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PROPOSITIONS FOR THE LEGEND OF A MAP SHOWING THE DISTRIBUTION OF FOSSIL PERIGLACIAL PHENOMENA AS EVIDENCE FOR PERMAFROST AT THE MAXIMUM OF THE LAST GLACIATION

(POST-DENEKAMP ca. 30,000 B.P. till PRE-BÖLLING ca. 13,000 B.P.)

Abstract

An annotated legend for a map at the scale of 1 : 1,000,000 showing the distribution of fossil periglacial forms and structures indicative of permafrost during the maximum of the last glaciations is presented. It is the result of proposals made by the authors and discussions among members of the I G U Working Group: Coordination of Periglacial Research in collaboration with the INQUA Commission for the Palaeogeographic Atlas of the Quaternary. The background of the legend is shortly summarized in the introduction.

In the annotations the general content of the map and criteria concerning the compilation of the map are discussed: the legend is based on the opinion that out of the whole range of fossil periglacial phenomena only ice-wedge casts, fossil sand wedges, deep fossil frost cracks, pingos and pingo-like scars and fossil permafrost depressions are reliable indicators of former permafrost. Other fossil periglacial structures as e. g. fossil ground wedges, sorted forms, cryoturbations and involutions are regarded as unreliable indicators of former permafrost and plotted on the map only on special conditions. Geomorphological forms (e. g. dry valleys, cryoplanation terraces) which are less well suited for palaeoclimatic reconstructions or whose formation does not necessarily require permafrost are not plotted on the map.

Recommendations are being made as to how to key the plotted features to specific references from which they are taken and with regard to an annotated list of graphical representations accompanying the map and showing in which way the plotted features are indicating permafrost during the maximum of the last glaciation.

INTRODUCTION

The aim of this paper is to present a legend for a map showing the distribution of fossil periglacial structures and forms by which the spatial extent of permafrost during the maximum of the last glaciation can be reconstructed. It is part of the project "Significance of periglacial structures and forms" which has been coordinated by S. KOZARSKI since 1977 and whose aim is to collect, on the basis of the available literature, information on the diagnostic value and the distribution of fossil periglacial phenomena in order to produce a map of permafrost of the northern hemisphere about ca. 30,000 years B.P. till ca. 13,000 years B.P. The work is done by a sub-group of the Coordinating Committee for Periglacial Research of the IGU, now the IGU Commission "The signi-

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ficance of periglacial phenomena" in close collaboration with the INQUA Commission on the Palaeogeographic Atlas of the Quaternary.

The authors proposed a legend for the map in early 1978 which has led to vivid discussions among members of the IGU Working Group "Coordination of Periglacial Research" which became the IGU Commission "The Significance of Periglacial Phenomena" in 1980. The proposed legend was also one of the major topics during the joint meeting of this IGU Working Group and the INQUA Commission for the Palaeogeographic Atlas for the Quaternary which was held in Belgium and the Netherlands in September 1978. The discussions focussed on the problem of the diagnostic value of periglacial indicators, in particular on the question of reliable indicators of former permafrost, and on the difficult problem of dating fossil periglacial phenomena. The latter is very important as the map can only be based on occurrences of diagnostic periglacial structures and forms from the same chronological and stratigraphic position (maximum of the last glaciation).

During the field excursions special attention was paid to defining simple criteria which enable the researcher in the field to identify fossil periglacial phenomena as evidence of the previous existence of permafrost.

The following annotated legend is the result of the authors' proposals and the above mentioned discussions. It provides a working framework which could lead in a short time to a document of high interest if a sufficient number of researchers takes part in mapping fossil periglacial phenomena.

The authors wish to express their thanks to all colleagues who participated in the discussions on the problems connected with the compilation of the map and the legend, especially to S. KOZARSKI, A. PISSART, and A. A. VELIČKO for their most valuable comments and suggestions.

THE GENERAL CONTENT OF THE MAP

It has been the idea of S. KOZARSKI (circular, July 1977) to develop a map showing the distribution of periglacial structures and forms as evidence for permafrost conditions at the maximum of the last glaciation.

This map shall be prepared at a scale of 1 : 1,000,000.

With regard to the content the following data should be plotted on the map:

1. symbols for fossil periglacial structures and forms indicative of former permafrost at the maximum of the last glaciation;
2. the 200 m-, 500 m- and 1000 m-contour lines to show the plotted features' locations as related to altitude above sea level;
3. the limit of the extent of permafrost at the maximum of the last glaciation as concluded from the distribution of diagnostic periglacial indicators;
4. the limits of the maximum of the last glaciation.

With regard to the topographic situation the following data should be plotted on the map:

SYMBOLS FOR THE MAP SHOWING THE DISTRIBUTION OF FOSSIL PERIGLACIAL
STRUCTURES AND FORMS INDICATIVE OF FORMER PERMAFROST

Reliable indicators of permafrost

1	2	3	4	
			[]	Permafrost wedge, genetic type unspecified
			[]	Epigenetic permafrost wedge, genetic type unspecified
			[]	Syngenetic permafrost wedge, genetic type unspecified
			[]	Epigenetic ice-wedge cast (filling unstratified)
			[]	Epigenetic sand wedge (filling vertically stratified)
			[]	Syngenetic ice-wedge cast (filling unstratified)
			[]	Syngenetic sand wedge (filling vertically stratified)
			[]	Systems of permafrost wedges
			[]	Polygonal pattern of permafrost wedges; diameter > 15 m
			[]	Frost crack (less than 1 cm breadth per 1 m length and deeper than the former active layer)
			[]	Pingo and pingo-like scars
			[]	Permafrost depression

Unreliable indicators of permafrost

			[]	Ground wedge
			[]	Large sorted form ($\phi > 2$ m)
			[]	Cryoturbations, involutions

Limit of former permafrost

Limit of the Weichsel maximum glaciation

- 1 = Structures formed before the maximum of Weichsel glaciation (older than Denekamp Interstadial)
- 2 = Structures formed during the maximum of Weichsel glaciation (after Denekamp Interstadial about 30 000 B.P. till the beginning of the Bølling Interstadial about 13000 B.P.)
- 3 = Structures originating from the time after the end of the Bølling Interstadial till the end of the Younger Dryas Stadial
- 4 = Structures from the last glaciation whose time of formation belongs to 1, 2 or 3, but is not very sure

1. the hydrographic system with rivers of the first and second order and the names of first order rivers;
2. main towns with names.

CRITERIA CONCERNING THE COMPILATION OF THE MAP

It has been the idea of the authors to develop a uniform legend as a set of criteria concerning the compilation of the map which shall serve as a guideline for all those colleagues in different countries participating in the project. Such a standardized legend and a set of criteria is an essential pre-requisite in order to keep the maps from various collaborators comparable to each other and to have a common basis for further discussions.

The discussion of the criteria is closely connected with the basic problem of the diagnostic value and the reliability of periglacial indicators as certain evidence for former permafrost. Against the background of the whole project the authors emphasized that the legend should contain only symbols for such fossil periglacial phenomena which can be regarded as certain evidence for former permafrost. This has been discussed as described in the introduction.

As a result the following principles and criteria are proposed with regard to the fossil periglacial structures and forms to be plotted on the map:

1. We regard only those fossil forms and structures as certain evidence for permafrost conditions at the maximum of the last glaciation which necessarily require permafrost for their formation and extend below the depth of the fossil active layer; as reliable indicators of past permafrost the fossil structures should extend deeper than 1.5 m in Central Europe; this is regarded as the average depth of the fossil active layer.

2. The following structures are regarded as unambiguously valid criteria for the previous existence of permafrost:

- epigenetic and syngenetic ice wedge casts,
- epigenetic and syngenetic fossil sand wedges which extend below the depth of the fossil active layer, and
- epigenetic and syngenetic fossil frost cracks which extend distinctively below the depth of the fossil active layer.

The ice wedge casts show deformations in relation with the melting of ice wedges and are commonly unsorted; the fossil sand wedges show vertical bedding; the fossil frost cracks are not broader than 1 cm per 1 m in length.

If long fossil frost cracks consist of several ground veins (syngenetic ground veins) they cannot be regarded as diagnostic of permafrost because each of the respective ground veins may have formed under the conditions of intense seasonally frozen ground and, therefore, may have been restricted to the respective fossil active layer.

3. Pingos and pingo-like scars are regarded as evidence of the previous existence of permafrost. In order to identify pingos and pingo-like scars there should

be certain evidence of a rampart on the ground surface or in exposure. Forms without a rampart are permafrost depressions.

4. Fossil permafrost depressions (depergelation forms, formerly so-called „thermokarst” forms) are fossil forms of previous depergelation (permafrost degradation, thawing of ice-rich permafrost); they provide certain evidence of the former existence of permafrost, but, normally, they do not indicate the time of their formation. They must be clearly distinguished from all other fossil enclosed depressions of all sizes, shapes and other origin, such as dead-ice hollows, solution hollows, deflation hollows, and hollows dug by man (marl pits).

5. Structures which form under permafrost conditions as well as under conditions of intense seasonally frozen ground and which are restricted in their vertical extent to the depth of the fossil active layer, e.g. ground wedges, sorted forms, cryoturbations and involutions, are insufficiently reliable indicators of the previous existence of permafrost. Normally, these fossil features are not plotted on the map. Only in cases when it is proved that their formation is exactly synchronous with genuine permafrost indicators in the same stratigraphical position they may be plotted.

Ground wedges are forms of thermal contraction in the active layer. They are not plotted on the map. If they form the upper part of a two-stage-ice-wedge cast only the ice wedge is plotted as an indicator of former permafrost.

A. PISSART suggested a modified symbol for fossil cryoturbations and involutions with a flat bottom. When it is proved that this flat base is related to the top of former permafrost this can be expressed by a horizontal line beneath the symbol for fossil cryoturbations and involutions.

The authors have not included this modification as an extra-symbol in the legend as they regard fossil cryoturbations and involutions as basically unreliable indicators of former permafrost. They think that it is even difficult with fossil cryoturbations and involutions with a flat base to prove that their formation is necessarily related to permafrost. However, if this is unambiguously proved, e.g. by the features' close spatial and stratigraphical association with valid permafrost indicators, the modified symbol as proposed by A. PISSART should be plotted on the map.

6. Other geomorphological forms of the former periglacial environment (dry valleys, cryoplanation terraces, etc.) are not equally well suited for palaeoclimatic reconstructions. They do not necessarily require permafrost for their formation. Currently active cryoplanation terraces occur in Iceland without permafrost; therefore they should not be plotted on a map of the reconstruction of Pleistocene permafrost areas. If cryoplanation terraces are taken into consideration, also other landforms, e.g. periglacial blockfields, climatically induced asymmetrical valleys and periglacial dry valleys will have to be plotted on the map. These, however, are geomorphological forms and which do not necessarily require permafrost for their formation.

It is the aim of this project to compile and map evidence of permafrost at the maximum of the last glaciation. When compiling the evidence one may find fossil

periglacial structures which are older or younger than the maximum of the last glaciation. These can be plotted on the map by using the symbols given under 1, 2 and 3 in the legend.

When we are sure that the periglacial feature dates from the last glaciation, but the exact age is not known, the respective symbols given under 1, 2 and 3 in the legend will be used in brackets (*cf.* 4).

ACCOMPANYING REFERENCES AND FIGURES

The map will be accompanied by a list of references from which the plotted features are taken. In order to identify the plotted symbols with the references it is recommended to key them to specific references. We suggest to use numbers which will be plotted close by the symbols on the map and put in brackets behind the respective references on the accompanying list.

It is recommended to develop graphical representations for the evidences of former permafrost plotted on the map from which the features' size, age, stratigraphical position and characteristics indicating former permafrost can be seen. These very useful figures will appear in an extra paper accompanying and commenting the map.

For example when the base of cryoturbations and involutions is flat and this is related to the top of permafrost (*cf.* point 5) this will be represented in such a figure in the extra paper because it shows the depth of the fossil active layer.

CONCLUSIONS

It is the aim of the map to produce information by which the spatial extent of permafrost at the maximum of the last glaciation can be reconstructed. From the discussion of the criteria concerning the diagnostic value and reliability of periglacial indicators as evidence for former permafrost can be concluded that the envisaged limit of former permafrost comes close to the limit of former continuous permafrost. At present it is very difficult to develop reliable criteria for the spatial delimitation of former discontinuous and sporadic permafrost. These types of permafrost were spatially associated with intense seasonally frozen ground. In these regional types of the former periglacial zone it becomes very difficult to distinguish many fossil periglacial phenomena as to whether they indicate former permafrost or intense seasonally frozen ground. A lot more research is needed on the formation, the diagnostic value and reliability of periglacial indicators of permafrost.

It will be left to the opinion of those participating in the compilation of the map on which features out of those in the proposed legend they base the reconstruction of the limit of former permafrost and which type of permafrost limit they envisage. This should be made clear in the above mentioned paper accompanying and commenting the map.