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GLACIATIONS IN THE VERKHOYANSK MOUNTAINS AND THEIR PLACE IN THE RADIOCARBON GEOCHRONOLOGY OF THE SIBERIAN LATE ANTHROPOGENE

PRESENT KNOWLEDGE OF THE RADIOCARBON GEOCHRONOLOGY OF THE LATE PLEISTOCENE AND HOLOCENE OF SIBERIA

Already in their first stage the geochronological investigations in Siberia made it possible to define the approximate time of the basic limits of the climatic fluctuations and glaciations in the Pleistocene, as well as to detect some parallelisms with other distant areas of the Old and New World (ALEKSEEV, *et al.*, 1965; KIND, 1965, 1966, 1968; KIND, *et al.*, 1969).

In the first approximation the chronological limits of the last two Upper-Pleistocene Siberian glaciations, i.e. the Zyryan glaciation (older than 30,000 years) and the Sartan glaciation (about 24,000—10,000 years BP) were defined. The age of the interglacial period which divides these two glaciations — called Karginian Interglacial — was dated 30,000—24,000 years and related to the European Paudorf and the Plum-Point or Farmdale of North America. Correspondingly, the Sartan glaciation was correlated to the maximum Würm and to the maximum or classical Wisconsin. Within the Zyryan glaciation the interstadial periods between 40,000 and 35,000—33,000 years were distinguished. Similar warmer periods were distinguished in a number of countries. In the Late Sartan period a short interstadial (consisting probably of two substages) was distiguished in the interval between 13,000 and 11,000 years, and this warmer period is chronologically related to the European Alleröd (possibly even to the Bölling) and to the Two-Creek Interstadial in North America.

Recently, as a result of geochronological investigations in the North Yenisey area and other Siberian regions new material has been collected, which made it possible to supplement the above scheme and to make it more precise. This concerns especially the age of the Karginian Interglacial and the chronology of climatic oscillations in the Late- and Post-Pleistocene. The results of these investigations and the foundations of the resulting supplements are presented in detail in a series of publi-

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cations (KIND, 1969 a, b; KIND, *et al.*, 1969; ČERDYNCEV, *et al.*, 1969). These relate to the following items:

(1) A series of C^{14} datings in the 43,500±700 (GIN—256) and 35,500±500 (GIN—258) range has been obtained from the analysis of wood and turf found in stratotype cross-sections in the lower Yenisey, and, among others, in flood alluvial deposits of the Karginian Terrace of the Small Kheta river, which were estimated by the palynological method (BARKOVA, 1961; ALEKSEEV, *et al.*, 1965). This gives reasons for extending the duration of the Karginian Interglacial as compared with previous interpretations. This interglacial, or a series of interglacial periods comprises, according to the new theory, the whole time interval between the Zyryan glaciation (50,000 years) and the Sartan glaciation (about 25,000—10,500 years BP). During this long period the climate fluctuated considerably.

In the Karginian Interglacial there were at least three warmer periods and two corresponding colder phases. The first amelioration began earlier than 45,000 years BP, but its age has not been yet precisely determined. The second warm period, according to the pollen spectrum, is related to the time interval between ca. 42,000—35,000 years. This amelioration, which can be traced at the same time also in other Siberian regions, was formerly associated with the late Zyryan warm period. The third warm period, 30,000 to 25,000—24,000, (interpreted formerly as the Karginian Interglacial) has not been ascertained in the area of the Yenisey mouth, where it corresponds to the development of erosional processes. It is distinctly marked, however, in other Siberian areas, and this is shown by a great number of radiocarbon datings.

(2) The age of the maximum stadial of the Sartan glaciation (19,900±500, GIN—311) has been defined on the basis of the vegetal detritus contained in ice-dammed lacustrine clays, associated genetically and spatially with the Sartan moraine in the Norilsk area (KIND, KRYUKOV, 1968). These data do not define precisely the beginning of the glaciation, they point, however, to the fact that about 20,000 years ago the northern area above the Yenisey river was covered with ice-sheet and extensive ice-dammed lakes.

(3) Late phase of the last, i.e. the Norilsk Stadial of the Sartan glaciation is estimated at 10,700±60 years (GIN—315). This applies also to the ice-dammed lacustrine sediments associated with the youngest and not extensive moraine of the Norilsk area. The above date defines the beginning of the process of shrinkage of mountain glaciers of this stadial.

(4) Radiocarbon datings of a number of palynologically investigated sections of Siberia enabled a more exact determination of the chronology of the climatic oscillations in the Holocene. The sudden amelioration of the climate in the transition period from the Late Pleistocene to the Holocene is dated for 10,300±1000 years. In the Early Holocene, about 9700—9500 years ago, there was a distinct though short-lasting deterioration indicated by the pollen spectra from some of the sections dated in the region of Norilsk, near the Igarka city, in the Middle-Yenisey basin,

as well as from other sections (KIND, GORŠKOV, ČERNYŠOVA, 1969; LEVKOVSKAYA, *et al.*, 1970). The long-lasting warm Holocene period — the Climatic Optimum — was fixed according to previous investigations to 8500—4500 years.

A modern approach to the absolute geochronology of the upper Anthropogene of the Siberian area above the Yenisey, based on C^{14} datings, is presented in detail in the enclosed diagram (left side of fig. 1).

The analysis of the geochronological data relating to other distant areas shows that the climatic changes and the glacial phenomena are not only similar in their general trends but also simultaneous in the whole Northern Hemisphere.

New theories concerning the duration and climatic characteristics of the Karginian glaciation of Siberia coincide with geochronological data from other continents and oceanic areas.

In Europe this period is known as Inter-Pleniglacial (GROSS, 1964) or Middle Würm (WOLDSTEDT, 1962), in England it is called the Upton-Worren Interstadial Complex (SCHOTTON, 1967; COOPE & SANDS, 1966), in Holland — Middle Interglacial (VOGEL & ZAGWIJN, 1967; VAN der HAMMEN, *et al.*, 1967), etc. In North America, this corresponds to the Port-Tolbot Interstadial in a broad sense (DREIMANIS, 1969; DREIMANIS & VOGEL, 1965; DREIMANIS, TERASMAE & MCKENZIE, 1966), to the Sydney Interstadial for Ohio (GOLDTHWAIT & FORSYTH, 1965) and to their counterparts in other areas of the U.S.A. In the European part of the U.S.S.R. this corresponds probably to the Mologo-Sheksninian Interglacial (MOSKVITIN, 1950; *et al.*), and the Karukiulas Interglacial in the Baltic area (PUNNING, 1969).

The climatic oscillations were simultaneous within the discussed period. Almost everywhere there was amelioration about 30,000—28,000 years BP (Paudorf, Stillfried B, Denekamp, and the analogous periods in Europe; Farmdale, Plum-Point, Bull-Lake Pinedale interglacials and the analogous periods in North America), a colder period about 32,000 years ago (formerly Würm 2), an amelioration within 41,000—37,000 years BP, Hungam Interstadial in Holland, an amelioration within the Alton period of the Wisconsin glaciation and so on; and also a still aerlier amelioration about 47,000 years BP ascertained for a number of European areas (for example the Peräpokjola Interglacial in Finland, KORPELA, 1969); in America this corresponds to the Port-Tolbot II Interstadial (Lake Erie area).

As far as the geochronological data relating to the oceanic areas are concerned, there is a number of data indicating that there was a pause in the Middle Würm, which divided two cold Upper-Pleistocene periods. On the EMILIANI's paleotemperature curve this period is found in the 50,000—25,000 years BP interval and is characterized by a complex scheme of temperature fluctuations (EMILIANI, 1964). This period is found as well on ERICSON'S curves for some of the Atlantic cores (ERICSON, 1961; ERICSON, EWING & WOLLING, 1964), although these temperature fluctuations are not apparent on his generalized curve. This theory is supported also by the data obtained by ROMANKEVIČ, BARANOV & KHRISTYANOVA, 1965), who point out that the amelioration in question is distinct in many borings in the ocean bottom.

In so far as the classical theories on the interrelation between sea trensgressions and interglacials, or sea regressions and glaciations are concerned, they can be considered as a confirmation of the existence of a remarkable amelioration in the Middle Würm, i.e. — the Wisconsin.

The rise of the World-Ocean level in the 50,000—30,000 years BP interval is evidenced certain oceanic areas: Voroncov Transgression in Alasca (MARKLIN, *et al.*, 1964; HOPKINS, 1967; KARLSTRÖM, 1964, 1965), twice-occurring rise of the Atlantic Ocean level on the Eastern coast (HOYT, WEIMER & HENRY, 1965), twice-occurring rise of the Mediterranean level (MÜLLER—BECK, 1967).

Not less striking is the chronological simultaneity between the lesser climatic oscillations in the Late Glacial and the Post-glacial of Siberia. The age assignated to the termination of the Norilsk stadial of the Sartan glaciation (about 10,700 years BP) makes it possible to correlate it with the Salpauselkä and with the Younger Dryas of Europe, as well as with the Valders stadial of North America. The Early-Holocene deterioration about 9700—9500 Years BP was found in some regions of the European part of the U.S.S.R. (KHOTINSKIJ, 1964), in Finland (VASSARI, 1962) and in Alaska (HOPKINS, MACNAIL & LEOPOLD, 1960; MCCULLOCH and HOPKINS, 1966; MCCULLOCH, 1967). It is interesting to note that this colder period was accompanied by a short-lasting lowering of the World-Ocean level at about the same time (MCCULLOCH & HOPKINS, 1966: Fig. 9; CREAGER & MCMANUS, 1967: Fig. 7).

There is a similar chronological conformity between the transition period from the Late Glacial to the Holocene (10,300±1000), the Holocene Climatic Optimum and the succeeding colder period.

ABSOLUTE CHRONOLOGY OF GLACIAL PHENOMENA IN THE VERKHOYANSK AREA

Detailed investigations of the stratigraphy of the Quaternary sediments, as well as of the history of glaciations of the Verkhoyansk mountain area and the adjacent regions were conducted by a large team of geologists from the Soviet Aerogeological Service. This team has for a number of years been occupied with the geological mapping of the total territory of the U.S.S.R. in the 1:200,000 scale.

As a result of these field studies six differently aged moraines and four rather small complexes of marginal forms have been found in the glacial valleys of the Verkhoyansk Mountains.

The age of these moraines has been determined on the basis of their relation to the sediments containing bone remains of fossil mammals. However, the relatively small number of fossil bones as well as the limited suitability of the paleontological method for a detailed plotting of the Middle- and Upper-Pleistocene stratigraphic levels have led to remarkable differences in the interpretation of the

geological age of the individual moraines. Under these circumstances it was necessary to use the radiocarbon method in order to determine the age of the particular series, whose mutual relation was explicit enough.

In 1966 the present author, together with V.V. KOLPAKOV and L.L. SULERŽICKIJ, initiated special field works and collected samples of wood and peat from sediments of various age in the Yundyulun river basin and in Lena valley, the Žigansk region. Further sampling was performed by V.V. KOLPAKOV in the years 1967—1968 in the basin of the lower Lena and along the Aldan. Several samples collected by the Soviet Aerogeol. Serv. geologists in different years were examined earlier. C_{14} analyses to determine the age of all the samples were made in the GIN Laboratory of the Academy of Sciences of the U.S.S.R. (ČERDYNCEV, *et al.*, 1969). Twenty two datings were obtained (see Fig. 1, right column).

The radiocarbon datings obtained have introduced such notable modifications in the estimates of the geological age of the particular series and, among others, of the moraine sediments that the whole history of glaciations in the Verkhoyansk Mountains region has received an entirely different interpretation (KIND, KOLPAKOV & SULERŽICKIJ, 1971).

Only one moraine among those found in the Verkhoyansk area proved to be too old for radiocarbon dating. This moraine was quite correctly defined as belonging to the Samarovo glaciation. Contrary to Western Siberia, where this glaciation had a maximum extension, in the Verkhoyansk area, the Samarovo moraine is of lesser extension than the younger moraines. It has been observed only in some cuttings on the steep banks of the right-hand tributaries of the Lena, and also in a boring in the Yundyulun basin. The Samarovo glacier reached the Lena probably only in the region of the Ulakhan-Kyuel lake, the Lena itself flowing at that time more to the East, along the old Sobopol-Sintekh valley, about 50 kms. closer to the Verkhoyansk Ridge than at present (KOLPAKOV, 1966). The river was dammed by the glacier and in the Sobopol-Sintekh valley, a thick series of clays containing cold pollen grains sedimented up-valley, the pollen being generally that of the dwarf birch and grass. These clays have been found in boring holes on the Mengkerečen river.

During the Samarovo glaciation, before the glacier's front there was a large cold desert, the traces of which are preserved in the form of a level of faceted quartz and flint pebbles (Žigansk region and other sites) or of diagonally stratified sands (right-hand bank of the Lena between Yakutsk and the mouth of the Aldan river). Eolian drifts cover the alluvial series, in which elephant (*Elephas trogontherii*) bones were found by N. I. GOGINA on the Tyung river, and on the Aldan (lower alluvial series of the 50 m terrace of the Mamontova Gora) the bones of elk (*Alees latifrans*) and of long-horned bison (*Bison longicornis*) were discovered by B. N. RUSANOV.

The succeeding moraine belongs to the greatest glaciation of the Verkhoyansk Mountain area. It can be observed in the lower part of the right-hand tributaries of the Lena and on the left bank of the Lena in the Žigansk region. This is a ground

moraine consisting of dark-grey, sometimes brown boulder-clays several metres thick. The geologists of the Soviet Aeorogeol. Service interpreted it as the Tazovsk moraine and the lacustrine-alluvial sediments above, which are covered by the third moraine — as the Kazan deposits. Radiocarbon datings prove that the interglacial sediments, as well as the moraines below and above this material, are much younger.

The composition of the lacustrine-alluvial interglacial sediments varies considerably. They are composed of grey sands evidently derived from the Verkhoyansk area, gravels and stones from the Verkhyoansk Mountains, sometimes silts mixed with sand or containing lenses of peat and logs of wood carried along by water. There is almost no base gravel, the socle surface is very uneven, its relative differences in level amounting to several tenths of metres, while the absolute height is ca. 120 m above sea level. The thickness of the deposits varies greatly, sometimes amounting to 40 metres. The moraine drifts are territorially associated with the valleys of the Lena and the Aldan and are rarely found along their tributaries. It is surprising that, although the deposits comprise also gravels and even boulders, the underlying moraine is practically unwashed. According to V. V. KOLPAKOV, this suggests that the accumulation of the series took place when support from the waters of the Lena were dammed, which might have been due to transgression of ice-sheet in the North.

Interglacial sediments contain fossil bones of the late-type of the Upper Paleolithic complex, including late mamoth, short-horned bison and other animals.

12 datings were obtained for the interglacial sediments by the radiocarbon method in the 40,000±700 (GIN—343) and 33,600±700 (GIN—339) years BP interval (fig. 1).

The datings obtained make it possible to associate the interglacial sediments discussed with the Karginian drifts in the Lower Yenisey area. A relatively short range of datings from the region of the Lena can be perhaps explained by the fact that sampling was to a great extent random; the samples were not collected in the whole section, but only where wood or peat were found.

The perfectly preserved moraine underlying the Karginian lacustrine-alluvial sediments may suggest that their accumulation took place soon after the glacier had receeded. On the basis of these deposits the age of the moraine can be fairly determined as Zyryan.

The third in age moraine belongs to the short Žigansk glaciation, which extended, however, almost as far as the Zyryan glaciation. The moraines of this stadial, rather thin, extend in some places as far the Lena and the Aldan. In the region of Žigansk and a little southward the glacier probably crossed the Lena valley, and extended to its left bank area, leaving erratic wind-worn stones covered by younger lacustrine-alluvial silts and sandy silts.

The Žigansk stadial moraine — ground moraine only — is represented by grey and dark-grey boulder clays several metres thick. In the valleys of the Lena and

the Aldan, the moraine lies on Karginian drifts, near the Verkhoyansk Mountains, but it lies as well on the substratum rocks, outcropping to the surface.

The boundaries of the glacier of the Žigansk stadial have not been accurately defined. The glacier of this stadial covered an extensive area and had the form of a piedmont glacier, but it was too short-lived to leave any terminal land-forms or drifts.

The alluvial series of limited extent on the 20—30 m Lena terrace is laid between desert and glacier drifts. The alluvial series is represented by coarse basel gravels, river-bed sands, sandy silts and oxbow muds. The rocky base is 5—10 m in height. These alluvia, just like the Žigansk moraine, are overlain by sand-containing alluvial-lacustrine silts, which are contemporary of the younger stadium of the Ulukhan-Kyuel glaciation.

Wood samples were collected during several years from the alluvium of a 20—30 m terrace 7—8 kilometres South of Žigansk, and their age was dated by C^{14} analyses to 29,500±500 (GIN—345) and 30,400±300 (GIN—224) years BP. These datings, together with those of the inter-moraine Karginian drifts, allow of a precise determination of the age of the Žigansk stadial. It is possible to state with certainty that it started 33,000 years and finished 30,000 years BP. Taking into account the fact that the GIN 224 and 345 datings relate to the middle part of the alluvial series of the second terrace which is eroded in the glacial deposits of this stadial, the lower time limit of this stadial will be still lowered and its duration will of course be shortened. In other words, the Žigansk stage was a short one indeed and comprised no more than 2000 or even less than 1000 years.

As far as age is concerned, the Žigansk stadial corresponds to a distinct deterioration of the climate about 32,000 years ago which in the Yenisey basin made itself evident by the formation of a level with cryogenic disturbances, while the cold interval before the Paudorf was characterized in Europe by the development of forests (former Würm 2) and by oscillation of the ice-sheet in some regions of North America which directly preceeded the Plum-Point and Farmdale Interstadials. On the other hand, the age of the interstadial between the Žigansk and the following Ulakhan-Kyuel stadial, which corresponds to the accumulation of the alluvia of the second terrace of the Lena and which is known as the Lower-Lena Interstadial, (beginning not later than 30,000—29,000 years) also corresponds to the age of the last Inter-Karginian (Lipovsk—Nakannovsk) amelioration i the Siberian areas lying more westward, and to the age of the above mentioned Paudorf Interstadial of Europe and also, to some extent, to the Plum-Point and Farmdale interstadials of North America.

The fourth, fifth and sixth moraines correspond to the Ulukhan-Kyuel, Sigenekhsk and Segemdynian stadials. No inter-moraine deposits were found between them; all the three moraines are not covered and occur on the surface. These three stadials were distinguished chiefly on the basis of geomorphological data. The pern fectly shaped, amphitheatrically distributed terminal moraines appearing in the-

glacial valleys descending from the mountains, are associated with the Ulukhan-Kyuel and Segemdin stadials. The end-moraine land-forms of the middle Sigenekhsk Stadial were distinguished only in some river valleys.

Among the amphitheatrical end-moraine forms, moraine ridges were distinguished, built of glacigenic and glaciofluvial deposits, varying in composition and ca. 100 m thick, their inner parts consisting of gravel in the lower and of sand or sand-containing silts in the upper portion. Such glaciofluvial and ice-dammed lacustrine clays are sometimes 50 m thick. The amphitheatres are arranged concentrically owing to the gradual decay of the glacier ice.

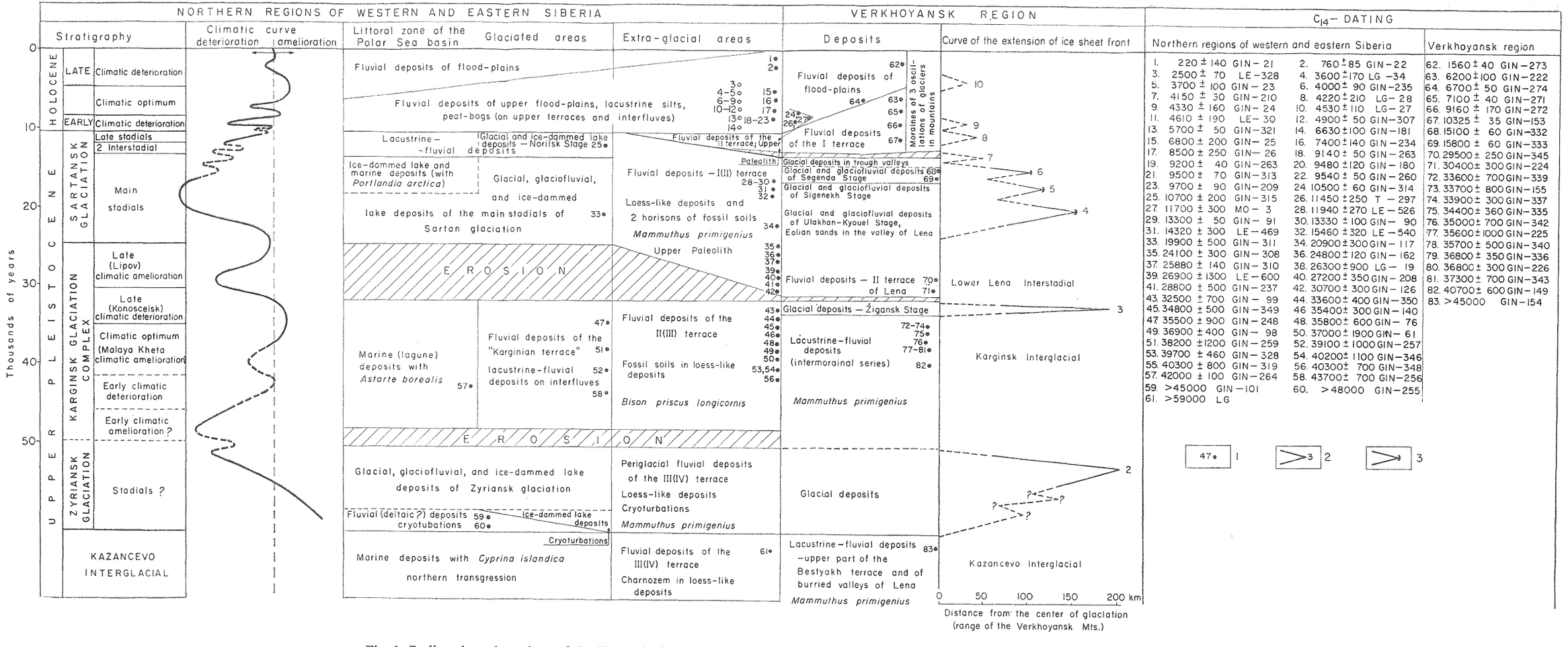
The horizon of fossil eologlyptoliths observed in the Lena valley from the mouth of the Vilyuj river to the Kyusyur village is associated with the moraine of the Ulukhan-Kyuel Stadial. It consists mainly of moraine boulders of the Žigansk Stadial which was exposed to wind action. It differs in composition from the Samarovo level of eologlyptoliths which consists exclusively of quartz and flint rock fragments.

Among the three last stadials only the glacio-lacustrine dark-grey stratified sands of the Segendinsk Stadial from above the Yundyulun river have been investigated by the radiocarbon method. These sands were accumulated in the inter-moraine lakes during the recession of the glaciers. They are 50 m thick. Sand accumulation was quick, but seems to have been of short duration, because the water usually broke through the terminal-moraine ridges and the lakes became drained.

The following results of the radiocarbon analysis for the upper part of the glacio-lacustrine sands of the Segendinsk Stadial on the Yundyulun river were obtained in two sections: 15,100±60 (GIN—332) and 15,850±60 (GIN—333) years BP. These datings correspond to the second half of the Sartan glaciation. The two preceeding stadials, i. e. the Ulukhan-Kyuel and the Sigenekhsk stadials, whose moraines were formed certainly after 29,000 years, and most probably after 26,000 years BP also belong to the Sartan glaciation, if the datings for other regions of Siberia relating to the warm period are taken into consideration.

The absolute age of the terminal or oscillation moraines in the glaciated valleys of the Verkhoyansk Mountains was not investigated. The largest and oldest of these moraines (the 7-th moraine) may be associated with the 14,000—13,000 years BP interval and the similary aged oscillations, which were ascertained in other distant areas. The next oscillation (8-th moraine) is said to be associated with the Norilsk Stadial of the northern area above the Yenisey rever (about 1100 years BP) and with the Salpausselkä in Europe. The two youngest, 9-th and 10-th moraines belong probably already to the Holocene. Possibly, the first corresponds to the early Holocene and the second to the post-altithermal deterioration.

That the 7-th and 8-th moraine were correctly related to the Pre-Holocene and Late-Sartan formations is indirectly testified by the fact that they are associated with the I above-flood terrace of the right-hand tributaries of the Lena



C_{14} – DATING

Northern regions of western and eastern Siberia				Verkhoyansk region	
1.	220 ± 140 GIN – 21	2.	760 ± 85 GIN – 22	62. 1560 ± 40 GIN – 273	
3.	2500 ± 70 LE – 328	4.	3600 ± 170 LG – 34	63. 6200 ± 100 GIN – 222	
5.	3700 ± 100 GIN – 23	6.	4000 ± 90 GIN – 235	64. 6700 ± 50 GIN – 274	
7.	4150 ± 30 GIN – 210	8.	4220 ± 210 LG – 28	65. 7100 ± 40 GIN – 271	
9.	4330 ± 160 GIN – 24	10.	4530 ± 110 LG – 27	66. 9160 ± 170 GIN – 272	
11.	4610 ± 190 LE – 30	12.	4900 ± 50 GIN – 307	67. 10325 ± 35 GIN – 153	
13.	5700 ± 50 GIN – 321	14.	6630 ± 100 GIN – 181	68. 15100 ± 60 GIN – 332	
15.	6800 ± 200 GIN – 25	16.	7400 ± 140 GIN – 234	69. 15800 ± 60 GIN – 333	
17.	8500 ± 250 GIN – 26	18.	9140 ± 50 GIN – 263	70. 29500 ± 250 GIN – 345	
19.	9200 ± 40 GIN – 263	20.	9480 ± 120 GIN – 180	71. 30400 ± 300 GIN – 224	
21.	9500 ± 70 GIN – 313	22.	9540 ± 50 GIN – 260	72. 33600 ± 700 GIN – 339	
23.	9700 ± 90 GIN – 209	24.	10500 ± 60 GIN – 314	73. 33700 ± 800 GIN – 155	
25.	10700 ± 200 GIN – 315	26.	11450 ± 250 T – 297	74. 33900 ± 300 GIN – 337	
27.	11700 ± 300 MO – 3	28.	11940 ± 270 LE – 526	75. 34400 ± 360 GIN – 335	
29.	13300 ± 50 GIN – 91	30.	13330 ± 100 GIN – 90	76. 35000 ± 700 GIN – 342	
31.	14320 ± 300 LE – 469	32.	15460 ± 320 LE – 540	77. 35600 ± 1000 GIN – 225	
33.	19900 ± 500 GIN – 311	34.	20900 ± 300 GIN – 117	78. 35700 ± 500 GIN – 340	
35.	24100 ± 300 GIN – 308	36.	24800 ± 120 GIN – 162	79. 36800 ± 350 GIN – 336	
37.	25880 ± 140 GIN – 310	38.	26300 ± 900 LG – 19	80. 36800 ± 300 GIN – 226	
39.	26900 ± 1300 LE – 600	40.	27200 ± 350 GIN – 208	81. 37300 ± 700 GIN – 343	
41.	28800 ± 500 GIN – 237	42.	30700 ± 300 GIN – 126	82. 40700 ± 600 GIN – 149	
43.	32500 ± 700 GIN – 99	44.	33600 ± 400 GIN – 350	83. > 45000 GIN – 154	
45.	34800 ± 500 GIN – 349	46.	35400 ± 300 GIN – 140		
47.	35500 ± 900 GIN – 248	48.	35800 ± 600 GIN – 76		
49.	36900 ± 400 GIN – 98	50.	37000 ± 1900 GIN – 61		
51.	38200 ± 1200 GIN – 259	52.	39100 ± 1000 GIN – 257		
53.	39700 ± 460 GIN – 328	54.	40200 ± 1100 GIN – 346		
55.	40300 ± 800 GIN – 319	56.	40300 ± 700 GIN – 348		
57.	42000 ± 100 GIN – 264	58.	43700 ± 700 GIN – 256		
59.	> 45000 GIN – 101	60.	> 48000 GIN – 255		
61.	> 59000 LG				

Fig. 1. Radiocarbon chronology of the Upper Anthropogene of Northern Siberia (North of Western and Eastern Siberia, region of Verkhoyansk)

1. stratigraphical position of C^{14} dating, years – in the right-hand part of the table; 2. nos. of moraines (explanation in the text); 3. amphitheatrical end-moraines

which spring from the Verkhoyansk Mountains. This terrace extends from the moraine ridge of the 7-th stadial and does not appear in the interior of the mountains. Several radiocarbon datings have been obtained for the exposed alluvial series of the terrace: 10,325±35 (GIN—135), 9260±70 (GIN—272), 7100±40 (GIN—271) and 6200±50 (GIN—222) years BP. On the basis of these datings it seems most logical to associate the incision of the rivers and the beginning of the formation of the I terrace with the Late-Sartan amelioration, whose age for the regions of Siberia lying more westward as fixed at the interval between 13,000 and 11,000 years BP, which corresponds to the Bölling and the Alleröd in Europe. This period also corresponds to the beginning of formation of the first river terraces in the adjacent areas. On the other hand, the formation of this terrace started most certainly just after the melting of the glaciers which resulted in the formation of the moraines of the 7-th range and after the drainage of water and of the associated glacial lakes. No doubt, these facts confirm the previous estimation of the 7-th moraine at 14,000—13,000 years BP.

The Post-Alleröd (Late-Sartan) deterioration which, distinct everywhere, caused oscillation of the glaciers in the North of Siberia (Norilsk Stadial), in Europe (Salpausselkä) and in America (Valders Stadial) was bound to appear also in the Verkhoyansk area and to bring about another oscillation of the mountain glaciers, which probably corresponds to the 8-th moraine.

Thus, several stadials of one uniform Sartan glaciation can be distinguished in the area around the Verkhoyansk Mountains. These stadials correspond to the moraines numbered 4 to 8. As mentioned above, no interstadial sediments dividing these moraines from one another were found. The time intervals between these stadials were most probably short and rather cold.

The particular stadials of this glaciation can be therefore rather considered as oscillations of the glacier's front with a general tendency to recede. In this respect the Sartan glaciation was similar to the glaciation of the North Yenisey area, to the glaciation of Northern Europe (W3) and to the main Wisconsin, to which it corresponds also in time.

CORRELATIONS AND CONCLUSIONS

The comparison of the schemes of the absolute geochronology of the Verkhoyansk and Yeniseyan areas of Siberia discussed above (Fig. 1) points to the fact that the main geological and climatic phenomena of the Late Anthropogene were in these regions practically simultaneous.

There is, however, an essential difference in the Upper-Pleistocene glaciation process of these region. It consists in the short-lived Žigansk stage, distinguished as an independent oscillation of glaciers, which is fairly distinct in the Verkhoyansk area and which has no counterparts, except for certain Northern regions of the U.S.A. and Canada.

As a result a problem arises: Should the Žigansk Stadial be referred to the Zyryan or to the Sartan glaciation? It is divided from the first one by a long warm period during which the series of inter-moraine sediments were accumulated. From the Sartan glaciation proper, on the other hand, it is divided by a distinct interstadial amelioration which is marked by certain geological processes, such as incision of rivers and accumulation of the alluvia of the II terraces.

With the geochronological scheme for the northern part of the Yenisey area as a basis, this stadial should be considered as belonging to the Karginian period. Chronologically, it corresponds to the last deterioration about 32,000 years BP (former W 2 in Europe). It can be associated with the pre-Plum-Point ice-sheet oscillation in Canada, which does not correspond to the main, but to the middle Wisconsin (DREIMANIS, 1969; DREIMANIS & VOGEL, 1956; DREIMANIS, TERASMAE & MCKENZIE, 1966)

During the Žigansk Stadial, on the other hand, the glacier covered a greater area then during any of the succeeding stadials of the Sartan glaciation. This is peculiar for the Verkhoyansk area.

Taking into consideration this peculiar local feature of the mountain glaciation, is it possible to elaborate a new geochronological scheme differing from that for other regions of Siberia and from the majority of schemes for other more distant areas? In other words, should the duration of the Sartan glaciation be extended, as compared to the duration of the Main Würm, classical Wisconsin and corresponding glaciations which were simultaneous and similar in character in various parts of the Northern Hemisphere?

In our opinion, the problem of division of these two glaciations is not essential, just like other divisions in all schemes, which are intended not so much to present the correct image of the development of nature as to give an expression to our knowledge of this development. Nevertheless schemes are necessary for the purpose of mutual communication, and also for making extensive correlations, but above all, to enable us to distinguish the peculiar features of processes occurring simultaneously in different distant areas and try to explain their cause.

Bearing this in mind, we believe that it is more correct to establish the boundary of the Sartan glaciation across the area surrounding the Verkhoyansk Mountains, over the Upper-Lena Interstadial corresponding to the Paudorf in Europe, as well as to include conventionally all the stages beginning with the 4-th (Ulukhan-Kyuel) stage to the 8-th stage, which can be found only in the mountains.

What is the cause of the peculiarity of the Upper-Pleistocene glaciations of the Verkhoyansk area, which are discernible not only by the unexpectedly wide extension of the glaciers of the Žigansk stadial, but also in the scale of the Samarovo glaciation, which was much lesser in extent than the last Zyryan glaciation? With our present rather incomplete knowledge of the general causes of glaciations a definite answer to this question cannot be expected. It seems that beside the specific development of climate of the Verkhoyansk mountain area and, among others,

the specific variations of humidity, constituting the main factor of the glacier's growth, the process of glaciation could be largely influenced by the altitude of the alimentation area, i.e. of the Verkhoyansk Ridge itself. It is very probable that during the Samarovo glaciation the absolute height of the mountains was even smaller than at present, and that the uplift of the Verkhoyansk Mountains was particularly quick in the Post-Samarovo period.

All that was said above is a mere speculation so far. Before solving these complex problems, a detailed inquiry into the still poorly known history of the climatic fluctuations and neotectonic movements of this area should be undertaken, covering many aspects of these questions.

Closing this article I wish to stress that taking as an example glaciations in the Verkhoyansk area, it is possible to prove that, in spite of the fact that the climatic changes in the Anthropogene were simultaneous, the geological processes resulting from these changes, and above all the glaciations, are evidenced in various dissimilar ways in the particular areas of the Earth.

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