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THE THEORETICAL AND PRACTICAL DEFINITION OF THE TERM »PERIGLACIAL« IN ITS GEOGRAPHICAL AND GEOLOGICAL MEANING

Abstract

Whereas the term *periglacial* is fairly well understood and defined from a geological point of view the geographically orientated periglacial research is still in need of a satisfactory and a scientifically precise definition of the term. The geographical definition aims at a theory and a practical method for the spatial delimitation of both the polar and alpine periglacial zones which can also be applied to the definition of palaeoperiglacial environments.

It can be shown that both actuoperiglacial and palaeoperiglacial environments can be defined with regard to their spatial extent only by means of spatial associations of diagnostic periglacial microrelief features and their specific climatic parameters.

On these grounds the periglacial environment can be subdivided into regional types which again can be defined by climatic parameters. A map showing the extent and regional differentiation of the present polar periglacial zone, idealized schemes showing its delimitation and subdivision and an idealized profile through the altitudinal periglacial zone are presented.

INTRODUCTION

The term *periglacial* was introduced by the Polish geologist WALERY ŁOZIŃSKI in the year 1909 (1912). Since then and in connection with the remarkable development of periglacial research the term has experienced:

1. a considerable extension of its meaning and application,
2. widely differing opinions concerning its precise definition (*cf.* BOESCH, 1960; BROCHU, 1960, 1964; DYLIK, 1962, 1964; DYLIKOWA, 1962; BLACK, 1966; BOUT, 1966),
3. some criticism with regard to its wide application (*cf.* ZEUNER, 1959; CAPELLO, 1962; MENSCHING, 1977) and even suggestions to abandon it altogether (LINTON, 1969).

In the beginning it was applied above all to denote the geomorphic and geological effects of the specific cold climatic conditions in the areas bordering on the margins of the Pleistocene ice sheets. In this comparatively restricted and primarily geological sense the term was clear and fairly well understood and defined.

Today it is used for a wide variety of cold climatic conditions, associated geomorphic processes, landforms and sediments regardless of geological age or proximity to a glacier. Apart from that it has always had a fundamental spatial meaning which has become the object of geographically orientated periglacial research. However,

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in contrast to the primarily geological concept there is still up to the present day no satisfactory and scientifically precise definition of the term *periglacial* from a geographical point of view.

Terms like *periglacial zone* or *periglacial environment* which are basically geographical terms have become very popular and are firmly established now (PÉWÉ, 1969; WASHBURN, 1973; EMBLETON and KING, 1975; JAHN, 1975; FRENCH, 1976; DEMEK, 1978), but it has proved extremely difficult to define them with scientific precision. It is the purpose of this paper to contribute to the geographical definition of the term *periglacial*.

THE PROBLEM AND WAYS OF APPROACH

To define the term *periglacial* from a geographical point of view means to develop a theory and a practical method for the spatial delimitation of a morphoclimatic zone where all geomorphic processes are effectively influenced by frost action and the presence of intensely frozen ground. In the Arctic, Antarctic and Subarctic this morphoclimatic environment appears as the recent polar periglacial zone, in the high mountains of the subpolar, middle and lower latitudes as the mountain, alpine or altitudinal periglacial zone.

For all recent and active periglacial environments we suggest the term *actuoperiglacial*, by *palaeoperiglacial* on the other hand we understand all inactive, former periglacial environments irrespective of geological age.

The geographical definition of the term *periglacial* presupposes the definition of an inventory of periglacial processes, landforms and sediments and also implies the problem of determining the boundary conditions, above all the climatic boundary conditions of the periglacial environment. Conclusions from this approach can be used by geologists for a more precise definition of the former periglacial environment. Taking the temporal besides the spatial dimension into account the geographical definition becomes the most complex and comprehensive definition of the term *periglacial*.

The problem of the geographical definition consists in finding universally acceptable, qualitative and quantitative criteria for the spatial delimitation which are reliable, diagnostic and practicable. This problem again results from:

1. the size and spatial variety of the areas to be delimited, or, in other words, the scale of the approach (*cf.* RAYNAL, CAILLEUX, 1976),

2. the world-wide occurrence of these regions in different latitudes, longitudes and altitudes and thus under a great variety of complex climatic conditions.

From this follows that for the spatial delimitation of the periglacial environment against other morphoclimatic zones we need simple, but diagnostic climatic threshold values. These, however, cannot be deduced from one of the numerous existing climate classifications because all these have been conducted for different purposes but not especially for the spatial delimitation of the periglacial zone. Some classifications have proved very useful for a general description and distinction of periglacial climatic conditions (*cf.* FRENCH, 1976), but they do not provide us with significant threshold values for the spatial delimitation.

Likewise, the periglacial zone cannot be defined by indirect climatic criteria such as the polar forest border or the upper timber line. Both are not static and the presence of trees does not exclude intense frost action or frozen ground.

In addition to this the spatial extent of the periglacial zone is not absolutely identical with the distribution and extent of permafrost. Such a limitation seems too restrictive because many geomorphic features which are regarded as periglacial do not require permafrost for their formation (WASHBURN, 1973). The term *periglacial* is more comprehensive than permafrost and implies areas underlain by intense seasonally or diurnally frozen ground which can be geomorphologically very effective, too.

ZONES OF FROZEN GROUND AND THEIR CLIMATIC THRESHOLD VALUES

Although the periglacial environment cannot be identified with the extent of one particular type of frozen ground, the distribution of various types of frozen ground and their specific climatic threshold values provide some basic climatic parameters for the spatial delimitation and regional subdivision of the periglacial environment (fig. 1).

Within the polar periglacial zone one can distinguish (BROWN and PÉWÉ, 1973; IVES, 1974):

1. continuous permafrost which can be delimited by the −6 °C to −8 °C mean annual isotherm;
2. discontinuous permafrost which underlies more than 50 % of the area and can be delimited by the −3 °C to −4 °C mean annual isotherm;
3. sporadic permafrost which underlies less than 50 % of the area and can be delimited by the −1 °C to −2 °C mean annual isotherm;
4. seasonally frozen ground which is spatially associated with discontinuous and sporadic permafrost and extends beyond the permafrost boundary. Especially on high mountains in low latitudes diurnally frozen ground occurs as a regular phenomenon above the 0 °C to −1 °C mean annual isotherm.

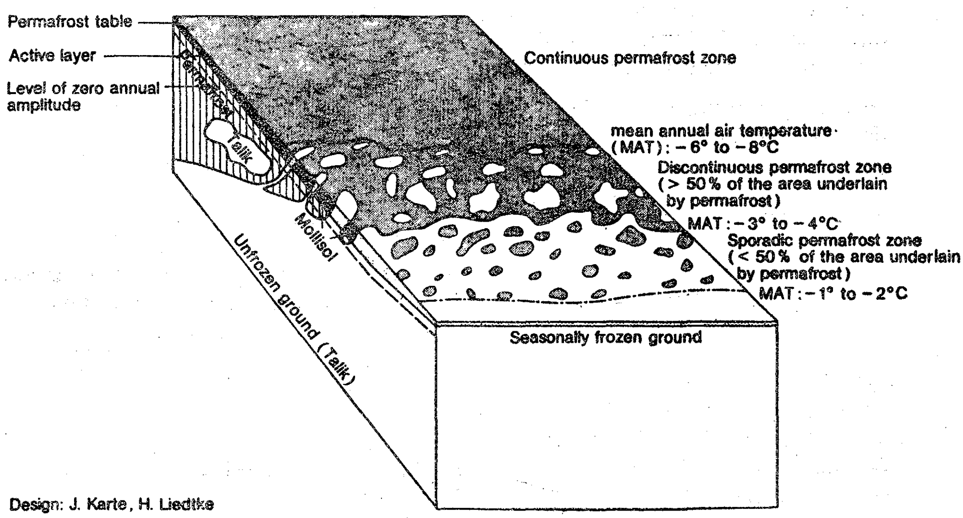


Fig. 1. Zones of frozen ground

Table I

Climatic threshold values for the distribution of periglacial geomorphic features

PERIGLACIAL GEOMORPHIC FEATURES	CLIMATIC THRESHOLD VALUES (the thermal threshold values represent upper limits against more moderate frost climatic conditions) MAT: mean annual air temperature T_c: mean air temperature of the coldest month MAP: mean annual precipitation
1. Periglacial geomorphic features whose formation requires **permafrost**:	
1.1. Features connected with **continuous permafrost**	
Ice-wedge-polygons	MAT: < –4°C to < –8°C MAP: > 50 to 500 mm Other climatic indication: rapid temperature drops in early winter
Sand-wedge-polygons	MAT: < –12°C to < –20°C MAP: < 100 mm
Closed-system-pingos	MAT: < –5°C
1.2. Features connected with **discontinuous permafrost**	
Open-system-pingos	MAT: < –1°C
1.3. Features which occur in connection with **continuous, discontinuous and sporadic permafrost**	
Depergelation forms ("thermokarst" forms, active layer failures, detachment failures, ground ice slumps, permafrost depressions, alas, "baydjarakhs", "dujodas", alas thermokarst valleys, beaded drainage, thaw lakes, oriented lakes, thermoerosional niches, thermoabrasional niches, degradation polygons, thermokarst mounds)	MAT: < –1°C Other important indication: high ground ice content
Seasonal frost mounds (frost blisters, hydrolaccoliths, bugor)	MAT: < –1°C to < –3°C
Palsas	MAT: < 0°C to < –3°C
Rock glaciers	MAT: < +2°C to 0°C MAP: < 1200 mm Other climatic indication: continental climates with high incoming radiation, sublimation, evaporation and little snowfall
2. Features whose formation requires intense **seasonally frozen ground** but which also occur in connection with **permafrost**:	
Seasonal frost-crack-polygons (ground wedges)	MAT: < 0°C to < –4°C T_c: < –8°C

tab. I (cont.)

Frost mounds (thufurs)	
Tundra hummocks (high latitude occurrences)	MAT: < −10°C
Earth hummocks (high latitude occurrences)	MAT: < −6°C
Earth hummocks (high altitude occurrences)	MAT: < +3°C
Nonsorted circles (Mud boils, Mud circles)	MAT: < −2°C MAP: > 400 to 800 mm
Sorted circles and stripes (⌀ > 1m)	MAT: < −4°C
Sorted circles and stripes (⌀ < 1 m)	MAT: < +3°C
Gelisolifluction microforms (lobes, steps, ploughing blocks)	MAT: < −2°C
Nivation- and cryoplanation-features (nivation hollows, cryoplanation terraces, frost riven cliffs)	MAT: < −1°C
3. Features which are linked to diurnally frozen ground and needle ice but which also occur in connection with seasonally frozen ground and permafrost:	
Miniature polygons Miniature sorted forms and stripes Microhummocks	MAT: < +1°C

THE ROLE OF PERIGLACIAL INDICATORS AND THEIR SPATIAL ASSOCIATION

Referring to what has initially and generally been stated about the morphoclimatic character of periglacial environments besides frost action and the presence of intensely frozen ground its geomorphic effectiveness (Troll, 1947) must be stressed as an essential diagnostic criterion which is common to all periglacial environments. An area in which frozen ground is geomorphologically effective is not necessarily an area where frost controlled geomorphic processes dominate. In this sense the delimitation of periglacial zone would prove a very difficult problem (Jahn, 1975).

Geomorphic effectiveness more generally refers to sufficient geomorphic manifestations on the land surface. Taking this into account the extent of the periglacial environment can only be delimited by the distribution of diagnostic periglacial geomorphic features, especially micro-relief features which serve as periglacial indicators. Climatic threshold values for their distribution which have been compiled from the existing extensive literature (tab. I) are very important for the desired climatic delimitation of the actuoperiglacial as well as for the reconstruction and delimitation of the palaeoperiglacial environment.

The authors are aware of the problems associated with the cited climatic threshold values. For many of the periglacial microforms it is not yet adequately known how their formation is controlled by climatic conditions: often their formation is indicated by other climatic parameters than their geographical distribution. For example the formation of thermal contraction features (ice-wedge polygons, frost-crack polygons) rather depends on rapid temperature decreases which cannot be expressed by mean annual temperatures. However, despite these limitations the latter threshold values are a legitimate means of geographical description of the features' distribution, and as such they are very useful for the geographical definition of the term "periglacial".

For the purpose of this paper it is not only important to know which periglacial indicators are diagnostic but also in which way they can be used for the spatial delimitation of the periglacial environment. It is essential that the delimitation cannot be based on the distribution and climatic threshold values of just one specific type of periglacial microforms, no matter how ubiquitously it occurs (e.g. sorted forms or gelisolifluction microforms). Nor can it be based reliably on just a locally isolated occurrence of such a feature. These isolated occurrences may indicate some geomorphic effectiveness of frozen ground but as controlled by specific, locally favourable ecological site conditions outside the area of their regular distribution these features cannot be regarded as valid indicators of the periglacial zone.

The spatial extent of the periglacial zone can only be delimited by means of the distribution and the boundaries of spatial associations of genetically different types of periglacial microrelief which can be regarded as climatic associations. Only when this criterion is applied it can be guaranteed that the delimitation of the periglacial zone is not based on a type or an occurrence of periglacial microforms reflecting exceptionally favourable local site conditions outside the actual periglacial zone.

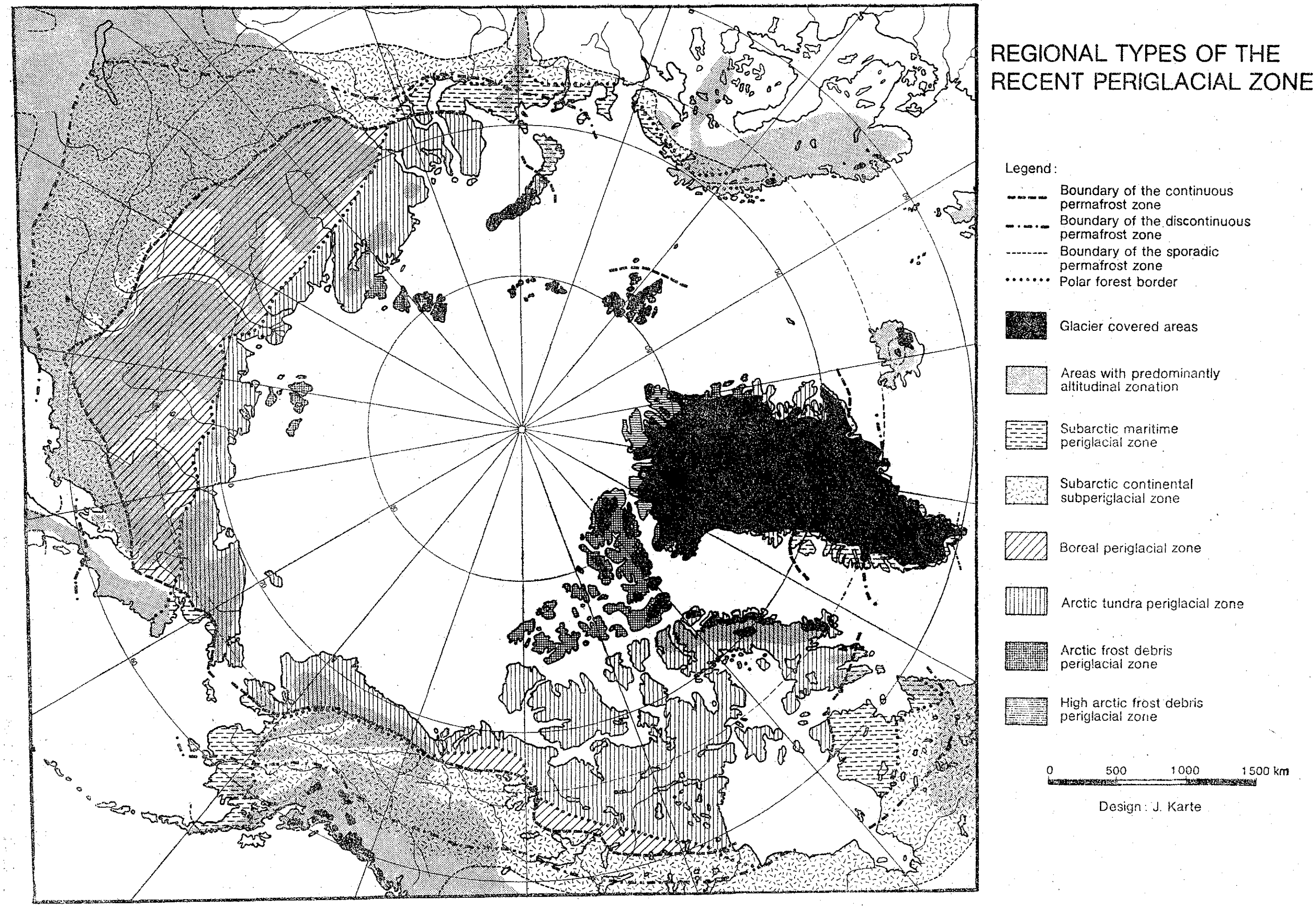
THE DELIMITATION AND REGIONAL SUBDIVISION OF THE POLAR PERIGLACIAL ZONE

According to the above criteria the polar periglacial zone is delimited by the boundary of the spatial association of periglacial microforms linked to level ground and gelisolifluction features and where this boundary line lies at sea level. Towards the equator this boundary line of spatial association rises; this is mainly due to the rising lower boundary of gelisolifluction features, and thus the polar periglacial zone gradually transcends into the altitudinal periglacial zone of subpolar, middle and lower latitudes.

Within the periglacial environment defined in this way and along its boundary the spatial associations of periglacial microforms are liable to latitudinal, altitudinal and peripheral-central variations. Taking these variations into account the periglacial environment is delimited in a differentiated way from region to region. Analogous to the great variety of boundary conditions the criteria for the spatial delimitation are regionally variable (HÖLLERMANN, 1976).

This differentiated delimitation is closely linked with the subdivision of the periglacial zone and the distinction of regional types whose boundaries are also indicated by climatic threshold values:

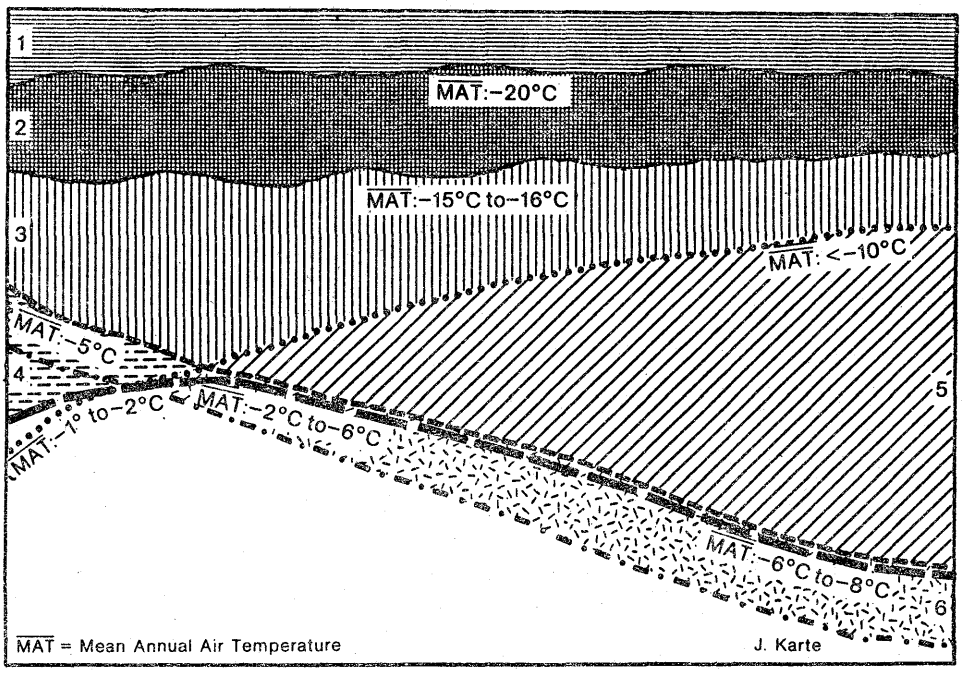
1. In the subarctic maritime environment, e.g. SW-Alaska the periglacial zone extends beyond the boundary of the continuous permafrost zone and is delimited


REGIONAL TYPES OF THE RECENT PERIGLACIAL ZONE
Legend:
Boundary of the continuous permafrost zone
Boundary of the discontinuous permafrost zone
Boundary of the sporadic permafrost zone
Polar forest border
Glacier covered areas
Areas with predominantly altitudinal zonation
Subarctic maritime periglacial zone
Subarctic continental subperiglacial zone
Boreal periglacial zone
Arctic tundra periglacial zone
Arctic frost debris periglacial zone
High arctic frost debris periglacial zone
0 500 1000 1500 km
Design: J. Karte

by the boundary of associations consisting of congeliturbation forms covered with vegetation (mainly turf hummocks), gelisolifluction features covered by vegetation (mainly lobes) and forms connected with the thawing of ice-rich sporadic permafrost (depergelation forms, formerly so-called thermokarst forms). This boundary correlates fairly well with the —1 °C to —2 °C mean annual isotherm and the boundary of sporadic permafrost. The mean annual air temperature amplitude is less than 25 °C.

2. With increasing thermal continentality (i.e. the mean annual air temperature amplitude exceeds 25 °C) the boundary of the periglacial zone runs through the boreal forest and approaches the boundary of the continuous permafrost zone. Here, the association of periglacial microforms whose formation requires the existence of permafrost becomes relevant for the delimitation of the periglacial zone (palsas, pingos, frost blisters, ice-wedge polygons, depergelation forms). From the more maritime environment towards more continental conditions the mean annual air temperature along the boundary decreases from —2 °C to below —8 °C.

3. Also, with increasing thermal continentality (i.e. the mean annual air temperature amplitude exceeds 25 °C) and with mean annual air temperatures between



BOUNDARY OF THE PERIGLACIAL ZONE
BOUNDARY OF THE CONTINUOUS PERMAFROST ZONE
BOUNDARY OF THE DISCONTINUOUS PERMAFROST ZONE
POLAR FOREST BORDER

Fig. 2. Regional types of the polar periglacial zone and their climatic threshold values

1. High Arctic frost debris periglacial zone; 2. Arctic frost debris periglacial zone; 3. Arctic tundra periglacial zone; 4. Subarctic maritime periglacial zone; 5. Boreal periglacial zone; 6. Subarctic continental subperiglacial zone

−2 °C and −4 °C there is a broad subperiglacial transition zone beyond the true periglacial zone where associations of "organic" periglacial landforms predominate (palsas, string bogs).

4. Towards the pole these regional types transcend into the tundra and frost debris periglacial zones which can be further differentiated and delimited by means of associations of periglacial microforms and their specific climatic parameters — a problem that cannot be dealt with in detail in the framework of this paper.

THE DELIMITATION AND SUBDIVISION OF THE ALTITUDINAL PERIGLACIAL ZONE

The lower boundary of the altitudinal periglacial zone is determined by the lower boundary of the association of different types of gelisolifluction features (lobes, steps, ploughing blocks). Like the snow-line and the upper timber line it rises towards the equator and in the direction of increasing continentality; it rises in a wave-like fashion (fig. 3), usually culminating in the respective central parts of high mountain areas (Höllermann, 1977; Höllerman, Poser, 1977).

With regard to its delimitation and altitudinal subdivision the mountain periglacial zone shows some distinct individuality from latitude to latitude and from longitude to longitude:

1. For the altitudinal periglacial zone in the high mountains of subpolar and middle latitudes a tripartite subdivision is typical which is mainly due to decreasing vegetation cover with increasing altitude (Kelletat, 1977a).

In the lower periglacial zone various types of gelisolifluction features and congeliturbation features covered by vegetation predominate. The lower boundary of their spatial association indicates the lower boundary of the altitudinal periglacial zone.

In the middle periglacial zone gelisolifluction lobes, turf banked lobes and sorted forms which are free of vegetation are spatially associated.

In the upper periglacial zone features of so-called "free" gelisolifluction and sorted forms predominate.

2. With the transition into the high mountains of the subtropics with prevailing winter precipitation and dry summers the lower periglacial zone of higher latitudes becomes discontinuous, sporadic and even ceases to exist (Hagedorn, 1977; Kelletat, 1977b). Lack of moisture during most of the year becomes a decisive factor for the delimitation of the altitudinal periglacial zone (Höllermann, 1974, 1977).

3. In the high mountains of the arid zone there is no recent periglacial zone (*cf.* Mensching, 1977), at most a "periglacial zone of thermal readiness" in the sense of Messerli (1973) with locally isolated frozen ground microforms which cannot be regarded as diagnostic indicators of a true periglacial zone.

4. With increasing humidity in the high mountains of the inner tropics there is an altitudinal periglacial zone which, however, cannot be further subdivided. In this environment of diurnally frozen ground and needle ice micro-relief features of free gelisolifluction and miniature sorted forms prevail.

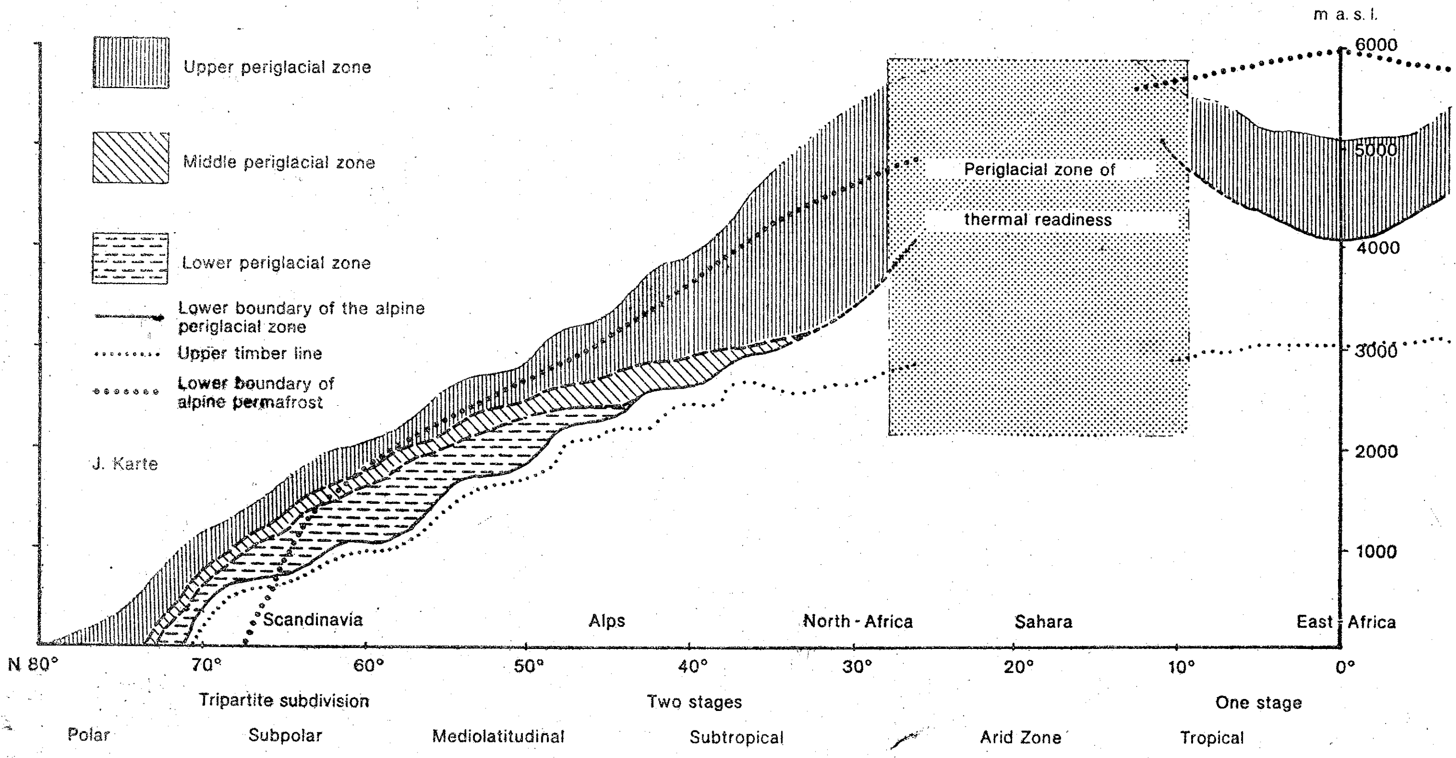


Fig. 3. Idealized meridional profile through the altitudinal periglacial zone between the Subarctic and the Equator

Up to now we have very few climatic threshold values for the lower boundary of the altitudinal periglacial zone and in addition to this these values are highly variable along the boundary. In the high mountains of subpolar latitudes the lower boundary is indicated by a mean annual air temperature of —2 °C; in the middle latitudes it varies between —1 °C and +5 °C (KELLETAT, 1977a), in the semi-humid subtropics between +3 °C and +6 °C (BROSCHE, 1977); in the high mountains of the inner tropics the lower boundary of the altitudinal periglacial zone lies slightly above the position of the 0 °C mean annual isotherm.

CONCLUSION

It was the purpose of this paper to stress the need of considering the geographical besides the geological aspect in the notion of the term *periglacial* and to contribute to a scientifically precise definition of the term from a geographical point of view. On the whole the following conclusions can be drawn and summarized:

1. The geographical definition of the term *periglacial* aims at the theoretical and practical delimitation of the spatial extent of the periglacial environment.
2. Permafrost and its distribution are no reliable criteria for the delimitation of the actuo- as well as the palaeoperiglacial environment, for the term *periglacial* is more comprehensive.
3. Besides frost action and the presence of intensely frozen ground the geomorphic effectiveness of the latter is a diagnostic criterion common to all periglacial environments.
4. The periglacial environment can only be delimited by means of diagnostic periglacial micro-relief features and climatic threshold values of their geographical distribution. For the delimitation climatic associations of genetically different micro-relief features are relevant rather than one particular type or a locally isolated occurrence.
5. It is the task of geographically orientated periglacial research to define the distribution of spatial associations of periglacial forms by means of simple climatic threshold values and thus to define the various zonal and altitudinal periglacial environments.

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