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THE DROP SOIL OF THE EISDEN TYPE

Abstract

The description term *drop soil of the Eisden type* is introduced for one type of drop soil with well defined characteristics. This type of drop soil is considered to originate by periglacial loadcasting, i.e. by loadcasting in a periglacial environment with active permafrost.

The drop soil of the Eisden type allows to draw some conclusions about the permafrost and the maximum thaw depth at the time of formation. For NE-Belgium it means the existence of a continuous permafrost and a maximum thaw depth of about 2 m during the Vistulian and probably during the Late-Vistulian.

INTRODUCTION

The literature about involutions is very abundant and heterogeneous and reveals a wide variety and complexity of forms and a multiplicity of suggested origins. From the consulted papers we may conclude that, especially before 1960, there was a very large agreement to consider involutions as a proof of a periglacial environment. Already in 1934 however the possibility of formation of *Taschenböden* in other than periglacial conditions was emitted by Dewers. Later sedimentologists described *contorted structures*, very much resembling some "periglacial structures" in different rocks and of different age, even in actual deposits. Many of these structures, especially those occurring in fine grained sediments, are simulated in experiments and are formed by processed unterlated to frost action (Dżułyński, 1965 & 1966; McKee and Goldberg, 1969; Anketell, Cegła and Dżułyński, 1970; and Lowe, 1975).

It is a fact that the significance of fossil involutions, as certain indicators of a periglacial environment, is questioned. Pissart (1970) for instance introduced the term *periglacial involution* to define all deformation in accordance with the term *cryoturbation* (Edelman, Florschütz and Jeswiet, 1936). It is, therefore, necessary to understand better the origin of different types of involutions so that some forms could be used with certainty as indicators of a specific periglacial paleo-environment.

The subject of this paper is to contribute to the knowledge of periglacial involutions and to describe and to discuss the origin of one form of drop soil.

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CHARACTERISTICS OF THE DROP SOIL AT EISDEN (BELGIUM)

THE PROFILE
(Fig. 1; Plate 1 and 2)

The described phenomena are situated in the gravel pit "Maaslandia" at Eisden (Belgium, Coordinates: 51°10′N; 5°40′E). These gravel deposits, at an absolute height of 40 m, belong to the Maas (Meuse) Eisden-Lanklaar terrace of Saale age (PAULISSEN, 1973). The terrace gravels are covered by a mantle of coversands, consisting of a discontinuous layer of Saale coversands, separated by an Eemian soil from a continuous mantle of Vistulian coversands, with the Holocene podzol soil on top.

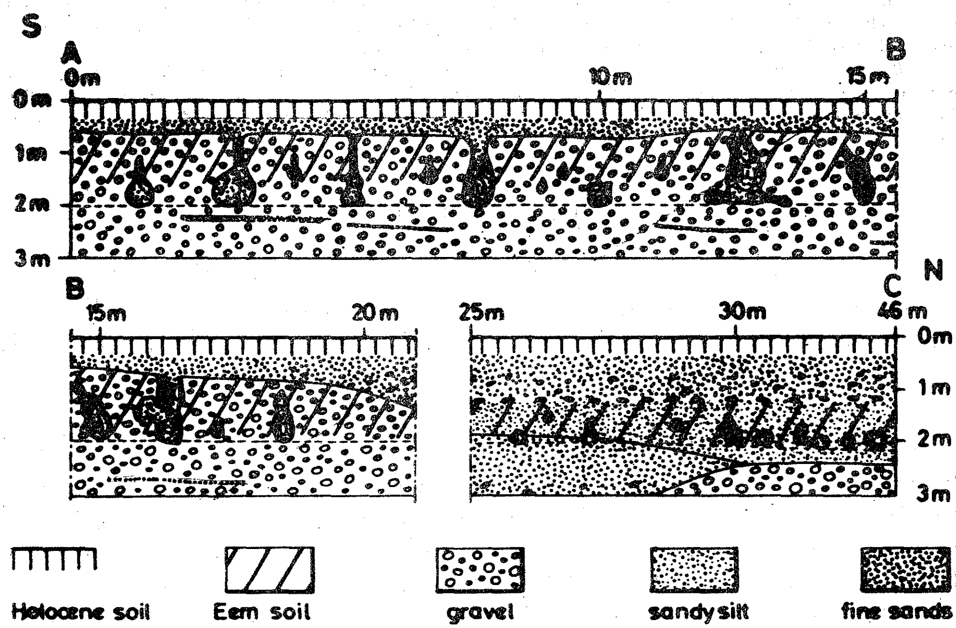


Fig. 1. Profile of the drop soil at Eisden

The involutions are best described in the western quarry wall. In this section, a gravel bar, covered by 0.5–1 m coversands pass laterally in a 3 m deep depression, completely filled up with the different coversands. The surface is completely flat. The gravel bar, mostly horizontally bedded is heterogeneous in grain size (mean grain size distribution: coarser that 16 mm: 30%; 2–16 mm: 48%; 0.1–2 mm: 16%; smaller than 0.1 mm: 6%).

A well preserved sand pocket horizon is exposed in the profile. The pocket soil consists of a great number of isolated columnar sand masses occurring on the same level in the gravel bar as in the sand depression. Their distance is irregular but in the mean around 2 m. The pockets are always filled with typical coversands (mode: 160 mu; sand-sorting: 0.66 phi; silt and clay fraction: less than 20 %). Individual pebbles however may be present. Secondary mineralisation occurs on the bottom of some pockets. It is important to note that no mixing or sorting of the gravels and the coversands originated during the pocket formation. Both materials conserve their own grain size characteristics after deformation. The original structure immediately around the sand pocket is disturbed. The gravels are oriented parallel to the pocket form. The original gravel structure can be preserved between farther spaced pockets.

The base of the majority of the pockets forms a horizontal surface, situated about 2 m beneath the actual surface (Plate 1). Some pockets do not reach this level, but not one passes beneath this horizontal limit. This limit is independent from the texture: it passes through layers of pure fine sands, through clayey loams and through gravels. It is striking that in the depression the base of the pocket horizon is situated in the middle of a silty layer and not on an important lithological contact as the transition silt-gravel situated only 30 cm below.

On a horizontal section, throughout the whole height of the pockets, they appear as isolated yellow sand circles within the reddish brown gravels and form apperently a patterned ground, resembling sorted circles (finer materials surrounded by coarser ones).

The profile shows that the sand pockets were caused by descending columns of sand to a general level, independent of structural layers, and that no relation exists with any type of wedge shaped patterned ground. These involutions date from the last glacial as they affect the Eemian soil and are fossilized by the Holocene soil.

POCKET TYPES

Three pocket types are distinguished:

— *drop-like pockets* (*Plate 2*)

They are rounded, nearly aerodynamic and show an internal concentric lamination indicating a downward sand liquefaction without further distortion. The pocket have variable diameters, mostly between 15 and 50 cm.

— *composite pockets* (*Plate 1 and 2*)

A large group is of the composite type as the sand accumulation is composed of different drops, with their own concentric lamination. The external form can be rounded or composed as parts of the pocket border are parallel to the structure of some individual sand drops within the pocket.

— *flat-based pockets* (*Plate 1*)

They are of the drop-like or the composite type, but with a flat base. Some pockets spread laterally at the base. This type mostly accentuates the presence of the horizontal surface at the base of the involutions. The drop-like and composite pockets, without flat base, are situated higher in the profile than the flat-based pockets.

The sand pocket is connected by a *neck* with the sand layers overlying the gravels. This neck, mostly preserved, is filled with overlying sands. The planimetric form of the neck is always smaller than that of the drops they are connected.

From the characteristics of the different types of the sand pockets, we may conclude that the pockets originated by liquefaction of the sand, shown by the internal structure of the sand drops, by the elongation of the neck, which can disappear, by the flattening and even broadening of the base. Several successive sand drops can follow the same path.

NOMENCLATURE OF THE DESCRIBED INVOLUTIONS

The described pockets belong to a group of involutions with identical general characteristics: involutions with a well pronounced rounded masses isolated in a layer with different lithological characteristics.

This group can be subdivided into:

— *isolated rounded pockets*, eventually without any contact with the layer they originated.

These forms are described as "cryoturbations of the Wiene type" (EDELMAN, FLORSCHÜTZ and JESWIET, 1936), as "bulles" and "larmes" (DYLIKOWA, 1961), as "involucja słupowa" (KOZARSKI and ROTNICKI, 1964), or as "shell shaped structures" (JOHNSSON, 1962). These forms are also near to the subaquatic "slumpball structures" (KUENEN, 1949) and to "load pockets" (SULLWOLD, 1960) in contemporaneous sedimentary structures.

— *isolated rounded pockets situated at the base of a neck*, connecting the structure with the overlying layer they originated.

These forms are described as "druipstaarten" (VAN GALEN, 1940), as "Tropfenböden" (STEUSLOFF, 1952; DÜCKER, 1954 and 1969; VON BÜLOW, 1964, and GRIPP, 1971), as "structures du type de gouttes" (DYLIKOWA, 1961,) as "drop-soil" (JOHNSSON, 1962), as "drip or plug involutions" (WEST, 1968), or as "drop-like structure" or "structura kroplowa" (GOŹDZIK, 1973).

The form of the involutions described in this paper is related to this of the second group. They form a drop soil as they consist of pockets, connected by a neck with the overlying layer the forms originated. All described drop soils occur, however, in fine sediments, mostly in a sand layer underlying a silty or a clayey unit. These drops are also smaller features, with a pocket generally not exceeding 10 cm in diameter.

This short review shows the multitude of forms described under different names. We feel that the term *drop soil* (Tropfenböden, sol à gouttes, druppelboden) must be retained as a good description of the phenomenon. Involutions on the top of gravel deposits, similar to the drop soil at Eisden, are described by DEWERS (1934) and STEEGER (1944) as "Taschenböden", a term they used unfortunately for different types of involutions.

In the above mentioned papers, differences in drop soil characteristics can be established in function of the areal density of the drops, the internal and external drop properties and the relation of the drop soil to polygonal structures and to the surrounding deposits. It is, therefore, necessary to distinguish different types of drop soils in function of their characteristics, to obtain full evaluations of this special type of involutions.

One type of drop soil we introduce is the *drop soil of the Eisden type.* It is a drop soil characterised by a high number of drops, unrelated to a polygonal structure and to a given lithological sequence. The drops show internal flowage structures related to the neck. The deepest drops form a horizontal surface and are flattened or are spread laterally at the base. This limit is not related to a lithological contact, but is situated in a homogeneous layer.

The drop soils described by STEUSLOFF (1954) and VON BÜLOW (1964) seem to belong to the same type.

ORIGIN OF THE DROP SOIL AT EISDEN

STATEMENT

The drop soil is not a primary phenomenon caused by the processes depositing the terrace gravels or the coversands, but is a feature surimposed on these deposits, as is indicated by the deformation of the original layers.

By considering the origin of these features, we do not discuss all hypotheses concerning the formation of involutions, also involved for patterned ground and treated by WASHBURN (1956). ROHDENBURG and MEYER (1969) discuss the origin of periglacial involutions in Middle Europe.

A valid suggested origin for the drop soil at Eisden has to be one that explains the drop formation by liquefaction of the sands into the gravels in a way that no sorting or mixing of the materials involved occurs. Indeed, the drop soil, consisting of sand and situated in the gravels, is connected with a neck to the overlying sand layer; individual drops are conserved within the pockets of the drop soil; the structures in some drops prove that the material has flowed from above; the gravels around the pockets are pushed away. The drop soil has a regular form and does not show any mark of deformation. This excludes the effect of cryostatic pressures during and after their formation.

Density differences in a water-saturated active layer mostly have been suggested for the origin of a drop soil (Dewers, 1934; Van Galen, 1940; Steeger, 1944; Steusloff, 1952 and von Bülow, 1964a)[1]. Gripp (1963–1971) attributed the origin of Tropfenböden to differential moving in thawing ground (Metakinese in mollisol). He postulates, however, that drop soils only occur at the contact between an 1 m-thick silt layer and the underlying pure sand, and that silt blocks are sinking in the underlying sand. The origin suggested by Gripp is invalid for the drop soil at Eisden because the two postulations do not occur. Anketell, Cegła, Dżułyński (1970) reviewed the results of experiments on deformations resulting from reverse density stratification sediments.

CONDITIONS FOR DROP SOIL FORMATION

Density differences

The densities are measured in the field with a rubber balloon density apparatus M & O Nr 106 on the gravels around the pockets and in the pockets of the drop soil (loamy sands and sands). The dry bulk density, the water-saturated bulk density and the porosity for the different materials is calculated (Table I).

Table I

	Bulk density (g. cm $^{-3}$)		Porosity (percent)	Unit weight
	Dry	Water-saturated		
Gravel I	2.11	2.30	18.8	2.60
Gravel II	2.30	2.44	13.5	2.55
Loamy sands I	2.07	2.26	18.6	2.60
Loamy sands II	2.05	2.26	21.1	2.60
Sands	1.84	2.14	30.0	2.64

In the actual conditions, the gravels have higher densities and lower porosities than the sands. Striking however is the very low porosity of the gravels. The values are of course material properties after the drop soil formation. They may not provide information concerning the primary distribution of densities. The porosities of the sediments have changed during deformation. We have thus to estimate the original material proper-

[1] Pfuhl (1932, see Dewers, 1934) was the first to introduce gravity differences as a possible origin for cryoturbations.

ties before drop soil formation. The density values of the coversands at the top of the drop soils are equal to the densities of the coversands in a whole. Density values of gravels are uncommon. Manger (1963) mentions at the surface of different stratigraphic units mean gravel porosities between 20.2 and 32.4 %. Dudgeon (1964) measured an average porosity of about 40 % as a mean for 6 gravel samples of different sizes.

In the terrace bodies and even at the top of recent fluviatile deposits of the Maas the gravels have a lower packing degree than the gravels around the drop soil. The loose packing of the these gravels prevented an accurate measurement of the porosity.

The conclusion is that in the original situation before drop formation there existed a reversed density gradient between the denser overlying coversands and the less dense underlying gravels. The pore volume of the gravels at the terrace top is reduced during the drop soil formation.

The water-saturated layer

In dry conditions the total normal stress is the effective stress within the materials and the gravitational weight difference caused by these density differences is ineffective as a real force. The bearing capacity of sand and gravel exceeds indeed by very far the pressure due to these density differences. Even if there could be any other supplementary pressure on this scale, there will be no pocket formation because the bearing capacity of the sands is lower than this of the gravels. The flow structures in the drops exclude a drop formation in dry conditions.

In a saturated layer, however, it is possible to neutralize completely the effective stress due to the intergranular contacts by the pore pressure. This situation gives the structure a temporary inherent stability and is especially known for fine sands forming quick sands, characterised by a complete lack of bearing power (Terzaghi and Peck, 1948; Scott, 1969).

To cause deformations by small density differences it is necessary to obtain in the soil the same conditions that permit load casting in the sediments. Load casting only occurs in a system with a reversed density gradient when a temporary liquefaction is created in the sediments and reversed density gradients are able to cause deformations. Drop soil formation needs reversed density gradient, a saturated soil and possibly supplementary pressures to cause a temporary loss of intergranular contacts. Drop soil formation does not need *a priori* a permafrost and an active layer.

MECHANISM OF DROP SOIL FORMATION

Most workers, except Gripp (1963), seem not to be conscious of the problem how to create a condition of inherent stability in a saturated soil. The pore pressure within the soil has to be able to neutralise the effective stress within the underlying deposits, *in casu* the gravels. This pore pressure is not due to any supplementary loading of water of sediment, because the drop originated on a terrace, while the Meuse was incised (PAULISSEN, 1973). An eventual increase of pore pressure due to lateral seepage may not be excluded.

The horizontal base of the drop soil indicates the lowest limit where the gravel layers have obtained the condition of inherent stability. This surface, forming a real barrier for the descending drops, corresponds with an important barrier within the gravels and is completely independent from the texture of the involved deposits (see description). This is the reason why this limit is considered as the *permafrost table* during the time of the drop formation. The absolute depth of this surface is estimated at about 2 m. A more precise determination of this depth is excluded, because the evolution of the coversand mantle is unknown. The saturation of the soil is due to melting, to atmospheric precipitation or possibly to laterally seepage from higher levels.

The supplementary pressure to neutralize the effective stress within the gravels has to be obtained within the 2 m active layer, composed of coversands and the top of the gravel deposits. The pore pressure alone is not sufficient. This supplementary power can only be obtained by pressures developed by the *refreezing of the saturated active layer*, and possibly by lateral seepage. The most favorable period to fulfil all conditions corresponds with the refreezing of the active layer after the summer thaw period.

Only in these cases, and probably during a short period of time, when the gound frost is creating a condition of temporary inherent stability, the positive static weight difference between the coversands and the gravels, permits *load casting*.

The drop soil described in the gravel deposits at Eisden is a typical form of load cast, originated under periglacial conditions with an active permafrost.

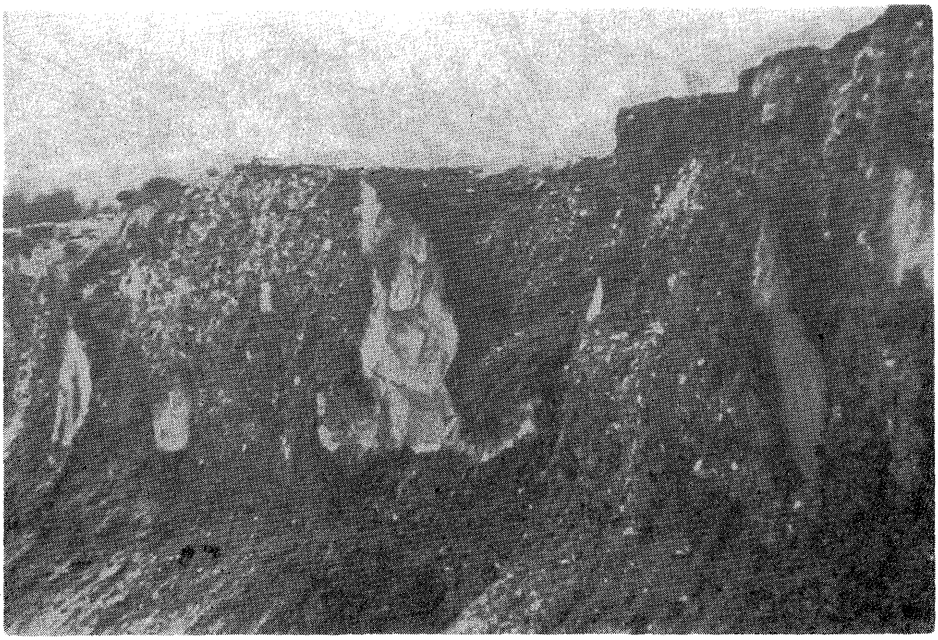
To stress this special type of load casting, we describe this process as *periglacial load casting*.

PALEO-CLIMATIC SIGNIFICANCE

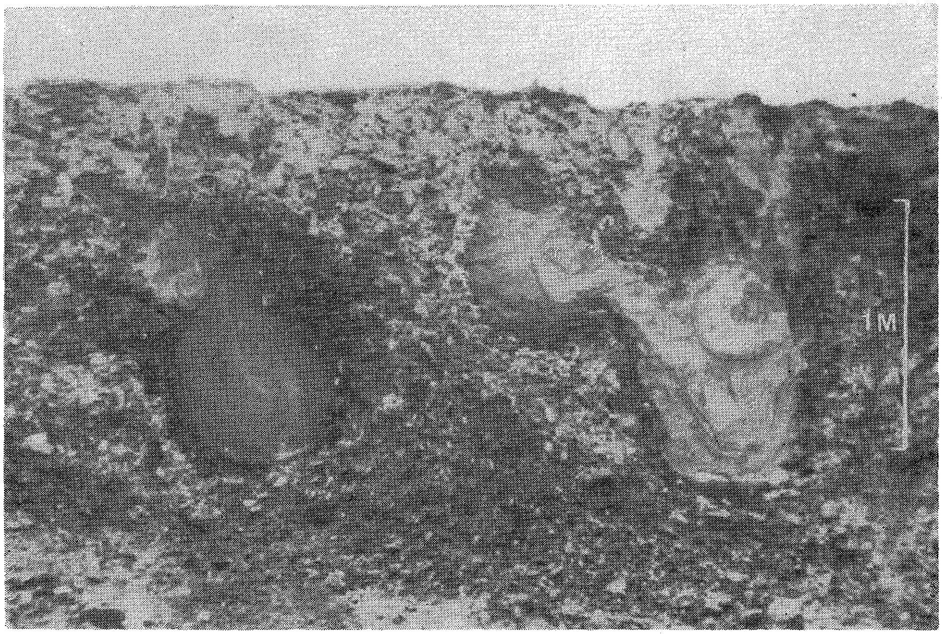
The horizontal surface at the base of the drop soil at Eisden, at about 2 m below the surface, is considered as the *permafrost table* during the period of formation of the drop soil, during the Vistulian and probably during the late Vistulian.

The presence of a permafrost in coarse-grained sediments during late Vistulian, more than 400 km South of the maximum icecap extension is important in view of the knowledge about the actual permafrost.

Indeed, in the zone of discontinuous permafrost, PÉWÉ, CHURCH and



Pl. 1. General view of a part of the drop soil at Eisden
(overlying coversands are excavated)



Pl. 2. Detail of the drop soil at Eisden, showing a drop-like and a composite pocket with internal flow structures
(overlying coversands are excavated)

ANDERSEN (1969) reported in the Donally Dome area (Alaska) the presence of the permafrost at 0.3 to 1 m in fine grained-sediments, where permafrost has disappeared in the gravelly outwash plains where relict permafrost occurs at a depth of about 10 m. They also demonstrated that in this area fossil ice-wedge polygons occur in coarse-grained sediments, while active ice-wedges are still present in fine-grained sediments.

From these observations, it is obvious that during the period of the drop soil formation at Eisden a continuous permafrost occurred in the whole region, a statement generally postulated on the basis of the suggested origin of patterned ground and involutions.

The important thickness of the active layer (about 2 m) suggests a barren ground surface without isolating vegetation cover (lichen, mosses and peat) at that time (BROWN, 1965 and 1971).

In most described drop soil a horizontal surface is mentioned at the base of the pockets (VAN GALEN, 1940; STEUSLOFF, 1954; VON BÜLOW, 1964). This surface always occurs within a homogeneous deposit, without any relation to a lithological boundary.

All workers, except GRIPP (1963), formally consider this limit as the permafrost table.

It is clear that this limit corresponds with the lowest limit of the layer obtaining temporary an inherent stability. This limit, however, is not necessarily always due to the permafrost table and can, in some cases, indicate the maximum depth where ground frost is able to change completely the material properties, without the occurrence of a permafrost. The significance of this limit is function of the material properties of the underlying deposits. For gravels and coarse sands, with a very high bearing capacity, a permafrost will be always necessary to obtain these special conditions. For very fine underlying sands, however, severe ground frost without permafrost may be sufficient to create all condition for load casting.

CONCLUSIONS

To contribute about the significance of fossil involutions as indicators of a periglacial environment, the authors introduce a type of drop soil: *the drop soil of the Eisden type*. This type of drop soil is unrelated to a polygonal structure and to a given lithological sequence. The drops, with internal concentric flow structures relating to the neck, form an horizontal surface at the base unrelated to lithological differences. The presence of this surface is stressed by the lateral outflowing of several drops.

The drop soil of the Eisden type is originated by periglacial load casting, i.e. by load casting under periglacial conditions with active permafrost.

This type of drop soil is important because it allows to state definitively the presence of the permafrost and the maximum thaw depth.

In N.E. Belgium this means, during the Vistulian and probably during the Late Vistulian, the presence of a continuous permafrost in the whole region and in the gravel deposits an active layer with a maximum thickness of about 2 m.

For full evaluation of the drop soils it is necessary to establish, especially for saturated fine sediments with reversed density gradients, in what condition ground frost without permafrost is able to cause a temporary loss of intergranular contacts and the resulting load casting.

Bibliography

ANEKTELL, J. M., CEGŁA, J. and DŻUŁYŃSKI, S., 1970 – On the deformational structures in systems with reversed density gradients. *Ann. Soc. Géologique de Pologne*, vol. 40; p. 3 – 30.

BROWN, R. J. E., 1965 – Some observations on the influence of climatic and terrain features on permafrost Norman Wells, N.W.T., Canada. *Can. Journ. of Earth Sciences*, vol. 2; p. 15 – 31.

BROWN, R. J. E., 1971 – Characteristics of the active layer in the permafrost region of Canada. *Nat. Research Council, Canada, Techn. Mem.*, vol. 103; p. 1 – 7.

CEGŁA, J. and DŻUŁYŃSKI, S., 1970 – Systems with reserved density gradient and their occurrence in periglacial zones. *Acta Universitatis Wratislaviensis, Stud. geogr.*, (in press).

DEWERS, F., 1934 – Kritische Betrachtungen zur Frage der Beschaffenheit und Entstehung der Taschenböden. *Abhandl. u. Vorträge Bremer Wiss. Ges.*, vol. 8 – 9; p. 306 – 329.

DÜCKER, A., 1954 – Periglazialerscheinungen in holsteinischen Pleistozän. *Göttinger geogr. Abh.*, vol. 16; p. 1 – 52.

DÜCKER, A., 1969 – Der Ablauf der Holstein-Warmzeit in Westholstein. *Eiszeitaler und Gegenwart*, vol. 20; p. 46 – 57.

DUDGEON, C. R., 1964 – Flow of water through coarse granular material. *Rep. N.S.W. Univ. Wat. Res. Lab.*, *N*° 76. See: LEE, I. K., LAWSON, J. D. and DONALD, I. B., 1968 – Flow of water in saturated soil and rock fill; p. 82 – 194 *in*: *Soil Mechanics – Selected Topics*, Ed. I. K. LEE, Butterworths, London.

DYLIKOWA, A., 1961 – Structures de pression congélistatique et structures de gonflement par le gel de Katarzynów près de Łódź. *Bull. de la Société des Sciences et des Lettres de Łódź*, vol. XII, 9; 23 p.

DŻUŁYŃSKI, S., 1965 – New data on experimental production of sedimentary structures. *J. Sed. Petrology*, vol. 35; p. 196 – 212.

DŻUŁYŃSKI, S., 1966 – Sedimentary structures resulting from convection-like pattern of motion. *Ann. Soc. Géologique de Pologne*, vol. 36; p. 3 – 21.

EDELMAN, C. H., FLORSCHÜTZ, F. und JESWIET, J., 1936 – Ueber Spätpleistozäne und Frühholozäne kryoturbate Ablagerungen in den östlichen Niederlanden. *Verh. Geol. Mijnb. Gen. voor Nederland en Koloniën, 's-Gravenhage, Geol. Serie*, vol. XI; p. 301 – 336.

Goździk, J., 1973 – Origin and stratigraphical position of periglacial structures in Middle Poland. *Acta Geographica Lodziensia*, vol. 32; 119 p.

Gripp, K., 1963 – Zur Entstehung von Tropfenböden. *Neues Jhb. Geol. Paläont.*, Stuttgart, Monatshefte 9; p. 490–492.

Gripp, K., 1971 – Tröpfenböden, räumlich untersucht. *Meyniania*, vol. 21; p. 9–16.

Johnsson, G., 1962 – Periglacial phenomena in Southern Sweden: I. Stratigraphy. *Lund Studies in Geography*, Ser. A., vol. 21, 1963; *Geografiska Annaler*, vol. 44; p. 378–404.

Kozarski, S. and Rotnicki, K., 1964 – Inwolucje w sandrze stadium poznańskiego na południe od Gniezna. *Biuletyn Peryglacjalny*, vol. 13; p. 15–52.

Kuenen, Ph. H., 1949 – Slumping in the carboniferous rocks of Pembrokeshire. *Quart. J. Geol. Soc. London* (1948), vol. 104; p. 365–385.

Lowe, D. R., 1975 – Water escape structures in coarse-grained sediments. *Sedimentology*, vol. 22; p. 157–204.

Manger, G. E., 1963 – Density of sedimentary rocks. *Geol. Survey Bull., Washington,* 1144-E; 55 p.

McKee, E. D. and Goldberg, M., 1969 – Experiments of formation of contorted structures in mud. *Bull. Geol. Soc. of America,* vol. 80; p. 231–244.

Paulissen, E., 1973 – De morfologie en de kwartairstratigrafie van de Maasvallei in Belgisch Limburg. *Verh. Kon. Academie voor Wetenschappen, Letteren en Schone Kunsten van België, Kl. der Wetenschappen,* XXXV, 127; 266 p.

Péwé, T. L., Church, R. E. and Andresen, M. J., 1969 – Origin and paleoclimatic significance of large-scale patterned ground in the Donnelly Dome Area, Alaska. *Geol. Soc. of America, Spec. Paper* 103; 87 p.

Pissart, A., 1970 – Les phénomènes physiques essentiels liés au gel, les structures périglaciaires qui en résultent et leur signification climatique. *Ann. Soc. Géol. de Belgique,* vol. 93; p. 7–49.

Rohdenburg, H. and Meyer, B., 1969 – Zur Deutung Pleistozäner Periglazialformen in Mittel-Europa. *Göttinger Bodenkundliche Berichte,* vol. 7; p. 49–70.

Scott, C. R., 1969 – Soil Mechanics and Foundations. MacLaren and Sons, London, 316 p.

Steeger, A., 1944 – Diluviale Bodenfrosterscheinungen am Niederrhein. *Geologische Rundschau,* vol. 34; p. 520–538.

Steusloff, U., 1952 – Periglazialer „Tropfen" – und Taschenboden im südlichen Münsterlande bei Haltern. *Geol. Jahrbuch,* Hannover, vol. 66; p. 305–312.

Sullwold, H. H., 1959 – Nomenclature of load deformation in turbidities. *Bull. Geol. Soc. of America,* vol. 70; p. 1247–1248.

Terzaghi, K. and Peck, R. B., 1948 – Soil mechanics in engineering practice. John Wiley & Sons, New York, 566 p.

Van Galen, I. J., 1943 – Eiszeitliche Befunde aus Utrecht (Nederland). *Geogr. en Geol. Mededelingen; Physiogr.-geol. reeks,* Utrecht, vol. 17; 39 p.

Von Bülow, W., 1964a – Ein Taschen- und Tropfenboden von Grebs (SW-Mecklenburg). *Geologie,* vol. 13; p. 353–360.

Von Bülow, W., 1964b – Der Tropfenboden von Rüterberg (SW-Mecklenburg). *Geologie,* vol. 13; p. 361–363.

Washburn, A. L., 1956 – Classification of pattern ground and review of suggested origins. *Bull. Geol. Soc. of America,* vol. 67; p. 823–865.

West, R. G., 1968 – Pleistocene Geology and Biology. Longmans, London, 377 p.