Հայաստանի Գիտությունների Ազգային Ակադեմիա
Национальная Академия Наук Армении
National Academy of Sciences of Armenia

Հայաստանի Կենսաբանական Հանդես
Биологический Журнал Армении
Biological Journal of Armenia

• Փորձարարական և տեսական հոդվածներ • Экспериментальные и теоретические статьи •
• Experimental and theoretical articles •

Biolog. Journal of Armenia, 3 (72), 2020

SUBFOSSIL PALYNOLOGICAL SPECTRA FROM THE SURROUNDINGS OF THE VILLAGE TSOVINAR (LAKE SEVAN, ARMENIA)

N.A. HAYRAPETYAN[1], E.V. KVAVADZE[2], I.I. SHATILOVA[2], I.G. GABRIELYAN[1], A.A. BRUCH[3]

1.Institute of Botany after A.L. Takhtajyan of Armenian Academy of Sciences, Armenia,
narine.hayrapetyan1993@gmail.com; ivangabrielyan100@gmail.com
2.Georgian National Museum, Tbilisi, Georgia,
ekvavadze@mail.ru; irashatilova@yahoo.com
3.ROCEEH Research Centre, Senckenberg Research Institute, Frankfurt/M, Germany,
angela.bruch@senckenberg.de

The palynological study of modern soils formed on the former bottom of Lake Sevan as a result of its artificial drainage is of great importance since many aspects of replacement of vegetation of aquatic ecosystems by continental vegetation are reflected in the palynological spectra. These processes having taken place over the past 90 years, caused by the artificial lowering of the level of Lake Sevan by 18 meters can be considered as a model of development of lakeshore vegetation under conditions of natural regression of the waters of Lake Sevan. The study has allowed us to define new markers for identifying regressive phases according to palynological data. Despite the presence of redeposited pollen and non-pollen palynomorphs (NPPs), the palynological spectra of soils correctly reflect existing vegetation of the cultural and natural landscapes of the study area.

Pollen – non-pollen palynomorphs – remains – pollen spectrum

Արհեստական ջրահեռացման արդյունքում Սևանա լճի նախկին հատակին ձևավորված ժամանակակից հողի պալինոլոգիական ուսումնասիրությունը մեծ նշանակություն ունի, քանի որ ջրային էկոհամակարգերի բուսականությունը ցամաքային բուսականությամբ փոխարինելու շատ ասպեկտներ արտացոլված են պալինոլոգիական սպեկտրում: Անցած 90 տարիների ընթացքում տեղի ունեցած այս գործընթացները, որոնք պայմանավորված են Սևանա լճի մակարդակի 18 մետրով արհեստական իջեցմամբ, Սևանա լճի ջրերի բնական ռեգրեսիայի պայմաններում կարող են համարվել ափամերձ բուսականության զարգացման մոդել: Ուսումնասիրությունը թույլ է տվել մեզ սահմանել նոր ցուցիչներ՝ պալինոլոգիական տվյալների համաձայն ռեգրեսիվ փուլերը որոշելու համար: Չնայած կրկին կուտակված ծաղկափոշու և ոչ ծաղկափոշային մնացորդների (ՈԾՄ) առկայությանը հողերի պալինոլոգիական սպեկտրը ճիշտորեն արտացոլում է ուսումնասիրվող տարածքի մշակովի և բնական լանդշաֆտների առկա բուսականությունը:

Ծաղկափոշի – ոչ ծաղկափոշային պալինոմորֆներ – մնացորդներ – ծաղկափոշու սպեկտր

Палинологическое изучение современных почв, образовавшихся на бывшем дне озера Севан в результате его искусственного осушения, имеет большое значение, так как многие аспекты замещения растительности водных экосистем континентальной растительностью отражены в палинологических спектрах. Эти процессы, произошедшие за последние 90 лет и вызванные искусственным понижением уровня озера Севан на 18 метров, может рассматриваться как модель развития прибрежной растительности в условиях естественной регрессии вод озера Севан. Исследование позволило нам определить новые маркеры для выявления регрессивных фаз согласно палинологическим данным. Несмотря на наличие переотложенной пыльцы и непыльцевой палиноморфа (АЭС), палинологические спектры почв правильно отражают существующую растительность культурных и природных ландшафтов исследуемой территории.

Пыльца – непыльцевые палиноморфы – остатки – спектр пыльцы

Studies of recent deposits by the method of spore-pollen analysis started in the South Caucasus in the 70s of the last century. Within the Lesser Caucasus, in the territory of Georgia, N. B. Klopotovskaya investigated recent soil samples in the Akhaltsikhe basin, on the southern slopes of Adjara-Imereti ridge and the northern part of Erusheti Highland (Klopotovskaya 1973). The preservation of pollen of Caucasian species of woody plants, their pollen productivity and many other questions of methodology were studied by this author. The conclusion was made that recent pollen spectra reflect the existing vegetation of the South Caucasus adequately.

The number of publications studying recent pollen spectra increased significantly by the end of the 20th century in the study region. Many nature reserves of the Caucasus and Georgia were studied in detail (Stuchlik & Kvavadze 1987; Kvavadze & Stuchlik 1990; 1993). It turned out that pollen dispersal from one vegetation zone to another is limited in forested areas of South Caucasus. However, pollen transport increases distinctly in open environments, i.e. the subalpine and alpine zones as well as in steppe regions of East Georgia as well (Kvavadze 1993; 1999; Kvavadze & Stuchlik 1993; Stuchlik & Kvavadze 1993; 1998).

Research on recent pollen spectra has not yet been conducted in Armenia despite the fact that paleopalynological studies began here in the 40s of the last century (Takhtajyan 1941; Delle 1962; Sayadyan & Aljoshinskaya 1993; Sayadyan et al., 1974; Tumajanov & Tumanyan, 1973; Scharrer 2013; Leroyer et al. 2016)**.** Also, NPPs have not been investigated yet.

Here, we present the first palynological analysis of Armenian soil samples to study the effect of lake level regression on pollen and NPP spectra in newly formed soils.

Materials and methods. Six samples of modern soil and one sample of cow dung were selected near the former shoreline of Lake Sevan near the village Tsovinar (province Gegharkunik), in the surroundings of Holocene peat bog deposits. The samples were taken both on plots with natural vegetation and on agricultural fields. Material was processed in the Polynological Laboratory of National Museum of Georgia in accordance with the modern standard methodology (Moore et al. 1991). The organic residue was studied in liquid glycerin under an Olympus BX43 microscope. Two full slides were counted. Pollen and NPP diagrams are drawn using Tilia 2.1.1 (Grimm 2016).

Results and Discussion. The palynological content of the six soil samples and one dung sample reflects the natural and cultural vegetation of the sampling area. In the following, the results for each sample are described in detail.

Sample № 1 was taken on a meadow where various herbs grow with a predominance of species of the family Poaceae. Wild oat (*Avena* sp.) dominates the grass cover. Many species of Chenopodiaceae grow there as well. The pollen spectrum of this sample is characterized by its rich content of pollen grains (fig.1 a). *Pinus* sp. dominates in the group of woody plants, with 30 % of all pollen counted. Pollen of *Juniperus* sp., *Ephedra* sp., *Juglans regia, Fagus orientalis.* are represented by single grains (Pl.1 a).

Representatives of Poaceae and Chenopodiaceae prevail among the pollen of herbaceous plants. The palynological spectrum also has a rather high content of *Polygonum aviculare* pollen. Pollen of higher aquatic and wetland plants *Myriophyllum* sp., *Typha* sp., *Sparganium* sp. were discovered (Pl.1 a). Spores of *Botrychium* sp. were found here as well. Microscopic remains of starch grains occur in the NPP spectrum. There are also many phytoliths of Cerealia, as well as charred parenchymal cells of wood (charcoal).

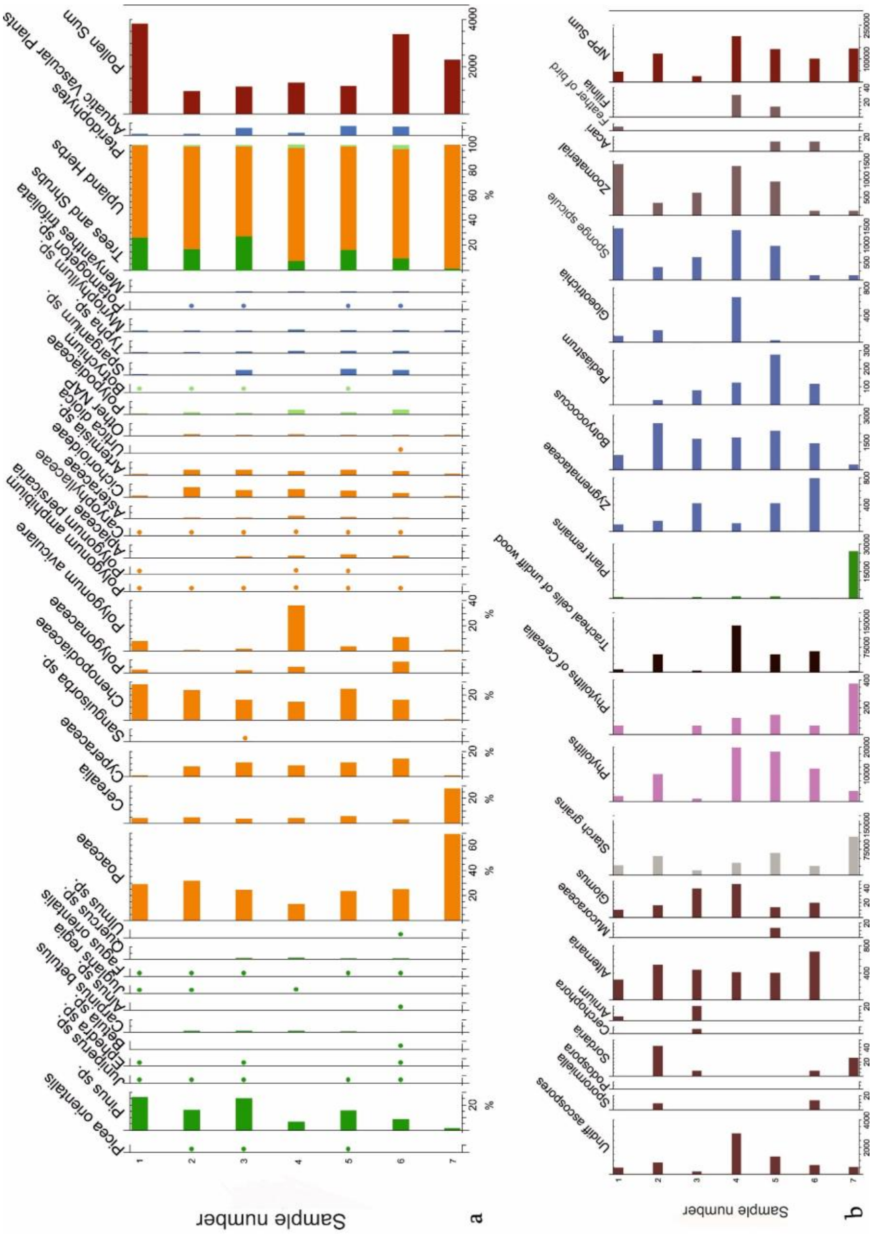

Fig.1 a. Pollen diagram of modern soil of Tsovinar
b. Non-pollen palynomorps diagram of modern soil of Tsovinar

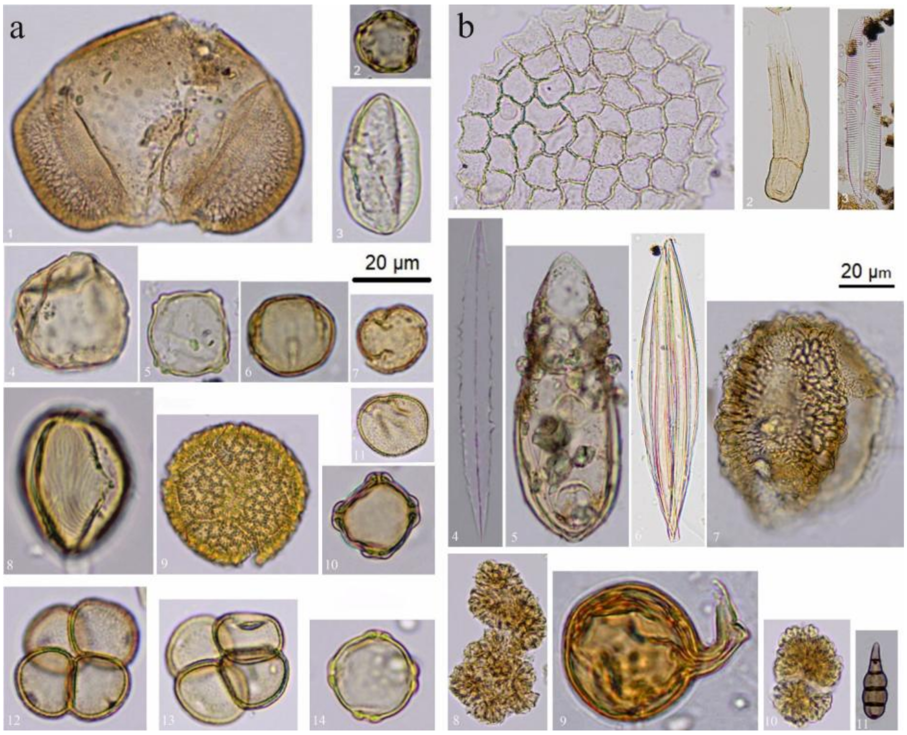

Plate 1. **a.** Pollen grains of from modern soil of Tsovinar: 1-*Picea* sp.; 2-*Alnus* sp.; 3-*Ephedra* sp.; 4-*Juglans regia*; 5-*Carpinus* sp.; 6-*Fagus orientalis*; 7-*Quercus* sp.; 8-*Menyanthes trifoliata*; 9-*Polygonum amphibium*; 10,14-*Myriophyllum* sp.; 11-*Sparganium* sp.; 12,13-*Typha* sp.
b. Non-pollen palynomorphs from modern soil of Tsovinar: 1-*Pediastrum*; 2-*Gloeotrichia*; 3-Diatom; 4-sponge spicule; 5-Acari; 6-*Spirogyra* (Zygnemataceae); 7-*Filinia* egg (Rotifera); 8,10-*Botryococcus*; 9-spore of Glomus; 11-spore of *Alternaria.*

There are many microscopic remains of zoological material in the spectrum of sample № 1. These are mainly epidermis, bristles, hairs and claw of insects, mites and other invertebrates. Spores of various fungi occur in high amounts, dominated by *Alternaria*. Quite interesting is that microscopic remains of lake sponges (sponge spicule) were found in sample № 1.

Sample № 2 was collected in cereal crops, where weeds *Chenopodium album* is also quite common. Pollen of Chenopodiaceae, Cyperaceae, Cichorioideae, *Artemisia* reach rather high contents. Besides fern spores of Polypodiaceae and *Botrychium* sp. pollen of wetland and aquatic plants *Sparganium* sp., *Typha* sp., *Myriophyllum* sp., *Potamogeton* sp. occur in this sample. Pollen of pine prevails among woody plants. But, unlike sample № 1, pollen grains of *Picea* sp. and *Carpinus* sp. appear in the spectrum (Pl.1 a). Starch grains (Fig.1 b) and tracheid cells of wood dominate the group of NPPs. There are many ascospores and particularly the fungal spores of *Alternaria* and *Glomus* (Pl.1 b). Spores of dung fungi *Sporormiella* and *Sordaria* appear as well.

While the number of remnants of freshwater green algae and cyanobacteria Zygnemataceae, *Botryococcus,* and *Gloeotrichia* is higher.

Sample № 3 was taken on a pasture meadow with a lot of Artemisia bushes. The pollen spectrum of this sample is similar to those of samples № 1 and 2. Pollen of *Pinus* dominates among woody plants, *Picea* sp., *Juniperus* sp., *Ephedra* sp., *Fagus orientalis* and *Carpinus* sp. are represented by single pollen grains. The spectrum of herbaceous plants is also similar. Among higher aquatic plants *Myriophyllum* sp., *Potamogeton* sp., and *Menyanthes trifoliata* are detected. Starch, charred cells of wood and other parts of plants also occur in the NPP group, as well as phytoliths of Cerealia. There are many spores of fungus *Alternaria*. Spores of *Arnium* and *Glomus* occur in higher amounts. Also, the number of remains of Zygnemataceae, Lake sponges is higher in comparison to sample № 2 (Fig.1 a, b).

Sample № 4 was taken at a country road, on both sides of which *Polygonum aviculare* grows abundantly. In the pollen spectrum, *Pinus* sp. dominates among woody plants. Pollen of *Juglans regia* and *Quercus* sp. is observed in small quantities. *Polygonum aviculare* clearly prevails the pollen of herbaceous plants, its amount being nearly 35% of all pollen. But also, the content of pollen of Chenopodiaceae, Poaceae, Cyperaceae, and *Artemisia* is rather high in the palynological spectrum.

Charred tracheid cells of wood prevail in the NPP group. Spores of fungi *Alternaria* and *Glomus* are observed in large quantities. *Botryococcus*, *Pediastrum* dominate the spectrum of green algae and *Gloeotrichia* (cyanobacteria) as well. Zoological material is less frequent, but remains of mites were found here. Eggs of rotifer *Filinia* were found in this sample (Fig.1 a, b; Pl.1 b,). Rotifers as a component of zoobenthos are always present in lake reservoirs and are good food for fish (Das et al. 2012.).

Sample № 5 was collected in the pasture. Of woody plants, pollen of *Pinus* sp. dominates the assemblage. Species of the family Chenopodiaceae dominate the herbaceous component. Pollen grains of Cyperaceae, *Polygonum aviculare, P. persicaria*, *P. amphibium*, Cichorioideae, and *Artemisia* sp. are detected as well. All higher aquatic and wetland plants which were found in the previous samples are also present here. *Alternaria* prevails in ascospores. Spores of mould fungi Mucoraceae were also found in sample № 5. There are many remnants of green algae and lake sponges (Fig.1 a, b).

Sample № 6 is selected under a thicket of *Urtica dioica*. The pollen spectrum of this sample is characterized by a rather rich composition of pollen of herbaceous plants. Besides *Pinus* sp., which dominates among woody plants here as well, pollen grains of *Betula* sp., *Fagus orientalis*, *Ulmus* sp., *Alnus* sp., *Juniperus* sp. and *Ephedra* sp. were found in the spectrum (Fig. 1 a). Pollen of Poaceae prevail in the group of herbaceous plants. The amount of pollen of Chenopodiaceae, Cyperaceae, *Polygonum aviculare*, and Polygonaceae is rather large in the spectrum. Pollen grains of *Artemisia*, Cichorioidae and other species of herbs were found as well together with many higher aquatic and wetland plants (Fig. 1 a).

Charred remnants of parenchymal cells of wood dominate the NPP group. There are many phytoliths, partly from Cerealia, and starch grains.

As in the other samples, here there are many remains of green algae, particularly those of Zygnemataceae (Fig. 1 b; Pl.1 b,).

Sample № 7 is a piece of cow dung, selected not far from the place where sample №2 was taken. Unlike the soil spectra, the palynologoical spectrum of dung has quite a different character. There is nearly no pollen of woody plants. Only single pollen grains of pine were found. Pollen of Poaceae (70%) and Cerealia (25%) dominate the group of herbaceous plants. The content of pollen of *Polygonum aviculare* and Cichorioidae is insignificant. Of higher aquatic plants, only pollen of *Myriophyllum* sp. was found. Starch grains dominate the NPP group. Spores of dung fungus *Sordaria* were found here, but no spores of *Alternaria*. Remnants of freshwater algae *Botryococcus* were found in small numbers (Fig.1 a, b).

Generally, subfossil pollen spectra of soils show the domination of pollen of plants related to anthropogenic indicators. These are, first of all, elements of agriculture, to which, in addition to pollen of cultural cereals, weeds accompanying them also belong (Behre 1981). In the material studied here, Cerealia are littered with *Chenopodium album*, *Polygonum aviculare*, *Polygonum persicaria*, pollen of which were well reflected in almost every palynological spectrum.

The second category of anthropogenic indicators in the palynological spectra is ruderal plants growing near human settlements, on roadsides and weedy places (Behre 1981). *Artemisia* sp., *Polygonum* sp., Cichorioidea, *Urtica dioica* belong to such weeds in the surroundings of the village Tsovinar. Pollen of these plants is fully reflected in the palynological spectra.

But in the palynological spectra, the natural vegetation of the upland steppes is also displayed, which surround the southern part of the coast and where wild grasses and sedges dominate. These two components of the steppes were well reflected in all subfossil pollen spectra (Fig.1 a, b).

Intensive impact of human economic activity on vegetation is seen clearly also in the composition of NPPs. Spores of fungus *Glomus* are a good indicator of agriculture and plowed lands (van Geel 1998). Spores of fungus *Alternaria* affecting ears, stalks and leaves of Cerealia, are markers of grain farming (Tralamazza et al. 2018). Spores of dung fungi *Sordaria*, *Arnium*, *Sporormiella*, *Cercophora*, *Podospora* growing on excrements of ruminant and ungulate animals (van Geel, Aptroot 2006; van Geel et al. 2003, 2011; van Leeuwen 2006) indicate the development of cattle-breeding in Tsovinar and its surroundings.

As it has already been noted, pollen of plants not existing on the plots is present in the spectra. They are not in the landscape near the study area, either. This is the pollen of higher aquatic and semi-aquatic plants *Polygonum amphibium*, *Typha* sp., *Myriophyllum* sp., *Menyanthes trifoliata*, *Sparganium* sp., and *Potamogeton* sp. Their pollen, as well as remnants of freshwater green algae in the group of NPP (*Pediastrum*, *Spirogyra*, *Gloetrichia*, *Botryococcus*), got into the spectra of soils as a result of contamination with lake and lake-march deposits of Sevan, left here after the drainage in 1930. After recent soils formed on the lake deposits, the sediments easily mixed with the new soil, for example by plowing. Such contamination may partially have happened as a result of peat extraction as well. According to the local population, in 1991-1995, during the big energy crisis in Armenia, peat layers of Tsovinar were used as fuel.

Acknowledgment. This work was supported by the German Ministry of Education and Research, grant project “Plant Biodiversity in Time and Space – Changes of vegetation and plant resources in the Southern Caucasus (PlantBITES)”**.** We are grateful also to the project members for their assistance and help during fieldwork

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Received on 28.07.2020