

THE RECENT NATURE OF THE SIBERIAN POLE OF COLD*

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ABSTRACT. The Siberian pole of cold is situated in the extreme north-east of Eurasia (in the region of the Cherskiy mountain system, in the upper parts of the basins of the Yana, Indigirka and Kolyma Rivers). Particularly low air and soil temperatures have been observed in the intermontane areas. Among these localities is the famous Oymyakon, where the lowest minimum temperature in the Northern Hemisphere has been recorded. In the climate of this area extreme aridity, connected with the intracontinental position of the territory, is combined with intense cold.

In the two highest massifs (Ulakhan-Chistay and Suntar-Khayata) small centres of recent glaciation (chiefly kars) are developed; there are also distinct traces of a more extensive older mountain glaciation. In the intermontane areas and on the principal level of the dissected hilly peneplain positive indications of a former glaciation are absent. However, the recent cryogenic phenomena represented by fossil ice, permafrost, taryns, as well as thermokarstic, solifluction and congelation features, are very abundant and diverse.

The widespread development of all these features gives this territory a periglacial aspect, and also provides the possibility of using the study of many recent phenomena for palaeogeographical purposes. From this point of view, the processes leading to the formation of loess deposits (cryogenic facies) and the formation of structural and thixotropic soils are of particular interest.

The recent natural landscapes in this region are represented by a dominant type of larch tundra-forest associated with comparatively typical taiga bog formations in the depressions and xero-cryophile meadow-steppe landscapes on the steeper and warmer southern slopes. Such a unique landscape combination connected with the specific climatic conditions of this region provide a basis for interpreting the recent natural conditions of the Siberian pole of cold as a survival of the "late glacial." At present these natural conditions are being intensively developed economically.

RÉSUMÉ. Le pôle Sibérien du froid est situé dans l'extrême Nord-Est de l'Eurasie (région du système montagneux de Cherskiy, parties supérieures des bassins des rivières Yana, Indigirka et Kolyma).

Des températures de l'air et du sol particulièrement basses ont été observées dans les régions situées entre les montagnes. Parmi ces régions se trouve notamment le célèbre Oimyakon, où le minimum de température de l'hémisphère Nord a été enregistré.

Dans le climat de cette contrée l'aridité extrême, jointe à la position intracontinentale du territoire, s'accompagne d'un froid intense.

Dans les deux plus hauts massifs (Ulakhan-Chistay et Suntar-Khayata) de petits centres de glaciation récente (principalement des kars) se sont développés; il existe aussi des traces distinctes d'une glaciation de montagne plus étendue. Dans les régions entre les montagnes et sur le niveau principal d'une pénéplaine entrecoupée de collines, il n'apparaît pas d'indication positive de glaciation antérieure. Cependant, le phénomène cryogénique récent représenté par de la glace fossile, des sols gelés, des "taryns" aussi bien que les caractères de karst thermiques, de solifluction et de congélation, sont très abondants et variés.

Les très large développement de tous ces caractères donne un aspect périglaciaire à ce territoire, et fournit aussi la possibilité d'utiliser l'étude de nombreux phénomènes récents à des fins paléogéographiques. A ce point de vue, les processus conduisant à la formation de dépôts de loess facies cryoturbé et à la formation de sols structuraux et thixotropiques sont d'un intérêt particulier.

Le paysage naturel récent de cette région est représenté par un type dominant de "toundra-forêt" à mélèzes associé avec des formations comparativement typiques de taiga marécageuse dans les dépressions et des paysages de "prairie-steppe" sèches et froides sur les pentes Sud plus abruptes et plus chaudes. Une telle combinaison unique de paysages liée aux conditions climatiques spécifiques de cette région fournit une base d'interprétation pour les conditions naturelles récentes du pôle Sibérien du froid en tant que vestige de la "dernière glaciation". Actuellement ces conditions naturelles ont été intensivement développées à des fins économiques.

ZUSAMMENFASSUNG. Der Sibirische Kältepol liegt im äussersten Nordosten Eurasiens (im Gebiet des Tscherskiy-Gebirges in den oberen Becken der Flüsse Jana, Indigirka und Kolyma). Besonders tiefe Luft- und Bodentemperaturen wurden im Zwischengebirgsgebiet gemessen. Zu diesen Plätzen gehört das bekannte Oimjakon, wo die tiefste Temperatur auf der nördlichen Hemisphäre beobachtet wurde. Im Klimadieses Gebietes treten infolge seiner ausgesprochen kontinentalen Lage extreme Trockenheit und heftige Kälte zusammen.

In den beiden höchsten Massiven (Ulakan-Tschistai und Suntar-Chajata) sind kleine Zentren einer rezenter Vergletscherung (vor allem Kare) entwickelt; man findet auch deutliche Spuren einer früheren, stärkeren Gebirgsvergletscherung. Im Zwischengebirgsland und im Hauptniveau der aufgedichteten, hügeligen Fastebene fehlen sichere Anzeichen für eine frühere Vergletscherung. Doch gibt es in reichem Masse die verschiedensten frostbedingten Erscheinungen wie fossile Eiskerne, Permafrost, oberflächliches Bodeneis, ebenso wie Ausprägungen von Thermokarst, Solifluktion und Gefornis.

Das weitverbreitete Auftreten all dieser Erscheinungen gibt dem Gebiet einen periglazialen Charakter und ermöglicht das Studium vieler rezenter Vorgänge für paläogeographische Untersuchungen. Aus dieser Sicht sind die Vorgänge, die zur Bildung von Lössablagerungen (cryogenetische Fazies) führen, und die Bildung von Struktur- und thixotropischen Böden von besonderer Bedeutung.

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Die heutigen Naturlandschaften des Gebietes sind durch einen vorherrschenden Typus von Lärchen-Tundra-Wald, verbunden mit vergleichsweise typischen Taiga-Moorbildungen in den Niederungen und xero-cryophilen Grassteppen-Landschaften auf den steileren und wärmeren Südhängen gekennzeichnet. Eine solch einzigartige Landschaftskombination ermöglicht in ihrer Verbindung mit den spezifischen Klima-Verhältnissen des Gebietes eine Deutung der heutigen natürlichen Situation des Sibirischen Kältepoles als ein Relikt aus dem Spätglazial. Gegenwärtig erfahren die natürlichen Bedingungen eine intensive wirtschaftliche Entwicklung.

THE Siberian pole of cold is located, as is known, in the north-east of the U.S.S.R., within an extensive geodetic trapezium formed by lat. 62° and 68° N. and long. 94° and 160° E. (Fig. 1). The main factor determining its existence is an intense refrigeration of this part of the Asiatic continent during the cold half of the year and the formation of a stable centre of high atmospheric pressure. Owing to such a meteorological situation, exceptionally low temperatures of the air during a very long Winter, virtually free of snow, are replaced here by a short but warm and arid Summer. The following climatological data illustrate some of the outstanding features of this region.

Climatological data	Meteorological stations	
	Oymyakon	Verkhoyansk
Absolute temperature minimum	-71° C.	-68° C.
Mean value of annual absolute temperature minima	-65° C.	-61° C.
Mean value of temperature (year)	-15° C.	-15.6° C.
Total precipitation (in mm.)	222	154
Total length of frostless period (days)	—	69

The middle part of the Siberian pole of cold area is occupied by the Verkhoyansk mountain range with peaks not exceeding 2,000 m. above sea-level. West of it is the central Yakutsk plain, which is the lowest and most eastern part of the middle Siberian upland. East of the Verkhoyansk range is a series of mountain masses of complex geological structure around the upper reaches of the rivers Yana, Indigirka and Kolyma, which includes the Yana-Oymyakon highland, the Suntar-Khayata range, the Matyushkin chain, the Cherskiy mountain system, etc. This territory includes two of the highest mountain areas which have been subjected to recent glacierization; the Suntar-Khayata and Buordakh Mountains are the highest groups with Mus-Khaya (2,959 m.) and Pobeda (3,147 m.) as the summit peaks of each range, respectively. However, the coldest regions within the area of the Siberian pole of cold are intermontane depressions within the mountain country on the rivers Yana, Indigirka and Kolyma. The coldest of these areas is the Oymyakon depression, where an absolute temperature minimum of -71° C. has been registered.

Obviously, the coldest area in the world inhabited by man has long interested Russian geographers, such as A. A. Krasnov, M. I. Sumgin, A. A. Grigor'yev, etc., as well as geologists I. D. Cherskiy, A. L. Chekanovskiy and V. N. Zverev, who have studied and described this territory. However, only recently have systematic geographical researches been organized in this territory. They have resulted from the demands of the rapidly developing national economy of Yakutiya and Kolyma, the natural resources of which include very rich deposits of gold, diamonds and other valuable minerals, and the surface provides varied agricultural and biological resources. The widespread character and increase in tempo of geographical research work in north-eastern Siberia have made it one of the best-known territories in the Soviet Union.

The author has had the opportunity of visiting this area twice.¹ The first trip, in 1952, was to the city of Yakutsk with a short excursion into the central Yakutsk plain. The second excursion, in 1959, also started from Yakutsk flying to the northern end of the famous Kolyma route to Magadan, crossing the Yana-Kolyma mountain land *en route*. This paper is concerned with the general impressions of the physical geography gained on these journeys, supplemented by some data from published sources.

Owing to the great expanse and variety of the relief and geological structure, the present-day natural landscape of the Siberian pole of cold area is far from uniform (Figs. 2 and 3, p. 1093). Yet, it is quite distinctive in the same way that its climatic conditions are so special. The main features of this landscape can be shown to be due to the later phases of the last glaciation. This first of all assumes that the specific climatic features of the Siberian pole of cold are, to a certain extent, an analogue of the climatic situation, characteristic of the end of the glacial period in the mountain-plain regions of middle and eastern Europe. Special

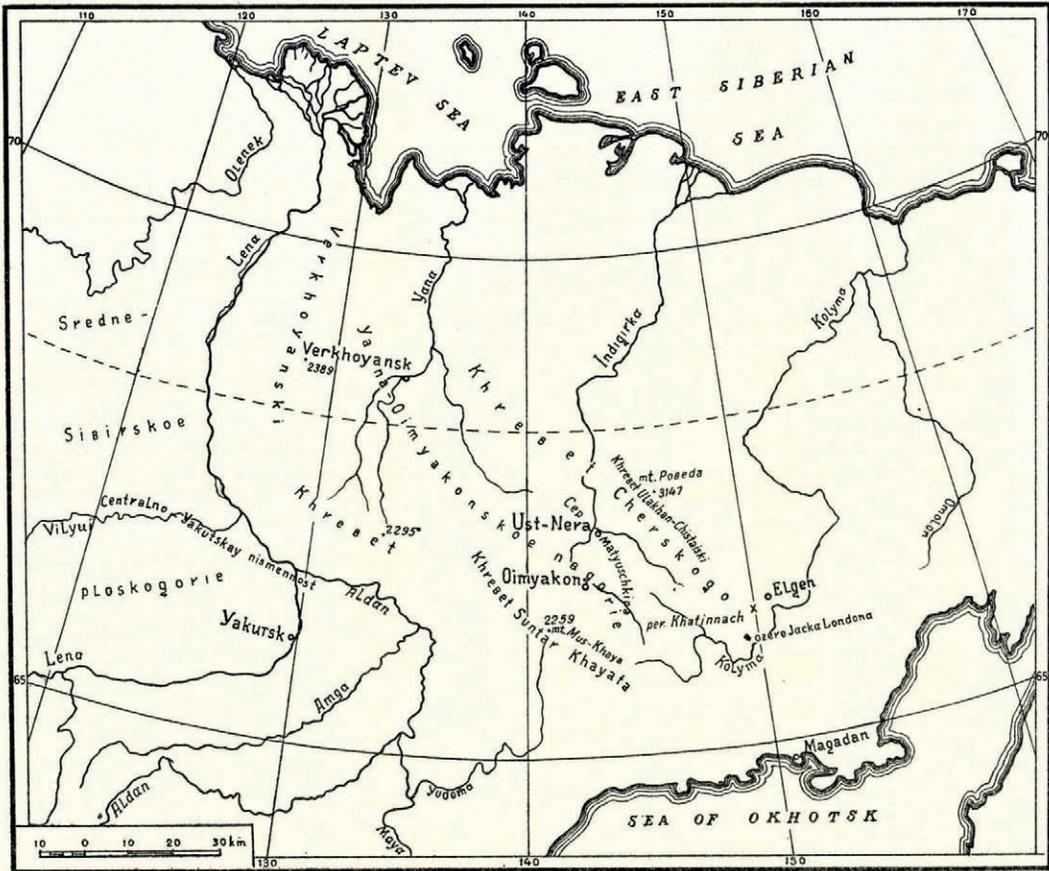


Fig. 1. Map showing the position of the Siberian pole of cold

importance is attached in these situations to the combination of intense aridity and severe cold during the long winter season (caused by strong azonal factors) with a short, warm Summer, characteristic of the mid-latitude geographical position of the compared regions.

Such a climatic analogy is confirmed by comparing many of the recent Siberian landforms with the old morphology of Europe.

The most important and widespread feature in the physical landscape of the territory of the Siberian pole of cold is the development of permafrost, icings* (taryns) and masses of

* An icing (taryn) is a build-up of ice on top of the existing ice cover of a river or the ground. River icings result from the freezing of water on river ice. Ground icings result from the freezing of ground water on the surface layers in permafrost regions.

fossil ice, despite the limited extent of recent glacierization. As already mentioned, the latter is developed only in two mountain areas and is of a small size. Thus, the area under ice in Suntar-Khayata amounts to only 160 km.², though individual glaciers may reach several kilometres in length and are up to 100 m. thick. At the same time, below the snouts of the recent glaciers, we find very fine trough valleys, with well-preserved moraines at a distance of 20–30 km. from the fronts of the glaciers.² During our trip to the Kolyma River area (in 1959) we visited a typical area of old glaciation, around Jack London Lake. We found here beautifully preserved trough valleys with a system of morainic forms, i.e. obvious traces of a recent mountain–valley ice cover.

Thus, this minor glacierized area of the Siberian pole of cold is a remnant of a somewhat larger mountain–valley glaciation, which existed here during the recent geological past. Unlike more western (as well as more eastern) territories with a much greater humidity than north-east Siberia, this area never had a thick continental ice cover. Since the ice bodies of this area were smaller in area and thickness than in adjacent regions, they were in existence for a long period owing to the constancy of climatic conditions.

Permafrost is developed almost everywhere; isings (taryns) are also very widely developed. In the mountainous areas of Suntar-Khayata and Jack London Lake they are especially thick and persistent. Masses of fossil ice are much more localized. They are especially characteristic of old alluvial plains. Within the central Yakutsk plain, for instance, masses of fossil ice are especially numerous, associated with typical thermokarstic relief* forms in unforested areas (“allasses”).

The origin and age of these cryogenic forms raises many interesting scientific problems. The age of permafrost is the subject of much discussion amongst Soviet geographers. Some of them have advanced a number of arguments in favour of a considerable age for the permafrost (for instance, a great thickness, intense supercooling, preservation of animal bodies, etc.). Others, on the contrary, have presented different proof of its later origin (like the freezing of flood plain deposits, etc.). It is quite possible, that both viewpoints should be combined; in other words, maybe one should assume that, having been formed a considerable time ago, permafrost within the area of the Siberian pole of cold continued to be formed under conditions similar to the present. Recent perennial river icings serve as an indirect proof of such an assertion.

Also, a matter of dispute is the question of the origin of fossil ice. Former views, that the majority of such forms represent buried old firn, or ice of atmospheric origin are losing more and more adherents. On the contrary, with greater insistence the viewpoint is advanced that these ice bodies are due to secondary infiltration (congelation ice according to P. A. Shumskiy³), i.e. that they are accumulations of frozen underground waters which have penetrated through frost clefs into the internal voids of the rocks.

Anyway, the wide development of these cryogenic forms throughout the entire area of the Siberian pole of cold is an important indication of the recent late glacial regime of this territory. It is more than probable that all such physical and geographical phenomena were extensively developed in the periglacial area of the Scandinavian ice sheet. However, it is obvious that their presence was not the only factor.

Recent natural landscapes in the area of the Siberian pole of cold can, generally speaking, be divided into four main types. The first type is represented by the so-called *goletz-y-treeless landscapes* of a mountain–tundra type with a characteristic micro-relief on all more or less horizontal stretches (Fig. 4, p. 1094). At the Khotynnakh Pass (720 m. a.s.l.), for instance, in the basin of the River Kolyma, the surface of a typical goletz,† consists of the following elements:

* Specific forms of relief that are developed by the processes of thawing of fossil ice in certain regions.

† In Siberia the term goletz is used to describe mountain peaks that rise above the tree line. Such peaks are either free of vegetation (stony) or covered with scarce grass or bushes.



Fig. 2. The typical landscape of the Siberian pole of cold

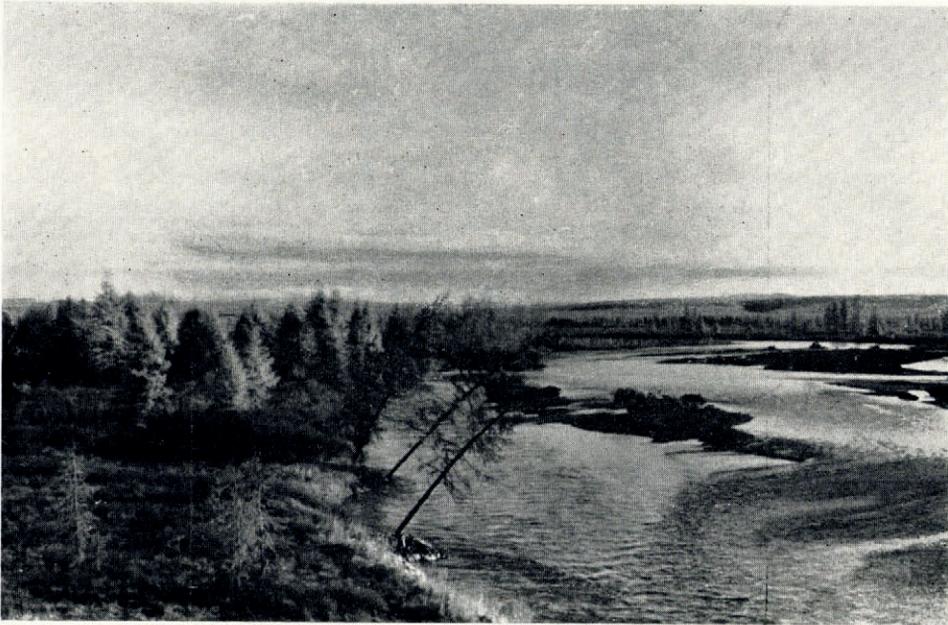


Fig. 3. A typical valley of the Siberian pole of cold



Fig. 4. Typical goletzy landscape; a treeless landscape of a mountain-tundra type with a characteristic micro-relief

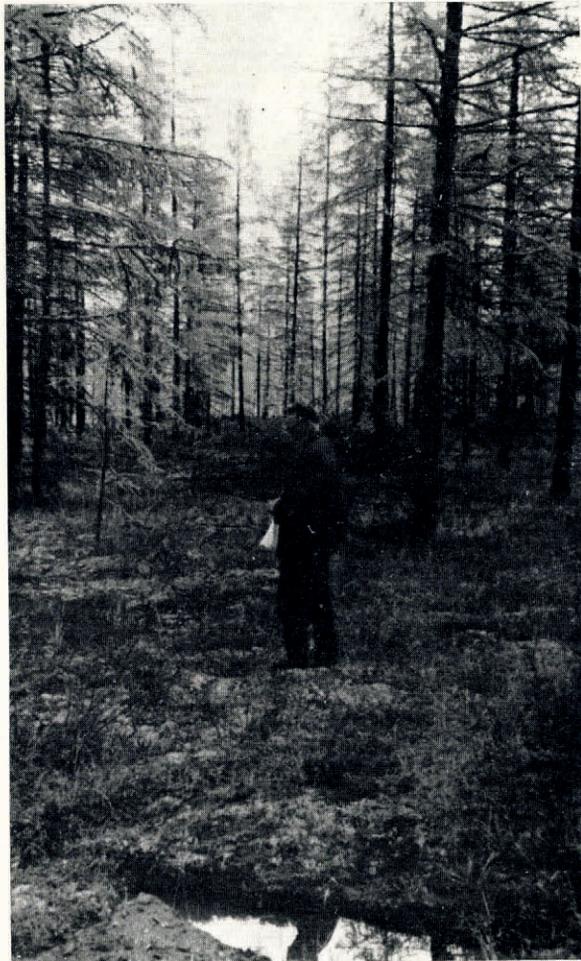


Fig. 5. Humid frozen larch taiga

1. Flat, bare knolls up to 2 m. in diameter and 0·5 m. in height, built of rubble, obviously squeezed out from below (occupying 30–40 per cent of the area).
2. Depressions between the knolls (up to 50 per cent of the surface) with a continuous moss–lichen cover and crippled bushes of dwarfed birches.
3. Patelliform depressions, which are actually separate expansions of large clefts with larger bushes of birch and young larch.

Soil sections cut in the goletz revealed peculiar cryogenic soils, which are acidic and well-leached, with distinct signs of an intense intermixing of the soil mass by the frost action and thixotropic phenomena.* Such goletzy landscapes, exhibiting the features described above, occupy all the upper zones of the large and small uplands in this region.

The second type of natural landscape in the territory of the Siberian pole of cold is the *humid frozen larch taiga* (Fig. 5, p. 1094). This type of landscape is developed here on all more or less flat (poorly drained) relief elements below the goletzy belt. As an example of such a landscape a stretch can be described in the basin of the River Indigirka (Ust'-Nera), located on a high terrace-like surface built of old pebbly alluvium. We find here a sparse larch taiga with birches and willows in the undergrowth. The soil is covered by a thick moss–lichen cushion; the ground is frozen to a depth of 60 cm. and the surface is slightly hummocky. The soil is rather peculiar—*cryogenic-solifluction*, very acid, with obvious signs of internal movements reflected in intense intermixing of the soil mass due to freezing and thawing.

A rather widely developed variety of this type of landscape is the *swampy frozen larch taiga*, associated with lower relief elements, as a rule undrained. A good example was seen on the Elgen state farm, also in the basin of the Kolyma River, on a low terrace above the flood plain. The taiga consists of sparse larch with an undergrowth of willow and dwarfed birch. The soil is covered by thick moss and lichen, the surface being hummocky. The ground is frozen to 40–80 cm. The hummocks consist of a mineral soil and stand above the intervening depressions to a height of 0·4–0·5 m. They consist of masses of soil pressed out from below along deep fissures. In the intervening depressions there is a *peaty cryogenic-solifluction soil* with a very acid reaction.

The third type of natural landscape in this region is represented by *dry frozen larch taiga*. These landscapes are also developed below the goletzy zone, but on well-drained stretches on gentle slopes. They are characterized by very sparse larch woods with a poorly developed grassy or moss and lichen cover. A characteristic feature of the soil is an abundance of frost cracks having the shape of large polygons. The cracks are deep and wide, being filled with loose soil material, and are wedge-shape in profile. Soil sections under such landscapes in Yakutiya and Kolyma are represented by soils of two different genetic types: on non-calcareous rocks—*cryogenic, ferruginous, acid (podsolized) soils*; on calcareous rocks—*cryogenic alkaline (solod) soils*. The genetic names of these soils indicate their characteristic features.

The fourth type of landscape in the territory of the Siberian pole of cold is the *frozen cold forest-steppe*. Its main occurrence is in the western part of the territory, within the central Yakutsk plain. It occupies here wide elongated declivities between ridges and slightly undulating old alluvial terraces. Separate fragments of such landscapes are also found east of the Verkhoyansk mountain range. They are associated here with flat but elevated parts of intermontane basins or with steep southern slopes. By the character of its vegetation the frozen cold forest-steppe is a meadow steppe with islets of birch clumps ("kolki"). Under its grassy patches *cryogenic black meadow soils* are developed, usually containing salts and solods; under the birch kolki there are patches of frozen solonetz[†] and solods.[‡] All these soils have a

* The ability of ground to flow under dynamic pressure in permafrost conditions, being in part destroyed naturally by mechanical impact but being restored to its original state subsequent to the impact.

† A soil type developed by the leaching of surplus salts by a lowering of the ground water level.

‡ A soil type derived from a solonetz by washing and degradation. The characteristics of the solonetz have been destroyed completely.

weakly alkaline reaction; at a shallow depth they contain carbonate salts and frozen ground. Their profiles often reveal wedge-like frost fissures and a very characteristic stratified scaly structure with signs of slight gleying, formed under the influence of fluctuations in the level of permafrost.

If the large areas of meadow flood plains and swamps are added to the forms listed above, the general picture of the main natural landscape of the territory of the Siberian pole of cold will be sufficiently complete. As has already been pointed out, it strikes the observer both by its general variety and by the contrast of its sub-types. This picture is completely unlike the monotonous landscape of "periglacial tundras," which was previously identified with the European "late glacial" period on the one hand and the territory of the Siberian pole of cold on the other. In this connection, it is important to stress that the characteristics of the present Siberian "late glacial" period described above offer a much better basis for palaeogeographical reconstructions of the old European late glacial landscapes than the speculative concepts which have been used to date, based mainly on palaeobiological data.

From this point of view, of special interest are two recent natural phenomena, characteristic of the territory of the Siberian pole of cold:

1. Different types and forms of cryogenic formations.
2. Surface sediments of a loess-like character.

The first have already been described in detail above and only the latter require brief description here.

It has already been pointed out that the majority of soils associated with the frozen forest-steppe of Yakutiya exhibit a weakly alkaline reaction and have accumulations of carbonate salts in their profiles. These soil features are closely associated with the character of the parent material, represented as a rule by powdery calcareous loams. Apparently the latter are of a different origin (alluvial, glacial, etc.), since they are superficial formations in a cold Siberian forest-steppe and they always have a loess-like appearance. In my joint monograph with K. K. Markov⁴ I suggested calling this type of superficial deposit the recent cold facies of loess-like deposits. It is more than probable that, by virtue of their origin, such formations are recent analogues of the sheets of loessic loams which usually overlie the moraines of the old glaciated regions of Europe. For this reason, the observations given above are of certain interest in connection with the problem concerning the origin of the loesses, which still remains in dispute.

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