*A. L. Washburn and G. C. Maarleveld*

## REPORTERS' COMMENTS ON PROBLEMS (1) AND (2)

Problems:

*(1) Genetic classification of periglacial slope deposits based on the lithologic facies*

*(2) Classification of periglacial slope deposits*

A. In reviewing the discussion of the various papers and field exposures dealing with problems 1 and 2, it is obvious that the most critical questions arose from uncertainties regarding the identification and relative importance of the processes responsible for a given deposit and/or landform.

Questions of classification are dependent on the processes involved, and the processes therefore constitute the overriding issue.

We conclude that the primary requirement is a better quantitative knowledge of the nature of periglacial and slope-related processes and their effects. Essential steps include (a) comparison of contemporary processes in different climatic and structural environments, and (b) the conduct of laboratory experiments.

B. The discussions also revealed highly critical questions arising from lack of knowledge concerning the nature of paleoclimates under which periglacial and slope-related processes operated.

We conclude that a series of paleoclimatic maps extending from the present back into the Pleistocene, based on independent criteria, would contribute greatly to knowledge of the evolution of slopes in periglacial and other environments.

### DISCUSSION

Professor R. Raynal: Le problème des grèzes litées est un de ceux qui traduisent les différences zonales dans le domaine de la morphologie périglaciaire. En procédant à des études comparatives on peut determiner que dans certaines grèzes l'eau de ruissellement de fonte est l'agent essentiel de mise en place (périglaciaire des régions relativement ensoleillés). Dans d'autres cas la gravité et le glissement de materiaux sur sol gelé sont les processus responsables (grèzes des régions périglaciaires "classiques").

Professor J. Hövermann: It seems to me that we should better distinguish between processes, forms and deposits which are typical periglacial phenomena, and others, which in many cases occur in periglacial regions but have more or less an accessoric character; they are common in regions under other climatic conditions.

For example grèzes litées are widespread in dry regions with influence of frost-weathering, which are not considered as periglacial ones; on the other hand mudflows are common in regions of more humid climate. with or without frost influence. So they cannot be regarded as real periglacial processes, even if they are observed in a periglacial region.

I think, it is inevitable, to distinguish between different periglacial regions, first of all between regions under more oceanic or humid conditions and other regions under more continental or dry conditions. Perhaps we have the possibility to define the periglacial region itself by typical periglacial phenomena, and to distinguish continental and oceanic or drier and more humid periglacial regions by additional forms and processes such as for example grèzes litées and mudflows.

*J. Hövermann and R. S. Waters*

# REPORTERS' COMMENTS ON PROBLEMS (3) AND (4)

Problems:

*(3) Modelling of periglacial slopes under various conditions defined by: (a) facies (in space) or phases (in time) of periglacial climate, (b) characteristics of the rock, (c) antecedent land-forms*

*(4) Essential features of periglacial slopes: gradients, forms, etc.*

During the paper sessions and excursions we have been shown three major types of slope or slope assemblage that were formed or modified under periglacial conditions.

(a) The first (fig. 1a), as illustrated by Professor Kar and Professor Klimaszewski, is composed of two parts — the upper being a bedrock surface and the lower a debris slope — with inclinations lying normally between 25° and 35° and less frequently ranging from 20° to 40°. Both parts are formed by the same complex of processes, namely, those of frost weathering (congelifraction) and rock-fall. Below the free face the upper part of the profile is the slope of debris transit, the lower part the slope of debris accumulation.

(b) The second type of slope (fig. 1b), as demonstrated by Professor Jahn e.g., is characterized by a solifluction layer consisting of a mixture of coarser and finer material. The slope angle is normally between 5° and 25°; the most common inclination appears to lie between 12° and 15°. On the steeper of these slopes the solifluction cover may rest directly on bedrock, but on other slopes *pseudoschichtung und hakenschlagen* occurs between the bedrock and the solifluction cover. The most important processes on these slopes are frost weathering and congelifluction with which additional subordinate processes may or may not be associated.

(c) The third type of slope (fig. 1c) with which we have been concerned is the glacis with an inclination of between 2° and 12°;

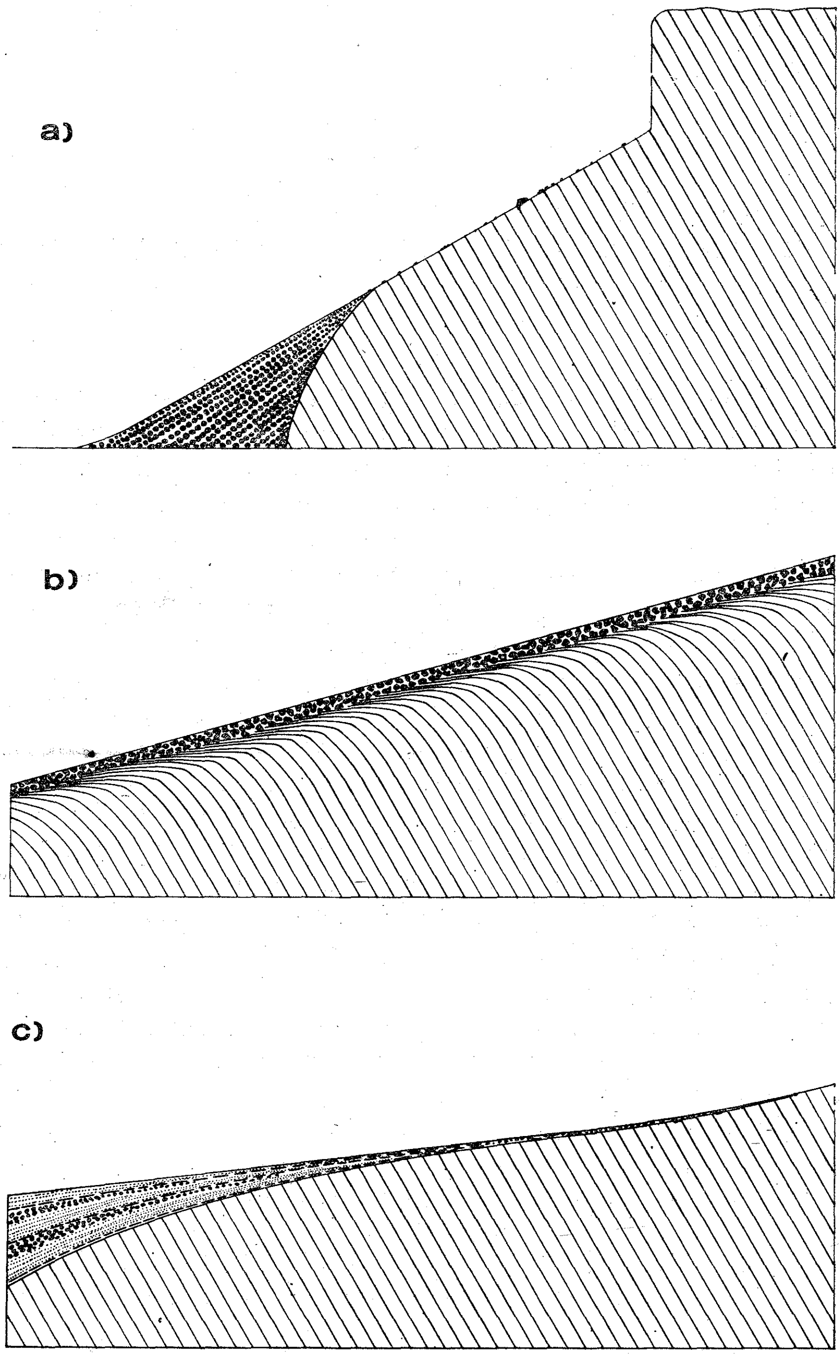


Fig. 1

its most common angle of slope lies between 6° and 8°. The glacis comprises two parts — a glacis d'érosion, and a glacis d'accumulation built of alternating layers of solifluction and finely-stratified slope deposits. It is essentially a product of ruissellement (chargé de debris de gelifraction) and solifluction.

The second of these three types of slope assemblages may be regarded as the typical, wholly periglacial, zonal slope. The first, as exemplified in Sikkim Himalayas and Tatry (Morskie Oko), is a periglacially modified glacial assemblage; and the third, as described from Belgium and seen in Beskid Makowski, is an azonal form, influenced by periglacial processes.

Quantitative data on the relative efficacy of the processes involved in the production of these slopes are urgently needed, as is evidence that will permit valid assessments to be made of the role (if any) of permafrost.

It would appear that under periglacial conditions there is a sequential development of the three types of slope in time. Likewise there may be recorgnized juxtapositions of the three categories of slope in space, both horizontally (latitudinally) and vertically (altitudinally). However in many locations these typical forms are not fully developed. One obvious reason for incomplete or seemingly aberrant development is to be attributed to rock structure and lithology. Professor Macar has demonstrated the relationship between slope form and rock type in the Ardennes. Moreover relict features ascribed to Tertiary and/or Interglacial morphogenetic processes are significant elements in the landscape, e.g., the steep-sided forms like tors. We have also been shown flatter surfaces which have suffered little or no periglacial modification. In such areas of low-angled surfaces periglacial processes were of morphogenetic importance in erosion and accumulation only where they followed interglacial refashioning of the relief by vertically eroding rivers, the incision of which had been initiated by tectonically-induced changes in base-level and/or bioclimatically-induced changes in fluvial discharge/load ratios.

Finally we wish to stress the need for more precise information on the relative significance of congelifluction and slope-wash as slope formers (a) in different parts of the periglacial zone (i.e. maritime v. continental areas) and (b) during the successive phases of a typical periglacial episode.

DISCUSSION

M. R. Raynal: Les versants périglaciaires du type 3 (glacis) s'allongent de l'océanique vers le continental, mais aussi du domaine géographique actuellement tempéré vers le domaine méditerranien. Il est évident que les processus responsables (dans le passé) varient entre ces deux derniers domaines. Est-ce que le ruissellement diffus, qui a été l'agent responsable du façonnement des glacis pendant les "pluviaux" méditerraniens, a joué un rôle comparable en milieu continental? On se contente de poser la question.

M. A. Pissart: Les trois types de pente que M. M. Waters et Hövermann viennent de nous rappeler à la mémoire ont toutes les trois des inclinaisons qui nous sont apparues comme caractéristiques dans les études morphométriques poursuivies en Belgique depuis plusieurs années. Les pentes de 25 à 35° correspondent évidemment aux éboulements de gravité; celles de 6 à 8°, remarquablement bien développées en Belgique en de longues sections rectilignes, semblent dues à la limite d'action de la solifluxion en nappe; quant aux pentes voisines de 15°, elles ont également été observées chez nous et si elles semblent particulièrement fréquentes, leur origine est cependant toujours incertaine.

M. L. Starkel: In studies of slope development, the changes of base levels must be taken into consideration. For instance, in the Alpine zone the direction of slope evolution was dissimilar to that in the old mountains.

The question is which slopes we call "periglacial". I think that true periglacial slopes are those developed in the contemporary periglacial zone. In Quaternary time, the regions of mid-latitudes underwent cyclic climatic changes but now there is another group of processes operating which is reflected in the present-day relief.

*P. Macar and J. Demek*

## REPORTERS' COMMENTS ON PROBLEMS (5) AND (7)

Problems:

*(5) Erosional glacis, altiplanation terraces, accumulational glacis, mutual relations between both these types of glacis, backwearing and downwearing under periglacial conditions*

*(7) The role of periglacial modelling in the development of polygenetic slopes, both Pleistocene and pre-Pleistocene*

The meeting has shown the importance of terrace-like forms or "glacis d'érosion" linked up with the main base level and also of altiplanation terraces developed without any relation to base level. Both occur under periglacial conditions.

The first ones, nearly rectilinear or slightly concave in profile, are developed essentially on soft rocks, in direct relationship with the alluvial plain of the main river. When this alluvial plain subsequently became a fluvial terrace, the "glacis d'érosion" continued to develop during the more recent cold phases. This is indicated by correlative sediments consisting essentially of "grèze-litée-like" deposits. Some of the glacis may reach a rather wide extent (several km in width) and then deserve to be called cryopediments.

Altiplanation terraces, on the contrary, are formed on the upper parts of hillslopes, without any relationship with a base level. They are of lesser extent than the glacis and are frequently more or less stepped near their upper border.

Gelifluxion deposits are typical of altiplanation terraces, and are very rarely observed on the glacis. On the latter, unconcentrated slope wash appears to have been the most important erosional process.

A quantitative study of the processes acting on these forms is recommended, with special regard to the study of the differences between the processes acting on scarps and those acting on treads.

It was confirmed that under periglacial conditions both parallel retreat of slopes and downwearing take place. Backwearing occurs during the development of altiplanation terraces, and seems necessary for the development of the glacis. However, no steep slope appears at the upper border of a glacis when this boundary does not correspond to harder rocks. This probably indicates some downwearing further up, while slopewash has brought a slow vertical lowering of the glacis itself. Downwearing has also been demonstrated by Professor A. Jahn in the Sudetes.

The mode of slope development depends above all on relative vertical differences (the possibility of a free face), the geological structure, and the gemorphological position.

The role of periglacial modelling of slopes previously developed under different climatic conditions has scarcely been mentioned. Many slopes, however, have experienced such changes and the question should be given more attention.

The discussion at number of localities has shown that the most general trend of hillslope development in periglacial conditions is the degradation of the upper slope section and the accumulation of related deposits at its foot. In some places the slightly modified slope profile from the periglacial period is preserved below the related deposits in the lower slope section.

A quantitative study of periglacial slope modelling by means of the analysis of related deposits is recommended.

*J. C. F. Tedrow and J. Brown*

# REPORTERS' COMMENTS ON PROBLEM (8)

Problem:

*(8) Soil formation processes, quantitative and qualitative evaluation of Pleistocene fossil soils, especially of actual and recent soil formation in the Arctic and Antarctic regions*

This report is divided into two sections: (1) questions relating primarily to genetic soil processes (J. C. F. Tedrow) and (2) questions relating to acquisition of date involved in soil-oriented, periglacial processes (J. Brown).

## GENETIC SOIL PROCESSES

Soils just north of the tree line have quite similar features to those of the northern forests; therefore the use of fossil soil features in reconstructiong Quaternary climatic events becomes questionable. Under present-day processes, Dwarf Podzols, the variously designated brown-colored soils of the well-drained sites, Gley and Bog soils are present in the main tundra belt as in the northern forests. It is unlikely that mineral assemblages, chemical or physical properties or gross morphology could be used effectively in reconstructing past polar climates, especially if climatic oscillation were of a minor nature. It appears, however, that thickness of the organic horizon in the northern forests is somewhat greater than analogous conditions of the tundra belt.

If climatic oscillations would be of high order, such as a present-day podzolic process operating on an old polar desert landscape, the possibilities of using fossil soil properties in reconstructing past climatic events would be more promising. The presence of desert pavement, pseudomorphs of saline minerals and related parameters would theoretically hold some promise in reconstructing earlier climates.

The implied pedogenic changes at the tree line have never been demonstrated and as more factual information becomes available it appears that the northern areas are comprised of pedogenic gradients rather than "steps". Fossil patterned ground, pollen as well as megascopic organic remains, C-14, and geomorphic and glacial evidence remain far more effective tools in reconstructing past climatic events than does soil morphology.

In 1958 J. T. Kosheleve (Izvestia Acad. Sci., U.S.S.R., Geog, ser., No. 3: 88—92) proposed a novel concept in that it was believed that microfrost structures were formed in the soil under polar conditions and that these structures were preserved in the landscapes of a now ameliorated climate. The work was supported with photographs. While we have not been able to confirm the hypothesis in North America, the concept merits further study.

A second subject that should be considered briefly is that of pedology and patterned ground. With the use of terms such as structure soils, polygonized soils, etc., the pedologist without polar experience may have a tendency to assume that genetic soil horizons are poorly developed or absent — which is often not the case. We have "sets of pedogenic processes" operating throughout the polar regions and accordingly the soil processes such as biotic activity, leaching, translocation, synthesis of compounds, together with the macro and micromorphology should be considered along with the form of patterned ground.

## SOIL-ORIENTED PERIGLACIAL PROCESSES

From the standpoint of a soil scientist, polar and other cold soils can include all those soils which occur in the present permafrost regions, soils subject to seasonal freezing and thawing in nonpermafrost areas, and those fossil soils conditions in temperate, subpolar and polar regions that formed under colder climates. We recognize that the polar and some alpine regions are presently active periglacial environments. It is these areas that are providing us with data necessary for interpreting the nature of past periglacial conditions such as we have observed and discussed over the past ten days. We are painfully aware of the fact that observations, data and interpretation are not yet adequate to completely evaluate the active periglacial environments or processes for application to the now inactive forms. Therefore, the problem I should like considered is one related to future periglacial soils research and is basically one of methodology. That is, what types of systematic soil measurements should be obtained in the present cold regions for solution of problems related to the past and present periglacial environments. I might suggest as a beginning that more data are required on depth of thaw in discontinuous permafrost zones, depth of seasonal freezing and occurrence of ground cracking in nonpermafrost regions, moisture and temperature regimes of permafrost soils, thickness of permafrost on the periglacial fringes, and of course, correlation of the present climate with each of the above observations. These programs need not be restricted to the field, but may also be carried out in the laboratory. Measurements of soil movement on slope have been considered under other problems. It is obvious that acquisition of these measurements in selected geographic settings will be invaluable to the geographer, geomorphologist, and soil scientist in resolving both problems of the present periglacial regimes as well as past ones.