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PALEOGEOGRAPHICAL STUDIES OF THE SEIM RIVER VALLEY

General description of the research area

The middle part of the Seim River drainage basin occupies the south-western slope of the Srednerusskaya Upland. Within the catchment area bedrocks have south-western inclination of seams, which results in certain geological zonality. Over the major part of the basin Cretaceous rocks, mostly chalk and chalky clay, underlie Quaternary sediments. Due to this fact, alluvial deposits of the Seim River are highly calcareous and clayey. Early Cretaceous and Paleogene sands and sandstones, exposed in the northern and southern periphery of the catchment area, represent a source of sandy alluvium. The Early Cretaceous layers are cut by the biggest tributaries of the Seim River (Svapa and Tuskar' rivers). These sediments overlay Jurassic clays and sandstones and Devonian limestones, which are not exposed in the modern river valleys. Paleogene sediments are preserved in patches on the watersheds mainly south of the imaginary line connecting Kursk and L'gov.

The Seim River catchment area is a part of the plain with watershed altitudes up to 200-230 m above sea level. It was formed by erosion and denudation during the Neogene and Quaternary periods and is dissected by modern river valleys to various extents (Poseim'ye, 1983). As the Seim River basin was mainly beyond the reach of the continental ice-sheets, the thickness of Quaternary deposits (loess-like silt) in the area is only 5 to 10 meters. Glacial and fluvioglacial deposits of the Dnieper Glaciation were found only on the western side of the Svapa River valley. River valleys are 80-100 m deep. The oldest of four main terrace complexes, identified in the Seim River valley (50-60 m above the river), was formed before the Dnieper Glaciation (Poseim'ye, 1983). The Seim River valley is characterised by alternate narrow and wide (lake-like) sections, corresponding to general morphostructure of the region. Within these lake-like sections 10-30 km long, the floodplain width is up to 5-6 km, while in the narrow sections it is only 1-1.5 km. The ancient fluvial relief forms are naturally more diverse and better preserved in the wider sections of the river valleys.

The boundary between broad-leaved forest and forest steppe coincides with the Seim River valley in its middle part. Accordingly, the area to the north of the river is covered largely by grey forest soils, while south of the river chernozem soils prevail. The region is characterised by temperate continental climate with the mean January and July temperatures of -8˚C and 19˚C respectively. The mean annual precipitation varies from 475 to 625 mm. About 60% of the sum correspond to the warm season (April-October), though the cold season precipitation (snow) is most important for the river feeding. Seim and its tributaries belong to the East European type of the water discharge regime (after B.D. Zaikov). They have a high flood in the end of March-April and summer - autumn low water level, occasionally interrupted by minor rain floods. The main hydrological characteristics of the studied rivers are shown in the Table 1.

Development of the river valleys during the last 18 thousand years

According to the morphological features of the Seim River basin, lithology of the sediments and the results of the radiocarbon dating (table 2), four main stages of the fluvial relief formation can be distinguished during the last 18 thousand years: (a) the first terrace formation; (b) development of the large meandering paleochannels; (c) degradation of the large meandering paleochannels; (d) the modern floodplain formation (fig. 1).

The development of the first river terrace (7-10 m above the low water level at present) took place about 19-17K years BP. The 1st terrace is characterised by paleocryogenic microrelief and devoid of the loess cover. It is correlated to the 1st terrace of the Desna River valley. Its age is estimated on the basis of archaeological data: the settlements of the Late Palaeolithic Man on the first river terraces in the middle part of the Dnieper River basin appeared not later than 15K years BP. The final stages of alluvium accumulation on the 1st terrace are dated by radiocarbon method to 17-19K years BP (Velichko et al., 1997). It was a stage of accumulation of flat-bedded and sometimes cross-bedded alluvial sand and aleurite under permafrost conditions. Consequently, thermokarst processes played an important role in the relief formation (key-site 1).

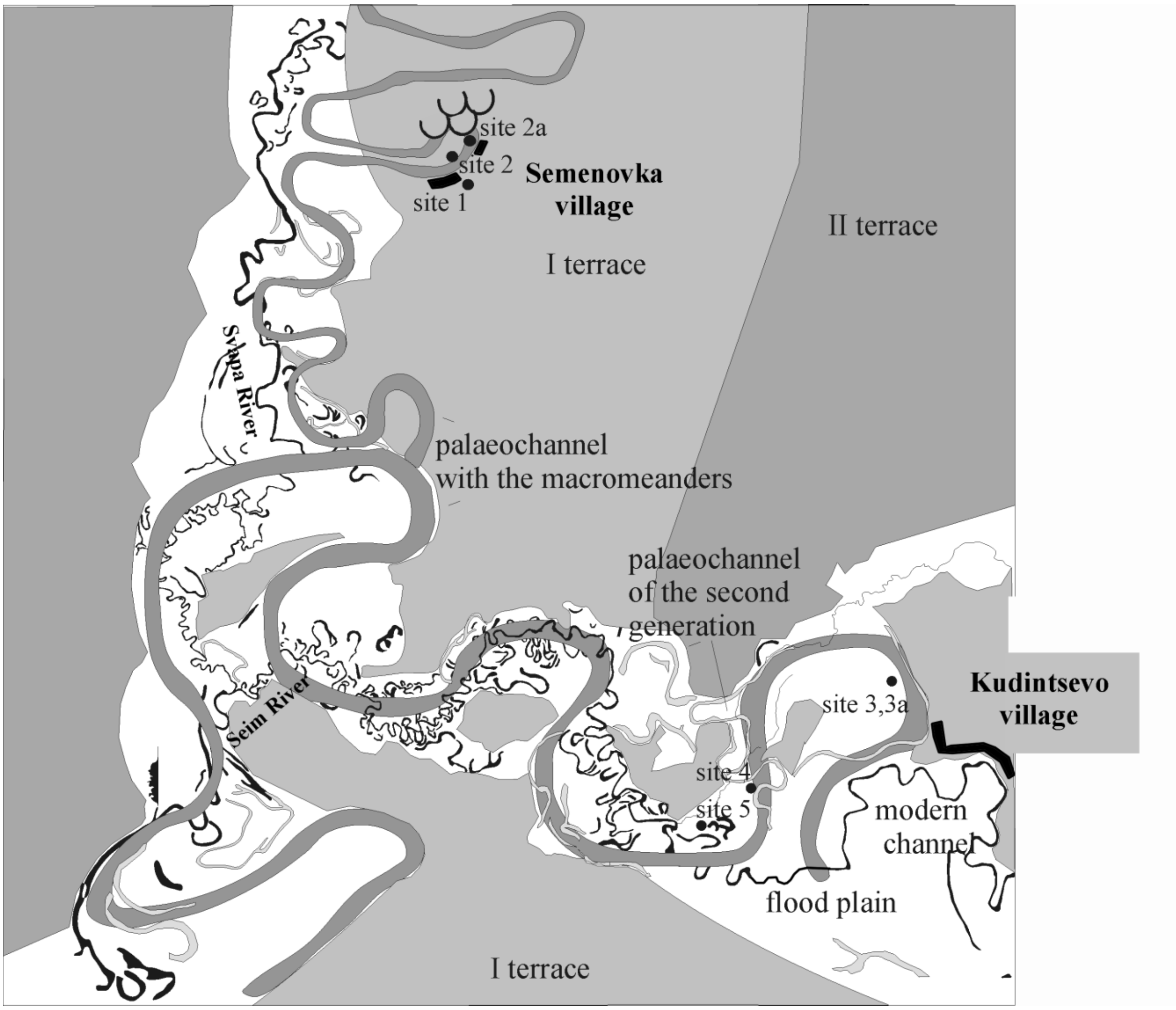

Fig.1. Morphology of the area of Seim and Svapa Rivers confluence and the disposition of the main geological and geomorphological features.

The next stage of the fluvial relief history was marked by development of large meandering channels in the valleys of the Seim River and its tributaries. About 14-17K years BP their maximum water discharges were much greater than the present-day ones. The flood levels were not lower than during the previous stage and higher, than at present. It means that the normal thickness of alluvium, equal to the interval between the highest points of the floodplain and the bottom of the deepest pools, was 10-12 m. Large paleochannels, formed at this stage, had a meander wavelength of 2800 m and a channel width of 250-500 m on the Svapa River (key-site 2) and 6000 m and 350-700 m on the Seim River (key-site 3). Based on Chezy formula application to the areas of the cross-sections, grain size of the bottom sediments of the paleochannels, and the floodplain surface slope, the maximum discharges of the Seim and Svapa rivers were reconstructed. They were 14500 m^3/s and 6400 m^3/s, respectively.

The stage of degradation of the large paleochannels with macromeanders lasted from 10K till 14K years BP. At this stage, chains of lakes were formed along the bottoms of large channels. Short channel sections connected the lakes. Later on, new channel sections were also formed inside such lakes after sediments rapidly filled them in. A secondary channel with smaller macromeanders near Kudintsevo village is an example of such post-sedimentation channel section (key-site 4). The size of this secondary channel formed about 12K years BP indicates that the bankfull discharge during its development was greater than the modern one, although it decreased significantly compare to the stage of large channel formation.

Hydrological regime of the rivers in the Seim River basin was not homogeneous during the stage of degradation of the large paleochannels. A general trend towards decreasing the maximum water flow was repeatedly interrupted by its considerable increases, as can be reconstructed from morphological evidence. For example, a high natural levee consisting of loamy deposits was formed along the macrobend of the large channel at the end of the stage of large paleochannels degradation (key-site 3a). At present the top of this levee is 4 m above LWL and is not submerged during floods, which indicates that the flood level at the time of its formation was higher than the modern one.

The further decrease of the water flow took place at the beginning of the Holocene. River channels close in size to the modern one were formed at that stage (key-site 5). The variations of flow during the Holocene are evidenced by difference in sizes between older (and more stable) larger bends of the river channel and more recent (and less stable) smaller bends. The greater aridity of climate at the Boreal time is indicated by an increase of aeolian process activity (key-site 2a). At that stage, the lakes on the high floodplain were overgrown by vegetation, and peat accumulation has begun, which probably indicates a lower ground water table. The decrease in floodplain submersion during floods in Subatlantic (about 1-1.2K years BP) was marked by formation of a soil profile with high organic content on the floodplain surface. Later on, due to more frequent flooding, this soil was buried under a layer of floodplain alluvium 0.5-1.0 m thick. The processes of channel transformation and channel bends avulsions also became more active during the last one thousand years.

Table 1. Hydrological and morphological characteristics of investigated rivers.

	Svapa R.	Seim R.
Basin area, km^2	6310	10 800
Modern discharges, m^3/s :		
Mean annual	23	42,5
Mean maximum	480	745
Maximum observed	1700	2400
Floodplain width, km	0,5-6	2-8
Bankfull channel width, m:		
Modern	15-60	20-100
Holocene	20-60	20-80
Late Glacial (“large meanders”)	300-400	500-1000
Meander half-wavelength, m:		
Modern channel	70-300	100-500
Secondary paleomeanders	100-300	80-400
Late Glacial “large meanders”	1000-1200	1700-3000
Paleodischarges during the stage of "large meanders", m^3/s :		
Mean maximum	1800	3600
Maximum	5200	14500

Table 2. Radiocarbon dates of alluvial deposits.

All dates were obtained in Radiocarbon Laboratory of the State Scientific Centre of Environmental Radiogeochemistry (Ukraine). Non-calibrated dates are used; all age estimates in the text are in radiocarbon age scale.

№	Site	Borehole	Depth, m	Organic matter used for dating	^{14}C age	Laboratory index
Seim River floodplain						
1	Large channel	S-1-1	2.85	shells	6165 ± 70	Ki-6983
2	— “ —	S-1-1	2.0-2.15	peat	4240 ± 55	Ki-6980
3	— “ —	S-1-1	8.16-8.24	shells	13920 ± 90	Ki-6982
4	— “ —	S-1-1	8.16-8.24	clay (dispersed organic matter)	14105 ± 120	Ki-6981

5	— “ —	S-1-4	6.8-7.0	clay (dispersed organic matter)	13800 ± 85	Ki-6984
6	— “ —	S-1-7	4,4-4,6	Clay with the peat	12630 ± 70	Ki-6985
7	Small channel	S-2-11	3.0-3.1	Clay with the peat	11455 ± 60	Ki-6986
8	— “ —	S-2-11	4.0-4.2	clay (dispersed organic matter)	12250 ± 70	Ki-6987
9	— “ —	S-3-12	3.5-4.0	clay with shells	6830 ± 70	Ki-6988
10	— “ —	S-3-19	3.2-3.3	wood	5700 ± 60	Ki-6992
11	— “ —	S-3-19	4.7-4.9	clay with shells	9240 ± 80	Ki-6993
12	— “ —	S-120	2.0	wood	250 ± 60	Ki-6994
Svapa River floodplain						
13	Large channel	SV-1-2	1.9-2.0	peat	9120 ± 70	Ki-6995
14	— “ —	SV-1-2	2.10-2.15	Clay with the peat	11755 ± 80	Ki-6996
15	— “ —	SV-1-2	5.5-5.6	Clay with the peat	14030 ± 70	Ki-6997
16	— “ —	SV-1-8	1.6-1.7	Clay with the peat	8870 ± 80	Ki-6998
17	— “ —	SV-1-8	3.9-4.0	clay (dispersed organic matter)	12360 ± 110	Ki-6999
18	— “ —	SV-301	3.2-3.4	clay (dispersed organic matter)	9070 ± 80	Ki-7006
19	— “ —	SV-301	3.6-3.8	clay (dispersed organic matter)	9630 ± 75	Ki-7007
20	Small channel	SV-2-1	2.1-2.3	wood	7545 ± 60	Ki-7000
21	— “ —	SV-2-1	3.0-3.1	Clay with the peat	10105 ± 65	Ki-7001
22	— “ —	SV-2-2	3.5-3.6	peat	8945 ± 80	Ki-7002
23	— “ —	SV-2-3	4.0-4.2	clay (dispersed organic matter)	8760 ± 120	Ki-7003
24	— “ —	SV-2-3	4.35-4.45	clay (dispersed organic matter)	9830 ± 70	Ki-7004
25	Floodplain	SV-200	0.55-0.60	charcoal	1100 ± 65	Ki-7005

Key-site 1. Late Pleistocene river terrace

East of the Svapa River valley an alluvial plain with elevations of 150-170 m above sea level is spread. Its width in the Svapa and Seim river valleys is 4-8 km. The highest terrace level (18-25 m above LWL) corresponds probably to 20-25 m terrace of the Middle Desna River, formed during Early Valdai glacial epoch (Velichko et al., 1977). The lower terrace consisting of two steps of 12-15 and 7-10 m above LWL is better preserved. Its surface is covered by numerous small depressions (so-called "steppe dishes"), which represent relic cryogenic micro-relief forms, according to A.A. Velichko (Velichko et al., 1996). These depressions have elongated or almost round shape with the diameters ranging from 20-30 to 80-100 m.

In the Svapa River valley, the lower terrace has a slightly undulated sub-horizontal surface. Its altitude above LWL is mostly 7-10 m. The terrace rises gradually towards its outer margin, where it joins the Early Valdai terrace. Original fluvial features can be hardly traced on the surface of this terrace. In places, there are series of elongated depressions, partly inherited by shallow valleys of modern streams, separated by low levees. The primary fluvial relief of the terrace was partly masked by subsequent accumulation of fine-grained sediments.

Morphological and lithological features of the low terrace can be seen on the topographical and borehole profile, located 500 m south of the western edge of Semenovka village (fig. 2). The profile crosses a medium size steppe dish. In the boreholes beyond the dish the top surface of the channel alluvium lies at the depth of 3.1-3.8 m. Alluvial sands are overlain by the sequence of flat-bedded sand, silt and clay deposits (table 3). According to the geomorphological position of the section and sediments texture, the upper layer represents a floodplain facies of alluvium, possibly with inclusions of windblown sediments. Within the steppe dish the top surface of alluvial sand is 1

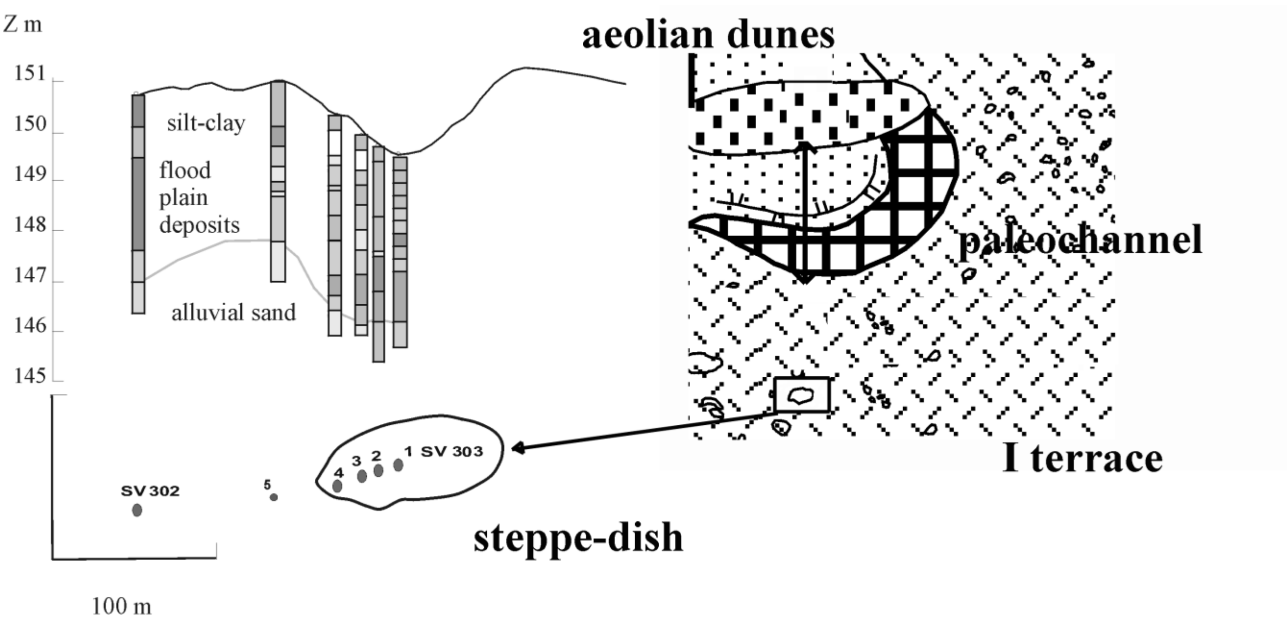

Fig.2. Borehole profile along the steppe dish, located 500 m south of the western edge of Semenovka village at the site 1.

m lower than beyond it, as it follows the terrace surface, and the thickness of floodplain deposits remains more or less constant along the section. This phenomenon may be connected either entirely with thermokarst process, or with the thermokarst widening of a fluvial pool. The layer of silty clay 2.0-2.5 m thick overlay the alluvial sand in the steppe dish. These deposits represent floodplain oxbow sediments or those of a thermokarst lake. Flat-bedded clay, silt and sand, possibly of aeolian origin, form the upper 1.5 meters of the sequence.

Table 3.

Borehole SV-303-1, 500 m south of the western edge of Semenovka village, in the central part of a steppe dish. Cored 26.08.98.

Depth, m	Deposits
0.00-0.30	Light-brown silty loam
0.30-0.60	Dove-grey silt, with ochreous spots, ferromagnesian concretions (up to 2 mm), with traces of gleization
0.60-0.80	Grey sandy silt
0.80-1.20	Pale yellow silt clay
1.20-1.50	Pale yellow clay
1.50-1.60	Grey silt
1.60-1.70	Grey fine silt sand
1.70-1.80	Pale yellow fine clay sand
1.80-3.40	Dove-grey sandy clay, with the interlayers of the ochreous sand and with numerous ochreous spots
3.40-3.80…	Pale yellow fine well sorted sand

In the valley of the Seim River, the low terrace is represented by two morphological units, which have different altitudes and are separated by clear shoulders. The flat surface with the altitude of 12-15 m above LWL is preserved at the peripheral part of the valley. It is similar to the terrace in the Svapa River valley. Along the floodplain margin the surface of this terrace is more irregular, with the altitudes varying from 3-4 to 7-10 m. Small steppe dishes and larger isometric depressions up to 500 m in diameter with the channels of water flow-off from the lakes, which formerly occupied them, cover it. Such depressions are called "alas" in the contemporary permafrost zone. They were probably formed after thaw of ice-wedges on the Late Valdai floodplain. The terrace is also dissected by the dendritic systems of elongated depressions (channels). These channels could be formed by erosion by streams during floods, which followed chains of thermokarst depressions in the lower parts of the floodplain. Such process is widely spread at present in the river valleys of Subarctic. The altitudes of the bottoms of these channels are 3-5 m above LWL, so that some of them can be occasionally flooded by the modern flow.

Fragments of the initial 7-10 m high surface with the steppe dishes, isolated by erosion processes, are preserved in places between elongated depressions, such as, for example, an outlier near Kholm village. Aeolian processes probably formed several rounded sand hills in the inner part of the terrace (near Zhilishche and Zyabkin-2 villages) with the heights of the tops 15-17 m above LWL. Elongated sand hills with the top heights of 4-5 m (and up to 10 m) above LWL are abundant along the concave banks of the large meanders. Lithological composition of one of such dunes can be seen in the outcrop along the river bank 1 km north of Kirpichnaya village: flat-bedded and cross-bedded sand with visible thickness of 7 m is exposed there.

Both topography and lithological composition of the low (7-10 m) terrace testify to its complex genesis as an accumulative alluvial terrace of the Late Valdai age, partly reworked by thermokarst and aeolian processes.

Large meanders (macromeanders)

Slopes and terraces bluffs of the Seim River valley are shaped by sequence of arcs with the radius of curvature exceeding that of the modern river channel bends by an order of magnitude. Systems of curved natural levees and large abandoned oxbows are well defined on the aerophotographs. The geometry of these natural levees can be used to reconstruct the evolution of large meanders from initial smooth bends to highly curved and finally cut-off meanders. This proves beyond doubts the fluvial origin of large meanders. Large levees are often well preserved in modern relief, their tops being 1-1.5 m higher than the hollows between them. Similar macrobends are widely spread on the rivers in United States and Britain (Dury, 1959, and other), as well as in Central Europe (Kozarski, Rotnicki, 1977; Starkel, 1995, and other). The regional analysis of macromeanders distribution showed that this phenomenon is typical for the floodplains and low terraces of the most medium-size and small rivers of the Russian Plain (Panin et al., 1992, 1999).

Kei-site 2, the Svapa River valley near Semenovka village

In the Svapa River valley, the paleochannel forms steeply curved meanders with the wavelength L of 2800 m and the length S of 3800 m (if measured along the channel). The mean coefficient of shape (S/L) for such meanders is 2.8, and up to 11 for sharp (finger-shaped) meanders. Such curvatures exceed considerably the optimum values for a meandering channel. A high resistance of the floodplain deposits can explain this discrepancy to erosion. Numerous traces of paleocryogenic microrelief forms can be seen on the aerophotographs. Accordingly, the high erosional stability of the floodplain can be attributed to the permafrost existence before 14K years BP. Contemporary rivers in the Yamal Peninsula, forming sharp meanders within wide floodplains with sediments cemented by permafrost, can be considered an analogue to the paleo-Svapa river during the stage of development of large meanders.

The paleochannel near Semenovka village 350 m wide (or 500 m wide for the bankfull stage) is clearly expressed in the modern topography (fig. 3). Its bottom is 4 m above the modern LWL, so that it is sometimes get submerged during the high floods. The coring shows a box-shaped profile of the channel trough. The top surface of the small and medium-grained alluvial sands of the channel facies lies at 141-142 m above sea level, or 1.5-2.5 m below the modern LWL. Floodplain aleurite and clay with lenses of clayey sand fill in the trough. The clay accumulation has begun not later than 14K years BP due to abandonment of the paleochannel (14030±70, Ki-6997) and went on during entire Late Glacial (12360±110, Ki-6999; 11755±80, Ki-6996). At the beginning of the

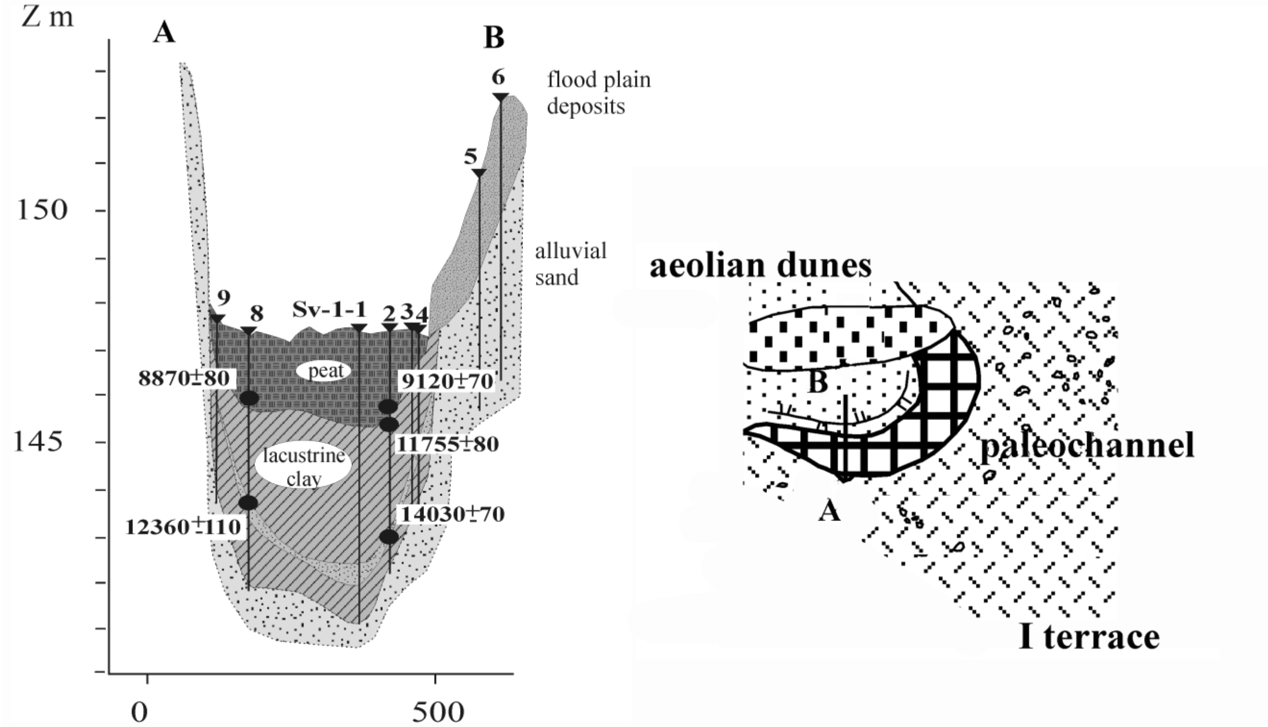

Fig.3. The paleochannel of pra-Svapa River with macromeanders near Semenovka village and its lithological composition at the site 2.

Holocene the paleochannel bottom was paluded. The peat formation started there in early Boreal (9120±70, Ki-6995; 8870±80, Ki-6998) (Table 4).

Table 4.

Borehole SV-1-2 at the northern edge of Semenovka village. Cored 17.08.98.

Depth, m	Deposits	Depth of sampling, m	^{14}C age	Laboratory index
0.0-2.0	Dark brown well decomposed peat	1.9-2.0	9120±70	Ki-6995
2.0-2.4	Dark brown peaty clay	2.1-2.15	11755±80	Ki-6996
2.4-3.8	Dove-grey clay, brown-dove-grey at the depth of 3.2-3.6 m			
3.8-4.2	Dove-grey sand with high silt content			
4.2-4.6	Dove-grey clay with high sand content and sand interlayers			
4.6-5.0	Dove-grey tight clay with low sand content			
5.0-5.4	Grey silty sand			
5.4-5 .6	Grey clay with high silt content, with peat inclusions in the lower 5 cm	5.5-5.6	14030±70	Ki-6997
5.6-6.2	Grey sandy clay with sand interlayers			
6.2-6.8	Sand			

The left side of the paleochannel cuts the 7-10 m terrace. Its right side is framed by a large levee of a symmetrical profile with the tops 9 m above LWL, that is, roughly even with the surface of the first terrace. The coring there shows a typical floodplain sediment sequence (Table 5): fine and medium sand with low content of pelitic fraction (up to 12%), similar to the channel alluvium found in the paleochannel trough, is covered by a layer of sandy loam and aleurite floodplain sediments 1.5-2.0 m thick. This levee was formed near the concave shore with the increasing meander curvature. Its closeness in height with the surface of the first terrace indicates that the latter was inundated during the floods at the time of the levee formation, thus being a floodplain by its hydrological regime. The difference in elevation between the Late Valdai paleochannel talweg and floodplain surface amounted to 10-12 m.

Table 5.

Borehole SV-1-6 at the northern edge of Semenovka village at the top of a natural levee. Cored 19.08.98.

Depth, m	Deposits
0.0-0.3	Brown light loam
0.3-0.65	Brown light loam with fine laminations, dusted with whitish aleurite
0.65-1.4	Light-yellow coarse aleurite interlaid with light-brown loam
1.4-5.8...	Yellow-brown well-sorted fine and medium sand with fine laminations and sparse interlayers of silty medium-grained sand

The slope of the terrace surface along the paleochannel axis is 6.5 cm/km. This value can be used as the water slope for approximate paleohydrological calculations. The water discharges in paleochannels were calculated using Chezi formula for different water stages. The cross-section parameters of the paleochannel were reconstructed according to the boundary between channel alluvial sands and oxbow lake clays formed after an active stream abandoned the channel. Presuming that the floodplain surface was not eroded during the floods, the critical velocity of erosion initiation was calculated for sand with the grain size of 0.25 mm. Such a velocity corresponds to the maximum floodplain inundation of about 0.7 m (153 m above sea level), with the stream velocities on the floodplain under 0.4 m/s. The Manning roughness coefficient was estimated for the rivers-analogues as 0.024. The calculations (table 6) show that at the stage of large paleochannels abandonment the flood water discharge at the mouth of the Svapa River (the basin area of 6310 km^2) reached 6400 m^3/s, while its contemporary maximum discharge is 1690 m^3/s (fig. 3a). The reconstructed value exceeds the mean maximum discharge of the Dnieper River near Rechitsa (the basin area of 58200 km^2).

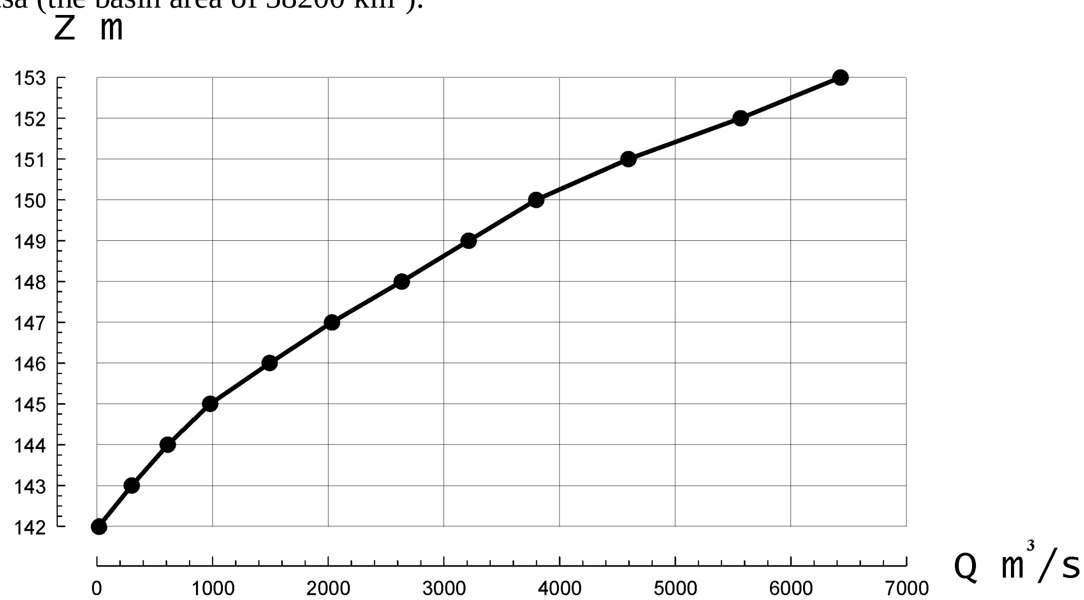

Fig. 3a. Discharge - stage curve for the paleochannel of pra-Svapa River near Semenovka, calculated with Chezy-Manning formula.

Table 6. Calculated hydrological parameters of the large paleochannel of the Svapa River.

Water level, m	Cross-section area, m^2	Paleochannel width, m	Mean depth, m	Mean velocity, m/s	Water discharge, m^3/s
142.00	83.49	211.16	0.40	0.18	15.11
143.00	560.85	277.71	2.02	0.54	301.02
144.00	918.72	328.17	2.80	0.67	613.04
145.00	1239.34	343.81	3.60	0.79	978.79
146.00	1608.72	349.84	4.60	0.93	1494.38
147.00	1938.54	351.90	5.51	1.05	2031.21
148.00	2278.58	356.62	6.39	1.16	2635.64
149.00	2658.21	389.13	6.83	1.21	3214.89
150.00	3022.00	417.58	7.24	1.26	3798.21
151.00	3485.00	448.06	7.78	1.32	4595.81
152.00	3927.11	453.12	8.67	1.42	5566.20
153.00	4496.90	512.06	8.78	1.43	6430.11

An apex of the macromeander is covered by aeolian dunes, which mask it in the present-day relief (key-site 2a). The samples of the oxbow lake clays, extracted by coring from the depths 0.6-0.8 and 0.2-0.4 m below the base of aeolian sand, were dated by radiocarbon method to 9630±75 (Ki-7007) and 9070±80 (Ki-7006), respectively. An extrapolated age of the beginning of aeolian sand accumulation is approximately 8700 years BP (fig. 4).

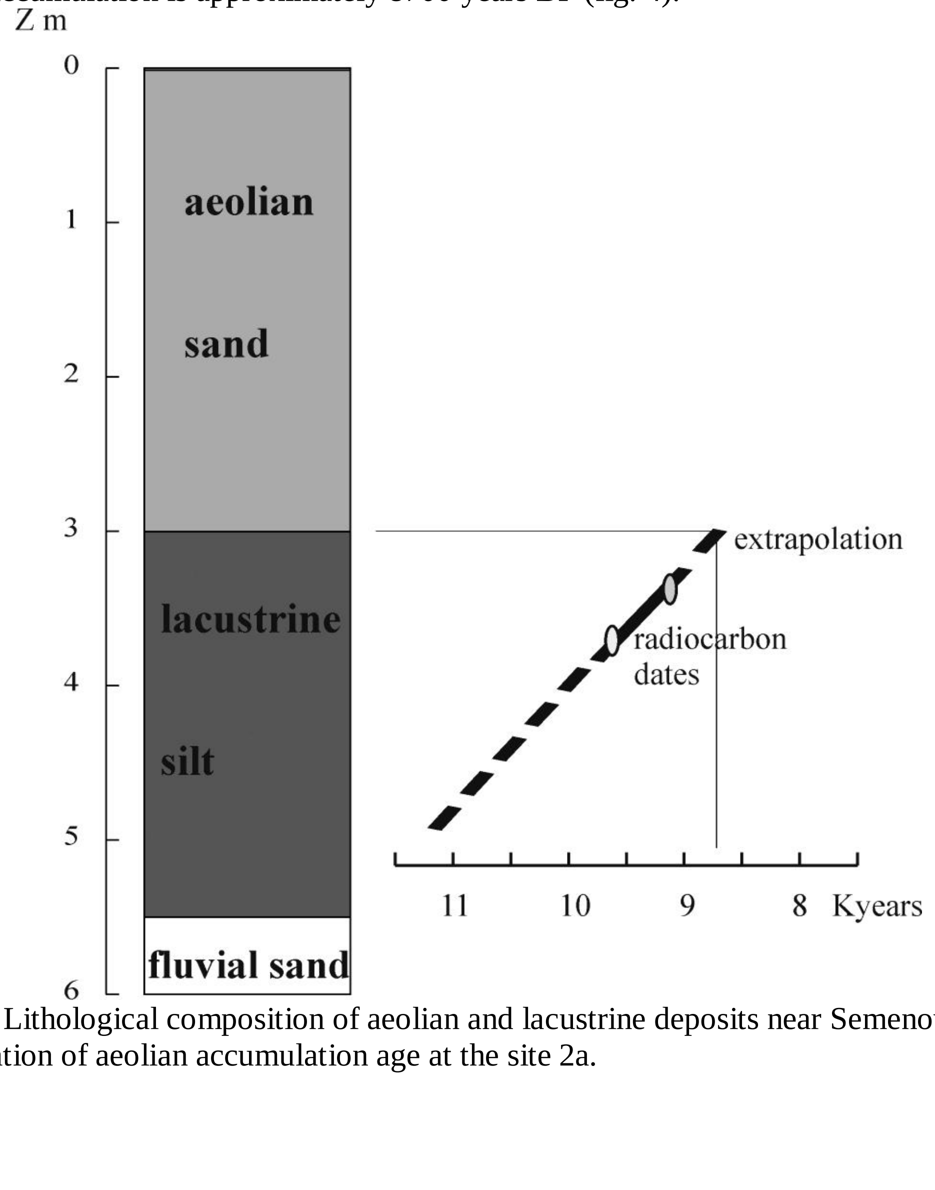

Fig.4. Lithological composition of aeolian and lacustrine deposits near Semenovka village and estimation of aeolian accumulation age at the site 2a.

Key-site 3, the large paleomeander of the Seim River near Kudintsevo village

Within this section of the valley, the paleochannel forms steeply curved meanders with the wavelength of 6000 m and the length along the channel of 7000 m. The mean coefficient of shape is 2.3. Such an omega-like shape of meanders, considerably exceeding the optimum values for a meandering channel, could have resulted either from low flooding levels or from high stability of the floodplain. The macromeander near Kudintsevo village represents a large loop, turned slightly up the valley, with the maximum deflection of 4 km and the half-wavelength of 3 km. Its apex cuts the Prutishche valley near its mouth. At the meander neck near Krasnaya Zarya village, the systems of natural levees and troughs of the upper and lower parts of this large bend come very closely to each other.

The lithology of the large channel infilling in the upper part of the bend was investigated by coring along the profile A-A' (fig. 5). Several boreholes (S-2, S-3, and S-6) reached the deposits underlying the channel alluvium. They are represented by poorly sorted sandy loam with the uniform distribution of all fractions from clay to coarse sand. These sediments contain secondary sulphides in the form of small concretions and pellicles (more than 47% of the heavy minerals in the fraction of fine sand). A long period of diagenesis in submerged (lacustrine or marine) conditions was necessary for their formation. As these sediments contain also the microfossils of presumably Cretaceous age (Hystrichosphaeridae), they probably represent an eluvium of the Cretaceous bedrocks.

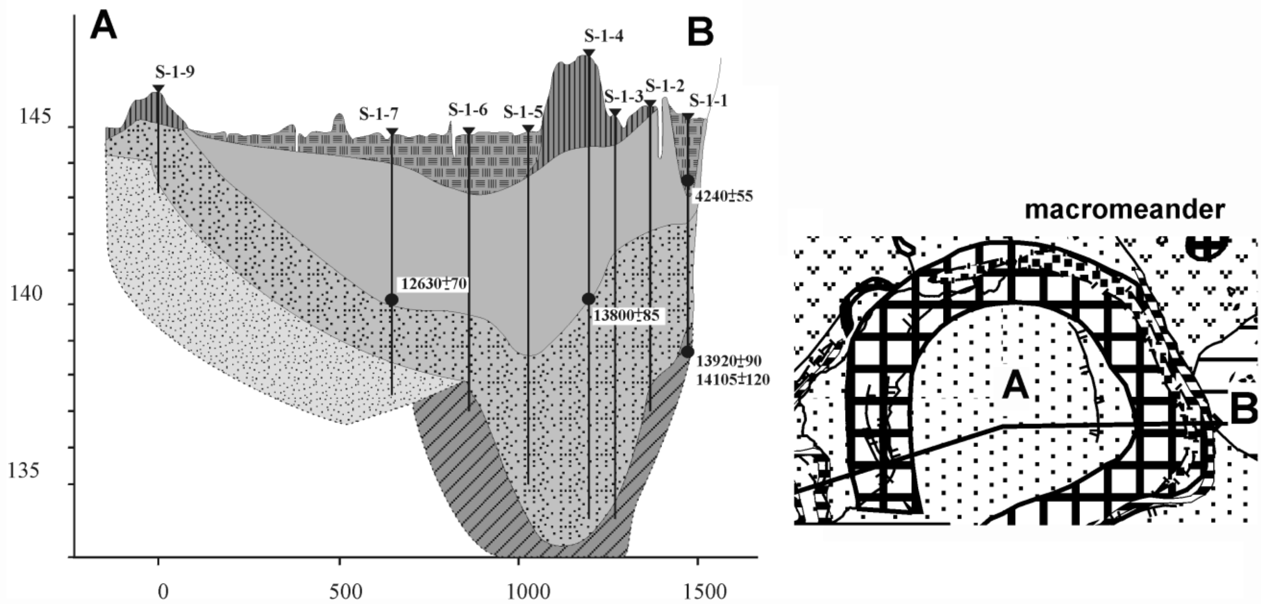

Fig.5. The paleochannel of pra-Seim River with macromeanders near Kudintsevo village and its lithological composition at the sites 3 and 3a.

The paleochannel cross-section has an asymmetrical triangular shape. Its deepest part (6-6.5 m) is shifted towards the concave bank of the macromeander. The concave bank is steep; it is composed of the bedrocks, covered with clayey eluvium and slope deposits containing fresh water molluscs' shells. The radiocarbon dating of the shells and of organic matter dispersed in the slope clays (13,920±90, Ki-6982; 14,105±120, Ki-6981) provides an age estimation for the latest stage of active lateral channel erosion, corresponding to the final stages of the macromeander development. The opposite gently sloping bank of the paleochannel is formed by a point bar, composed of medium-grained sand (borehole S-7), similar to the sand in the meander neck (S -9, S -10).

The deposits filling the paleochannel include three main horizons: sand, clay and peat. The lowermost horizon (fine-grained sand with interlayers of clayey sand) represents the channel facies of alluvium formed at the final stage of the macromeander development. The sand is overlain by dove-color grey clay and aleurite accumulated largely in the oxbow lake on the floodplain. Near their base, these deposits are generally sandier and contain interlayers of sand. In the upper part they are less sandy, as the running-water oxbow lake gradually became more closed. The deposits at the base of the second layer were radiocarbon-dated by the bulk organic matter to 12,630±70 years B.P. (Ki-6985) and 13,800±85 years B.P. (Ki-6984). We assume that the latter date indicates the time of the macromeander abandonment, as it corresponds to the above-mentioned dates obtained for the slope deposits.

An accumulation of the oxbow lake clays continued till the middle Holocene (6165±70, Ki-6983). In the end of this stage of accumulation a peculiar relief feature was formed: a large levee following the bend of the macromeander and consisting of the same clayey deposits as those of the second (floodplain lake) layer in the filling of the paleochannel (key-site 3a). This levee is 200 m wide with the top marks 3.5 m above the LWL, so that it is not inundated even during the highest contemporary floods. The height of the levee indicates the possible flood water levels of the Seim River at the time when it was formed. Later on, grey forest soil typical for the region was developed on the surface of the levee.

Not later than 4240±55 years B.P. (Ki-6980) accumulation in the running-water lakes on the floodplain was replaced by peat accumulation. After the layer of peat 2 m thick was formed, the surface of the sediments, filling in the paleochannel, reached the height of 1.4-1.5 m above the LWL, that is, became almost level with the rest of the high floodplain of the Seim River.

On the neck of the paleomeander a series of natural levees and troughs is preserved. The levees are 100-200 m wide and 2.5-3.0 m high above the LWL. They consist of sandy clay within the top one meter and of channel alluvial sand below it. Within its oldest part, the surface of the macromeander neck reach 3.5-4 m above the LWL, so that at present it is not flooded. The difference of altitudes between the paleochannel talweg and the top of the channel alluvium in the meander neck (that is, the surface of the Late Valdai floodplain) is 9-10 m. This value is almost equal to the one estimated for the Svapa River. The slope of the floodplain surface along the axis of the paleochannel is 7.5 cm/km. It can be used instead of the water slope for the approximate paleohydrological calculations. Paleodischarges were calculated for several water stages with Chezi formula for two areas of the channel cross-section. In the first case, the boundaries of the cross-section followed the base of the sandy channel alluvium, or the bottoms of the deepest pools in the paleochannel at the stage of the maximum runoff. In the second case, they followed the base of the floodplain lake clay, which corresponds to the initial stage of the paleochannel abandonment (fig. 5a). As the surface of the floodplain was not eroded during the floods, the critical velocity of erosion initiation was calculated for sand with the grain size of 0.28 mm. The velocity of the water streams on the floodplain was under 0.45 m/s, which corresponds to the maximum floodplain inundation of about 0.8-1.2 m. The calculations (table 7) show that at the period of maximum runoff the water discharge of the Seim River near L'gov (the basin area of 10800 km^2, the contemporary maximum flood discharge of 2400 m^3/s) reached 14500 m^3/s. It corresponds to the maximum discharge of the Dnieper River near Kiev (the basin area of 328000 km^2). At the initial stage of abandonment of the large paleochannel the flood discharge reached 6500 m^3/s (Table 8), which means that it was still greater than that of the Dnieper River near Rechitsa (the basin area of 58200 km^2).

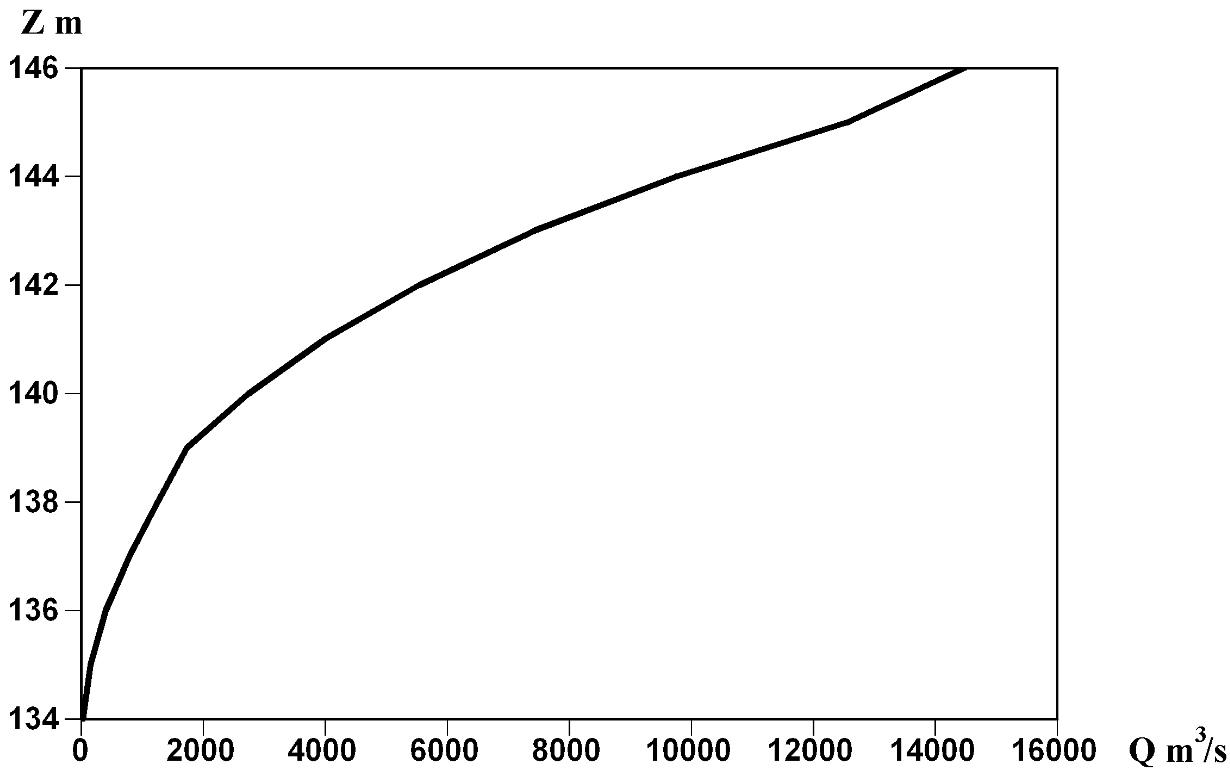

Fig. 5a. Discharge - stage curve for the paleochannel of pra-Seim River near Kudintsevo, calculated with Chezy-Manning formula.

Table 7. Calculated hydrological parameters of the large paleochannel of the Seim River at the stage of maximum runoff.

Water level, m	Cross-section area, m^2	Paleochannel width, m	Mean depth, m	Mean velocity, m/s	Water discharge, m^3/s
134	106	200	.53	.24	25
135	377	320	1.18	.40	150
136	728	380	1.92	.56	400
137	1162	450	2.58	.68	790
138	1670	560	2.98	.75	1250
139	2404	850	2.83	.72	1730
140	3359	990	3.39	.82	2740
141	4411	1110	3.97	.91	3990
142	5594	1230	4.55	.99	5540
143	6937	1360	5.10	1.07	7420
144	8387	1450	5.78	1.16	9750
145	9949	1520	6.55	1.26	12560
146	11470	1520	7.55	1.26	14480

Table 8. Calculated hydrological parameters of the large paleochannel of the Seim River at the initial stage of its abandonment.

Water level, m	Cross-section	Paleochannel width, m	Mean depth, m	Mean velocity, m/s	Water discharge,

	area, m^2				m^3/s
139	33	120	.27	.15	5
140	308	540	.57	.25	75
141	997	760	1.31	.43	430
142	1867	980	1.91	.55	1030
143	3041	1300	2.34	.64	1930
144	4400	1370	3.21	.79	3460
145	5856	1520	3.85	.89	5190
146	8900	1520	4.85	.89	6540

Key-site 4, the Seim River valley near Kudintsevo village, the secondary meandering paleochannel

In the lower part of the large paleomeander of the Seim River, a secondary meandering channel with the width of 100 m and the wavelength of 1280 m can be seen (fig. 6). Its bends are omega-shaped and arc-shaped. There are well-developed series of natural levees and troughs near the necks of meanders. This paleochannel was filled in with clayey sediments (table 9) not later than 12,300 years B.P. (^{14}C dates 12,250±70, Ki-6987 and 11,455±60, Ki-6986). As only fragments of this paleochannel can be found in the modern relief, the reconstruction of its development represents certain difficulties. It is possible, that the channel was a continuation of the trough filled in with peat, located in the upper part of the meander, although this trough is hidden at the apex of the large meander near the mouth of Prutishche. Within the Seim River floodplain downstream from the large meander near Kudintsevo village (key-site 3), the fragments of paleochannels, close in their widths and meander wavelengths to the above-mentioned secondary paleochannel, are found.

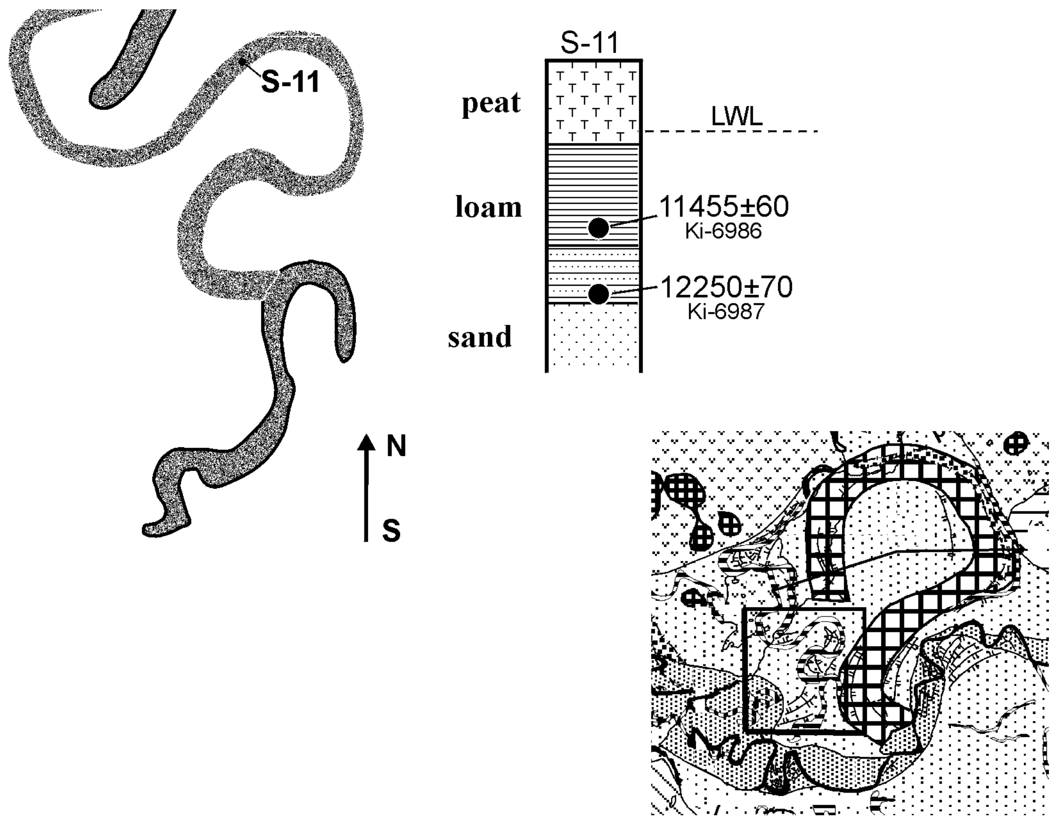

Fig.6. Secondary meandering channel in the lower part of the large paleomeander of the Seim River near Kudintsevo village and its lithological composition at the site 4.

Table 9. The borehole C-2-11 cored within the secondary paleochannel in the lower part of the large paleomeander.

Depth, m	Deposits			
0.00-1.55	Brown-black peat			
1.55-3.35	Brown-yellow clay with abundant mollusc shells	3,0-3,1	11,455 ± 60	Ki-6986
3.35-4.20	Dark-brown clay	4,0-4,2	12,250 ± 70	Ki-6987
4.20-4.30	Dove-colour – brown clay			
4.30-5.50	Poorly sorted clay sand (from fine to medium-grained)			

Key site 5. The Holocene floodplain.

The modern belt of channel meandering in the Seim and Svapa valleys forms large bends, which inherited the latest position of the large paleochannel. It is indicated by close similarity of the wavelengths of the curves of the meandering belt and those of the macromeanders, and by spatial conformity between the modern meandering belt and natural levees formed during the stage of the large meanders' development.

The modern floodplain forms a band along the meandering belt. There are two main types of modern floodplain. The floodplain of the first type is narrow (500-700 m), its width does not exceed that of the meandering belt. Such floodplain sections were formed at the areas, where the modern channel cuts the sediments, filling in the large Late Valdai channels. The channel is rather stable there due to low erodibility of clay sediments, exposed in the high channel banks. Therefore, the rate of lateral erosion within such sections is very low. Oxbows seldom occur at such sections of the floodplain. Presumably, only a few cutoffs of the river meanders took place there during the Holocene. The meanders of the modern channel have relatively large wavelengths (600-800 m) compare to an average one within the studied part of the Seim River valley.

The modern floodplain of the second type was formed in the areas with sandy deposits. It is up to 1-2 km wide and has abundant oxbows and natural levees on the surface. The variability of the surface altitudes is rather high due to a complicated fluvial relief, the difference between levees and troughs being about 3 m. Within such sections meanders of the modern channel have relatively small wavelengths (200-400 m in the Seim valley and 150-300 m in the Svapa valley).

Coring in the Seim and Svapa river valleys revealed a typical lithological composition of the Holocene floodplain (table 10): a layer of peat 0.5 –1.5 m thick upon 2-5 m layer of clay or sandy loam with interlayers of silty sand. The top surface of fine and medium-grained alluvial sand of the channel facies or oxbow lake deposits is situated at the depth of 3-6 m below the floodplain surface (fig. 7).

Table 10. Borehole S-1-19. Central part of an oxbow on the Holocene floodplain.

Depth, m	Deposits			
0.0-0.7	Dark-grey clay			
0.7-1.05	Brown-black peat			
1.05-1.9	Dove-colour – dark grey clay with the lenses of peat			
1.9-2.85	Brown peat			
2.85-4.1	Green-grey clay with remnants of wood	3,2-3,3	5,700 ± 60	Ki-6992
4.1-5.15	Grey fine and medium-grained sand with abundant molluscs shells	4,7-4,9	9,240 ± 70	Ki-6993
5.15-5.7	Dove-colour – grey clay with lenses of sand			
5.70-6.10	Clayey fine sand with molluscs shells			

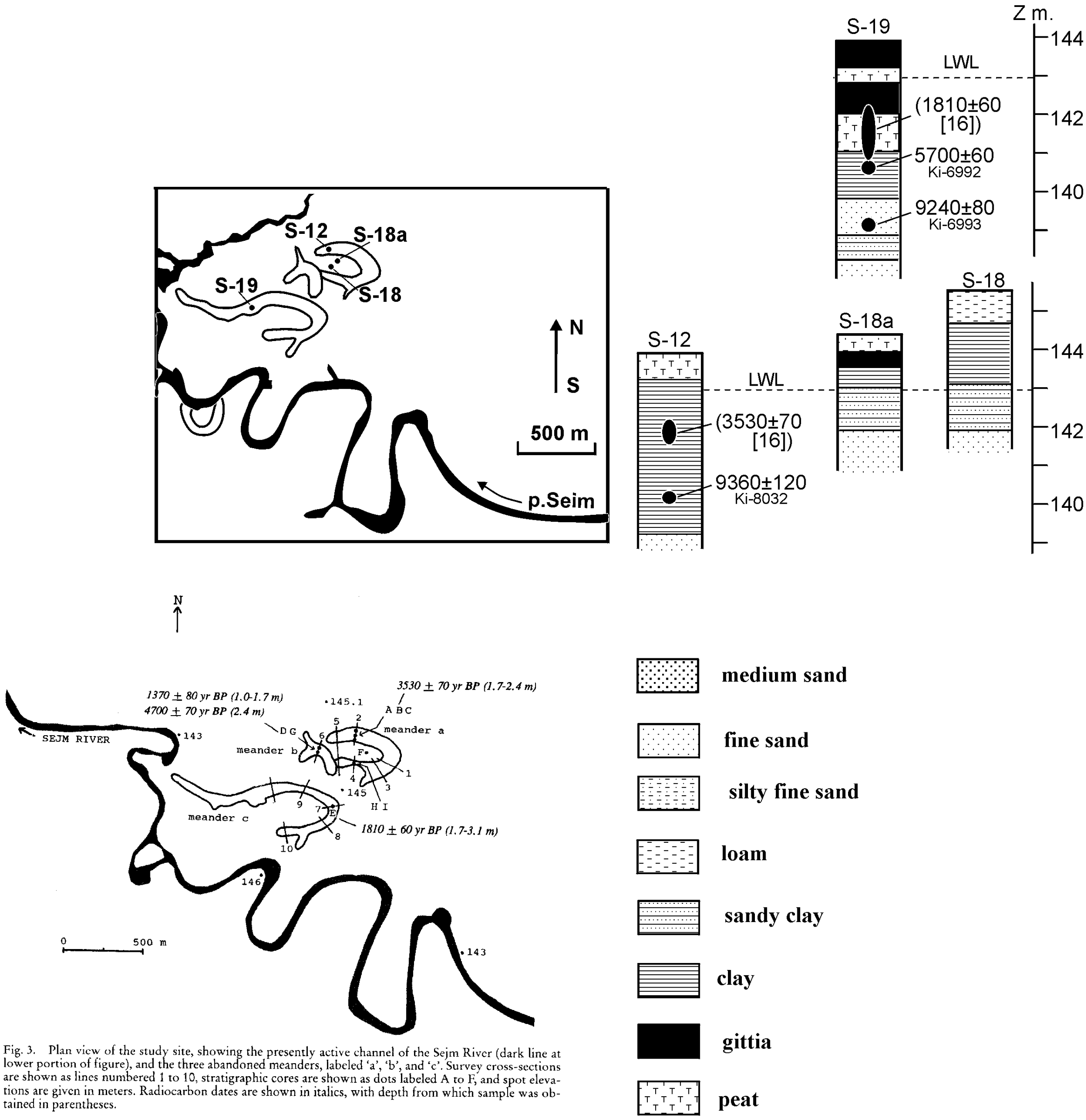

Fig. 7. The Holocene floodplain of the Seim River near Kudintsevo village and its lithological composition (a) under investigations of authors and (b) of Wohl and Georgiady (1994) at the site 5.

Based upon their position in the floodplain topography, the oldest oxbows were chosen for the radiocarbon dating. The earliest ^{14}C dates received on such oxbow lake deposits should correspond to the beginning of the modern floodplain formation. In the oxbows, situated on the modern floodplain of the Seim River, the lake deposits at the base of the section, just above alluvial sands (at the depth of 4-5 m) were dated to 9,240 (Ki-6993) and 6,830 years B.P. It shows that these oxbows were cut off not later than 9 and 7 thousand years ago. These dates correspond well with those obtained by Wohl and Georgiadi (1994). The lake sediments obtained from the same oxbows at the depth less than 3 m radiocarbon are characterised by ^{14}C dates from 1.8 to 4.7K years B.P. The dates from the Svapa River valley show that the first cutoffs of the meanders within the modern floodplain occurred not later than in early Boreal time (8,945±80; Ki-7002 and 9,830±70; Ki-7004).

One of the characteristic features of the Holocene floodplain sediment sequence is a buried soil profile with high organic content. A well-developed A-horizon indicates that the soil evolution took place over a long period of time. The soil is buried under a layer of floodplain sediments 0.5-1 m thick. It is exposed in the outcrops along the banks of Seim and Svapa channels. In the outcrop of the floodplain deposits, situated in the lower section of the Svapa River, the soil contains abundant charcoal particles, which were radiocarbon dated to 1100±65 (Ki-6994). An age of the charcoal indicates an approximate time of soil formation.

During the last few centuries, the lateral erosion of the modern floodplain was active within the sections with sandy sediments. Comparison of old maps, aerophotographs and field investigations indicate several quite recent meander cutoffs. The fragment of wood extracted from sediments of one of the recent oxbow lakes was dated to 250±60 years B.P.

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