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Palynostratigraphy of the Poozerie Glaciation (Vistulian) in Belarus

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A palynological examination was applied to sediments of the last glaciation (Poozerie, Vistulian) in Belarus. Accompanied by geologic setting of deposits, as well as radiocarbon and thermoluminescence dating, the Poozerie sequence could be ascribed to three substages, i.e. Kulakovo, Dvina and Naroch. The Kulakovo substage (early Poozerie) corresponds to the oxygen isotope stage 5d-a, and comprises the West Dvina megastage with the short Black Shore interstage and the megainterstage (two stages of Mirogotshi and Sloboda, and three interstages of Chericov, Suraz and Polotsk). The Dvina substage (Pleniglacial), corresponding to the oxygen isotope stages 4 and 3, consists of the Mezin and Orsha megastages and the separating megainterstage with three middle Poozerie interstages (Turov, Shapurovo and Borisov) and two stages (Rogachevo and Michalinovo). The Naroch substage (oxygen isotope stage 2) represents the Late Glacial. There are several interstages during the Poozerie Glaciation: Chericov (Amersfoort), Suraz (Brörup), Polotsk (Odderade), Turov (Moershoofd), Shapurovo (Hengelo) and Borisov (Denekamp).

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INTRODUCTION

The Late Quaternary in Belarus comprises an interval from about 130 ka ago to the present time and consists of the Murava Interglacial (Eemian), Poozerie Glaciation (Vistulian, Valdai) and the Holocene. The Poozerie Glaciation is a bright, interesting and important event to understand a vegetation evolution in Europe. Many monographs are devoted to the stratigraphy and palaeogeography of this interval (B. Frenzel, 1980; B. Menke, 1982; J. E. Mojski, 1993). However, original data of the last glaciation in Belarus (*cf.* Fig. 1) are still poorly known in other European countries. Vegetation development in this time was described by L. N. Voznyachuk, M. A. Valchik (1978), B. N. Gurskij *et al.* (1981, 1983), L. N. Voznyachuk (1981), N. A. Makhnach *et al.* (1981), A. F. Sanko (1987) and A. V. Matveev (1990). This analysis and a critical review of the actual material allow considering that the Poozerie Glaciation corresponds to the oxygen isotope stages 5d-a, 4, 3 and 2. It covers an interval from 115 ka (according to A. Sanko) or 90 ka (according to Ya. Yelovicheva) till 10 ka ago, therefore lasted at least 80 or 105 ka, respectively (Ya. Yelovicheva, 1992*a*, *b*; Ya. Yelovicheva *et al.*, 1996). In the area occupied by the ice sheet of the Poozerie Glaciation there is a till and glaciofluvial sediments, whereas in the extraglacial area there are alluvial, lake and marshy sediments to 10–40 m (occasionally to 60 m) thick. They are commonly sands, clay, clayey sands, clayey silt, silt, occasionally marls, gyttja and peat. The previously glaciated area retained a fresh landscape with eskers, kames, end moraines, glacial hummocks and depressions.

SUBDIVISION OF THE POOZERIE GLACIATION

The Poozerie stage is composed of the substages Kulakovo, Dvina and Naroch (Table 1).

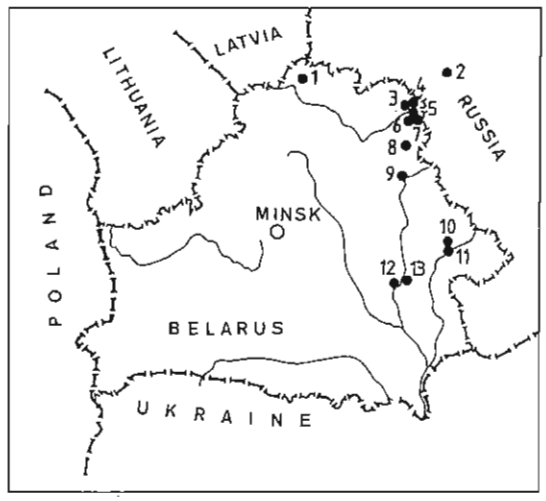


Fig. 1. Key sections of the Poozerie Glaciation

1 — Staiky (Polotsk interstage; analysis by K. Demeshko), 2 — Pryalitsa (Mezin megastage; analysis by Ya. Yelovicheva), 3 — Black Shore (Black Shore interstage, West Dvina stage 1–2; analysis by K. Tarasevich), 4 — Borisov Gora (Borisov interstage; analysis by V. Kadatcki), 5 — Suraz (Suraz interstage; analysis by I. Grigorovich, L. Kurjerova), 6 — Sloboda (Sloboda stage; analysis by I. Grigorovich, L. Kurjerova), 7 — Shapurovo (Shapurovo interstage; analysis by N. Makhnach), 8 — Michalinovo (Michalinovo stage; analysis by O. Kondratene), 9 — Orsha (Orsha megastage; analysis by V. Kadatcki), 10 — Mirogotshi (Mirogotshi stage; analysis by Ya. Yelovicheva, K. Demeshko), 11 — Chericov (Chericov interstage; analysis by Ya. Yelovicheva), 12 — Rogachevo (Rogachevo stage; analysis by N. Makhnach), 13 — Tursk (Turov interstage; analysis by N. Makhnach)

KULAKOVO SUBSTAGE (EARLY POOZERIE GLACIATION)

It covers an interval 115–70 ka (according to A. Sanko) or 90–49 ka (according to Ya. Yelovicheva), and is correlated with the oxygen isotope stage 5d-a. The Kulakovo substage comprises the West Dvina megastage with the short-term Black Shore interstage and the megainterstage with two stages of Mirogotshi and Sloboda, and three interstages of Chericov, Suraz and Polotsk.

West Dvina stage 1 (pz-s-1-a) is represented by a loose pine-birch or birch-pine forest with spruce, alder, and herbs in an open area. Pollen and spores were calculated into groups by V. Grichuk (tree pollen from a total of trees, shrub pollen from a total of shrubs, herb pollen from a total of herbs, and spores from a total of spores). There is a high content of herb pollen (24–38%) mainly *Artemisia*, Chenopodiaceae, Gramineae, including Asteraceae, Caryophyllaceae, Rubiaceae, Polygonaceae and Ranunculaceae. Among the aquatic-marshy plants there were mainly Ericaceae, Pyrolaceae, Potamogetonaceae and Cyperaceae. Trees were predominated by *Pinus* (22–28%) and *Betula* (20–24%, bush-like forms included). A considerably smaller role was played by *Picea* (2–4%), *Alnus* (2–6%) and *Quercetum mixtum* (4–6%) with *Quercus*, *Tilia*, *Ulmus* and *Carpinus*. Shrubs include *Corylus* (4–12%), *Salix* (2–4%) and *Hippophaë*. Among the spores a leading place belongs to Bryales and *Sphagnum*, and Polypodiaceae whereas Lycopodiaceae and *Selaginella selaginoides* are less significant.

Black Shore interstage (pz-s-1-b) is represented by a pine and quite often a birch forest, accompanied by herbs. In a structure of pollen spectra a role of herbs was reduced a little (to 24%): there is a drop of *Artemisia* and Gramineae, and a rise of Chenopodiaceae, Ericaceae and Cyperaceae, whereas contents of Rubiaceae, Polygonaceae and Ranunculaceae remained the same. Among trees there are maxima of *Pinus* (82%) and *Betula* (50–90%), drop of *Picea* (2%), *Quercetum mixtum* (2%) with rare pollen of *Carpinus* and former content of *Alnus* (3%). Among the shrubs there are *Corylus* (4–10%) and *Salix* (4%), and *Ephedra*. The spores contain similar contents of *Sphagnum*, Bryales, Polypodiaceae and Lycopodiaceae.

West Dvina stage 2 (pz-s-1-c) is represented by spreading of a birch forest with pine, and herbs of open communities. The pollen spectrum indicates a sharply increased content of herbs (38–50%), mainly of *Artemisia*, accompanied by Chenopodiaceae, Gramineae, Asteraceae, Caryophyllaceae, Polygonaceae, Ranunculaceae and Rubiaceae. The aquatic-marshy plants include *Myriophyllum verticillatum*, Potamogetonaceae and Cyperaceae. There is an outstanding predominance of *Betula* (38–90%), and low contents of *Pinus* (8–12%), *Picea* (1–4%), *Alnus* (1–6%), *Quercetum mixtum* (0.5–6%) with *Quercus*, *Tilia* and *Carpinus*, and shrubs of *Corylus* (2–14%) and *Salix* (0.5–6%). Bryales prevail among the spores, whereas *Sphagnum* is partly accompanied by Polypodiaceae, *Selaginella selaginoides* and Lycopodiaceae.

Chericov interstage is represented by a birch and birch-pine forest (pz-s-2-a), then by a pine-birch and birch-pine forest with spruce (pz-s-2-b). In a pollen spectrum the interstadial starts with a content of herbs below 18%: mostly *Artemisia*, plenty of Chenopodiaceae, Gramineae, and also with Asteraceae, Caryophyllaceae, Rubiaceae, Ranunculaceae and *Myriophyllum verticillatum*. Trees are predominated by *Betula* (92%), accompanied by *Pinus* (10%). Among the shrubs *Salix* and *Ephedra* are sporadic. Spores comprise mainly Bryales, and partly Polypodiaceae. To the end of the interstadial a content of herbs is equal to 8–28% with predominant *Artemisia*, a lot of Gramineae, Chenopodiaceae, Asteraceae, Caryophyllaceae, Rubiaceae, Polygonaceae, some Ranunculaceae, and Cyperaceae, Ericaceae and Pyrolaceae in aquatic-marshy environments. A role of *Pinus* (46–62%), *Picea* (2%) and *Alnus* (2%) raised, accompanied by a drop of *Betula* (34–54%). *Corylus*, *Ephedra* and Rhamnaceae are rare. Among the spores there are mainly Bryales, with abundant *Sphagnum*, Polypodiaceae and Lycopodiaceae.

Mirogotshi stage (pz-s-3) is represented by a less dense bireh forest including pine and well developed herb communities. The spectra are characterised by an increasing role of herbs (18–46%), mainly *Artemisia*, a lot of Gramineae, Chenopodiaceae, Asteraceae, Caryophyllaceae, Polygonaceae and Ranunculaceae. An absolute maximum of *Betula* is noted (76–95%, together with a stunted form), accompanied by *Pinus* (4–22%), *Picea* (2%) and *Alnus* (1–2%). *Quercus* and *Tilia* are rare, with shrubs of *Corylus* and *Salix*. Among the spores *Sphagnum* prevails, with a participation of Polypodiaceae.

Table 1

Chronology and stratigraphy of the Poozerie Glaciation in Belarus

				10.3 ka	
Late Poozerie (Naroch) oxygen isotope stage 2	Late Dryas stage III	DR-III	pz-f-6		10650 ± 160 Tln-325 Volosovo 10660 ± 130 Mik-26 Morino 10810 ± 100 Ta-135 Studenetc 10870 ± 100 Tln-137 Latyshi
				10.8 ka	
	Alleröd interstage	AL	pz-f-5		11020 ± 90 Mik-25 Goza 11050 ± 100 Vib-41A Goza 11060 ± 100 Vib-41 Goza 11080 ± 100 Vib-41B Goza 11160 ± 100 Ta-1225 Sudoble 11230 ± 250 Lu-138 Komarishki 11430 ± 460 Lu-75A 11550 ± 100 Ta-1226 Sudoble 11600 ± 110 Mik-9 Latyshi 11720 ± 140 Mik-10 Latyshi
				11.8 ka	
	Middle Dryas stage II	DR-II	pz-f-4		
				12.3 ka	
	Bölling interstage	BL	pz-f-3		
				12.7 ka	
	Early Dryas stage I	DR-I	pz-f-2		12860 ± 110 Vs-366 Chernihovo
				13 ka	
	Raunis interstage	RN	pz-f-1		13630 ± 100 Lu-617 Latyshi
				13.9 ka	
	Orsha megastage (max)		pz-s-14		16190 ± 120 Lu-1148B Chizovka 16950 ± 120 Lu-1148A Chizovka 17150 ± 300 Tln-329 Chizovka
				17 ka	
Middle Poozerie (Dvina) oxygen isotope stage 3	Usvachi preglaciation		pz-s-13		17460 ± 210 Tln-309 Drychaluki 17600 ± 400 Mik-1 Drychaluki 17770 ± 170 Lu-95A Drychaluki 17880 ± 240 Tln-471 Drychaluki 17900 ± 160 Lu-95B Drychaluki 18020 ± 110 Tln-36 Drychaluki 18100 ± 160 Tln-435 Drychaluki 18150 ± 190 Mik-15 Drychaluki 18700 ± 230 Tln-437 Drychaluki 19370 ± 180 Lu-96 Drychaluki 19700 ± 220 Tln-486 Drychaluki 20330 ± 150 Tln-470 Drychaluki 21600 ± 450 Tln-513 Drychaluki 22500 ± 210 Lu-91 Shapurovo 23630 ± 370 Lu-97A Drychaluki 24550 ± 300 Tln-327 Drychaluki 24550 ± 300 Lu-97A Drychaluki 26630 ± 370 Lu-97A Drychaluki
				26 ka	
	Borisov interstage		pz-s-12		28170 ± 750 Lu-105 Borisova Gora
				28 ka	
	Michalinovo stage		pz-s-11		33100 ± 850 Lu-1149A Michalinovo 34780 ± 510 Lu-1149B Michalinovo

Table 1 continued

				35700 ± 1000 Tln-322 Michalinovo
			30 ka	
	Shapurovo interstage	pz-s-10a-b		29150 ± 850 Lu-78A Shapurovo 31550 ± 350 Tln Shapurovo 36400 ± 800 Lu-92B Shapurovo
			35 ka	
	Rogachevo stage	pz-s-9a-e		35300 ± 2300 Lu-1324 Sloboda Kaspl. 37240 ± 720 Lu-1324 Sloboda Kaspl.
			39 ka	
	Turov interstage	pz-s-8		44400 ± 1700 Lu-74 Krasnaya Gorka
			44 ka	
oxygen isotope stage 4	Mezin megastage	pz-s-7		
			49 ka**/70 ka*	
	Polotsk interstage	pz-s-6a-c		>53300 Tln-414 Borisova Gora
			55 ka	
	Sloboda stage	pz-s-5a-d		>41700 Lu-82 Sloboda Kaspl. >50000 Lu-309 Sloboda Kaspl.
			60 ka	
Early Poozerie (Kulakovo)	Suraz interstage	pz-s-4a-b		
			68 ka	
	Mirogotshi stage	pz-s-3		
			73 ka	
oxygen isotope stage 5a-d	Chericov interstage	pz-s-2a-b		
			79 ka	
	West Dvina stage 2	pz-s-1-c		
			82 ka	
	Black Shore interstage	pz-s-1-b		>46000 Tln-52
			86 ka	
	West Dvina stage 1	pz-s-1-a		104000 ± 8000 Tln-363 Orlyaki 111000 ± 5000 Tln-379 Milovidy
			90 ka**/115 ka*	

* - after A. Sanko, **- after Ya. Yelovicheva.

Suraz interstage is represented by a birch forest with admixture of pine (pz-s-4-a), by pine and pine-birch forest with larch and spruce (pz-s-4-b), and by pine forest with birch and spruce (pz-s-4-c). A beginning of the interstage is indicated by a sharp abbreviation of a role of herbs (4–8%), with lower values of *Artemisia*, and presence of Chenopodiaceae, Gramineae, Asteraceae and Polygonaceae, predominance of *Betula* (84–94%), involvement of *Pinus* (8–16%), and sporadic *Picea*. Among spores there are mostly Bryales and Polypodiaceae, and also *Sphagnum* and Lycopodiaceae. In the middle Suraz interstage a role of herbs increases (2–22%), with predominance of *Artemisia*, high content of Gramineae and participation of Chenopodiaceae, Asteraceae, Rubiaceae and Polygonaceae, the aquatic-marshy plants of Ericaceae, Pyrolaceae, Cyperaceae and *Typha*. Among trees *Pinus* predominates (66–88%), there is a lower content of *Betula* (8–34%, including a stunted form), *Picea* (0.5–2%) and *Larix* (0.5–1%), whereas *Quercus* and *Ulmus* are sporadic, and among shrubs there is *Hippophaë*. Spores are represented mainly by Bryales, with participation of *Sphagnum* and Lycopodiaceae.

At the end of the Suraz interstage a pollen spectrum is indicated by a small content of herbs (4–18%): similar contents of *Artemisia* and Gramineae, participation of Chenopodiaceae, Caryophyllaceae, Polygonaceae and Ranunculaceae, and *Typha*, *Myriophyllum verticillatum* and Cyperaceae among the aquatic-marshy plants. Trees are predominated by *Pinus* (84–98%), there is a small content of *Betula* (4–12%), *Picea* (2%), and with shrubs of *Corylus*, *Salix* and Rhamnaceae. Among the spores there are abundant Bryales and *Sphagnum*, with Polypodiaceae and Lycopodiaceae, including *Lycopodium annotinum* and *L. selago*.

Sloboda stage is represented by a pine and pine-birch forest with a developed herb cover (pz-s-5-a), a thinned-out pine-birch forest with herb communities in open places (pz-s-5-b), groups of birch with pine and well developed herb communities in open places (pz-s-5-c), followed by a thinned-out pine-birch forest with spruce (pz–s–5–d), and well developed herb communities in open places. A slightly increasing content of herbs (16–20%), with predominant *Artemisia* and Gramineae, insignificant role of Chenopodiaceae and Ranunculaceae, presence of Asteraceae and Polygonaceae indicate

a beginning of the stage. Among the aquatic-marshy plants there are Ericaceae, *Typha* and *Myriophyllum verticillatum*. A content of *Pinus* is reduced (66–82%), replaced by *Betula* (14–32%, with sporadic stunted forms). There is also *Picea* (2%) and *Larix* (0.5%), and *Alnus* is sporadic too. Among the spores there are mainly *Sphagnum* and Bryales, with participation of Lycopodiaceae. In the middle Sloboda stage there is a sharp increase in contents of herbs (74%), with predominance of *Artemisia*, a lot of Gramineae and Ranunculaceae. Chenopodiaceae, Asteraceae, Caryophyllaceae and Polygonaceae are also present and Pyrolaceae among the aquatic-marshy plants. A tree community is predominated by *Pinus* (66%), with participation of *Betula* (28%), *Quercetum mixtum* (6%), and single *Hippophaë* among the shrubs. *Sphagnum* and Bryales represent spores.

There is the absolute maximum of herbs (88–92%) in a spectrum of the Sloboda stage. *Artemisia* and Ranunculaceae predominate, with lower contents of Chenopodiaceae, Gramineae, Asteraceae and Polygonaceae. Among the forest plants there is mainly *Betula* (76–94%, including the stunted forms), accompanied by *Pinus* (6–20%) and *Ulmus* (3%), rare *Salix* from shrubs and sporadic spores of Bryales. The end of the Sloboda stage is indicated by high contents of herbs (68%), mainly *Artemisia* and Ranunculaceae, with less Chenopodiaceae, Gramineae, Caryophyllaceae, Polygonaceae and Ericaceae. A role of *Pinus* (66%) and *Picea* (3%) increases, whereas *Betula* is less abundant (26%, including the stunted forms). *Quercus*, *Tilia* and *Corylus* are rare. *Sphagnum* is among the spores.

Polotsk interstage is represented by a birch forest with pine (pz-s-6-a), followed by a birch-pine and pine-birch forest with spruce (pz-s-6-b) and a birch forest with pine and spruce (pz-s-6-c). In pollen spectrum a content of herb plants is sharply reduced (6–15%). At the beginning of the interstage *Betula* (85–95%) predominates, and a role of *Pinus* (2–10%), *Alnus* (2%), *Corylus* (2%) and *Salix* (3%) is insignificant. A middle part of the interstage is indicated by increasing contents of *Pinus* (to 40%), *Picea* (5%), *Quercus* (1%), *Tilia* (1%), *Fagus* (1%) and *Corylus* (1%), accompanied by a drop of *Betula* (60%). A rising content of *Betula* (76%), *Alnus* (1%) and *Corylus* (2%) and a drop of *Pinus* (22%) and *Picea* (1%) indicate the end of the interstage.

DVINA SUBSTAGE (MIDDLE POOZERIE GLACIATION)

This interval lasted from 49 ka (according to Ya. Yelovicheva) or 70 ka (according to A. Sanko) to 13 ka ago, and it is correlated with the oxygen isotope stages 4 and 3. It comprises the Mezin and the Orsha (maximum) megastages, separated by the Usvachi lake-alluvial preglacial episode, preceded by the middle Poozerie megainterstadial, composed of three interstages (Turov, Shapurovo, Borisov) and two stages (Rogachevo, Michalinovo). The Orsha megastage corresponds to a maximum development of glacial processes. During the Mezin megastage the ice sheet advanced closely to the northern boundary of Belarus, and during the Orsha megastage it occupied its northern part, i.e. the Poozerie region. This substage is represented by a till (to 30 m thick), glaciofluvial, glaciolacustrine, periglacial lake, solifluction and alluvial sediments.

Mezin megastage (pz-s-7) is represented by birch-pine thinned-out forest communities with alder and willow. Well-developed and diverse herb formations occupied open areas. In pollen spectra collected from gravel, pebbles, silt with organic detritus, there are mainly herbs (61–74%), with low content of spores (16–19%) and forest plants (10–20%). Herbs are represented mainly by Asteraceae (17–37%), Gramineae (26–33%), Chenopodiaceae (to 30%) and Caryophyllaceae (20–27%), with participation of *Artemisia*, Polygonaceae, Ranunculaceae, *Draba*, Geraniaceae, Primulaceae, *Armeria*, Polemoniaceae, Labiatae (including *Clinopodium*) and Plantaginaceae. Among the aquatic-marshy plants there is a lot of Cyperaceae. Spores are composed almost exclusively of Bryales, whereas *Sphagnum* and *Botrychium* are rare. Among the trees *Betula* takes a leading place (61–93%), with less *Pinus* (to 35%) and *Alnus* (to 4%). Among the shrubs a role of *Salix* (20–31%) is great, and *Corylus* and *Helianthemum* are sporadic.

Turov (Krasnaya Gorka) interstage (pz–s–8) is indicated by a sparse birch with pine, alder and willow, and local herb communities. The spectra from gyttja, peat and sands indicate varying contents of herb pollen (18–50%): mostly Gramineae, a lot of Cyperaceae, Asteraceae, Rosaceae (including *Sanguisorba officinalis*), Labiatae, *Humulus lupulus*, Polygonaceae, Chenopodiaceae, Caryophyllaceae, Ranunculaceae, Rubiaceae, Dipsacaceae, Alismataceae, Geraniaceae, Umbelliferae, Primulaceae and Plumbaginaceae (including *Armeria*). Among the trees there is mainly *Betula* (87–98%), *Pinus* (2–10%), *Alnus* (to 2%) and *Salix* (to 2%). Contents of spores vary from 2 to 11%, with predominant Bryales and *Sphagnum*, and Polypodiaceae are rare.

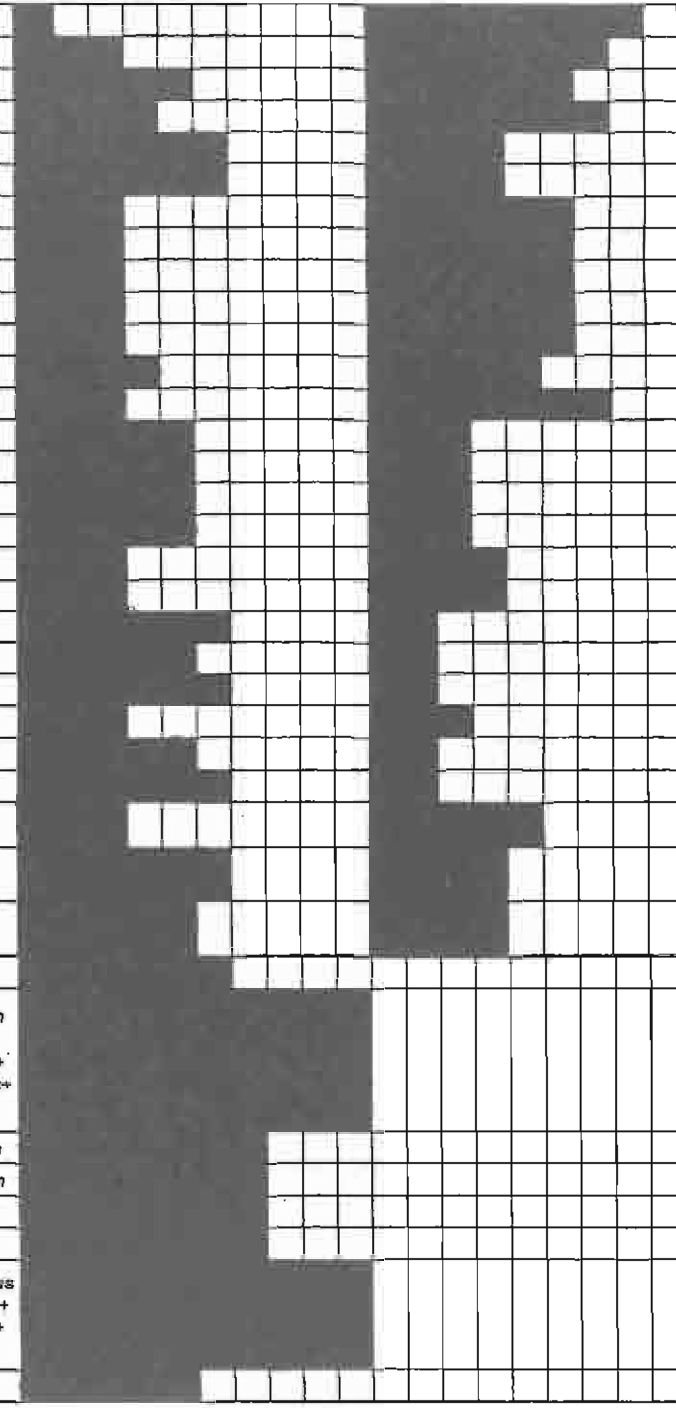
Rogachevo stage is represented by a sequential change. It begins with a sparse birch-pine forest with willow and well developed herb communities in open areas (pz-s-9-a), followed by a sparse birch forest with pine and alder, and well developed herb communities in open areas (pz-s-9-b), pine-birch thinned-out forest patches with willow and well developed herb communities in open areas (pz-s-9-c). The stage terminates with a birch-pine with spruce thinned-out forest with well-developed herb communities in open areas (pz-s-9-d), and a birch-pine sparse forest with alder and well-developed herb communities in open places (pz-s-9-e). Pollen spectra from peats with sand, silts with peat and clayey sands indicate a varying predominance of herbs (60–88%) over trees (6–26%) and spore plants (10–28%). Among the herbs there are mainly Gramineae and *Artemisia*, with participation of Chenopodiaceae, Caryophyllaceae, Papaveraceae, *Armeria*, and also Polygonaceae, *Koenigia islandica*, Ranunculaceae, *Draba*, Rosaceae, Leguminosae, Geraniaceae, Linaceae, Umbelliferae, Labiatae, Plantaginaceae, Rubiaceae, Dipsacaceae, Campanulaceae and Asteraceae. The aquatic-marshy vegetation is predominated by Cyperaceae, along with Sparganiaceae, Alismataceae, *Myriophyllum* and *Pedicularis*. Among the spores there are mainly Bryales, accompanied by *Sphagnum*, *Botrychium*, Polypodiaceae and *Selaginella selaginoides*. Different relations of trees suggest subdivision into several stages:

Table 2

Chronology of the Late Pleistocene and Holocene in Belarus

Oxygen isotope stages	Years BP	Stratigraphic subdivision: Stages	Substages	Chronozones	Index	Regional pollen assemblage zones	Vegetation zones: arctic	tundra	forest-tundra	taiga	mixed forest	broad-leaved forest	Ice sheet margin: glaciation centre	Sankt-Petersburg	N boundary of Belarus	Western Europe: T. van der Hammen et al. (1971)
1	600	HOLOCENE	Buroro	Subatlantic	SA-3	*Pinus*+*Betula*+NAP							200	600	100 140 180 km	SA
	1600				SA-2	*Picea*+*Pinus*+*Betula*+NAP										
	2500				SA-1	*Pinus*+*Betula*+NAP										
	4000		Semenovo	Subboreal	SB-2	*Picea*										SB
	5000				SB-1	*Pinus*+*Quercetum mixtum*										
	6000			Atlantic	AT-3	*Quercus*+*Carpinus*+*Fagus*										AT
	6600				AT-2	*Tilia*+*Pinus*+*Betula*										
	8000				AT-1	*Ulmus*										
	8800		Yastrebinsky	Boreal	BO-2-3	*Betula*+*Quercetum mixtum*										BO
	9200				BO-1	*Betula*+*Pinus*+*Ulmus*										
	10000			Preboreal	PB-2	*Pinus*+*Betula*+*Picea*										PB
	10300				PB-1	*Pinus*										
2	10800		NAROCH	Late Dryas stage III	DR-III	*Betula*+*Pinus*+NAP										DR-3
	11800			Alleröd interstage	Al-3-2-1	*Pinus*+NAP/*Picea*+NAP/*Pinus*+NAP										All
	12300			Middle Dryas stage II	DR-II	*Betula*+NAP										DR-2
	12700			Bölling interstage	BL	*Betula*+*Pinus*+NAP										BL
	13000			Early Dryas stage I	DR-I	*Betula*+NAP										DR-1
	13900			Raunis interstage	RN	?										

MIS	Age	Superhorizon	Horizon	Subdivision	Stage	Index	Pollen assemblage	Correlation
	17000	POOZERIE	DVINA		Orsha megastage	pz-s-14	—	
	26000				Usvachi preglaciation	pz-s-13	*Betula*+*Pinus*+NAP	
3	28000			megasinterstage	Borisov interstage	pz-s-12	*Pinus*+*Betula*+*Picea*+NAP	Denekamp
	30000				Michalinovo stage	pz-s-11	*Pinus*+NAP	
					Shapurovo interstage	pz-s-10-b	*Pinus*+*Betula*+NAP	Hengelo
	35000					pz-s-10-a	*Betula*+*Pinus*+*Picea*+NAP	
	39000				Rogachevo stage	pz-s-9-e	*Betula*+*Pinus*+*Alnus*+NAP	
						pz-s-9-d	*Betula*+*Pinus*+*Picea*+*NAP*	
						pz-s-9-c	*Pinus*+*Betula*+NAP	
						pz-s-9-b	*Betula*+*Pinus*+*Alnus*+NAP	
						pz-s-9-a	*Betula*+*Pinus*+NAP	
	44000				Turov interstage	pz-s-8	*Betula*+*Alnus*+NAP	Moershoofd
4	49000				Mezin megastage	pz-s-7	*Betula*+*Pinus*+*Alnus*+NAP	
5 a-d			KULAKOVO	megainterstage	Polotsk interstage	pz-s-6-c	*Betula*+*Picea*	
						pz-s-6-b	*Betula*+*Pinus*+*Picea*+NAP	Odderade
	55000					pz-s-6-a	*Betula*+*Pinus*	
					Sloboda stage	pz-s-5-d	*Pinus*+*Betula*+*Picea*+*NAP*	
	60000					pz-s-5-c	*Betula*+*Pinus*+NAP	
						pz-s-5-b-a	*Pinus*+*Betula*+NAP/*Pinus*+NAP	
					Suraz interstage	pz-s-4-c	*Pinus*	
						pz-s-4-b	*Pinus*+*Betula*+*Larix*+*Picea*	Brörup
	68000					pz-s-4-a	*Betula*+*Pinus*	
	73000				Mirogotshi stage	pz-s-3	*Betula*+*Pinus*+NAP	
					Chericov interstage	pz-s-2-b	*Pinus*+*Betula*+*Picea*	
	79000					pz-s-2-a	*Betula*+*Pinus*	Amersfoort
	82000			megastage	West Dvina stage 2	pz-s-1-c	*Betula*+*Pinus*+NAP	
	86000				Black Shore Interstage	pz-s-1-b	*Pinus*+*Betula*+NAP	?
	90000				West Dvina stage 1	pz-s-1-a	*Pinus*+*Betula*+*Picea*+*Alnus*+NAP	
5e		MURAVA			Dorochevichi (late interglacial)	mr-10	*Pinus*+*Betula*+NAP	Eemian
					Komotovo climatic optimum	mr-9	*Pinus*+*Betula*+*Picea*+*Quercetum mixtum* /*Pinus*+*Carpinus*+*Quercetum mixtum*+ *Alnus*/*Pinus*+*Taxus*+*Quercus*+*Carpinus*+ *Ulmus*+*Alnus*/*Pinus*+*Betula*+*Picea*+*Alnus*+ *Quercetum mixtum*+*Corylus*	
					Borhov cold snap	mr-8-d	*Pinus*+*Picea*+*Alnus*+*Quercetum mixtum*	
						mr-8-c	*Pinus*+*Betula*+*Picea*+*Quercetum mixtum*	
						mr-8-b	*Pinus*+*Picea*+*Quercetum mixtum*	
						mr-8-a	*Picea*+*Pinus*+*Quercetum mixtum*	
					Chericov climatic optimum	mr-7-6-5-4-b-a-3	*Picea*+*Carpinus*/*Carpinus*/*Taxus*+*Carpinus* +*Alnus*+*Quercus*+*Ulmus*+*Taxus*+*Corylus*+ *Alnus*/*Quercetum*+*Ulmus*/*Pinus*+*Betula*+ *Quercetum mixtum*	
	120000				Ulanovo (early interglacial)	mr-2-1	*Pinus*+*Quercetum mixtum*	



— predominance of *Betula* (70–85%), maximum of *Pinus* (19%) and *Salix* (14%), sporadic *Helianthemum*;

— predominance of *Betula* (80–85%) alongside with low values of *Pinus* (5–18%), *Alnus* (5%), *Viburnum* (to 3%), *Hippophaë rhamnoides*, *Salix* and *Corylus*;

— absolute maximum of *Pinus* (to 50%), high content of *Betula* (56%), presence of *Corylus*, *Salix*, *Viburnum*, *Helianthemum* and *Hippophaë rhamnoides*;

— climax of *Picea* (15%), a lot of *Betula* (56–76%), less *Pinus* (25–30%), also *Alnus*, *Salix*, *Juniperus*, *Helianthemum* and *Hippophaë rhamnoides*;

— predominance of *Betula* (50–65%), a lot of *Pinus* (35%), a rise of *Alnus* (10%) and *Viburnum* (8%), presence of *Hippophaë rhamnoides*.

Shapurovo interstage represents a development from a sparse birch forest with pine and spruce, and herb communities (pz-s-10-a), to a pine-birch forest with a herb cover (pz-s-10-b). In the sediments (peat, clayey sands, silt, clay) there is a varied content of tree (20–45%) and herb pollen (25–40%), and of spores (15–36%). Among the herbs *Artemisia* and Chenopodiaceae are the most common, accompanied by Gramineae, Caryophyllaceae, Ranunculaceae and Brassicaceae. There are abundant spores of Bryales and *Sphagnum*, and less abundant of Polypodiaceae. Trees of the earlier part of the interstadial are represented mainly by *Betula* (40–72%), with less *Pinus* (5–30%), *Alnus* (15–20%), *Corylus* (2–30%), *Carpinus* (5%), *Ulmus* (2%) and *Picea* (5%). *Alnaster*, *Ephedra* and *Salix* represent shrubs. Sediments of the upper part of the interstadial contain abundant *Pinus* (20–42%) and *Betula* (40–53%), and also *Alnus* (5–20%), *Corylus* (1–5%), *Picea* (1–2%), *Carpinus* (2–10%) and *Quercus* (3%). *Salix* is rare.

Michalinovo stage (pz-s-11) is represented by rare pine, sometimes with birch and spruce, and well developed herb communities in open area. In clays or silts the trees are up to 43%, herbs to 50%, and spores to 7%. Among herbs Cyperaceae are the most abundant, accompanied with *Artemisia*, Poaceae and also Asteraceae, Chenopodiaceae, Caryophyllaceae, *Rubus* cf. *Hamaemorus*, Umbelliferae and Valerianaceae. There are numerous spores of *Equisetum* and *Botrychium boreale*, and rare of *Selaginella selaginoides*, Bryales, *Sphagnum* and Polypodiaceae. Trees are represented mainly by *Pinus* (84%, including *Pinus* cf. *sibirica*), *Betula* (11%, including *Betula nana*) and *Picea* (2%, including *Picea obovata*). There are shrubs of *Alnaster*, *Salix* and *Ephedra*.

Borisov interstage (pz-s-12) is represented by a pine-birch forest with spruce and alder, and well developed herb communities in open area. Spectra from silt with peat indicate a presence of herbs (10–40%), trees (40–60%) and spores (5–20%). Among the herbs Chenopodiaceae and *Artemisia* predominate, alongside with Caryophyllaceae, Gramineae, Polygonaceae, Saxifragaceae, *Rubus chamaemorus*, Polemoniaceae and Asteraceae, and in the aquatic-marshy plants there are Cyperaceae and *Calluna*. The spores are predominated by Bryales and *Sphagnum*, with Polypodiaceae, *Selaginella selaginoides*, *Lycopodium* and *Botrychium*. Among the trees *Pinus* is the most common (60–80%), accompanied by *Betula* (10–45%, including *Betula nana*), *Picea* (10%), *Alnus* (5–18%, including *Alnaster*), and also *Ulmus* (5%) and *Acer* (0.5%). *Corylus* (3–5%), *Salix* (1–5%), *Ephedra* (2–5%) and *Hippophaë rhamnoides* (2–3%) represent shrubs.

Usvachi preglaciation (pz-s-13) is represented by a sparse birch forest, pine-birch rare forest groups with spruce, formations of willow, and well developed herb communities in open area. In a spectrum from sands, silt and clayey sands there are mainly trees (40–80%), with participation of herbs (5–30%) and spores (5–20%). They represent unclear communities as some have been redeposited from the Murava Interglacial (Eemian). Thermo- and mesophilous plants reach quite often up to 40%, and there is a lot of *Osmunda*. *Pinus* reaches 15–60%, *Betula* 13–60% (including *Betula nana*) and *Picea* 5–20%. There are constant values of *Alnaster* and *Salix*, whereas *Viburnum* and *Ephedra* are rare. Among herbs there is a lot of *Artemisia*, Chenopodiaceae and Gramineae, with Polygonaceae, Ranunculaccae, Caryophyllaceae, Brassicaceae, Umbelliferae, Asteraceae, Rosaceae, Plantaginaceae, Saxifragaceae and Leguminosae. The aquatic-marshy plants are predominated by Cyperaceae, accompanied by Ericaceae, *Typha*, *Myriophyllum* and Iridaceae. Among spores there are mainly Bryales, Polypodiaceae and *Sphagnum*.

Orsha megastage (pz-s-14) is represented by glacial and glaciofluvial sediments of the present landscape, formed 17–13.9 ka ago.

NAROCH SUBSTAGE (LATE POOZERIE GLACIATION)

It covered an interval from 13.9 to 10.3 ka ago and corresponds to the oxygen isotope stage 2. During this time a gradual deglaciation occurred, interrupted by repeated standstills of the ice sheet margin. Therefore this substage is composed alternatively of three interstages (Raunis, Bölling and Alleröd) and three stages (Dryas I, II and III). Sediments (0.5–5 m thick) are represented by sands, clay, clayey sands, clayey silt, sapropelic peat, marls and sapropel (I. I. Bogdel, 1984; Ya. Yelovicheva, 1992*a*, 1993).

Raunis interstage (pz-f-1, RN, 13.9-13 ka ago) is represented by sands, however, there is no palynologic description.

Early Dryas stage I (pz-f-2, DR-I, 13–12.7 ka ago) is represented by steppe herb communities, tundra communities, and sparse forest groups of pine and pine-birch with pine and spruce. Pollen spectrum is predominated by herbs (Chenopodiaceae, *Artemisia*, Caryophyllaceae, Polygonaceae), trees are represented by *Betula* (including stunted forms) and *Pinus*, occasionally *Picea*, and spores comprise Polypodiaceae and Lycopodiaceae.

Bölling interstage (pz-f-3, BL, 12.7–12.3 ka ago) is indicated by an increased role of forest plants (birch, pine-birch, pine with the birch, spruce, quite often broad-leaved forest plants, alder, nut-grove), and herb communities in open area. A spectrum is predominated by high values of herbs (20–30%), predominance of *Pinus* (60–80%), small development of *Betula* (10–20%) with its stunted forms, and also of *Picea* (2–5%), sporadic *Alnus* and *Salix*.

Middle Dryas stage II (pz-f-4, DR-II, 12.3–11.8 ka ago) is represented by steppe herb communities in open area, tundra associations, rare birch and pine groups with shrubs of alder and willow. The sediments contain much herb pollen (to

40%). Among forest plants a content of *Betula* has increased (to 40%, with constant stunted forms), accompanied by a small reduction of *Pinus* (40–50%).

Alleröd interstage (11.8–10.8 ka ago) is expressed at first by a pine forest with spruce, birch and vast herb cover (pz-f-5-a, AL-1). It is followed by a spruce or a pine forest with spruce, birch, broad-leaved forest plants, nut-grove and alder with a developed herb cover (pz-f-5-b, AL-2). Finally, there is a pine forest with spruce, birch and a developed herb cover (pz-f-5-c, AL-3). A pollen spectrum contains less herbs (20–30%) and *Betula* (5–30%), and more trees. Among the latter there are conifers (*Pinus* 50–80%, *Picea* 10–40%, i.e. the lower maximum of spruce), small-leaved (*Alnus* 30%) and broad-leaved forest plants (2–5%, including *Quercus*, *Tilia*, *Ulmus*, and also *Corylus*).

Late Dryas stage III (pz-f-6, DR-III, 10.8–10.3 ka ago) is peculiar for its rare pine, pine-birch and birch, with spruce and well developed herb communities of open area. A pollen spectrum indicates an increased content of herbs (to 40%) and *Betula* (20–40%), with a constant involvement of stunted and shrub forms. A role of *Pinus* is still high (60–80%), accompanied by a drop of *Picea* (10–15%).

CONCLUSIONS

The presented materials testify that influence of the Poozerie Glaciation was expressed by repeated changes in plant communities (Table 2). During interstadials taiga occupied a large area. During stages a forest-tundra developed, and the glaciation maximum (Orsha stage) corresponded to a wide spreading of arctic and tundra zones. At this time in the territory of Belarus there was specific periglacial vegetation with representatives of forest, tundra and steppe communities. Such complex of taxons makes possible reconstruction of tundra-forest-steppe vegetation. A large role was played by herbs (*Artemisia*, Chenopodiaceae, Gramineae, Polygonaceae, Ranunculaceae, Caryophyllaceae, Plantaginaceae, Rubiaceae, Valerianaceae, Rosaceae, Asteraceae, Cyperaceae, etc.), with xerophytes (late glacial) and hydrophytes (early glacial). They were accompanied by forests with coniferous and small-leaved plants (*Pinus*, *Larix*, *Picea*, *Abies*, *Betula*), more varied in comparison with a modern taiga with limited cold-stable foliage-fall (turgai) plants. The main role was played by arcto-boreal and boreal taxons. The following arcto-boreal plants were the characteristic components of the Poozerje periglacial vegetation, and they are not inherited by a modern flora of Belarus and grow considerably further to the north: *Alnaster fruticosus*, *Pinus sibirica*, *Lycopodium pungens*, *L. alpinum*, *Selaginella selaginoides*, *Dryas octopetala*, *Botrychium boreale*, *Picea obovata*, *Betula* sect. Fruticosae and *B. nana*. Steppe plants (xerophytes, halophytes, mezoxerophytes) formed a specific group among a periglacial flora, at present growing to the south of the studied region. They include *Chenopodium acuminatum*, *Ch. botrys*, *Salicornia herbaceae*, *Kochia prostrata*, *Salsola*, *Suaeda*, *Eurotia ceratoides*, *Artemisia* s/g *Serifidium*, *Ephedra distachya*, and also *Hippophaë rhamnoides*. The arcto-boreal and steppe exotic elements in a fossil palynoflora testify a colder and drier environment, in comparison with a modern one, that is peculiar to a development of ice sheets. Representatives of this flora during interstadials suggest a certain climatic improvement, in comparison with conditions of a thermic minimum. A cold and dry climate of a stadial was characterized by the temperature 1–6°C less than at present and precipitation of 75–100 mm less. During a maximum of the Poozerie Glaciation, the temperature was much below the present, i.e. in January from –16 to –12°C and even less, in July from 15 to 17°C and more, a precipitation dropped to 500–600 mm, and a climate was considerably severe due to a negative heat balance. A moderate-cool, humid and from time to time dry climate was peculiar during the interstages, when the temperature was 0.5–3°C lower, and the precipitation 25–100 mm less.

Climate-derived changes of the vegetation in the territory of Belarus during the Poozerie Glaciation are reflected by repeated migrations of arcto-boreal, xerophytic steppe and taiga plants, corresponding to a rhythmic alternation of stadial and interstadial conditions. Ice sheet advance of the Poozerie Glaciation caused a migration of thermophilous plants of the Murava Interglacial to the south, south-east and south-west. They could survive there and yield a place to boreal and arcto-boreal elements coming from the north, north-west and north-east. Periglacial vegetation occupied the largest area during cold stadials and the maximum glaciation (forest tundra-tundra-arctic zone), and it was replaced by a taiga during interstages. A deglaciation was followed by gradual migration of arcto-boreal and boreal plants, then replaced by thermophilous vegetation of the Holocene.

The presented natural events during the Poozerie (Vistulian) Glaciation testify their complexity and adequacy in the territory of Western and Eastern Europe, along with their specific features in Belarus (see Table 2). The Chericov interstage corresponds to Amersfoort, Suraz to Brörup, Polotsk to Odderade, Turov to Moershoofd, Shapurovo to Hengelo, and Borisov to Denekamp. The application of palynologic data for the palaeogeographic and stratigraphic correlation of the Late Pleistocene seems to be the most reliable among the methods to study sediments of the Quaternary.

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PALINOSTRATYGRAFIA OSADÓW ZLODOWACENIA POOZIERSKIEGO (WISŁY) NA BIAŁORUSI

Streszczenie

Na podstawie metod palinologicznych przedstawiono podział stratygraficzny osadów ostatniego zlodowacenia (poozierskiego, wisły) na Białorusi (fig. 1). Badania prowadzono równolegle z badaniami geologicznymi oraz datowaniem osadów metodami radiowęgla i termoluminescencji (tab. 1). Wyróżniono trzy podpoziomy: kułakowski, dźwiński i naroczski. Podpoziom kułakowski, odpowiadający stadium izotopów tlenu 5d–a, składa się z megastadiału zachodniodźwińskiego i megainterstadiału (w skład którego wchodzą stadiały mirogoski i słobodski) oraz trzech interstadiałów (czerikowskiego, suraźskiego i połockiego). Podpoziom dźwiński (pleniglacjał, stadia izotopowe 4 i 3) zawiera dwa megastadiały (mezyński i orszański), między którymi jest megainterstadiał z trzema interstadiałami (turowskim, szapurowskim i borysowskim) i dwoma stadiałami (rogaczewskim i michalinowskim). Najmłodszy podpoziom, naroczski odpowiada późnemu glacjałowi zlodowacenia poozierskiego (stadium izotopowemu 2). Odpowiednikiem interstadiału czerikowskiego jest amersfoort, suraźskiego — brörup, połockiego — odderade, turowskiego — moershooft, szapurowskiego — hengelo i borysowskiego — denekamp.