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Excursions
des 26 et 27 septembre 78

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FOSSIL PERIGLACIAL PHENOMENA IN NE—BELGIUM

Excursions in the kempen on 26 and 27 september 1978

INTRODUCTION

by F. Gullentops

During these two last days of the Symposium we intend to show a choice of fossil periglacial phenomena as can be observed for the moment in the Kempen. They are of various nature, geomorphological, sedimentological or pedological, but most of them are related to the last glaciation. We will essentially try to demonstrate the difficulty of interpreting the exact environmental conditions responsible for a certain sediment, structure or relief, and of situating this environment in a reliable time scale.

In general we tend to overestimate the duration of an environment represented by sediments while stability or erosional phases are less readily budgeted in time. For cryopedological phenomena this is often complicated by the difficulty of relating a cryoturbation to its contemporaneous topographical surface and eventually to prove the existence of fossil permafrost and determine the depth of the active layer.

As we tried to argue in our lecture in Birmingham, 1977, our Vistulian climate was much less characterized by deep frost than by the importance of the snow cover. Permafrost must have been very short lived and proofs for more than one short spell of a few thousand years are lacking. Snow cover on the other hand was longlasting especially during the humid cold Hesbayan substage or first half of the Periglacial. Vegetation was more hampered by this long snow cover than by the temperature. Depth of freezing was on the contrary rather limited by the insulating snow cover. The snowline was in the Ardennes close above the summits (800 m?) and our climate most comparable to the subnival zone of the actual Alpine environment. Snow meltwater activity was essential.

During the Brabantian substage the increased continentality reduced the snow cover, increased the depth of frost penetration, and the drier summers facilitated eolian activity. Despite of colder winters the snowline may have lifted as is seen now in the Alps from west to east due to increasing continentality.

Point I-1: PIT "ALPHEN 'T ZAND" (NETHERLANDS)

by J. Vandenberghe

Situation

The excavation occurs on the relatively flat interfluve between two southern tributary systems of the river Maas. The altitude of the top of the section is about +23 m. As indicated by the Geological Map the subsoil is formed by the silty fine sands to clays of the Kedichem Formation. However, they are here overlain by coarse fluviatile sediments (N). On the particular place the general flat relief is transformed in a slightly undulating landscape for the greater part caused by aeolian activity.

Description of the section

In the lower parts a fully developed Holocene podzol is preserved. It is overlain by drift sands (A and B). The podzol is formed in late glacial dune sands (C) or in older sediments.

Apart from these dune and drift sands the youngest sediments are loamy cover-sands (D). They are underlain by slightly cross-bedded coarser sands without silt and clay (E). They are for the present interpreted as dune sands. At the base a pebble row always can be found (a). Some wind-faceted and wind-polished pebbles were found in it. A series of soil wedges starts from this level (±0.4 m deep, 1 or 2 cm broad).

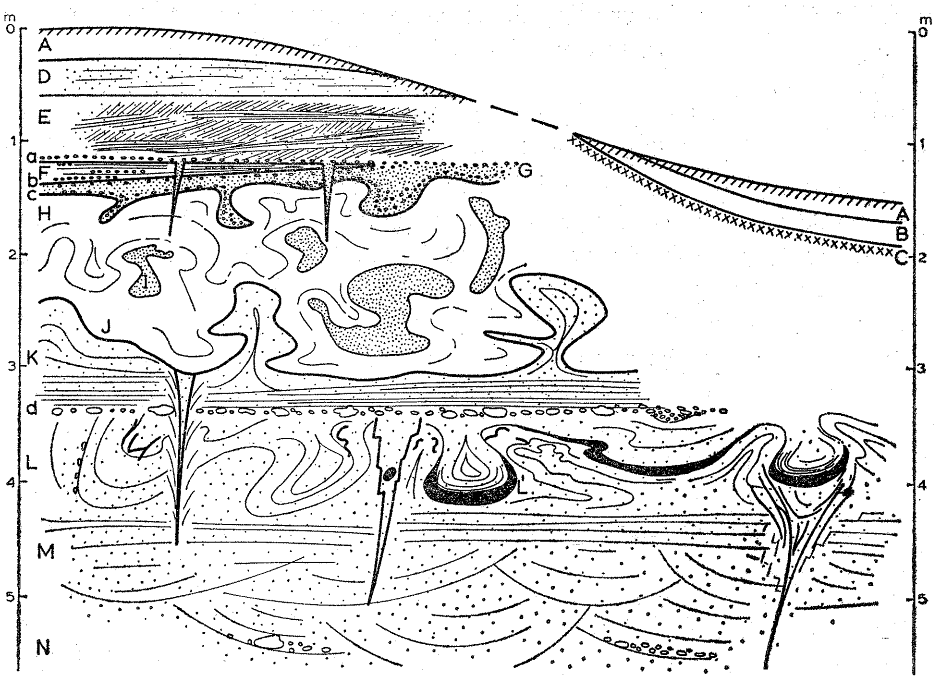

Fig. 1. Schematic representation of the lithologic sequence and the periglacial features in the pit Alphen 't Zand (The Netherlands). For explanation, see text

A horizontally stratified loam with local pebble rows occur at certain places (F). At the base another pebble row (b) occurs, coming together with pebble row (a) where F is lacking. A dune sand G is similar to E but is cryoturbated. At the base a new pebble row (c) is found as well. The loamy layers F and D (partly) show grey spots as possible indicators of hydromorphic soil formation. The pebble rows a and b are thought to be equivalent to the Beuningen gravel complex.

Beneath this series a thicker strongly cryoturbated loam layer (H-J) occurs with inclusions of gravelly sands identical to the sands E and G. In other excavations it can be seen that this loam complex consists of two loam layers (H and J) and dune sands (I) between them.

The top of the underlying medium to coarse waterlaid sands (K) is sometimes cryoturbated as well. At the top also deep frost cracks start. The underlying sands L are similar but they contain small loamy beds and pebble rows and are strongly cryoturbated. The K and L are separated by a pebble row d consisting of relatively large boulders of especially quartz, flint, sandstone, quartzite, ... in contrast with the small pebbles of especially quartz and flint in the pebble rows a, b and c. The layers N, M and L seem to represent a continuous fluviatile sedimentation series going from coarse gravel bearing sands (N) to coarse sands (M) and to finer sands (L), all deposited in gullies.

Laterally a clayey peat layer or a podzol is developed at the top of the L-deposits. Especially the clayey peat (L') is sunk down in, sometimes regularly spaced, pockets. In this way the underlying sand is squeezed out between the pockets. Afterwards the cryoturbated series L is cut off by the pebble row d. The series L and M are pierced by large ice wedges formed under permafrost conditions. The development of these ice wedges and the cryoturbation of the sands L can be situated in the Early Vistulian because they postdate the peat (L') and podzol formation from probably Eemian age.

Point I-2: WEELDE

by F. Gullentops

This old sandpit is situated on a flat interfluvium plateau, remnant of an early-Pleistocene perimarine plain. It is covered by about 3 meters of essentially aeolian Vistulian sediments (fig. 2).

(1) The Holocene soil (a weak grey-brown podzolic succeeded by a heather podzol) is developed on top of a dune sand complex (1—10). The sand is loosely packed without silt matrix and its bedding is regular with occasionally slightly inclined filling-in stratification.

The upper part is more homogeneous, essentially a constructional facies corresponding to the actual dune morphology. Elsewhere occurs near its base a thin leached zone, the Usselo soil of Allerød age.

The lower part is rich in granule layers representing deflation horizons. The most typical is the one-granule-thick basal layer discordant on the underlying plications. The quartz granules have a very rugose surface due to sandblasting corrasion. In general the coarse dune sands are placed entirely in the Tardiglacial. We can here not

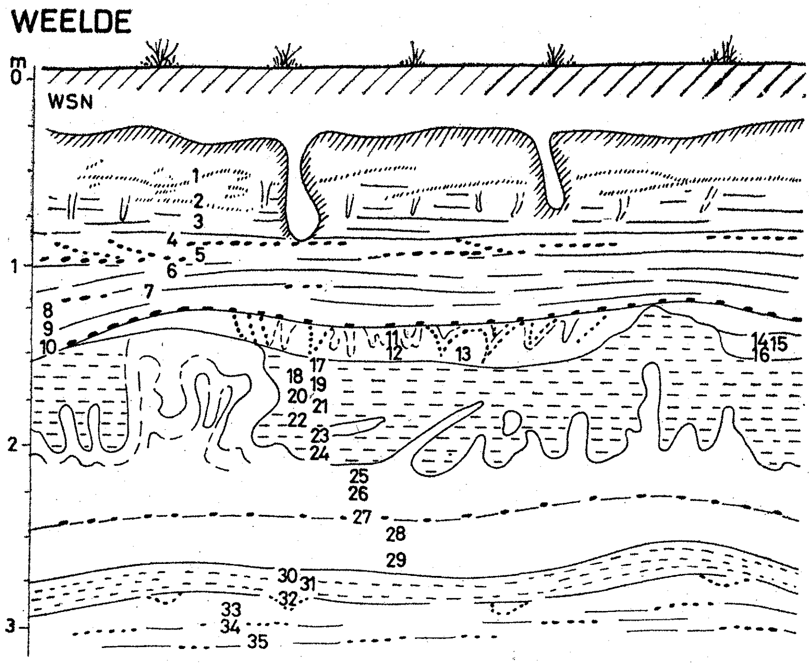

Fig. 2. Section of Vistulian aeolian sediments in old sandpit at Goor Heide, Meerle (Weelde)

exclude however that their basis would be somewhat earlier. If the general conditions can be characterized certainly by dry continental summers and scanty vegetation, there are in fact no direct indications on the temperature conditions during the aeolian active phases. An important role will have been played by the negative instability of the environment; indeed a rapid evolution to worse edaphic conditions will exterminate one vegetation and leave the soil very vulnerable before a new colonisation has taken place.

(2) Interesting problems are presented by the underlying cryoturbated complex (11—29). The uppermost horizon 11—13 has a similar appearance on various faces of the sandpit. It consists typically of a 30 cm thick slightly loamy fine sand with apparently mixed granules. On second view, the granules are organized in loose layers which are intensely plicated with upward convexities and downward more pointed forms. Sometimes the whole layer is eroded by the pavement 10, mostly the plications are only slightly attacked, showing that the top of the plications was very close to the surface at the moment of the cryoturbations. The top 17 of the underlying loam does not follow these plications, showing that the cryoturbation was a very superficial but nevertheless intense phenomenon.

The underlying silt layer (17—24) is a very regular horizon on this plateau remnant with constant thickness and grain size. There is no doubt on its aeolian origin and it proves the existence of a stable environment favorable for captation of aeolian dust. This means a suitable vegetation and such physical conditions of the soil that the dust is not continuously washed away.

This layer has an extremely disturbed appearance which is caused by the completely irregular penetration of the underlying sands upward in and through the silt. Apparently closed sand patches relate laterally to the underlying sand. Sometimes there is so much sand that the silt layer is isolated in silt knots. The whole disturbance is clearly due to the injection of fluid sand in the stiffer silt. Under the more vigorous upward thrust the silt layer bulges upward and can even be broken completely through. We relate these dynamics to pressure in the supersaturated active layer when refreezing.

Questions to be solved are:

1. Are the two cryoturbation layers separated in time? Will we find places where the upper cryoturbation disturbs the older one or where between the two sufficiently thick other sediments are preserved?

2. Or will we continue to find the same succession indicating that both disturbances are due to one cold cycle just before deflation 10? Earth hummocks on the surface and mollisol injection somewhat deeper.

3. For reaching the supersaturated sand conditions and the upward pressure do we need permafrost underneath or is a completely saturated groundwater table enough? If permafrost we will eventually find still deeper disturbances due to it, as great ice wedges, and all these will have formed in relation to surface 10.

Point I-3: BEERSE

by F. Gullentops

In the northern Kempen an important number of big quarries exploit the perimarine, Early Pleistocene Kempen clays. In a no more visible pit E. Dricot (1962) found a complete cold cycle which was coined Beersien. On the other hand De Ploey (1961) unraveled the stratigraphy of the overlying upper-Pleistocene deposits.

We visit one quarry which gives an idea of the information available in these rapidly changing pits.

Observations can be made on following points:

1. Sedimentation of loose Tardiglacial dune sands.

2. A regional coversand complex with the typical coversands on top overlaying an aeolian silt layer, the base of which becomes sandy and begins with an eroding gravelly layer.

3. A sand with peat complex only preserved in depressions in the subsoil and showing a very convoluted horizon.

4. In the clay surface when this is situated higher are very typical kettles in which remnants of the third complex are preserved.

Dricot, E. M., 1962 — Microstratigraphie des argiles de Campine. *Bull. Soc. Belge Géol.*, 70; p. 113—141.

De Ploey, J., 1961 — Morfologie en Kwartair-stratigrafie van de Antwerpse Kempen. *Acta Geogr. Lovaniensia*, 1; 130 p.

Point I-4: ZAMMEL

by F. Gullentops

On the perfectly flat Kempen plain near Westerlo, the interfluvium between the river Nete and a tributary is formed by a low 3—5 m and broad 200—400 m interfluvium with a ENE direction. Classically one would interpret it as an erosional landform, but a well placed sandpit in Zammel shows the contrary.

The whole relief is essentially formed by finely layered slightly glauconitic fine sands with low compaction. The layering is visible by small changes in the grain size and by the variable silt content. The layers are very slightly inclined to the south, absolutely parallel with the topography. Each thin layer can be followed over several tens of meters in the transverse SN direction, the layers thinning out towards the top. Of two loamy layers the one near the top is present on all the pit faces but nevertheless it locally thins out and disappears. In a longitudinal profile the stratification is less regular, inclined beds appear filling up small depressions.

In the deeper parts of the pit there have been visible frostcracks and a convoluted structure with upward pressure. On the south side of the pit the sand is covered by a patch of typical Tardiglacial dunesands with the Holocene soil succession.

These sands represent a very typical facies of the late Brabantian coversands. They are local ridge-forming deposits, blown out of adequate periglacial river plains and heaped up parallel to the river. The situation itself excludes all other upslope transport but aeolian. However, if the setting is understood, the same cannot be said of the nature of the micro-environment responsible for the layering.

This form is a special case of coversand ridges. We like to stress its local derivation out of an active river plain and its resemblance to river levées (oeverwallen) and indicate them as "wind wallen" in Dutch.

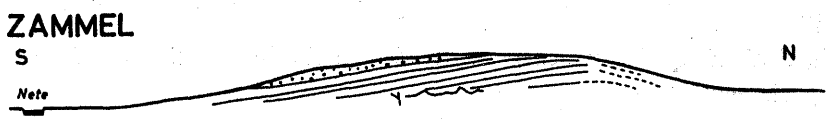

Fig. 3. Transverse profile through Brabantian aeolian sand-ridge north of the Nete-River at Zammel

Point I-5: RAMSEL CLAYPITS

by F. Gullentops and J. Vandenberghe

The claypits of Ramsel will be used to demonstrate two different types of phenomena.

1. Large areas of the Kempen are characterized by very flat topography, representing really a plain sloping together with the drainage, $\pm 1‰$. Apart from some infilled valleys the plain is of erosional origin. In the claypits the Tertiary subsoil is close to the surface and consists of Rupelian (Oligocene) clay, covered sometimes here by small remnants of Diestian (Miocene) glauconite sands (u-w in Ramsel N).

Elsewhere the plain is eroded in different sands. In 1966 we explained such plains as periglacial pediments. The two pits of Ramsel show that the eroded surface is covered by typical sediments. They consist of sets, in general between 20 and 30 cm thick, each set composed of inclined laminae, tangential to the base. The laminae are coarse sand, becoming coarser towards the base, charged with granules and small pebbles, occasionally, when resting on clay as in Ramsel S, with clay pebbles eroded from the local subsoil. Several, 2—3, rarely more of these layers may be present.

It is clear that the transporting agent is water, but the general designation of fluviatile does not render all the information.

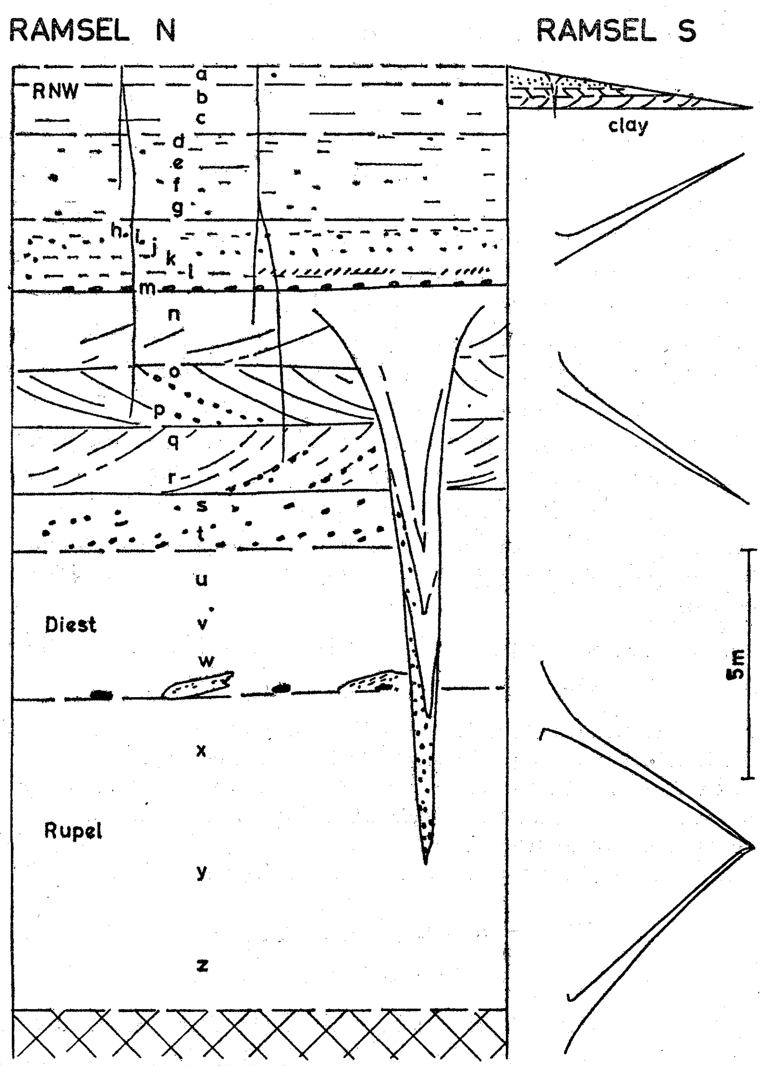

Fig. 4. Section in quarry Ramsel North of Brabantian coversands resting upon crossbedded "fluviatile" Vistulian sands covering Tertiary subsoil

On the very low angled quarry face of Ramsel South the horizontal design of the frostcracks can be followed

We interprete these layers indeed as pediment fans, formed by ephemere sheetflood rills that collect, spread over the fan, depositing their coarser load, collect again. They represent the true syngenetic sediments with the erosion of the pediment. Because the sheetfloods are produced by the diurnal rhythm of the snowmelting, the term periglacial pediment is indeed adequate. This environment was active during the snowrich Hesbayan.

2. In Ramsel N can be seen vertical sections through frost wedges affecting the earlier sediments. The wedges have a width of ca. 20 cm on top and taper off very regularly to the base. The depth is rather constant between 1.10 and 1.30 m. The width is not affected by traversing different sediments.

The adjacent layers are clear cut and no pressure phenomena are observed. The wedge is filled with the neighbouring material which has glided in it so that the successive stratigraphy can still be recognized.

All these observations are explained by a formation as thin contraction cracks during the winter with slight sliding of the walls upon thawing. The phenomenon repeats itself on the same place during a number of winters, so that the collapsing widens and deepens.

The very slightly inclined pitface of Ramsel S allows to observe the horizontal pattern of these frost wedges. They must form a geometrical network with 7 to 10 m distance of the wedges and rather orthogonal intersecting.

Although a very conspicuous periglacial phenomenon, it needs only a stability phase of a few hundred years with freezing depth of ca. 1.20 m and reduced snowcover. Dating of this environment will be rather precise. Earlier a wedge was found in Ramsel N cutting through a peat layer for which a date of 28,100 B.P. was obtained. Now it is visible at the base of the silty layer just covering the frost wedge a very thin organic layer deposited in a small depression characterized by water plants and carex. A date will be obtained here. We remember that in similar conditions we obtained in Brugge a formation of the same type of frost wedges between 26,220 and 24,760 B.P.

Ramsel N shows also a penetration by later very thin frost cracks originating higher in the succession.

GULLENTOPS, F., MULLENDERS, W. et COREMANS, M., 1966 — Etude de la plaine alluviale du Kaatsbeek à Diepenbeek (Limbourg belge). *Acta Geogr. Lovaniensia*, 4; p. 141—150.

VANDENBERGHE, J., 1977 — Geomorfologie van de Zuiderkempen. *Verh. Kon. Acad. v. Wetenschappen, Letteren en Schone Kunsten van België, Kl. d. Wet.*, XXXIX, vol. 140.

VANDENBERGHE, J. and GULLENTOPS F., 1977 — Contribution to the stratigraphy of the Weichsel Periglacial in the Belgian coversand area. *Geologie en Mijnbouw*, 56; p. 123—128.

Point I-6: ROTSELAAR

by F. Gullentops

On the west side of the alluvial plain of the Dyle river is situated an undulating sandy-loam region with a conspicuous ridge, 2—3 m high and several hundred meters broad, bordering continuously the alluvial plain.

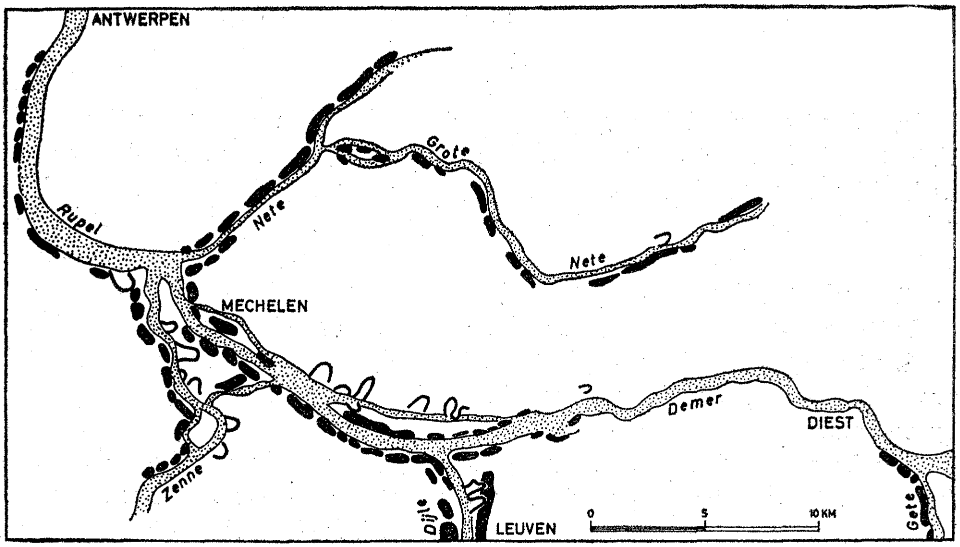

Fig. 5. Aeolian Brabantian "windwallen" especially well developed on the S—W side of the contemporaneous floodplains in the Rupel basin

We studied a similar ridge together with Mme VANMAERCKE-GOTTIGNY along the Scheldt river and will show there that it formed by aeolian accumulation blown out of the braided-river plain of the late Brabantian Scheldt. Similar topographic "wallen" are very common along the major axis of our rivers. The "wallen" are typically interrupted where small tributaries enter, whose valleys are strangled and sometimes literally obstructed by the "wallen". We mapped those of the Rupel basin. They are always coarser than the surrounding aeolian material as can be read from our pedological maps. The map shows an absolute preferential direction. It is clear that the "wallen" are best developed on the south and west sides of the periglacial river plains and that the wind direction which best explains the orientation is a north-eastern (fig. 5).

So it can be stated that during the late Brabantian our major river plains were excellent local sources for aeolian material, the coarsest fractions of which built up flat elongated ridges along the river plains. During the deflation time (late summer?) north-eastern winds prevailed clearly. We call the ridges "wind wallen". The map shows how the southern loam rivers Gete, Dyle and Zenne had broad sandy loam "wind wallen". The Demer was much more important and its "wind wallen" form one perfect arc even along a valley which is abandoned during this activity. Most important for local geomorphology is that the Demer-Rupel turned already nicely to Antwerp, but that the Scheldt was still following another course.

The last day point II-6, the excursion road will cross another "wind wallen" along the Demer at Halen.

Point II-1: ZOUTLEEUW

by F. Gullentops

In 1969 we described the very nice closed depression "Het Vinne" near Zoutleeuw. This 2 km long depression was eroded in Landenian (Eocene) sediments and only drained by a small incised outlet to the nearby Gete valley. To the contrary of the neighbouring landscape no loessic material is preserved on the bottom of the depression but only lake sediments and peat are present, the base of which would be at the earliest Allerød.

In the recent Holocene the alluviation of the Gete plain hampered the drainage of the depression which finally became a lake. Inundation water from the Gete reversed in the lake building up a small delta. The lake is drained since last century by pumping.

The formation of the depression being clearly periglacial we explained it by the freeze and thaw action of abundant springs draining the Landenian water table. We used the word pingo for it and take this back. Indeed the rim of the depression is not formed by gliding of sediments on the pingo ice core, but consists of undisturbed Tertiary. Nor can we expect that there ever was an ice hill, a pingo of this dimension.

Icings are known from permafrost regions, but their morphological activity has not attracted much attention. More than the Aufeis the annual formation of ice sills at the freezing table in abundant springs could have a strong vertical as well as regressive erosion effect during summer thawing. Permafrost conditions do not seem necessary because the discharge of the water table would then diminish considerably.

MULLENDERS, W. and GULLENTOPS, F., 1969 — The age of the pingos of Belgium. *in*: T. L. PÉWÉ — The periglacial environment. McGill-Queen's Univ. Press, Montreal; p. 321—336.

Point II-2: KESSELT

by F. Gullentops

In 1954, we described the loess quarry of Kesselt and it has up till now remained accessible with a wealth of information and problems. The presence of the conspicuous Kesselt-soil, which has been recognized over a large area, allowed us to situate the phenomena of the last (Vistulian) glaciation in the framework of two substages: Brabantian and Hesbayan.

Following facts and problems merit discussion:

1. SEDIMENTATION OF THE HESBAYAN LOESS

Grain size (a perfect aeolian suspension silt) and mineralogy (homogeneous upon various subsoils) show it to be of aeolian origin. When looked at closer the homogeneous appearance becomes distinctly layered, and it becomes clear that during the final deposition some kind of sorting intervened due to the presence of abundant water. We believe this to be the meltwater of snow and the loess essentially present as dust in the wintersnow. Very special is that the thin layer stay parallel so that the meltwaters did not get powerful enough to erode. We see only two possibilities:

(a) The meltwaters at 0 °C in equilibrium with the snow run under the snow on top of frozen ground too hard to erode and too cold to melt.

(b) The meltwaters trickling under the snow percolate easily in unfrozen soil. This depends finally on how much snow there was and how early in autumn it began to fall. This last situation is prevailing one in the subnival zone of the humid western Alps, where we have always found unfrozen ground under the thawing snow patches. This type of sedimentation, which we adhere for the moment, would show that the Hesbayan climate is very snowrich and had a short appearing period with the soil in fact insulated from the wintercold.

2. FOUR, MORE OR LESS CLEARLY TRANCHING GRAY HORIZONS INDICATE SOILS THAT INTERRUPT THIS CLIMATE

They are characterized by a 5 to 15 cm thick bleached horizon and a very diffuse and weak iron enrichment underneath.

We followed in 1954, a nomenclature by FREISING and called these *Nassböden*. As the word implies the bleaching was facilitated by reduction of the iron oxides in humid conditions. To have reducing, marshy conditions on such a permeable material as loess in hilly country one needs permafrost. The *Nassböden* became so the coldest spells of the Hesbayan.

We now have changed our explanation. We no longer believe that this environment was one of an arctic permafrost with only 20—30 cm of summer thawing. A negative reason is that these soils show no important syngenetic cryoturbations. A positive reason is that these soils are the only horizons of organic live. All the mollusc-shells found (mostly the types *Succinea oblonga* and *Pupilla muscorum*) are on top of the leached horizon while the soil itself is rather rich in annelid pearls.

So the soils are interpreted as stability phases without (or with strongly reduced rate of) loess sedimentation in less rigid edaphic conditions. Without gley conditions the soils are of a podzolic nature. In calcareous soil the acid leaching of the iron is however impossible. It can however be chelated to organic complexes in which we think that lichenic acids played an important role. Estimating the mean duration of such a soil 3000 years and giving as much to each loess depositing episode then we have about 25,000 years of the pre-Kesselt Vistulian climate documented here.

3. CRYOTURBATIONS

Different disturbances are found in the Hesbayan loess. Small wedgelike forms can be found on nearly all levels; 15—20 cm deep, and a few cm broad they generally appear in constant distances of 20—30 cm. In horizontal cut they form a reticular pattern. Above the highest nannopodzol one level is particularly well developed with somewhat bigger dimensions up to 60 cm depth and 40 cm distance. They represent hummocky ground in different phases of development from incipient to mature.

Small deep frost cracks, a few mm thick start from the Kesselt soil and may penetrate 4 m in the Hesbayan loess.

At this moment are visible two ice wedges which disturb the lower nannopodzols. In perpendicular cut they are not much more than 10 cm wide, but widen in the weathered horizons. Ice growth pressure is demonstrated by the upturned soil horizons. The filling does not show any stratification.

We may consider that it needed a few hundred years to built up these ice wedges in permafrost conditions. The problem is to find the soil level of that permafrost.

4. THE KESSELT SOIL

The Kesselt soil is a conspicuous but complex horizon. It is the superposition of a decalcified, oxidized and homogenized loess by a calcareous very slightly organic loess both excessively intermingled by plications. Becoming upward more brown and downward more gray, the contrast is most intensive at the contact. The plications are rather regular inclined tongues in the direction of the slope.

The Kesselt soil is the brown decalcified horizon approaching a brown podzolic soil type and representing a much better climatic phase, the only one which we give the rank of an interstadial. The new gray calcareous loess is the beginning of a new cold phase, the Brabantian.

After deposition of some of this new loess the vigorous intermingling occurred. This seems to need rather plastic water-saturated conditions, so an active layer and underlying permafrost. The thin frost cracks are related to this level; maybe the somewhat deeper ice wedges also?

5. THE EROSION RAVINES

Just before the Kesselt soil and partly contemporaneous with it, exists an erosional phase during which the Hesbayan loess is ravined with rather steep-walled gullies several meters deep. The gully is then filled up with reworked loessic deposits with numerous structures of running water. The weathering of the Kesselt soil is developed on top of it, but the colour may not be as reddish. We do not yet understand the climatic significance of this very important phenomenon. It certainly shows a great instability of the environment; in this case a positive instability as conditions turn abruptly to the interstadial. It certainly needs running water and we prefer rain above snowmelt for the heavy discharge. Our tentative explanation is that the abrupt change to a better climate could not be followed as rapidly by a new vegetation and that the colonisation-vacuum was exploited by the gullying.

Was the gully then filled up progressively when the new equilibrium set in?

6. THE BRABANTIAN LOESS

This loess responds much better to the image of standard loess, it is more yellow, powdery with a faint strength. It is certainly aeolian dust but we must consider that it obtained these typical characteristics not by the deposition but by the syngenetic slight pedological change it suffered. It obtained the typical cohesion and high porosity by redistribution of the calcareous content by dissolution and reprecipitation in the drier steppe-like environment which characterizes the continental cold Brabantian climate.

Point II-2 bis: PRIMARY LOESS RIDGES IN HASPENGOUW (FR. LA HESBAYE)

by E. Paulissen

Between Vroenhoven and Lanaken we crossed a linear topography of broad ENE—WSW ridges separated by large depressions. The height difference between the ridge and the depression is some 10 m, with slopes up to 3 %. North of Kesselt, the ridges are developed on 3 valley terraces of the Meuse developed in a meander bend about 5 km. These terraces are separated from each other by S—N oriented scarps of about 10 m. This terrace landscape has been changed drastically by the loess into a ENE—WSW linear topography with 2 ridges and 3 depressions. The main original landscape elements like the meander border and the terrace scarps remain however visible as gentle slopes on the individual ridges.

A complete transection ridge-depression is studying on the Terrace of Caberg-Pietersem (Saale glaciation, Paulissen 1973). The height difference between ridge and depression is 6 m, formed by a slope of 2 % (coordinates of the pit: 5° 38′ 45″ E, 50° 52′ 45″ N). Figure 6 summarizes the construction of this catena. The typical Brabantian loess deposited in a steppe-like environment (see pit Kesselt) forms the ridge and rests on a small core of the Hesbayan loess, fossilized by the Kesselt soil. From the field evidence we conclude for the existence of primary loess ridges in Haspengouw formed during Vistulian time and more specially during its second stadial, the Brabantian. The topography is flattened during late-Brabantian and historical times. It is likely to consider these loess ridges as longitudinal forms constructed by ENE-winds.

The problem is to know whether this ENE-orientation corresponds with the direction of the winds carrying the loess from its source area or whether the orientation of these primary ridges is connected with a local wind pattern deviating in some way from the general wind pattern.

An additional argument in favour of the first hypothesis is provided by F. Gullentops who expressed the opinion that NE-winds have been very important

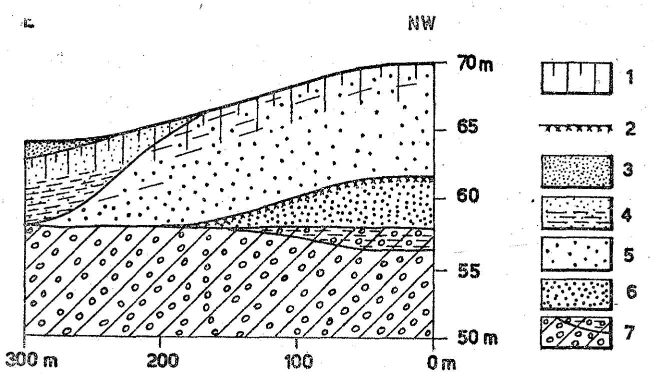

Fig. 6. A ridge-depression catena of a primary loess ridge in Haspengouw
1. Holocene soil; 2. Kesselt soil; 3. colluvium; 4. Late-Brabantian layered silt and sand deposits; 5. Brabantian loess; 6. Hesbayan loess; 7. gravel and coarse sand of the Terrace Caberg-Pietersem

during the late-Brabantian by the formation of the "wind wallen" (see above). The hypothesis of an eventual relationship between ridges and local winds is deduced from our assumption, based on fieldwork, that in this area thick loess patches of Brabantian time are related to the S—N oriented and 50 m deep entrenched valleys (Meuse, Demer, Jeker), so that we suggest that these valleys have funneled the loess-bearing Brabantian winds into a N—S direction. If this assumption is correct, we have still to explain why the ridges are constructed under an angle of about 50° from the funneled wind direction.

Point II-3: THE PERIGLACIAL GRAVEL DEPOSITS OF THE MAIN TERRACE OF THE MEUSE AND THE POSTERIOR PERIGLACIAL LANDSCAPE EVOLUTION

by E. Paulissen and F. Gullentops

Location: Maasmechelen — Pit Sibelco N.V. (5°38′E, 50°57′30″N; alt. 90 m).

A long walk in this large pit, where Miocene glass sands are extracted, permitted us to study the gravel deposits of the Main Terrace of the Meuse, the valley system of the Kikbeek eroded in these gravels, the epigenetic involutions on top of the Terrace gravels and on the valley slopes and finally a section in a late glacial dune.

1. GENERAL MORPHOLOGICAL SITUATION

The Campine plateau forms the major morphological unit in NE Belgium and dips regularly to the North with a slope of 0.13% over 70 km. The entire plateau is covered by fluviatile deposits of the Meuse and the Rhine and a large part of its surface was situated in the confluence area Meuse-Rhine during the formation of the Main Terrace. The fluviatile deposits are subdivided into two lithological units: a sand facies, 2—7 m thick, in the west passing to the east into a gravel facies. The fluviatile sands attain thicknesses of more than 50 m in the Central Graben (the Netherlands), situated North of the Campine plateau, and described there as "The Sterksel Formation". The gravel deposits of the Main Terrace, we study in this pit, attain thicknessses of 15 m and are deposited here in an eight km-large bend parallel with the eastern plateau border.

In a forthcoming paper (Paulissen and Gullentops, *in press*) we will deal with the geomorphological, lithological, mineralogical, petrographical and tectonical characteristics of the Campine plateau.

2. THE PERIGLACIAL GRAVEL DEPOSITS OF THE MAIN TERRACE

A complete section through the fluviatile deposits was studied. The base of the fluviatile deposits is undulating, with height differences of about 5 m and consists of different channels of variable dimensions eroded in the white Miocene sands. The first accumulation in these channels are homogeneous clays or horizontal layered clayey sands. Perturbations occur on the contact clay-sand. This unit belongs lithostratigraphically to the sand facies of the Main Terrace (*in casu*: the Sands of Winterslag).

The sand channels are covered by an important gravel sheet 12—15 m thick (the gravels of Zutendaal). A channel lag deposit consisting of cobbles and some boulders forms the base of the gravel unit and erodes nearly horizontally the underlying deposits. The gravel deposits form an aggradation unit, as GULLENTOPS (1960) pointed out already, deposited during different aggrading cycles, each cycle consisting of a coarser channel-lag deposit at the base fining up to a fine gravel or even a sand layer or a clay lens at the top. Each cycle is deposited in a broad undeep channel. Point bar structures occur in deeper channels. Near the base of the gravel unit we found a 30 m large channel, filled up with a 5 m high delta-like foreset of gravels dipping at 15—20°. These delta-like deposits are constructed during flood regimes in a braided river when a divaging channel with high competence crosses a river channel formed during a previous lower regime.

The whole set of structures observed in the gravel deposits are fundamentally different from the large and homogeneous gravel structures forming by the actual Meuse, a single channel river (PAULISSEN, 1973), and are considered to be typical of a *braided river*.

Intra-formational indications of cold climate during the period of gravel aggradation are rare. Until now frost wedges have never been found. We only found some isolated perturbations (cryoturbations?) on the contact of layers with a different texture (as described already by MACAR, 1954) and interstratified gravel beds with the gravels in a vertical position (as described by GULLENTOPS, 1960). Angular blocks of very loose pure Miocene sands are found within the gravels: they have been eroded from frozen river banks and were transported in a frozen state. Common are the big Ardennes boulders (up to several tons), generally considered as being transported on floating ice. These boulders occur mostly in the lower part of the gravel deposits, but can be found on each level. HACQUAERT and TAVERNIER (1947) mention in the basal part of the deposit at As a high percentage of wind worn flints.

We consider these gravel deposits as *periglacial* (see also MACAR and ALEXANDRE, 1957; GULLENTOPS, 1960), not only on the basis of the sporadic intra-formational indications of a cold climate, but also on the basis of the fluviatile characteristics of the gravel deposits and on the brusque change in the bed load of the Meuse (first sand, later gravel). This change implies an accelerated mechanical weathering in the basin (Ardennes and the Vosges — the Moselle being still an affluent of the Meuse). This means in our climatic belt a change to colder climate, so that the lithological transition sand-gravel is due to the onset of a colder climate.

The age of these gravel deposits is hypothetic. No intra-formational dating elements exist until now. The deep red weathering on the top of the gravel deposits — *the As soil* — (first mentioned by BOURDIER in 1946) is generally considered to be formed during the Holstein Interglacial, so that the periglacial gravel deposits could date from the Elster glaciation.

3. THE VALLEY OF THE KIKBEEK

After the aggradation of the main terrace gravels, the Meuse eroded an important 40 m deep valley. An intense drainage pattern has developed on the plateau, in function of the particular conditions of this landscape unit. The Sibelco pit showed different morphological and geological profiles through the valley system of the Kikbeek, one of the valley systems developed nearly perpendicular to the Eastern plateau border. The Kikbeek valley is 3 km long, has a maximum depth of 30 m and a flat bottom from 150 m enlarging to 300 m down valley.

In an earlier paper we dealt with the age and the origin of the flat bottom valleys, mainly based on successive sections in the same valleys due to the progress of the exploitation front in this pit (GULLENTOPS et PAULISSEN, 1972). Organization and orientation of the valleys indicate that they are initiated by regressive erosion of sources from the eastern plateau border. The main development is by sheetwash and fluvial erosion which was able to erode the total thickness of gravels, without however any concentration of the coarser elements on the bottom of the valleys, as we saw in large excavations along the bottom of the Kikbeek valley. Fluvial erosion on a moving active layer could be sufficient to understand this phenomenon. This activity has taken place essentially in the Saale glaciation. This fossil valley bottom forms a terrace about 2 m above the actual valley bottom. The Vistulian evolution of the valleys is considered as secondary: a small alluvial fan is formed on top of the Eisden-Lanklaar terrace, a Saale-terrace of the Meuse (PAULISSEN, 1973) and under a late glacial dune (see *5*, p. 363).

The Kikbeek valley is also a nice example of an assymetrical valley with a steep SW-facing slope. The actual asymmetrical form is due to the accumulation of a 6 m thick Vistulian coversand layer on the NE-facing slope, covering the gentler slope of an existing asymmetrical profile, modeled in the gravels and underlying Miocene sands, with only 1 meter slope deposits at the base of the gentler slope.

The Vistulian coversand accumulation on the NE-facing slope is very homogeneous. The 2 m thick top layer of the coversands is however strongly mixed with gravels derived from the up-slope. This implies changing conditions (wetter climate?) at the end of the aeolian phase.

4. THE EPIGENETIC INVOLUTIONS ON TOP OF THE MAIN TERRACE GRAVELS

The walls of the pit we visited have a different morphological position: the SE and SW walls, about 500 m long, are situated on the plateau surface (abs. height — 90 m), while the NW wall exposes the thalweg of a small dry valley with a 3% slope to the NE and maximal depth of 10 m.

In the SE and SW plateau-wall a continuous layer of 2.5 m deep epigenetic involutions occurs, while on the NE valley wall this involution layer is absent.

4.1. The cryoturbation horizon on top of the plateau

Already more than 30 years ago, CAILLEUX (1942), GEUKENS (1946) and HACQUAERT and TAVERNIER (1947) described in the gravel pit at As the very intense cryoturbation horizon on top of the Main Terrace gravels.

An important characteristic of the plateau involutions is their horizontal base through the whole exposure. The mean abs. height of the deepest involutions is

87.5 m (St dev.: ± 0.26 m; deepest involution at 87.15 m). Under this limit the gravels conserve all their original fluviatile depositional characteristics, but loose all original stratification above this limit.

Many times the sand element is dominant in the cryoturbated horizon. The gravel layer is then only disturbed in the upper 0.5 m, and forms a flat surface over several meters, with some flame-like injections of the underlying gravels (or exceptionally a fluviatile silt layer). These injections are very well limited within the sands and can dip in variable directions.

When the sand masses are individualized within the gravels they show pocket or drop forms, with a diameter from 1 to 5 m, mostly flat bottomed. Some pockets are formed by a series of drops. Sand drops, with internal contoured structures often occur within the involution layer. The gravel masses within the involution horizon loosed all horizontal stratification. The long axis of individual gravels are oriented mostly vertically or structured parallel to the involuted forms.

The contact between the fine and the coarse material within the involution layer is always brusque, with an aerodynamical form.

This description is based on two perpendicular walls, but has to be relativized in the sense that it is only two-dimensional for a given involution. It is absolutely necessary for a complete description to excave these complex forms in three dimensions.

We have to stress that the fine material (sands, silty sands and silts) are aeolian deposits. They are in no way sorted out from the coarser material, but are allochthoneous in origin and are deposited as a layer above the gravels.

The stratigraphical succession of the coversands is as follows: a gravel layer, situated at about 0.5 m beneath the surface, truncates the cryoturbated horizon and is covered by coversands and the Holocene soil. This gravel layer truncates in some places a fossil B-horizon, considered as being of Eemian age (see DECKERS en BAEYENS, 1963; GULLENTOPS et PAULISSEN, 1972; PAULISSEN, 1973). This fossil soil covers some involutions and is deformed by others.

At the actual state of knowledge we see in this cryoturbated layer a superposition of different periods of involutions dated from the two last glacials.

To understand the paleo-environmental conditions of this plateau on very permeable sediments, it is necessary to mention that from the onset of the Saale glaciation until now the Meuse valley bottom, at 1.5 km east of this site, was always situated 40—50 m lower than the plateau level (PAULISSEN, 1973). This means that this part of the plateau was always well drained in all climates without permafrost. The horizontal limit at the base of the big cryoturbation horizon is considered as *the mean level of the permafrost table* above which a saturated condition was possible, necessary for formation of involutions in these sediments. These involutions are considered to be formed *in the supra-permafrost layer.*

4.2. Elongated involutions, related to soil wedges (fig. 7)

On the slope from the plateau into the valleys, the important cryoturbation layer disappears. In the upstream valley-end we observe in vertical profile individual

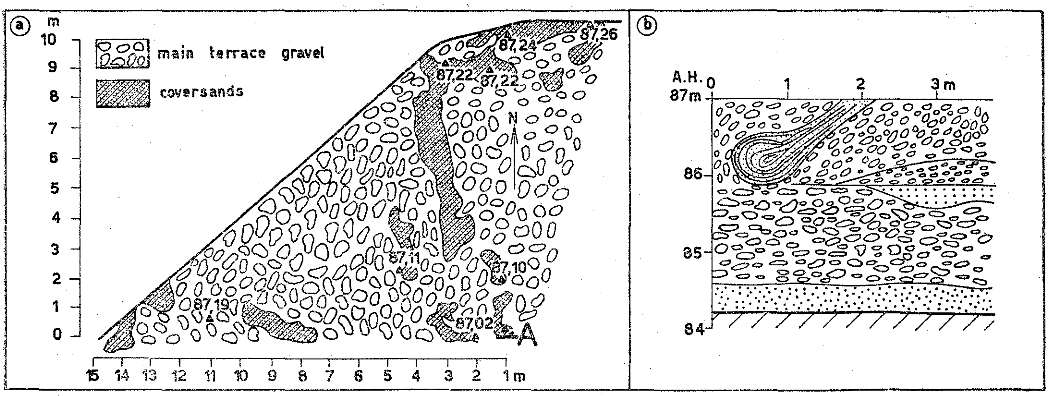

Fig. 7. Maasmechelen — Pit Sibelco N.V. Elongated involutions, related to soil wedges

a. horizontal section; b. vertical section of involution A

drop-like involutions, with one example of a drop involution connected by a neck with the overlying coversands, and slided downvalley by mass movement. The drop involutions are spaced at distances from 4—10 m. Downstream the valley, the drop involutions are eroded and disappear below the abs. height of 86 m. On the transition plateau-valley, the absolute height of the involution basis dips regularly to about 86 m. On the slope below 86 m only flame-like 0.5 m high involutions of very loose gravels in the coversand occur.

These involutions are considered to be Vistulian, and are truncated by a later pre-Holocene erosion.

At approximately 0.5—1.0 m above the base of the involutions we cleaned a horizontal surface to study the planimetric form of the involutions. All involution forms are clearly elongated. Many units are isolated. The most important unit, 6 m long, is orthogonally connected with another very elongated form. Based on our actual knowledge we consider these involutions as being arranged in a polygonal (orthogonal?) pattern.

The contact of the terrace gravels with the infilling material of the involution is very brusque, but irregular. The forms are filled up with pure aeolian coversands with hardly any stone. As can be seen in vertical and horizontal profile, the same filling consists of different sand drops.

A possible suggested origin for these elongated involutions has to be one which explains the elongation of the form and explains the drop formation by flowing of the coversands into the gravels in a way that no sorting or mixing of the involved material occurs.

The horizontal base of the pockets forms a real barrier for the descending drops, and is situated within pure gravels. This barrier forms the lower limit of a saturated gravel layer, obtaining in some conditions such pore water pressure that the shearing resistance of the gravels is very reduced or even neutralized. In such circumstances sand drop can originate within the gravels due to density differences (see point II-4; Gullentops and Paulissen, 1978).

This is the reason why this limit is considered as the *permafrost table* and why the elongated involutions are considered to have originated within the supra-permafrost layer. The elongation of the involutions is due to a cracking system, not affecting the deposits underneath the permafrost table, and attributed to *soil wedges,* developed in the seasonally frozen layer.

5. THE LATE GLACIAL DUNE PROFILE AT OPGRIMBIE

This profile, published by PAULISSEN and MUNAUT in 1969, exposes a Late Glacial dune over a distance of 250 m and is still completely accessible.

This Late Glacial sand dune, situated in the southern coversand area (50°57′17″N, 5°38′62″E) has been built up during three accumulation periods: namely during the Earliest Dryas, the Early Dryas and the Late Dryas stadials. The 3 stadial dune building periods are separated by 2 interstadial soil catenas, each composed of a bleached layer on the dune-crest and passing into a humic layer on the lee-side.

The upper catena, situated between dune phases II and III is composed of a peat layer, palynologically Alleröd, and dated 11,910 B.P.±170 (Lv-457) passing into a bleached layer with charcoal: *the Usselo soil.*

The lower catena, situated between dune phases I and II, is composed of a sandy peat layer, palynologically Bølling, and dated 12,640 B.P.±190 (Lv-456) passing into a bleached layer, which is defined here as the *Opgrimbie soil.* It was at our knowledge the first site where the existence of a bleached layer of Bølling age was proven.

Grain size characteristics of the late glacial dune sands, ecological observations during the Late Glacial periods and the importance of the profile for lithostratigraphical subdivision of the Late Glacial are discussed in the paper.

In the actual profile we observe that the (sub)actual root systems have a tendency to concentrate in nearly vertical planes. These planes are probably disiccation cracks developed from the dune top during Late Dryas time.

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Point II-4: THE EISDEN-LANKLAAR TERRACE

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Location: Eisden — Gravel pit Maaslandia (coordinates: 5°41′E, 51°00′40″N).

1. The Eisden-Lanklaar Terrace, situated along the Eastern plateau border, is located at 40 m. The fluviatile deposits show the same characteristics as the gravel sheet of the Main Terrace. This terrace is aggraded during stadial of the Saale glaciation (PAULISSEN, 1973).

Perturbations, considered as cryoturbations, eroded by later fluvial activity have been found within this gravel formation.

2. Numerous Vistulian cryoturbations affect the top of this gravel terrace. We described (PAULISSEN, 1973) vertical and horizontal profiles of large pocket soils — 3—5 m in diameter and 1 m deep. They were extremely well developed in the middle of the pit where a fluviatile clay was deposited in a large depression above the gravels.

At the border of this depression we described (GULLENTOPS and PAULISSEN, 1978) a drop soil, consisting of a great number of isolated columnar sand masses occurring on the same level in the gravel bar as in the sand depression.

The sand filling up the drops is a typical coversand. The profile showed that sand pockets were formed by descending columns of sand with internal flow structures to a general level, independant of the structure of the underlying layers.

This type of drop soil, with drops characterized by a lateral outspreading at a horizontal base level was named *the drop soil of the Eisden type*. We believe that this type has paleo-climatic significance because it originated in the supra-permafrost layer (the base being the permafrost table) by periglacial load casting.

3. Actually the gravel exploitation is going more to the west, and, more deposits are covering the Eisden-Lanklaar Terrace. The exploitation is going actually in a fan coming from one of the dry valleys.

The section is situated in a large Maas depression in the terrace gravels. The section is as follows (from top to bottom).

I. Yellow coversands (10 YR 7/4), mixed with some gravels, with the holocene soil on the top (0.5—1.0 m thick).

II. A gravel layer truncating the underlying deposits, 0.1—0.2 m thick on the average. At some places, this gravel layer forms some gullies, filled up with gravel and yellow coversands.

III. Dark brown to red brown (5—7.5 YR 5/8) clayey fine sands and silty sands, containing clay coatings. This unit is homogeneous at the top with many degradation spots, and is stratified horizontally at the base. Numerous yellow coversand drops (10 YR 7/4) perturbate this layer. We consider this layer as truncated hydromorphic Eemian soil, formed in Saale coversands (Formation of Dilsen), perturbated by Vistulian involutions. This unit, 1.5—2.0 m thick, is limited abruptly from the underlying white sands. The limit is marked by a thin gravel layer.

IV. White fine to medium sands, very pure. This unit shows many gully structures and is a fan deposit of reworked Tertiary sands (2 m thick).

V. A peat layer, maximum 10 cm thick, never cryoturbated, follows continuously the underlying depression. The dating of this layer is important (o.a. the first element in dating unit 3).

VI. A gray clayey silt, humic at the top, is filling the depression (1 m thick).

VII. Coarse Meuse sands on top of the terrace gravels.

All drops are situated in layer III and stop at about 10 cm above the base. All drops are round or composed, with various diameters, smaller than 0.5 m however. Not one is affecting the pure sands.

In one wall we observe two frost wedges, spaced at 6 m, 1 m deep and 0.10 m large. In the white sands, the wedges show downfaulting. These wedges are considered as *composite wedges,* originated as soil wedges. The transition in the wedge from a drop to a wedge is probably the place of the permafrost table, separating the drop-like part formed in the supra-permafrost layer from the ice-wedge situated in the permafrost.

Such interpretation corroborates with the other arguments in favour of the existence of a permafrost during a part of the Vistulian glaciation.

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PAULISSEN, E., 1973 — De morfologie en de Kwartairstratigrafie van de Maasvallei in Belgisch Limburg. *Verh. Kon. Acad. v. Wet. Letteren en Schone Kunsten van België, Kl. d. Wetenschappen,* XXXV, 127; 266 p.