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THE GLACIAL COMPLEX IN THE NOTION OF THE LATE CENOZOIC COLD AGES

INTRODUCTION

The understanding of the Quaternary and particularly that of the cold ages remains under the overpowering influence of glacial phenomena credited with such importance that glaciations are very often treated as synonymous of cold epochs or periods. The latest review of hypotheses on climatic changes (DYLIK, 1974) has shown, that all the theories or models aiming at finding out the causes mentioned were drawn as hypotheses of glaciation factors.

Without denying the fact that glaciations were most typical phenomena of great climatic deterioration and had a great influence on the paleogeography of the Quaternary and even on that of the late Cenozoic one cannot agree with the view that glaciers and glaciations are the only symptoms of cold climate. This conception is by no means limited to formal matters e. g. to the questions whether one ought to speak more properly of cold periods or of glaciations, especially in the case of areas extending outside of their extension. The signs of glaciations and still less those of glaciers are not sufficient to acquire a knowledge of the Quaternary, of its stratigraphy, its climatic changes, its land relief and all that composes the paleogeography of the period. It results from the limited extent of glaciations in time and space and from insufficient knowledge — aggravated moreover by many doubts — of their connections with climatic changes.

The most direct determination of present and ancient climatic conditions are the values of temperature and those of precipitation. The data on paleotemperatures based on the research of the ratio of the content of oxygen isotopes in deep-sea sediments (EMILIANI 1955, 1958) have revolutionized the opinions on the frequency and stability of climatic fluctuations in the Quaternary. They turned out to be far more numerous than those anticipated in the well-known scheme elaborated by PENCK and BRÜCKNER. Still more exact were as it seems the paleotemperature curves constructed by the Danes on the ground of the ratio $\delta(O^{18})$ representing the O^{18}/O^{16} ratio in the Greenland glacier (DANSGAARD, *et al.*, 1969; DANSGAARD, TAUBER, 1969). The accuracy of the method is attested by the fact, that on the curves $\delta(O^{18})$ are marked distinctly the warm twentieth and thirtieth years of the present century. Conclusions concerning precipitation in the past (the Quaternary can be drawn from the evidence of the existing cirque glaciers (ANDREWS, *et al.*, 1972) and glacier caps of the Antarctic, Greenland and Iceland and reconstructions of the snow line (FLINT, 1971). The methods are, however, deceptive in continental frost and dry areas where there are no glaciers and where both nowadays and in the past snowfalls were very scarce.

The data relative to the main climate elements, such as temperature and precipitation in the geologic past are known as obtained indirectly from the evidence of organic remains in particular from palynologic analyses which give excellent results leading to quantitative determinations of the temperature and precipitation values. But it should be noted that organic remains in glacial sediments are very rare.

This reservation reminds us of the importance of the paleoclimatic and paleogeographic cyclothemes. The sequence of glacial and extraglacial cyclothemes provides undoubtedly valuable paleogeographic and paleoclimatic evidence. There are, however, many limitations to their testimony. The existence of the cyclothemes discussed is limited in space and time; they are not to be found outside the maximum reach of glaciations and they were not formed in a given area of middle geographic latitudes in the time of the entire cold age; the cyclothemes were absent before the maximum extent of the continental ice-sheet and ceased to be formed after its decay in vast peripheral areas of the given glaciation. As a rule they do not contain any organic remains or fossil soils. Finally, the glaciers, which have formed the sediments, are not a reliable, direct and simple index of climatic changes as already mentioned above and as will be further developed in a later part of this discussion. Hence, the stratigraphy of the continental Pleistocene and consequently also its paleoclimatology is largely based on nonglacial and, particularly, on periglacial sediments (SOERGEL, 1919; HORBERG, 1953; Colloque international..., 1960).

The most important manifestations of cold climate on the northern hemisphere in high and middle latitudes are glaciers and permafrost as well as periglacial phenomena. Therefore, the climatic evidence of those symptoms and the paleoclimatic meaning of their traces left in the Pleistocene landscape sediments require consideration.

THE PALEOCLIMATIC EVIDENCE OF GLACIERS

The first doubts on the subject of the climatic and paleoclimatic testimony of glaciers are suggested by the fact that they are commonly treated jointly without making any distinction between their types (MEIER, 1965). Yet, the conditions of the origin of mountain glaciers preserved in local topographically determined situations and the continental glaciations situated in subarctic areas and in particular the Pleistocene continental glaciations extending over wide areas of middle latitudes, differ from each other.

It appears that conclusions relative to thermal conditions of glacial phenomena are considerably limited and that deductions in that respect call for greater caution.

That insufficient knowledge of the connections between glacial phenomena and climatic changes (MEIER, 1965) relates to both precipitation and thermal conditions.

It is known that snowfalls, as conditioning directly the formation and development of glaciations, require temperatures below 0°C. The preservation of snow and its transformation into glacier ice are possible only where negative mean annual temperatures prevail (DOSTOVALOV, KUDRYAVCEV, 1967). In consequence, the important role of temperature as affecting the lower snow line is generally acknowledged. In this case, however, the thermal conditions are not the only decisive factors because the scarcity or lack of snowfalls can bring about the absence of thermally conditioned permanent snow on the heights.

We are allowed to believe that the mountain and continental glacier fronts are situated in places where the prevailing thermal conditions facilitate the equilibrium and relative stability of the glacier edge position. The temperature, however, is not always a decisive factor of the position of a glacier edge. The limit of its extent and its relative stagnation depend largely on the inflow of glacier masses due to the abundance of snowfalls usually in areas far remote from frontal (marginal) glacier parts. As a result glacier ranges are not always thermally conditioned. It is known that outside the limits of at least the maximum Pleistocene continental ice-sheets low temperatures prevailed and this undoubtedly indicates that cessation of the glacier's extension was due to not lack of precipitation but to excessive temperatures. A confirmation of this conclusion can be found also in the limitation of glacier extents in the colder and arid areas of East Europe and Asia and in the western parts of North America.

Snowfalls are of decisive importance for the origin and development of both mountain- and continental glaciers. Therefore, the view that the expansion of glaciers requires larger snowfalls i. e. greater atmospheric humidity, more intensive evaporation and higher atmospheric temperature were expressed still before the end of the XIX century. Among many varieties of this conception is the modified hypothesis of SIMPSON who in his publications of 1934 and 1940 locates glaciations between the maxima and minima of the thermal curve (FLINT, 1971).

Glaciations increase as snowfalls become more abundant. Larger snowfalls on Spitsbergen favor the development of glaciers in spite of higher summer temperatures than on the island of Wrangel which is colder but where the scarcity of snow leads to underdevelopment or absence of glaciers (MARKOV, *et al.*, 1965). The extension of North American and European ice-sheets depended on the inflow of precipitation rather than on the rate of climatic cooling (MARKOV, *et al.*, 1968). In the same work the coincidence between local phases of the NE-Siberian glaciations and the global amelioration of the climate is pointed out.

The glaciation of the eastern part of the Baffin Land is conditioned by snowfalls and that is why the glaciation of this area had its greatest extension in the earliest phase of the last cold age. The fact occurs repeatedly in all the Arctic areas (ANDREWS, *et al.*, 1972).

The increasing severity of climate induced a decrease of precipitation and the resulting shrinkage of glaciers. Hence, the decrease of glacier volume began at the time when the Earth entered the phase of the full cold age (ANDREWS, *et al.*, 1972; FLOHN, 1969). Likewise in Siberia during the continental phases of frosty climate the glaciers shrank and died out as a result of scanty alimentation (MARKOV, *et al.*, 1968).

The formation and development of glaciation was favored by low temperatures which induced snowfalls and preserved snow and glacier ice not only during the summer periods but over hundreds and thousands of years. Very low temperatures, however, accompanied by disappearance of precipitation, hinder the development of glaciers and may cause them to shrink. The course of the development of glaciations cannot therefore be unreservedly parallelized with that of thermal changes. It is also certain that the maximum extents of continental glaciations are not synchronous with the maxima i. e. thermal minima or pleniglacials, or still more correctly with the climax of the cold ages.

The correctness of this conclusion is supported by paleogeographic reconstructions based on examinations of the periglacial series separated by layers containing organic remains (DYLIK, 1966, 1967; JAHN, 1969; HAMMEN, *et al.*, 1969, 1971; MOJSKI, 1969a, b; PAEPE, PISSART, 1969; ZAGWIJN, 1961). The conclusion is further confirmed by the curves of paleotemperatures of DANSGAARD, *et al.* (1969) expressed in values of $\delta(O^{18})$ or in the O^{18}/O^{16} ratio in the Greenland glacier, and also by the insolation gradient curves close after the Brörup till ca. 50,000 years B. P. and further ca. 42,000—35,000 B.P., and the greatest minima ca. 22,000 and ca. 14,000 B. P. The minima of thermal gradients as shown by KUKLA (1972) fall on the time before 65,000 years and before 17,000 years. The thermal minima of last cold age fall on the time preceding the maximum extent of the Würm ice-sheet and after its partial regression.

All these facts show clearly that glaciers and glaciations are predominantly dependant on snowfalls and that their importance in reconstructions of ancient thermal conditions is very limited. They provide no reliable evidence under conditions of very low temperatures, both in early and in late phases of cold ages. In other words, they afford evidence of cold and humid conditions i. e. they are symptoms of cold oceanic conditions. Glaciers were poorly developed in frosty and continental areas where if the climate was very cold and arid they were completely absent and where permafrost (also called subsurface glaciation) developed instead of glaciers and of surface glaciation.

THE PALEOCLIMATIC EVIDENCE OF PERMAFROST

Permafrost is formed in areas which totally differ from those with occurrence of glaciers and glaciations, namely in areas of very low temperatures and scarce precipitation. Mean annual temperatures of -3°C and below together with scanty precipitation determine the conditions of permafrost formation (DOSTOVALOV, KUDRYAVCEV, 1967).

As early as at the down of the concept of continental glaciations, Jan CZERSKI (1882) set forth an alternative conception of permafrost by demonstrating that in the area of East Siberia a very cold and dry climate had prevented the formation of glaciers but favored the development of permafrost. Later research by Russian workers has removed all doubts and confirmed the opinions of the eminent Polish scholar (MARKOV, *et al.*, 1965).

The extension of glaciers of both the present and the Pleistocene glaciations is — or was — decreasing with distance from the Atlantic. The Pleistocene glaciations, the Würmian in particular, reached farthest to the South in areas bordering on the Atlantic, but became reduced in the interior of the Eurasian and North American continents where their spread was gradually decreasing or where they even failed to develop in spite of the close proximity of the Pacific and Arctic Oceans.

Permafrost is a manifestation of cold and continental climates contrary to glaciations which provide evidence of cool and oceanic climates. Both testify to the degree of humidity of the climate—this degree being high in the case of glaciations and very low in that of permafrost. It is worth noting that there is a difference in the indirect evidence of precipitation as far the manifestations of both these cold climate symptoms are concerned. The presence of permafrost provides direct evidence of poor precipitation in the whole area of its occurrence. It would be impossible, however, to draw unreservedly similar conclusions from the distribution of Pleistocene glaciations. Ice-sheets were shifted under the pressure of ice bodies that were growing as a result of increasing snowfalls but this did not necessarily occur over the whole glaciated area. Permafrost constitutes therefore a much more direct index of atmospheric precipitation than continental glaciers.

Also in contrast with glaciers, whose connection with thermal conditions is still unsatisfactorily known and rather limited, permafrost and the associated periglacial phenomena provide direct indications of temperature. The thermal conditions of permafrost formation and of its development are very precisely determined. Well known are also the limit values of temperatures indispensable for the development of a whole range of frost-caused phenomena such as pingos, icings and especially for the formation of frost fissures and fissure-ice polygons. Their formation requires mean annual temperatures of -5°C to -6°C, large, contrasting thermal gradients and abrupt temperature oscillations of an order from -20°C to -40°C (DYLIK, 1963).

Like permafrost itself and the processes occurring within, so do also other periglacial phenomena promptly and directly respond to climatic changes. This refers chiefly to frost weathering, to stone circles, stone stripes and other periglacial structures, as well as to congelifluxion and eolian processes, whose traces preserved in Pleistocene sediments are among the most reliable paleoclimatic and paleogeographic indicators.

Very deep and persistent permafrost has been formed in areas of the greatest continental bodies of the globe – NE-Eurasia and NE-America which border on the freezing Arctic Ocean. The formation of the East Siberian permafrost began towards the end of the Tertiary (BAULIN, 1958, 1962; BAULIN, *et al.*, 1967; DOSTOVALOV, KUDRYAVCEV, 1967; MARKOV, *et al.*, 1965, 1968; POPOV, 1957) or in the early Pleistocene (KATASONOV, 1969; MARKOV, 1973) and is still preserved to-day. Its stability is exceptional and comparable only with that of the great ice-caps of such oceanic polar areas as Greenland, Iceland and, first of all, the Antarctic which was glaciated in the Neogene or at any rate in the Pliocene (CAILLEUX, 1963; FLOHN, 1969). The permanence of both these cold climatic symptoms was determined by the persistence of cold climatic conditions during the late Cenozoic in cold and oceanic polar areas in the case of ice-caps and in severely cold, arid and continental ones in that of permafrost.

Conditions were different in the regions of middle latitudes in Europe and in the eastern part of North America which are characterized by a greater sensibility to climatic changes and where any symptoms of changes show a greater mobility. Expansion and shrinkage of ice-sheets are the most common expressions of this mobility. Many periglacial phenomena, however, although rather underestimated in the general approach to the paleoclimatology and paleogeography of the Quaternary, show a still greater mobility and a more ready response to climatic changes.

Even the almost stagnant early Pleistocene permafrost of East Siberia shows a considerable mobility in areas situated farther westward. Already on the boundary of Central and East Siberia POPOV (1957) has stated a transgression of permafrost onto the morainic sediments of the Norilsk region. Frost-caused phenomena in Europe display even greater dynamics.

It is known, that permafrost existed in Europe long, ca. 40,000 years, before the maximal advance of the last glaciation, undoubtedly after the Brörup and probably earlier. The well-known conditions of the formation and persistence of permafrost go to prove that it was not the temperature put a stop to the further southward extension of the würmian ice-sheet. Its spreading was brought to a standstill by the scarcity of alimentation with snow, by the insufficient inflow of ice bodies and by the increasing continentality of climate to the south and east of Europe, where permafrost occurred instead of glaciers.

Permafrost has persisted only in areas free of ice-sheets which thawed under the glacier cover, except perhaps in marginal areas where the thickness of glacier-ice was sufficiently negligible. Permafrost has shifted, however, northward into areas released from their glacier cover, where temperatures were sufficiently low and precipitation was reduced. Up to the Younger Dryas inclusively permafrost expanded from Central Poland to Southern Sweden, thus testifying to a continental cold climate.

THE PALEOGEOGRAPHIC SIGNIFICANCE OF PLEISTOCENE GLACIAL AND PERIGLACIAL PHENOMENA

The formation, extension and waning of the great continental ice-sheets constitute important paleogeographic features of North America and Europe. The eustatic movements associated with the development and decay of glacier bodies contributed directly to a diversification of the previously variable configuration of continents and seas. Indirectly, they affected the course of fluvial erosion and valley cutting as well as the origin of marine terraces and the formation of coast lines.

The growth of continental glaciers, of shelf ice and of other forms of sea-ice influenced the cooling of climate over vast areas outside the reach of continental and marine glaciations, foremost by the increasing albedo and by its effect on the circulation of air masses, especially through the increase and intensification of anticyclonic movements. As well-known, WILSON (1964, 1966) and FLOHN (1969) explained the climatic deterioration of the whole Earth in the late Cenozoic by the spreading of the Antarctic shelf-ice that reached up to 55° S. lat. These vast ice surfaces induced a gigantic increase of the albedo and consequently a lowering of the mean annual temperatures by 5—6°C. That considerable increase of the albedo on the surface of North American and European ice-sheets is likely to have affected the intensification of periglacial phenomena in areas adjacent to glacier-caps.

The question of the paleoclimatic evidence of traces of the ancient glacial phenomena is a difficult one. This difficulty results first of all from insufficient knowledge of the interrelations between phenomena and climatic changes; and it is known that these relations are not simple and direct and that the delay in the reaction of glaciers to climatic changes can be measured in hundred and thousand of years (MEIER, 1965).

Simplest of all is the dependence of glacier formation and development on atmospheric precipitation. But as mentioned above, our knowledge of the response of ice-sheets to temperature changes, is rather limited. It is enough to recall that glaciers under oceanic conditions were most readily developed during the early phases of cold ages i. e. under relatively milder thermal conditions (ANDREWS, *et al.*, 1972), whereas in the extremely continental areas of NE-Siberia they advanced only during the world-wide climatic amelioration (MARKOV, *et al.*, 1968). At the same time it should be remembered that the shrinkage of glaciers was taking place not only as a result of the warming of climate but also under totally opposed conditions of considerably falling temperature and of consequent reduction of precipitation (ANDREWS, *et al.*, 1972; MARKOV, *et al.*, 1968).

The views of the authors cited above are in perfect agreement with the geophysical model of FLOHN (1969). After the phase of intensive shelf-ice production, the Antarctic glacier was decreasing in thickness and changing into a cold-type glacier. As a result of the previous extension of sea-ice the albedo increased, and simultaneously, owing to the advectional fall of temperature in tropical seas decreased by

5—6°C as a result of the cooling down of air and oceanic currents from the North and South. This lead to a reduction of evaporation by ca. 30%. Thus arose the arid phases of the climax of the cold age in which glaciers have shown a minimum of development and were rather stagnant.

The considerations above provide some indications concerning the paleoclimatic interpretation of the traces of Pleistocene glaciations and especially of the last one, as recorded in the land-forms and sediments. The task is not easy and is moreover aggravated with doubts as it will appear in any attempt to interprete the climatic significance of the maximum extent of the Würm glaciation.

The land-forms and sediments which determine the maximum reach of the last glaciation show beyond any doubt that this transgression was preceded by abundant snowfalls which, however, were not synchronous with the achievement of the extreme limit of this glaciation. The motion of the glacier was retarded in relation to the increased alimentation, that was most intensive in the Scandinavian glaciation center which was remote from its terminal margin. The presence of permafrost, prior to the glacier advance and the thermal minima, as shown by the paleotemperature curves indicates that the glacial maximum — or the maximum extension of the ice-sheet — did not coincide with the maximum i. e. the climax of the cold period. As concerns atmospheric precipitation only rough estimations can be derived from the maximum range of the glaciation. Still more limited are the conclusions relative to the thermal conditions. The temperature must have been low enough to induce snowfalls and the mean annual temperature must have been below 0°C in order to preserve the glacier ice from melting. As a matter of fact the temperatures were even very low, but this conclusion does not result from the evidence of the glacier but only from the presence of permafrost.

The traces of ice-sheet waning i. e. of its recession most probably testify to an amelioration of the climate, but at the same time to reduced precipitation; hence the assumption that deglaciation took place in a dry and cold phase. If it were the case, the decay of the glacier may be thought to have taken place by virtue of the mechanism postulated in the model of Flohn; analogically Andrews, *et al.* (1972) and Markov, *et al.* (1968) hold that the traces of ice-sheet stagnation provide a most reliable evidence of dry and severely cold climatic conditions.

Moreover, the testimony of glaciation is limited in space and time. Continental glaciers encroached upon permafrost areas extending far beyond the maximum reach of glaciation. There existed also vast permafrost regions which never bordered on glaciers. As a result, the surface of permafrost was by at least 8 millions km^2 larger than the one occupied by continental ice-sheets. In the predominant continental part of Europe, permafrost was developed during the early phase of the waxing Würm, i. e. probably when the glacier had not yet crossed the Scandinavian Peninsula. Permafrost existed then in continental Europe about 40,000 years before the Scandinavian ice-sheet had reached its maximum extension. The limitation in time of the climatic evidence of glaciation is most distinctly expressed by the fact that in the area in question, the ice-sheet existed hardly several thousands of years, i. e. during ca. 10% of the whole cold age (FAIRBRIDGE, 1972).

Meanwhile the permafrost, that had existed for several tens of thousand years before the maximum transgression of the continental ice-sheet, had shifted into the areas abandoned by glacier-ice, those of northern Poland, Germany, the European part of the USSR and to the southern terrains of Denmark, Sweden and Finland persisting there until the end of the Pleistocene. On account of both the space of its extension and its duration in time permafrost is a potentially richer source of information about climatic changes during the last and most probably also during the previous cold ages.

Apart from its quantitative superiority, permafrost provides also the most reliable qualitative record of climatic changes, especially of climatic deterioration. The interrelations between permafrost and such major climatic elements as temperature and precipitation — are much simpler and more direct than the dependance of a glacier on climatic fluctuations. The reactions of permafrost itself and of many periglacial phenomena to climatic changes are direct and almost immediate. POPOV (1957) is therefore justified in his opinion that permafrost traces in Central and East Europe constitute a more conclusive evidence of the existence of continental ice-sheets than are glacial sediments. Similarly JAHN (1960) has shown that traces of the oldest cold age (or of the oldest cold ages) can be deciphered only on the basis of such periglacial features as strong eolisation which are preserved in so called preglacial sediments. Besides, wind-worn sand grains have for a long time been found helpful in determining the lower limit of the Pleistocene. Nowadays this important climatic index has gained due to appreciation owing to the significance of eolianites (LIETZ, SCHWARZBACH, 1971; FAIRBRIDGE, 1972).

Independantly from the views expressed by the present writer, many other enunciation have emphasized the paleoclimatic significance of Pleistocene periglacial phenomena. On the ground of investigations in the Central and High Atlas DRESCH and RAYNAL (1953) have ascertained that periglacial elements provide a better index of past climates and that periglacial environments are of greater morphogenetic significance than glacial ones. TRICART (1955a) has demonstrated the synchronous character of glacial and periglacial phenomena which is marked by the interrelation of glaciofluvial and periglacial sediments. He has further proved, in accordance with our argument, that periglacial phenomena are distinguished, by their greater continuity. They lasted from the beginning to the end of the cold age, only modifying their form according to climatic fluctuations. They constitute therefore a more exact reflection of climatic changes. Investigations of glacial sediments and land-forms alone is not sufficient to ascertain the sequence of climatic changes for, e. g. the recession of a glacier can be as well the result of an amelioration of climate as that of a decrease of precipitation with prevailing low temperatures. It appears possible to corelate periglacial phenomena with remote glaciated areas and with particular phases of the development of glaciations. Finally, important is the opinion of TRICART that the connection between dynamics of glacial phenomena and climate is less direct and more complex.

In another work, TRICART (1955b) basing on the fact that the intensity of periglacial processes is closely and directly related with climate, argues that the climate of the Riss in the Southern Alps was not colder than that of the Würm. Therefore, it should be assumed that the greater extension of the penultimate — Riss — glaciation is to be ascribed to more abundant precipitation and not to lower temperatures. It seems that this explains likewise the absence of glacial sediments from cold ages prior to the Mindel. These ages were certainly more dry and probably also much colder.

CONCLUSIONS

The late Cenozoic deterioration and the changes of climate that took place in that time are recorded by multiple and diversified manifestations depending on time, geographic latitute and position in relation to the configuration of continents and seas as well as to the land relief and especially to the course of mountain ranges. If for the sake of simplification, the organic symptoms of life be set aside, there remain, first of all the traces of morphogenetic glacial, periglacial and pluvial processes and the nearly direct evidence of ancient temperatures as preserved in deep-sea sediments and in the ice-bodies of glacier-caps that have persisted till the present time.

Traces of glacial phenomena, whether directly recorded by landforms or indirectly manifested by the results of eustatic movements are undoubtedly of the utmost importance for the paleogeography of the late Cenozoic and in particular for that of the Pleistocene. The paleoclimatic evidence of the glacial sediments and land-forms is, however, much more limited than that of other symptoms such as, first of all, fossil permafrost and periglacial phenomena occurring in the past in cold climates of continental areas.

Pleistocene glacial phenomena in high geographic latitudes were limited in space and were merely episodes as compared with the duration of cold ages. In contrast, periglacial phenomena were spread over vast areas and were almost uninterruptedly active, vanishing only under ice mantles and during periods of intervening warmer oscillations. Periglacial processes responded vividly and directly to climatic changes, contrary to continental ice-sheets whose reaction was considerably retarded. The traces of old glaciations indicate an abundance of atmospheric precipitation and changes in their intensity with the reservation that the changes in abundance of precipitation and the behaviour of glaciers including their formation, extension, stagnation and shrinkage were but relatively synchronous. The paleothermal record of glaciers is still less known, more limited and aggravated with many doubts. Periglacial phenomena constitute a more direct source of information with regard to precipitation and in particular to thermal changes.

Glaciations are closely associated with cold varieties of oceanic climates. They cannot therefore provide any indications of climatic changes in continental areas, whereas permafrost and periglacial phenomena are the only morphogenetic records in continental areas. They further indicate the dry and severely cold phases occurring periodically during the cold ages in such — nowadays rather oceanic — areas, as western Eurasia and eastern North America.

Therefore there is no justification for referring to cold ages or epochs as glacial periods or epochs and to define cold ages and temperate substages as glacials, interglacials and interstadials. The usage of such designations as „glacial" and its derivations is misleading, especially in connection with areas that were never glaciated. The application of such definitions to geographic middle latitudes is likewise unfounded considering the episodic character of glaciation in these regions and, first of all, the reduced paleoclimatic evidence of glaciers.

Questions of terminology are not, however, the most important ones, for in the nomenclature of many branches of science there exist terms, the meaning of which has changed long ago, in relation to their previous etymologic connotation. One of them is e. g. the term *periglacial* which has lost its initial etymologic meaning.

Essential is the fact that glaciations are not the only or most common paleogeographic feature of the late Cenozoic. They constitute a manifestation of cold climate which is typical of oceanic areas in high and middle geographic latitudes. Their paleoclimatic evidence is still more limited. The great cold ages, the late Cenozoic in particular, should not remain overshadowed by glacial phenomena. A thorough knowledge of these periods requires that all the traces of climatic changes must be taken into consideration. In order to acquire that knowledge of the cold ages in continental areas attention must be focussed on permafrost, frost-caused processes and other periglacial phenomena.

Translation by J. Rakowiecki

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