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PALEOGEOGRAPHY AND STRATIGRAPHY OF MAMONTOVA GORA, CENTRAL YAKUTIA

The section in Mamontova Gora (Mammoth Mountain) lies in central Yakutia on the left side of the river Aldan, 325 km up from its outlet into Lena. The section is situated within the Aldan accumulational plain, which forms the bottom of a tectonic trough, part of the pre-verkhoyansk depression. In this section appears hardly the upper horizon of sediments belonging to the depression (Neogene and Pleistocene). Five terrace horizons have been distinguished here: 80 m, 50 m, 30 m, 20 m, 6–9 m, 1.5 m. The unique character of the discoveries in the sediments of the Mamontova Gora induced many scientists to study this section. The results of their research work are widely known, but in all the works dealing with this subject, mainly the results of floristic and faunistical analysis are separately taken into consideration.

We believe, that the methodics of investigations of every stratigraphic profile ought to be complex. The complexity guarantees proper controle and interaction of various simultaneously applied research methods. The group of scientific workers from the Geographical Departament of the Moscow University tried such a methodics in their laboratory works on loose Pleistocene sediments.

The complex of both lithostratigraphic and biostratigraphic methods was applied for the characteristic of each sediment horizon from Mamontova Gora. The following methods were tried: grain-size distribution, proportion between light and heavy fraction of slicks, surface character of quartz sand grains, azimuths of dips, cycles of sedimentation of cross-stratified series, roundness coefficient of pebbles, petrologic character of pebbles, mineralogical composition, composition of clay minerals, degree of secondary alteration of minerals, examination of frost texture, ratio values: $\frac{Al_2O_3}{SiO_2}$, $\frac{R_2O_3}{SiO_2}$, content of the carbonates (according to CO_2), cumulative composition of organic matter, spore- and pollen analyses, determination of macro-vegetational remains, determination of afforestation degree of the territory, correlation of floristic elements and determination of mammals and mollusca remains.

Lithologic-facial analysis is the most general method, which is applied for the examination of younger sediments. Its indispensability and specificity relating to terrigenous sediments were often emphasized by E. V. Šancer (1966).

Lithologic-facial examination of deposits is of principal value in the complex analysis, as every facies gets its own properties of mineralogical, grain-size distribution and chemical composition during the sedimentation and hypergenesis process. This should be wholly taken into account in the paleogeographic interpretation.

Due to detailed field observations and generalization of analytic material the following facies have been distinguished in the Mamontova Gora section: river-bed facies, flood facies, and specific covering silt facies. The sediments accumulated contemporaneously with the tectonic down-movement are recognized within the river-bed deposits (first stage – N).

Every facies has its own dynamic regime of sedimentation. The last from the facies enumerated originated under equal conditions of flowing water--basin regime.

A big thickness of sediments, constant grain-size gradation, dips of layers prevailing in the section and thickness of cross-stratified series indicate the compensatory sedimentation. The comprehensive analysis of composition of terrace covering silts leads to conclusion of their water-laid, alluvial origin. Slight carbonate silts with rich humus content and only in places stratified were accumulated under intensive mechanical weathering conditions, when rivers were overloaded with suspended material.

A confrontation of structural and textural characteristics of examined sediments such as: extinction of cross-stratification (angles and directions of dips, parameters of wave-features), morphoscopy of sand grains (surface character of quartz particles, per cent and roundness coefficient of quartz grains), roundness coefficient of pebbles, median diameter (Md) and weighted mean diameter (α) and coefficient of sorting of sediment (So) gives a characteristic of each facies cited.

Grain-size distribution shows, in general, conditions of sedimentation i. e. the dynamics of environment and, indirectly, the intensity of relief--forming processes and of tectonic movements. Each grain size has its adequate value of environmental activity of transportation and sedimentation.

The values of median diameter in mm (Md) and of coefficient of sorting (So) were used in the comparative characteristic of beds, as well as fractional grain-size distribution of beds. Both values make general indicator of grain-

-size composition. The median diameters were calculated according to the cummulative curve; coefficient of sorting was taken from the formula: So $= M_3 : M_1$ (where M_3 – value in the upper (75%) quartille, M_1 – value in the lower (25%) quartille).

For the paleogeographic interpretation of mineralogical composition of sands (light and heavy fraction) and of petrologic character of pebbles the principle of mineralogical resistance is used (Sudakova, 1966).

The degree of resistance of mineralogical and petrologic spectrum of rocks is formulated by some numerical coefficients. Coefficient of resistance (CR) is the ratio of the sum of proportional content of weathering-resistant components to the sum of proportional content of non-resistant ones. The low value of CR testifies to a high resistance degree of minerals and poor intensity of weathering, which are typical of the cool and dry climate. High value of CR means high per cent of secondary alterated minerals and the predominance of kaolinite in clay fraction. This value is typical of the spectra of warmer and more humid regions.

Geochemical characteristic of sediments is based on data given by general chemical analysis of 0.25 mm fraction, its humus content, collective and grain-size composition and calcium carbonate content (according to CO_2).

The values of non-molecular proportions $\frac{SiO_2}{AL_2O_3}$ and $\frac{SiO_2}{R_2O_3}$ were also utilized for the interpretation of data. Those coefficients were taken into account only in such a case, if the mechanical composition of the sediments had no effect on the coefficient value.

The value of proportion $\frac{R_2O_3}{SiO_2}$ was assumed conventionally for the convenient comparison of the data from geochemical characteristic with those obtained from other analyses. The high value of this proportion means the increase of hypergenetic process of alteration in warm and moist climate; the low value is characteristic of a contrary picture.

The methods of defining cumulative humus composition is the most appropriate for paleogeographic conclusions (Dobrodeev, Glušenkova, 1968). In the Mamontova Gora sediments a very clear differentiation of humus composition may be observed according to mutual relations of humic acids carbon (R_h) and fulvic acids carbon (R_f). The present-day soils of the Aldan Basin are characterized by humus of a forest type ($R_f > R_h$). The highest content of humic acids (humus of steppe type) was found in loess-like silts in 30 m and 20 m terraces in the Mamontova Gora section.

The cumulative composition of humus in loess-like silts on the grounds of the proportion of humic acids to fulvic acids, compounds of humic acids with sesquioxides and high value of insoluble residue indicates an aquatic origin of silts.

The characteristic of vegetation has been obtained from micro- and macro--floristic examinations. In the composition of macroflora the determination of imprints of leaves, fruits, cones and fossil seeds was given. The analysis of microflora from numerous outcrops of each terrace enables to make a generalized spore- and pollen diagram.

The essence of interpretation of fossil spore- and pollen spectra is the comparison with the present-day spectra and the determination of their common features and mutual differences. The present-day spore- and pollen spectra of Central Yakutia and of the North East of the USSR have been examined repeatedly (Vaskovskij, 1957; Giterman, 1963; Popov, 1961). As the present-day common spore- and pollen spectrum indicates a zonal type of flora in the lower Aldan, fossil spectra must have shown types of Pleistocene vegetation.

In sedimentation cycle in Mamontova Gora the regular interchange of forested and non-forested landscapes took place due to development of climatic conditions. The increase of the forestation degree of the territory, as compared with the present-day picture, is manifested by species requiring warmth and moisture (fir, spruce, latifolious genuses, etc.). That testifies to a warmer and more moist climate, whereas the growth of the tundra-steppe asociations with the polar flora species indicates dry and cool climatic conditions. "Daursky" larch might have appeared in those asociations, as the larch is the least fastidious among tree species as regards climatic conditions.

The general change of the flora, climate and the entire natural environment caused also the alternations in animal species. The new groups supplemented or ousted the previous ones. Faunistical complexes appeared and disappeared and interchanged in time (Vangengejm, 1961). The examination of animal bone remains enabled to reconstruct the details of this continuous process. The faunistical complexes cited divide an inorganic material of the section to some time-stages. Morphological features of the different parts of the skeletons indicate the adequate ecological conditions and further more – the natural environment, in which the animals lived.

The examinations in Mamontova Gora reveal no traces of fauna in the Neogene sediments. The Upper Pleistocene deposits show only insignificant content of the traces mentioned, whereas in the sediments of the Middle and Lower Pleistocene the fauna remains are frequent enough. The taphanomic data have great significance for the interpretation of the material collected. Therefore detailed description was made for the area under research as regards the inviolability of the fauna remains and conditions of their conservation.

This made it possible to link up the separate finds with the appropriate horizons.

The remains of small mammals and molluscs, found in the Mamontova Gora sediments, belong to animal species very similar to the present-day ones whereby their ecology is well-known. Three different ecological groups were recognized among the remains of the rodents: (a) elements of the forest fauna, (b) neutral elements of fauna, (c) elements of the tundra fauna. The reconstruction of the natural conditions, based on the similar materials and connected with the results of spore- and pollen analysis, is the most credible (Agadzhanyan, Boyarskaya, 1969).

On the grounds of the synthesis of factographic material, gained by different research methods of the Mamontova Gora section, the following hipothetic curves have been drawn, which are to show development tendencies of separate components taken from the natural complex: tectonic curve, the curve of the intensity of weathering, of the forestation degree, of mutual relation between the floristic elements, of coefficient of continentality, of the development of the underground glaciation (permafrost) and climatic curve.

The tectonic curve is made on the basis of the analyses of terrace horizons and facial character of the sediments. It shows the tendency of tectonic fluctuations during the sedimentation of Mamontova Gora complex.

Defining the value of the tectonic upheaval as the stages between forming of two successive terraces, we took into account the normal thickness of alluvial deposits, the facial composition of sediments and the height difference between the levels of two terraces examined. The analysis of thickness and the character of the sediments testify to the fact, that after the long-lasting period of subsidence and accumulation of thick deposits in the Neogene (compensatory sedimentation) the period of slight stabilization and rising of the territory followed as well as formation of erosion-accumulational terraces.

The confrontation of the various characteristics (structure, thicknesses, coefficients of dynamics of the environment, etc.) leads to the conclusion of the decrease of amplitude and tectonic rising rate from the Lower to Upper Pleistocene.

The curve of weathering intensity is built up on the grounds of the generalization of mineralogical and geochemical data. It illustrates the increase and decrease of the weathering intensity according to climatic fluctuations.

The curve of forestation degree shows the tendency to fluctuation of forest extent during the Neogene and Pleistocene. The curve has been built up as a result of examination of micro- and macroflora from the Mamontova Gora sediments. The maximum afforestation of the area is connected with growing warmth and humidy of the climate, whereas deforestation means the colling down process and decrease of precipitation.

The curves of interrelation of floristic elements were built up according to W. Szafer's method (1961). Six elements were divided out: subtropical, mediterranean, American-East-Asiatic, holarctic, arctic and cosmopolitan, which on the whole make 100%[1]. In Mamontova Gora these elements appear in various mutual relations in various horizons. The increase of some of them, decrease, extinction or appearance of others were conditioned by directions of climatic changes.

The coefficient of continentality, hypothetically presented by us, is constructed according to N. N. Ivanov's method (1953). The degree of continentality of the climate is expressed by the deviation of annual amplitudes from the average amplitude characteristic of the entire parallel given. Vegetation is related to values of the coefficient in the definite way. And that is the reason, why analysing the successive development of vegetation cover during formation of the Mamontova Gora sediments, the process of continentality development can be presented according to uniformitarianism method.

The diagram of the coefficient of continentality is connected with the tendency of the underground glaciation (or permafrost) formation, which tendency was re-created by us on the basis of the examination of cryogenic deformations in the section. For some paleogeographic constructions we used B. N. Dostovalov's (1952) and A. I. Popov's (1965) conclusions, that small diameter of polygons between the veins and, *vice versa*, considerable width of the veins themselves, measured perpendiculary to their strike, testify to the high continentality of climate.

The climatic curve has been constructed on the grounds of all methods from comprehensive analysis. Geochemical, mineralogical, lithological-facial features of the sedimentary rocks and specificity of flora and fauna – all are indicative of past climates (Sinicyn, 1967).

Rich data obtained from various methods of the comprehensive analysis was worked out statistically with the help of correlative analysis (Agadzhanyan, *et al.*, 1967).

Considering the methodical premises of comprehensive analysis of the sediments from Mamontova Gora we will deal in a short way with the results of that analysis and some paleogeographic conclusions (see fig. 1).

In the Neogene period (1-st stage) the area underwent continuous tectonic depression, as well as compensatory sedimentation. A homogeneous bed of

[1] To the composition of arctic element the hyperarctic element was included according to B. A. Yurcev (1966).

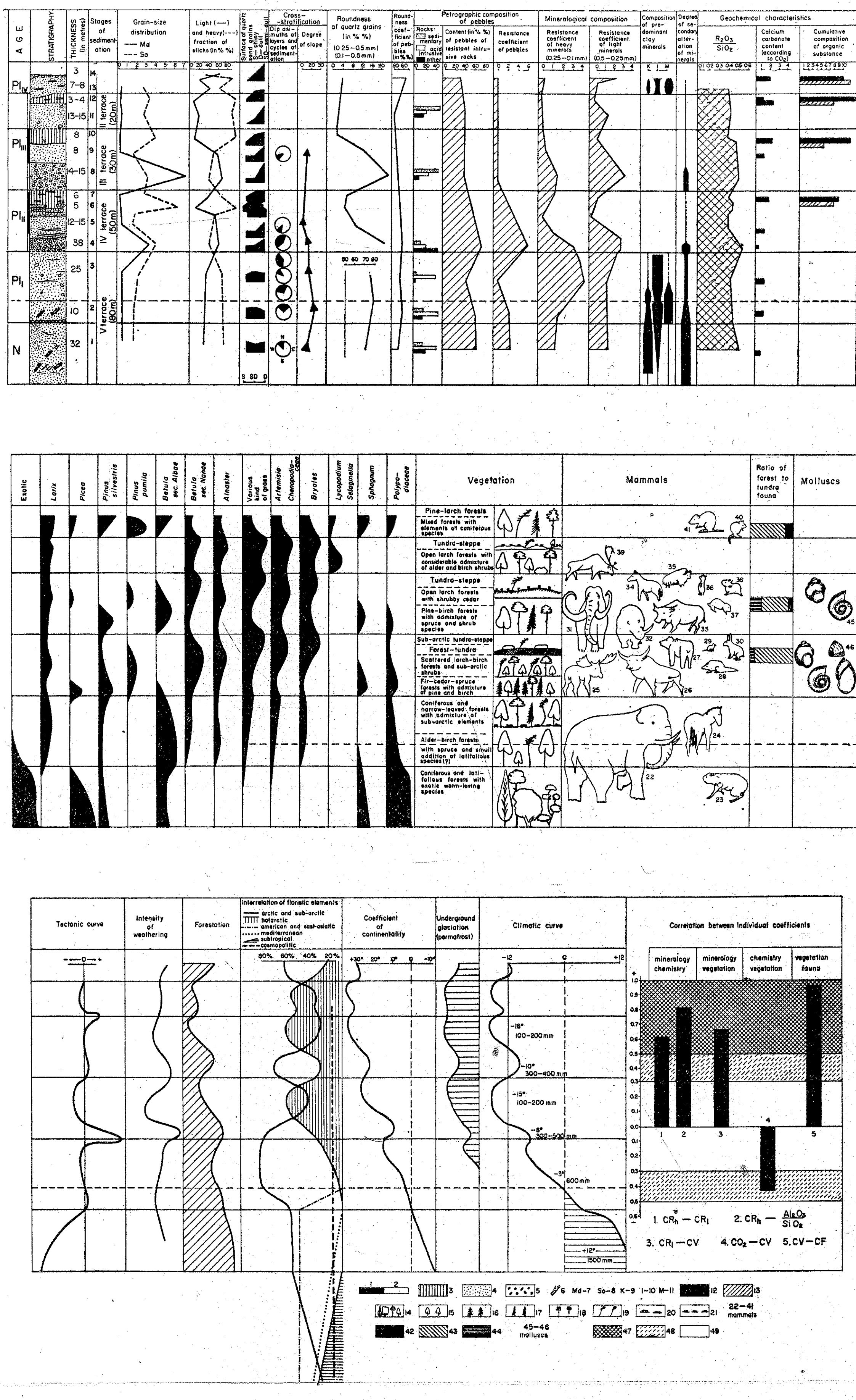

Fig. 1. The Profile of Mamontova Gora (made by: A. K. Agadzhanian, T. D. Boyarskaya, N. I. Glušenkova, N. G. Sudakova, W. S. Horiev)

1 – cold stages; 2 – warm stages; 3 – loess-like silts; 4 – sands; 5 – pebbles; 6 – fossil wood; 7 – median diameter; 8 – sorting coefficient; 9 – kaolinite; 10 – hydrated mica; 11 – montmorillonite; 12 – humic acids; 13 – fulvic acids; 14 – coniferous-latifolious forest; 15 – narrow-leaved species; 16 – fir-tree; 17 – spruce; 18 – pine-tree; 19 – larch; 20 – shrubs of narrow-leaved species; 21 – tundra-steppe; 22 – *Mammuthus* sp.; 23 – *Trogontherium cuvieri*; 24 – *Equus stenonis* aut *sanmeniensis*; 25 – *Alces latifrons postremus*; 26 – *Bison priscus longicornis*; 27 – *Ursus* sp.; 28 – *Castor fiber*; 29 – *Sorex* sp.; 30 – *Lepus* sp., 31 – *Mammuthus primigenius*; 32 – *Coelodontha antiquitatis*; 33 – *Bison priscus deminutus*; 34 – *Equus caballus*; 35 – *Ovibos* sp.; 36 – *Lemmus obensis*; 37 – *Dicrostonyx torguatus*; 38 – *Citellus* sp.; 39 – *Rangifer tarandus*; 40 – *Clethrionomis*; 41 – *Arvicola terrestris*; 42 – forest fauna elements; 43 – indifferent elements of fauna; 44 – tundra fauna elements; 45 – *Gyraulus gredleri* (Gredl), *Lymnaea auricularia* (L); 46 – *Gyraulus* ex. gr. *albus* (Müll), *Lymnaea auricularia* (L), *Valvata piscinalis* (Müll), *Pisidium conf. Supinum* Schmidt, *Vallonia pulchella* (Müll); 47 – good connection; 48 – satisfactory connection; 49 – without any connection

sand was accumulated, which is characterized by the high dispersion of sediments, low value of sorting coefficient, low angles (18–20°) and constant directions of dips, poor roundness of pebbles, etc.

Well-comparable results of mineralogical, geochemical and paleobotanical analyses indicate moist and warm climatic conditions. High value of resistance coefficients of terrigenous minerals, high degree of chemical alteration (maximum amount of the secondary altered minerals, predominance of kaolinite in clay fraction) testify to extreme intensity of weathering as compared with all the later stages of landscape development.

During the Noegene the area was covered by forest in maximum extent. The forest was characterized by the large number of various species and the predominance of exotic coniferous and latifolious trees (*Myricaceae*, *Yuglandaceae*, *Carya*, *Pterocarya*, *Castanea*, *Carpinus*, *Fagus*, *Quercus*, *Rhus*, *Nyssa*, *Ulmus*, *Tilia*, etc.). On the basis of paleocarpological analysis P. I. Dorofeev dates the lower part of 80-m terrace as Miocene in age.

Climatic conditions of that period can be characterized by mean annual temperature of +12° and precipitation – 1500 mm. Very similar data have been given by G. P. Včerašnaya as a result of the examination of leaves imprints. The flora from that period was similar to present-day vegetation of the temparate zone of sheding-leaves forests of North China and mixed forests of North America along the Appalachian Mountains plateau.

The lower boundry of the Pleistocene is defined due to comprehensive analysis.

After the long-lasting period of tectonic subsidence and accumulation of the big thickness of sand (the lower part of 80-m terrace) followed relative tectonic stabilization or perhaps tectonic upheaval and denudation of the sediments for the homogeneous cross-stratified sands are clearly divided from the overlying pebble horizon by zone of washing-away processes and of accumulational discordance.

The overlying 10 m horizon (2-nd stage), defined as the lower limit of the Pleistocene, may be characterized as follows: higher value of dips (25–30°) and of azimuths of dips, decreasing amount of the secondary altered minerals, predominance of hydrated mica in the composition of clay fraction, appearance of montmorillonite and beidellite and reduced rate of chemical weathering.

Composition of vegetation underwent the most important changes in time between the Neogene and Pleistocene. The main part of exotic warm-loving plants disappeared and the taiga associations – open coniferous and narrow-leaved forests – begun to predominate. It is probable, that in their composition some elements of latifolious most resistant to frost plants could be found, the reduction of which took place gradually.

The process of the expansion of taiga formations and growth of young polar plants took place simultaneously with the reduction of stenothermal elements.

The parallel change of all components in fairly defined horizon in the section could have been caused by one reason only, i.e. cooling-down and aridity of climate.

During the Lower Pleistocene (the upper part of 80-m terrace – 3-rd stage) the slight tectonic depression of the area took place. In the composition of clay minerals from that period invariably predominates hydrated mica with an admixture of beidellite and montmorillonite. The formation of permafrost begun in this period. The sediments of the Lower Pleistocene were already freezing up and syngenetic ice veins developed, although the continentality did not reach its maximum.

In the composition of the vegetation predominated open coniferous forests. The expansion of the "daursky" larch was connected with the increase of the continentality of climate ($C = +15°$).

The Pliocene and the Lower Pleistocene fauna is not examined exhaustively up till now and the larger area of its common occurrence is almost unknown. Among the forms, which preceded the Pleistocene the following ones are determined: *Equus* cf. *sanmeniensis*, *Alces latifrons*, *Trogontherium* cf. *cuvieri* and others (Vangeigejm, 1961).

An elephant tooth from the "bičevnik" is regarded as connected with sediments of the upper part of the 80-m terrace. The morphology of the tooth found has some archaic features and the elephant may belong to the mammoth family, though the situation of discovery in this place is not clear enough.

Generally, fauna from the Lower Pleistocene is still represented by stenothermal forms. Some of them are the same as those from the regions, situated farther to the South.

Two periods – of cooling-down and warming-up – were separated within the Middle Pleistocene (sediments of 50-m terrace, 4–7-th stages).

Initially, the rivers strongly incised in the sediments of 80-m terrace to the depth of 70 m, because of active tectonic upheaval.

In the mineralogical-geochemical aspects the sediments of the first part of the Mid-Pleistocene are characterized by the high values of the resistance coefficients of light and heavy fractions, the high per cent of the destroyed and secondary altered minerals, ferruginous coatings and increasing intensity of weathering.

The whole area was strongly afforested at that time. In the composition of forest spruce and fir-trees are main components, which are characteristic of the dark, coniferous complexes. The warming of climate caused a partial shaving of permafrost and provoked thermokarst processes. The ice veins within Low-Pleistocene sediments became smaller, but did not melt completly. It indicates, that the warming-up was not effective enough. That milder period may be characterized as follows: mean annual temperature –8°, precipitation 300–500 mm, coefficient of continentality +10°.

The second part of the Middle Pleistocene was colder and more arid. In the mineralogical spectrum the content of chemically unstable minerals was higher, causing slight decrease of resistance coefficient. The intensity of chemical weathering decreased too.

The plant species were reduced by the extinction of the great part of trees. The gradual diminishing of such species as spruce or fir-tree, which require rather mild climatic conditions, indicates the falling of the mean annual temperature and, first of all, decreasing amount of precipitation in comparison with previous periods (temperature –15°, precipitation 100–200 mm). The increasing continentality of climate (C = +20–25°) caused the development of larch-birch forests and forest-tundra as well as progressive formation of permafrost. Syngenetic ice veins appeared. At the same time on the surface of the wide accumulation plain, covered by the Lower Pleistocene sediments, a new dissection of silts took place due to colluvial-solifluction processes, as well as the origin of ice veins of the second horizon and filling-in of thermokarst depressions.

Fauna was represented by species typical of palaeolithic complex. The remains of the early mammoth, long-horned bison and *Equus caballus* were found. In the analogous sediments on the river Viluj the other scientists found the remains of the musk-ox and long-haired rhinoceros. In the silts of 50-m terrace we found the remnants of the beaver dam and water-deposited remains of small mammals: *Sorex* sp., *Lepus timidus, Ochotona hyperborea, Lemmus obensis, Stenocranius gregalis, Mocrotus oeconomus, Microtus* sp. Such a picture of fauna indicates the severe climate.

In the Upper Pleistocene two warmer periods were separated (sediments of 30 m, 20 m and low part of 9-m terraces).

During the warmer periods (8, 11-th stage) the weathering processes increased (CR of minerals is 2), as well as the amount of destroyed and secondary altered minerals.

The vegetation cover was composed of pine-birch forests with or without a slight addition of dark needle-forest species.

Slight amelioration of climatic conditions as compared with the previous period caused a partial shaving of the Lower and Middle Pleistocene sediments. The climate can be characterized as follows: mean annual temperature –10°, precipitation 300–400 mm.

During the colder periods (9, 10, 12-th stages) the intensity of weathering decreased considerably. In vegetation cover dominated grass complexes and there occurred expance of the forest-tundra and tundra-steppe landscapes. The arctic elements displayed their maximum growth.

In the composition of fauna the representatives of the Upper Palaeolithic complex predominated (small forms): *Mammuthus primigenius*, *Bison priscus deminutus*, *Equus caballus*, *Rangifer tarandus*. The remains of the rodents and hare-like species were found, too. For the 9 and 10-th stage the predominance of the lemming fauna is characterized (*Lemmus obensis* mainly), which indicates the severe tundra conditions.

The cold periods provoked the development of syngenetic ground veins within the Upper Pleistocene and of syngenetic ice veins within the Mid- and Lower Pleistocene sediments. But the Upper Pleistocene period had severe and more continental climate (mean annual temperature –16°, precipitation 100–200 mm, C = +35–40°).

It is obvious that the results of the comprehensive paleogeographic analyses of the sediments from the section in Mamontova Gora confirm K. K. Markov's point of view (1967) on the directional and rhythmical changes of nature during the Pleistocene. Rhythmical fluctuations, caused by the tectonic and climatic reasons were expressed in mutual changes of warm and cold periods.

Generally, warmer periods are characterized by high resistance coefficient, high per cent of secondary altered minerals, predominance of resistant rocks in pebble series and high degree of hypergenetic alteration. The occurrence of forest phytocenosis with or without latifolious species is characteristic of the vegetation, as well as the rodents for the fauna composition (predominance of forest forms). The appropriate reduction of the continentality of climate and underground glaciation can be observed. Mean annual temperatures and precipitation are higher then present-day ones. The warm periods differ from each other by qualitative and quantitative data.

During the cold periods complete transformation of sediments composition took place as well as a change of animal and vegetal worlds. Those periods are characterized by: high admixture of aleurite – the product of frost weathering, low resistance coefficent of minerals, poor chemical alteration, high content of hydrated mica in composition of clay fraction, the predominance of open forest, forest-tundra, tundra and tundra-steppe landscapes and lemming fauna, the increase of continentality of climate and the underground glaciation, lower mean annual temperatures and precipitation in the comparison with the present-day ones.

Formation of loess-like silts of problematic origin, which cover the terrace alluvia of the river Aldan, are closely connected with the cold periods. Their characteristic properties: high content of "loess" fraction (30–40%), content of calcium carbonate, high porosity (46%), low degree of the minerals weathering, spore-pollen spectra, the similarity to the tundra-steppe vegetation associations – allow to regard the silts as a product of severe climate.

Taking into accounı the observed microstratification in the profile of silts, the insertions of rinsed-out pieces of wood, the occurrence of beta-kertschenite and vivianite – typical representatives of the subaqual environment – the silts were deposited in the aquatic environment. In such an aspect the gradual interpenetration of rhythmical stratified sands and silts becomes plain enough as silts occur just over the sand in the profile of every terrace.

According to it the sedimentation of silts was not a continuous process, but it finished the accumulation cycle of each terrace. The conclusion on different age of silts of various terraces results from the defined differences of indicators of: grain-size composition, cumulative composition and content of humus, calcium carbonate content, mineralogical and chemical composition. In table I some average indicators are given.

Table I

Terrace horizons	80 m	50 m	30 m	20 m	Present-day bottom
1. Mean weighted diameter (α mm)	0.08	0.03	0.04	0.05	0.06
2. % of 0.001 mm grain-size	12.8	24.6	12.4	12.6	15.5
3. % of loess-grains (0.01–0.05 mm)	36.5	20.3	35.4	27.3	19.5
4. Resistance coefficient of heavy minerals	6.5	1.6	0.8	0.4	0.8
5. Resistance coefficient of light minerals	3.6	0.65	0.75	0.5	1.0
6. % of $CaCO_3$	1–2	3.0	7–10	4.0	3.0
7. % of humus		1–3	1–1.5	1.0	1.2
8. Cumulative composition of organic substances $\left(\frac{\text{C humic acids}}{\text{C fulvic acids}}\right)$	0.90	0.61	2.30	2.02	0.73
9. Degree of chemical alteration	3.62	3.94	4.18	4.0	–

As mentioned above, due to all the analytic data the problem of age and origin of silts from the Aldan valley near Mamontova Gora can be determined univocally. Silts, contrary to some scientists believe, are not of the same age, mantling different hipsometric horizons, but they end accumulation of terraces of various age. Diversified composition of silts revealed some signs of directional evolution of sedimentation conditions during the Pleistocene.

Some peculiarities in silt composition and textural properties of silts indicate aqueous, mainly alluvial sedimentation. During further stage of hypergenesis silts underwent periglacial frost processes, being simultaneously widespread over the land surface. (The areal displacement of silts explains frequently occurring mixed character of fauna of different age.) The alteration of the upper series of "non-stratified" silts provoked their further loessification.

All the data indicate that the loess-like silts were deposited in the period of deterioration of the climate (colder and arid), river waters, being loaded with suspended muds and non-decomposed organic remains, become to accumulate.

The upper horizons of the non-stratified silts due to their composition reveal paleogeographic environment after their sedimentation.

The hypothesis on the alluvial and frost origin of the loess-like silts differentiated in age from the Aldan terraces sufficiently explains the specificity of their composition.

The directed development of the natural complex, as a whole, was expressed in:

(1) the decrease of amplitude and of rate of tectonic upheaval during the Pleistocene,

(2) the progressive reduction of chemical weathering and mineralogical changes,

(3) the complication of the mineralogical composition (from the lower to the upper horizons) caused by the migration of the new unresistant components,

(4) the progressive impoverishment of the overgrowth, the extinction of exotic species, the appearance of typical taiga phytocenosis and arctic elements of flora,

(5) the appearance of the smaller mammals and their adaptation to more severe conditions,

(6) the increase of continentality of climate and underground glaciation,

(7) the decrease of the amplitudes of climatic fluctuations from the warmer to colder periods.

The composition indicators: grain-size distribution, mineralogical and chemical parameters, spore-pollen spectra, faunistic remains etc., as well as the elements of the landscape itself show close though complicated interrelations. Interdependence or lack of it, the strictness of their relationship may be ascertained with numerous correlational coefficients. For the mathematical illustration of the problem the following coefficients have been applied:

L^0 – angle of dips of beds

C_{org} – content of organic matter

CO_2 – content of carbonate

α – welghted mean diameter of grains

$\frac{Al_2O_3}{SiO_2}$ – weathering coefficient

CR– resistance coefficient

CV– coefficient of vegetation

CF– coefficient of fauna

Two last coefficients show the relationship of hadrophilous and stenothermal species to xerophilous and hardy ones. Increasing CV and CF indicates the change of nvtural conditions in the given area, that provoked the growth of forests and appearance of the tundra fauna, whereas their decrease testifies to the expanse of tundra-steppe landscapes and the respective fauna.

The analysis of cited correlation coefficients has a predominance as compared with build-up curves analysis, because it shows the interrelations in the more objective way.

Three types of the relatilonship between the features were set-up:

(1) direct connection (the increase of one feature causes the incresae of the other),

(2) inverse connection (the increase of one feature causes the decrease of the other),

(3) lack of any connection (one feature changes without any connection with the other)

The most direct interrelation has been set up between the following coefficients: CV–CF, CR–CV,CR $\frac{Al_2O_3}{SiO_2}$, $\frac{Al_2O_3}{SiO_2}$ CV, CO_2–CV

Translated by K. Chrzanowska

References

Agadzhanyan, A. K., Boyarskaya, T. D., Glušankova, N. I., Karupkhin, C. C., 1967 – Izmenenie korelacionnogo analiza veščestvennogo sostava otloženij dla paleogeografičeskikh rekonstrukcij, na primere razreza Mamontova Gora (Application of correlative analysis of physical composition of sediments in paleogeographic reconstructions, Mamontova Gora). *In:* Matematičeskie metody v geomorfologii; Moscow.

Agadzhanyan, A. K., Bardin, V. I., Boyarskaya, T. D., Glušankova N. I., Sudakova, N. G., 1967 – Rezultaty paleogeografičeskikh issledovanij razreza Mamontova Gora (Resultats of the paleogeographic investigations in the Mamontova Gora). *Vestnik Mosk. Gos. Univ.*, ser. geog., No. 6.

Agadzhanyan, A. K., Boyarskaya, T. D., 1968 – Prirodnaya obstanovka Nižne-Aldanskoj vpadiny vo vtoroj polovine plejstocena (Natural conditions of the Lower Aldan depression during the second part of the Pleistocene). *In*: Novejšie otloženiya i čelovek; Moscow.

Boyarskaya, T. D., Sudakova, N. G., 1967 – Périodes froides du Pléistocène de la Sibérie Orientale. *Biuletyn Peryglacjalny*, No. 16.

Boyarskaya, T. D., Khorev, V. S., 1968 – Klimatičeskie osobennosti plejstocena Vostočnoj Sibiri, na primere razreza Mamontova Gora (The Pleistocene climatic peculiarities in East Siberia – Mamontova Gora). *In*: Novejšie otloženiya i čelovek; Moscow.

Dobrodeev, O. P., Glušankova, N. I., 1968 – Paleogeografičeskoe značenie sostava gumusa pogrebennykh počv i novejšykh otloženij (Paleogeographic significance of humus composition of fossil soils and of Pleistocene sediments). *Vestnik Mosk. Gos. Univ.*, ser. geog. No. 1.

Dostovalov, B. N., 1952 – O fizičeskikh usloviyakh obrazovaniya morozobojnykh treščin i razvitiya treščinnykh ldov v rykhlykh porodakh (Physical conditions of development of frost fissures and fissure ice in loose deposits). *Sb. issled. večnoj merzloty v Yakutskikh respub.*, vyp. 3.

Giterman, R. E., 1963 – Etapy razvitiya četvertičnoj rastitelnosti Yakutii i ikh značenie dla stratigrafii (Stages of development of the Quaternary vegetation in Yakutia and their meaning for stratigraphy). *Trudy Geol. Inst.* vyp. 78.

Ivanov, N. N., 1958 – Ob opredelenii veličiny kontinentalnosti klimata (Estimation of value of the continentality of climate). *Izv. Vses. Geog. Obšč.*, vyp. 4–6.

Markov, K. K., Veličko, A. A., 1967 – Četvertičnyj period (Quaternary Period), t. 3, ed. Nauka; Moscow.

Popov, A. I., 1961 – O sporovo-pylcevykh spektrakh sovremennykh rastitelnykh soobščestv Centralnoj Yakutii (Spore and pollen spectra of present-day vegetation in Central Yakutia). *In*: Materialy po rastitelnosti Yakutii.

Popov, A. I., 1965 – Podzemnoe oledenenie Severnoj Evrazii (Underground glaciation in Northern Eurasia). *Podzemnyj led*, vyp. 2.

Sinicyn, V. M., 1967 – Vvedenie v paleoklimatologiyu (Introduction to paleoclimatology). Ed. Nedra, Leningrad.

Sudakova, N. G., 1966 – K metodike izučeniya mineralogičeskikh kompleksov četvertičnogo alluviya v različnykh klimatičeskikh usloviyakh osadkonakopleniya i gipergeneza (Methods of the examination of mineralogical complexes of the Quaternary alluvium under various climatic conditions of sedimentation and hypergenesis). *In*: Sovremennoj i četvert. Kont. litogenez; Moscow.

Szafer, W., 1961 – Flora mioceńska ze Starych Gliwic na Śląsku (summary: Miocene flora at Stare Gliwice, Upper Silesia).

Šancer, E. V., 1966 – Očerki učeniya o gipergenetičeskikh tipakh kontinentalnykh osadočnykh obrazovanij (Outline of teaching on the hypergenetic types of terrestial sediments). Ed. Nauka, Moscow.

Vangengejm, Z. A., 1961 – Paleontologičeskoe obosnovanie stratigrafii antropogenovykh otloženij Severa Vostočnoj Sibiri (Paleontological fundaments of the stratigraphy of anthropogenic sediments of Northeast Siberia). *Trudy Geol. Inst.*, vyp. 48.

Vaskovskij, A. P., 1957 – Sporovo-pylcevye spektra sovremennoj rastitelnosti soobščestv krajnego Severo-Vostoka SSSR i ikh značenie dla vostanovleniya četvertičnoj rastitelnosti (Spore and pollen spectra of present-day vegetation of the North-East of the

USSR and their significance in reconstruction of Quaternary vegetation). *Materiały po geol. i polezn. isk. Severo-Vostoka*, No. 11.

Yurcev, B. A., 1966 – Gipoarktičeškij botaniko-geografičeskij poyas i proiskhoždenie ego flory (Hypoarctic botanical and geographical zones and origin of its vegetation). *Komar. čteniya*, 19, Ed. Nauka, Moscow.

DISCUSSION

(prepared by N. G. Sudakova)

The discussion which took place after the participants had become acquainted with the profile in Mamontova Gora had for its subject the essential problems of stratigraphy and paleogeography of the model profile of the Neogene and Pleistocene (Quaternary) formations of Eastern Siberia. The participants of the Symposium had an opportunity to compare their own conclusions arrived at during the excursion with the results of complex investigations of the mineral composition of the sediments and of the paleontological remains contained in the sediments.

Prof. J. Dresch expressed the opinion that the main merit of the investigations was the use of many parallel methods. Only one study, namely the study of the microfauna was, in his opinion, missing to make the study complete. Prof. Dresch congratulated his Russian colleagues of their interesting studies.

Most vivid discussion was aroused by the problems of the general development of the River Aldan valley, interrelations between the climatic and tectonic factors. J. Demek, J. Dresch, A. Cailleux, R. F. Flint, J. Büdel, R. Galon, N. V. Kind pointed out that the problem is very complex.

J. Büdel and N. V. Kind were of the opinion that the climate is the main factor in the formation of terrace levels, but, according to J. Büdel, erosion is associated with cold periods.

R. F. Flint did not reject the idea that the formation of terraces was climaticaly conditioned. In this case, however, the paleontological data could not be the convincing proof. According to R. F. Flint, the main argument in favour of the climate or tectonics in the formation of terraces was the geomorphological factor, and, consequently, the problem of the terrace formation is for the most part a geomorphological problem.

J. Dresch remarked that the tectonic curve was the most disputable point in the investigations. R. F. Flint also maintained that the presented tectonic curve was not sufficiently justified, as were most of the tectonic curves presented ever in literature. J. Demek advised that, in order to obtain a better documentation of the tectonic curve, investigations of a series of terraces should be carried out during a 50-year's period, based on the reper points.

A. Cailleux said that the system of terraces is developed in the course of the isostatic rise of the continents over the whole Earth, at the expense of removing a huge masses of deposits from the land surfaces.

T. L. Péwé, Z. A. Vangengejm, and A. A. Veličko were concerned with the problem of the cover silts. This problem was widely discussed while considering the origin and the age of the silts of the Aldan terraces.

T. L. Péwé stated that there was a great similarity between the Yakutian cover silts and the silts occurring inside Alaska.

Alaska's cover silts are similar to loess deposits, they have similar mineral composition, and are characterized by a great number of ice wedges and numerous fossil relics of great mammals of Wisconsin and Ilinoian ages. It should be noted that ice veins (like those of the Aldan Valley) were for the greatest part origined in the Wisconsin and Post-Wisconsin periods.

Several facial types of the loess-like silts of Alaska were distinguished, according to the place in which they occur. In the watershed areas, within the hilly landscape, the silts are of slope-facies type, with the signs of the mass movement and with a great number of remains of great mammals found in the permafrost. The silts of the lacustrine facies, containing the fresh-water molusca, occur at the valley floors.

According to T. L. Péwé, loess-like cover silts which occurred in watershed surfaces of inland Alaska are for the most part the eolian formations. They are the result of blowing off the forest-free surfaces within the valleys during the Pleistocene. The material carried over by the wind underwent various alterations, depending on the place of accumulation. The earlier-laid material also underwent changes by frost processes.

Also Z. A. Vangengejm stresses in her pronouncement that the faunal relics in the Yakutian silts occurring at various geomorphological horizons have been dated as Upper-Pleistocene. A. A. Veličko was dubious about the correct interpretation of the age of the silts of the Aldan terraces, because, as he said, the determination of different properties of mineral composition of the silts could be caused by different facial conditions of their accumulation. According to N. G. Sudakova, the fact that the silts are "facially differentiated" as well as other important evidences placed the eolian hypothesis of the origin of the silts in a very difficult position.

As a result of vivid exchange of opinions on the loess-like silts and because of their great importance in solving the stratigraphic and paleogeographic problems the authors decided that it was necessary to give their opinion on the origin and the age of the silts of the Aldan terraces:

(1) The origin – Investigations and obtained results do not apply to

the polygenetic loess-like formations – described by Lunsgersgauzen – which spread over the vast territories of Yakutia. Our observations relate solely to the silts of the Aldan terraces, which constitute a genetically and facially homogenous complex, and which are paragenetically directly associated with alluvial facies. Arguments favouring the alluvial origin of the formation are: characteristic structure, consistent disposition and gradual change from horizontally stratified underlying sands to stratified silts, the presence of rounded pieces of wood, fresh-water molusca, congenital mineral composition, direction of the change of features within each terrace – from the underlying sands towards the silts, etc.

In a later epigenetic stage of development each of the silt covered terraces underwent characteristic alterations in the area of the permafrost hypergenesis. These alterations were, under the Yakutian conditions, very strong and occurred mainly in the Middle and Upper Pleistocene. The composition of the deposits structure, grain-size gradation was changed; there was an increase in the content of the paleontologic relics (great mammals, wood, etc.).

(2) The age – The time of accumulation of the silts should be distinguished from the date of their hypergenetic alteration, which occurred afterwards.

From the mode of occurrence and distinct properties (mineral composition of new formations, general increase in carbonate content, bulk of organic matter, humus content, degree of weathering of light and heavy minerals) it becomes clear that the silts in the terraces of different height are various in age. There can be also observed a downward direction of the change of lithological and paleontological features both within each terrace (from the underlying sands towards the silts) and within the cover silts, from the highest and oldest terraces towards the lower and younger ones.

The remains of great mammals contained in the terrace silts of different height are of various character. The Mid-Pleistocene fauna (which corresponds in Alaska to the Illinoian fauna is present in the silts of the 50 m terrace. In the silts of the young terraces, as well as in the silts occurring in the area of permafrost hypergenesis – including the 50- and 80-m high terraces – the fauna belonging to the Upper Pleistocene complex prevails at the secondary bed.

Such a distribution of the fauna-containing horizons is, in the terraces.

Besides, the frequent occurrence of the upper Paleolithic faunal complex in the frozen waste horizon, which includes great ice veins and thermokarst hollows, makes it possible to date the climatic period of the maximum development of the underground glaciation and the deep hypergenic-permafrost alteration of Yakutian silts for the Upper Pleistocene. From T. L. Péwé statement it can be seen that our observations are consistent with those made in Alaska.

(3) The methodological premises which make it possible to solve the paleogeographic and stratigraphic problems are following: (a) the conditions of accumulation are reflected in the composition, texture and disposition of the material; it is also necessary to take into account the micropaleontological remains associated with these sediments (spores, pollen, microflora and microfauna) and, to some extent, macropaleontological relics (of mammals and trees), with special attention paid to the conditions under which they had been buried; (b) the conditions of further alteration of sediments, already after their accumulation, as a result of frost-weathering, slope, eolian and other processes are evident, both in the sediments themselves and in the paleontological ramains.

It is necessary to take into account here the specific conditions of lithogenesis in East Siberia, where, during the whole Middle and Upper Pleistocene, permafrost of considerable thickness favoured the operation of processes typical of permafrost hypergenesis. During long intervals there occurred in the hypergenesis zone epigenetic changes of mineral composition of the sediments (grain-size gradation, structure, calcium carbonate content, etc.); at the same time there existed specific conditions in which the relics of great mammals and trees had been buried, which enable an estimation of the absolute age (of the remains, but not of the sediments). Therefore, while investigating the organic remains (fauna, wood), it should be borne in mind that there is always the danger of obtaining the hypergenetic age of sediment alteration and the age of burying of these relics, rather than the age of the existence and formation of the whole sedimentary series.

The exchange of opinions on the essential problems of palegeography and stratigraphy will no doubt be helpful in preparing a more objective concept*.

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* The results of the radiocarbon investigations were obtained already after the excursion to Mamontova Gora. The silts, independent of the level at which they were found, proved to be Upper-Pleistocene in age, which in our opinion, confirms the hypothesis presented by the authors. However, the number of these analyses is too small and it should be increased.