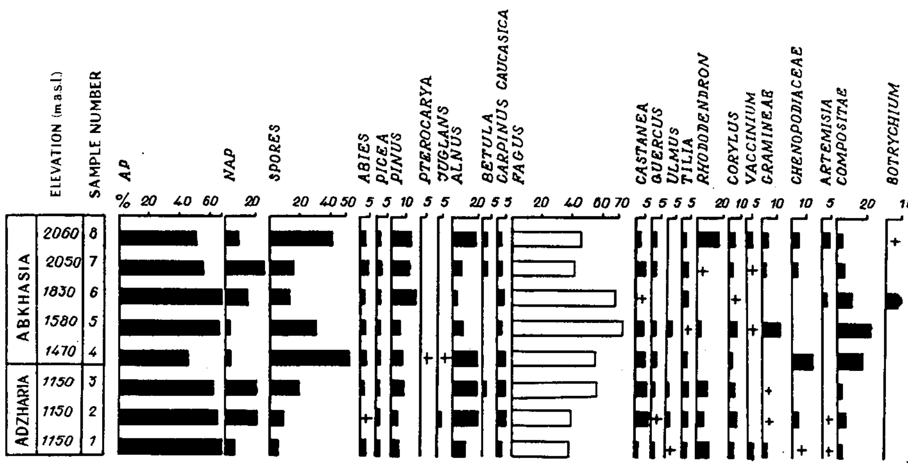

Fig. 6. Subfossil spore-pollen spectra of the soils in the beech forests of West Georgia

pollen including that of arboreals and spores of forest ferns. Thus, in the mountain tundra the wind creates a forest-like (according to the low-land criteria) type of the spectrum. However, in reality 80–85 % of this spectrum is due to transferred pollen. The great role of pollen transfer in the tundra which increases with altitude elevation is also shown in the works on the Spitsbergen mountains (Środoń 1960).

DEPENDENCSE OF POLLEN PRODUCTION ON CHANGES IN ECOLOGICAL CONDITIONS IN THE MOUNTAINS

The analysis and comparison of subfossil SPS of the same phytocenoses in various parts of Transcaucasia have related interesting peculiarities of pollen productivity of the dominant species.

More than a half of the mountains forests in Georgia is occupied by *Fagus orientalis.* In the humid marine climate of Colchis the amounts of its pollen in the recent deposit spectra accounts, on the average, for 50–70%, while in the East of the country where the precipitation is one-third as much, its pollen content hardly reaches 20–30%. As mentioned by Kvavadze and Stuchlik (1991) the following regularity can be traced: the more humid is the climate, the higher is the *Fagus* pollen content (Figs 6, 7).

The oposite situation is observed in the pollen spectra of hornbeam and oak forests: polliniferous capasity of *Carpinus* and especially, that of *Quercus* rise just in East Georgia with its more arid climate. The amount of the Georgian oak pollen in the spectra of recent deposits in West Georgia seldom exceeds 10–15%, while in East Georgia it can reach 40% and more.

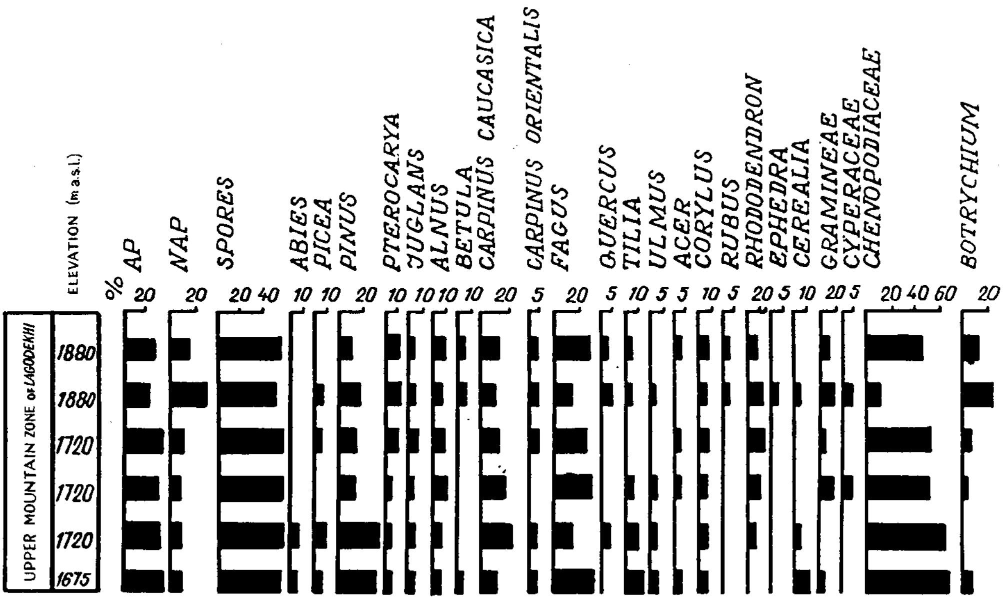

Fig. 7. Subfossil spore-pollen spectra of the soils in the beech forests of East Georgia (the Logodekhi reservation)

Some distinguishing characters are marked in the pollen productivity of *Castanea sativa* which increases in humid conditions like that of *Fagus*.

In the high-mountain regions, near to upper forest boundary there occur extremal conditions for the life of arboreal plants. That is why many of them go over to vegetative reproduction and, therefore, their pollen production drops abruptly. For example, under the canopy of elfin woodland the *Fagus* pollen content in the spectra does not exceed 20–30%. According to our data, the productivity of prostrate from of *Pinus mugo* in the high-mountains regions of the Carpathians is considerably lowering. Here the amount of the *Pinus* pollen seldom exceeds 25–30%, while the spectra of the pine forests reveal its maximum content (up to 90–95%).

At the upper boundary of the Caucasus forests the pollen productivity of *Betula*, *Salix*, *Acer spicatum*, *Quercus ponticus* decreases. It is interesting to note that with altitude elevation the pollen productivity of *Rhododendron* is not reduced, but on the contrary it increases. In the alpine belt of Caucasus where *Rhododendron caucasicum* forms unpassable thickets, the amount of its pollen in the soil spectra is equal to 40%, while the soil spectra of similar thickets in subnival and high-mountain forests hardly contain the *Rhododendron* pollen or the participation of the latter does not exceed 2–5% (Stuchlik & Kvavadze 1987). Probably, the high-mountain conditions for *Rhododendron myrtifolium* seem not to be so favourable. In the Carpathians under the thickets of this species, its pollen either is absent from the spectra, or it is found in the form of single grains. Besides, we have noticed that throughout the Caucasus polliniferous capacity of various species of *Rhododendron* is not the same.

The comparison of the recent pollen spectra of the mountain tundras of the Caucasus and the Khibini Mountains has shown that such an excellent indicator of glacial cooling as *Selaginella selaginoides* increases spore productivity just in the highlands of the Khibini Mountains reaching 20% and more in the spectra (Fig. 8). However, in the subnival belt of the Caucasus its content seldom accounts for 2–4% and it can usually be found as single spores. A similar picture can be observed in the case of *Lycopodium alpinum*. In the Khibini Mountains the content of its spores in the spectrum is very high – 80% (!), while in the Caucasus it seldom exceeds 10%.

The revealed regularities reflecting the dependence of sporification and pollen productivity on ecological conditions in the mountains show once again how it is difficult to give a correct estimate of fossil spore-pollen spectra.

On the basis of the aforementioned, principles we can conclude that lack of large-scale actuopalynological investigations in each individual region leads to discrepancy between palaeogeographical schemes of the Holocene in the Caucasus and in the studied mountain ridges.

Our ivestigations have demonstrated broad prospects of systematic usage of a relatively new scientific trend – actuopalynology – for palynological studies of mountains regions. The following regularities have been established:

1. In the formation of recent spore-pollen spectra in the mountains of paramount importance are wind regime, sedimentation intensity, chemical and granulometric composition of the deposits.

2. In the complex relief of Transcaucasia the mechanism of spread of pollen and spores of plants is determined not only by their morfological peculiarities, but also by the wind direction, its average speed, duration and seasonal dynamics. Density of the stand of trees is also of importance in forest spectra formation. In open forest formations the amount of the pollen transferred from other altitudinal belts is much larger tham that in a dense forest with a well developed undergrowth.

3. The percentage of the transferred pollen reaches its maximum in open landscapes of the subnival belt where the local vegetation is scarce, and the force of the wind carrying the pollen from the lower belts is very great. This process is most of all pronounced on the ridges of ranges and summits of mountains.

4. The pollen transfer of many arboreal plants for long distances on the wind velocity in the period of their blossoming. Depending of the wind regime under different phisico-geographical conditions, the pollen of the same plants is spread by air differently. It should be also emphasized that in the humid damp climate of South Colchis the pollen is transferred much worse than in drier climatic conditions of other regions.

5. The most important regularity consists in variability of the pollen regime of plants due to changes in ecological conditions in the mountains of the Caucasus caused both by a rise of the absolute altitude and by advance to the east to the regions of more arid climate. For example, the pollen productivity of such dominant arboreal species as *Fagus*, *Quercus*, *Carpinus*, *Castanea* in different regions is different. The changes in the ecological conditions in the mountains often results in changes in the morfological traits of the pollen.

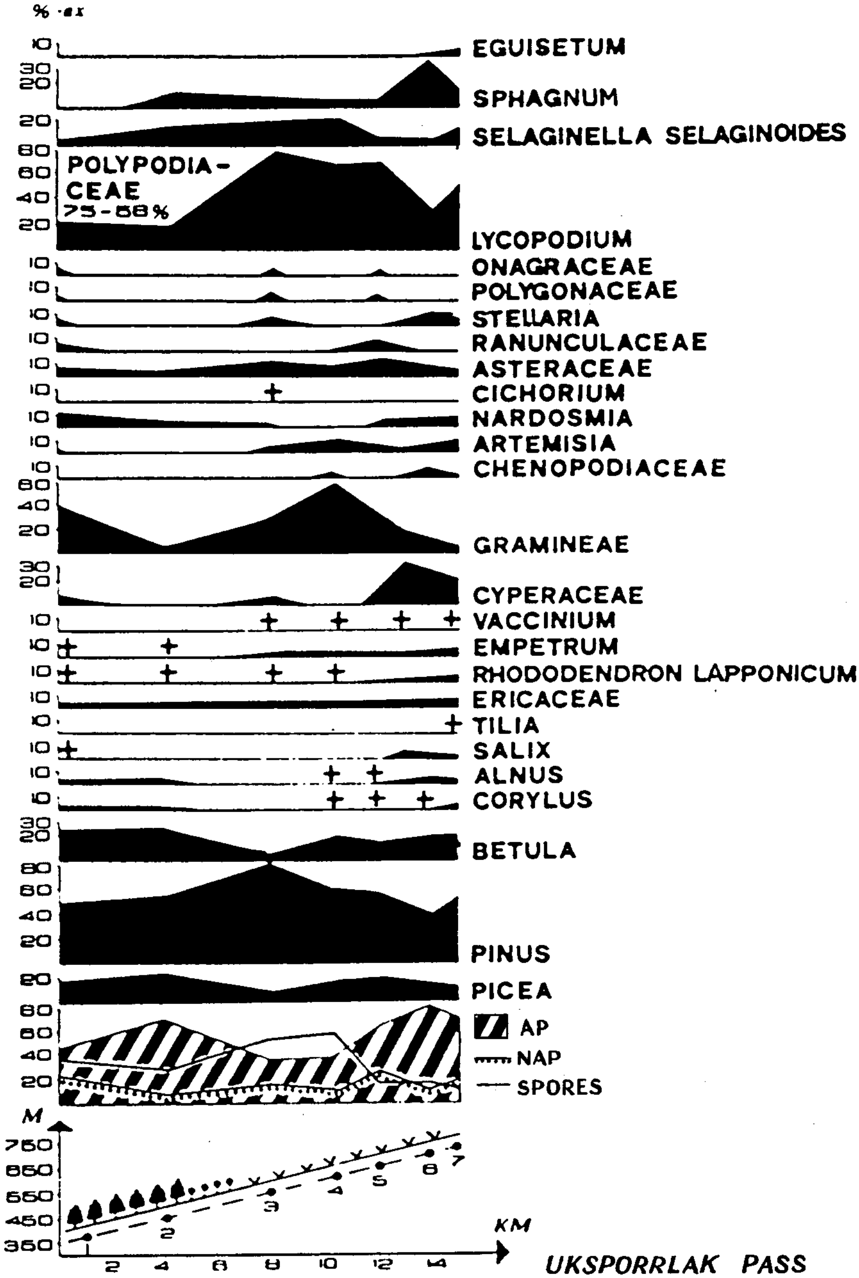

Fig. 8. Subfossil spore-pollen spectra of the soils along the longitudinal profile of the Khibini Mountains: (1 – birch forest; 2 – shrub formations of *Betula nana*; 3 – tundra)

6. Red soils deposits of crescent lakes and bogs are distinguished by the best conditions of the pollen preservation in the lower part of the Transcaucasian mountains. Bottom sediments of shallow lakes are characterized by a high pollen concentration. In the high mountains almost all genetic types of deposits are rich in pollen and spores. The best preservation conditions are recorded in the deposits of periglacial lakes, in bogs and peat soils under *Rhododendron* thickets. Low pollen concentration is typical of mearge skeletal soils of arid regions, deposits with enhanced carbonization and all types of deposits with coarse mechanical composition.

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