THE SEM CHARACTERISTICS OF THE PALYNOTERATICAL “CEMETERIES” OF TWO CHERNOBYL TYPES AND OF THE NEANDERTHAL TIME CLIMATIC EXTREME ABOUT ~65 kyr B.P.

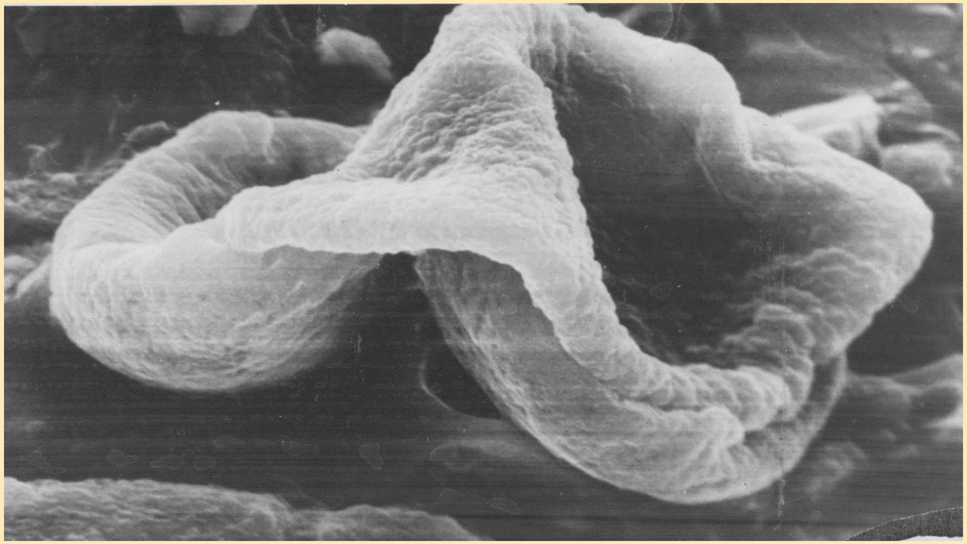
G.M. Levkovskaya[1], N.V. Shamal2, A.N. Bogolyubova3, G.F. Baryshnikov4, V.P. Lyubin1, E.V. Belyaeva1, M.V. Anikovich[1], S.N. Lisitsyn[1], N.I. Platonova[1], V.F. Tarasevich[3], A.K. Kasparov[1]

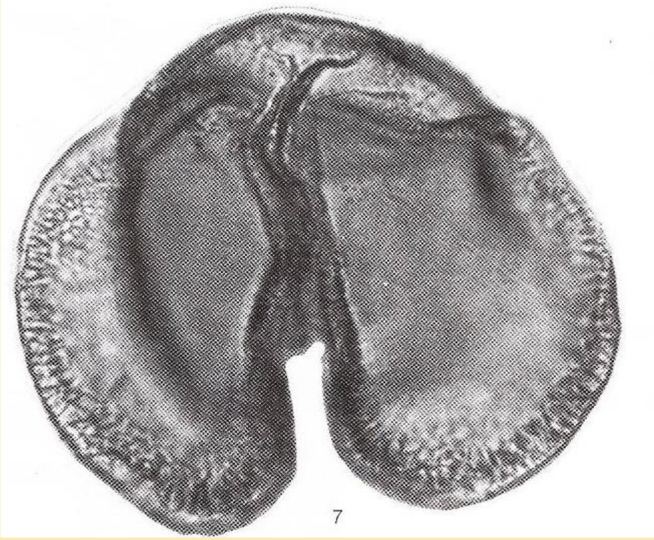
[1] *Institute for the History of Material Culture RAS, St. Petersburg, Russia, ggstepanova@yandex.ru*

[2] *Institute of Radiobiology NAS, Gomel, Belarus*

[3] *Komarov Botanical Institute RAS, St. Petersburg, Russia*

[4] *Zoological Institute RAS, St. Petersburg, Russia*





Pollen of *Picea:* 1. teratomprph from Chernobyl (SEM) 2. pollen standard (light microscope)

MATERIALS STUDIED

Palynoteratical complexes from:

- Surface soil samples from 3 locations of the Chernobyl 30 km exclusion zone with two types of radioactive contamination [Levkovskaya et al., 2011, 2022].
- Sediments from the desquamation layer of the Caucasian Barakayevskaya caves site with Neanderthal child mandible [Levkovskaya, Lyubin, Belyaeva, 2012].

METHODS OF THE RESEARCH

Collection of palynoteratical statistics in each sample:

- marking each abnormal feature of each pollen grain;
- estimation of the proportion of the gross morphologically standard and gross abnormal pollen grains of all taxa together;
- calculating percentages of five groups* within the morphologically abnormal pollen:
    1. dwarf,
    2. underdeveloped,
    3. defective,
    4. dwarf + underdeveloped,
    5. dwarf + underdeveloped + defective.

* These groups reflect the types and levels of ecological impact [Levkovskaya et al., 1999, 2022].

INNOVATIONS IN THE METHODS OF THE RESEARCH

- using SEM as a new source of statistical palynoteratical information: coating with gold/palladium of macerated sediments with pollen complexes (instead of single pollen grains);
- using playnoteratical complexes as a source of information on geobotanical stresses of natural and anthropogenic origin [Levkovskaya et al., 1999; 2022].

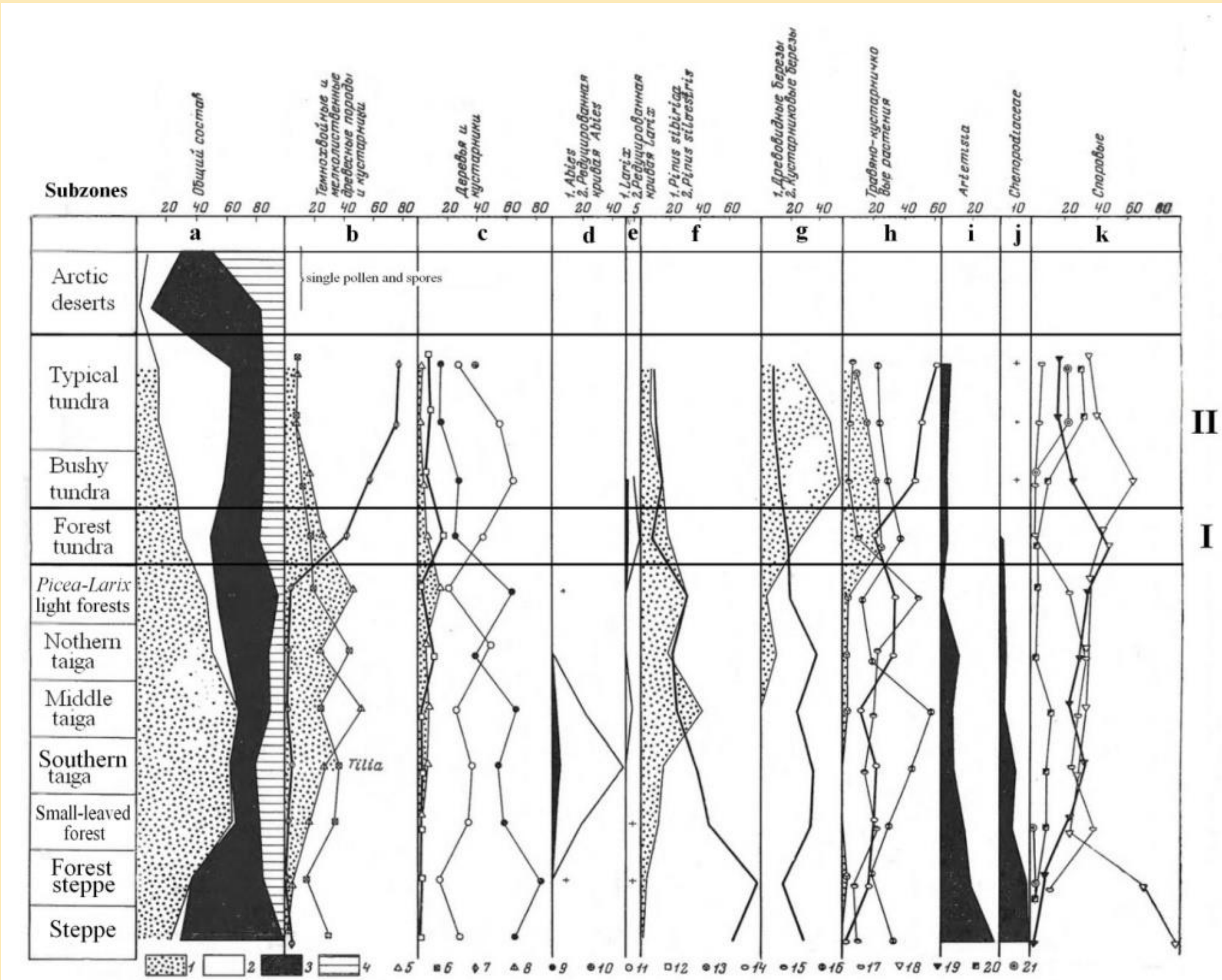
THE BASIS FOR INTERPRETATION OF THE CHERNOBYL MATERIALS

The studies of the Chernobyl material has begun in 1999 after the article "Palynoteratical complexes as indicators of the natural ecological stress, past and present" was published in Kraków [Levkovskaya, 1999].

The proposed approach for the interpretation of the Chernobyl materials is based on vast palynoteratical statistics obtained for:

- ecologically clean sediments of different glacials and stadials from many regions of the former USSR (Moldova, Russian Plain, Altai, Taymyr Peninsula, Caucasus),
- surface soil samples from Southern Arabia [Levkovskaya et al., 2017];
- surface soil samples from all geobotanical subzones of West Siberia [Levkovskaya, 1973].

SOUTHERN SIBERIA
AVERAGED POLLEN COMPLEXES OF ALL MODERN GEOBOTANICAL SUBZONES



General composition of this published diagram [Levkovskaya, 1973] shows the connection of dwarf palynomorps' maximum (a: white field) with climates of modern forest tundra (I) and southern parts of tundra (II). In this areas *Alnaster* sp. and *Betula nana* communities have maximal distribution. Palynoteratical statistics on the forest-steppe and steppe zones is absent.

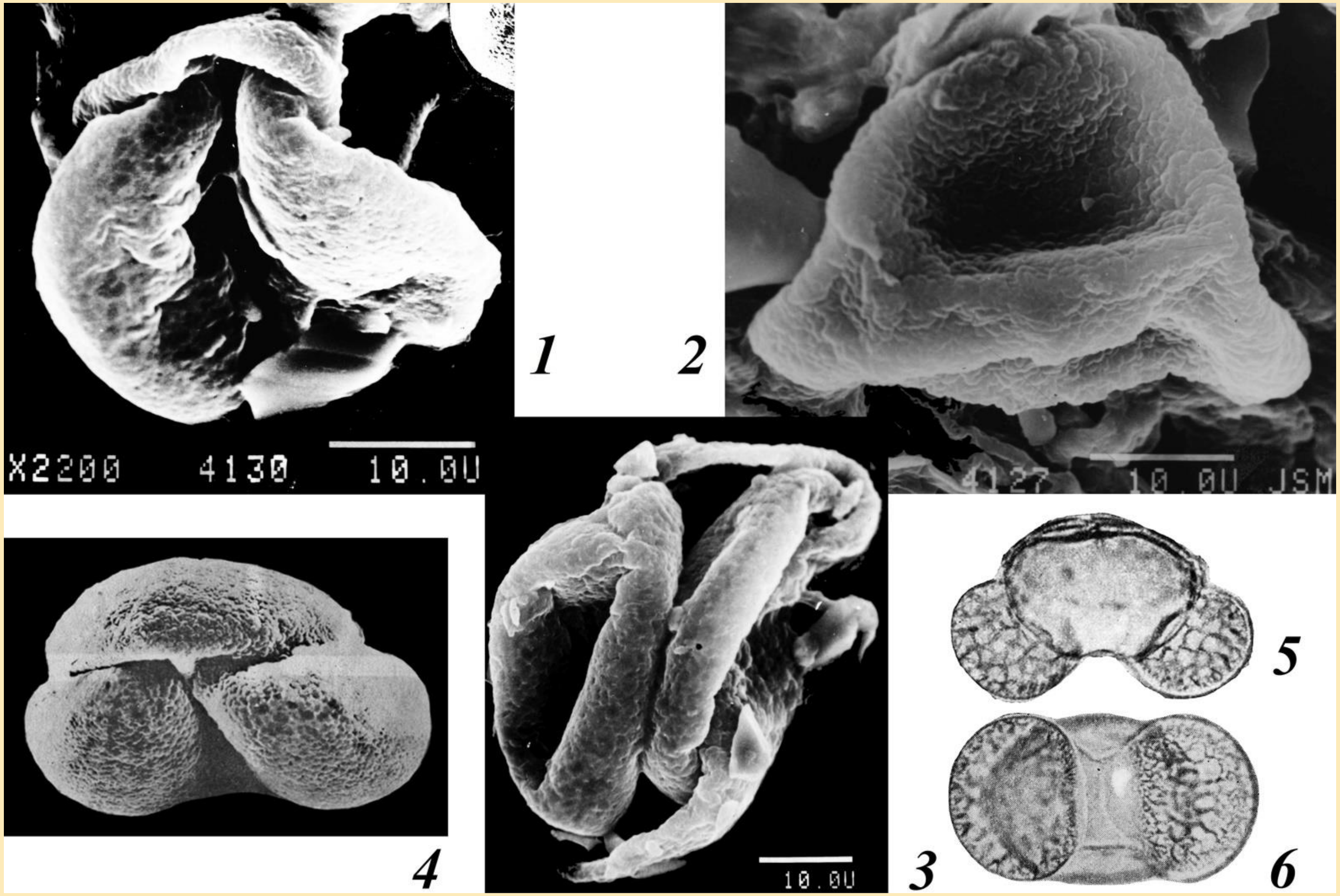
TWO TYPES OF THE CHERNOBYL POLLEN COMPLEXES FROM THE SEDIMENTS WITH HIGH LEVEL OF RADIOACTIVE CONTAMINATION

RADIOACTIVE SURFACE CONTAMINATION OF SOILS SAMPLED ON THE SECOND YEAR AFTER THE CHERNOBYL CATASTROPHE

Location	*Distance from the ChNPP, km*	*Equivalent dose rate, μSv/h**		*Specific radioacivity on the soil surface, Bq/kg**			
		at soil level	1 m above soil level	^{90}Sr	^{137}Cs	^{241}Am	^{239,240}Pu
Kryuki	16	22	17	4500	270000	81	48
Lesok	22	8.9	7.6	9100	84100	140	83
Masany	12	5.3	4.2	14000	52000	150	99

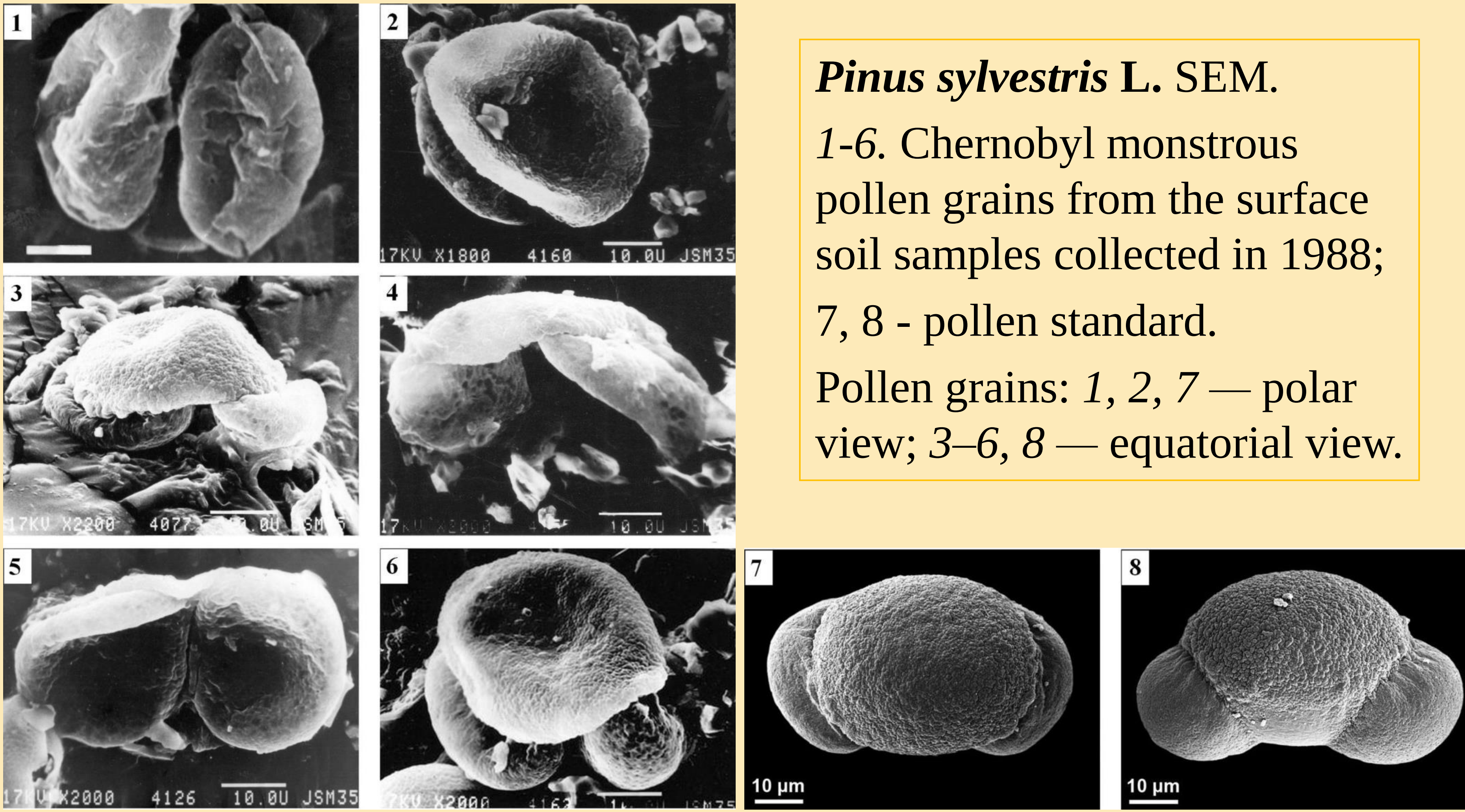
Blue – maximum contaminations

VARIATIONS OF *PINUS* POLLEN MONSTROSITY IN THE CHERNOBYL COMPLEXES



Pinus sp.: *1-3* – monstrous (due to mutations) pollen from Chernobyl;
4-6 – normal modern pollen under: *4* – SEM, *5*, *6* – light microscope.

VARIATIONS OF *PINUS* POLLEN MONSTROSITY IN THE CHERNOBYL COMPLEXES



***Pinus sylvestris* L.** SEM.

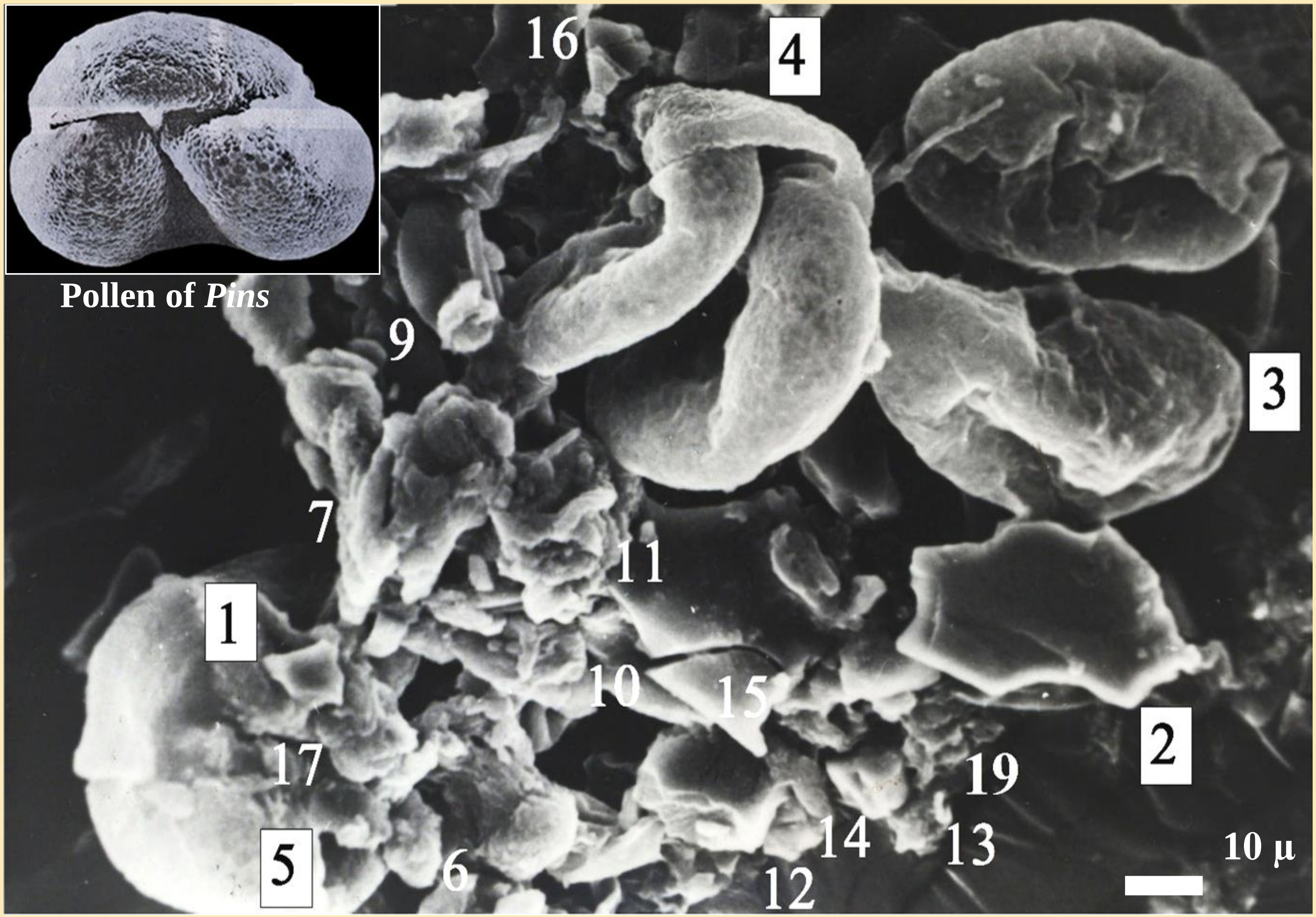
1-6. Chernobyl monstrous pollen grains from the surface soil samples collected in 1988;

7, 8 - pollen standard.

Pollen grains: *1*, *2*, *7* — polar view; *3–6*, *8* — equatorial view.

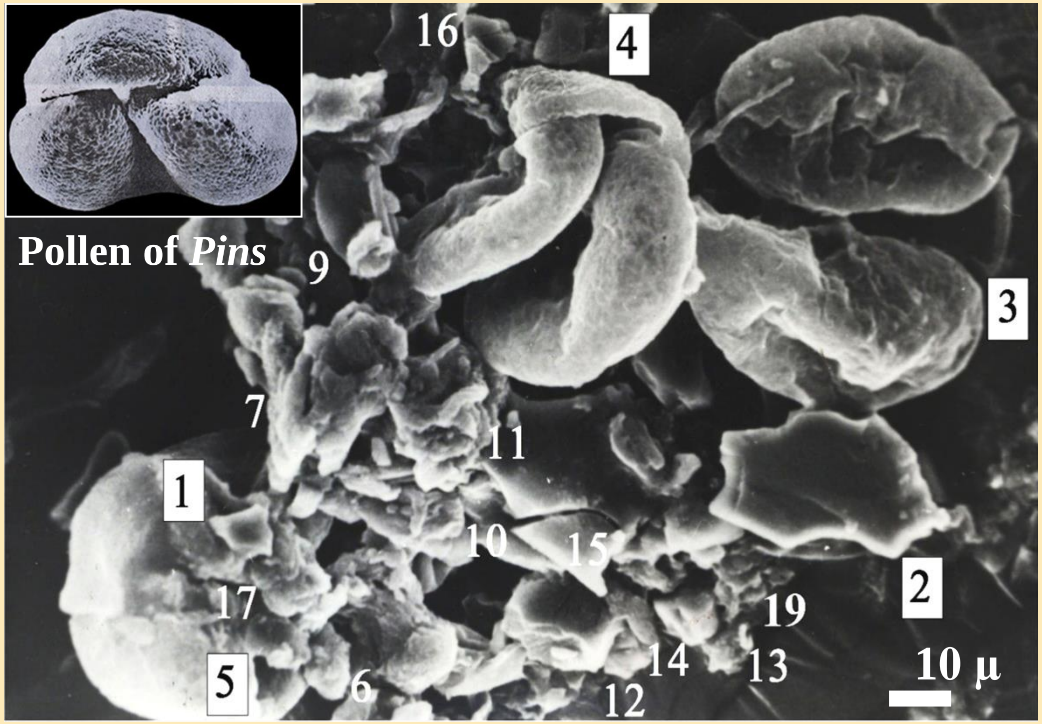
KRYUKY. 16 Km from ChNPP. Palynoteratical complex TYPE 1. Area with the highest contamination with ^{137}Cs – 270000 Bq/kg

In this “cemetery” each form is underdevelopled + monstrous + mostly dwarf



KRYUKY. 16 Km from ChNPP. Palynoteratical complex TYPE 1. Area with the highest contamination with ^{137}Cs – 270000 Bq/kg

In this “cemetery” each form is underdeveloped + monstrous + mostly dwarf

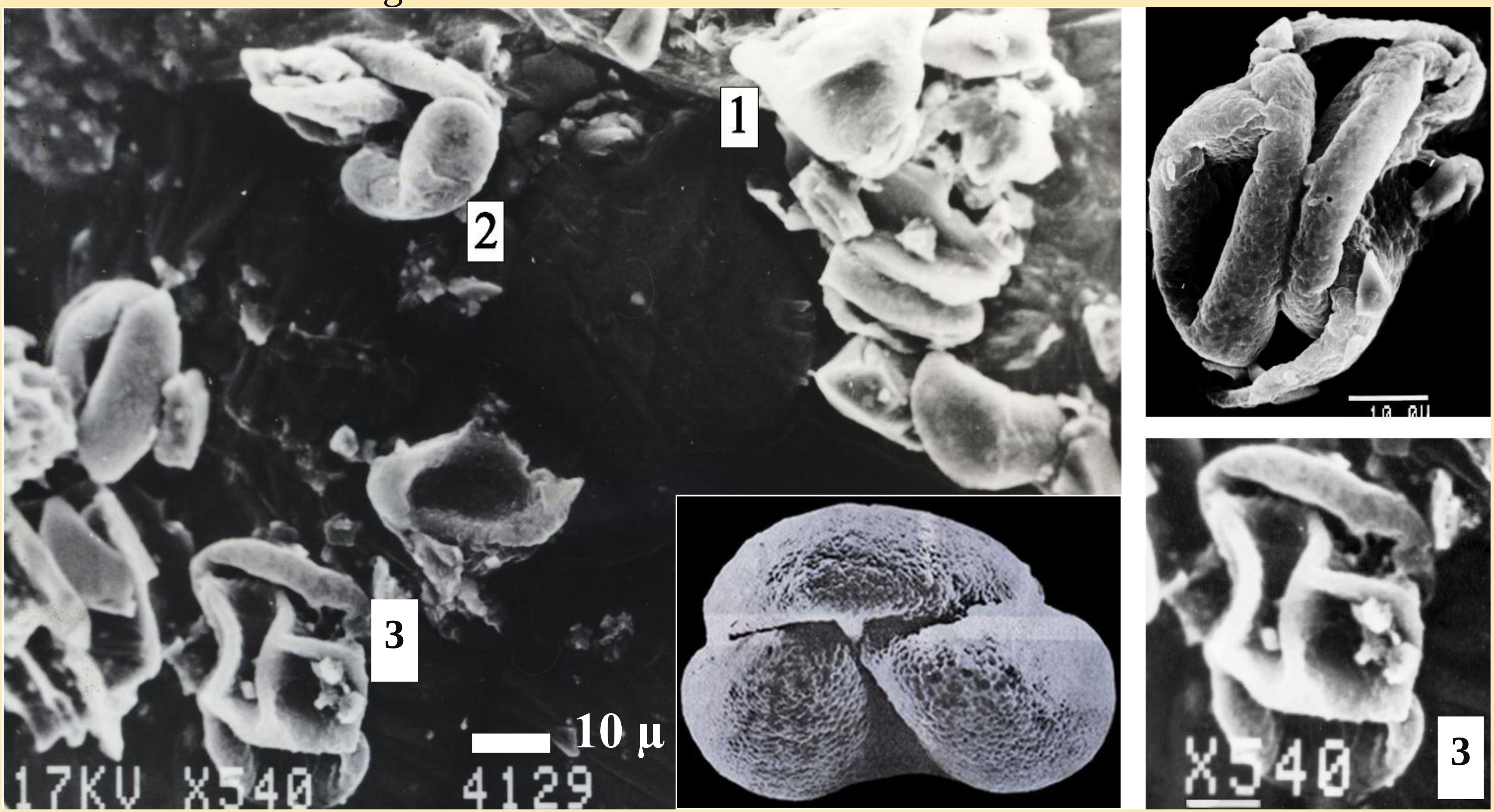


SEM. X540
Identified pollen:
1 – dwarf *Betula* sp.:
3, 4 – monstrous *Pinus* sp.;
13 – ultra dwarf *Alnus* sp..

The pollen grains are:
- sterile, and with numerous erosions;
- monstrous, with varied abnormalities: *Pinus* (3) has varied thickness of exine, *Pinus* (4) is asymmetrical with unusually large sacks;
- most forms are small: the largest grains of *Pinus* sp. are ~65 μ (3) and ~55 μ (*4*), while the standards are ~60-80μ. [Kupriyanova et al., 1983].

MASANY. 12 km from ChNPP. Palynoteratical complex TYPE 2. Area with the highest contamination with ^{90}Sr, ^{241}Am, $^{239,240}Pu$

In this “cemetery” each form is underdeveloped (missing most traits) + monstrous (with some twisted forms) + mostly dwarf and with thick exine covered with white matter of unknown origin

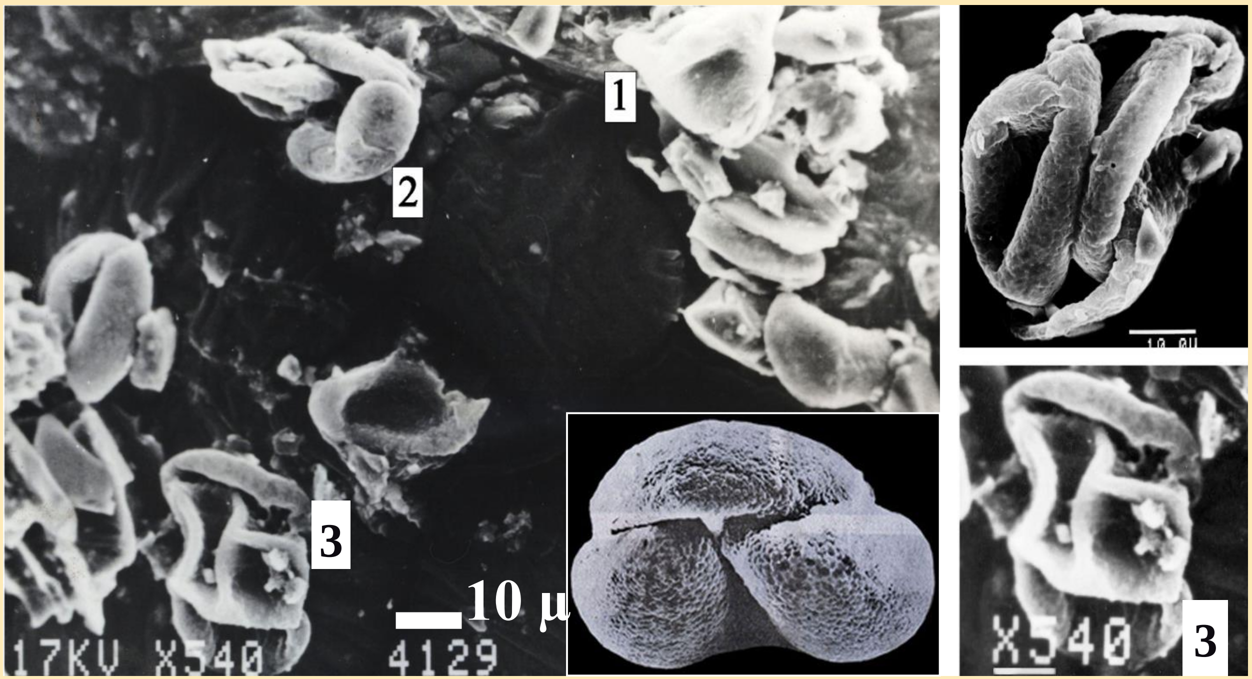


[Levkovskaya et al., 2011]

Normal pollen of *Pinus*

MASANY. 12 km from ChNPP. Palynoteratical complex TYPE 2. Area with the highest contamination with ^{90}Sr, ^{241}Am, $^{239, 240}Pu$

In this “cemetery” each form is underdevelopled (missing most traits) + monstrous (some forms are twisted) + mostly dwarf



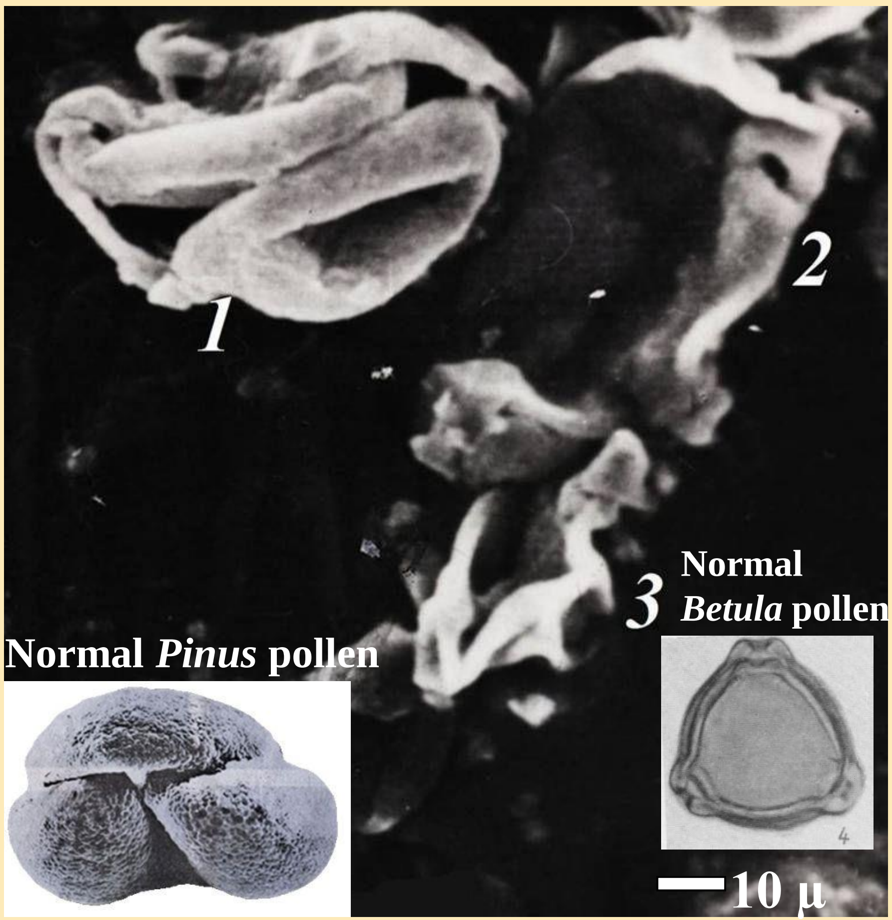
SEM. X540
Pollen of:
1-3 – Pinaceae
(monstrous forms)

[Levkovskaya et al., 2011] Normal pollen of *Pinus*

Complex TYPE 2 (Masany and Lesok) differs from TYPE 1 (Kryuki) by:
- appearance of twisted Pinaceae forms;
- white matter of unknown origin covering pollen grains;
- underdeveloped forms miss most morphological traits except of thick exine.

LESOK. 22 Km from ChNPP. Palynoteratical complex TYPE 2. Area of high contamination with ^{241}Am, $^{239,240}Pu$ and ^{90}Sr, but lower than in Masany

This fragment of a "cemetery" is a variation of the complex TYPE 2. The forms are characterized by the incomplete development (*1*, *2*, *3*), twisted monstrosity (*1*), and thick white exine (*4*).

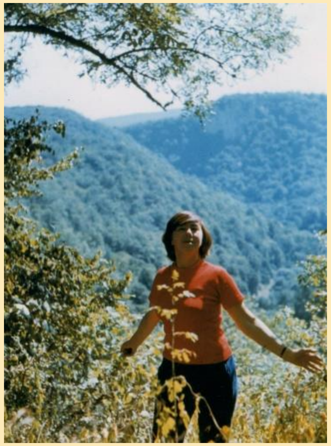


BARAKAYEVSKAYA CAVE SITE (MODERN BROADLEAF FOREST BELT)

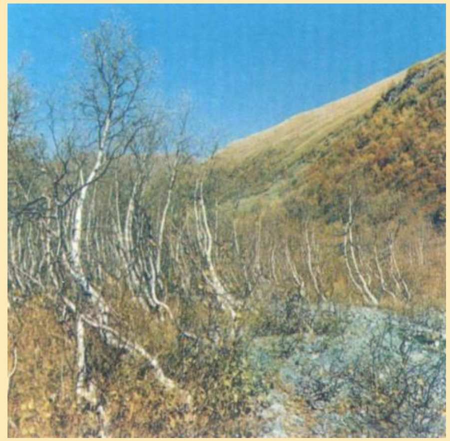
THE TIME OF THE CRYOXEROFILOUS STAGE OF THE LAST GLACIAL EPOCH IN THE CAUASUS

BARAKAYEVSKAYA CAVE SITE. RECONSTRUCTION OF CLIMATIC EXTREME BASED ON TRADITIONAL POLLEN DATA

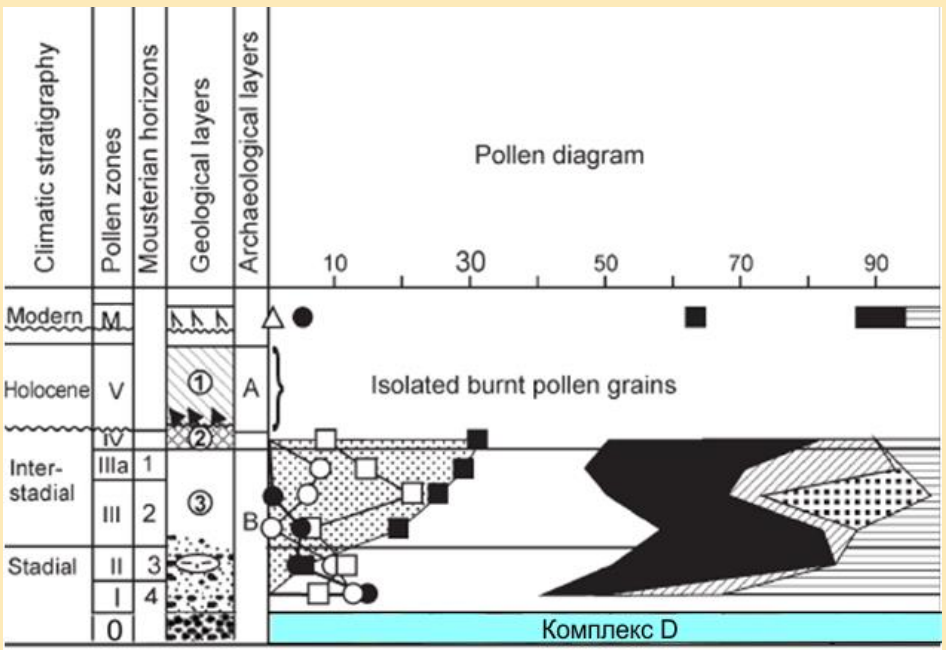
A



B



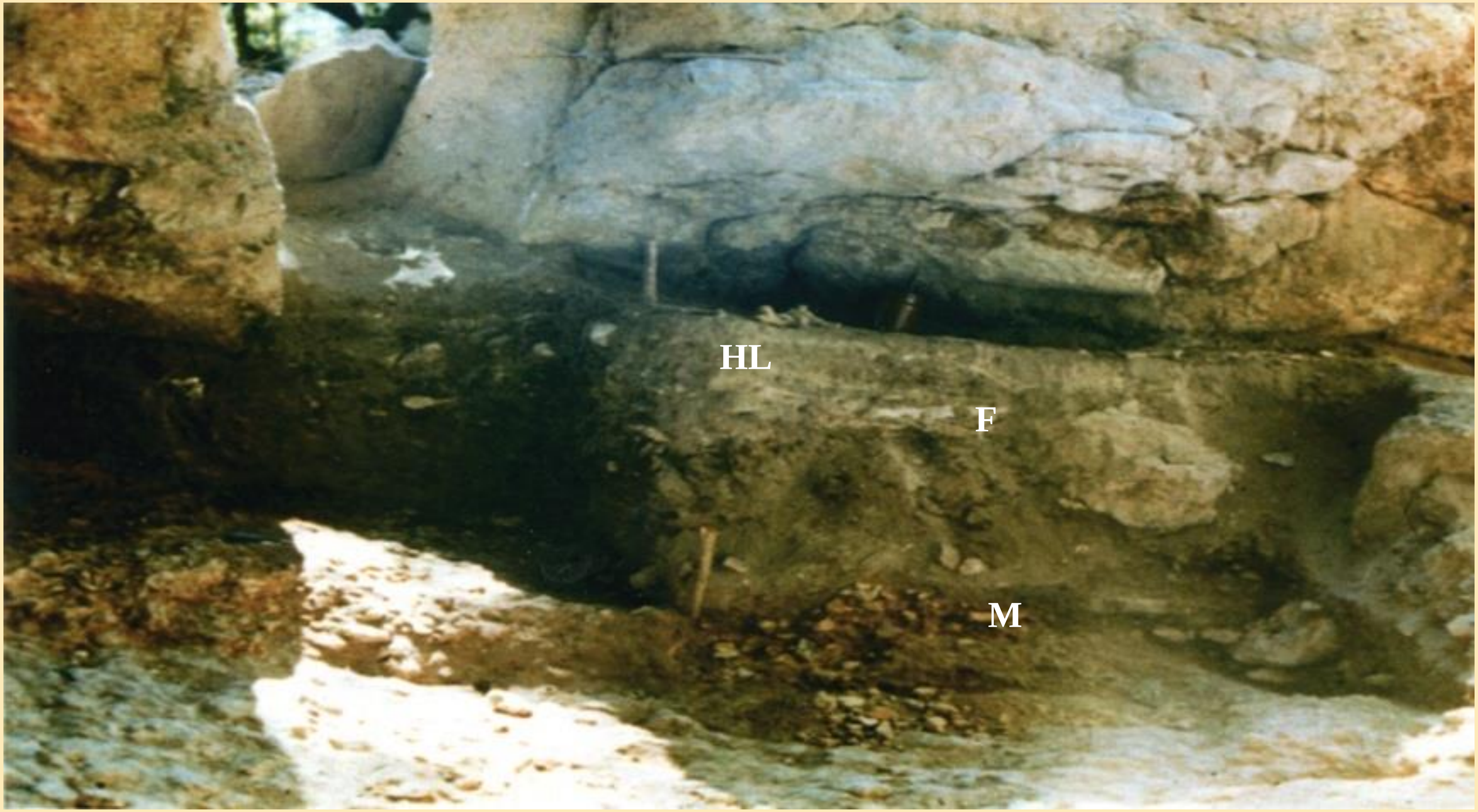
C



A – modern conditions of the Barakayevskaya cave site: lower part of the broadleaf forest belt.

B, C – modern analogies of the reconstructed palaeovegetation for pollen zones:
B – border of alpine and subalpine belts (pollen zone 0);
C – subalpine belt (pollen zone I).

BARAKAYEVSKAYA CAVE SITE.
RECONSTRUCTION OF CLIMATIC EXTREME BASED ON GEOLOGICAL DATA



The bottom of the Mousterian layer (M) with Neanderthal child mandible is associated with the frost desquamation horizon formed under alpine continental climate.

BARAKAYEVSKAYA CAVE SITE. RECONSTRUCTION OF CLIMATIC EXTREME BASED ON PALAEOZOOLOGICAL DATA

760 animal bone fragments were identified [Baryshnikov, 1994, p.75].

The faunal assemblage is dominated by the steppe species – 58,7%

1- mouflon, 2- horse, 3- buffalo, 4- pika, 5- ground-squirrel, 6- hamster

BARAKAYEVSKAYA CAVE SITE. RECONSTRUCTION OF CLIMATIC EXTREME BASED ON PALAEOZOOLOGICAL DATA

The alpine species were second in occurrence – 26,7%.

Only 2% belonged to the forest species.

1 - steinbock, 2 - marmot, 3 - European snow vole, 4 - Caucasian snow vole

CHARACTERISTICS OF THE POLLEN COMPLEX FROM THE BARAKAYEVSKAYA CAVE SITE AND OTHER ESPECIALLY SEVERE NATURAL ENVIRONMENTAL CONDITIONS

The complex of the Barakayevskaya extreme has all features of the complex from glacial sediments published by Ye. N. Ananova (1966):

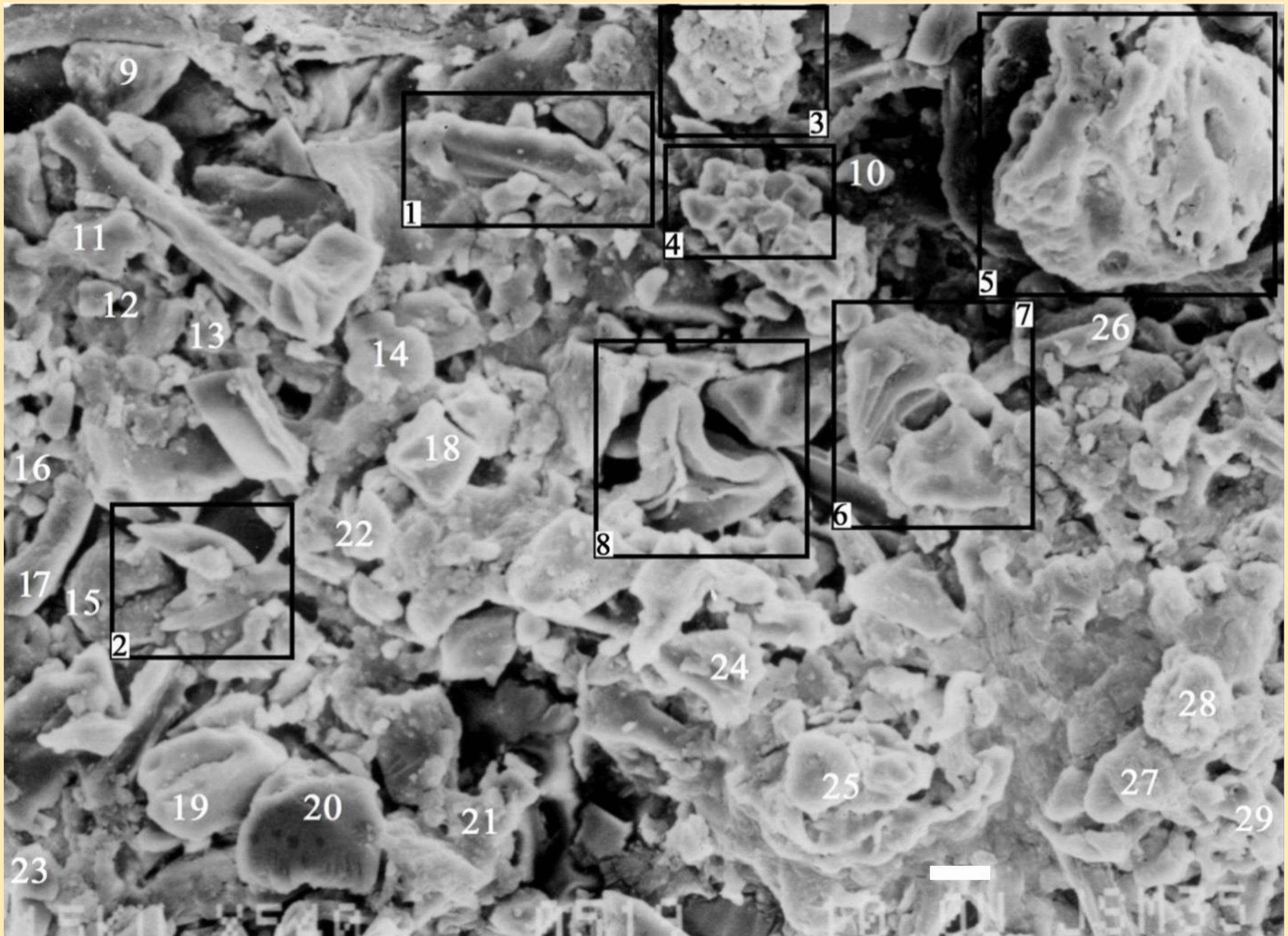
In this complex most pollen grains are:

- aboritve;
- missing sculpture and some other traits;
- flattened;
- ultra dwarf;
- occur in polyades;
- of grey colour (under light microscope);
- with glassy gloss (under light microscope).

The complexes with domination of unidentified forms are often omitted. But their position should be shown on diagrams.

BARAKAYEVSKAYA CAVE SITE. PALYNOTERATICAL COMPLEX OF THE UPPER LIMIT OF ALL FLOWERING PLANTS

The Barakayevskaya complex looks like the “cemetery” of ultra dwarf and very thin palynomorps. It matches the description of the glacial complex by Ye.N.Ananova (1966) .



SEM. X540

Pollen:

3 – Asteraceae;

4 – poliade of Betulaceae;

8 – *Juniperus* (?);

14 – unidetified palynomorph;

27 – ultra dwarf Pinaceae.

Spores:

8 – Cretaceous spore from the cave roof.

CONCLUSIONS

SIMILARITY OF PALYNOTERATICAL CHARACTERISTICS OF POLLEN COMPLEXES OF NATURAL AND TECHNOGENIC ORIGIN

1. General features of the complexes of the severe geobotanical stresses of the Neanderthal time and of the Chernobyl catastrophe are characterized by the sterility of most forms and by almost complete absence of the determinable morphologically typical pollen grains and spores.
2. The data on the subfossil pollen complexes of the West Siberia (1973) show: a. almost complete absence of palynoterates in the forest zone; b. the small maximum of deformed forms – at the nothern limit of trees only; c. the domination of dwarf forms – in tundra zone; d. underdeveloped - at the border of arctic and polar tundra subzones.
3. Almost complete absence of morphologically normal pollen grains is an indicator of the geobotanical stresses of natural or anthropogenic origin.

FEATURES OF THE PALYNOTERATICAL COMPLEXES OF NATURAL EXTREMES

The main features of the natural extreme complexes:

1. Ugly (deformed) forms are rare (unlike in the Chernobyl complex).

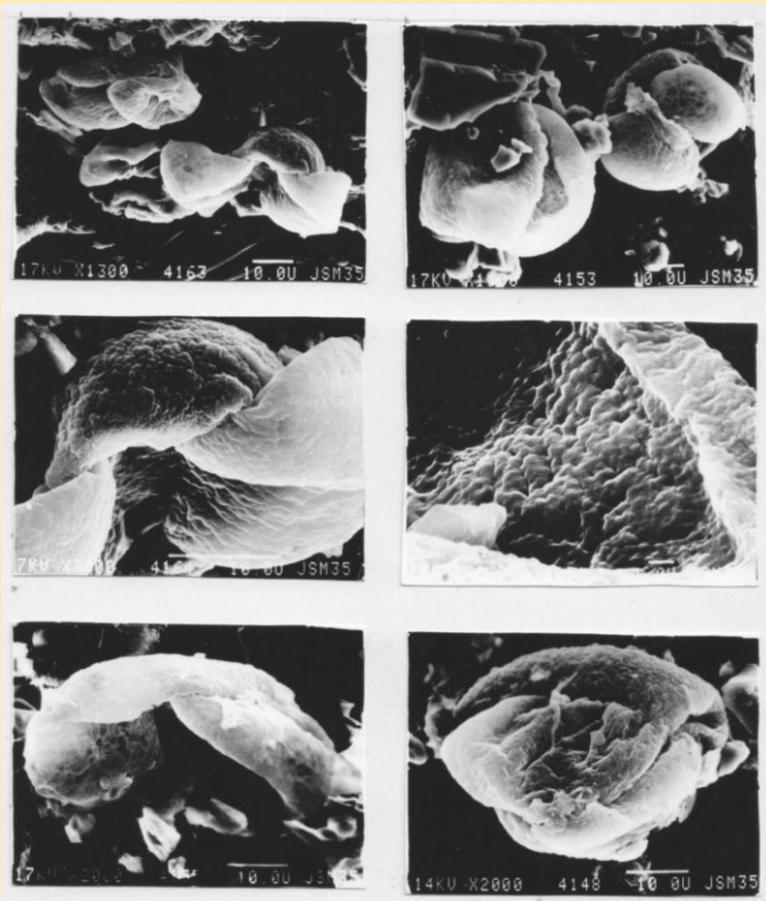
2. Three types of dominating pathologies:
   - nanism of pollen grains simultaneously in different taxa.
   - forms are underdeveloped due to the immaturity.
   - each form is simultaneously dwarf and underdeveloped, which reflects especially severe conditions.

FEATURES OF THE CHERNOBYL TYPE PALYNOTERATICAL COMPLEXES

The Chernobyl forms (A) differ from the forms of natural extremes (B) by :

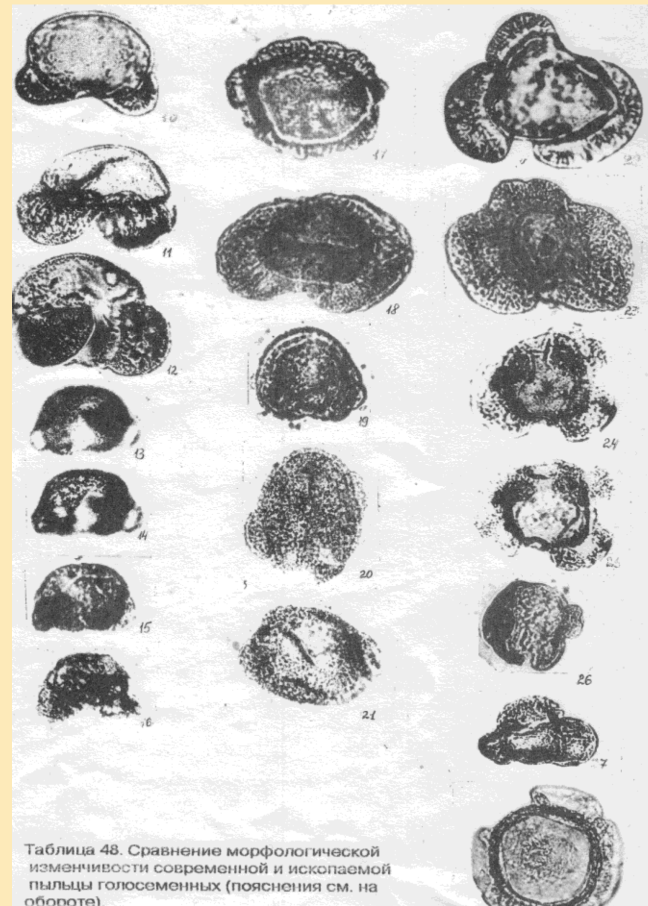
- the higher instability of all features as a result of mutations;
- number and deeper level of all pathologies.

A



By G.M. Levkovskaya

B



By N.D. Mchedlishvili

SOME PRACTICAL RECOMMENDATIONS

1. For the differentiation of the geobotanical catastrophes of natural and anthropogenic origin it is important to collect the palynoteratical statistics on all abnormalities of each pollen grain from all studied sediments or anthers, because single abnormal pollen grains are present in each anther.
2. For the reconstruction of the especially unfavorable ecological conditions it is very important:
   - to show the levels (on pollen diagrams) or locations (on maps) with domination of morphologically abnormal pollen grains, especially underdeveloped;
   - to obtain SEM micrographs of the “cemeteries” of the abnormal pollen grains.

THE PROSPECTS OF THE RESEARCH

To determine the improvement of the environmental conditions 38 yeas after the Chernobyl disaster with decrease of radioactive load from the short half-life radionuclides*, it is necessary to:

- collect the samples form the same locations as soon as possible;
- study them using same methods;
- asses changes in the palynoteratical complexes, when ^{90}Sr and ^{137}Cs radioactivity decayed.

* Major radioactive contaminants' half lives (years):
^{90}Sr – 28.8, ^{137}Cs – 30.17, ^{241}Am – 432.2, ,^{240}Pu – 6 651, ^{239}Pu – 24 100.

REFERENCES

1. *Levkovskaya G.M., Matsko V.P., Skvernyuk I.I., Orekhova V.G., Kartseva L.A.* 2011. [Pollen quality and the specific features of the palynoteratical complexes from the soil samples from the Chernobyl area (data on the sediments with high radioactive contamination] // [Problems of the modern palynology. Proceedings of the XIII All-Russian palynological conference]. Syktyvkar. P. 271-277.

2. *Levkovskaya G.M., Kasparov A.K., Bogolyubova A.N.* 2022. Differentiation of the past and present geobotanical optima and crises using palynoteratical statistics. // Actual problems of the modern palynology: Proceedings of XV All-Russian Palynological Conference. Moscow. P. 201-205. https://doi.org/10.54896/9785891188532_2022_41 (In Russian)

3. *Levkovskaya G., Lyubin V., Belyaeva E.* 2012. Late Caucasian Neanderthals of Barakaevskaya cave: chronology, palaeoecology and palaeoeconomy (Chapter 16) // Caves in context. The cultural significance of caves and rockshelters in Europe. P. 225–253. https://doi.org/10.2307/j.ctvh1djk4.20

4. *Levkovskaya G.* 1999. Palynoteratical complexes as indicators of the ecological stress, past and present // Proceedings of the 5th European Palaeobotanical and Palynological Conference. Acta Palaeobotanica. Suppl. 2. P. 643 – 648. http://bomax.botany.pl/pubs/#article-2110

REFERENCES

5. *Levkovskaya G.M., Shamal N.V., Baryshnikov G.F., Bogolyubova A.N.* 2022. Types of palynoteratical responses of the plants reproductive sphere to the Chernobyl accident and natural climatic exterma of the Neanderthal epoch // [Dynamics of the Holocene ecosystems. Materials of the all-Russian conference]. St. Petersburg. P. 431-437. https://elibrary.ru/item.asp?id=53727580&pff=1

6. *Levkovskaya G.M.* 1973. The zones peculiarity of the modern vegetation and the subfossil pollen spectra of the Western Siberia. // Methodical problems of palynology. Proc. of III International palynological conference. Moscow. P. 113-120. (In Russian)

7. *Ananova Ye.N.* 1966. [Abortive pollen in glacial sediments] // Bulletin of the Commission for Study of the Quaternary. №32. P. 18-22. http://www.ginras.ru/library/pdf/32_1966_bull_quatern_comission.pdf (In Russian)

8. Baryshnikov G.F. 1994. [Vertebrates from the Barakayevskaya Mousterian site]. // [The Neanderthals of the Gups Gorge in the North Caucasus]. Ed. V.P. Lyubin. Maykop. P. 69-75. (In Russian)

9. [The Neanderthals of the Gups Gorge in the North Caucasus]. 1994. Ed. V.P. Lyubin. Maykop. 238 p. (In Russian)

THANK YOU!