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LATE PLEISTOCENE GEOCHRONOLOGY OF EUROPEAN RUSSIA

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ABSTRACT. I constructed a Late Pleistocene geochronological scale for European Russia employing ^{14}C dating and paleobotanical studies of several reference sections.

MIKULINO (RISS-WÜRM) INTERGLACIAL AND EARLY VALDAI (EARLY WÜRM) STAGES AND INTERSTADIALS

I employed a modified ^{230}Th/^{234}U dating method (Arslanov *et al.* 1976, 1978, 1981) to determine shell ages. I learned that ^{232}Th is present only in the outer layer of shells; thus, it is not necessary to correct for ^{230}Th if the surface (~30% by weight) is removed. A great many shells were parallel-dated by ^{14}C and ^{230}Th/^{234}U methods; results corresponded well for young shells (to 13–14 ka). Older shells appear to be younger due to recent carbonate contamination. Shells from transgression sediments of the Barents, White and Black Seas were chosen as most suitable for dating, based on appearance. Table 1 presents measured ages for these shells.

The data show that the inner fractions of shells sampled from Boreal (Eem) transgression deposits of the Barents and White Seas date to 86–114 ka. Shells from sediments of the Black Sea Karangat transgression, which correlates to the Boreal, date to 95–115 ka. ^{230}Th/^{234}U dating of shells and coral show that shells have younger ages than corals; this appears to result from later uranium penetration into shells (Arslanov *et al.* 1976). Boreal transgression sediments on the Kola peninsula can be placed in the Mikulino interglacial based on shell, microfauna, diatom and pollen studies (Arslanov *et al.* 1981). According to the oxygen-isotope record from deep-sea cores, interglacial substage 5e corresponds to the Dilikulino (Eem, Sangamon) interglacial in the interval 128–116 ka (Morley and Hays 1981). By considering the trend of ^{230}Th/^{234}Th age reduction for shells, it can be stated that the Karangat and Boreal transgressions (85–115 ka) correlate to the Mikulino interglacial.

Distinct cooling at the end of the Mikulino (Early Valdai) is identified from pollen studies of the Krotkov Cape liman clays (Taman peninsula) (Arslanov *et al.* 1983). Mollusk shells from the middle of the clays date to 95–100 ka (Table 1). Tree pollen comprises 93–98% of total pollen, with 55-65% pine, 27–35% fir and 12% birch. This association indicates taiga forest. According to oxygen-isotopic, micropaleontologic and geochronologic investigations of ocean sediments, coral terraces and continuous lake and bog sections, abrupt climatic cooling occurred from 116–110 ka (Würm I). The Kurgolovo stage of the Russian plain glacial zones appears to correspond to this cooling. During the Mikulino interglacial and Early Valdai interstadial, loess loams interbedded with soil horizons were deposited in Russian plain periglacial regions (Velichko 1977). Two worldwide transgressions occurred in the Early Würm at *ca.* 100–105 and 80–85 ka BP and are recorded by the presence of emerged coral terraces on Barbados, in the eastern Caribbean Sea, and New Guinea and Timor, in the southwest Pacific Ocean.

Widespread continental sediments of two Early Würm interstadials (Amersfort/Brerup and Odderade in western Europe, Tarasovo and Kruglizky in Belorussia, Jonenis I and Jonenis II in Lithuania) correspond to the two oceanic transgressions discussed above. These sediments are well defined in the Grande-Pile section (France) and correspond to substages 5c and 5a of the oxygen-isotope scale (Woillard and Mook 1982).

TABLE 1. ^{230}Th/^{234}U Ages of Marine Mollusk Shells from Barents, White and Black Sea Transgression Sediments (A = outer fraction, B = inner fraction)

Laboratory number	Age	Mollusk species and location
LU-455B	97,000 ± 4000	*Cyprina islandica* from the section base, Svjatonossky gulf, Kola peninsula
LU-452A	102,000 ± 4000	*Astarta borealis* from the Malaja
LU-452B	114,000 ± 4000	Kachovka exposure, Kola peninsula
LU-464A	85,500 ± 3200	*Cyprina islandica* from the exposure
LU-464B	86,000 ± 3900	On Chapoma River, Kola peninsula
LU-808A	129,400 ± 4900	*Cardium edule* from the marine sediments of Maly Kut section, Taman peninsula
LU-808B	115,000 ± 3100	Same as above
LU-805A	125,000 ± 5000	*Paphia senessens* from the middle part of the marine sediments of Eltigen section, eastern coast of Kerch strait
LU-805B	102,290 ± 3200	*Paphia senessens* from the middle part of the marine sediments of Eltigen section, eastern coast of Kerch strait
LU-802A	90,600 ± 3100	*Cardium tuberculatum* from the same layer
LU-802B	107,400 ± 3800	*Cardium tuberculatum* from the same layer
LU-804-1A	88,900 ± 2200	*Cardium edule* from the Krotkov cape section, western part of Taman peninsula
LU-804-1B	98,000 ± 2400	Same as above
LU-804-2A	98,900 ± 2200	Same as above
LU-804-2B	100,500 ± 2100	Same as above

Early Valdai interstadials followed the main Early Valdai (Würm) glacial stage. This interstadial (isotopic stage 4) ranges from 72–58 ka (Morley and Hays 1981); the polar front migrated south to 45°N latitude (Ruddiman and McIntire 1977). Scandinavian ice sheets expanded south to ~60°N latitude only during this stage; southernmost Sweden (Sconia) was not affected by Würm glaciation earlier than 21 ka (Berglund and Lagerlund 1981).

Early Valdai sediments were studied in the following sections: Shestichino in the Jaroslavi region, Kileshino (near Selizharovo) in the Tver region and Migovo (near Grodno) in Belorussia. According to paleobotanical data (F. J. Velichkevich and E. A. Spiridonova), these sediments deposited in tundra and tundra-forest conditions date to >47–49 ka (Arslanov 1975; Spiridonova *et al.* 1981). To date, the Early Valdai (Visla) glacial moraine cannot be identified on the Russian plain, nor over much of western Europe.

THE MIDDLE VALDAI NON-GLACIAL INTERVAL

The interval between Early and Late Valdai glaciation includes the Middle Valdai interstadial complex (mega-interstadial), which contained warming and cooling phases. ^{14}C dating of plant remains shows that the Middle Valdai (Würm, Visla) mega-interstadial continued from 58–60 to 25 ka (Arslanov 1975; Woillard and Mook 1982), and according to the oxygen-istope scale, from 27 to 58 ka (Morley and Hays 1981).

Data from 31 Middle Valdai sediment sections are listed in Table 2, and include only those studied by palynological or paleocarpological methods. The oldest date was determined for the Rokai section near Kaunas: 52 ka ± 1.69 ka. Pollen data indicate that tundra-forest vegetation expanded at this time (Gajgalas *et al.* 1987).

TABLE 2. ^{14}C Dates of Organic Remnants from Middle Valdai Sediments

Lab no.	^{14}C age (BP)	Section location, sample material, depth
LU-28C	25,440 ± 270	Dunaevo, Lovat River basin, peat from 6.4 m
LU-28B	25,600 ± 360	Dunaevo, Lovat River basin, peat from 6.4 m
LU-1237	26,980 ± 590	Njom, Vychegda river basin, peat from 5.2 m
LU-105	28,170 ± 750	Belorussia; plant detritus
LU-646	29,080 ± 580	Novomonchalovo, near t. Rzhev, Tver region, wood
LU-107	31,470 ± 590	Shenskoje, at Kesma River, Tver region, wood from 4.5 m
LU-339	32,650 ± 720	Shenskoje, Kesma river exposure, Tver region, borehole, peat from 9.7–10 m
LU-1319	31,100 ± 730	Mamyl, Pechora River, Komi Republic, peat from 13 m
LU-159	32,260 ± 730	Lejasziemes, Gauja River, Latvia, plant detritus from upper layer
LU-311	34,500 ± 790	Lejasziemes, Gauja River, Latvia, plant detritus from lower layer
LU-1633	33,460 ± 1060	Birzhai, Lithuania, borehole
LU-1149A	33,100 ± 850	Michalinovo, near Vitehsk, Belorussia, plant detritus, coarse fraction
LU-1149B	34,040 ± 350	Michalinovo, near Vitehsk, Belorussia, plant detritus, fine fraction
LU-645	33,690 ± 360	Novomonchalovo, near t. Rzev, Tver region, wood
LU-513A	33,520 ± 470	Sozva River, Lower Pechora basin, peat, insoluble fraction
LU-513B	34,540 ± 1570	Same sample, soluble (in 2% NaOH) fraction
LU-92A	36,400 ± 800	Shapurovo, near Surazh, Belorussia, peat
LU-1620	36,360 ± 1300	Shapurovo, near Surazh, Belorussia, peat
LU-98	37,960 ± 1000	Sloboda, near Surazh, Belorussia, peat
LU-150	37,200 ± 910	Vjazynka, 30 km NW from Minsk, peat
LU-599	38,230 ± 240	Dzhiguta, near Sukhumi, wood from 1.75–1.90 m
LU-512A	38,670 ± 870	Tyrybei, Hvostovaja River, Lower Pechora basin, peat, insoluble fraction
LU-512B	39,840 ± 570	Tyrybei, Hvostovaja River, Lower Pechora basin, peat, soluble fraction
LU-588	39,170 ± 470	Kyltovka, Vychegda River basin, Komi ASSR., wood from 4.7–4.9 m
LU-63	39,800 ± 800	Grazhdansky prospect borehole, N Leningrad, peat
LU-22	40,380 ± 800	Grazhdansky prospect borehole, N Leningrad, peat
LU-15A	40,490 ± 870	Kashin, Tver region, coarse fraction
LU-15B	41,700 ± 730	Same sample, fine fraction
LU-550	40,650 ± 790	Shapkino II, Shapkina River, lower Pechora basin, peat
LU-517B	40,860 ± 1260	Shapkino II, Shapkina River, lower Pechora basin, peat
LU-94	40,800 ± 1900	Suchona near v. Selische, Vologda region, peat from 20.0–20.2 m
LU-93	41,100 ± 1500	Same borehole, peat from 19.75–20.0 m
LU-632	41,810 ± 600	Kileshino, near Selizharovo, Tver region, wood
LU-648	41,200 ± 710	Dzhiguta, near Sukhumi, wood from 3.7–3.9 m
LU-647A	42,760 ± 660	Dzhiguta, near Sukhumi, wood from 4.7–4.8 m
LU-606	44,130 ± 630	Dzhiguta, near Sukhumi, wood from 5.0–5.1 m
LU-181	41,290 ± 320	Dolgopolka, near Tutaev, Jaroslavl region, wood
LU-533	42,810 ± 1200	Urdjuga, Malozemelskaja tundra, peat
LU-519	42,660 ± 970	Shapkina I, Shapkina River, lower Pechora basin, peat
LU-596	43,300 ± 780	Vaskelovo, near Leningrad, peat
LU-1053	43,440 ± 1460	Jula, Pinega river basin, Arkhangelsk region, peat
LU-1262	45,000 ± 1150	Same exposure, wood
LU-1206	45,210 ± 1430	Juizh, North Dvina basin, Arkhangelsk region, peat
LU-673	45,770 ± 1160	Chernaja Rechka, near Leningrad, peat from 2.8 m
LU-164	46,030 ± 1710	Krasnaja Gorka, Dneiper River, Belorussia, peat from 6–7 cm top peat layer
LU-186	46,770 ± 830	Krasnaja Gorka, Dneiper River, Belorussia, peat from 12–15 cm
LU-133	45,260 ± 800	Krasnaja Gorka, Dneiper River, Belorussia, peat from 18–21 cm
LU-624	46,880 ± 1270	Bor, exposure on Lower Pechora, peat
LU-674	47,410 ± 1270	Chernaja River, Bolshezemelskaja tundra, wood
LU-566	47,520 ± 1000	Kyltovka, Vychegda River basin, wood from 11.1–11.3 m
LU-601	47,320 ± 1050	Dzhiguta, near Sukhumi, wood from 5.85–5.95 m
LU-1438	52,000 ± 1690	Rokaj, near Kaunas, Lithuania, wood

At 48–45 ka BP, climatic conditions in the northeastern Russian plain (North Dvina, Vychegda and Pechora basins) were similar to the present (Arslanov *et al.* 1980b, 1984). From 45–42 ka, cooling had set in. A grass community of wormwoods and a yernik-tundra were widespread at the time. Later, between 42.5 ka and 38 ka, warming occurred and forest vegetation appeared (Arslanov *et al.* 1980b).

Two warming phases can be distinguished during the Middle Valdai. The first, the Krasnogorsky (Rokai) and "Grazhdansky prospect" interstadials, occurred in the interval, 52 ka–36 ka. Cooling occurred at 45 ka–42.5 ka on the northeastern Russian plain. The second Middle Valdai warming, the Dunaevo interstadial (Brjansk interval in periglacial regions) took place from 32 ka–25 ka. The Lejasziemes cooling interval (36 ka–32 ka) divided these two warm phases. At the cooling maximum, 34 ka–33 ka, grass tundra was present in Latvia (Lejasziemes), in northeastern Belorussia (Michalinovo) and in the Lower Pechora basin (Soz'va) (Arslanov *et al.* 1980b, 1981; Yoznjachuk *et al.* 1981). This major northern hemisphere cooling was noted in western Europe (between the Denekamp and Hengello interstadials) in Siberia (Konoshelsk climatic deterioration) and in North America (Cherrytry glacial stage).

During the Dunaevo interstadial on the Russian plain, birch-pine and fir-pine forests dominated in the northeast (Dunaevo), central (Shenskoje, Novomongolovo) and northwest regions (Spiridonova *et al.* 1981). The three climatic phases, interstadial "Grazhdansky prospect" (45 ka–36 ka), Lejasziemes cooling (36 ka–32 ka) and Dunaevo interstadial (32 ka–25 ka), are comparable to three climatic phases in Siberia, western Europe and North America during the same period. These phases also correspond to oxygen-isotope stage 3 (Arslanov 1975).

Abrupt Middle Valdai warming was observed in middle and high latitudes from west to east (Arslanov 1975). During its optimum (48 ka–45 ka and 42 ka–39 ka), low bush-tundra dominated in regions adjoining the Atlantic Ocean and North Sea; forest tundra was present near the northern taiga border, in Belorussia, and a northern taiga was present in northwestern and central regions of the Russian plain. Taiga forests similar to recent ones spread north of the Dvina River and Vychegda basin. Discontinuous fir-pine-birch forests of the northern Pechora basin are expanded to the Barents Sea coast, farther north than at present.

From 48 ka to 45 ka, the forest formation (Shapkino I, II, Sozva, Ghernaja River, Urduga, Tarubei sections) was distributed on the area of recent forest tundra, Bolszezemelskaja and Alozemelskaja (Arslanov *et al.* 1980b). Obviously, Middle Valdai optima were typical interstadial stages in western and central regions of the Russian Plain. The interglacial is termed the Kargino in Siberia. A mirror-like situation was observed in Canada (Lamb 1977). Thus, Europe and eastern North America were under cold climatic conditions in the Middle Würm. This could be a result of 1) the close proximity of the Laurentian and Scandian continental ice sheets; 2) a warm current, the Gulf Stream, circulated no farther than 55°N (Ruddiman and McIntire 1977), causing cooling in western Europe and in the western part of the Russian plain. Regions distant from the Laurentian and Scandian ice sheets and from the cold Atlantic Ocean (northeastern Russian Plain, Siberia, central and western Canada) were under interglacial climatic conditions in the Middle Würm. This was probably caused by high summer insolation in the high latitudes at 55–40 ka. The degree of insolation was just below that during the Mikulino interglacial and Holocene optimum (Arslanov 1975, 1982). Comparison of climatic-geochronologic data for two sections, Chernaja near the Barents Sea and Dziguta near Sukhumi, revealed that the Chernaja area had a coniferous forest with small birch admixture at 47 ka (Middle Valdai optimum) instead of recent forest–tundra. At the same time, silver fir and spruce forest with beech admixture dominated in the Sukhumi region; such vegetation can be observed now at ≥1200 m asl (Arslanov *et al.* 1980a).

LATE VALDAI GLACIAL STAGE AND DEGLACIATION

The Valdai glacial maximum has not been definitely dated. Some scientists believe the Early Valdai stage to be the maximum. I believe that the maximum occurred in the Late Valdai, based on ^{14}C dates from organic remains from sediments overlain by moraine deposits of the glacial maximum from western Belorussia to the Pechora basin. Table 3 shows data for eight sections. Other results suggest that submoraine organic layers formed during the Middle Valdai non-glacial interval. There appear to be no Middle Valdai glacial intervals in western Europe nor on the Russian plain, so the Middle Valdai age of submoraine sediments indicates that overlying glacial sediments were deposited during Late Valdai glaciation. This conclusion is supported by oxygen-isotopic data, with the maximum southward drift of the polar front at 17 ka–18 ka and by

TABLE 3. ^{14}C Ages of Valdai Submoraine Organic Sediments

Lab no.	Age	Section location, sample material
LU-616A	16,650 ± 150	Rubezhniza, 7 km SE of Liosno, Belorussia, plant detritus
LU-616B	19,270 ± 770	Same sample, soluble (in 2% NaOH) fraction
LU-1148A	16,950 ± 120	Chizhovka, Dubrovno region, near Vitebsk, plant detritus
LU-1148C	16,540 ± 150	Same sample, soluble fraction
LU-95A	17,700 ± 170	Drichaluki, 2.5 km N of Surazh, Belorussia, plant detritus, upper layer
LU-96	18,370 ± 180	Drichaluki, plant detritus, middle layer
LU-1756	19,780 ± 150	Drichaluki, plant detritus, middle layer
LU-1810	17,430 ± 1780	Drichaluki, arcto-boreal plants
LU-1619	24,690 ± 370	Drichaluki, plant detritus, lower layer
LU-1618	21,110 ± 590	Drichaluki, plant detritus, lower layer, arcto-boreal
LU-615A	21,080 ± 340	Kasplane, 5 km from Surazh, plant detritus
LU-615B	19,550 ± 190	Same sample, soluble fraction
LU-91	22,500 ± 210	Shapurovo, 3 km SE of Surazh, plant detritus from 1.8 m
LU-18B	21,410 ± 150	Puchka, near v. Pokrovskoje, Kubenskoje Lake basin, Vologda region, peat and wood from 6.2 m
LU-18A	21,880 ± 110	Same sample, cellulose
LU-90A	25,100 ± 240	Gozha, 13 km N of Grodno, Neman River, peat, fraction ≥1 mm
LU-90B	24,860 ± 230	Same sample, fraction ≤1 mm
LU-1616A	26,610 ± 220	Irkhino, western bank of Kubenskoje lake, Vologda region, peat
LU-1616B	32,090 ± 450	Same layer, wood
LU-1149A	33,100 ± 850	Mikhalinovo, 8 km SW of Liosno, Belorussia, plant detritus, fraction ≥0.25 mm
LU-1149B	34,040 ± 350	Same sample, fraction ≤0.25 mm
LU-1257	34,030 ± 810	Tomasha, Tomasha river, 3.6 km from the mouth, Arkhangelsk, gyttja
LU-399	38,900 ± 480	Kileshino, 4 km N of Selizharovo, Tver region, wood from peat lens in moraine
LU-525	39,610 ± 490	Kileshino, wood from peat lens in moraine
LU-527	46,670 ± 910	Same exposure, wood from moraine
LU-632	41,810 ± 600	Same section, wood under sand, with gravel and boulder
LU-513A	33,520 ± 470	Sozva-1, Sozva river, tributary of the Pechora River, peat under limno-glacial sediments
LU-1113	40,680 ± 1180	Sozva-2, the section at the same locality, peat under moraine
LU-533	42,810 ± 1200	Urdjuga, Sula River basin, Pechora tributary, peat under moraine
(5 dates)	40,650 ± 790 to 45,280 ± 1200	Shapkina I, II, Shapkina River, Lower Pechora basin; peat under moraine

CLIMAP data on the maximum distribution of the Laurentian and Scandian ice sheets at 18 ka–20 ka (Belenger 1982; CLIMAP 1975, 1985).

Short-term warming occurred after the Late Pleistocene glacial maximum (Arslanov 1975). Organic sediments correlated with the interval mentioned above have not been identified on the Russian plain. This phase was followed by abrupt cooling 16.5–15 ka; morainal Veps-stage sediments formed on the Russian plain at this time. Events following the second glacial maximum are established: Raunis, Bølling, Allerød, divided by Oldest, Older, and Younger Dryas cooling. Recently, two new Raunis interstadial sections were studied in Latvia: Burzava and Jidumnicki (Arslanov *et al.* 1981). Interstadial peat dates to 13 ka.

CONCLUSION

Table 4 presents the Late Pleistocene time scale for European Russia. Names of interstadials and cooling phases correspond to the names of sections where they were first studied (Dunzaevo, Lejasziemes, Michalinovo, "Grazhdansky prospect", Shapkina, Krasnaja Gorka, Shestichino, Jonenis I, II, Tosno).

TABLE 4. Late Pleistocene Geochronology Scale of European Russia

Climatic-geochronologic subdivision	Age (× 10^3) BP	Oxygen isotope stage
Holocene	10.0–0	1
Valdai glaciation		
Late Valdai stages and interstadials		
Younger Dryas	11.0–10.0	2
Allerød	11.8–11.0	2
Older Dryas	12.0–11.8	2
Bølling	12.4–12.0	2
Oldest Dryas	12.4–13.0	2
Raunis interstadial	13.7–13.0	2
Veps stage	15.0–13.7	2
Climatic amelioration	16.5–15.0	2
Max stage		
Bologoje - Edrovo stage	25.0–16.5	2
Middle Valdai mega-interstadial		
Dunaevo (Brjansk) interstadial	32.0–25.0	3
Lejaszieme (Michalinovo)		3
Climatic deterioration	36.0–32.0	3
Interstadial "Grazdanskij prospect"	42.5–36.0	3
Shapkino climatic deterioration	45.0–42.5	3
Krasnogorsk (Rokaj) interstadial	58.0–45.0	3
Early Valdai stages and interstadials		
Shestikhino climatic deterioration	72.0–58.0	4
Kruglizy interstadial (Jonenis II)	85.0–72.0	5a
Climatic deterioration	95.0–85.0	5b
Tosno interstadial (Jonenis I; Upper Volga)	105.0–95.0	5c

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