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POTENTIAL LONG-CHRONOLOGY DEVELOPMENT ON THE NORTHWEST SIBERIAN PLAIN: EARLY RESULTS

Key-Words: Subfossil wood, tree rings, dendrochronology, Holocene, Yamal Peninsula, polar timberline.
Parole chiave: legno subfossile, anelli annuali, dendrocronologia, Olocene, penisola Yamal, limite del bosco boreale.

Abstract

In the northwestern sibirian plain an absolute chronology (Larix sibirica) has been developed back to 1248 B.C. Earlier, as yet, discontinous "floating" chronologies illustrate the potential and progress in developing a single chronology reaching back to 5500 B.C. and beyond.

Introduction

Knowledge of climate changes during the Holocene, particularly where these can be highly resolved (i.e. to the year or season), is of great interest for understanding the context of recent and future climate changes (BRADLEY, JONES 1993). This information is also needed for the evaluation of relationships between climatic conditions, different natural processes and human activity (BRAY 1971).

Among various kinds of proxy data, tree-ring information is notable because the chronologies are absolutely dated and may be well replicated. The development of extensive chronology networks allows the variability of tree growth and derived information on limiting growth factors to be explicitly represented in both the spatial and temporal domaines.

The strongest climatic signal is found in tree-ring series derived from trees that grow at the geographical and ecological limits of their distribution, especially at the polar timberline. High-latitude areas or sites located within the forest-tundra ecotone are extremely suitable for reconstructing temperatures on the basis of tree-ring analysis. Air temperatures during the summer months, particularly of June and July in the year of ring formation, frequently have the largest effect on ring-width variability (JACOBY, D'ARRIGO 1989; BRIFFA ET ALII 1990; GRAYBILL, SHIYATOV 1992).

At present only a few very long high-latitude chronologies have been developed and, as yet, the longest continuous series from subarctic regions of the Northern Hemisphere extend back only about two thousand years.

We describe the early progress in a project which aims to develop two multi-millennial (8-9 thousand years) tree-ring chronologies for the northwestern part of the West-Siberian Plain using living trees and subfossil wood from each of two species: Siberian larch (*Larix sibirica* Ldb.) and Siberian spruce (*Picea obovata* Ldb.) species. These chronologies represent special potential for a range of important studies:

– the reconstruction of Holocene summer temperature changes;

– the reconstruction of forest ecosystem dynamics, particularly of changes in the position of the polar timberline;

– the reconstruction of past climate variability on different timescales and hence an evaluation of the precedence of recent changes.

– the reconstruction of ice condition changes in the Barents and Kara Seas, rivers and lakes of the northern part of the West-Siberian Plain;

– routine absolute dating of various kinds of wood remnants in Holocene deposits, and hence of archaeological and historical monuments.

Material

The purpose of this brief paper is to present the results in hand at a preliminary stage of this ongoing work where there is, already, a significant body of sample data – recent chronologies, earlier but as yet floating series, and a good indication of the long-term distribution of subfossil samples based on radiocarbon dates.

Geographical Region

Well-preserved subfossil wood exists at high latitudes in Siberian Holocene deposits. This is the result of intensive accumulation and the good preservation of buried wood in the permafrost. Subfossil wood remains are particularly plentiful in the north-western part of the West-Siberian Plain, in the region of the southern Yamal Peninsula (ZITKOV 1913; SUKATCHEV 1922; ANDREEV ET ALII 1935).

These tree remains are indicators of displacements of the polar timberline due to climate changes. During the warmest period of the Holocene, the northern treeline reached the central region of the Yamal Peninsula (up to 70° N) as shown by the remains of trees preserved in peat deposits (TIHOMIROV 1941). At present the polar timberline passes through the most southern part of this peninsula at a latitude of 67° 30'N. Open larch and larch-spruce-birch forests are located mainly along river banks, in the middle and lower parts of valleys. The upper reaches of these rivers are treeless.

Already, by 1964, attention had been drawn to the potential significance of Yamal subfossil wood for reconstructing climatic and other natural processes over many thousand years, as a result of field-work carried out within the valley of the Khadyta-Yaha River in the southern part of the Yamal Peninsula (SHIVATOV, SURKOV 1990). The systematic collection of subfossil wood samples was begun, in 1982, in the basins of the Khadyta-Yaha, Yada-Yahody-Yaha and Tanlova-Yaha rivers (Figure 1). All of these small rivers (120-150 km length) are located in the southern part of the Yamal Peninsula and all of them flow from the North to the South. At the time of writing, about 1300 cross-sections of subfossil stems and roots have been collected. The predominant species of these samples is Siberian larch (93.5%) with most of the remainder being

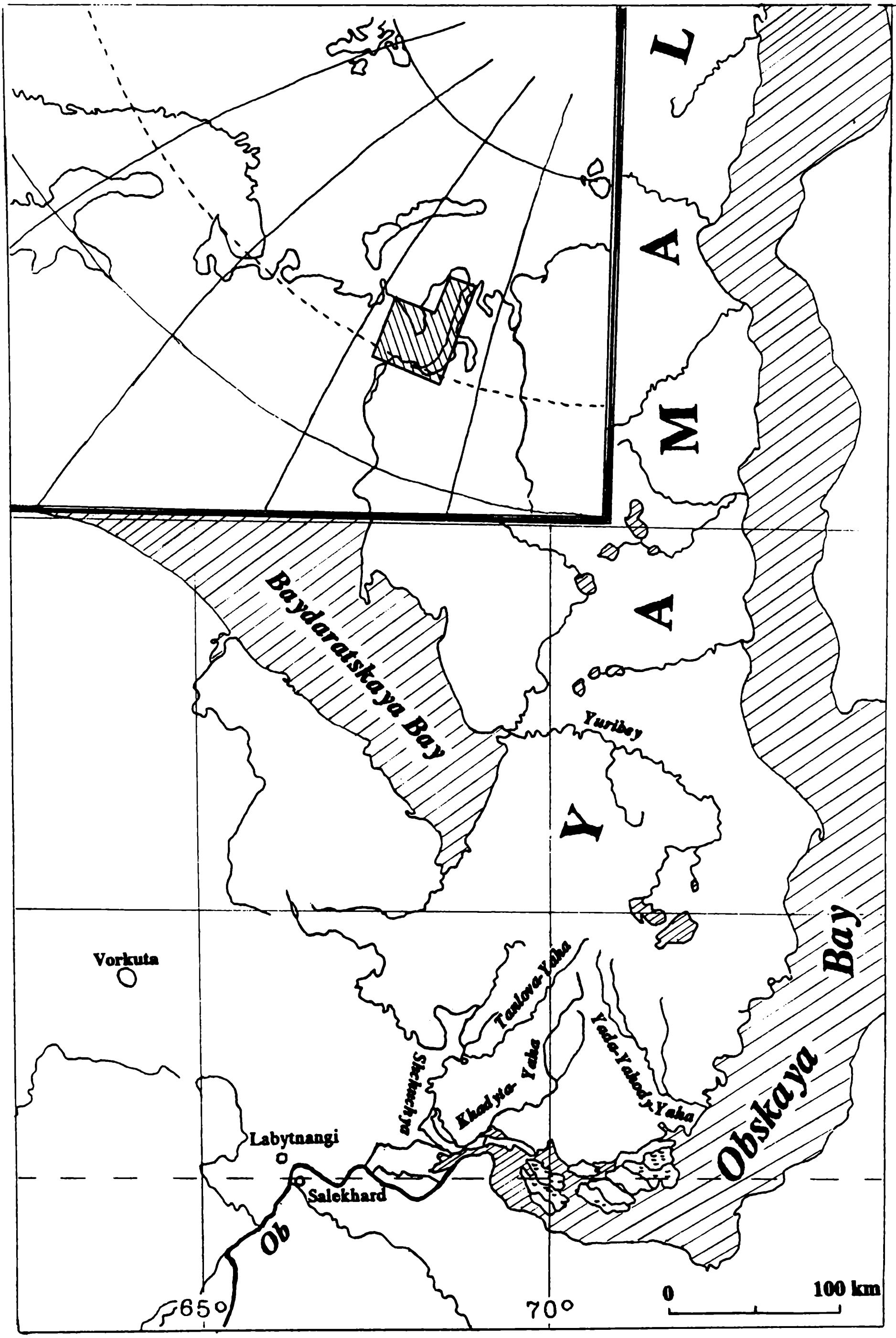


Fig. 1 - The region of subfossil wood collections described in the text.

Siberian spruce (5.5%) and the rest, Mountain birch *Betula tortuosa* (1%). All of these samples are now stored at the laboratory of Dendrochronology of the Institute of Plant and Animal Ecology (Ekaterinburg, Russia).

Within the same region, increment cores from 170 living larch and spruce trees have also been collected and four 3-400 year-long chronologies have been developed (SHIYATOV 1984).

Geological Deposits

Remains of dead trees can be found on surface, but these tend to be up to a maximum of one thousand years old (SHIYATOV 1993). There is also subfossil wood at the bottom of thermokarst lakes, but this source of material is more difficult to collect and has not, as yet, been explored. By far the most significant sources of subfossil wood remains, often as trunks in near complete state, with bark, roots and large branches, are alluvial deposits and peat.

Alluvial deposits

The main sources of subfossil wood are alluvial deposits. In the southern part of the Yamal Peninsula, there is a very intensive lateral erosion of river banks (up to 2-4 metres per year). Living trees, growing along the river terraces, are undermined and often fall into the running water (Figure 2). This occurs mainly in spring and early summer, when water level and stream velocities are high. Some fallen trees remain at the bottom of the river near to their growth sites. Some are transported by the water and

Fig. 2 - Living larch and spruce trees falling into the Khadyta-Yaha river, Yamal Peninsula. Photo by S.G. Shiyatov.

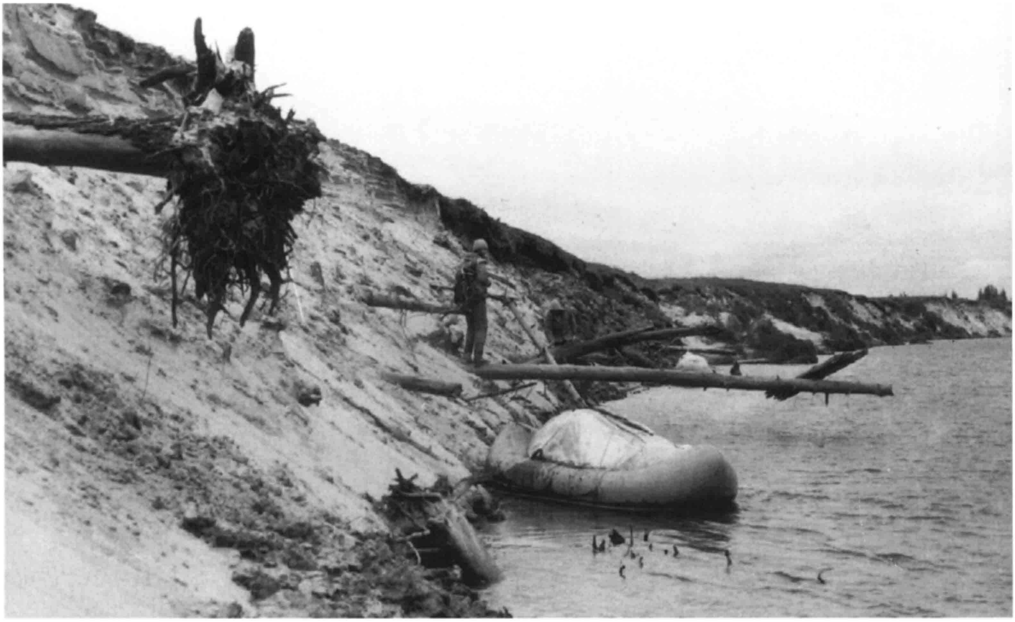


Fig. 3 - Subfossil wood of larch and spruce in alluvial deposits of Khadyta-Yaha river, Yamal Peninsula. Photo by S.G. Shiyatov.

deposited some distance away on beaches, or become entangled in bushes growing on the river banks. After a few years, these trees are buried by sand and silt deposits. As the river channel is continually moving, these buried trees soon become incorporated within the permafrost layer. Subfossil wood lies usually up to 5-6 metres below the surface and can be exposed by the river, perhaps after many hundreds or thousands of years. Most subfossil remains are typically composed of dark-grey wood, though some have yellow wood in the centre. The frequency of log deposits is variable. In the best case, 50-60 stems may be exposed within a distance of 200-400 metres along the river (Figure 3). All the rivers located in the southern part of the Yamal Peninsula are situated within the same homogeneous climatic area and wood transportation by water is thought to be no more than 50-100 km. This is why individual tree-ring chronologies obtained from different sites in this area are very similar.

Peat

The second important source of subfossil wood is peat deposits (Figure 4). In this area, there are a large number of peats to a depth of 2-3 metres. The largest logs are usually found at the base of these peats, where they are exposed by the erosional activity of lakes and rivers. Large lakes, with dimensions of more than one kilometre, are very strongly affected by wave erosion which is typical for regions with permafrost and where there are often strong winds during summer months. Such wood remains are *in situ* because these trees likely grew in some depression and were subsequently engulfed by later

Fig. 4 - Subfossil wood in peat deposits on the shore of a lake in the basin of Khadyta-Yaha river, Yamal Peninsula. Photo by S.G. Shiyatov.

peat formation. The radiocarbon dates indicate that these wood remains are the oldest recoverable up to 9400 years BP (SHIYATOV, EROKHIN 1990; Table 1).

Sampling Procedure

For collecting the subfossil material we use helicopters and boats. Initial transport is by helicopter to the upper reaches of a river, then small boats are used for locating and collecting cross-sections from wood exposed along the river. The best preserved material is usually found at the base of trunks and roots. Many of these remains are radially cracked and it is necessary to tie cross sections cut from these trunks or roots, using aluminium wire 2-3 mm in diameter immediately after sawing. This wire is left in place afterwards as the sections are dried.

Sample Ring Number Distribution

All of the wood samples collected are dried and their ring-widths measured along one or two radii. The distribution of the number of rings in the samples to date is shown in Figure 5.

Most wood samples contain 80-120 rings. Many samples have from 140 to 300. A small number have 300-400 rings. Considering that the sensitivity of the individual tree-ring series tends to be very high (mean sensitivity coefficients range from 0.3 to 0.6), most chronologies can generally be dated using standard cross-dating techniques applied between samples.

Results

At present, 55 subfossil wood samples

NN	ID	Lab.No.	Part of tree	Location	Deposits	No. of rings	Radiocarbon dates		Crossdating dates (AD)
							C-14 age (BC)	Calibrated age (BC)	
1	934	B-6072	stem, outer rings	Tanlova	alluvial	28	8220±40	7200	
2	290	B-6031 IPAE-77	root, all rings	Khadyta	peat	79	8180±40 8400±240	7400	
3	350	IPAE-79	root	Khadyta	peat	59	8180±230	7140	
4	333	IPAE-78	root	Khadyta	peat	127	8000±200	6900	
5	370	B-6032 IPAE-80	stem, inner rings	Khadyta	peat	111	8000±50 7730±220	6900 6500	
6	684	B-6060	stem, outer rings	Yada	alluvial	189	7920±40	6730	
7	253	IPAE-74	root	Khadyta	peat	75	7820±200	6640	
8	170	IPAE-73	root	Khadyta	peat	48	7800±170	6620	
9	829	B-6038	stem, outer rings	Yada	alluvial	382	7780±40	6590	
10	274	IPAE-76	root	Khadyta	peat	64	7640±220	6430	
11	1101	B-6077	stem, outer rings	Tanlova	alluvial	124	7260±40	6080	
12	269	IPAE-75	stem	Khadyta	peat	118	6550±170	5400	
13	1024	B-6074	stem, inner rings	Tanlova	alluvial	254	6200±40	5150	
14	830	B-6039	stem, outer rings	Yada	alluvial	243	5740±40	4620	
15	732	B-6062	stem, outer rings	Yada	alluvial	354	5730±40	4550	
16	995	B-6073	stem, outer rings	Tanlova	alluvial	127	5720±40	4540	
17	906	B-6042	stem, inner rings	Yada	alluvial	301	5030±30	3860	
18	769	B-6035	stem, inner rings	Yada	alluvial	243	4590±40	3330	
19	915	B-6070	stem, outer rings	Yada	alluvial	145	4520±40	3200	
20	904	B-6069	stem, outer rings	Yada	alluvial	216	4370±40	2920	
21	656	B-6059	stem, outer rings	Yada	alluvial	133	4290±40	2900	
22	911	B-6044	stem, inner rings	Yada	alluvial	296	4210±40	2800	
23	1050	B-6075	stem, outer rings	Tanlova	alluvial	234	4120±40	2700	
24	659	B-6034	stem, outer rings	Yada	alluvial	350	3970±30	2510	
25	710	B-6061	stem, outer rings	Yada	alluvial	243	3890±40	2370	
26	742	B-6063	stem, outer rings	Yada	alluvial	226	3800±30	2200	
27	45	IPAE-157	stem	Khadyta	alluvial	127	3630±190	2020	
28	823	B-6037	stem, outer rings	Yada	alluvial	243	3620±40	2010	
29	404	IPAE-154	stem	Khadyta	alluvial	169	3600±150	1970	
30	644	B-6033	root, outer rings	Yada	alluvial	148	3590±30	1960	
31	1089	B-6076	stem, outer rings	Tanlova	alluvial	185	3580±30	1920	
32	40	IPAE-156	stem	Khadyta	alluvial	129	3540±280	1870	
33	793	B-6036	stem, outer rings	Yada	alluvial	127	3530±30	1860	
34	861	B-6067	stem, outer rings	Yada	alluvial	151	3390±30	1680	
35	771	B-6064	stem, outer rings	Yada	alluvial	60	2850±40	1000	
36	841	B-6040	stem, outer rings	Yada	alluvial	256	2750±30	900	
37	864	B-6041	stem, inner rings	Yada	alluvial	162	2010±30	30	4-165
38	811	B-6065	stem, outer rings	Yada	alluvial	176	1960±30	65 AD	89 BC-86 AD
39	908	B-6043	stem, inner rings	Yada	alluvial	208	1910±30	90 AD	1 BC-206 AD
40	828	B-6066	stem, outer rings	Yada	alluvial	143	1230±30	790 AD	703-845
41	921	B-6071	stem, outer rings	Yada	alluvial	244	920±30	1100 AD	896-1139
42	879	B-6068	stem, outer rings	Yada	alluvial	109	890±30	1170 AD	1060-1168
43	1145	B-6078	stem, outer rings	Tanlova	on surface	25	680±30	1300 AD	1283-1307

No. 21 is *Picea obovata*

Tab. 1 - List of radiocarbon datings of subfossil wood samples of *Larix sibirica* from the Yamal Peninsula made at the Institute of Plant and Animal Ecology (IPAE) and at the Physics Institute of the Bern University (B).

SUBFOSSIL					
Year	absent			%	ind. %
-1172	1	of	4	25	51
-1171	1	of	4	25	12
-1168	1	of	4	25	13
-1142	1	of	5	20	50
-1127	1	of	5	20	15
-1126	1	of	5	20	10
-1029	1	of	10	10	57
-1021	1	of	10	10	55
-988	1	of	10	10	17
-987	1	of	10	10	12
-986	2	of	10	20	17
-971	1	of	12	8	44
-969	1	of	12	8	67
-964	1	of	12	8	14
-899	1	of	10	10	29
-886	1	of	9	11	42
-882	4	of	9	44	5
-860	1	of	11	9	20
-823	2	of	8	25	18
-792	1	of	6	17	15
-547	2	of	5	40	61
-543	1	of	6	17	91
-318	1	of	5	20	29
-294	1	of	5	20	66
-292	1	of	6	17	24
-288	1	of	6	17	61
-287	2	of	6	33	25
-261	1	of	5	20	30
-248	1	of	5	20	13
-246	1	of	5	20	25
-241	1	of	5	20	12
-239	1	of	5	20	25
-139	2	of	7	29	9
-119	1	of	7	14	14
-118	1	of	7	14	11
16	1	of	8	13	26
49	1	of	9	11	11
134	1	of	22	5	33
143	4	of	21	19	7
155	1	of	21	5	54
207	1	of	16	6	54
426	1	of	6	17	19
492	1	of	9	11	19
493	1	of	9	11	16
495	1	of	9	11	16
536	1	of	12	8	38

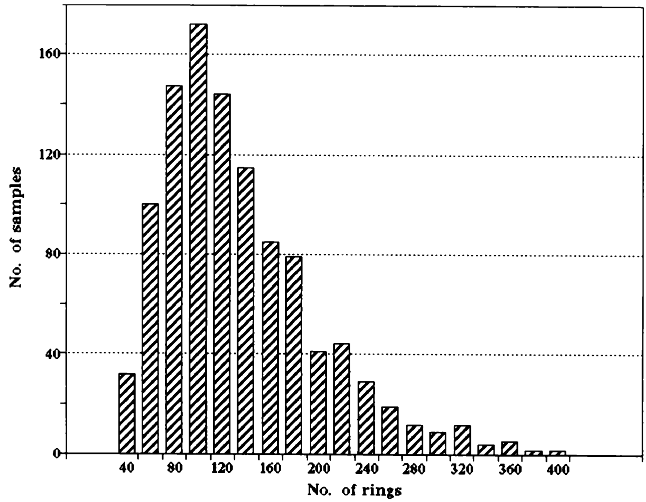
SUBFOSSIL continued ...					
Year	absent			%	ind. %
546	1	of	12	8	12
579	1	of	16	6	41
589	1	of	19	5	31
596	1	of	18	6	22
598	1	of	18	6	51
623	3	of	17	18	6
636	2	of	17	12	32
637	4	of	17	24	9
639	3	of	17	18	9
640	7	of	17	41	7
644	1	of	18	6	22
646	2	of	18	11	26
700	2	of	8	25	31
707	1	of	9	11	31
718	1	of	8	13	33
773	1	of	8	13	38
777	1	of	9	11	67
814	3	of	9	33	12
816	3	of	9	33	10
818	3	of	10	30	14
867	1	of	11	9	34
903	1	of	11	9	12
904	1	of	10	10	30
914	1	of	9	11	25
915	1	of	9	11	61
959	1	of	10	10	59
1006	1	of	12	8	28
1007	1	of	12	8	28
1170	2	of	12	17	8
1259	1	of	10	10	28
1270	1	of	11	9	36
1278	3	of	11	27	15
1290	1	of	10	10	44
1300	1	of	9	11	18
1302	1	of	9	11	58
1323	1	of	7	14	18
1334	1	of	8	13	53
1342	1	of	9	11	8
1347	1	of	9	11	14
1380	1	of	12	8	38
1453	5	of	13	38	9
1456	1	of	13	8	20
1460	1	of	13	8	24
1466	1	of	12	8	30
1529	2	of	7	29	10

continued ...

Tab. 2 - Current numbers of identified "missing rings" in the larch chronology data. The precentage of rings absent in subfossil and living-tree data are shown separately, along with the actual chronology index value for the appropriate year (also shown as a percentage)

SUBFOSSIL					LIVING	
Year	absent	%	ind. %		absent	%
1560	1 of 7	14	6			
1714	1 of 11	9	49		1 of 16	6
1718			73		1 of 16	6
1730			45		1 of 20	10
1732			28		2 of 20	5
1739	3 of 9	33	50		1 of 20	5
1742			23		3 of 20	15
1749			57		1 of 20	5
1752			67		1 of 21	5
1755			72		1 of 21	5
1783			39		1 of 22	5
1788			83		1 of 22	5
1789			92		1 of 22	5
1795			102		1 of 22	5
1806			68		1 of 22	5
1808			97		1 of 22	5
1812			35		1 of 22	5
1814			54		1 of 22	5
1815			30		1 of 22	5
1816	2 of 3	67	2		16 of 22	73
1817			33		1 of 22	5
1818	3 of 3	100	4		14 of 22	64
1819			22		6 of 22	27
1820	1 of 3	33	9		12 of 22	25
1824	1 of 3	33	66			
1825			38		2 of 22	9
1828			47		1 of 22	5
1831			28		5 of 22	23
1833			31		4 of 22	18
1837			49		1 of 22	5
1867			21		3 of 23	13
1882			39		1 of 23	4
1883			50		1 of 23	4
1884			29		1 of 23	4
1885			28		1 of 23	4
1889			20		1 of 24	4
1891			32		1 of 24	4
1903			46		2 of 24	8
1934			45		1 of 24	4
1946			46		1 of 24	4
1947			40		1 of 24	4
1967			102		1 of 20	5
1971			50		1 of 20	5
1975			40		1 of 20	5

Fig. 5 - Ring-number distribution of the subfossil wood samples collected to date.



have been dated by the radiocarbon method (Table 1). These datings were carried out in the Laboratory of Historical Ecology of the Institute of Plant and Animal Ecology, Ekaterinburg, Russia, and in the Radiocarbon Laboratory of the Physics Institute of the Bern University, Bern, Switzerland. These datings show that the absolute age of the oldest subfossil wood reaches 9200-9400 years BP. The dates in some are distributed more or less evenly through time, though there is some apparent concentration such as 1500-3000 and 6400-7200 years BC (calibrated age). Wood samples appear notably less abundant in other periods (particularly in the 1st century BC), initially suggesting that conditions were likely less favourable for tree growth during the periods. The data also show that it will be possible to develop two tree-ring chronologies, one for *Larix sibirica* and another for *Picea obovata*, each 7-9 thousand years long.

The difference between dendrochronological and calibrated radiocarbon ages is generally no more than 40 years (Table 1). There is a good agreement between radiocarbon and tree-ring dates for the samples NN 38 and 40-43. For the other two samples (NN 37 and 39) there are only insignificant differences. We can therefore conclude that, in the permafrost regions, radiocarbon datings of wood samples aged 2000 years and less are very accurate.

The Absolute and Floating Ring-Width Chronologies

The main difficulty in developing tree-ring chronologies in this region is the occurrence of frequent "missing" rings. In some samples with generally narrow rings, up to 5-10% of the rings are absent (Table 2).

At present, the length of the continuous and absolutely dated larch chronology is 3243 years, from 1248 BC to 1994 AD. The second longest spans approximately 1310-1350 BC to about 5500 BC, but this chronology is not yet firmly anchored in time. The gap between the absolutely dated and "floating chronologies" is no more than 100 years. There is a rather long gap be-

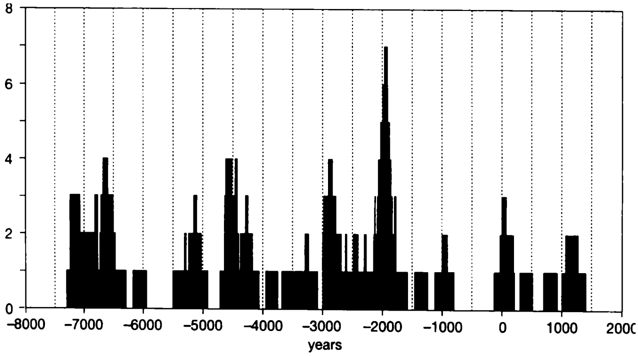


Fig. 6 - Distribution of the calibrated radiocarbon dates of subfossil wood.

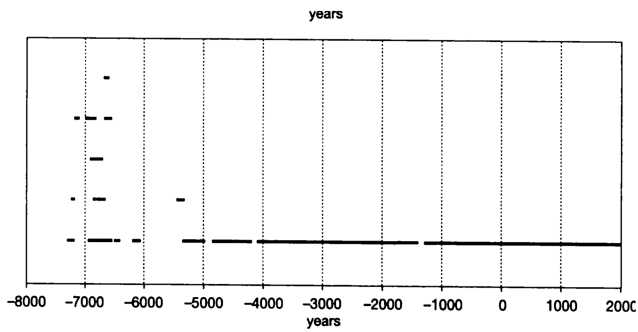


Fig. 7 - Absolutely-dated (recent) and floating chronologies for the Yamal material.

tween 5500 and 6000 BC and some other floating chronologies during the interval from 7500 to 6000 BC (Figures 6 and 7). The length of absolutely dated and continuous spruce chronology is 1270 years, from 725 AD to the present. There are also seven floating spruce chronologies which are about 200-400 years long. The spruce chronologies crossdate well with the larch chronologies. Figure 8 shows one version of the absolutely-dated larch chronology, standardized according to the "Corridor Method" described in detail in Cook *et al.* (1990).

Ring-Density Chronologies

Developing ring-density chronologies should allow us to reconstruct additional climatic parameters, the May-August mean temperatures, in particular. About 10-20% of the samples are well preserved and believed suitable for densitometric analysis. The outer part of almost all of the samples (usually sapwood) is invariably heavily decayed.

Up until now, cross-sections of 30 subfossil trees have been analysed by the densitometric technique.

Conclusions

There is a great potential to develop multi-millennial-length tree-ring chronologies for the northwestern part of the West-Siberia plain: – perhaps covering almost all of the Holocene. In some periods, conditions were

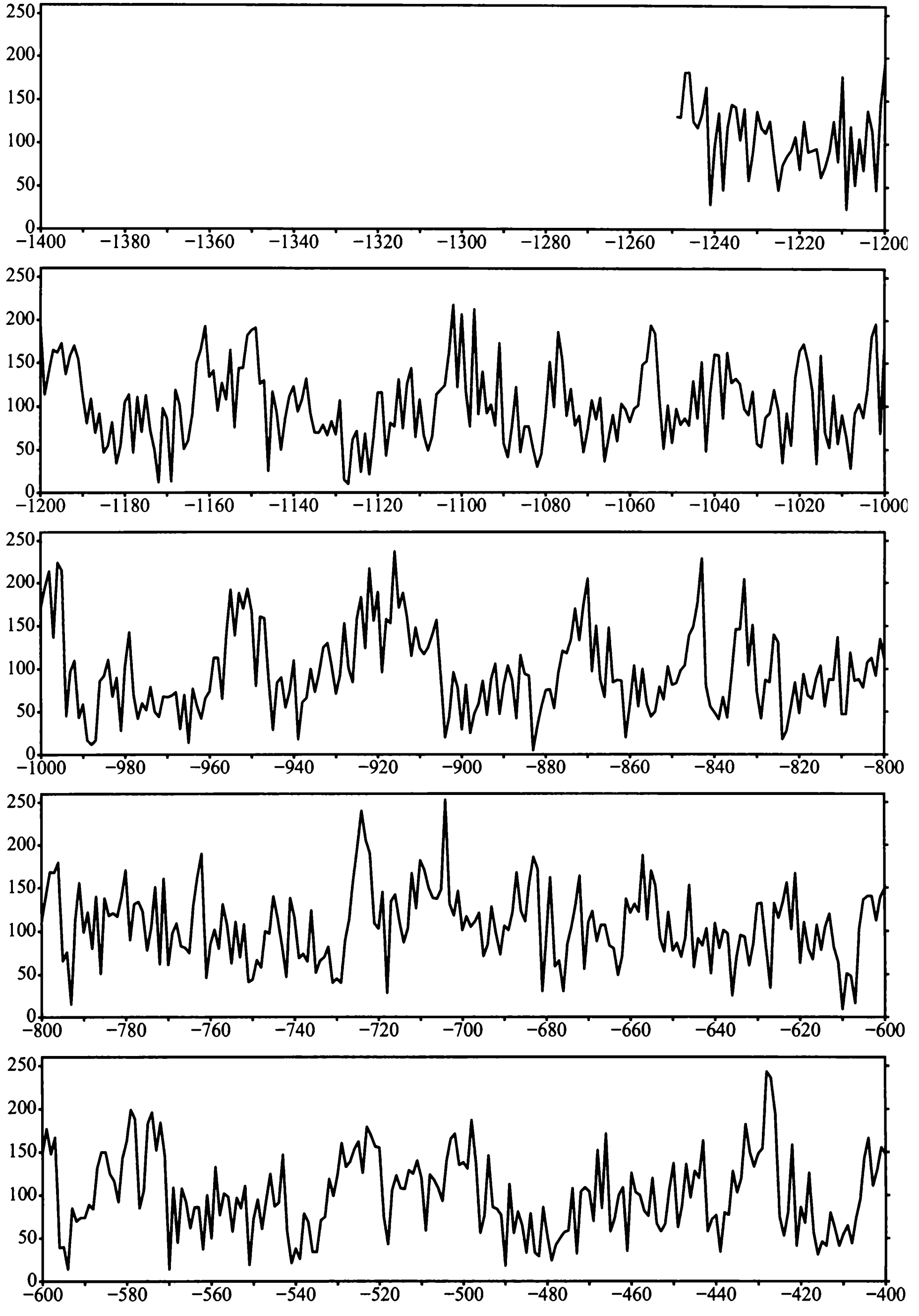


Fig. 8 - Corridor-standardized version of the absolute Yamal larch chronology.

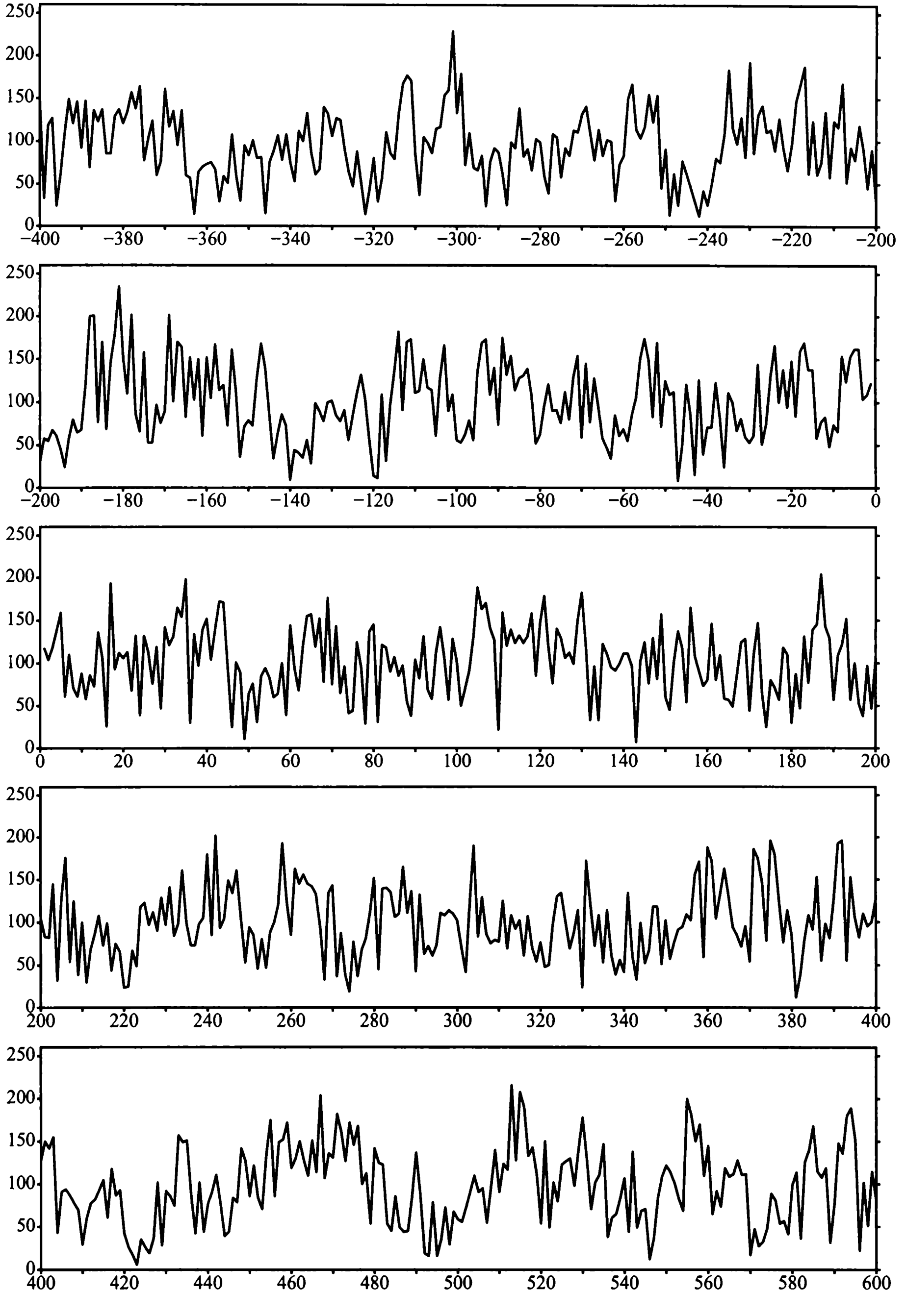

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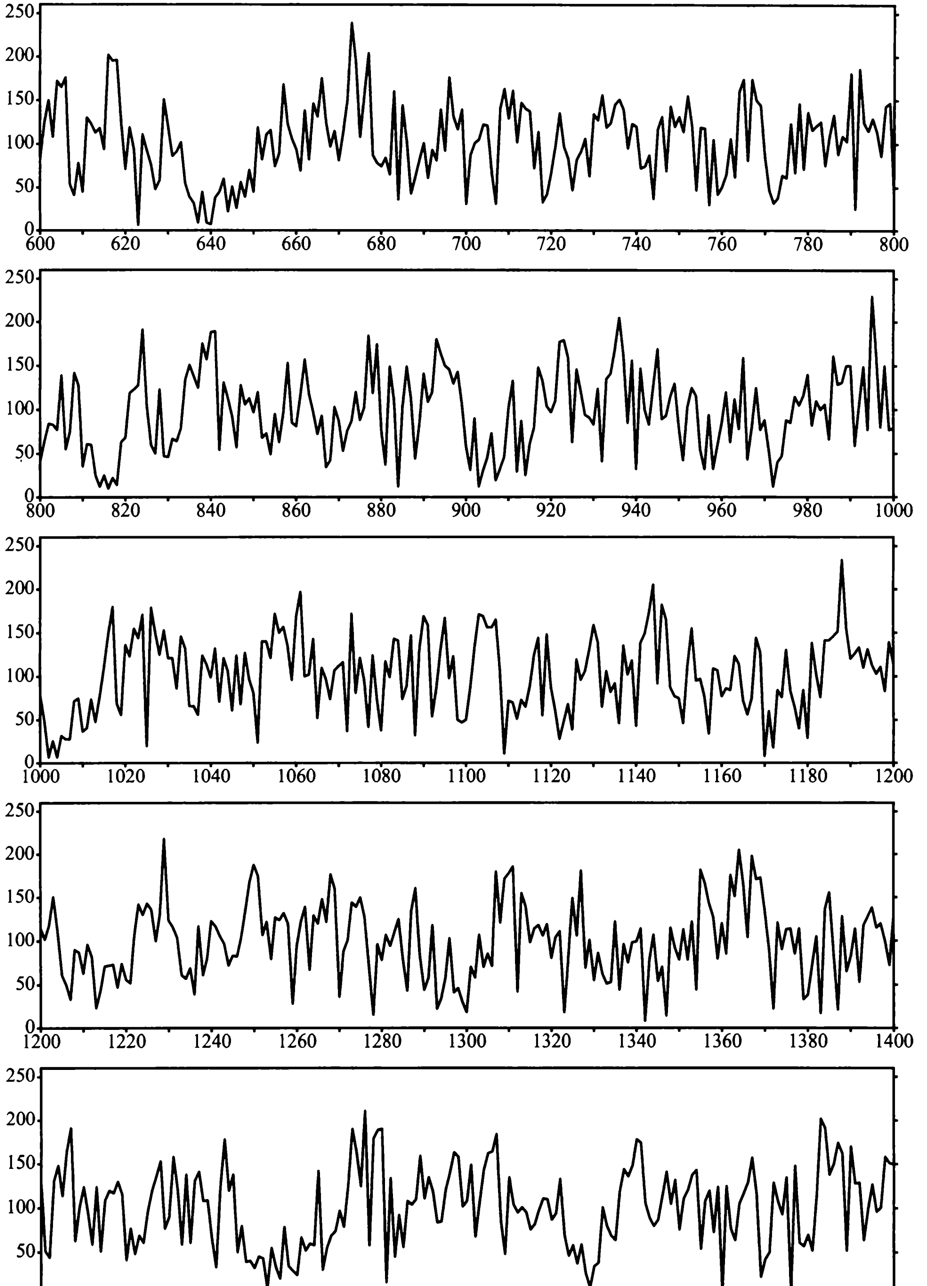
Fig. 8.



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1200 1220 1240 1260 1280 1300 1320 1340 1360 1380 1400
1400 1420 1440 1460 1480 1500 1520 1540 1560 1580 1600

Fig. 8.

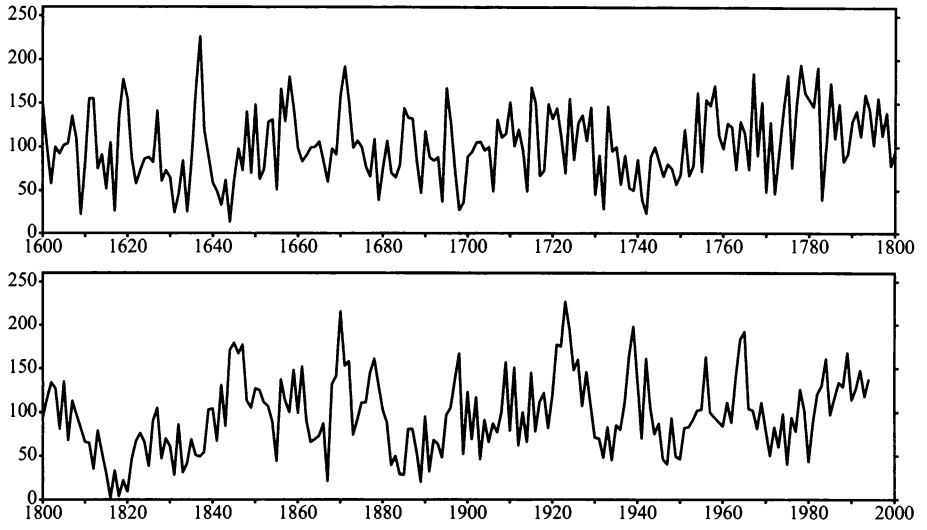

Fig. 8.

apparently unfavourable for tree growth and it may prove difficult to find many subfossil samples. However, cross-dating against material from the southern part of the Yamal Peninsula should facilitate chronology bridging across these periods. We hope to find suitable wood in contemporaneous deposits in other regions, south of the present polar timberline.

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SUMMARY

Potential long-chronology development on the Northwest Siberian Plain: early results

A large amount of well-preserved subfossil wood exists in the Holocene deposits of the northwestern part of the West-Siberian Plain. This is the remains of *Larix sibirica* and *Picea obovata* stems, roots and branches. Radiocarbon dating indicates that this wood reaches ages back to 9400 years BP, providing a good opportunity for the development of multi-millennial temperature-sensitive tree-ring chronologies. Considerable success has already been achieved in developing a continuous ring-width chronology extending back from the present into the pre-Christian era and work on earlier radiocarbon-dated subfossil chronologies, as yet uncorrected dendrochronologically, indicates that a 9000-year chronology is achievable in the medium term.

ZUSAMMENFASSUNG

Entwicklung einer mehrtausendjährigen Jahrringchronologie in der nordwestlichen sibirischen Tiefebene; erste Ergebnisse

In der nördlichen westsibirischen Tiefebene befinden sich viele, gut erhaltene Baumstämme, Wurzeln und Äste von Lärchen (*Larix sibirica*) und Fichten (*Picea obovata*) aus dem ganzen Holozän. Radiokarbondaten belegen, dass das Material seit 9400 Jahren in Flussedimenten abgelagert wird. Somit besteht die Möglichkeit zu Entwicklung einer temperatursensitiven mehrtausendjährigen Chronologie. Die absolute Chronologie reicht zurück bis ins Jahr 1248 BC. Die längste schwimmende Chronologie umfasst nahezu 3000 Jahre. Die Entwicklung einer 9000-jährigen absoluten Chronologie rückt in den Bereich des Möglichen.

RIASSUNTO

Elaborazione di una cronologia anulare plurimillenaria per la pianura siberiana: dati preliminari

Nella pianura settentrionale occidentale della Siberia si trovano moltissimi resti di tronchi, radici e rami di *Larix sibirica* e *Picea obovata* dell'Eocene. Secondo i rilievi radiometrici i reperti risalgono al 9400 BP, per cui esiste la pos-

sibilità di costruire una cronologia plurimillenaria con riferimenti climatici. La cronologia assoluta finora costruita arriva al 1248 B.C., mentre una cronologia fluttuante arriva a 3000 anni. In prospettiva si dovrebbe riuscire in tempi brevi a mettere a punto una cronologia di 9000 anni.

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