SONDERDRUCK AUS:

Wolfgang Schirmer (Editor)

Dunes and fossil soils

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Dune phases and soils in the European sand belt

WOLFGANG SCHIRMER

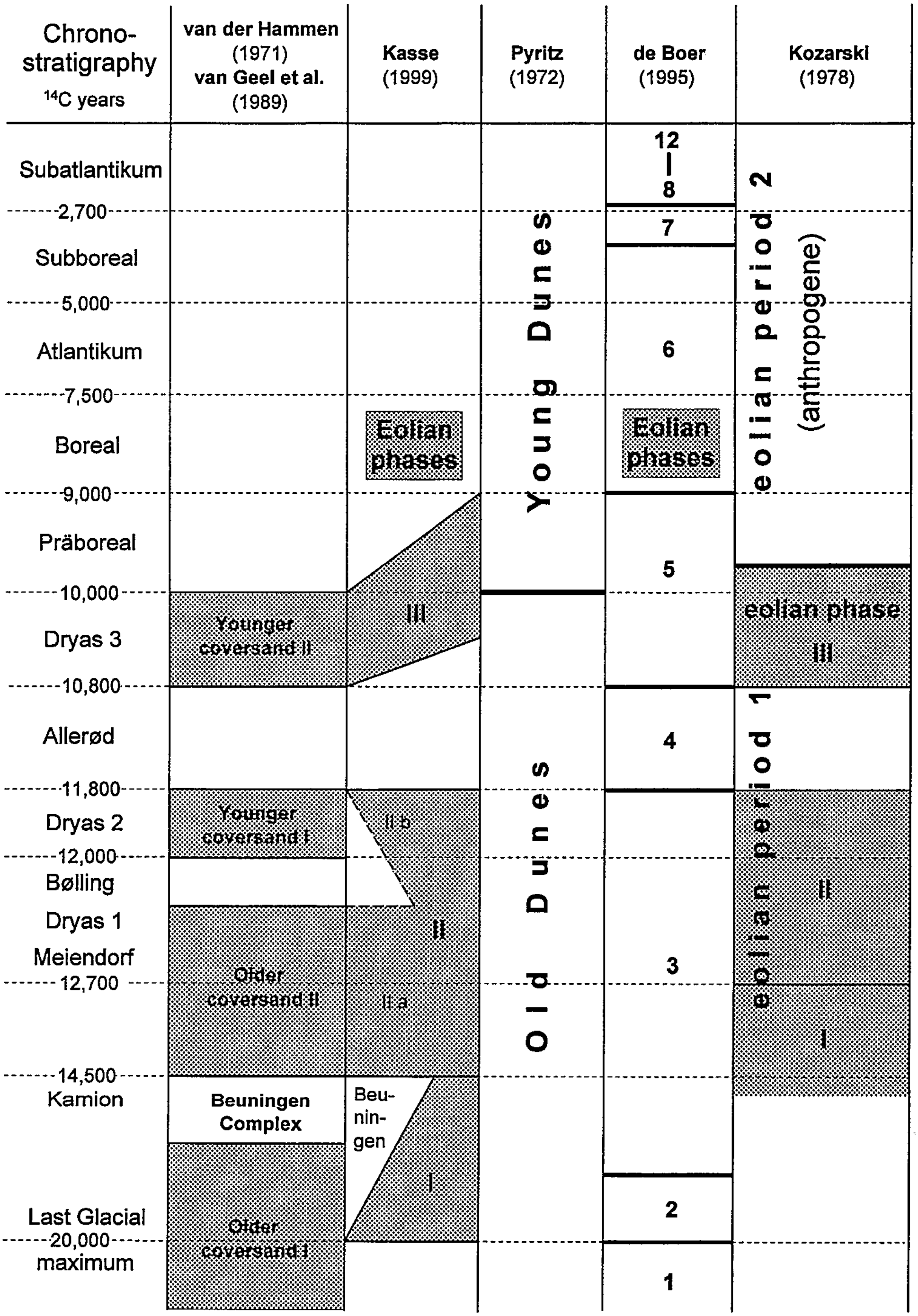
Abstract: The time span between dissipation of the permafrost and development of dense vegetation was the favoured period for eolian sand accumulation. It is the period from the late Pleni-Weichselian until early Preboreal. Similar conditions existed during the earlier Weichselian prior to the Last Glacial Maximum (LGM). Dune formation has been preserved since the early Upper Weichselian in southeastern Poland.

From the LGM on, six periods of eolian activity can be recognized (Tab. 1). Period 1: Fluvio-eolian period (28,000–ca.14,000 a BP): Period with much deflation, sand deposition as niveo-eolian and fluvio-eolian accumulation, thin-bedded as well as homogenous fine, silty sand and cold-climate indicators. Period 2: Eolian coversand period (~14,000–12,200 a BP): Period producing flat and widespread sand veneers with small dunes, silty sand and small frost indicators. Period 3: Dune period (Dryas 2: 12,200–11,800 a BP): First major dune period besides coversand deposition. Period 4: Dune and dune transformation period (Dryas 3 and early Preboreal: 10,800–9,500 a BP): Period of mainly dune transformation besides formation of new dunes, also river dunes. Period 5: Little dune transformation period (Preboreal–early Atlantic): Period of quiescence with thick brown and podzolic soils, with local and little dune transformation. Period 6: Man-triggered dune period (mid-Atlantic to recent times): Period of predominant soil formation as arenosols (regosols) and podzols on vegetated dunes, scattered human forest clearing and consequent dune transformation.

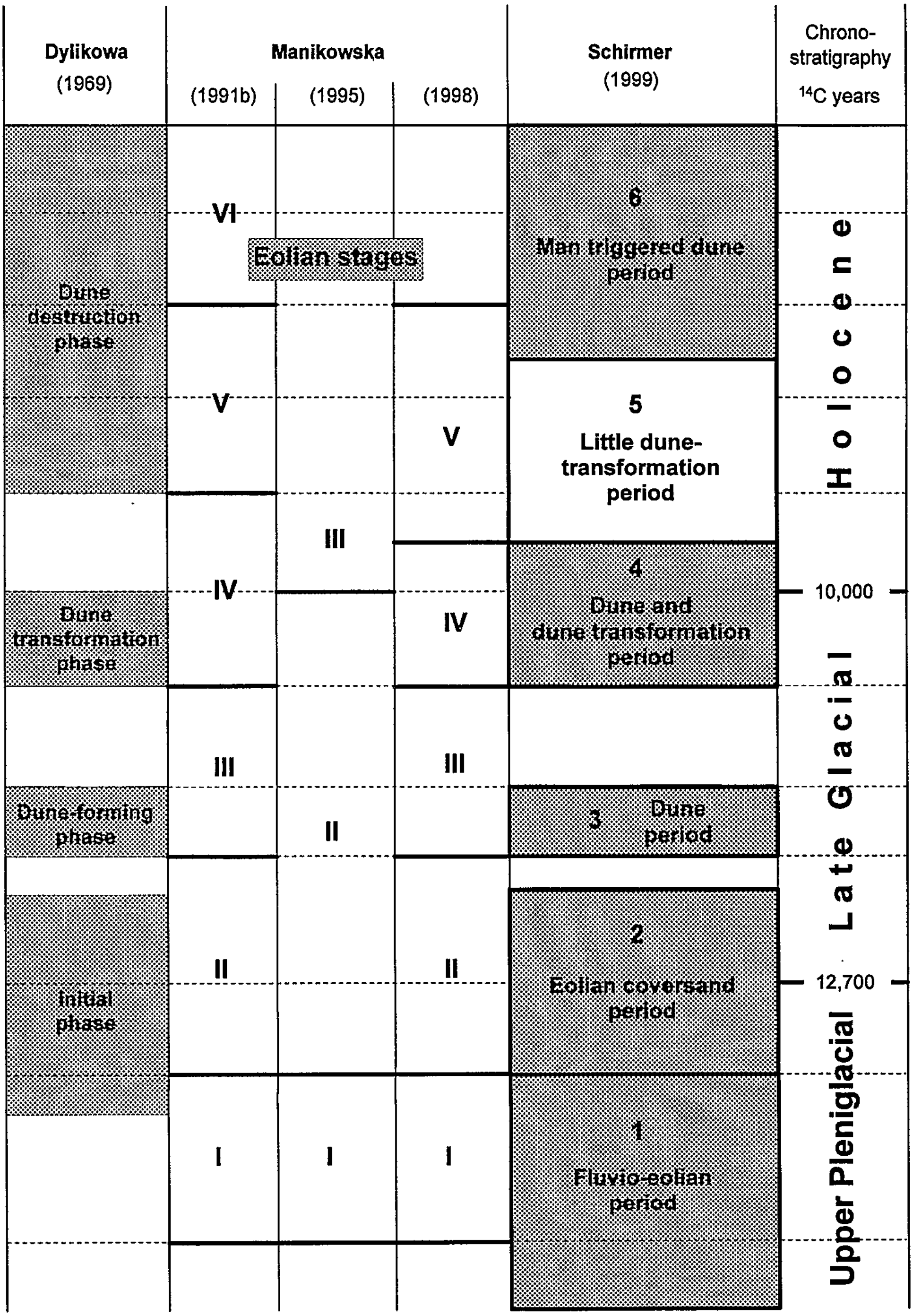
Soil formation within the eolian deposits starts during late Pleni-Weichselian interstadials with arenosols or very faint cambisols. The Finow Soil of Allerødian age presents the first thicker cambisol. The next younger one is the rusty soil of Preboreal age. A possible share of Holocene pervasive soil formation on these brown soils has to be checked. Since the Boreal period the soil development changes to podzolic soils due to changing sand properties, vegetation and climate. In case of short pauses in-between eolian sand movements arenosols (regosols) are formed only during all periods mentioned.

The following report preferably reflects on the objectives gathered during the field symposium „Dunes and fossil soils of Vistulian and Holocene age between Elbe and Wisła" August 24 to 28, 1998 (SCHIRMER 1999a) (location map in Fig. 1) as well as on the details of the Proceedings Volume presented here (location map Fig. 2).

The dune activity in the north Central European Lowland, the European sand belt, shows conspicuous spatial facies differentiation from the western to the eastern part. This is due to the climatic gradient from more atlantic to more continental climate. A



Tab. 1: Various schemes outlining periods of eolian activity in the north Central European Lowland, arranged from west to east.


Dylikowa
(1969)
Manikowska
(1991b)
(1995)
(1998)
Schirmer
(1999)
Chrono-
stratigraphy
14C years
Dune destruction phase
Dune transformation phase
Dune-forming phase
Initial phase
VI
V
IV
III
II
I
Eolian stages
III
II
I
V
IV
III
II
I
6
Man triggered dune period
5
Little dune-transformation period
4
Dune and dune transformation period
3
Dune period
2
Eolian coversand period
1
Fluvio-eolian period
Holocene
10,000
Late Glacial
12,700
Upper Pleniglacial

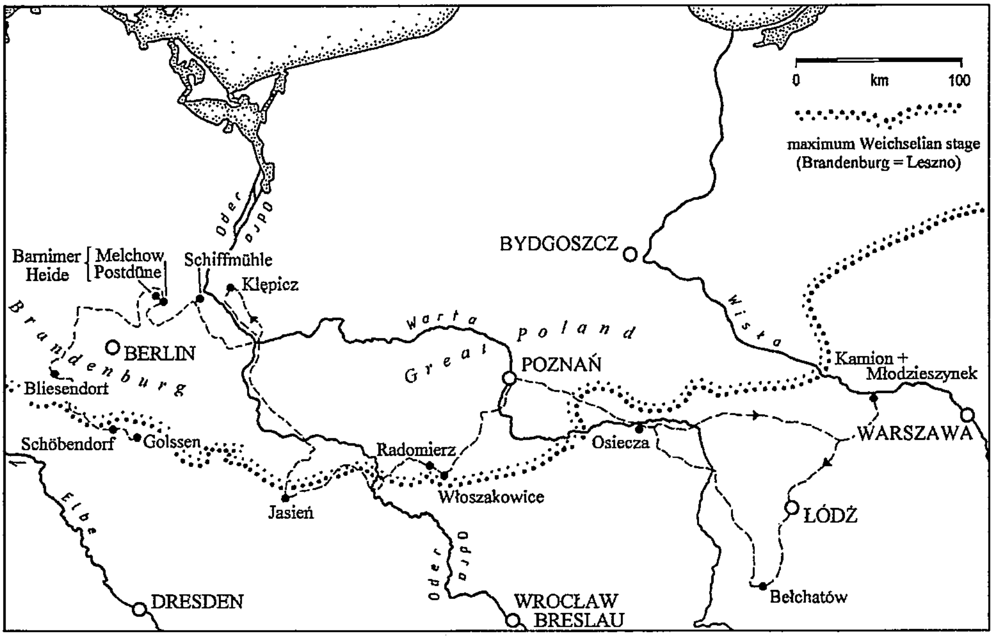


Fig. 1: Location map and route of the field symposium „Dunes and fossil soils of Vistulian and Holocene age between Elbe and Wisła" August 24 to 28, 1998.

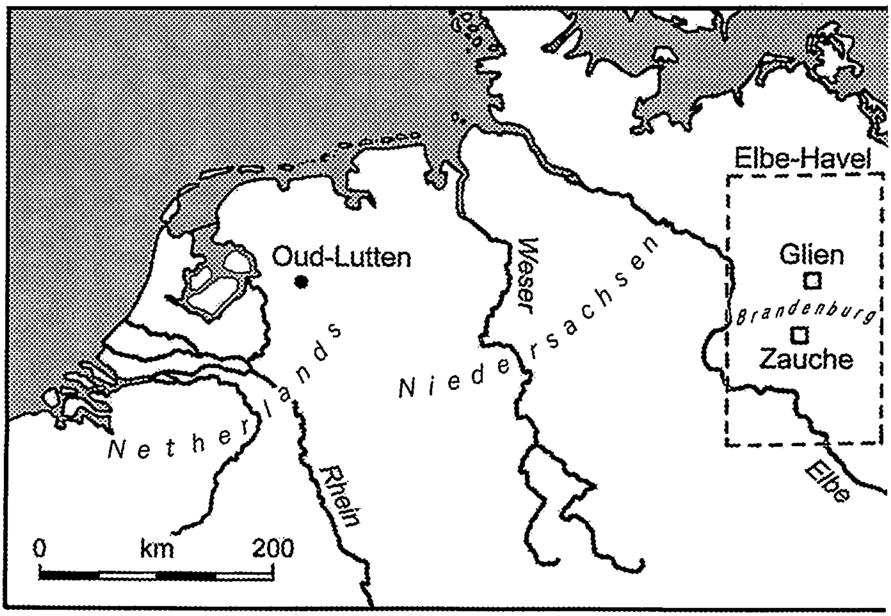
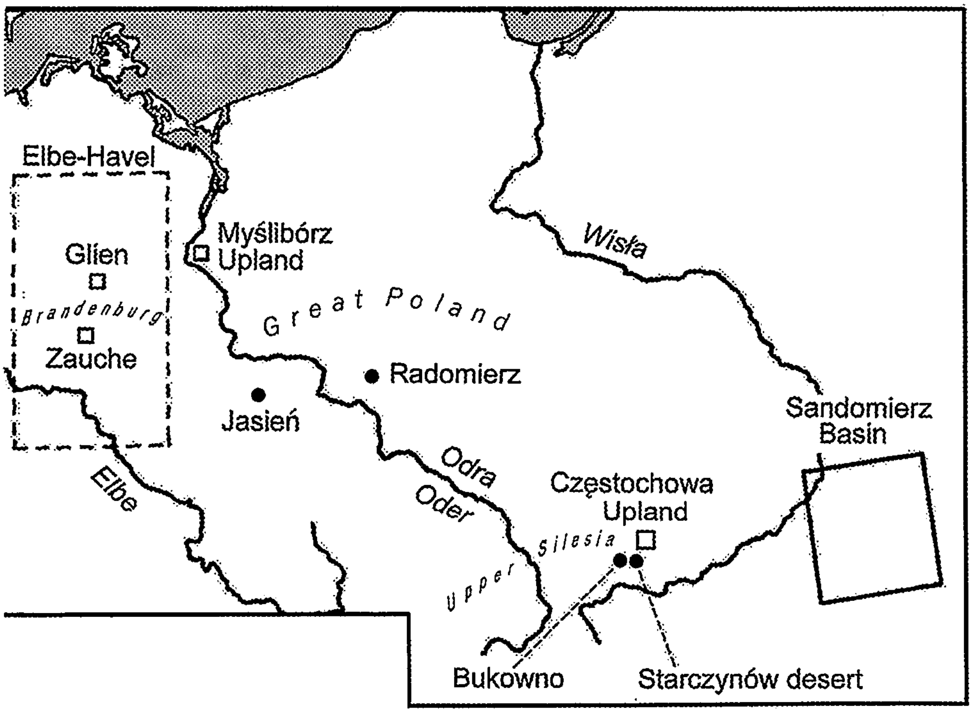


Fig. 2: Location map of the places and areas presented in this Proceedings Volume.

certain differentiation in age from south to north is due to the rejuvenation of the landscape following the northward melting ice. Moreover, some of the investigated varieties may be due to differences in specialization of regional research.

The oldest eolian activity[1] documented in this area are sand wedge fills of late Saalian age. In Bełchatów in middle Poland (Fig. 1) they cut Warthian till (Goździk 1998). From the Eemian through Middle Weichselian (Fig. 3) there is a gap of records of eolian activity concerning sand transport. Yet, as eolian activity is documented through the Upper Pleni-Weichselian glaciation period (UWG), comparable activity can be assumed for the Lower Pleni-Weichselian cold period (MWG 1 or MIS 4[2]), too. The lack of eolian documentation may be due to the loose consistence of eolian sand deposits, easily erodable by solifluction, delution[3] and wind.

The later Middle Weichselian period (MIS 3) is characterized by a vivid alternation of interstadials and short stadial periods in-between (Fig. 3). It should likewise have produced eolian sand. Then climatic conditions close to that of the early Late Glacial should have existed. However, deposits of the Middle Weichselian period are scarsely preserved at all due to immense erosion during the following Upper Pleni-Weichselian period with the last glacial maximum.



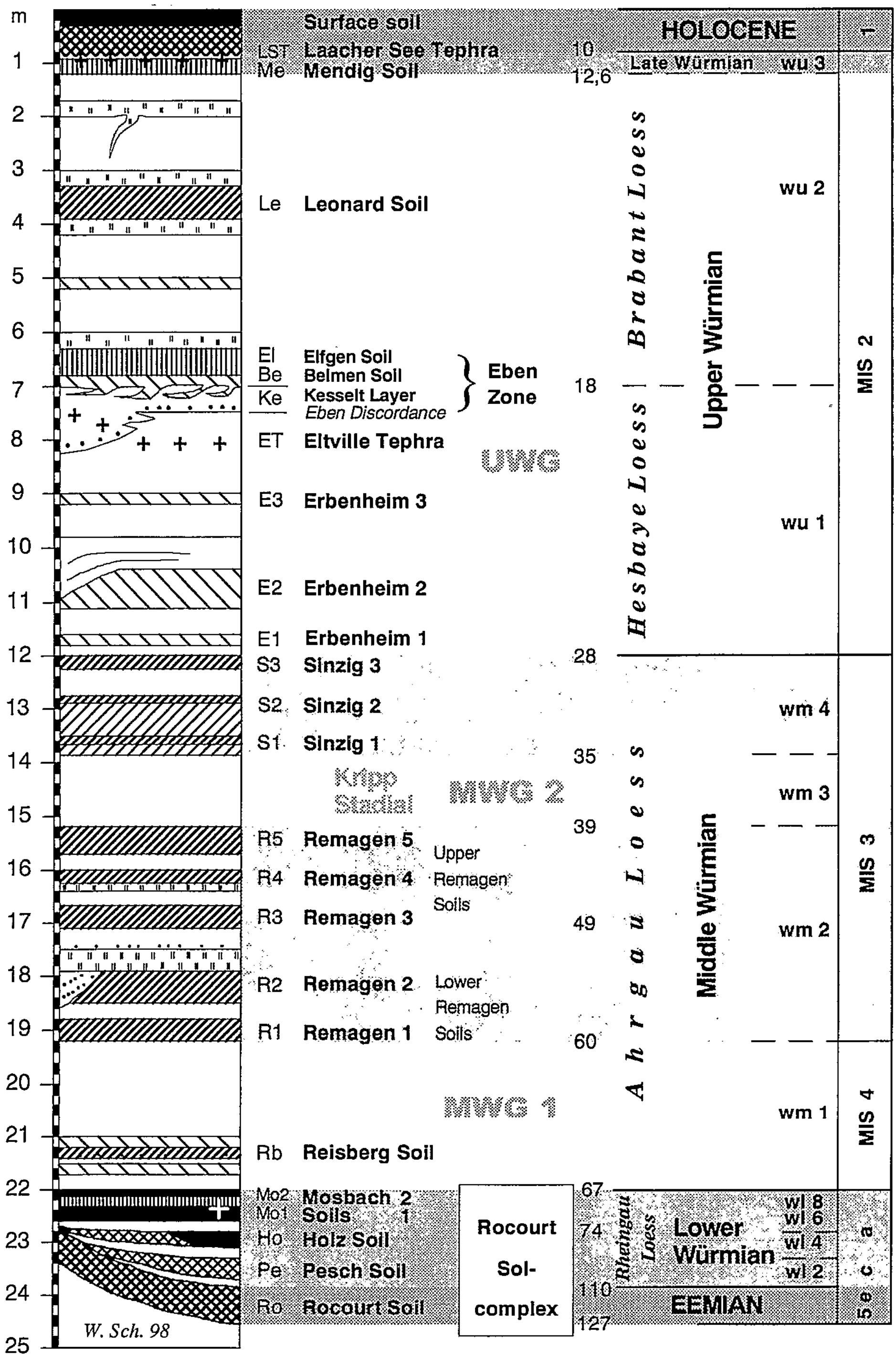


Fig. 3: Last Glacial Rhein loess sequence (from SCHIRMER 1999b).

1. Eolian activity periods since the Upper Weichselian

The eolian deposits recorded up till now range in age from the boundary Middle Weichselian/ Upper Weichselian up till recent times, starting with about 30,000 years BP.

The main objectives presented during the dune symposium and in this Proceedings Volume are gathered in Fig. 4. According to these results the eolian deposits can be grouped into six eolian activity periods with individual characteristics (Tab. 1).[4] To each of the six eolian periods outlined below, a short item is attributed that marks a typical, although not exclusive, feature of that period.

Period 1: Fluvio-eolian period (28,000–~14,000 a BP)

Period with much deflation, sand deposition as niveo-eolian and fluvio-eolian accumulation, thin-bedded as well as homogenous fine, silty sand and cold-climate indicators.

The period around the Last Glacial Maximum (LGM) is thought to be a period of strong wind activity that produced mainly deflation (abrasion). Consequently gravel and ventifact horizons forming residual deposits are assigned to the LGM, e. g. the Beuningen Gravel Bed of The Netherlands (cf. Kasse 1999) and the ventifact horizons described by Dücker & Maarleveld (1957), de Boer (1995), Schlaak (1999), Kozarski & Nowaczyk (1991), Antczak-Górka (1998, 1999) and Manikowska (1995: 134). It is generally assumed that the topsoil was under continuous permafrost conditions while being deflated. Several records of ice wedge casts of this period (Fig. 4 and Böse 1991) support this opinion.

The deflation produced eolian coversand that locally was transformed into thin-bedded niveo-eolian sand layers. Runoff transformed them into thin-bedded fluvio-eolian layers or thicker-bedded deluvial[5] sand layers. All mentioned sediment types give evidence of their primary eolian origin by the grain-size and well sorting of the sand and matted surface of the quartz grains. According to Manikowska (1995: 132) this abrasion period supplied the braided river beds of that time with sand to a high degree. It corresponds to the fact that the Maxiwürm Terrace of the Central European rivers is topped by a rather sandy and less silty flood sediment (Schirmer 1995a: 37).

A proper sediment trap during deflation periods are frost wedges. Thus the eolian activity is also documented as infill of sand wedges (Blume & Hoffmann 1977, Manikowska 1995: 133, Goździk 1998, Kasprzak 1998). In rare cases little dunes are recorded from eastern Poland where they occur as independent dunes (Wojtanowicz 1999). De Boer (1995: 118) gives record of longitudinal dune complexes that parallel meltwater drains of Urstromtäler between the Brandenburg and Frankfurt glacier stages. On the other hand mere abrasion prevailed in middle Poland (Manikowska 1995: 135).

The sand deposit is generally finer than the following younger eolian sand layers and is marked by a high silt content. The silt content often occurs in laminae (Kasse 1999). de

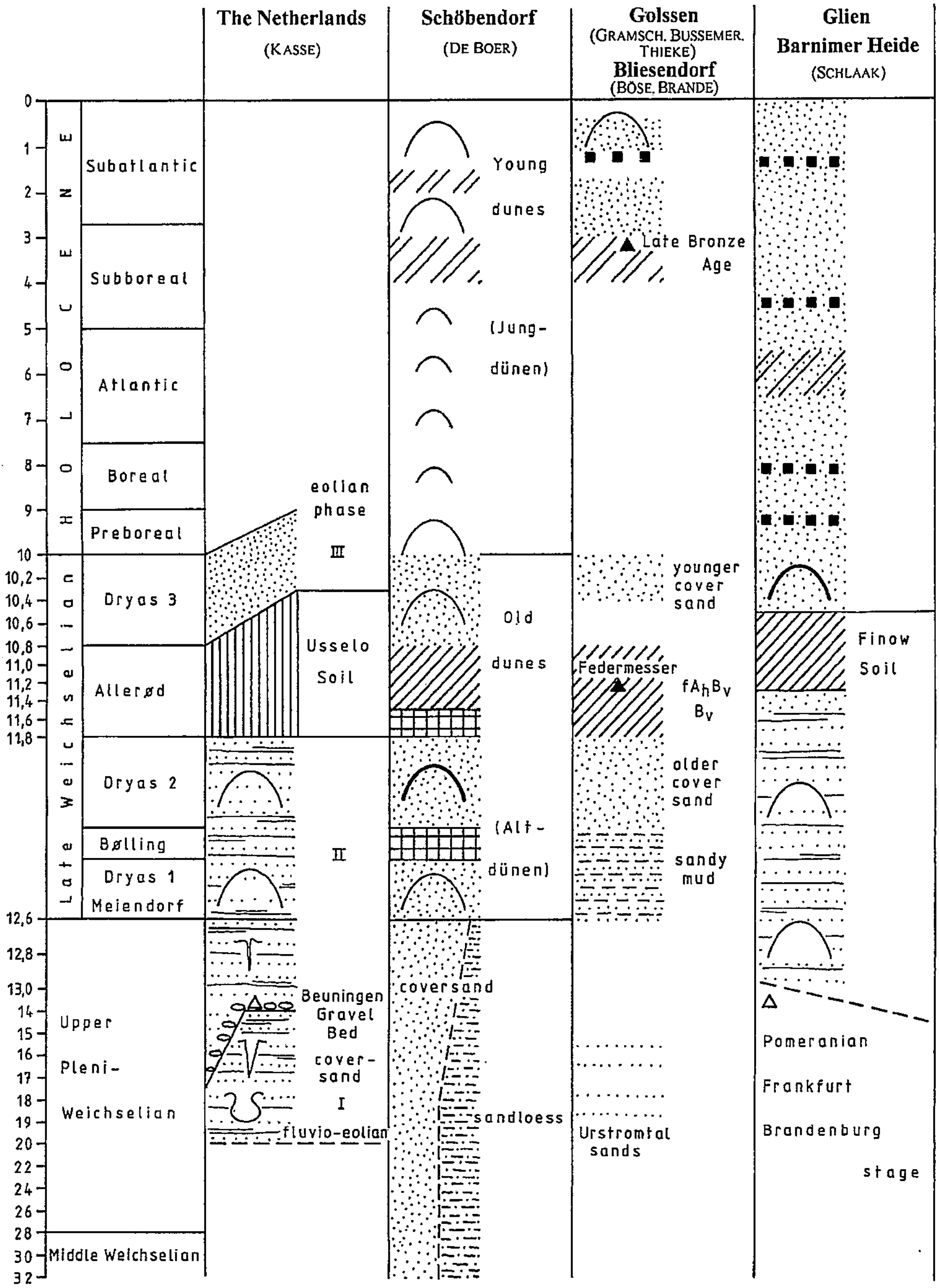
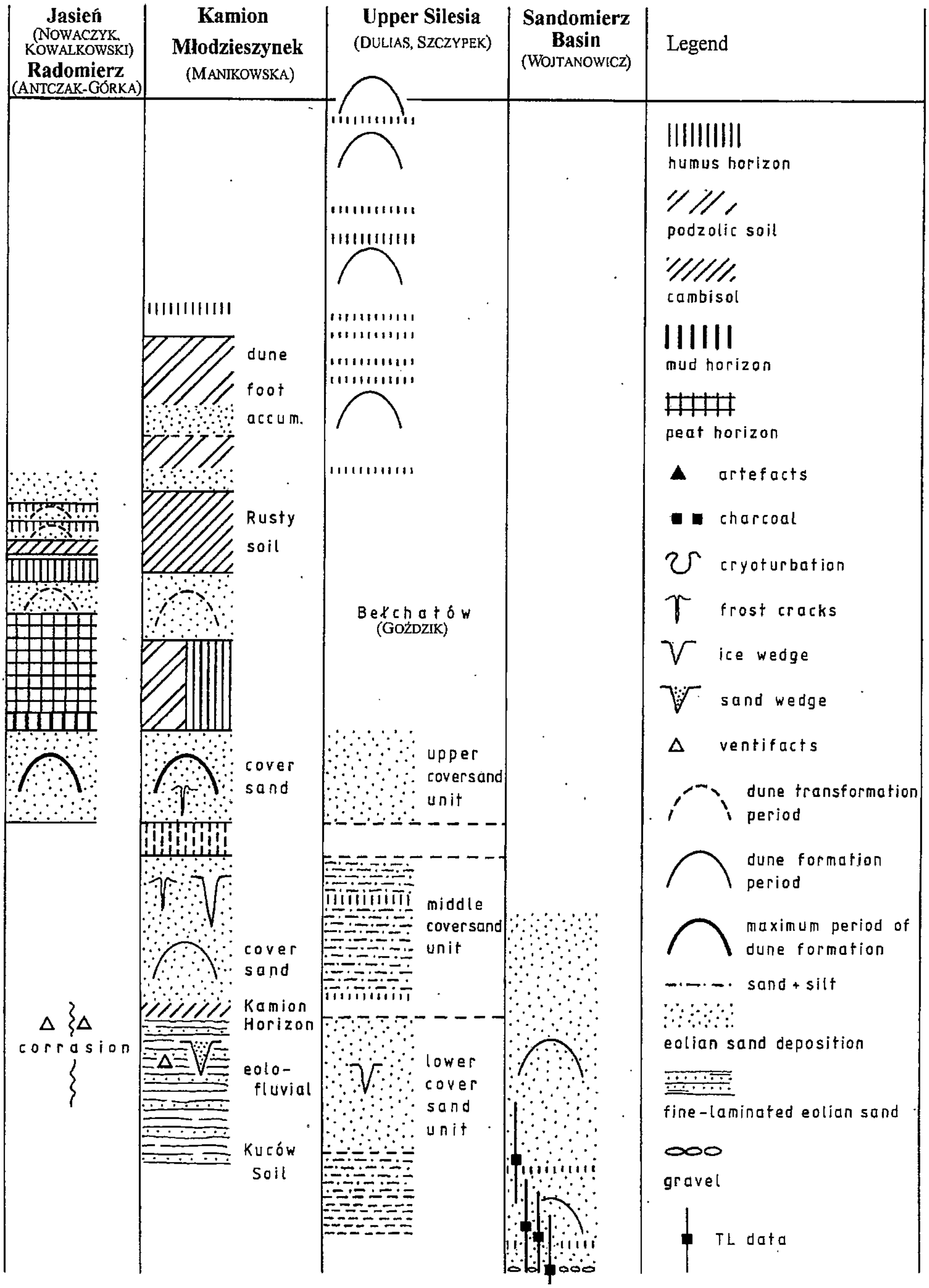


Fig. 4: Correlation of eolian sand deposits and fossil soils in the north Central European Lowland presented during the Dune Symposium and in this Proceedings Volume arranged from west to east.


Jasień
(NOWACZYK, KOWALKOWSKI)
Radomierz
(ANTCZAK-GÓRKA)
Kamion
Młodzieszynek
(MANIKOWSKA)
Upper Silesia
(DULIAS, SZCZYPEK)
Sandomierz
Basin
(WOJTANOWICZ)
Legend
dune
foot
accum.
Rusty
soil
cover
sand
cover
sand
Kamion
Horizon
eolo-
fluvial
Kuców
Soil
corrasion
Bełchatów
(GOŹDZIK)
upper
coversand
unit
middle
coversand
unit
lower
cover
sand
unit
humus horizon
podzolic soil
cambisol
mud horizon
peat horizon
artefacts
charcoal
cryoturbation
frost cracks
ice wedge
sand wedge
ventifacts
dune transformation period
dune formation period
maximum period of dune formation
sand + silt
eolian sand deposition
fine-laminated eolian sand
gravel
TL data

BOER (1995, 1998) gives record of sandloess[6], an eolian facies that mediates between loess and eolian sand. KASSE (1999) notes as characteristics for this period concave lenses of coarse sand, small-scale current ripple lamination and clayey-silty drapes, frequent cryogenic structures as cryoturbations and vertical platy structures.

WOJTANOWICZ (1999) presents TL ages of an eastern Polish dune embracing the time span between 32 ± 5.4 and 22 ± 3.7 ka BP — thus giving the oldest ages of eolian activity in the north Central European Lowland up till now. His sand sequence is interrupted by two interstadial soils, the older one at about 29 ka, the younger one at about 22 ka according to TL data of overlying sand. The latter may correspond to the Kuców Soil, a tundra soil of 21,200 ± 220 a BP and 21,970 ± 810 a BP noted by MANIKOWSKA (1998: 97 = 1995: Tab. 1). WOJTANOWICZ (1999) connects the two soils with the Dutch Hengelo and Denekamp interstadials. In case their ages are correct, only the lower one is of late Middle Weichselian age and may be connected with the Denekamp Interstadial respectively with one of the Sinzig interstadial soils of the Rhein loess sequence (Fig. 3). The younger soil is of Upper Weichselian age and cannot be connected with a Middle Weichselian interstadial. However the Rhein loess sequence shows that the Upper Weichselian period likewise encompasses several interstadial soils to be connected with. Unfortunately reliable absolute dates of these soils are absent up till now.

The fluvio-eolian sequence of the eolian period 1 ends up in a non-deposition period at about 14.5 ka BP. In The Netherlands this time is marked by the end of the residual Beuningen Gravel Bed. In Middle Poland it is marked by the Kamion Horizon ^{14}C dated to 14,500–14,000 a BP (cf. Chapter 3).

Period 2: Eolian coversand period (~14,000–12,200 a BP)

Period producing flat and widespread sand veneers with small dunes, silty sand and small frost indicators.

During this period coversand prevails besides little dunes. The sand relief remains generally low. MANIKOWSKA (1995: 144) describes a dune hillock up to 4 m high covered by a Bølling soil. DE BOER (1995: 119) reports of pre-Bølling dune cores. On the other hand BÖSE (1991: 21) considers the Oldest Dryas to be the time of main dune formation in the Berlin area. She explains the start of the dune formation as consequence of the dissipation of permafrost and the lack of fluvial and melt water in the Urstromtäler. DE BOER (1995: 106) combines the beginning of bow-shaped dunes during this period with the start of scattered vegetation. On the other hand it could be demonstrated (e. g. WALTER 1951, STENGEL 1992) that bow-shaped dunes form in barren landscapes, too, depending from gustiness of wind, from mechanical cluster formation and electrostatic attraction and repulsion of electrically charged sand grains. In addition there are examples that plant growth is able to promote dune formation (e. g. WALTER 1951, SCHELLING 1957, MEYER 1984). Within the course of period 2 the augmentation of vegetational growth should have started with the Meiendorf Interstadial (cf. U. SCHIRMER 1999). It follows that hence formation of dune forms should increase.

The fine-bedded fluvio-eolian character of the coversand decreases from west towards east. The eolian sand is still rich in silt. MANIKOWSKA (1995: 144) records up to 40 % silt that can occur as silty laminae.[7] In the west KASSE (1999) notes this period being the „most prominent phase of eolian deposition" and being the feeder for many later eolian sand reactivations. Cold-climate indicators are generally smaller than that of period 1. MANIKOWSKA (1991b: 134) notes numerous frost fissure polygons with primary sand infill.

The period ends up in the quiescence phase of the Bølling Interstadial. This interstadial is rarely represented, in Schöbendorf south of Berlin by a very weak peat (DE BOER 1995: 118) and in Kamion by an initial A horizon (MANIKOWSKA 1991a: 138), a small organic horizon dated to 12,235 a BP. KASSE (1999) explains the general lack of Bølling deposits by a scattered vegetation cover allowing the eolian work to continue.

As the Bølling Interstadial generally was a warm but short phase it is argued that vegetation encroached the European sand belt but left only a small humic cover as that of the Kamion site. This thin cover may have been widely abraded by the quickly succeeding dune period 3.

Period 3: Dune period (Dryas 2: 12,200–11,800 a BP)

First major dune period besides coversand deposition.

From the Fläming towards east, in some areas this period is suggested being the main dune phase of the inland dunes (DE BOER 1995: 117, MANIKOWSKA 1991a: 143). MANIKOWSKA (1995: 145) gives record of a parabolic dune of that age up to 15 m high and 5,000 m long. In addition, coversand goes on being produced.[8] In The Netherlands (KASSE 1999) and north of Berlin (SCHLAAK 1999) a certain amount of last fluvio-eolian activity is recorded visible by a local alternation of sand and silt laminae. Permafrost seems to have dissipated.

Whether this period is to be separated from period 2 or not is questionable. KASSE (1999) brackets period 2 and 3 (Tab. 1). As the weak soil of the Bølling Interstadial has only been found in few localities KASSE argues that observations attributed to this period 3 should often also comprise period 2. On the other hand, at those localities where the Bølling soil horizon was found, period 3 was recognized being the period of main dune formation. Thus augmentation of research on this period is needed.

This period ends up in the long quiescence phase of the Allerød Interstadial during which forest vegetation fixed the dune surface. As consequence in all areas there occur fossil soils of the Allerød period (see Chapter 3).

Presence of Palaeolithic man on coversand is recorded by GRAMSCH (1998) (see Appendix 2).

Period 4: Dune and dune transformation period (Dryas 3 and early Preboreal: 10,800–9,500 a BP)

Period of mainly dune transformation besides formation of new dunes, also river dunes.

This period seems to be a great dune period in the western part of the sand belt more than in its eastern part. Forming of new dunes is recorded from The Netherlands in the west through Great Poland in the east (KASSE 1999, SCHLAAK 1993, DE BOER 1995, KOZARSKI 1978). In The Netherlands and the German Niederrhein area it is a conspicuous dune phase of river dunes (see Appendix 3). In some areas this period is even recognized being the period of main dune formation, e. g. north of Berlin (SCHLAAK 1999). In the area west of Poznań KOZARSKI & NOWACZYK (1991: 118) state the Dryas 3 to be the main period of dune as well as coversand formation. Besides new dune formation older dunes were reactivated and/or transformed. On the other hand in middle and eastern Poland dune transformation activity is recorded only. After MANIKOWSKA (1995: 141) new dune forms dating to Dryas 3 have not been found in middle Poland so far.

Cold climate indicators seem to be very rare in eolian sand of this period. BÖSE (1991: 24) gives record of frost fissures.

After the Allerød period the eolian activity started as late as middle Dryas 3 and continued through the first part of the Preboreal period (NOWACZYK & ROTNICKI 1972[9], SCHLAAK 1997, NOWACZYK 1998a, KASSE 1999). Likewise KOZARSKI & NOWACZYK (1991) give 9,700 a BP for the extinction of eolian deposits.

Eolian period 4 ends up in the Holocene soil formation. Sometimes this period is the very end of the dune activity. In case of further dune activity the Holocene soil is split into short soil formation periods (see Chapter 3).

Period 5: Little dune transformation period (Preboreal – early Atlantic)

Period of quiescence with thick brown and podzolic soils, with local and little dune transformation.

This period is dominated by the formation of the Holocene soil on top of the dunes, mostly as brown cambic soil. Locally the dune slope and dune toe areas are subject to eolian reactivation of the dune sand. Several humic horizons and charcoal horizons interbed with eolian sand. A certainly rare case is that of Upper Silesia where DULIAS (1999) gives record of newly formed dunes during the early Atlantic period. MANIKOWSKA (1995: 143) records an intermittent iron podzolic soil of Boreal age. On the other hand in many areas the first eolian activity after period 4 is chronicled not earlier than period 6 thus indicating period 5 being a mere standstill phase of eolian activity.

Eolian period 5 ends up in a podzolic soil of Atlantic to Subboreal age. MANIKOWSKA (1995: 143) gives record of an iron-humus podzol of Atlantic age. Likewise a podzolic soil of this age is recorded by SCHLAAK (1999). In case of the Silesian dunes (DULIAS 1999) this soil position is represented by a bundle of humic soils indicating that here strong eolian activity gave only short pauses of interruption for vegetational recover and soil formation.

For this eolian period the question arises what triggers the clearing of vegetation and allows the revival of eolian activity. Most of the authors suggest that natural forest fires gave rise to vegetation clearence. However, it should be taken into account that also Mesolithic gatherers and hunters took advantage from promoting forest fires. Clearence areas within a forest give rise for augmentation of special shrubs and herbs and attract animals, thus making hunting easier.

Period 6: Man-triggered dune period (mid-Atlantic to recent times) ·

Period of predominant soil formation as arenosols (regosols) and podzols on vegetated dunes, scattered human forest clearing and consequent dune transformation.

Besides places where the Holocene soil developed from the early Holocene up till now without interference, there occurs pretty often eolian sand reactivation in places where the vegetational cover has been cleared. It starts with the Neolithic settlement during the Atlantic period (e. g. KOZARSKI & NOWACZYK 1991: 119, SCHLAAK 1999). A first cumulation of sand reactivation occurs during the Bronze Age (Lusatian Culture) (KOZARSKI & NOWACZYK 1991: 119). Later transformations of eolian sand areas are due to the local history of human settlement or single human activites as forest clearence, plaggen manuring or sand exploitation: Clustering of eolian sand reactivation is recorded from eastern Germany and western Poland during the Slavonic period of forest clearence in the early Middle Ages (SCHLAAK 1998: 31), from Brandenburg during the second half of the 12th century triggered by land clearence (BRANDE et al. 1999) and from Niedersachsen during 1770–1850 AD caused by heath cultivation (MEYER 1984). In some cases new dunes arose as in abandoned sand excavation areas (SZCZYPEK & WACH 1999) or in military training places. There is nearly no eolian sand area without dense clustering of younger Holocene fossil soils (see NOWACZYK 1998b; DULIAS 1999 in Fig. 4). The increase of dune revival events towards recent times is due to augmentation of historical records. The quiescence periods in-between are represented by podzolic or humic soils and/or charcoal horizons.

This period of inland dune transformation or in rare cases also of new dune formation is exclusively bound to man's land clearence activity.

2. Sand properties

Though publications on the European sand belt show a lot of grain-size data of eolian sand, there is no comprehensive study on the grain-size variety in space and time so far. One problem is that lateral short-distance grain-size variation (e. g. WALTER 1951, STENGEL 1992) and vertical stratigraphical variation can equal in dimension. Consequently, grain-size data produced from vertical sections can only roughly be evaluated.

Authors agree that during period 1 through 3 the eolian sand is richer in silt than later.

Their data show that the mean values of grain-size in general are gradually increasing from Pleni-Weichselian towards Holocene. It is a clear loess component that accompanies the sand during the Pleistocene, more or less alternating with the sand by thin layers, or homogeneously incorporated into the sand. This is due to the fact that prior to the Allerød period eolian sand has been deflated from a landscape nearly unvegetated or scantily vegetated. Hence all grain-sizes were offered to be deflated. This contrasts to the Holocene period. Then sand reactivation is concentrated to preexisting eolian sand fields. By its renewed deflation the silt content is more and more separated from the saltational transport that causes the new sand body. Supply of fresh silt is cut off by the vegetational cover. Consequently, from the Late Glacial on, the more frequent the sand is reworked by the wind the poorer it gets in silt.

This is an essential prerequisite for the soil formation and one reason for the change from cambisol on Pleistocene eolian sand to podzol on Holocene eolian sand.

3. Soil formation in the European sand belt

The formation of the fossil and recent soils in eolian sand is one of the most interesting and most controversially disputed point of soil formation. On the other hand typical soils once calibrated are often the best indicators to date the underlying sand deposits.

3. 1 The controversies

The main point of controversy is due to the great pore volume of eolian sand which makes it difficult to state whether soil forming processes in a field section happened successively or simultaneously. A typical example for this fundamental discussion during the field symposium was that at the Radomierz site southwest of Poznań (Fig. 1) presented by BARBARA ANTCZAK-GÓRKA (1998, 1999).

At this site the Leszno (Brandenburg) Till Plain is buried 1.8 m below the surface and is overlain by a 0.3 m thick fossil deflation pavement the entire clast population of which comes up to 64 % of ventifacts. This residual layer is overlain up to the surface by an eolian coversand of 1.5 m thickness (inclusive a basal 20 cm thick transitional bed of medium sand with rare small pebbles).

The following soil horizons (not mentioned by ANTCZAK-GÓRKA) were noted during the symposium field visit (Fig. 5):

Ah	0.3 m coversand
Bv	1.0 m coversand
Sw	0.5 m transitional and residual layer
Bt	till

The following possible explanations were discussed in the field:

1. The soil is a so-called Fahlerde formed during one single soil forming action. The porous eolian coversand allows the formation of a brown weathered cambisol horizon

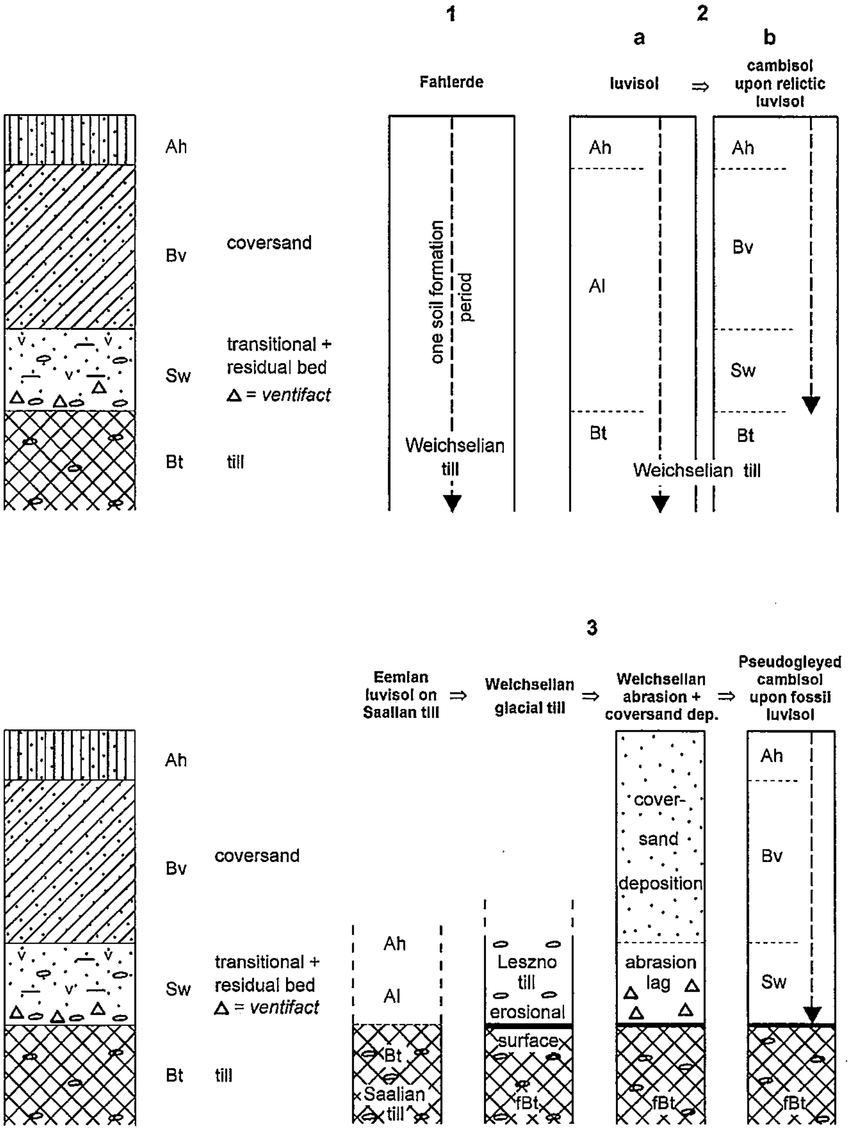


Fig. 5: Three possibilities to explain the soil formation within the Weichselian coversand overlying boulder clay by the example of the Radomierz Site.

(Bv), the underlying till causes damming of water that forms the bleached horizon (Sw). The solid till rich in silt and clay forms an illuvial horizon (Bt). This soil formed since the Late Weichselian.

2. The soil formation embraces two processes: a. Formation of a luvisol in the course of which the coversand acted as lessivé horizon (Al), the till as illuvial horizon (Bt). b. Later soil formation transformed the Al into a cambisol (Bv). Thus the studied soil

belongs to two different soil forming processes acting since the Late Weichselian.

3. A possible and quite different explanation was mine. The Bt horizon is — due to its strong development — a fossil Eem soil upon Saalian till. The Bv horizon is the Late Glacial–Holocene soil on Weichselian coversand. The residual layer is the only remnant of the Leszno till highly deflated and transformed into the ventifact horizon. The Bt horizon on top of the till caused stagnation of water (Sw horizon) since the deposition of the cover bed. Thus the studied soil belongs to two different interglacial periods, the basal luvisol to the Eemian, the topping cambisol (Pseudogley-Braunerde) to the Late Glacial/Holocene period.

ad 1. This explanation is suggested by KOPP (1970) to be the normal soil formation process in periglacial coverbeds.

ad 2. In northern Central Europe this idea is mainly promoted by ROESCHMANN (1994); however, he considers the age of the soil formation to belong to the Holocene only, not to the Late Glacial.

ad 3. This explanation would fit to many observations in Brandenburg, where the main corpus of the till plains turned out to be formed during the Saalian glaciation period, and the inland ice of the Brandenburg stage left only a small cover of deposits on top of the Saalian sedimentary body (MARCINEK et al. 1983: 16). Likewise in the northern Alpine foreland the maximum Würmian glaciation is suggested to have caused only little morphological transformation activity and left only a thin depositional cover (ELLWANGER, pers. communication).

3.2 Soil development in dunes since the Last Glacial retreat

Generally each standstill of morphological activity is marked by a certain soil formation. Successively during periods of high morphological activity those traces are mostly destroyed. However, there are some rare and very early records of fossil soils.

Kamion Horizon (MANIKOWSKA 1991a: 146, 1995: 130)

MANIKOWSKA (1991a: 138) records a decalcified brown alluvial soil formed on top of a 2 m thick flood deposit that veneers the Otwock Terrace of the river Wisła. The soil is covered by a 8 m thick dune sand. The soil consists of a 10 cm thick silty-clayey humic top soil. The underlying subsoil of 50 cm forms a sandy-silty deposit with iron oxide enrichment, homogenization and decalcification. The humus provided ^{14}C ages of 14,590 ± 270 a BP, 14,300 ± 300 a BP and 13,500 ± 290 a BP (the latter age for humic acids).

Consequently the Kamion Horizon is a floodplain soil preserved by the shelter of dune sand in a very early stage of the Weichselian ice retreat. MANIKOWSKA correlates the Kamion Horizon with the Epe Horizon (KOLSTRUP 1980: 227) from the eastern Netherlands. Perhaps correlation is possible with the Leonard Soil, the youngest fossil soil within the Rhein loess sequence (Fig. 3) (see Appendix 4).

Bølling Soil

The weak peat observed by DE BOER (1995: 118) in Schöbendorf south of Berlin forms the fluvial base of a dune field and is — like the Kamion Horizon — not an inner dune soil. The only inner-dune soil of Bølling age hence published is that from the Kamion dune field (MANIKOWSKA 1991a: 138). On top of dune sand preserved up to 1.5 m thickness, an initial A horizon was developed consisting of „one or two very thin, 0.5–1.5 cm, layers of organic material" ^{14}C dated to 12,235 ± 260 a BP. The soil has been buried by a 10 m high dune.[10]

Allerød Soil

There is nearly no dune area not documented by an Allerødian soil. Thus it is not the presence of an Allerød soil that is surprising but its varying soil type.

A humic horizon (A horizon) is recorded from The Netherlands and adjacent westernmost Germany (as Usselo horizon, HYSZELER 1947) as well as from Brandenburg (DE BOER 1995: 119) and Młodzieszynek (Fig. 1) close to Warszawa (MANIKOWSKA 1998). In the latter area the Allerød soil often is transformed into a humic soil sediment thus marking the interstadial position by one or several soil sediment layers. The immaturity of the soil of that area may be due to little eolian activity of intra-Allerødian age.

In other places of the same area the Allerød soil is represented as a weak podzolic soil (MANIKOWSKA 1995: 131).

A cambisol is recorded from Brandenburg north of Berlin as Finow Soil (SCHLAAK 1993: 79). Likewise it occurs south of Berlin (BUSSEMER 1998 and BUSSEMER & THIEKE 1998; see Appendix 2). The Finow Soil (SCHLAAK 1993, 1997, 1998, 1999) occurs both lying on glaciofluvial deposits and on eolian older coversand up to 5 m in thickness. Thus its morphology is mostly even to undulated (SCHLAAK 1998: 30). It is a 5–15 cm thick brownish soil, a dystric cambisol. It lacks a humus horizon. Destratification reaches down to 15 cm depth below the soil. The soil has an increased share of pelite mostly in favour of the coarse silt and clay fraction, that is higher in the upper part than in the lower part of the soil. It shows new smectite formation and enrichment of Al and Fe in comparison to its parent rock.

Laterally towards depressions the Finow Soil corresponds to a series of sand-peat layers dating from 11,400 to 10,130 a BP, in its lower part embracing the Laacher See tephra. Charcoal remnants from the soil yielded ^{14}C ages between 11,330 and 10,290 a BP. SCHLAAK (1998: 28) estimates the soil to comprise about 1,200 years ranging from the Allerød Interstadial into the Dryas 3 period (SCHLAAK 1999). JÄGER & KOPP (1999) record a lateral transition from an Allerødian peat into a gleyic gelisol.

Likewise peat (NOWACZYK 1998a, MANIKOWSKA 1995: 131) or a peaty gleyic soil (KOWALKOWSKI et al. 1999) formed in other areas in depressions on top of eolian sand. The peaty gleyic soil yielded ^{14}C ages between 10,879 ± 210 and 10,200 ± 210.[11]

Dryas 3 (Younger Dryas) soil formation ?

In the section of Werneuchen 1 situated 30 km northeast of Berlin in close extramarginal position to the Frankfurt glacier stage, BUSSEMER (1998: 34) describes an ice wedge that vertically cuts a fossil soil. The parent sand below the fossil soil yielded a TL age of 9.6 ± 1.3 ka, the sand fill of the ice-wedge a TL age of 11.3 ± 2.1 ka BP. Both the fossil soil and the ice wedge are horizontally cut by 1.5 m thick eolian sand of young Holocene age. Based on the TL ages BUSSEMER concludes an intra-Dryas 3 age of the fossil soil.

The story of the earth always provides us with surprises, even in earth science. However, a dating method in state of being newly tested should not be applied to produce new revelations of the earth history. Considering the thousands of carefully studied pollen profiles of the Dryas 3 period that show a clear decline and incline of the climate we should be cautious to change well proved results by means of two TL data. The fossil soil may also be an equivalent of the Finow Soil or might have been caused by pervasion of younger weathering processes from the recent surface through the eolian sand cover rich in pores. Later soil processes would pass through the vertically orientated fill of the ice wedge and settle in the older eolian sand aside the ice wedge that is much richer in silt than the Holocene eolian sand. This at least should be taken into account.

Holocene soil formation

The Holocene soils are the continuation of Late Glacial soil formation in those areas where no or no essential morphological dynamics acted. Therefore Holocene soils in flat areas normally embrace a component of Late Glacial soil formation. In case of a depositional socle of Dryas 3 age it is possible to check the true component of Holocene soil formation. Moreover, in case of intermittent Holocene deposition it is possible to yield distinct time sectors of the Holocene soil formation. These cases are perfectly realized in dune fields.

Older Holocene soil formation (Preboreal to Boreal)

A rusty soil, cambic arenosol, is recorded from Poland developed on top of Dryas 3 dunes and covered by Boreal eolian sand (MANIKOWSKA & BEDNAREK 1994, MANIKOWSKA 1998: 95, KOWALKOWSKI et al. 1999). The rusty soil is dated to Preboreal and early Boreal age. The ^{14}C dates of plant macroremains vary from 9,740 ± 100 to 8,630 ± 140 (MANIKOWSKA & BEDNAREK 1994: 34). It is a Bv horizon enriched in iron and Al oxides. Towards the Boreal period it changed locally into podzolization to form a podzolic-rusty soil. In places this rusty soil survives as relic subsoil for recent podzolic soils.

KOWALKOWSKI et al. (1999) describe the rusty soil of Jasień as 15–20 cm thick evenly rusty coloured horizon without features of pedogenesis in situ. ^{14}C ages between 10,150 ± 80 and 9,870 ± 120 a BP are somewhat older than those of the rusty soil at Kamion. In case they are reliable they would point to earlier cease of eolian sand redeposition.

Besides brown soils there are, of course, also initial humus horizons and arenosols (regosols). These soils appear sporadicly throughout the Holocene eolian sand deposits wherever short pauses between eolian redeposition occur.

It seems that from the Preboreal on chances for eolian sand redeposition are given rather locally being controlled for example by forest fires. Consequently during the older Holocene soil forming processes are the normal. Eolian revival occurs frequently but happens sporadicly in space and time. Thus the ages of the buried soils differ while their soil types conform.

Mid Holocene soil formation (Atlantic to mid Subboreal)

The time of close forestation in Europe is certainly equivalent to the time of lowest eolian revival of sand transport. Consequently thick soils are developed on eolian sand until human interference cleared the vegetation. The change from cambisol to podzolic soils recorded by MANIKOWSKA for the Boreal period spreads obviously widely over the European sand belt. This change is known since JÄGER & KOPP (1969). Though some of the Bv horizons survived far into the later Holocene as relic horizons (e. g. MANIKOWSKA & BEDNAREK 1994: 37) the soil formation on eolian sand of this period is the podzolic soil.

This change in soil type is — as mentioned in Chapter 2 — due to tapering of the pelite content of the eolian sand towards the Holocene. For the pelite content is an essential prerequisite for the formation of a Bv horizon. MANIKOWSKA & BEDNAREK suggest that the brown soil grew under scattered trees (pine with birch and willow), rich grass vegetation and relatively dry climate. The threshold via podzolization was given by the change to a denser forest with less grass accompanied by a more humid climate. Furthermore it was promoted by the proceding decline of basic cations in the parent rock.

Dune pervasion by soil formation

The process of pervasion of eolian sand by soil formation has hardly been regarded so far. As mentioned above the Holocene eolian sand is poor in pelite content. This implies only little weathering capacity of the Holocene eolian sand and it perfectly invites rain water to pervade downdune. By downward arriving at the Pleistocene eolian sand that is richer in pelite, the pervading rain water finds a substratum proper for weathering. A good example for this process is the pervasion of the Laacher See pumice in the Mittelrhein Basin. At the base of this pumice weathering transforms the Allerødian calcaric regosol into a cambisol during Holocene times (SCHIRMER & IKINGER 1995, IKINGER 1996). Likewise in dunes with similar large porosity pervasion of weathering should be taken into account. A good deal of brown cambisol formation underneath the Holocene eolian sand may result from succeeding pervasion processes. Sometimes this pervasion leaves traces visible as small subhorizontal, undulating small brown streaks and bands — a well known feature likewise mentioned by KOWALKOWSKI et al. (1999: ch. 5).

4. The European sand belt in space and time

In central Europe a west–east extending loess belt covers the upland area with its basins. Adjoining to the north a likewise west–east extending sand belt covers the north Central European lowland forming the European sand belt. Within this sand belt there is an augmentation of dune formation from west towards east.

Both belts, the loess and the sand belt, interfinger. The loess belt encroaches the adjacent northern lowland forming a seam at its southern rim with interfingering of silt and sand. Within this rim the youngest loesses of Late Pleni-Weichselian age alternate with eolian sand (GEHRT 1998). In addition within the sand belt there occur patches of loess or sandloess e. g. along the Lower Rhein (SIEBERTZ 1992, 1998), in the Münster Basin (RABER & SPEETZEN 1992), in Niedersachsen (VIERHUFF 1967), perhaps in western Poland (ISSMER 1999; see also Appendix 1).

On the other hand within the loess belt there are basins with immense eolian sand activity nourished by different sources. The Regnitz Basin for example is nourished mainly by Keuper sand and fluvial redeposited Keuper sand (HABBE et al. 1981). The Unterfranken Basin is fed by Main river sand (HAGEDORN et al. 1991) exploited from the same Keuper sand area. The Oberrhein Basin is fed by river sand of the Rhein and Main (WALTER 1951). The Pannonian Basin is nourished by alluvial fans and river deposits of the Danube and its tributaries (BORSY 1991).

All in all the upland loess belt and the lowland sand belt are separated both in space and time. The separation in space is based on the availability of loose sand on the one hand and silty debris on the other hand inclusive their possibility to settle without being deflated anew. The separation in time seems to be based on permafrost. Under continuous permafrost in sand areas mostly deflation took place polishing ventifacts by sand and ice crystals and producing eolian coversand. In areas supplied by periglacial silty debris strong winds deflate silt enough from the permafrost surface to form loess blankets. Since the permafrost dissipated and the surface dried, augmented sand deflation could start in sand areas, whilst in areas of silty debris the surface soil becomes more and more wet and solid and starts to be vegetated by grass cover thus preventing deflation. First scattered vegetational appearence in the sand belt augmented the obstacles in the flat landscape and caused wind channels thus giving rise for changing the eolian accumulation forms. The apogee of the dune formation should lie in an optimally balanced period between dissipating of permafrost with onset of first plant growth on the one hand and encroachment of dense vegetation on the scattered vegetated land on the other hand.

Concerning the estimations of the peak of dune formation in different investigation areas the results differ highly (Tab. 2):

Tab. 2: Estimated peak of dune formation in different areas. Eolian activity periods after Tab. 1.

Eolian activity period	Chronostratigraphical age	area	author
4	Dryas 3	north of Berlin	SCHLAAK 1999
		Polish western Pomerania	KOZARSKI & NOWACZYK 1991: 78
3	Dryas 2	south of Berlin	DE BOER 1995: 117
		Wisła river dunes of Kamion	MANIKOWSKA 1991b: 143
2	upper Plenigl.	around Berlin	BÖSE 1991: 21

On the one hand these records certainly reflect the effect of local investigation. On the other hand a certain shift from south to north is visible, too. The oldest dune formation of the European sand belt of 32 ka, recorded from southeastern Poland by WOJTANOWICZ (1999), is a period proir to the glaciation in the northern part of the European sand belt that became ice-free much later to start with dune formation. The summit of eolian activity in the Dryas 3 period is recorded from the area closely extramarginal to the Pomeranian glacier stage that started with ice retreat at about 15 ka.

During the period of dense vegetational cover since Preboreal times only sporadic sand reactivation is possible. It occurs in places of forest burning, caused either naturally or anthropogenically, and in places of human land clearence. However, these sporadic reactivations mostly happen as consequence of the great late Pleni-Weichselian – Late Glacial eolian sand period that provided the large sand masses ready to be deflated anew.

During Pleni-Weichselian and early Late Glacial the periods of eolian activity were much longer than the periods of quiescence in-between. Vice versa from the Allerød period on the periods with denser vegetation were much longer than the periods of eolian activity.

Soil formation within the eolian deposits starts during late Pleni-Weichselian interstadials with AC soils or very faint B horizons. The Finow Soil of Allerødian age presents the first thicker B horizon. The next younger one is the rusty soil of Preboreal age. A possible share of Holocene pervasive soil formation on these brown soils has to be checked. Since the Boreal period the soil development changes to podzolic soils (cf. JÄGER & KOPP 1969) due to changing sand properties, vegetation and climate. During all periods mentioned there were pauses between eolian sand movements short enough to form only arensols (regosols).

Appendix 1

Loess deposits in Polish Western Pomerania

In the midst of the sand belt within the Pomeranian end moraine belt of Polish Western Pomerania there occur silts in small basins and on south slopes within the rolling endmoraine landscape. As KOZARSKI & NOWACZYK (1991) chronicle, BERENDT (1908)[12] described them as glacial deposits, DAMMER (1941) proposed an eolian origin (so-called Flottsand), CEGŁA & KOZARSKI (1976)[13] designate them loess. ISSMER (1998, 1999) provides sedimentological details. The silts occur in a laminated and massive facies. They have to be younger than the underlying Pomeranian Phase and Chojna (resp. Angermünde) Subphase (around 15 ka BP). They exhibit periglacial structures and are covered by flow till. Therefore KOZARSKI & NOWACZYK (1991) and ISSMER (1998, 1999) assign them to the Oldest Dryas before Bølling.

A group of loess patches far beyond the northern limit of the continuous loess belt needs critical proof. High fine-sand share, an average low rate of the typical loess fraction 0,063–0,020 mm, absence of loess molluscs, prevailing bedding of the fine-sandy silts, the field-morphological facies as well as their vertical position within the melt-down phase of the glacial sequence suggest that the eolian nature of these silts is not conclusive. The previously postulated nature as glacial silt perhaps reworked by runoff should be seriously taken into account.

Appendix 2

Fossil soils at the Golssen site

GRAMSCH (1998), BUSSEMER (1998) and BUSSEMER & THIEKE (1998) present a dune area, the site Golssen, south of Berlin (Fig. 1) situated in the Głogów–Baruth Urstromtal. There, the dune area „Gehmlitz" forms a small undulated sand ridge which is a good kilometer long and up to 5 m high. The eolian sand rests upon fluvial sand of a younger level of the Urstromtal, the Younger Baruth Urstromtal.

In a section of 1996 of BUSSEMER (1998) and BUSSEMER & THIEKE (1998) a good meter of eolian coversand is overlying the fluvial sand. The coversand is subdivided by a fossil cambisol with the horizon sequence fAh-AhBv-Bv into an older and younger coversand. According to TL ages the older coversand yielded ages of 14–11 ka BP, the base of the younger coversand an age of 10.7 ± 1.0 ka BP. As consequence the intermittent cambisol should be an equivalent of the Allerødian brown Finow Soil (SCHLAAK 1993: 79).

In another section excavated in 1968 (GRAMSCH 1998) the fossil soil provided artefacts from the Late Palaeolithic Federmesser Culture. Additionally ceramic sherds of Late Bronze age were found within the same strata. GRAMSCH explains the mixture of both cultures in the same strata caused by migration downward from the surface of the fossil cambisol into its B horizon by pedomechanic processes.

However, there remains a contradiction between both groups: After Bussemer (1998) and Bussemer & Thieke (1998) the younger coversand is much older than Bronze Age, after Gramsch (1998: 16) it has been deposited „soon after resp. generally after the Bronze Age". Looking at the description of the sections given by the authors, Bussemer (1998) and Bussemer & Thieke (1998) describe a brown cambisol of the horizon sequence fAh-AhBv-Bv (Braunerde), whereas Gramsch presents a podzol of the horizon sequence fAh-Ae-Bs (actually, in his description of 1998: 13 he notes: „humus horizon (A-horizon) 7–9 cm...eluvial horizon 8–15 cm...brown earth horizon (Bv-horizon)" and calls the soil „sand-brown-podsol").

In a third excavation only presented for the field symposium in August 1998 we saw a single fossil soil as good podzol with the horizon sequence fAh-Ae-Bs. This excavation did not produce artefacts.

Consequently, a strong discussion started during this first stop of the field symposium. Alojzy Kowalkowski mentioned that Braunerde and podzol can occur laterally within the same soil formation, Braunerde in dryer, podzol in wetter positions. In contrast Dietrich Kopp stated that Braunerde is of Late Glacial age, podzol of Holocene age, therein iron-rich podzol of older Holocene age, iron-poor podzol of younger Holocene age. My own statement was the proposal given in Fig. 6 that would clear the discrepancy between the two groups of excavators: Instead of two eolian sand units there might be three in the Gehmlitz dune field, an older Late Glacial one (period 2 after Tab. 1), a younger Late Glacial one (period 3) and a post-Bronze Age one (period 6). They are separated by two fossil soils, the Allerødian Braunerde of Bussemer's excavation and the Holocene podzol in the 1998 excavation. These two fossil soils locally converge to one soil at places where the Dryas 3 dune transformation was not active. The former Braunerde soil changed during the Holocene into a Braunerde-podzol or a podzol. And such a place of convergence of both fossil soils was possibly found in the 1968 excavation of Gramsch. This would explain the coexistence of Late Glacial and Young Holocene artifacts in one and only soil.

A similar soil history has been demonstrated in Bliesendorf southwest of Berlin where the soil formation starting with the Late Glacial was not fossilized earlier than the 12th century by eolian sand (Böse et al. 1998, Brande et al. 1999).

The course of the field excursion led to the Kamion dune field south of Wyszogród where Barbara Manikowska demonstrated that during the Allerød period weak podzols developed. This soil type of Allerødian age seems to be inconsistent with Kopp's statement given above. However, his statement would be right in general, when he allows to vary it in that way, that there is a tendency of soil development since the declining Last Glacial from forming cambisols (Braunerde) during the Allerød and the Preboreal period towards strong iron podzols during the mid Holocene, changing to podzols poorer in iron towards the recent times.

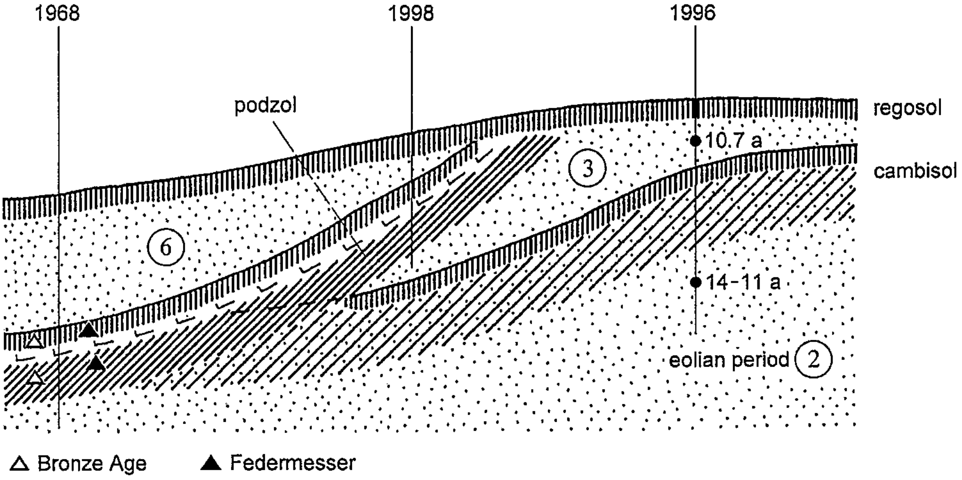


Fig. 6: Gehmlitz sand field close to Golssen south of Berlin. Proposal to clarify the discrepancy in the presentation of three excavations (1968, 1996, 1998).

Appendix 3

Climate of the Dryas 3

During the Dryas 3 (Younger Dryas) period a river terrace was deposited wide-spread in Central Europe, known from many valleys from the Alpine Foreland to the Northern Lowland. It is the Ebing Terrace, likewise called Niederterrasse 3 (SCHIRMER 1983, 1995a). According to cross sections of the terrace body the river pattern changes from meandering to braided. In both cases during the later part of the fluvial activity — whether new deposition or redeposition — the river produced sand plains enough to provide abrasion plains to be deflated. Along the river Rhein the Schönbrunn Terrace — equalling the Pomeranian phase — and the Ebing Terrace itself are crowned by dunes of the Dryas 3 period on both sides of the river. Thus one reason for the cumulation of eolian activity not earlier than in the later part of Dryas 3 is the time necessary to provide sand planes wide enough for large-scale abrasion. In addition another reason, an increased dryness in the second part of Dryas 3 mentioned by KASSE (1999), may be effective. On the other hand there are arguments for the bulk of fluvial deposition in the early Dryas 3. On top of the Ebing Terrace there are thick cold-climate flood deposits prior to the Holocene ones and epigenetic cold-climate indicators as drop soils and cryoturbations on the rivers Main and Rhein (SCHIRMER 1995a: 40).

Summarizing, there are indicators for river activity concentrating during a wet early Dryas 3 period thus providing wide sand plains that easily could be deflated during a dry second Dryas 3 period.

Appendix 4

The boundary Pleni-Weichselian/Late Weichselian

Several researchers draw the boundary with the first warming after the Last Glacial Maximum (LGM). By finding the Kamion Horizon MANIKOWSKA (1995: 131) regarded this interstadial phase as the first warming after the LGM and hence she suggested to draw the boundary between the Pleni-Weichselian and the Late Glacial with the beginning of the Kamion Horizon.

However, looking at the Rhein loess record (Fig. 3) there are at least two interstadials in the loess between the LGM and the eventual climate improvement of the Meiendorf-Bølling-Allerød group. There is the Elfgen Soil as calcaric regosol preceded by the Belmen Soil as weak humic gelic gleysol, and later follows the Leonard Soil as brown calcaric cambisol. These soils are separated by thick loess stacks of the eolian Brabantian loess rich in frost cracks and ice wedges. The largest ice wedges of the Last Glacial at all occur within this Brabantian loess.

This implies that the first part of the Last Glacial stage, the Marine Isotope Stage (MIS) 2, was obviously humid and cold thus triggering the augmentation of inland ice until the LGM. In contrast the period after the LGM was obviouly dry and cold and produced the largest ice wedges within the loess formation. Apart from the change from humid to dry there were several warm interstadials interrupting the MIS 2 cold period. One of them (probably Kesselt Layer till Elfgen Soil) caused the dissipation of continuous permafrost and might have triggered the ice to surge towards its maximum advance (SCHIRMER 1999c).

Drawing the base of the Late Glacial with the beginning of the first warming after the LGM means to draw it together with the maximum ice advance or immediately after it. In doing so the maximum cold dry climate with its large ice wedges would be included into the Late Glacial. Undoubtedly this period of cold dry loess deposition has to be part of the Pleni-Weichselian though there are some interstadial periods intercalated. Consequently the beginning of the Late Glacial should be drawn posterior to the Pleni-Weichselian, with the first interstadial that shows a tracable biological climate improvement towards the Holocene — and this is doubtless the interstadial group of Meiendorf-Bølling-Allerød (BOCK et al. 1985, U. SCHIRMER 1999).

Annotations

[1] Means: eolian activity concerning sand transport. As this article concerns eolian sand all statements on eolian activity concern sand transport and exclude loess transport if not especially noted.

[2] UWG = Upper Weichselian Glaciation, MWG 1 = Middle Weichselian Glaciation 1, MIS = marine isotope stage equaling oxygen stage.

[3] The term *colluvial* equals the German term *deluvial* (action: *delution*), also the

term *ablual* (LIEDTKE in GALBAS et al. 1980: 10), whilst the German *kolluvial* is restricted to down slope transport of soil material, mostly induced by man's impact on the landscape.

[4] Gathering observations during the field excursion for getting a scheme of the eolian deposits, the outlines of the sixfold scheme presented here came into existence during the first days. During the fourth excursion day BARBARA MANIKOWSKA presented her own scheme (MANIKOWSKA 1998: 93) of five eolian stages, by the way in her very clear and distinct manner. Both schemes matched highly. Of course, hers was better geared than mine. Later by studying more literature I found that MANIKOWSKA varied her stage scheme several times (Tab. 1: MANIKOWSKA 1991b, 1995, 1998). The 1991b paper offers a sixfold scheme that excellently matches with my own one.

[5] see annotation 3.

[6] Sandloess is an intermittent member within the range loess—eolian sand with a content of 20–50 % sand mass (AG Boden 1994: 164).

[7] To this period belong the silts of Polish Western Pomerania (Locality Klępicz in Fig. 1). See Appendix 1.

[8] After KOZARSKI & NOWACZYK (1991: 118) and NOWACZYK (1998a) in Great Poland first coversand deposition started as late as the Dryas 2 period. Also BUSSEMER & THIEKE (1998) state in Golssen south of Berlin the start of eolian sedimentation not earlier than Late Glacial. This may be due to observations from single outcrops.

[9] quotet in KOZARSKI (1978: 293)

[10] The Bølling soil is a very rare phenomenon in Europe at all. In areas of low morphological variety the soils of the Bølling and Allerød period are incorporated into the recent soil. In rare cases these Late Glacial soils were separated from the Holocene soil by thicker Late Glacial accumulations as flood deposits, slope debris, eolian sand or the Laacher See volcanic ash. The Late Allerødian Laacher See Tephra preserved the early Allerødian soil as pararendzina (calcaric regosol) on top of loess, the Mendig Soil. Moreover, after pollenanalytical data this Mendig Soil embraces the onsets of soil formation from the beginning of the Meiendorf Interstadial through the Bølling Interstadial up till the Allerød period (SCHIRMER 1996).

Deposition during the Dryas 2 period separating the Bølling and Allerød soils is even more rare.

[11] The soil formation of the Allerød period is the most intensive soil formation during the Late Glacial. Normally, it is incorporated in the surface soil. Together with the weak Meiendorf and Bølling soils, it is the first onset of the post-glacial soil formation. Consequently the Allerødian soil is only preserved in case of being covered. In most cases this happened by Dryas 3 deposits. Besides the eolian sand preservation of the Usselo Soil, the Finow Soil and related soils, preservation by floodplain deposits took place producing the fossil Trieb Soil, a pseudo-chernozem

developed along central European rivers (Schirmer 1977: 310, 1995a: 39). Buried by the Laacher See Tephra in 13,000 cal BP the Mendig Soil has been preserved as calcaric regosol on top of loess (Schirmer 1995b: 529, 1996) (cf. annotation 10).

[12] cited in Kozarski & Nowaczyk (1991: 110)

[13] cited in Kozarski & Nowaczyk (1991: 110)

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