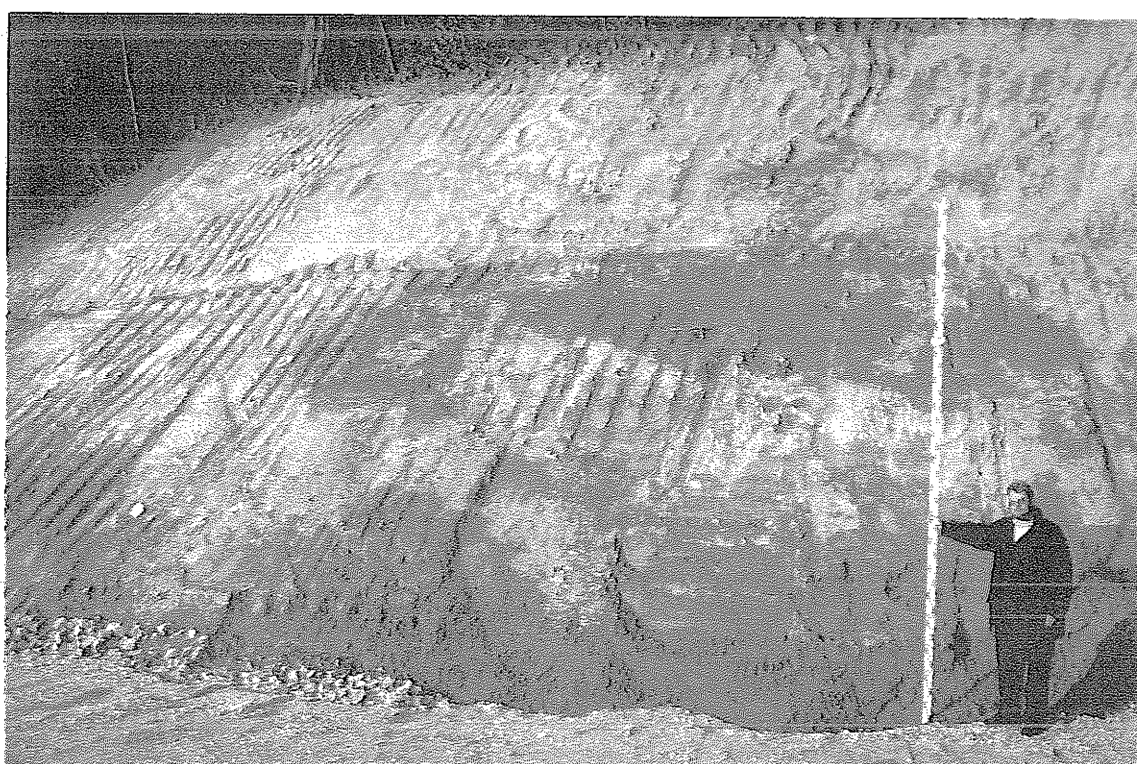
Loessfest '99

Loess in the Middle and Upper Rhine Area

Michael Weidenfeller & Ludwig Zöller (eds.)

Field Guide

FIELD EXCURSIONS March 25 - 27 1999



Loess section of the Haarlass site, Heidelberg (after K.C. von LEONHARD 1823/24)

International conference in celebration of the 175th Anniversary of the first recognition of the origins of the loess by von Leonhard

Loess in the Middle and Upper Rhine Area

Revised edition

Michael Weidenfeller[1] & Ludwig Zöller[2] (eds.)

K.C. von LEONHARD

Bonn and Heidelberg, Germany, March 25 – April 1 1999

INQUA IGCP - UNESCO/IUGS

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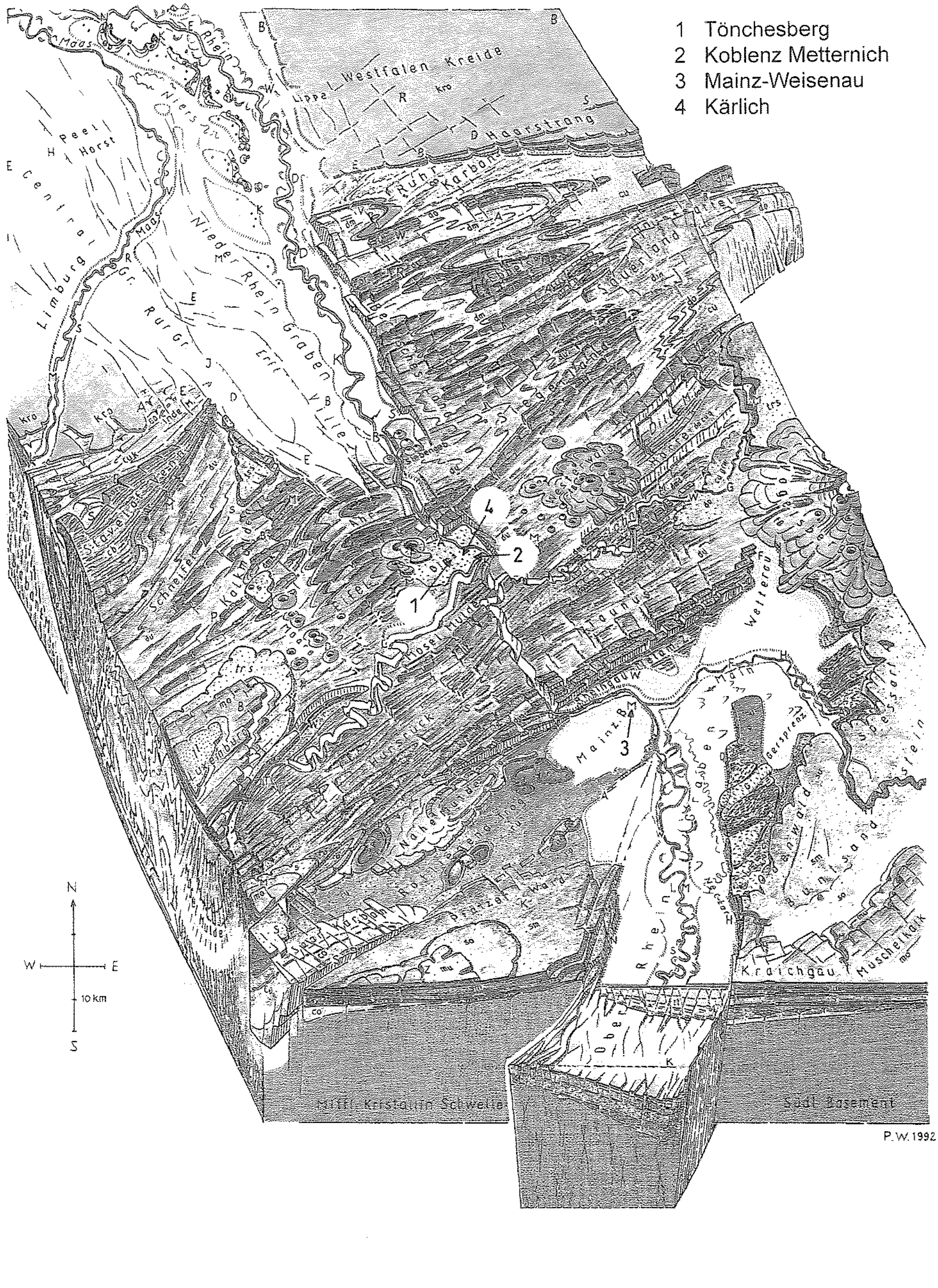
1 Tönchesberg
2 Koblenz Metternich
3 Mainz-Weisenau
4 Kärlich
Westfalen Kreide
Haarstrang
Ruhr Karbon
Sauerland
Peel Horst
Central Gr.
Limburg
Maas
Rhein
Niers
Nieder Rhein Graben
Rur Gr.
Erft
Ville
Lippe
Eifel
Mosel Mulde
Taunus
Wetterau
Main
Mainz B.
Hunsrück
Nahe
Odenwald
Spessart
Kraichgau
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First excursion: March 25 1999

Stop 1: Tönchesberg

Theme: **The Late Middle and Upper Pleistocene Loess/Palaeosol deposits of section Tönchesberg/East Eifel area**

Guides: **Manfred Frechen[1], Wolfgang Boenigk[2] & Ulrich Hambach[2]**

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Topics: Loess stratigraphy, last interglacial/glacial cycle, early glacial soil complex, Quaternary volcanism; Neanderthal encampment site; reverse magnetization, Blake event Test site for luminescence chronology

Access: Motorway A61, exit Plaidt; turn left, direction of Ochtendung; turn right to Ochtendung center; turn right small road to Fressenhof; follow road for about 3.5 km; Tönchesberg lava pit on the right

Geological setting: The Rhenish Shield, "Rheinisches Schiefergebirge", is an area, which has undergone several periods of uplift and erosion since the Upper Carboniferous/ Permian. In the area of interest, the bedrock consists of Devonian sediments. In the Neuwied basin, which is an area of subsidence, a detailed record of Tertiary and Quaternary sediments cover the Paleozoic bedrock. The Tertiary sediments range from the marine Lower Oligocene through the terrestrial Pliocene. About 800,000 years ago, the uplift of the Rhenish Massif accelerated, as evidenced by the incised deep channels of the river Rhine ("Rhein") and Moselle ("Mosel") and its terrace stair case. Loess and loess derivatives were accumulated since the Midle Pleistocene, as evidenced by the loess/palaeosol sequences at section Kärlich. The volcanic activity of the East Eifel Volcanic field began during the interglacial (oxygen

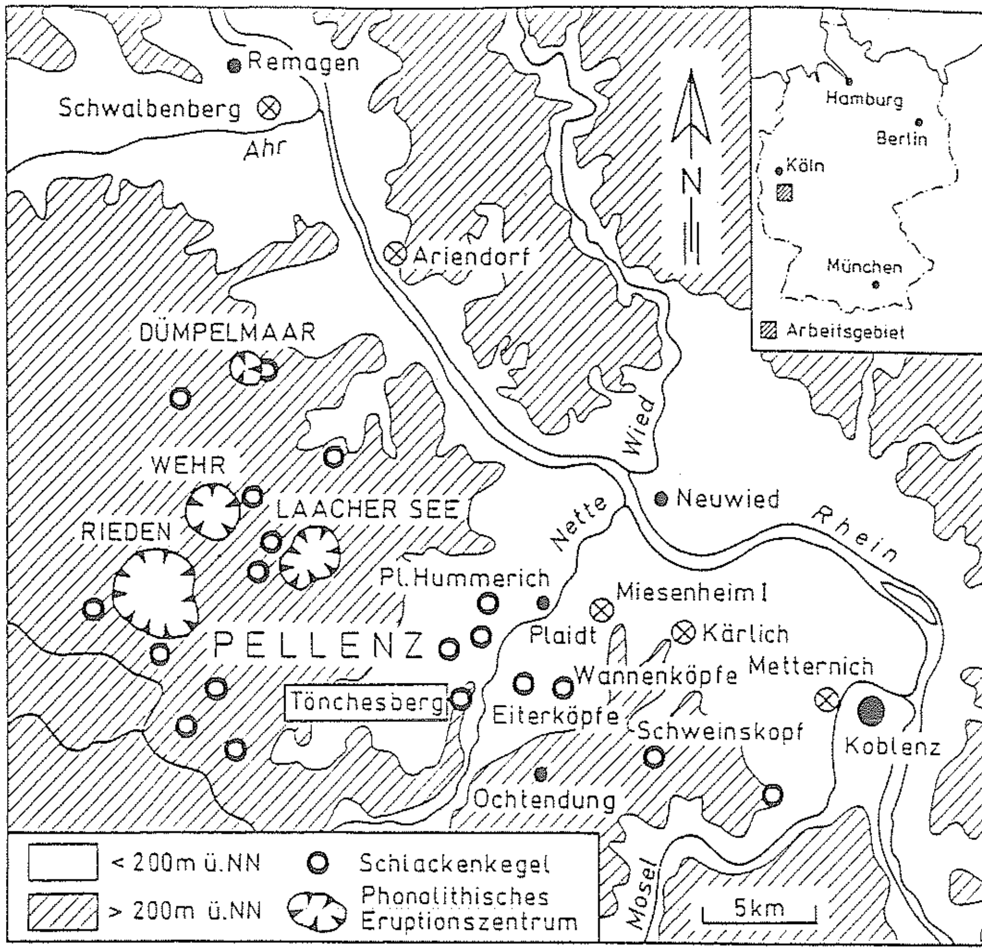

Fig. 1: Map showing the locality of the Tönchesberg section in the East Eifel Volcanic Fields, Middle Rhine area

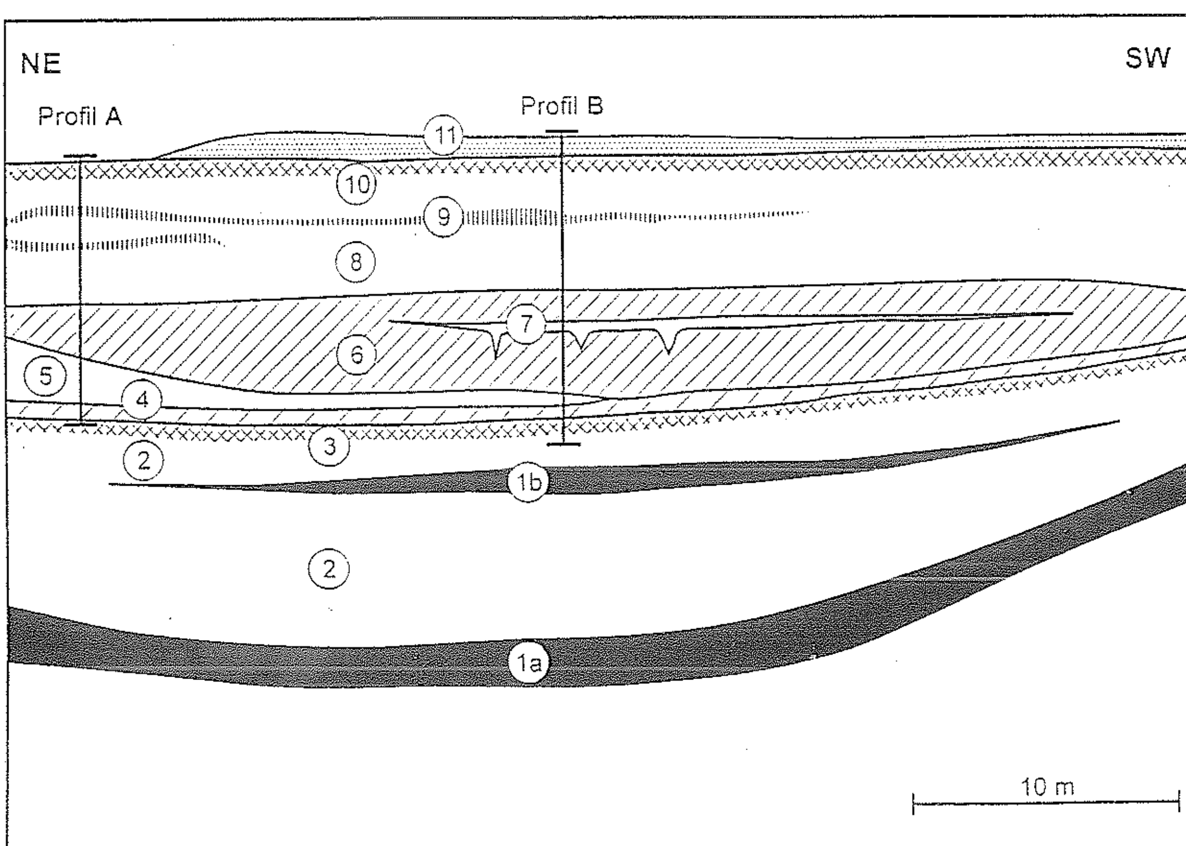

Fig. 2: Lithololocical sketch of the south-east wall of section Tönchesberg, including profiles A and B (after BECKER et al., 1989)

1: Basaltic tephra
2: Loess of the pennultimate glaciation (= Saalian, stage 6)
3: Bt horizon of a brown forest soil (Eemian, substage 5e)
4: Reworked soil material, pedosediment
5: Reworked layered loess
6: Early glacial (stage 5) humic horizons (chernozem-like soils)
7: Marker loess with frost wedges
8: Middle and Upper Weichselian loess and loess derivations (stage 3 and 2)
9: Duplicate weak brown soil
10: Pararendzina (Alleröd)
11: Pumice of Laacher See Volcano

isotope stage, OIS 15) which tops Unit F at the Kärlich site (BOENIGK & FRECHEN 1998). The Quaternary volcanism coincides with increasing rates of uplift, as evidenced by the terrace stair case of the river Rhine.

The Tönchesberg Volcano, early penultimate glacial, OIS6

The Tönchesberg volcano belongs to a group of scoria cones which erupted after the cataclysmic eruption of the "Wehr Volcano" about 13.5 km in the northwest of the Tönchesberg (fig. 1). The Hüttenberg tephra, an isochronous marker horizon from the Wehr volcano, is exposed below the initial maar-like deposits at the base of several scoria complexes in the vicinity of Tönchesberg volcano (BOGAARD & SCHMINCKE 1990; FRECHEN 1995, 1999). However, this marker horizon has not yet been found below the pyroclastic deposits of Tönchesberg.

A preliminary eruption age was determined to 202±14 ka by preliminary $^{40}Ar/^{39}Ar$-laser-single-grain dating for the Tönchesberg scoria. The initial volcanic activity of Tönchesberg was explosive, a phreatomagmatic eruption style with initial maar-like deposits, which at present are exposed at the northeast wall of the quarry. The eruption was followed by Strombolian activity which built up most of the scoria cones. At least 5 eruption centers were determined by geomagnetic measurements and field evidence. In the final stage basaltic dykes intruded into the scoria cones, exposed at the northern quarry wall. After the volcanic activity, the inter- and intra-crater depressions formed important sediment traps recording the climate and environment change of the past 180 ka (fig. 2).

The penultimate glacial deposits, OIS 6: 180-130 ka

The Tönchsberg scoria complex erupted during the early stage of the penultimate glaciation ("Saalian"). At the crater base volcanic debris was accumulated, followed by two air fall tephra from near distance (Plaidter Hummerich and Korretsberg volcanoes, fig. 1). Reworked volcanic debris and loess-like sediments were accumulated by solifluction processes indicating a rather cold climatic environment. The volcanic debris is covered by more than 8 m of loess and reworked layered loess-like sediments intercalated by weak tundra or frost gleys ("Naßboden"), which are characteristic for the younger part of the penultimate glaciation in Central Europe.

The snail fauna from the loess-like sediment above the uppermost mafic ash fall is dominated by the glacial *Pupilla* species: *Pupilla sterri* and *Pupilla triplicata*, *Succinea oblonga* and

Vertigo pygmaea were determined from these sediments. *Pupilla triplicata* is an indicators for warmer conditions during glacials or early glacials (KOLFSCHOTEN & ROTH 1993).
Small mammals like *Dicrostonyx* indicate a tundra or steppe-like environment which is in agreement with the presence of macro mammals like *Equus sp.* and *Rangifer tarandus* (KOLFSCHOTEN & ROTH 1993; TURNER 1990). Interglacial species are absent in the record indicating an early glacial to glacial environment. A skull of a hominid, described as late pre-Neandertals, was recently found in penultimate glacial deposits of the Wannenköpfe volcano about 3.5 km in the east of the Tönchesberg, demonstrating the existence of hominides, which had successfully adapted to the glacial climate and environment during the late Middle Pleistocene (BERG 1997).

The last interglacial, OIS 5e, 130-117 ka

A Bt horizon of a red brown forest soil ("parabraunerde") is designated to be an equivalent of the last interglacial, Eemian or OIS 5e. The discontinuity on top of the Bt horizon proves a kind of climatic instability at the end of the Eemian resulting in erosion and destruction of the vegetation and the upper part of the brown forest soil. TL ages of FRECHEN (1991, 1992, 1994) and ZÖLLER et al. (1991) indicate a deposition age of > 110 ka.
Faunal and floral remains of interglacial climate and environment were described in the pedosediments covering the Bt horizon. An archaeological find horizon with a dense concentration of chipped quartz was found in the Eemian Bt horizon. However, the artifacts are designated to be of penultimate glacial age.
A dark brown and a red brown horizon, which are both defined as A horizons, as evidenced by soil-micromorphology and field observations, are deposited on top of the Bt horizon. The upper red brown A horizon was altered to a brown soil. A reverse magnetization, which is correlated with the Blake event (~117 ka), was recognized in the pedosediment by BECKER et al. (1989) and REINDERS & HAMBACH (1995), hence a soil formation during OIS 5c (OIS 5e) is very likely for the two A horizons. The pollen spectra contains 98% *Pinus* and 2% *Picea*, which are mainly pollen accumulated by long distance transport. However, the floral remains include pieces of charcoal from *Pomoideae*, *Prunoideae*, *Quercus*, *Ulmus* and *Acer* indicating a deciduous forest (BITTMANN 1991). The snail assemblage, investigated by KOLFSCHOTEN & ROTH (1993), of the two soil horizons consists of a mixed assemblage, designated to be of forest-steppe (*Bradybaena fruticum* fauna) and meadow-steppe (*Chondrula tridens* fauna). The species *Jaminia quadrideus* is a typical snail for open

environments, which are sun exposed. By summarizing the floral and faunal remains, it is likely, that both soils above the Eemian Bt horizon represent deciduous forest.

The presence of small mammals, like *Microtus arvalis* and *Arvicula terrestris*, are in agreement with the floral interpretation. The macro mammal remains include species, dominated by aurochs (*Bos primigenius*) and fallow deer (*Dama dama*), which are typical for interglacial and moderate forest climate conditions. The occurrence of horse (*Equus sp*), wild ass (*Equus cf. hydruntinus*, extinct) and rhinoceros (*Dicerorhinus cf. hemitoechus*, extinct) indicates more open conditions like grass-steppe. Besides these species the red fox (*Vulpes vulpes*), the northern lynx (*Felis lynx*) and red deer (*Cervus elaphus*) are present in the early last glacial deposits.

The Early glacial, OIS 5d-a, 117-76 ka

On top of the brown soil reworked loess and loess were deposited. The upper part of the loess horizon was superimposed by a chernozem-pseudogley during an interstadial designated to be OIS 5c. The palaeosol is covered by humic-rich reworked horizons and the upper part is superimposed by a parabraunerde-chernozem (BtAh), which is more intense than the chernozem-pseudogley. The BtAh horizon is designated to correlate with OIS 5a by luminescence dating and loess stratigraphic evidence (BOENIGK & FRECHEN 1999; FRECHEN 1994).

The Middle glacial, OIS 4 and 3, 76-24 ka

Pellet sands and reworked humic-rich sediment, intercalated by weak soils, were accumulated on top of the prabraunerde-chernozem (BtAh). The weak soils are evidenced by bioturbation and an enrichment of organic matter during a short term of surface stability. The early Middle glacial deposits are difficult to interpret owing to lack of reliable dating material at the Tönchesberg section. The Early Middle glacial displays a number of warm intervals during OIS 3 in the north-west European pollen record (BEHRE 1989), at La Grande Pile (WOILLARD & MOOK 1982) and Moershoofd in the Netherlands (ZAGWIJN 1998).

The reworked humic-rich sediments of the early Middle glacial are covered by a 10 cm thick loess horizons including frost wedges. The loess is defined as a marker loess and is interpreted elsewhere as an European wide dust storm (ROUSSEAU et al. 1998) defining the abrupt end of interstadial conditions. A deposition age of 60-70 ka was determined for the marker loess at the Tönchesberg section by combined IRSL and TL dating. Pellet sands and loess-like sediments, the latter intercalated by two weak brown soils, were deposited subsequently.

The upper part of the Middle glacial is characterised by loess-like deposits, which are intercalated by two weak brown soils indicating interstadial intervals. It is likely to compare the two interstadials with the Dutch Hengelo (39-36 ka) and Denekamp (32-38 ka) intervals of the Middle Weichselian (RAN & HUISTEDEN 1990). Age control is provided by high resolution IRSL and TL dating (FRECHEN 1991, 1992, 1994 resulting in IRSL ages ranging from 25 to 50 ka for the loess-like sediments. The TL age estimates are slightly overestimated, ranging from 33 to 52 ka (fig.3).

Snail assemblages are dominated by the *Pupilla* fauna indicating cold climate conditions.

The last glacial maximum, OIS 2, 24-13 ka

The record of the last glacial maximum (Upper Weichselian) is not complete owing to significant erosion before 17 ka. The Upper Weichselian loess exposed at Tönchesberg have IRSL and TL ages ranging from 12 to 17 ka. A major hiatus around 17 ka is typical for many loess sections in the area of interest. A weak gleyed horizon is intercalated in the homogenous loess deposits.

The Alleröd-interstadial, >12.9 ka

The Upper Weichselian loess was superimposed by a strong dark brown soil indicating interstadial climate and environment conditions. The soil is covered by a 1.5-2.5 m thick tephra horizon of the cataclysmic Laacher See eruption. The Laacher See erupted 12.9 ka ago and is designated to be an important tephrochronological marker horizon in Central Europe. Faunal and floral remains from below the tephra indicate a climate, which is similar to that of recent climate and environment in Uppland, Central Sweden (WALDMANN 1996). At the time before the Laacher See eruption, a hemiboreal mixed forest dominated by *Acer platanoides*, *Quercus robur*, *Populus tremula*, *Betula spp.*, *Rhamnus catharcita*, *Tilia cordata*, *Salix spp.*, *Ulmus glabra*, *Corylus avellana* and *Pinus sylvestris* existed in the area of interest (WALDMANN 1996).

The Tönchesberg section contains the most complete sequence for the early glacial period of the Weichselian glaciation. The loess/palaeosol sequence serves as a reference profile for the other crater profiles of the East Eifel Volcanic Field, which are not as well preserved and complete as the Tönchesberg record.

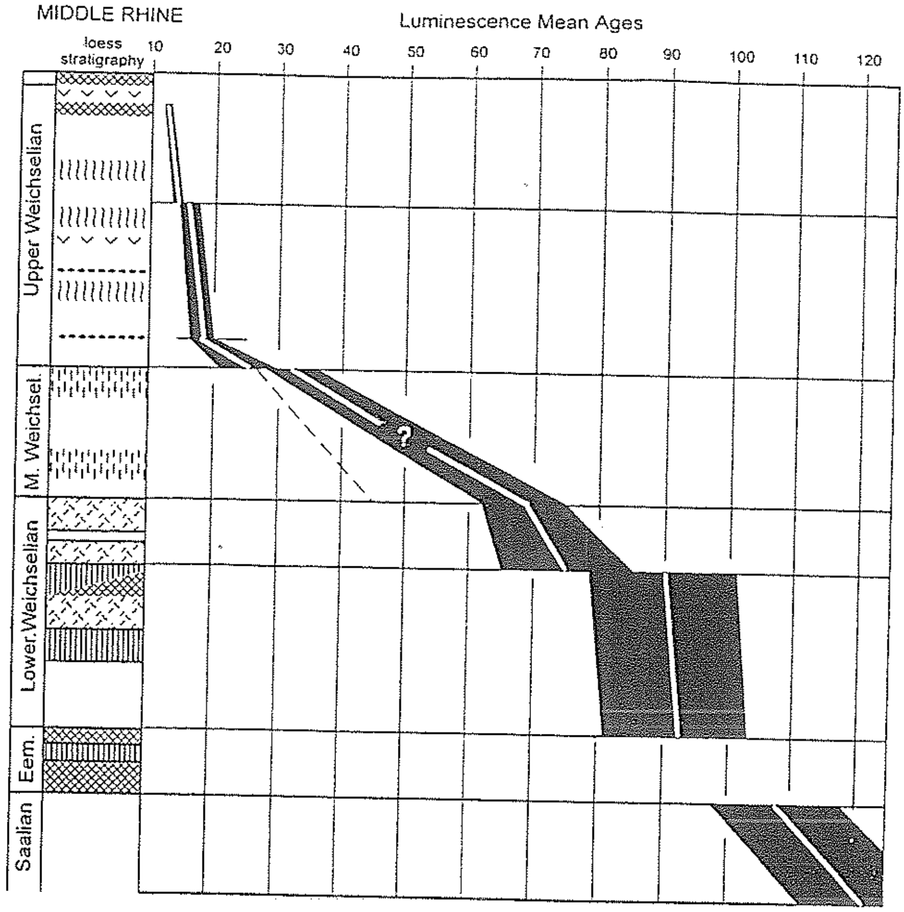

Fig. 3: Idealized chronostratigraphy of the loess/palaeosol sequence from the Middle Rhine Area based on combined IRSL and TL dating (from Frechen 1998).

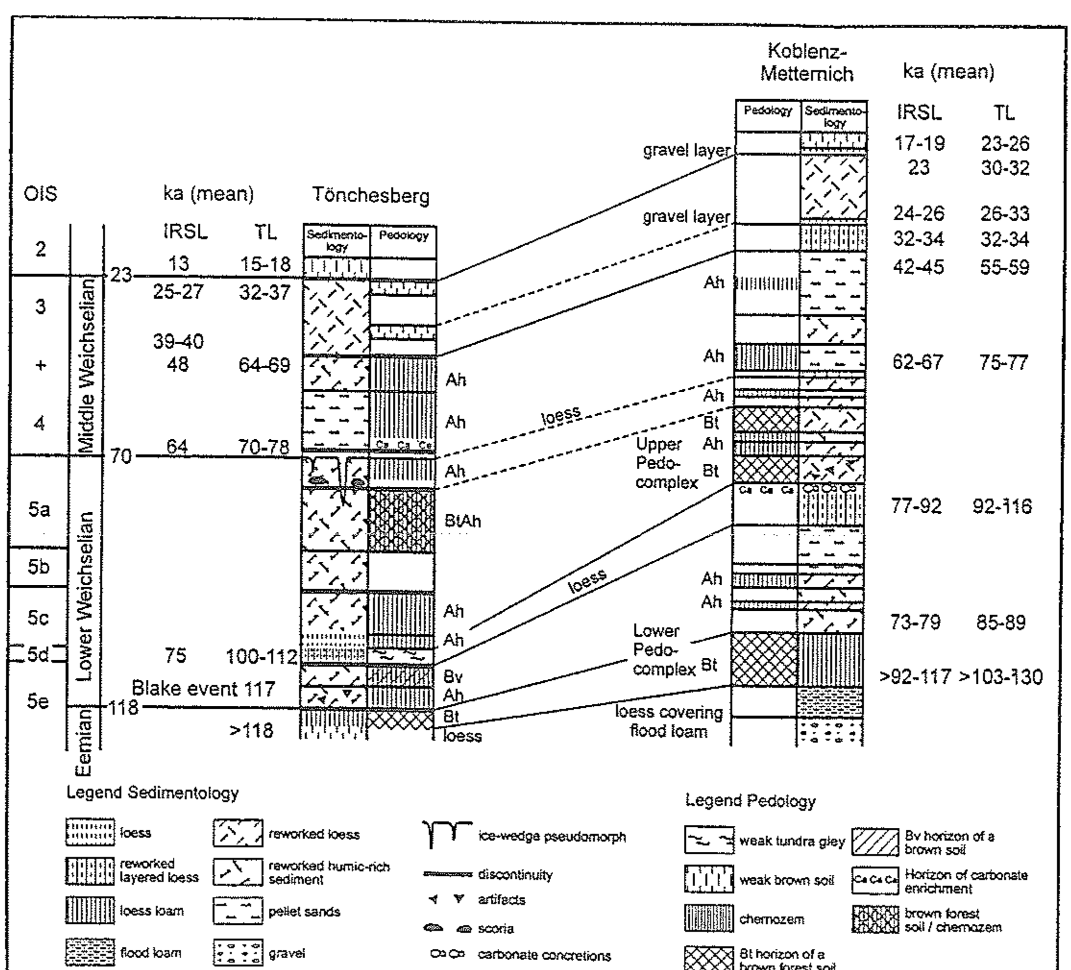

Fig. 4: Correlation of the loess/palaeosol sequence from the sections at Tönchesberg and Koblenz-Metternich (Bt= clay-rich B horizon of brown forest soil; Ah= humic-rich A horizon).

Rock magnetism

Rock magnetism is a powerful tool for the characterization of sedimentary environments. The applied techniques are relatively rapid, simple, sensitive, non-destructive and inexpensive. In the last years significant progress was achieved in using rock magnetic parameters as proxies for provenance, depositional and postdepositional processes, palaeoclimatic variations, etc. (e.g. DEKKERS 1997).

Loess-palaesol sequences (LPSS) comprise alternating successions of palaesols in loess. The palaeosols were formed under wetter and warmer climatic conditions and are characterised by the enhancement of magnetic minerals. Hence, magnetic low-field susceptibility (κ, KAPPA) may serve as a climatic proxy and its course with depth allows for the correlation of LPSS with the marine oxygen isotope record. The main source for the magnetic signal in palaeosols is thought to be the increased concentration and activity of magnetite (Fe_3O_4) producing bacteria (e.g. HELLER & EVANS 1995). However, this primary magnetite fraction is subjected to various alteration processes and may oxidise in whole or in part during early diagenesis to maghemite (γ-Fe_3O_4) and/or hematite (α-Fe_3O_4) (REINDERS et al. 1999).

At the Tönchesberg site profile B of BECKER et al. (1989) was sampled (~5 cm spacing) for rock magnetic investigations. The whole suit of concentration dependent parameters (CDP's) (κ, isothermal remanent magnetisation (IRM), anhysteretic remanent magnetisation (ARM) as well as grain-size indicative parameters were determined. Here we present the results of the κ, the IRM and the ARM measurements. The ARM is widely accepted as a proxy for the concentration of single domain (SD) magnetite grains. Its ratio to κ is used here as a proxy for the intensity of pedogenesis. In Fig. 5 the CDP's and their interparametic ratios are plotted as a function of depth. Three palaeosols (palaeosol complexes) can be recognised below 6 m (Eemian and Early Weichselian, OIS 5d-a). In profile B only two palaeosol complexes are evident in the uppermost 6 m (Early Middle Weichselian, OIS 4 and Alleröd soil). The peak values of κ, IRM and ARM at 10.2 and 5.9 m are caused by detrital input of volcanic material. REINDERS & HAMBACH (1995) identified the Blake Magnetic Polarity Episode (~ 117 ka) in the pedosediments just above the Eemian Bt horizon.

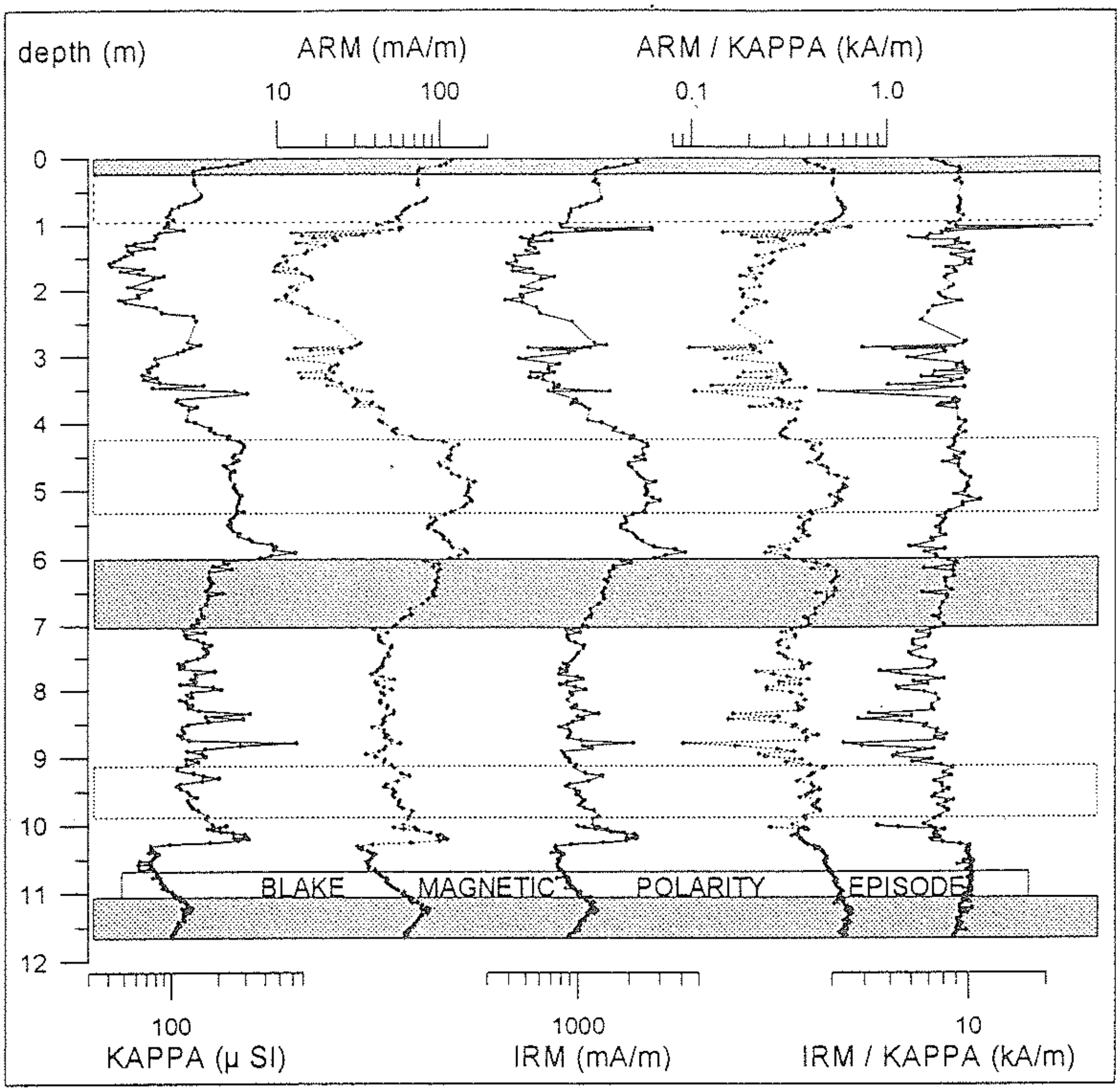

Fig.5 : Rock magnetic parameters at the Tönchesberg site (profile B) plotted as a function of depth. Grey shaded horizons: paleosols which are already visible in the field. Horizons framed by dashed lines: evidence from rock magnetic parameters for in situ pedogenesis.

Archaeology

Preservation of artifacts suggests that hominides could survive under cold climatic conditions of the penultimate glaciation and under the moderate climate documented by the early last glacial humic-rich horizons above the last interglacial soil.

Three early glacial archaeological layers are known from the loess/palaeosol sequence. The most important one is situated in the humic horizon directly above the Bt horizon of the brown forest soil, including more than 500 lithic artifacts, e.g. blade tools, backed tools and hammer stones.

The sediments have been described by BECKER et al. (1989), HENTZSCH (1990), BOENIGK & FRECHEN (1994, 1999) and BOENIGK et al. (in press). A similar sequence is exposed at Metternich (fig. 4). Systematic TL dating was provided by FRECHEN (1992, 1994). Palaeomagnetic investigations were contributed by BECKER et al. (1989) and REINDERS & HAMBACH (1995) describing reverse magnetic polarity. Archaeological excavations were undertaken by (CONARD 1992).

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Stop 2: Koblenz-Metternich

Theme: **The Late Middle and Upper Pleistocene Loess/Palaeosol deposits of section Koblenz-Metternich, Moselle valley**

Guides: **Michael Weidenfeller[1], Wolfgang Boenigk[2], Manfred Frechen[3], Ulrich Hambach[2] & J. Reinders[4]**

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Topics: Loess stratigraphy, last interglacial/glacial cycle, early glacial pedocomplex, Upper Weichselian tephra

Access: Motorway A 61, exit Koblenz-Metternich, direction of Koblenz; after 2 km turn right to Koblenz-Güls; in Koblenz-Güls turn left to Koblenz-Metternich, loess site on the left

Geological setting: The Koblenz-Metternich section is situated in the valley of the river Moselle ("Mosel") at the southern border of the Neuwied basin (fig.1) which is part of the Rhenish Shield ("Rheinisches Schiefergebirge"). In the area of interest, Tertiary sediments are missing. Quaternary fluvial sediments are covering the Devonian bedrock. After an increase of tectonic uplift of the Rhenish Shield about 800, 000 years ago, the rivers Rhine, Moselle and Lahn incised into the Devonian bedrock as evidenced by the terrace stair case. In this part of the Rhenish Shield it is possible to subdivide the Quaternary terraces into three groups: Main Terraces ("Hauptterrassen"), Middle Terraces ("Mittelterrassen") and Lower Terraces ("Niederterrassen"). Main, Middle and the Older Lower Terrace ("Ältere Niederterrasse") are covered with flood loam, loess sediments and their derivatives, respectively. The Younger

Lower Terrace ("Jüngere Niederterrasse") is only covered by flood loam. Beside the very detailed loess/palaeosol sequences from sections within inter and intracrater depressions of the East Eifel Volcanic Field, continuous loess records have been described in lee position from the valleys of the rivers Rhine and Moselle.

At section Koblenz-Metternich, loess and loess derivatives were deposited up to 24 m thick on terrace sediments of river Moselle. The sediments of Koblenz-Metternich have been described by GÜNTHER (1907), MORDZIOL (1926), HOFER (1937), REMY & PAAS (1959), REMY (1960, 1968), LÖHR & BRUNNACKER (1974). Sedimentological, pedological and soil chemical investigations were carried out by BOENIGK, FRECHEN & WEIDENFELLER (1994) (fig.2). Systematic thermoluminescence dating was provided by FRECHEN, BOENIGK & WEIDENFELLER (1995). In a detailed high-resolution luminescence dating study, 45 samples were investigated by thermoluminescence (TL) and infrared optically stimulated luminescence (IRSL). For both methods the regeneration (REGEN) and the additive method (ADD) were used for the analysis of the accumulated dose. Altogether 180 independent age estimates were determined to determine the deposition age of the sediments. Palaeomagnetic investigations were contributed by HAMBACH, REINDERS & KRUMSIEK (this volume), micromorphological results by BOENIGK, FRECHEN & SCHWEITZER (in press) and archaeological excavations were undertaken by CONARD, BOSINSKI & ADLER (1995).

The penultimate glacial deposits, OIS 6

At section Koblenz-Metternich, the fluvial deposits consist of quartzite, sandstone, schist and quartz gravel. Volcanic minerals like clinopyroxene and hornblende are dominating the sand grain-size fraction, garnet was found quite often (BOENIGK, FRECHEN & WEIDENFELLER 1994). The heavy mineral spectra indicates, that these sediments are designated to be of Middle or Lower Pleistocene deposition age. BOENIGK & FRECHEN (1998) demonstrated for the fluvial sediments from the section at Kärlich, which include deposits of the river Moselle, that the Middle Pleistocene sediments are influenced by the volcanic activity of the East and West Eifel Volcanic Field, as evidenced by the presence of pyroxenes in the heavy mineral spectra. At section Koblenz-Metternich, REMY & PAAS (1959) defined the terrace on morpohological reason as an equivalent of the lower Middle Terrace ("Untere Mittelterrasse") of the river Moselle. These fluvial sediments are designated to be of the penultimate glacial deposition age (oxygene isotope stage, OIS, 6), as evidenced by luminescence dating of the loess deposits on top of the gravel. The fluvial sediments are covered by carbonate-free flood loam, indicating more moderate climate and environmental conditions. In the final part of the penultimate glaciation, loess was accumulated.

The last interglacial, OIS 5e

A red brown forest soil ("Parabraunerde") formed upon penultimate glacial loess. TL and IRSL age estimates of the soil sediments range from 102 to 130 ka and from 92 to 117 ka, respectively (FRECHEN, BOENIGK & WEIDENFELLER 1995) (fig. 3 and 4). The Bt horizon is designated to represent the last interglacial maximum (OIS 5e, Eemian soil). The lithological and chronostratigraphic situation is similar to that of the Tönchesberg profile (FRECHEN, BOENIGK & HAMBACH: this volume).

The Early glacial, OIS 5d-a

A reworked humic-rich sediment was deposited on top of the Bt horizon. Micromorphological investigations (BOENIGK, FRECHEN & SCHWEITZER in press) give evidence for two chernozems or forest-steppe horizons. The part of the loess/palaeosol sequence, ranging from the Eemian soil to the top of the upper chernozem, is called "Lower Pedocomplex". On top of the upper chernozem reworked humic-rich sediments were accumulated and covered by pellet sands and reworked loess. TL age estimates range from 63 to 97 ka. On top of the reworked loess, typical aeolian loess with a carbonate content of 25 % was deposited. In the lower part of this horizon, cryoturbation features are likely. The upper part of the loess horizon was superimposed by intensive soil formation, as indicated by a red brown, clay-rich Bt horizon and a carbonate enrichment with loess dolls (Ø < 6cm) in the C horizon. Clay coatings are not as common as in the Bt horizon of the Lower Pedocomplex, the clay content and hydromorphic features are less.

The palaeosol is covered by humic-rich reworked sediments, which are superimposed by two chernozems in profile A (Foto 1). A light yellow silty loess-like sediment (< 5cm thickness) was deposited on top of the uppermost chernozem. The chronological results underline, that this sediment is not an equivalent of the "marker loess" at section Tönchesberg (FRECHEN, BOENIGK & HAMBACH: this volume). A pure aeolian input for a marker loess, as required after the definition of KUKLA (1994), is unlikely. The sequence, ranging from the sediments from the base of the upper Bt horizon to the base of the "marker loess" is defined as "Upper Pedocomplex".

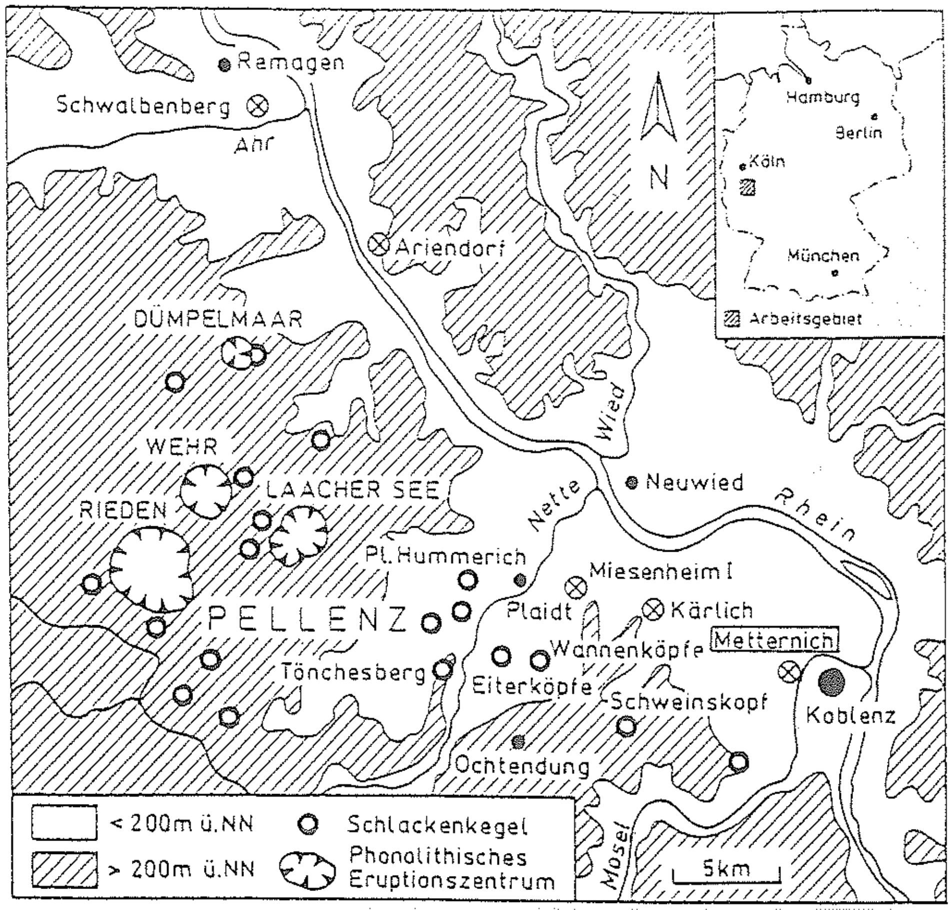

Fig. 1: Map showing the locality of the Koblenz-Metternich section in the Mosel valley

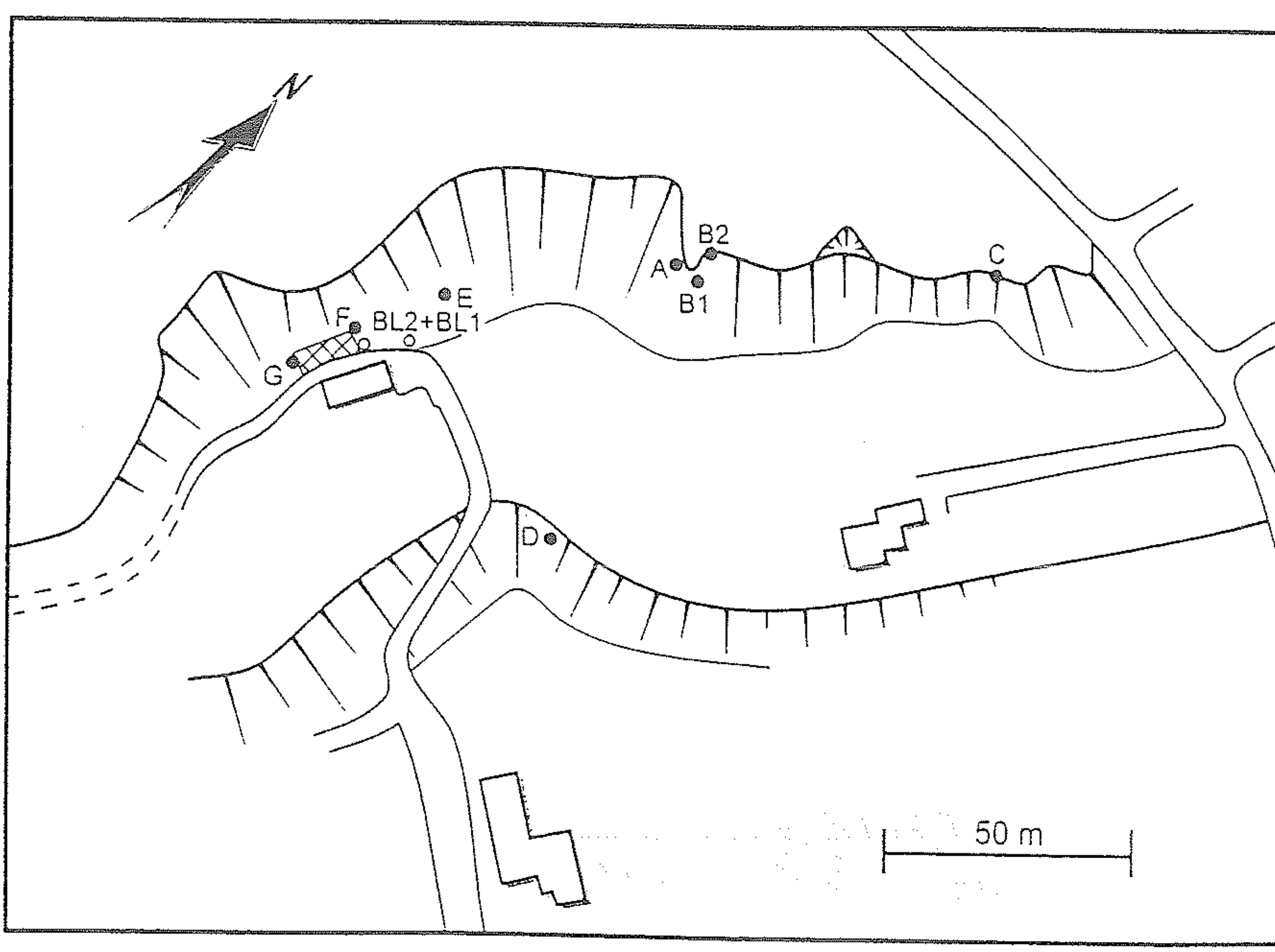

Fig. 2: Position of the profiles (A, B1, B2, C, D, E, F, G) and the drillings (BL1, BL2) at Koblenz-Metternich section

Upper Pedocomplex

Lower Pedocomplex

Photos 1 & 2:
Koblenz-Metternich
Profile A

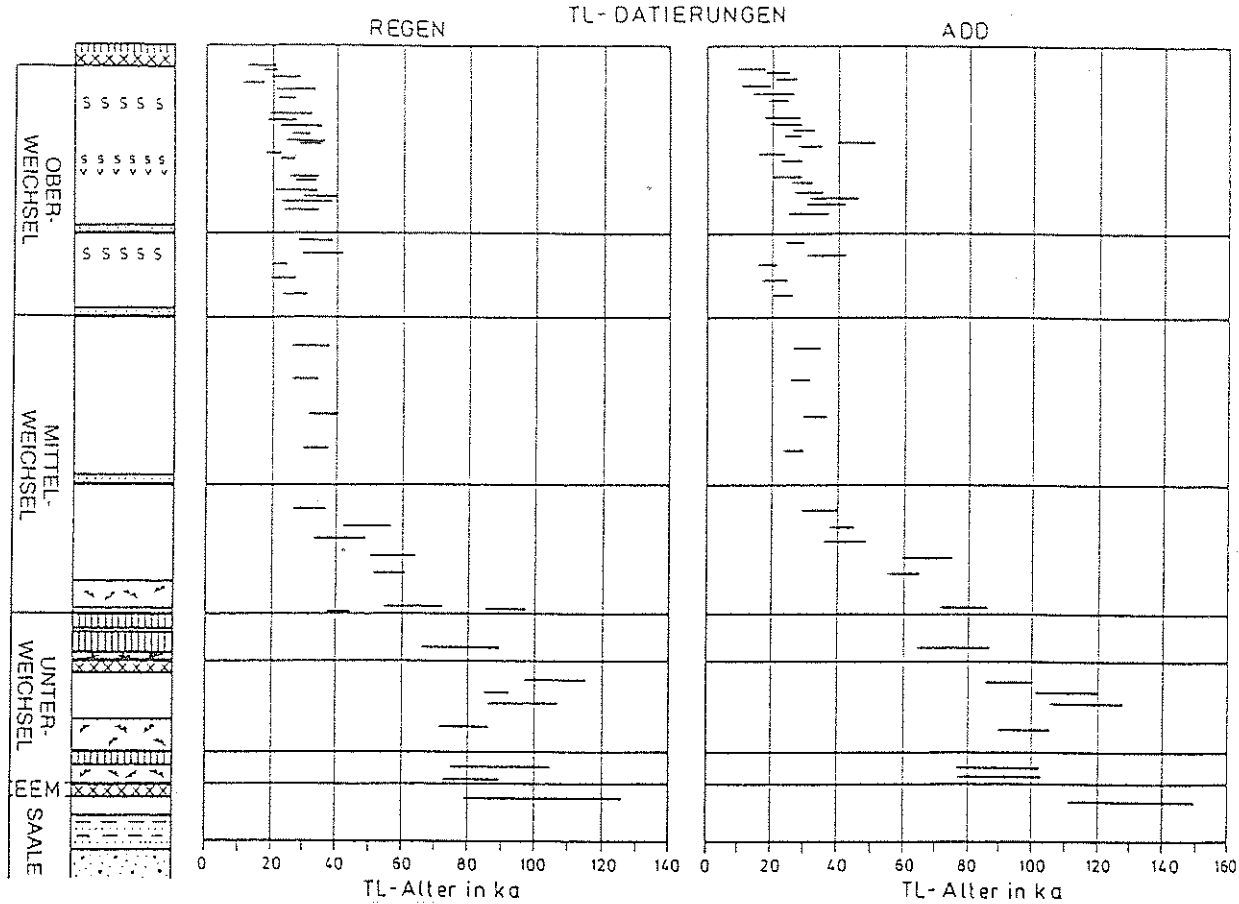

Fig. 3: Comparison of the TL ages in the loess section of Koblenz-Metternich, determined by regeneration (REGEN) and additive (ADD) method (after FRECHEN, BOENIGK & WEIDENFELLER 1995)

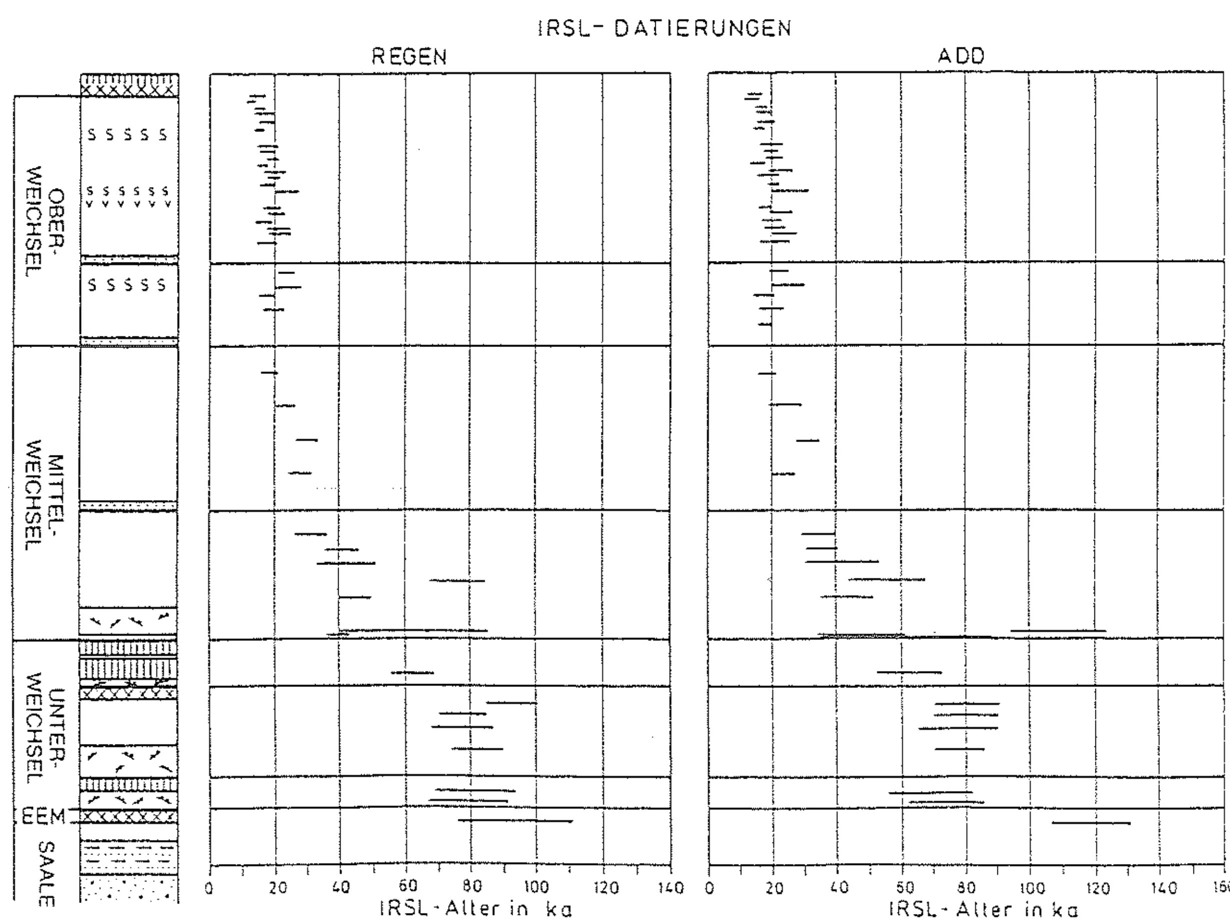

Fig. 4: Comparison of the IRSL ages in the loess section of Koblenz-Metternich, determined by regeneration (REGEN) and additive (ADD) method (after FRECHEN, BOENIGK & WEIDENFELLER 1995)

Middle Palaeolithic artefacts were found 80m southwest of profile A (CONARD, BOSINSKI & ADLER 1995), where the Upper Pedocomplex is exposed (fig.5). Profiles E, F and G give evidence for a more detailed record of the Upper Pedocomplex (BOENIGK, FRECHEN & SCHWEITZER 1999). Between "marker loess" and Bt horizon of the Upper Pedocomplex, a Bt horizon with intensive fabric and clay coatings is intercalated (fig.6).

The Middle glacial, OIS 4 and 3

On top of the marker loess-like horizon, reworked humic-rich sediments and reworked loess were accumulated (profile B). In the lower part of the reworked humic-rich sediment, LÖHR & BRUNNACKER (1974) found a tephra, the "Metternicher Bims". During the field investigations of the previous years, this tephra was not exposed. The stratigraphic position and the eruption age are under discussion.

The overlying loess/palaeosol sequence is an equivalent of those sediments from the section at Tönchesberg (fig.8). REMY (1968) postulated, that the boundary between Lower and Middle Weichselian is represented by a reworked soil between two loesses. In the 1994` field campaign, this soil was not exposed but represented by an erosional plane and a loess-rich gravel horizon (1^{st} gravel horizon). TL age estimates range from 60 to 40 ka. However, between first and second gravel horizon, no obvious age increase with depth was determined. TL and IRSL age estimates range from 18 to 30 ka for the latter sediments. The boundary between middle and late glacial (OIS 3/2) is defined at the second erosional plane and gravel horizon. The boundary between Lower and Middle Weichselian is likely at the base of the "marker loess", as evidenced by luminescence age estimates.

The last glacial maximum, OIS 2

The Upper Weichselian record is characterized by the deposition of reworked and aeolian loess, intercalated by three weak gleyed horizons and a third erosional plane and gravel horizon in profile B. No age increase with depth was determined for the sediments between the second and third gravel horizon. Thus, the Middle and Upper Weichselian loesses were deposited by a very high accumulation rate. Due to the high accumulation rate, no luminescence age difference was determined for the sediments between the hydromorphic soils ("Naßböden"), which are typical for Upper Weichselian loess sequences in Central Europe.

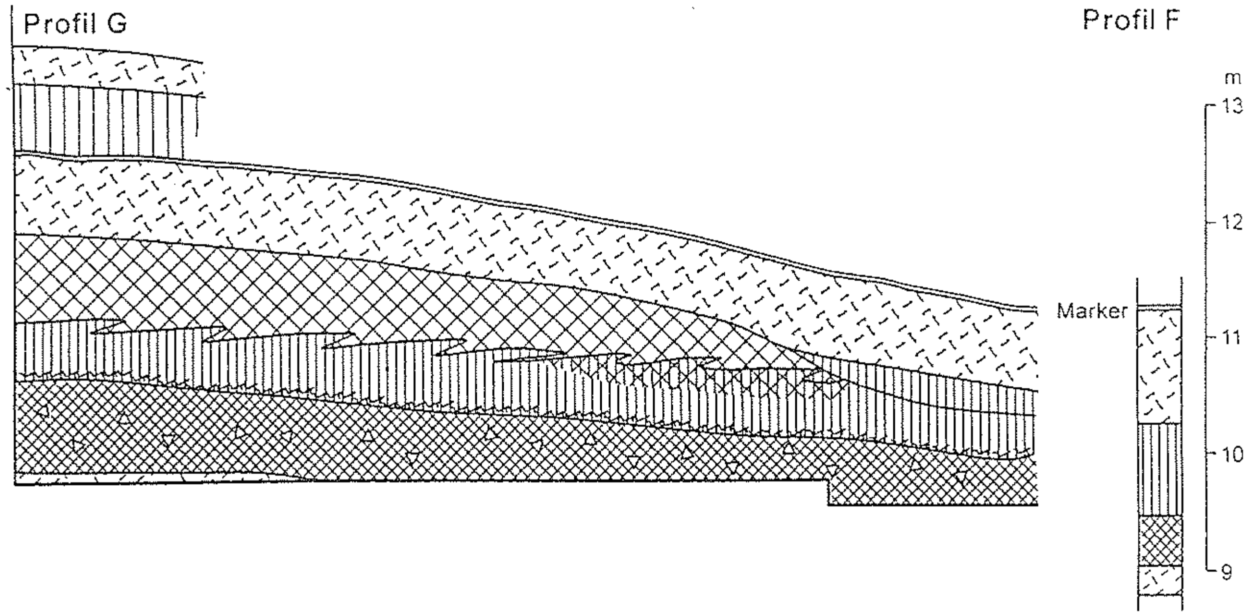

Fig. 5: Loess/palaesoil sequence between profile G and F
(after BOENIGK, FRECHEN & SCHWEITZER 1999)

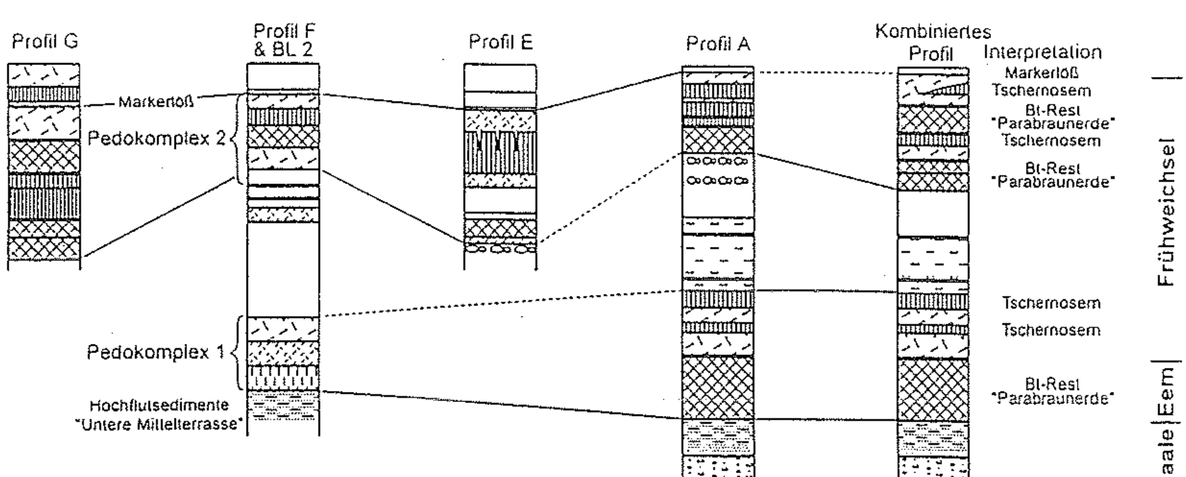

Fig. 6: Correlation between the profile A, E, F, and G and compilation to a combined profile
(after BOENIGK, FRECHEN & SCHWEITZER 1999)

In profile C a thin layer of basaltic ash is sandwiched by loess. The eruption age was indirectly determined by luminescence dating and ranged from 17.5 to 22 ka at the section at Koblenz-Metternich. The luminescence age estimates do not have sufficient resolution in order to distinguish between the "Eltville" and "Rambach" tephra (FRECHEN & PREUSSER 1996). The exposed tephra is defined as an "Upper Weichselian Tephra".
In profile C, IRSL age estimates increase with depth, ranging from from 13 to 23 ka. The youngest loess was accumulated between 13 and 15 ka. The Upper Weichselian sediments were covered by pumice of the cataclysmic Laacher See eruption during the Alleröd-Interstadial about 12.9 ka ago.

Rock magnetism

Rock magnetism is a powerful tool for the characterisation of sedimentary environments. The applied techniques are relatively rapid, simple, sensitive, non-destructive and inexpensive. In the last years significant progress was achieved in using rock magnetic parameters as proxies for provenance, depositional and postdepositional processes, paleoclimatic variations, etc. (e.g. DEKKERS 1997).
Loess-palaesol sequences (LPSS) comprise alternating successions of palaesols in loess. The palaeosols were formed under wetter and warmer climatic conditions and are characterised by the enhancement of magnetic minerals. Hence, magnetic low-field susceptibility (κ, KAPPA) may serve as a climatic proxy and its course with depth allows for the correlation of LPSS with the marine oxygen isotope record. The main source for the magnetic signal in palaeosols is thought to be the increased concentration and activity of magnetite (Fe_30_4) producing bacteria (e.g. HELLER & EVANS 1995). However, this primary magnetite fraction is subjected to various alteration processes and may oxidise in whole or in part during early diagenesis to maghemite (γ- Fe_30_4) and/or hematite (α- Fe_30_4) (REINDERS et al. 1999).
At the site Koblenz-Metternich profile A and B of BOENIGK et al. (1994) was sampled for rock magnetic (0-19.3 m, 10 cm spacing) and palaeomagnetic (19-26.5 m, 2.4 cm spacing) investigations. For the entire section the whole suit of concentration dependent parameters (CDP's) (κ, isothermal remanent magnetisation (IRM), anhysteretic remanent magnetisation (ARM) as well as grain-size indicative parameters (e.g. S-parameter) and the anisotropy of κ (AMS) were determined. Here, we present the results of the κ, IRM, ARM measurements and the S-parameter. The ARM is widely accepted as a proxy for the concentration of single

domain (SD) magnetite grains. Its ratio to κ is used here as a proxy for the intensity of pedogenesis. In Fig. 7 the S-parameter, the CDP's and their interparametic ratios are plotted as a function of depth. From 18 down to 25 m the profile almost parallels the Tönchesberg site (profile B). The lowermost 2 m, however, probably represent a detailed record of latest Saalian to Eemian sediments. At least five interstadial paleosols can be recognised in the Middle to Upper Weichselian part of the profile.

Discussion

The Lower Pedocomplex consists of a strong Bt-horizon of a brown forest soil and two chernozems or forest-steppe horizons. The Upper Pedocomplex is characterized by two Bt horizons of brown forest soils and at least two chernozems and several horizons of humic rich reworked pedosediments. The Bt horizon of a brown forest soil ("Parabraunerde") is not an equivalent for a complete interglacial cycle. It is likely that forest soils occur during an interstadial of the Lower Weichselian (oxygene isotope stage 5c and 5a).

On the base of soil stratigraphy and chronological results, the Upper Pedocomplex can be correlated with the Lower Weichselian humic-rich horizons at section Tönchesberg (fig.8). At section Koblenz-Metternich, the interstadial soils of the Middle Weichselian record are much more detailed than at the Tönchesberg section. Due to the two intercalated pedocomplexes in Koblenz-Metternich, including three Bt horizons of brown forest soils and at least four chernozems, the stratigraphic position of the fluvial terrace (Lower Middle Terrace) designated to have formed during the penultimate glaciation, is under discussion. However, if the chronological results are taken into account the last interglacial/early glacial sequence, which is the equivalent of oxygen isotope stage 5, is much more complicated and detailed in the loess record of the Middle Rhine area than previously thought.

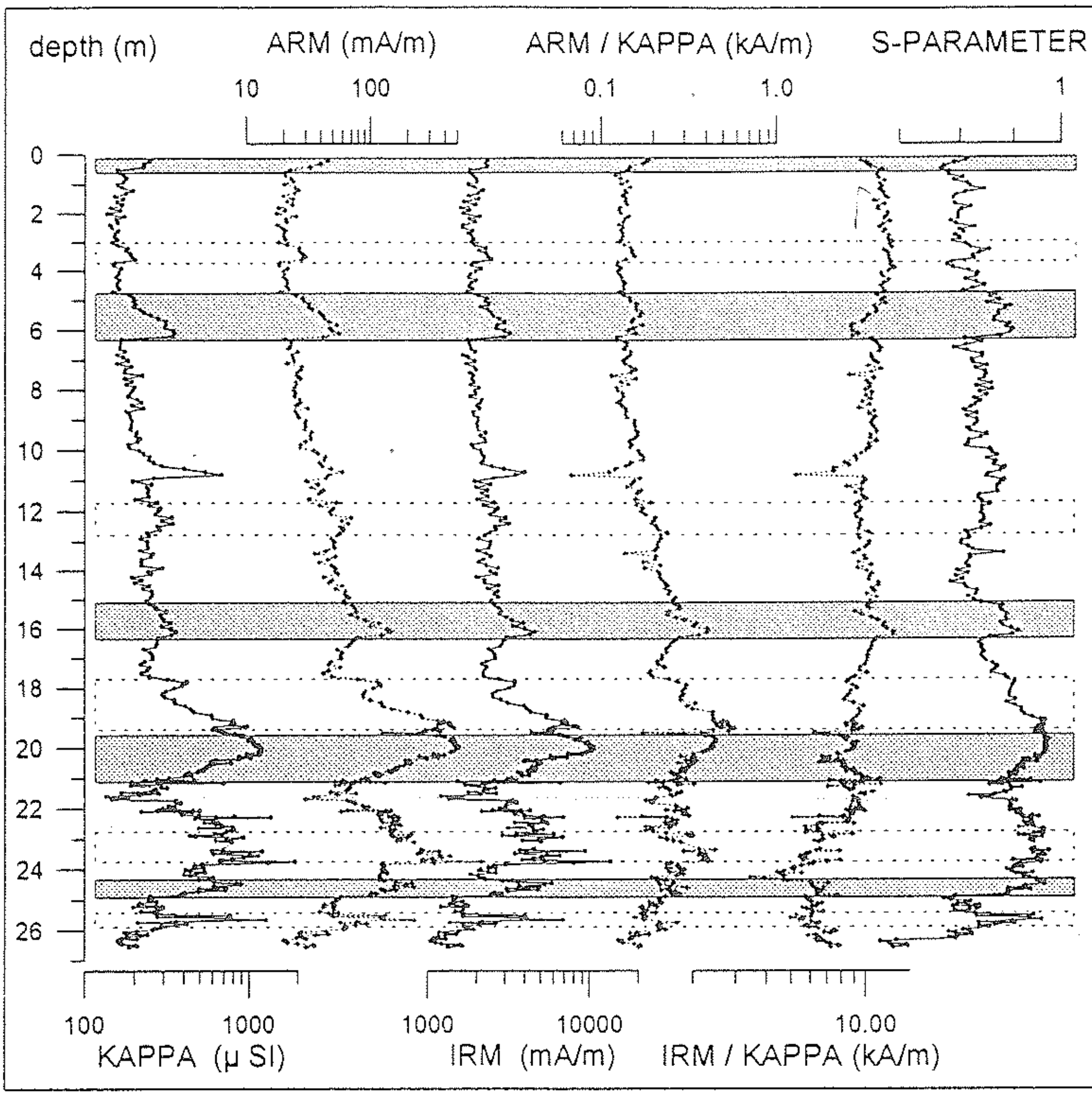

Fig. 7: Rock magnetic parameters at the site Koblenz-Metternich (profile A & B) plotted as a function of depth. Grey shaded horizons: paleosols which are already visible in the field. Horizons framed by dashed lines: evidence from rock magnetic parameters for in situ pedogenesis.

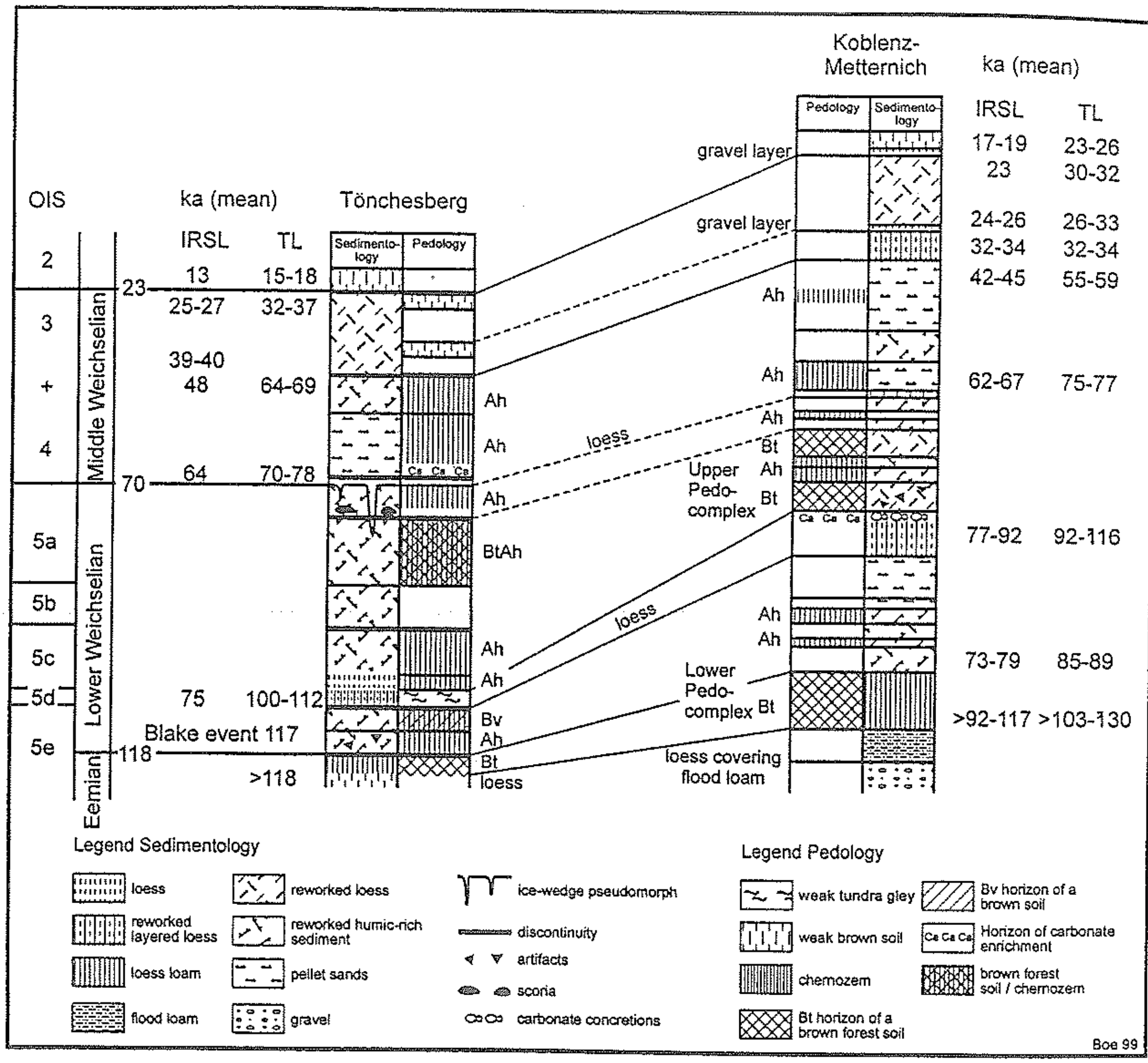

Fig. 8: Correlation of the loess/palaeosol sequence from the sections at Tönchesberg and Koblenz-Metternich (after FRECHEN, BOENIGK & HAMBACH in this volume) (Bt = clay-rich B horizon of brown forest soil; Ah = humic-rich A horizon).

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Stop 2: Koblenz-Metternich

Theme: **The loess-paleosol sequence (LPSS) from Koblenz-Metternich: Independent paleo- and rock magnetic dating approach identifies Dansgaard-Oeschger cycles (DOCS)**

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Methods

The Mettenich LPSS (river Rhine area, Germany) comprises the last glacial/interglacial cycle in a 27 m thick succession (BOENIGK et al. 1994). The lower 13.5 m were quasi-continuously sampled for paleo- and rock magnetic studies (~ 2.4 cm spacing). Sample recovery and preparation was conducted as outlined in REINDERS & HAMBACH (1995). Rock magnetic parameters (RMPS) were determined for at least every second sampling level. Measurements included the determination of concentration dependent parameters (CDPs): magnetic low-field susceptibility (κ), acquisition of isothermal and anhysteretic remanent magnetizations (IRMS, ARMS), and of parameters sensible to variations of magnetic grain-size (frequency dependent susceptibility, χ_{fd}), coercivity (alternating field demagnetization (AFD) of IRM and ARM, $S_{035} = (1 - IRM_{@0.35T"back\ field"} / IRM_{@2.4T})/2))$ and depositional environment (anisotropy of κ, (AMS)). IRMs of selected samples were thermally treated to identify mineral magnetic constituents. Paleomagnetic investigations comprise ca. 120 (ca. 1300) stepwise AFD (blanket 20mT-AFD) corresponding to a density of two paleofield determinations per sampling level.

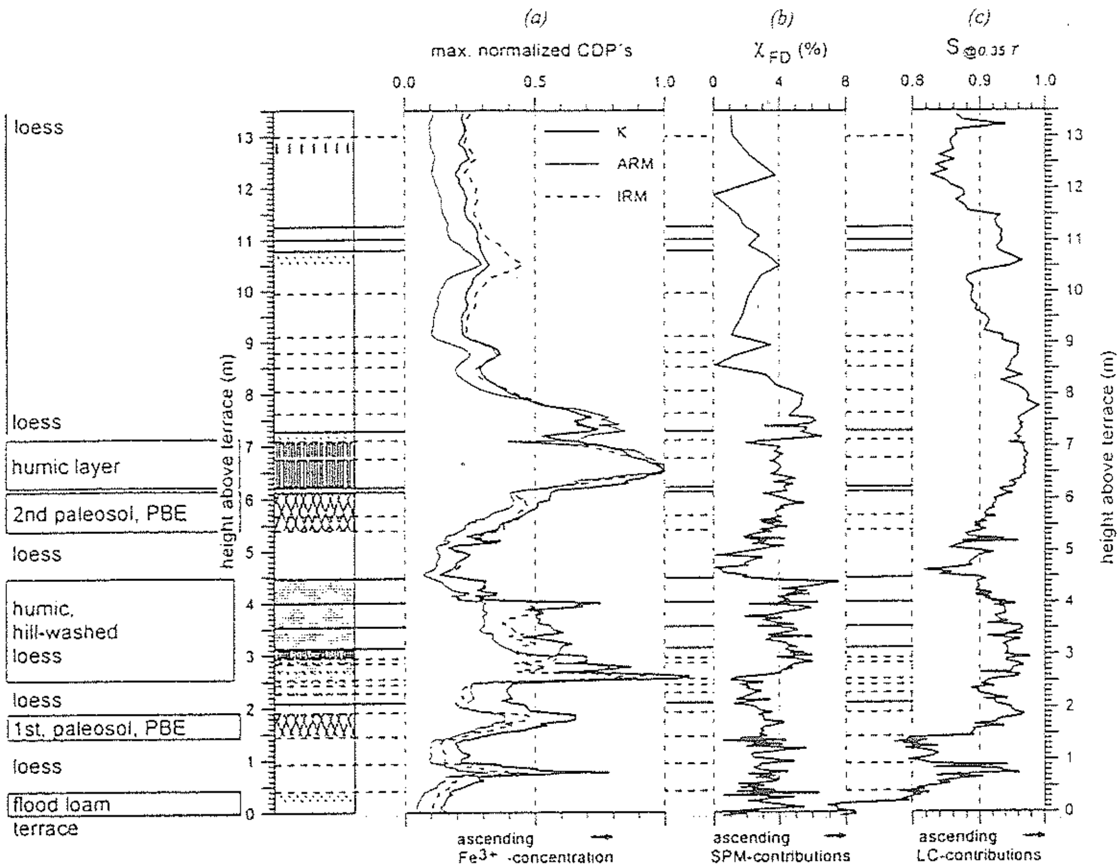

Figure 1: Height / stratigraphy dependence of RMPs. Left side: Stratigraphy after Boenigk et al. (1994). Horizontal bold lines: hiati, broken lines: facies changes. (a) CDPs normalized with respect to the pedogenic maximum. (b) χ_{fd} indicates relative contributions of super-paramagnetic (SPM) minerals (e.g. Heller & Evans 1995). (c) S_{035} decreases with ascending HC-contributions. It approaches unity for purely low coercive (LC) mineral assemblages.

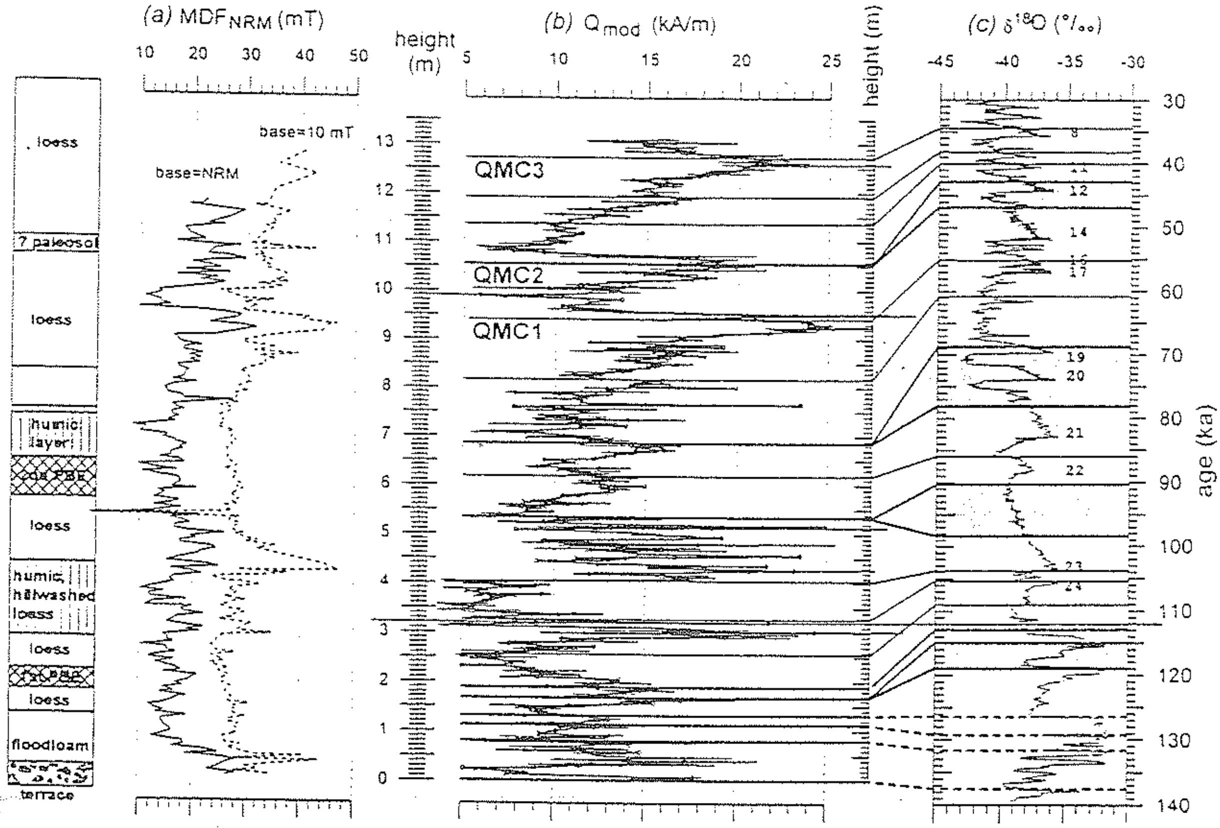

Figure 2: Geochronological approach. Left: revised lithology column. (a) Medium destructive field (MDF) of the NRM for different base values. (b) Q_{mod} smoothed in 2.5 cm intervals with standard deviation. (c) GRIP $\delta^{18}O$-data. Bold numbers: interstadials (IS) (Dansgaard et al. 1993). Proposed correlation of Q_{mod} and GRIP-record is indicated by tie lines between panels (b) and (c). Grey shades mark age intervals not represented at the Metternich section.

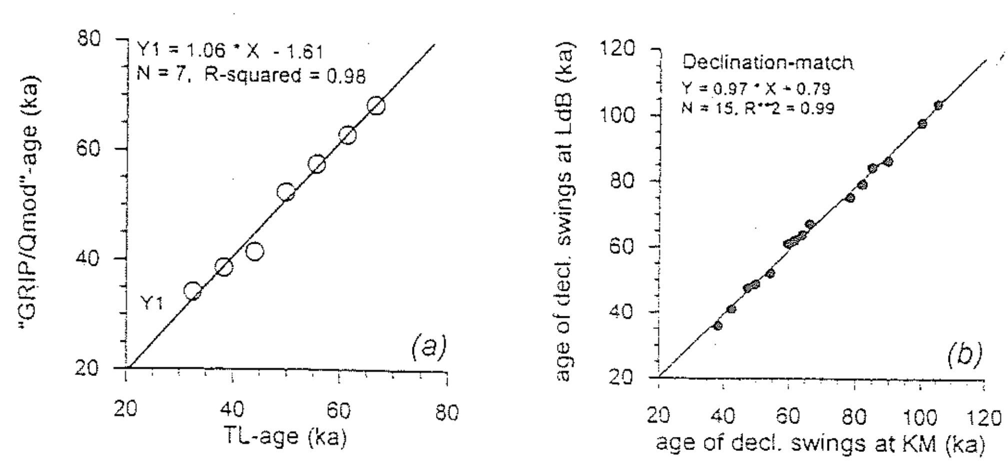

Figure 3: Evaluating GRIP-Q_{mod} ages using (a) TL-data, (b) "secular variation stratigraphy".

Rock magnetic investigations

Thermal IRM-demagnetizations identify only maghemite clearly, but suggest that hematite contributes to the high-coercive (HC) fraction. Magnetite and titano-magnetites/-maghemites may be present, but the evidences are weak. Obviously, an expected primary, authigenic magnetite fraction related to pedogenetic processes (e.g. HELLER & EVANS 1995) did not survive early diagenesis in large amounts, but was oxidized to maghemite/ hematite. Despite this diagenetic influence, the results of rock magnetic investigations suggest a long term paleoclimatic control of magnetic mineral concentration and grain-size assemblage by high (low) values of CDPs, magnetic grain-size- and coercivity- proxies in the paleosols (loesses) (fig.1). Short term, small scale variations of RMPs resolve facies changes and hiati proposed by BOENIGK et al. (1994) remarkably well. This observation and an integrative multi-parameter approach (including interparametric ratios, AMS, IRM coercivity fractions) which was applied to access the duration - time/depth-relation - of diagenesis and its implications for short term environmental changes suggest that 1. the intensity of diagenetic processes was controlled by the intensity of pedogenesis (hence, paleoclimate), and 2. that diagenetic processes did not reach far into the sediment column under normal conditions (outside the parabraunerde paleosols (PDEs) (REINDERS 1999).

Paleomagnetic investigations

The ratio of the NRM-intensity with κ, ($Q_{mod} = NRM_{@20mT}/\kappa$, but also $NRM_{@20mT}$/(ARM, IRM)) displays saw-tooth patterns in the upper loess (7 - 13 m, fig. 2 (b)). The course of these Q_{mod}-cycles (QMCs) is characterized by increasing ratios with ascending height, prior to the drastic decrease. Peak values are accompanied by local maxima of the MDF (figure 2 (a)) indicating that the NRM-intensity is controlled by magneto-mineralogical changes, hence by paleoclimate, and not by the strength of the Earth's magnetic field (EMF). These ratios were correlated to the GRIP δ^{18} O record, which reflects European paleoclimate (THOUVENY et al. 1994), under the premise that peaks of the QMCs are related to moister climates (REINDERS in prep.). IS 12 is not represented because: 1. The rock magnetic signature at ca. 10.5 m points to a paleosol. QMC2 was consequently tied to IS 14. 2. Accumulation rates do not vary by far more than one order of magnitude under comparable environmental conditions, leading to the correlation QMC3 - IS8, the youngest relatively long lasting DOC. The same argument holds for the correlation of QMC1-IS 17. The age model is consistent with thermoluminescence (TL) ages (FRECHEN et al. 1995, fig. 3(a)) up to 70 ka B.P.

corroborating the inference that NRM-normalizations describe an in-situ signal and reflect rapid climate variations - DOCs. The correlation of high Q_{mod}-values with moister climates was then speculatively expanded to the lower part of the section (h < 7.0 m), where luminescence methods rapidly approach their limits (FRECHEN et al. 1995). This part of the chronology was evaluated using the Lac du Bouchet paleofield record (LdB-PFR, THOUVENY et al. 1990, scaled after THOUVENY et al. 1994) and the Metternich-PFR (KM-PFR) which was acquired as a depositional remanent magnetization. It was preserved, despite being partly affected by diagenesis. Reversals of the EMF proposed for the last 140 ka are not recorded, because they tend to occur within those time intervals seldom represented in terrestrial sediments, rather than because of their short duration (REINDERS 1999). The declination-series of the KM-PFR closely resembles the LdB declination. The ages of contemporary characteristic declination swings (defined by amplitude and duration) deviate by 3.2 kyr at the most (fig. 3(b) and allow to extend the chronology back to 100 ka B.P.

Conclusions

A direct correlation of RMPs to the paleoclimate trend ("susceptibility dating") can be misleading, because in-situ signals cannot be discriminated. Diagenesis related to pedogenetic processes affect primary magnetic minerals, but they do usually reach not deep into the sediment column. The paleomagnetic record at the Metternich site reflects in-situ acquisition of an independent signal (declination) which is not erased during diagenesis but merely stabilized (enhanced coercivity) by the oxidization of part of the remanence carrying magnetic mineral fraction. Normalizations of the NRM-intensity with respect to CDPs hence do not primarily mirror paleointensity fluctuations of the EMF but paleoclimate. They can be used to date the Metternich-LPSS, which is characterized by episodic accumulation (rates between 6 cm/kyr and 50 cm/kyr). The significance of the GRIP δ^{18} O-record for European paleoclimatic variations is corroborated by the results of this study.

Acknowledgements

GRIP-data provided by NSIDC, University of Colorado, and WDC-A for Paleoclimatology, NGDC Boulder, Colorado. The LDB-PFR was kindly provided by N. Thouveny (Marseille).

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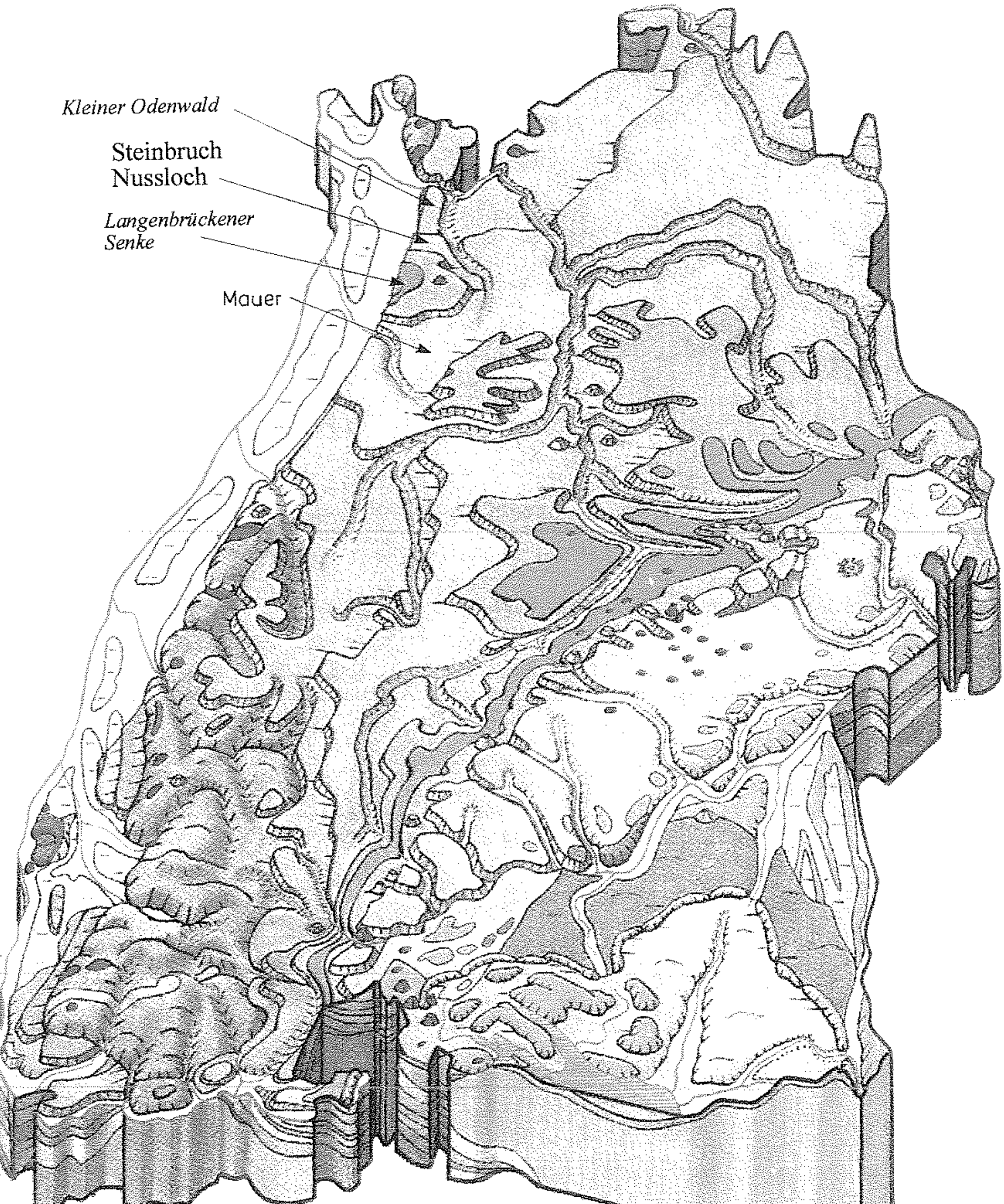
SECOND EXCURSION: March 26 - 27 1999


Kleiner Odenwald
Steinbruch
Nussloch
Langenbrückener
Senke
Mauer

SECOND EXCURSION: March 26 - 27 1999

Stop 1: **Nussloch**

Theme: **The last glacial-interglacial cycle in the loess section at Nussloch and underlying upper Tertiary loams**

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The Nussloch section is located in a limestone quarry (Heidelberger Zement AG) 10 km south of Heidelberg and 3 km east of the Upper Rhine Graben, in the northeastern part of the Kraichgau rolling land, Germany, at 49°19'N - 8°43'E and 217m asl. The basement of the loess consists of Middle Triassic limestone and dolomite ("Muschelkalk"). The stratigraphy of the last glacial-interglacial cycle is stacked from two sections within the quarry. The main section comprises 16 m thick loess from MIS 3 und 2 and is seperated from the underlying interglacial soil remnants by a major hiatus. The second section adds 4 m of loess and loam till the bottom of the MIS 5 pedocomplex. Similar loess sections in the quarry were studied previously[1]. In the past few years new exposures with more detailed records of the last glacial-interglacial cycle were created in the quarry due to the strong activities of the operating company. The new exposures have been carefully studied by the authors in co-operation with members of the BIMACEL project (Biological and Magnetic records and dating of climatic Changes in western European Loess series, co-ordinator Dr. D.-D. Rousseau, Montpellier, project EV5V-0298, program Environment of the EU) and Dr. U. Hambach & J. Reinders, (Geology Dept., Univ. of Cologne). As the research is still going on we presently cannot give final interpretations.

The oldest palaeosol exposed is a (sub)tropical red loam covered by yellowish loams with pi-solithic iron concretions ("Bohnerzlehme"). The latter are widespread relict soil sediments in

[1] BENTE & LÖSCHER (1987), ZÖLLER et al. (1988), ZÖLLER (1995)

the Kraichgau rolling land and are supposed to be of middle Pliocene age, the red loam may date back to the Upper Miocene[2]. The red loam contains more clay (ca 40%) than the "Bohnerzlehm" (ca 25%), the dominant clay mineral of the red loam is kaolinite, illite is hardly detectable despite its predominance (besides quartz) in the unweathered limestone. The heavy mineral composition consists mainly of zircon, rutile and turmaline with minor contents of anatas and brookite. In the upper part of the "Bohnerzlehm" additional contents of garnet, epidote and green amphiboles point to admixture from Pleistocene sediments. The iron content in the red loam (ca. 7%) is considerably higher than in the "Bohnerzlehm" (ca. 2%, without concretions >60 µm). The older landscape evolution in the area is summarised in table 1.

Table 1 Most important geomorphogenetic and sedimentologic-pedogenetic phases in the Kraichgau area since the upper Miocene[3]

Age (ma)	**Epoche**	**climate**	**Morphogenesis**	**formation of soils and sediments**
0 2.4	Pleistocene	Pleistocene glacials and interglacials	Loess landscape, increasing dissection due to	loess sedimentation and palaeosols
3.5	Upper Pliocene		Continued uplift	erosion of tertiary cover sediments
4.5	Middle Pliocene	semi-arid	First uplift, wide terraces, subsidence of the eastern Upper Rhine Graben	erosion/reworking of red loams, *Bohnerzlehme*, pisolites in graben sediments
5	Lower Pliocene	*drying out to*	Lowland character in the Kraichgau area	coarse sediments spread over Kraichgau plain
	Upper Miocene	semi-humid(?)	"equilibrium plain" from upper Rhine graben sediments to Keuper hills	red loam on plain over middle Triassic limestone

[2] EITEL (1996); only very recently M. Löscher found silicified trochites in the red loam. They originate from the crinoide limestone in the Upper Muschelkalk, the nearest outcrops of which are found at a distance of 500 m from the exposure. These observations point to a more or less sedimentary origin of the red loam (soil sediment).
[3] after EITEL (1996), table 1, p 130

The tertiary loams are best preserved in karstic depressions and sometimes overlain by a loess loam resembling the lower Pleistocene "Riesenböden"[4], thick and intensively weathered lessivé-pseudogleys. The next younger sediments, a sequence of alluvial and aeolian sand alternating with sandy loess and loess are supposed to have been deposited during the upper Rissian (MIS 6) as suggested by TL dating[5] and aminostratigraphy[6]. Therefore, the up to 2 m thick and sometimes two-fold fBt-horizon at the top of this sequence is assigned to the last interglacial (MIS 5), but at present it cannot be precluded that the lower part of the fBt developed already during the Rissian late glacial period.

Unlike in the more northern Rhein-Main area with its up to three "Mosbach humus zones"[7] only one dark brown humus zone is developed in the lower Würmian part of the Nussloch section. Instead, a grey-brown up to 60 cm thick decalcified horizon interpreted as a boreal forest soil is intercalated between the fBt and the humus zone, which is decalcified in its major lower part but contains some carbonate and loess snails in its upper part (fig. 1). We suggest that this boundary marks the MIS 5/4 transition. It is covered by a calcareous greyish-brown loess and a weak humic gley labelled "Nussloch soil"[8].

Younger parts of the profile were preserved at this locality but have partly been stripped off recently to enlarge the quarry. The stratigraphy is still most complete up to the "Lohne soil", an arctic brownearth terminating the Middle Würmian. Between the Gräselberg soil (a weak brown soil with tundra-gley features and termitating the formation of a loess and sand ridge) and the Lohne soil the formation of a topographic depression (presumably initiated by the migration of the axis of a karstic hollow mould) led to very strong abluation from the sandy loess and sand ridge. In the hollow mould terrific fossil thermokarst features are visible. Temporary water fill of permafrost cracks widened by thermokarst during retreat of the permafrost is witnessed by mud layers and gleyification of underlying strata. A 1 m long column taken out of humous waterlain sediments in the centre of the thermokarst hollow documented a climatic oscillation from an arctic environment to interstadial and back to arctic conditions. Macrofossils of wood extracted from the interstadial layers are subjected to AMS-^{14}C-dating, a first result is 31.8±3.7 ka BP[9].

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[4] BRUNNACKER (1964, 1982)
[5] ZÖLLER et al. (1988)
[6] GNIESER (1997)
[7] SEMMEL (1974, 1989)
[8] ZÖLLER (1995)
[9] HATTÉ et al. (1998)

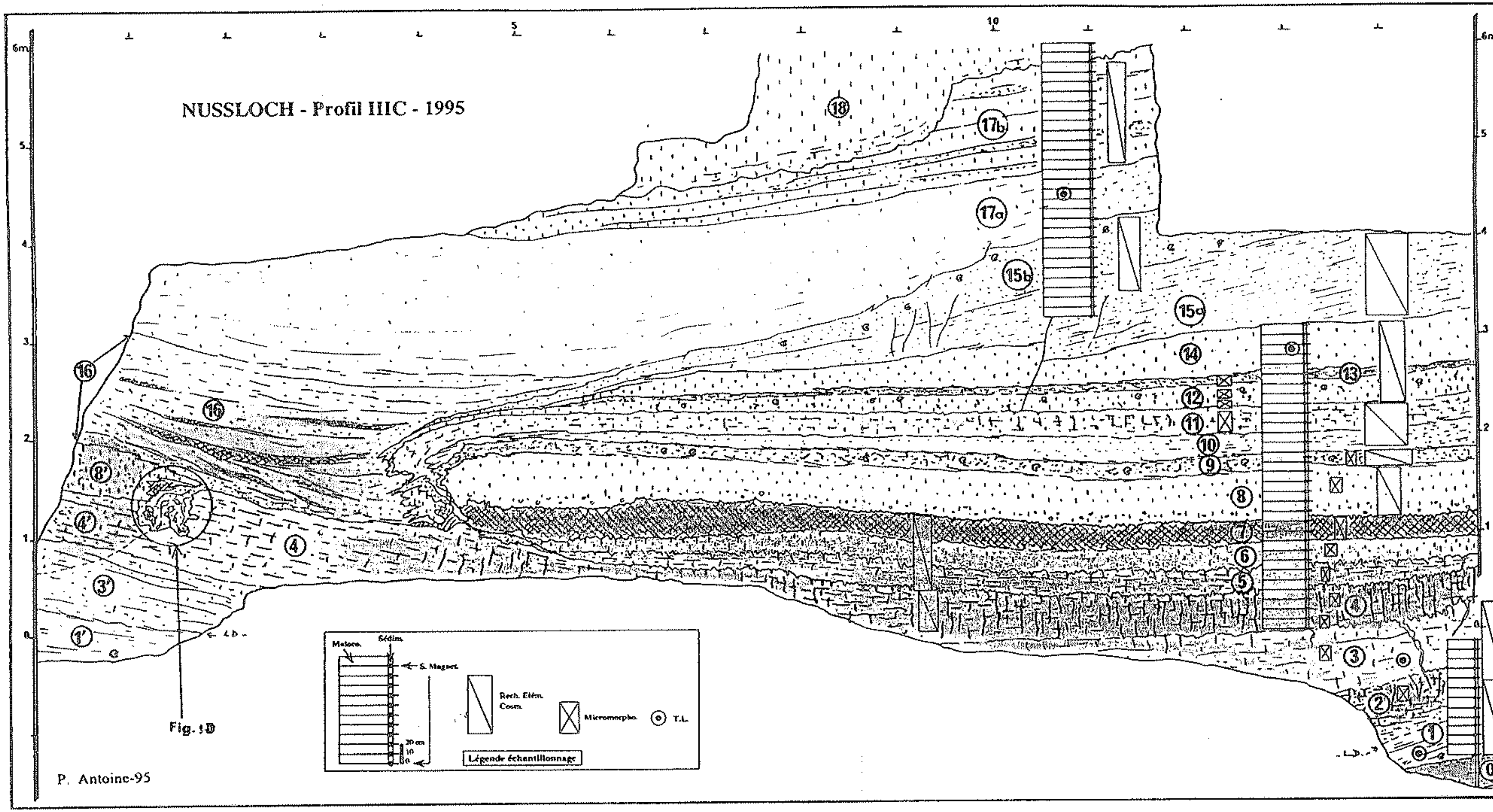

Fig. 1: Stratigraphy of the last glacial-interglacial cycle at Nussloch (lower part) after Antoine

Fig. 1: Stratigraphy of the last glacial-interglacial cycle at Nussloch (lower part) after Antoine

0: reworked Tertiary sandy loam with pisolites, 1: sandy loess, 1': hydromorphic facies of 1, 2: Bt-horizon of a para-brownearth, 3: sandy-clayey loam, greyish-brown, banded, 4: Bt-horizon of a para-brownearth, 4': hydromorphic facies of 4, 5: grey forest soil from colluvium, affected by frost action, 6: brwon-grey loam, pieces of charcoal, 7:clayey calcareous humus zone, 8: greyish-brown loess, 8': greyish-green hydromorphic facies of 8, 9: tundragley ("Nussloch soil"), 10: calcareous loess, 11: brownish sandy loess, 12: calcareous loess, 13: gleyed horizon on top of 12, 14: light grey-brown calcareous loess, more sandy towards the top, 15a: loamy middle sand, 15b: weak interstadial soil (?) from middle sand, 16: sequence of stratified loamy-sandy layers and organic interstratifications, thermokarst features at the base, 17a: calcareous sandy loess, 17b: calcareous hydromorphic loess, grey-green to grey-blue, 18: light-brown loess.

Nussloch 95-96, Stratigraphy (P1-P2-P3)

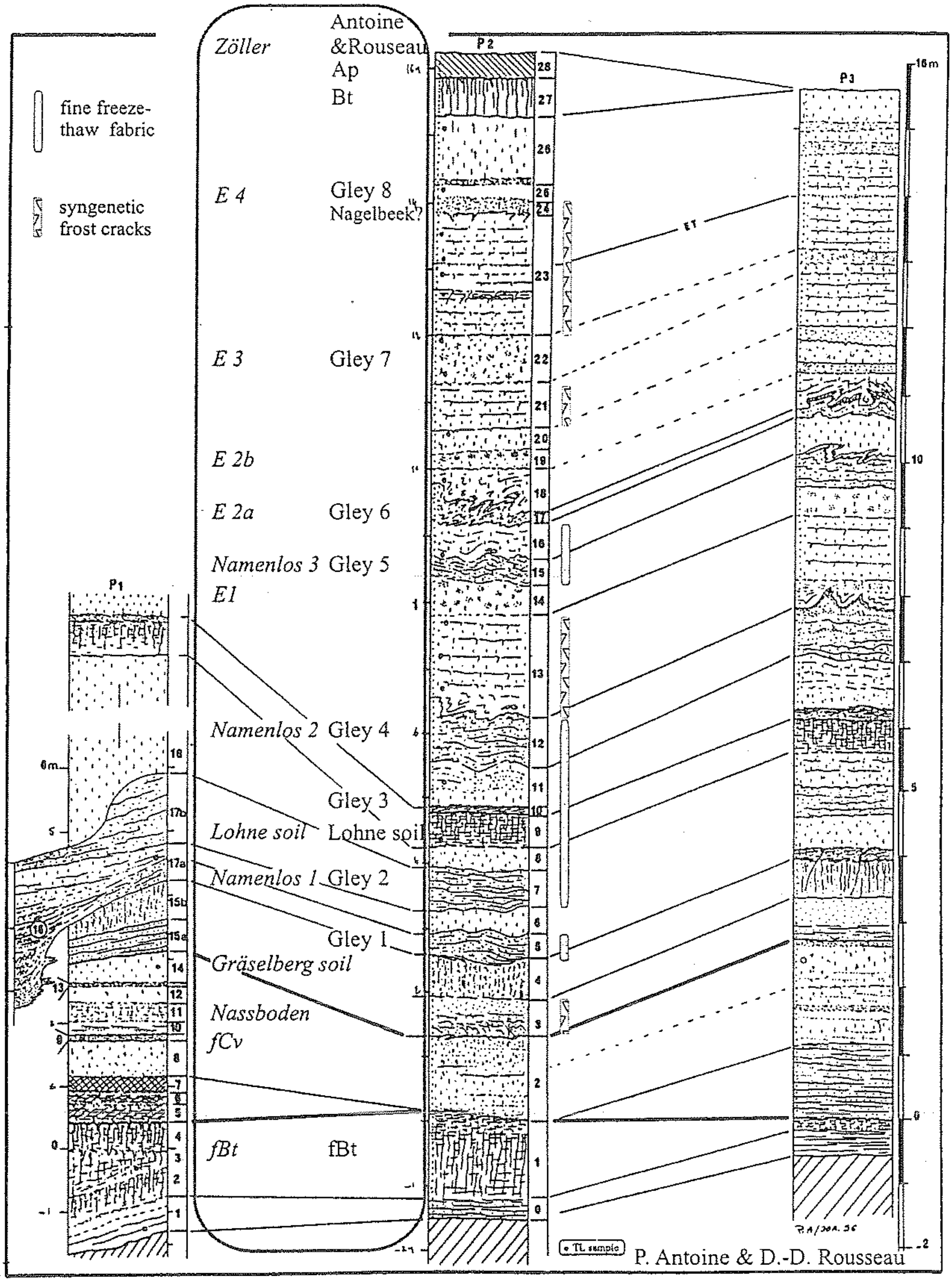

Fig. 2 : Stratigraphy of the last glacial-interglacial cycle at Nussloch (upper part) after Antoine & Rousseau and correlative terminology after Zöller.

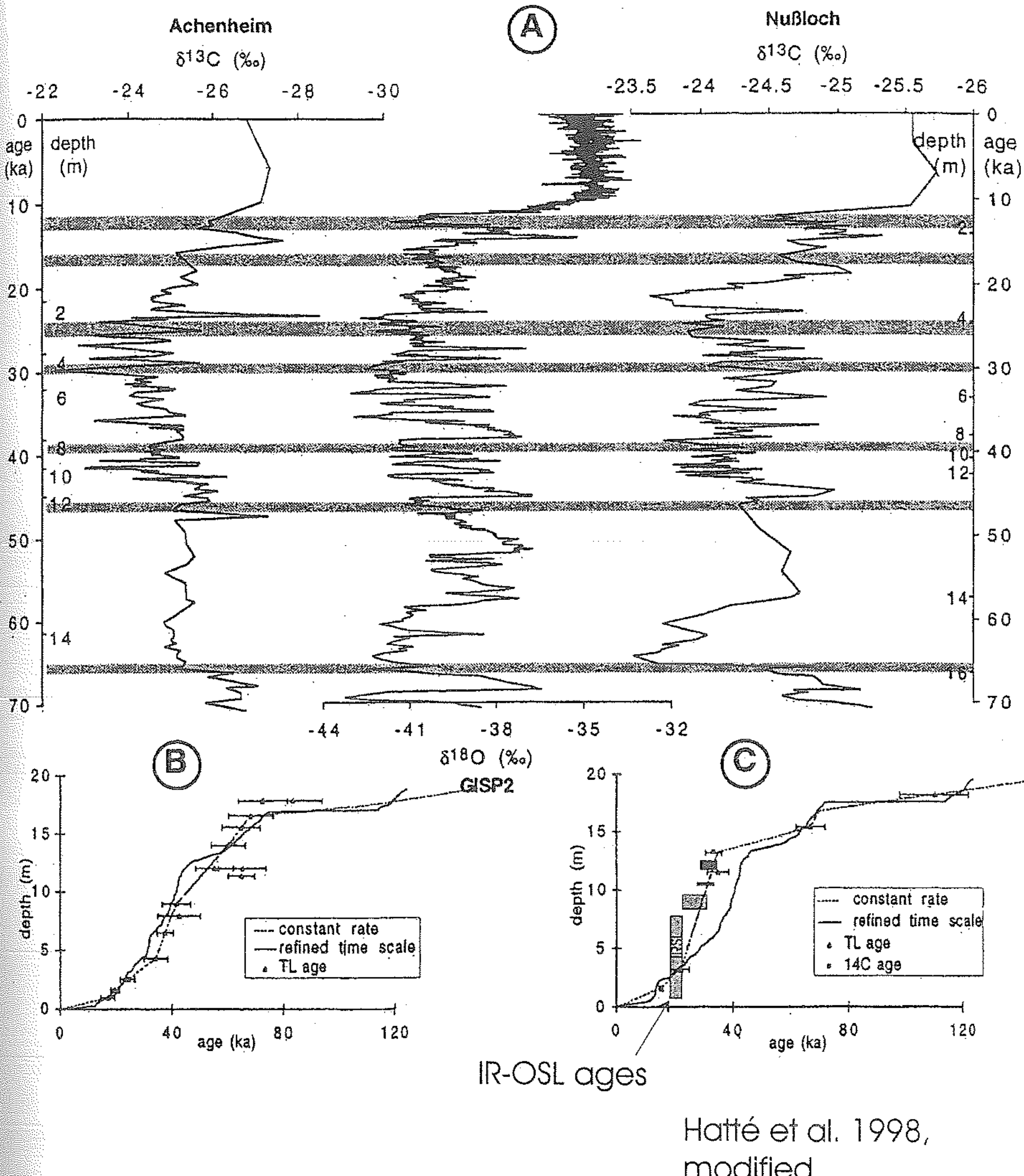

Fig. 3: Suggested correlation of loess stratigraphy at Nussloch and Achenheim (Alsace) with the Greenland ice (GISP2) record, based on $\delta^{13}C$ measurements of organic matter in loess (from Hatté et al.,1998), and TL/IR-OSL age limits plotted in the graph.

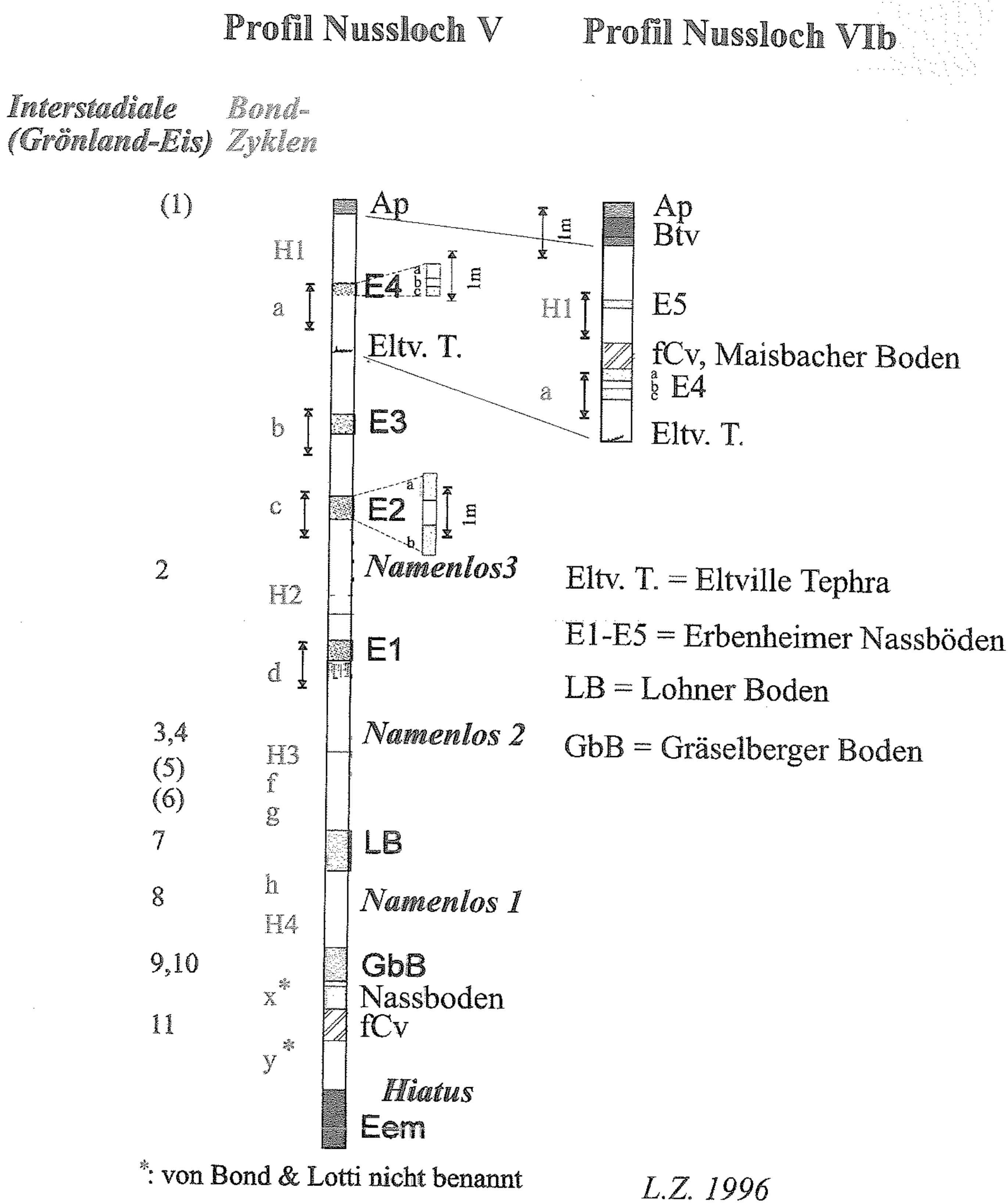

Fig. 4: Suggested correlation of loess stratigraphy at Nussloch with North Atlantic Bond cycles and Greenland ice interstadials for the past 50 ka, based on organic matter contents, magnetic susceptibility and TL/IR-OSL ages (Zöller, unpublished).

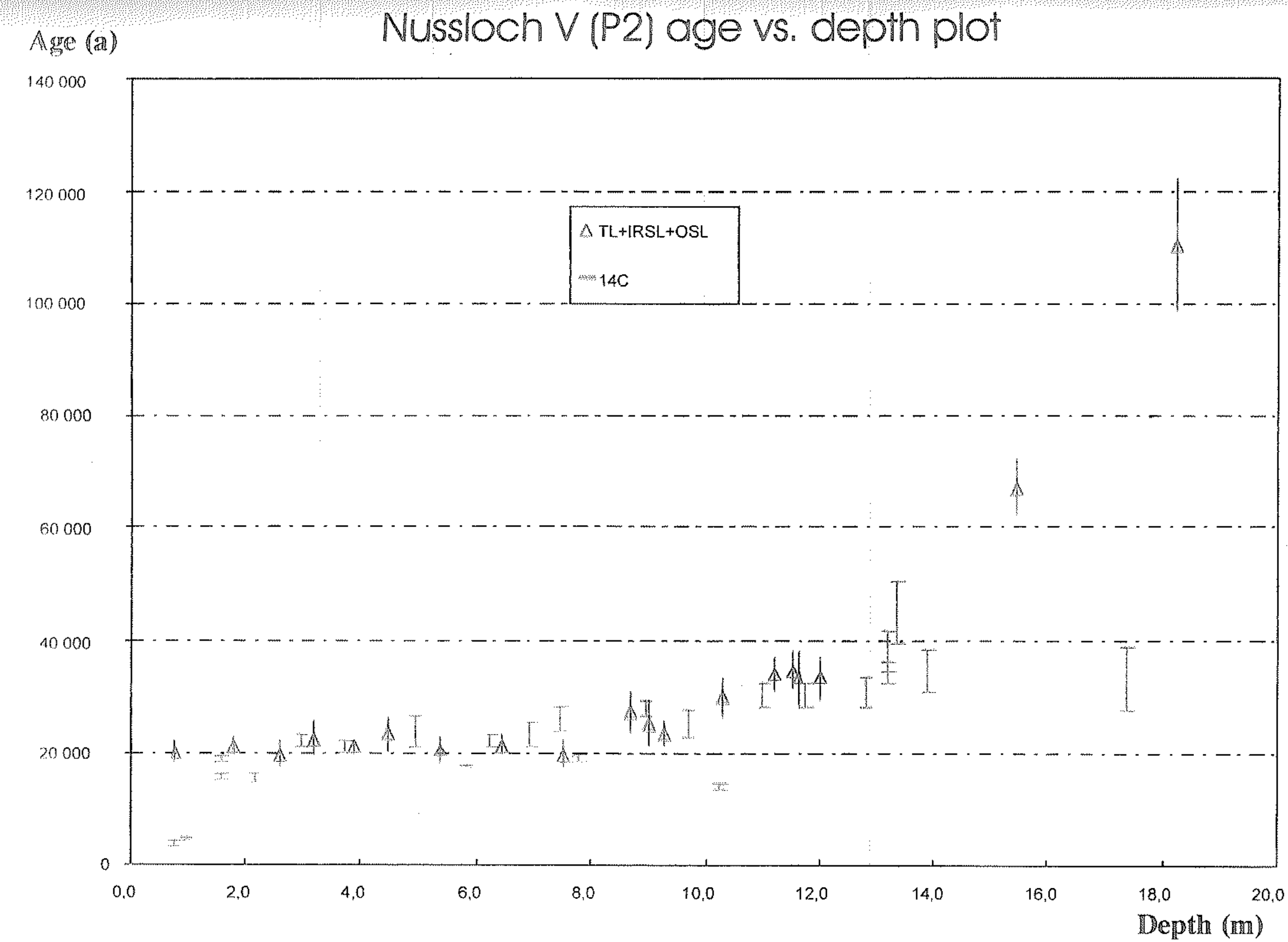

Fig. 5: Age (TL/IR-OSL and ^{14}C-AMS ages) versus depth plot for the loess section at Nussloch (HATTÉ, unpublished and LANG, unpublished).

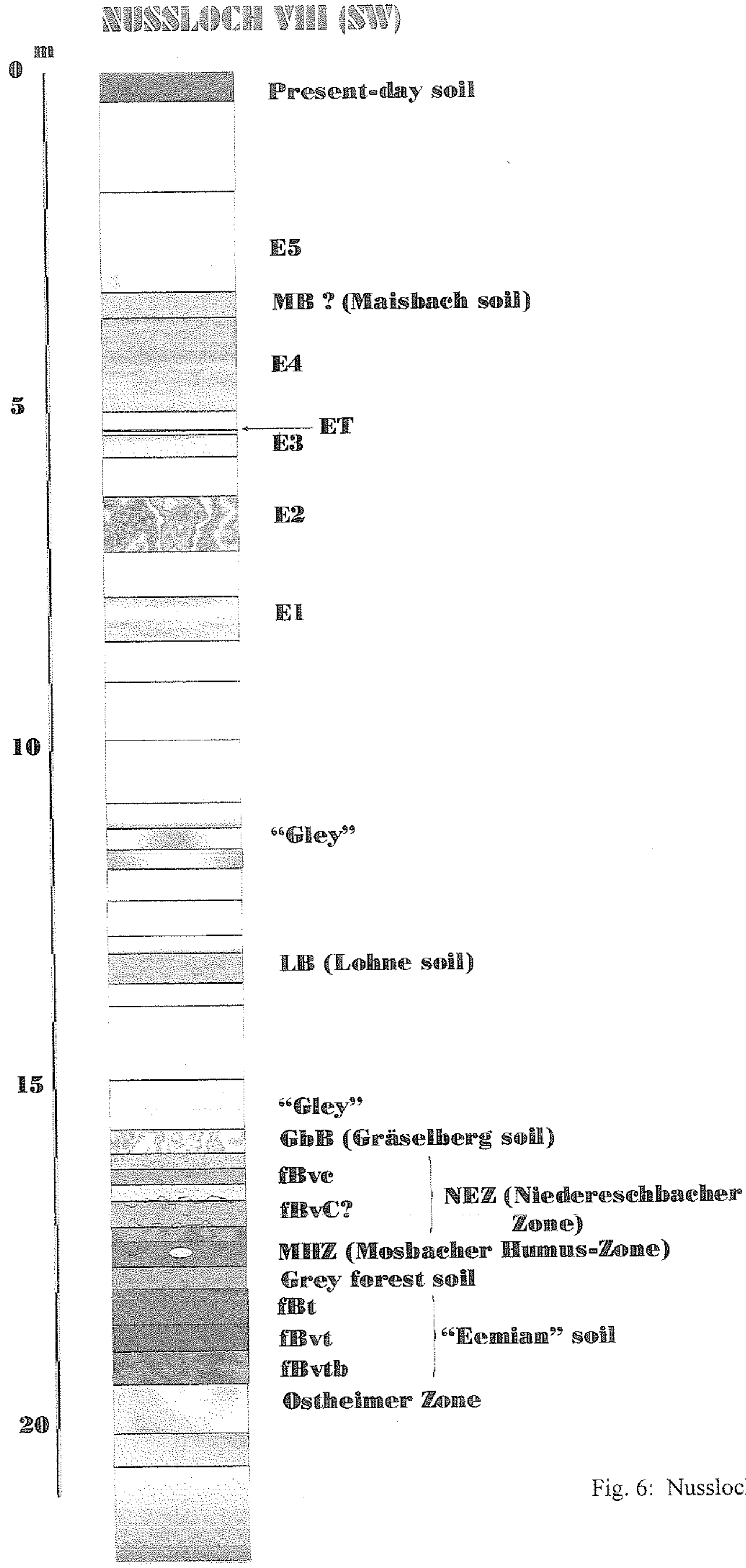

Fig. 6: Nussloch VIII

In the second section which best exposes the upper Würmian loess the stratigraphy overlaps with the previously described one. The fBt is partly eroded due to the regionally well-known cryogenic geomorphodynamics of the "Niedereschbach" zone[10] (NEZ). All overlying layers including the Nussloch soil were stripped off as well, but remnants of the lower Würmian humus zone can sometimes still be seen. It is obvious in this part of this section that the NEZ is present in its typical denudative facies as well as in a sandy aeolian facies of predominant accumulation. The upper Würmian loess is preserved in an extraordinary complete stratigraphy (fig. 2). The reason is that the Lohne soil forms the nearly horizontal basement of a *greda* ("loess dune"). The profile includes the basaltic "Eltville tephra" (previously labelled Eltville tuff[11]), which in one place in the leeside of the greda is even doubled as could be confirmed by magnetic susceptibility measurements[12]. The tephra was deposited during the LGM. The "classic" regional loess stratigraphy of the last glacial[13] can be extended by tundra-gley like and by weak brownish soils. In particular, a previously not seen weak brown soil now labelled "Maisbach soil" and a diffuse tundra-gley like "Nassboden" on top of the Maisbach soil labelled E5 in accordance to E1-E4[14] are only developed in a loess sheet in the leeside of the greda. AMS-^{14}C-dating of loess snails from this youngest loess yielded an age of 15.3±0.5 ka cal BP[15]. The finds show that during the geomorphic built-up of the greda by aeolian sedimentation in its centre and contemporary gelisolifluctive destruction at its margins the most complete loess stratigraphy was recorded in the centre of the greda. About at the time of the Eltville tephra eruption the loess landscape got stabilised, however ("persistance"[16]), and since then loess sheets were preferably deposited in leeside positions. Thus, the most complete stratigraphy of loess younger than the LGM is found in a different geomorphic position.

The chronology of the stacked Nussloch loess section relies on TL/IR-OSL dates[17] and AMS-^{14}C-dates from loess snails[18], from wood and from organic matter[19]. Based on available

[10] SEMMEL (1974, 1989)
[11] SEMMEL (1974, 1989)
[12] kindly supplied by Dr. Liping Zhou, Univ. of Cambridge, GB, in June 1997
[13] SEMMEL (1974, 1989)
[14] SEMMEL (1974, 1989), see also BENTE & LÖSCHER (1987)
[15] HATTÉ et al. (1998)
[16] BRUNSDEN (1993)
[17] ZÖLLER (1995), ZÖLLER et al. (1988), LANG (unpublished)
[18] ZÖLLER (1995), HATTÉ et al. (1998)
[19] HATTÉ (unpublished)

chronometric data high resolution correlations with long palaeoclimatic records of the last glacial cycle, in particular with the GISP2 Greenland-ice record, are developed now. One approach uses $\delta^{13}C$-values measured from the organic carbon fraction of numerous loess samples and tries to establish a detailed chronology by clipping and stretching of the record between the chronological marks and from correlation with GISP2 ice $\delta^{18}O$ record[20] (fig. 3). Another approach compares the organic carbon content and magnetic parameters (ARM/κ) curves from the refined stratigraphy at Nussloch with the high resolution north Atlantic palaeoclimatic and palaeooceanographic records, which are well correlated with Greenland ice cores (GRIP and GISP2)[21]. Results obtained so far are plotted in fig. 4.[22] The suggested correlation is to be extended backwards to the last interglacial when all data (including high resolution malacolological data) which are presently in work will be available. New IR-OSL[23] (fig. 3 and 5) and ^{14}C-AMS dating results[24] suggest, however, some modifications of the chronology proposed previously. According to these new dating results, up to 8 m of loess was deposited during the LGM (ca. 20 ka) in a time period too short to be further resolved by OSL and ^{14}C-AMS dating techniques.

To summarise, the stacked Nussloch loess section appears well-suited to demonstrate that high resolution palaeoclimatic and palaeoecological information can equally be obtained from loess records as from other long records.

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Stop 1: Nussloch

Theme: **Rock magnetism**

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Rock magnetism is a powerful tool for the characterisation of sedimentary environments. The applied techniques are relatively rapid, simple, sensitive, non-destructive and inexpensive. In the last years significant progress was achieved in using rock magnetic parameters as proxies for provenance, depositional and postdepositional processes, paleoclimatic variations, etc. (e.g. DEKKERS 1997).

Loess-palesol sequences (LPSS) comprise alternating successions of palesols in loess. The paleosols were formed under wetter and warmer climatic conditions and are characterised by the enhancement of magnetic minerals. Hence, magnetic low-field susceptibility (κ, KAPPA) may serve as a climatic proxy and its course with depth allows for the correlation of LPSS with the marine oxygen isotope record. The main source for the magnetic signal in paleosols is thought to be the increased concentration and activity of magnetite (Fe_3O_4) producing bacteria (e.g. HELLER & EVANS 1995). However, this primary magnetite fraction is subjected to various alteration processes and may oxidise in whole or in part during early diagenesis to maghemite (γ-Fe_3O_4) and/or hematite (α-Fe_3O_4) (REINDERS et al. 1999).

At the site Nußloch, profile V (compare HATTÉ et al. 1998, ZÖLLER 1995) was sampled for rock magnetic (10 cm spacing) and palaeomagnetic (2.4 cm spacing) investigations. For the entire section the whole suit of concentration dependent parameters (CDP's) (κ, isothermal remanent magnetisation (IRM), anhysteretic remanent magnetisation (ARM)) as well as grain-size indicative parameters (e.g. S-parameter) were determined. Here, we present the results of the κ, IRM, ARM measurements and the S-parameter. The ARM is widely accepted as a proxy for the concentration of single domain (SD) magnetite grains. Its ratio to κ is used here as a proxy for the intensity of pedogenesis. In Fig. 1 the S-parameter, the CDP's and their interparametic ratios are plotted as a function of depth.

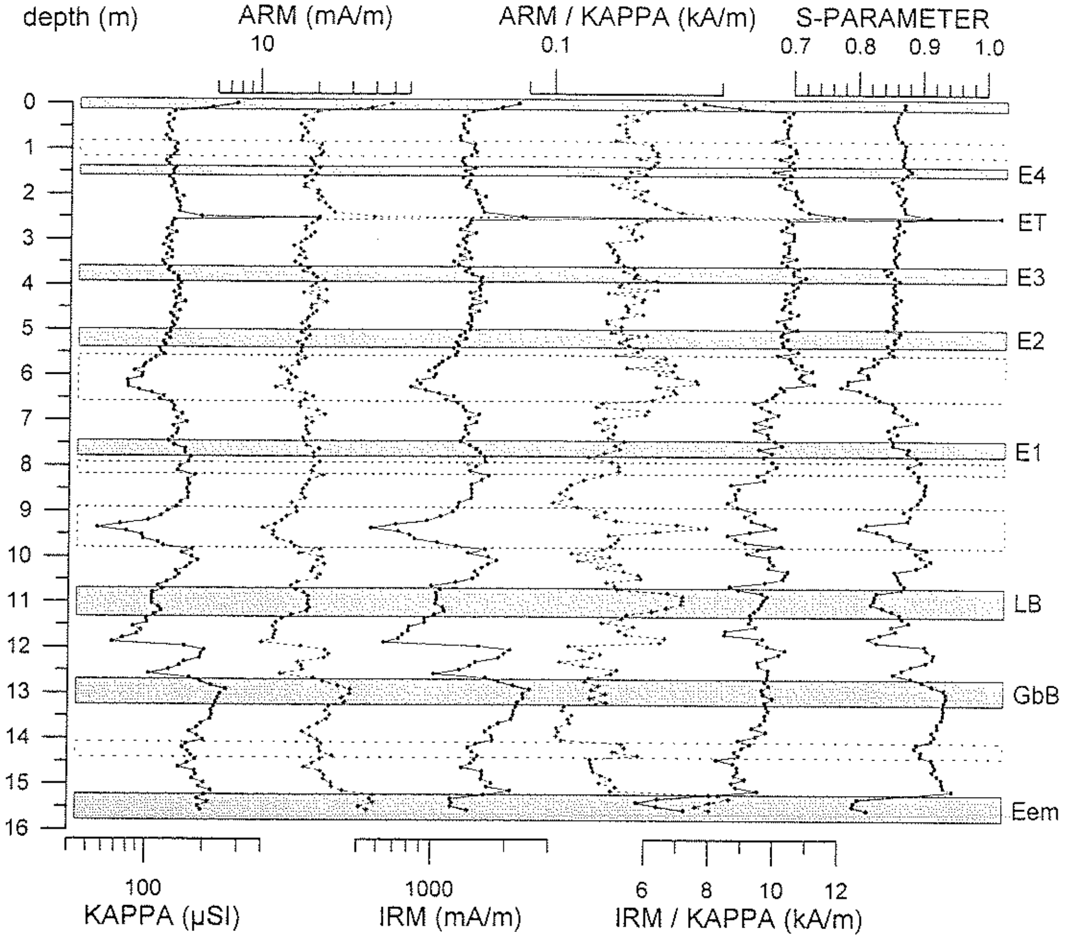

Fig. 1: Rock magnetic parameters at the site Nußloch (profile V) plotted as a function of depth. Grey shaded horizons: paleosols which are already visible in the field. Horizons framed by dashed lines: evidence from rock magnetic parameters for in situ pedogenesis.

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Stop 2: Mauer

Theme: **The palaeolithic site of Mauer**

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In 1907 the mandible of *Homo heidelbergensis* was found in sandy deposits in a former meander of the River Neckar at the Mauer site (sand pit "Im Grafenrain"). At that time it was the oldest human fossil known in the world, estimated 500 ka old. Until recently it was still believed to be the oldest human fossil in Europe, but in 1994 human remains older than the Matuyama/Brunhes geomagnetic reversal (778 ka) were detected in Atapuerca (Burgos, Spain).

Since the pit "Im Grafenrain" was abandoned in 1962, no stratigraphic research using modern methods was carried out there for decades. With a remarkable amount of man-power, mainly by Dr. Manfred Löscher and advanced scholars of his geology courses at the Gymnasium Sandhausen, three profiles (A and B at the eastern side and N at the northern side) exposed the sediments covering the "Mauer sand" (fig. 1, upper part). In December 1989 and April 1990 the fluvial sediments were dredged at profile B below the "upper Mauer sand to a depth of 5.5 m below the actual floor of the pit (fig. 1, section "Baggerloch" in the middle). The hole exposed the "lower Mauer sand" including the horizon in which the human jawbone was found. Below the Mauer sand lies a very dense, decalcified clay continuing below the dredgehole. In 1991 two drillings were cored down to the basement of the Quaternary sediments, which for the first time could be studied in their complete stratigraphic sequence. Borehole II was situated next to the dredgehole and, under the thick clay and silt exposed decalcified gravel overlying calcareous gravel. The latter rests on Middle Triassic limestone at a depth of 13.5 m below the present surface. Borehole II was drilled 115 m southwest of the dredgehole near the small shelter. It exposed alternating calcareous and decalcified oxbow sediments over sand with gravel, which rests on Middle Triassic limestone at a depth of 16 m below the present surface. Altogether, the thickness of the Quaternary sediments at the Mauer site amounts to almost 50 m.

Stratigraphy:

At first sections A and B, although at a horizontal distance of less than 30 m, could not be easily correlated due to erosional unconformities. The two-fold meander cut-off of the Neckar – first at Wiesenbach, later at Neckargemünd – had increased the relief and caused repeated phases of strong erosion in the non-consolidated fluvial and aeolian sediments. Only with the help of TL dating we were able to correlate sections A, B and N.

In section A the last glacial loess is 4 m thick and includes two buried brown initial Bw horizons originationg from MIS 3 interstadials. The last glacial sequence starts with a soliflucted layer with incorporated reddish-brown clayey solum derived from the last interglacial soil. This reworked horizon is well-known as "Niedereschbacher Zone" (NEZ) in the German loes stratigraphy. Only a minor part of the Bwt-horizon of the last interglacial soil is preserved in situ, as indicated by a non-soliflucted former frost crack which was infilled by pedogenic clay. Below the remnants of this soil a 5.5 m thick calcareous loess including several fossilised tundra-gleys ("Bruchköbeler Naßböden") is preserved as the aeolian filling of a small valley that had incised itno older sediments (loess and fluvial loam and sand) at the beginning of the penultimate glacial. At the bottm of the valley fill soil sediments reworked from an older interglacial para-brownearth occur ("Ostheimer Zone").

In section B only the uppermost last glacial loess can be directly correlated with section A. The last interglacial soil was completely eroded at the time of the NEZ. At a depth of 7.5 m a buried in situ Bt-horizon begins. It is well developed in a loess loam and topping a flood loam deposited in a small channel. It is possible that a soil developed at the top of the upper Mauer sand, but so far could not be clearly distinguished from the oldest soil in loess. The channel is cut into the uppermost Mauer sand. Thus, loesses from three glacial cycles cover the youngest Mauer sand. This stratigraphic frame is confirmed by the evidence from section N. We do not know, however, if there was a long hiatus between the deposition of the upper Mauer sand and the oldest loess.

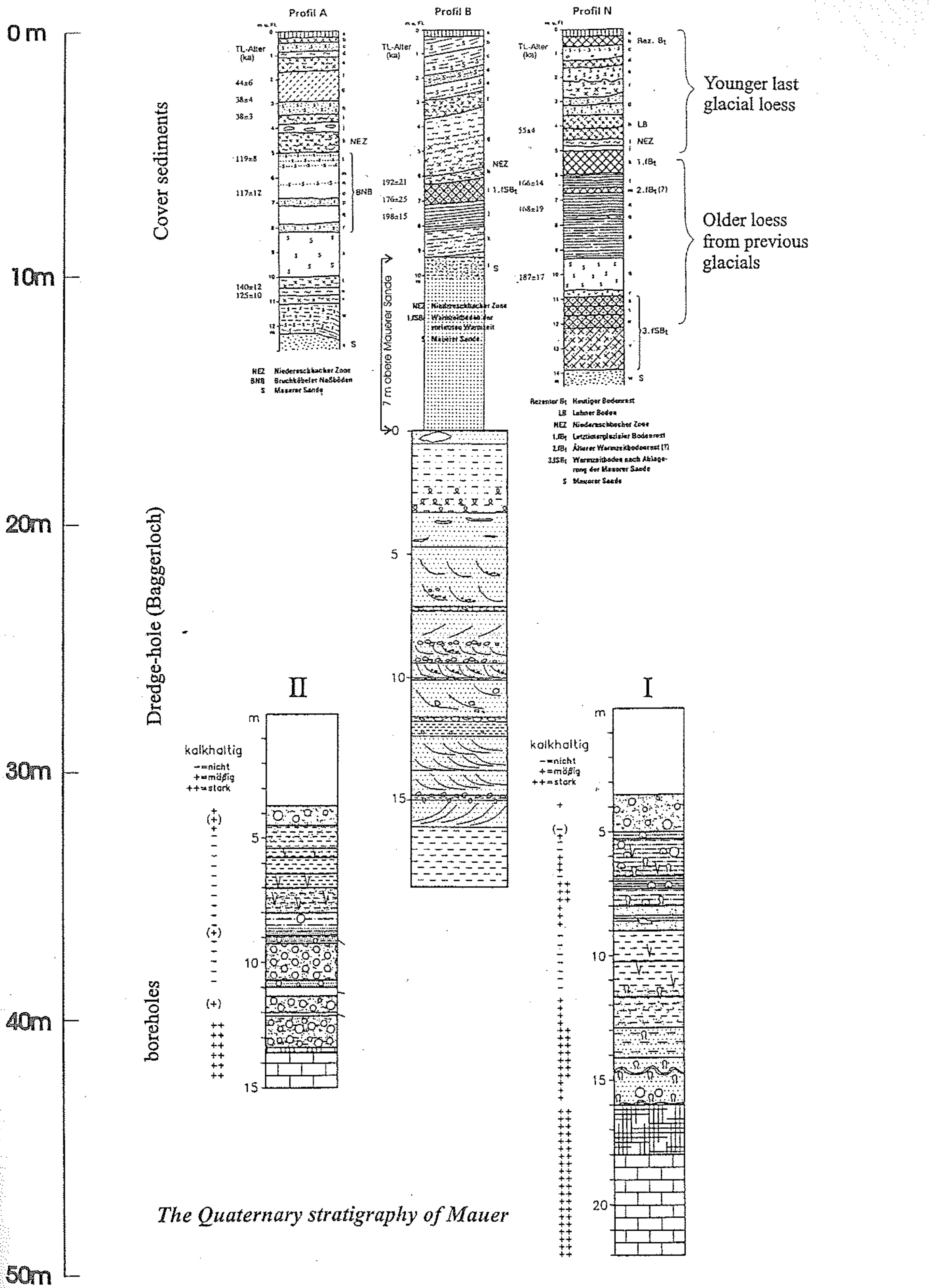

Fig. 1: Generalised stratigraphy of the Quaternary sediments in the former sand pit "Im Grafenrein" at Mauer.

The upper Mauer sand so far has not yielded much paleoclimatic information, but its deposition must have started under cold climate. The upper and the lower Mauer sand are separated by a 3.5 m thick silty loam named "Lettenbank". At its top the Lettenbank is decalcified (paleosol?) and truncated at a very small angle and immediatedly covered by blocky, subangular to weakly rounded gravel imbedded in the upper Mauer sand. The biggest sandstone block is 1.2 m long and can only have been transported as an ice-rafted block. The Lettenbank itself exhibits numerous sedimentary turbation structures which might be cryoturbations as well as load casts. In deeper layers of borehole I (see below), however, these turbated features coincide with a cold steppe climate pollen assemblage. Pollen grains in the Lettenbank itself are too rare for unambiguous environmental interpretation, but numerous opal phytolites from steppe grasses were found in it. Only at the bottom of the Lettenbank the occurence of some pollen from spruce may indicate the end of an interstadial.

From the lower Mauer sand containing the archaeological layer most of the more than 5,500 animal bones from Mauer have been collected. Those fossils which undoubtedly origin from the lower Mauer sand witness a warm interglacial climate known as the "Mauer forested period" ("Mauerer Waldzeit"). The is almost identical with the Upper Mosbach fauna and the Miesenheim-I fauna near Andernach and is now placed into the upper Cromerian complex.

In the clay below the Mauer sand at section B and in borehole II pollen preservation was too bad for analysis. No stable remanent magnetisation could be derived from that clay. Magnetic susceptibility measurements, however, suggest the correlation with the fine-grained sequence below the Mauer sand in borehole I. This sequence is rich in organic matter in its upper part and contains even macrofossils from wood. Pollen preservation is good, and the palynological analysis revealed that two periods with a cool forest climate (decalcified layers) separated by a period of cold steppe climate preceded the interglacial "Mauerer Waldzeit". As all of these oxbow sediments as well as clay lenses embedded in the lower Mauer sand proved to be normally magnetised the "Mauerer Waldzeit" must be considerably younger than the Matuyama/Brunhes geomagnetic reversal.

Dating:

Direct physical dating of the Mauer sand is very difficult as the period under consideration is too old for many Quaternary dating techniques, and the lack of any volcanic tephra so far has prevented the use of K/Ar or $^{40}Ar/^{39}Ar$ dating. At the Miesenheim-I site a tephra overlying the fauna-bearing loessic layer was dated ca. 463±2 ka by $^{40}Ar/^{39}Ar$. This age can serve as a minimum age for the lower Mauer sand. U-series and ESR dating of mammal teeth from Mauer so far yielded minimum ages of ca. 300 ka. TL dating of potassium feldspars from the archaeological horizon at Mauer appears to be more promising. A first dating attempt resulted in a TL model age of 552±155 ka. No correction for long term fading of the TL signal was applied; anomalous fading (short term) was not detected. Further research into the application of TL or OSL dating could lead to smaller error limits.

A synoptic view of all results obtained so far enables us to bracket the geological age of the "Mauerer Waldzeit" between marine isotope stages (MIS) 17 (659-712 ka) and 13 (474-528 ka). Recent results from research into micromammals from the Mauer site almost precludes MIS 17, and MIS 15 (568-621 ka) at present appears to be most likely the geological age of *Homo heidelbergensis*, but MIS 13 remains under consideration as well.

Table 1 summarises two possible chronologies for the Quaternary sediments at the Mauer site.

Table 1

Layer / soil	**Chronology I MIS**	**Chronology II MIS**
present-day soil (forest soil)	1	1
last glacial loess	2-4	2-4
last interglacial forest soil	5	5
2nd last glacial loess	6	6
penultimate interglacial forest soil	7	7
3rd last glacial loess	8	8
? interglacial soil at the top of upper Mauer sand	9	?
upper Mauer sand, cold climate	10	12
? interglacial soil at the top of the Lettenbank	11	13
Lettenbank (cold climate, but not extreme)	12	14
Mauerer Waldzeit	**13**	**15**
? cold, but not extreme steppe climate	14	16
cool forest period (boreal climate)	15	?
cold steppe climate	16	?
cool forest period (boreal climate)	17	?
cold climate	18	max. 18

Further reading:

G.A. WAGNER & K.W. BEINHAUER (eds): *Homo heidelbergensis* von Mauer. Heidelberg 1997.

G.A. WAGNER & K.W. BEINHAUER (eds): Schichten von Mauer. Reiss-Museum der Stadt Mannheim (Edition Braus) 1992.

Mannheimer Geschichtsblätter Beiheft 1. *Homo erectus heidelbergensis* von Mauer, Kolloquium 1, Resümees/Summaries (K.W. BEINHAUER, R. KRAATZ & G.A. WAGNER, eds). Sigmaringen 1996.

Stop 3: Mainz-Weisenau

Theme: **Loess section of Mainz-Weisenau**

Guide: **Arno Semmel**

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The quarry of the Heidelberger Zement AG offers an excellent insight into the sediment and soil development of the older Würm loess. Together with the quarry of the Dyckerhoff Zement AG, Wiesbaden, which lies 10 km to the north, it is the best profile of older Würm loess in the Rhine Main area - and probably in Germany - today (SEMMEL 1995; 1995a; 1997).

The Holocene soil in this area is a "Parabraunerde" (Luvisol). It developed from a chernosem during the last +/- 5 000 years. In the quarry of Mainz-Weisenau we can only see strongly eroded forms of that Luvisols only (man-made erosion). In one place at Mainz-Weisenau, theres is a chernosem below colluvium with an age of +/- 6 000 years (SEMMEL 1995b).

The base of the Würm loess (fig. 1, photo 1) is represented by a strongly brown (10 YR 7/6) fossil argillic B-horizon (photo 2) with an illuvial carbonate horizon. This soil developed on a grey loess of normal palaeomagnetic polarity and provided luminescence datings of 110 ka (average ages, see fig. 2). The maximum clay content of this horizon amounts to 28.5 % (tab. 1).

The fossil B-horizon is eroded. In top of it lies a gray sandy solifluction cover with debris of Pliocene limestone. Loess follows above this layer. In this loess, we find already a mollusc fauna containing *Columella columella* (tab. 2), which indicates a fully glacial climate. The assumption that this mollusc belongs to the Upper Würm only (CHALINE & JERZ 1984: 186), is not correct.

The "Untere Mosbacher Humuszone" (SCHÖNHALS et al. 1964) lies above this oldest Würm loess. Humuszones resembling chernosem soils, but they are not homogeneous. They originate from phases of accumulation and soil formation. Therefore, we sometimes find (brownish) mottled Ah- and Cc-horizons, as well as layers with rubbles of Ah-material and Cc-material (Photo 3). The brownish, mottled parts show the highest clay content and the lowest content of coarse silt (tab. 1). This can be considered as a sign for autochthonous soil formation. The dark Ah-material possesses the highest susceptibility (fig. 3).

Tab. 1: Particle size distribution and humus content

	Ton	fU	mU	gU	fS	mS	gS	humus (%)
OMHZ	26.1	5.9	12.7	45.0	9.6	0.5	0.2	0.7
loess	18.4	5.8	13.2	49.9	11.1	0.7	0.6	--
MMHZ	25.2	5.0	14.7	45.2	9.0	0.8	0.0	0.4
loess	19.0	5.9	11.3	50.8	11.8	0.9	0.3	--
UMHZ	27.0	5.5	14.0	39.8	11.1	2.2	0.5	0.3
loess	20.8	4.9	12.1	48.7	11.0	1.8	0.7	--
fBt	28.5	5.4	13.0	42.5	8.6	1.3	0.7	--
loess	16.4	8.7	16.2	32.1	22.2	3.2	1.3	--

The result of pollen analyses (fig. 4), which show distinct horizons, can also be regarded as an evidence for different layers in the Untere Mosbacher Humuszone (UMHZ). The result of these investigations reflects the development of vegetation at that time, and shows a climatic change from colder (pine maximum) to more moderate conditions (fir and spruce maximum), and then again to a colder climate (pine maximum). Concerning the climate of the UMHZ, the mollusc fauna is pointing at an interstadial climate also (tab. 2). In addition, the fauna contains even species characteristic of an interglacial climate (*Monachoides incamatus, Aegopinella sp.*).

On top of the UMHZ follows loess with the "Mittlere Mosbacher Humuszone" (MMHZ). It is sometimes differentiated in two parts. Finally, after a another loess layer, the "Obere Mosbacher Humuszone" (OMHZ) terminates the complex of the older Würm loess. The results of pedological, pollen and mollusc investigations resemble those of the UMHZ (tab. 1 and 2; fig. 2 and 4). Only one difference should be noted: the mollusc fauna of the OMHZ does not contain any interglacial but only steppe and forest steppe species (BIBUS et al. 1996: 23).

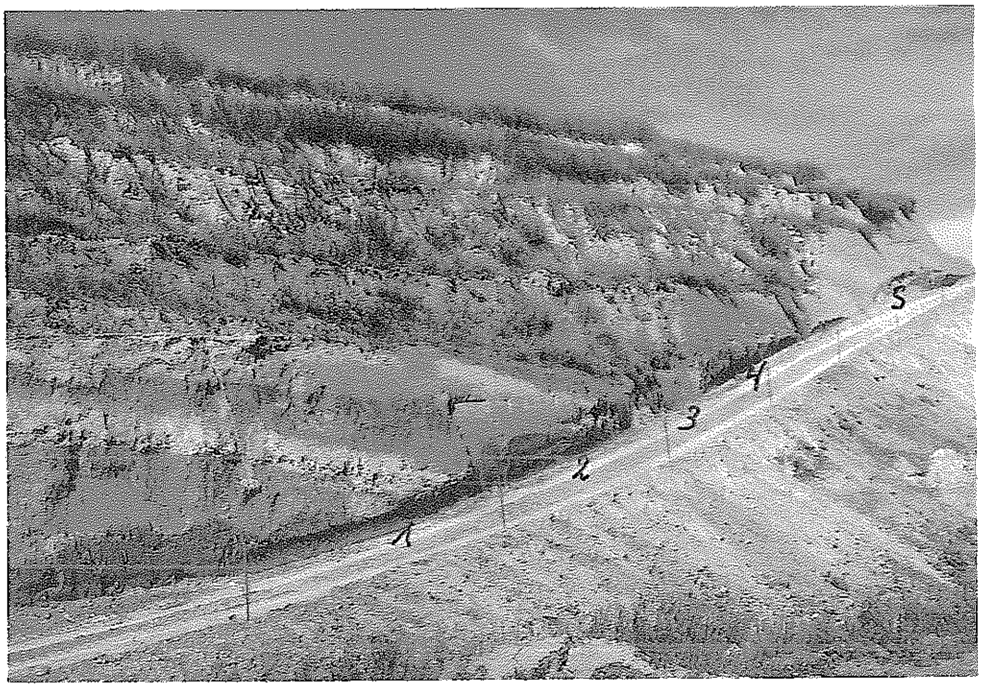

Photo 1 : **The older Würm loess**

1: fBt-horizon

2: UMHZ (Untere Mosbacher Humuszone)

3: MMHZ (Mittlere Mosbacher Humuszone)

4: OMHZ (Obere Mosbacher Humuszone)

5: Niedereschbacher Zone

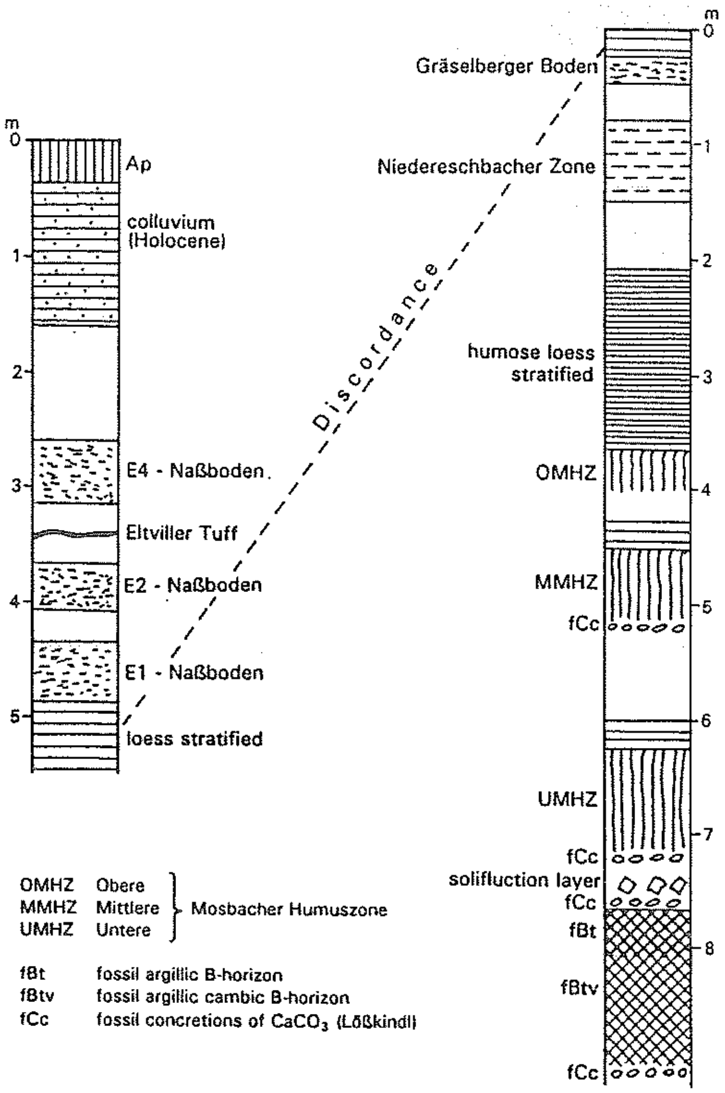

Fig. 1: Profile of the Würm loess

Photo 2: **Thin section of the fBtv-horizon**

Arrow: CaCO3-concretions at a pore; double arrow: orientated clay material (section high 2 mm)

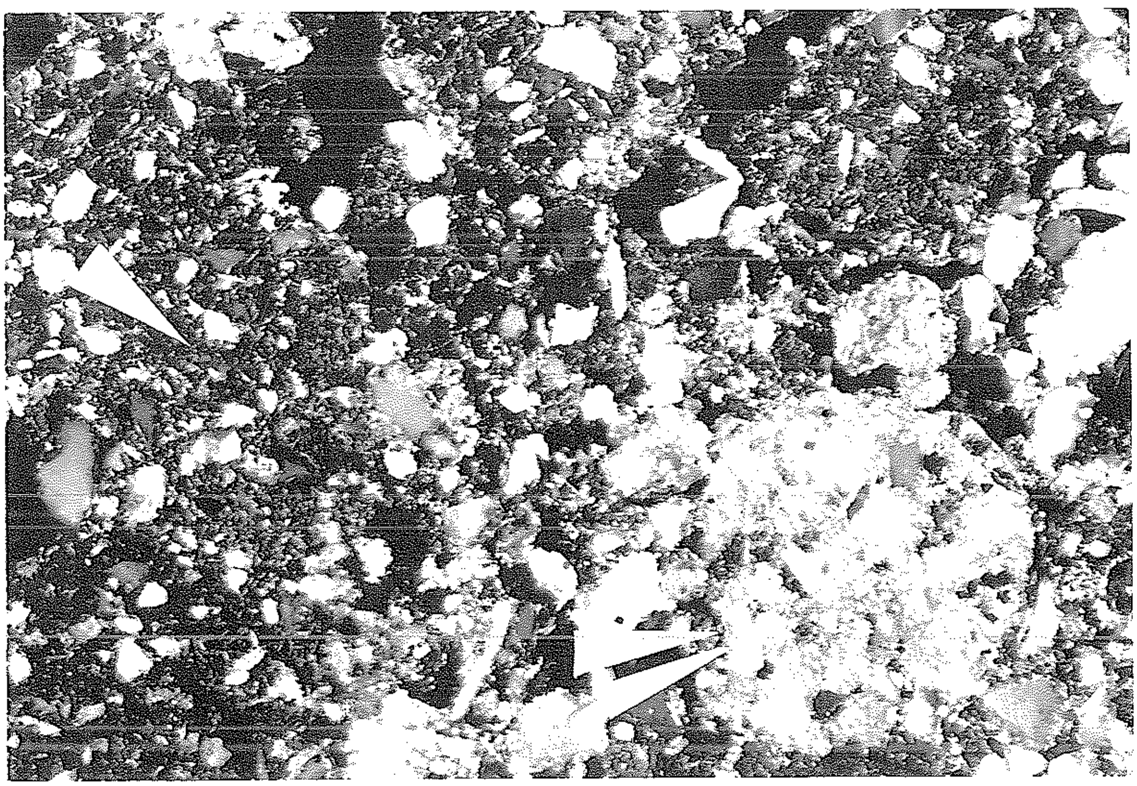

Photo 3: **Thin section of the UMHZ**

Arrow: rubble of Ah-material; double arrow: rubble of Cc-material (section high 0.7 mm).

Photo 3 by Th. Poetsch, Institut für Geographie, Universität Hamburg.

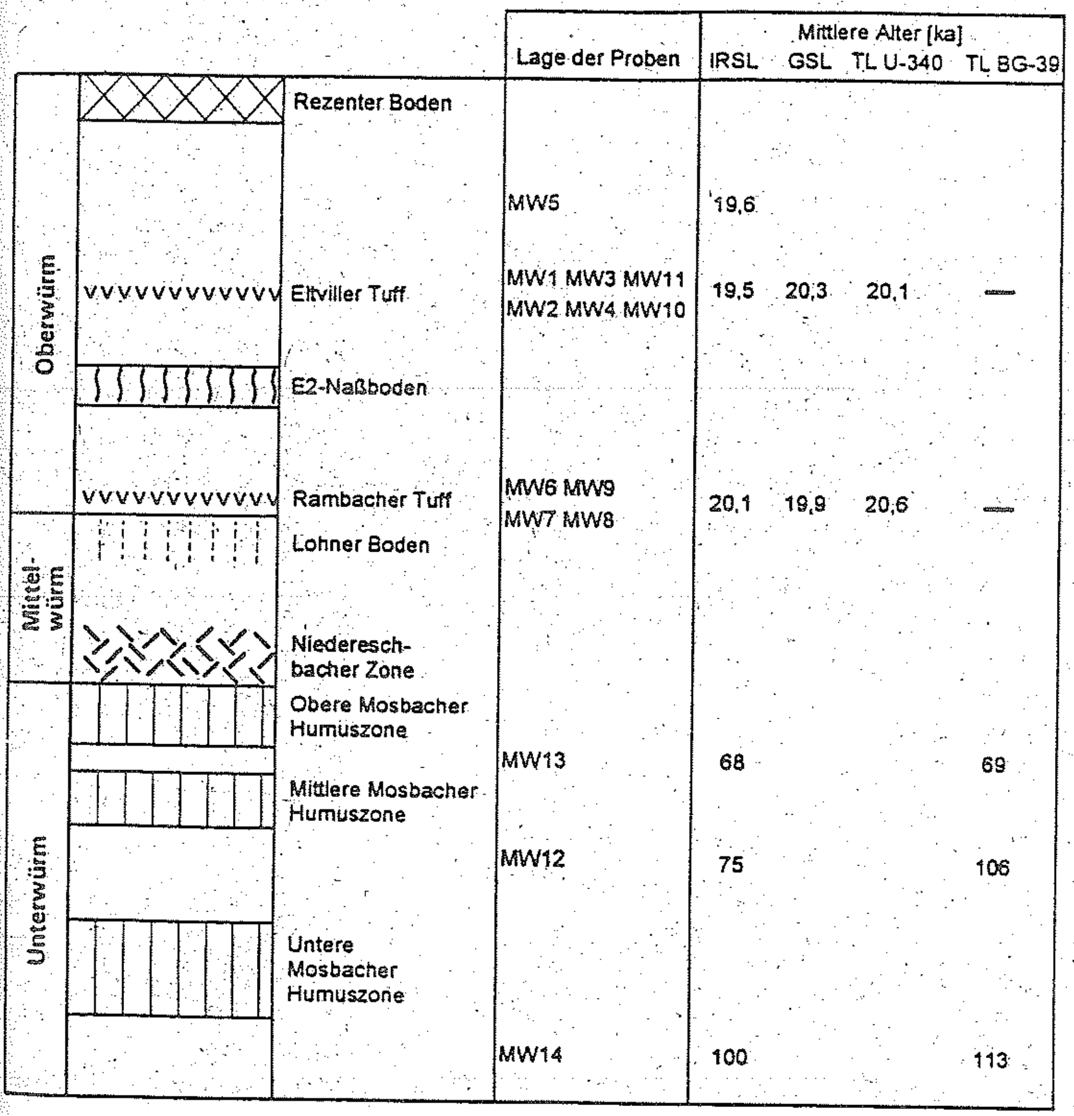

Fig. 2: Luminescence dates (after FRECHEN & PREUSSER 1996)

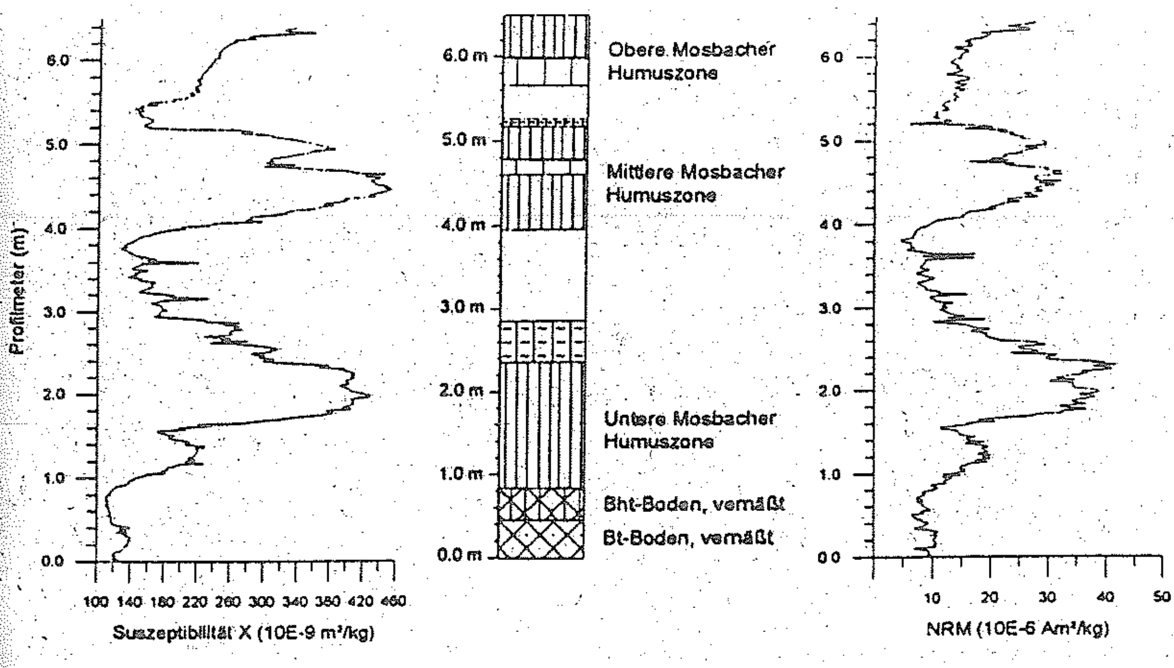

Fig. 3: Susceptibility (after BIBUS et al. 1996)

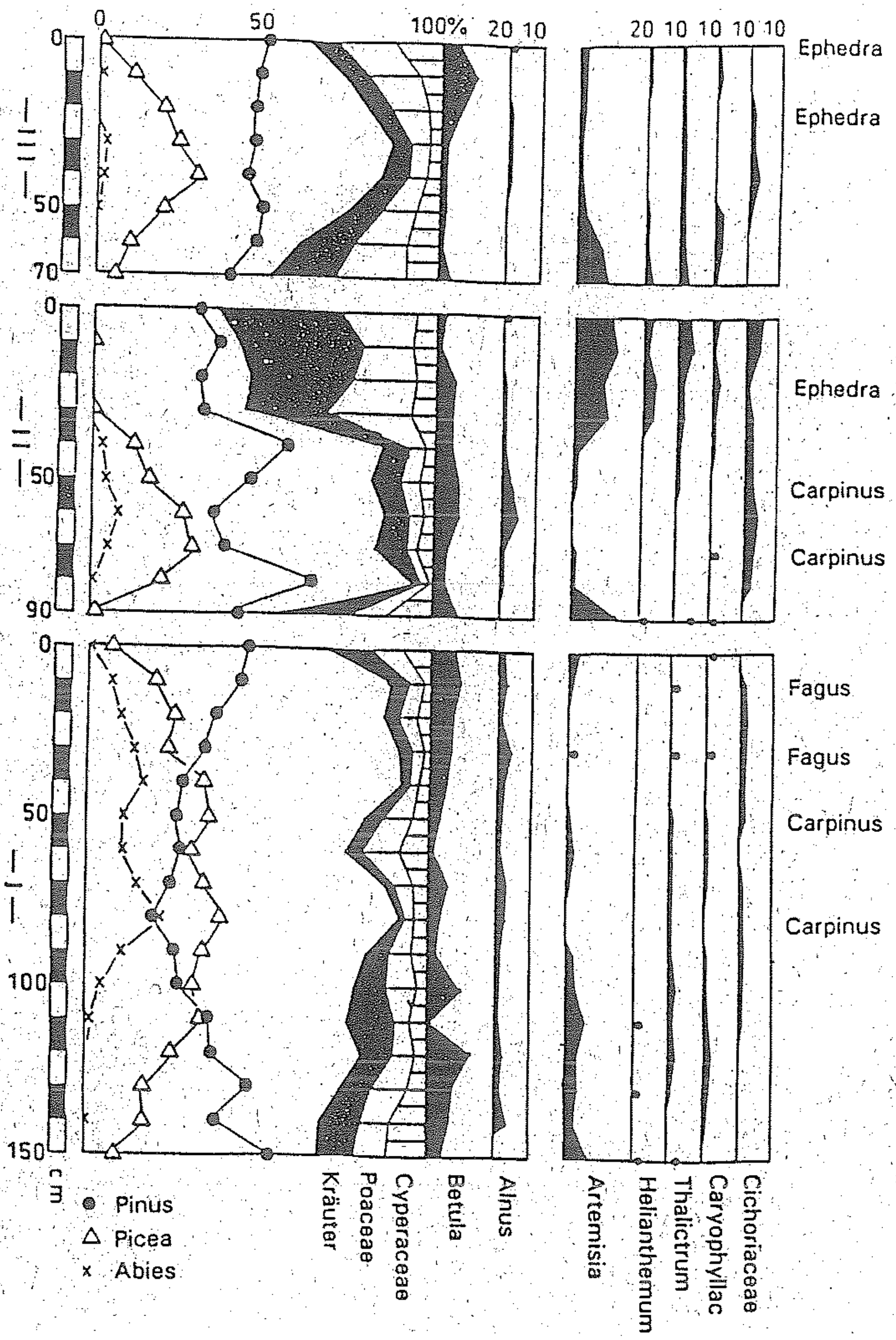

Fig. 4: Pollen content (after BIBUS et al. (1996)

Tab. 2 **Mollusc fauna (after J. WEDEL, Hessisches Landesamt für Bodenforschung, Wiesbaden)**

	fBt	loess	UMHZ
Discus rot.	1	-	-
Limacidae	1	-	-
Cecilioides ac.	4	3	-
Pupilla sterri	-	2	-
Helicopsis str.	-	-	1
Pupilla musc.	26	11	4
Truncatellina cyl.	2	-	-
uccinea obl.	5	2	-
Carychium trid.	1	-	-
allonia sp.	-	-	2
allonia exc.	-	-	1
allonia pulch.	-	-	3
egopinella sp.	-	-	1
onachoides inc.	-	-	1
olumella columella	-	4	-
upilla loess.	-	1	-
rtigo parc.	-	2	-
ianata arb.	-	1	-
trea cryst.	-	-	1
chia sp.	-	2	1
chia hisp.	9	4	-
usilia parv.	-	1	-

he whole complex of the "Mosbacher Humuszonen" there is no evidence for the "Blake t" (written communication by Dr. Reinders, Geological Institute of the University of gne) and for volcanic activity (tab. 3).

Tab. 3 **Heavy minerals content (%, after THIEMEYER 1993: 184)**

	aug.	epid.	garn.	hbl.gr.	hbl.br.	rut.	tit.	tour.	zirc.
loess	1	40	24	27	1	1	-	4	1
teph.I	23	22	4	11	30	2	2	1	4
teph.II	88	3	4	2	-	-	-	-	1
NDZ	-	32	6	56	-	1	-	2	+
OMHZ	2	53	14	24	+	-	-	3	2
loess	-	51	13	27	+	1	-	2	4
MMHZ	+	41	19	33	1	+	+	4	1
loess	-	52	18	20	+	1	-	4	3
UMHZ	1	50	26	13	+	1	+	4	3
loess	2	45	25	17	-	2	-	3	4

theph. I: Laacher See Tuff; teph. II: Eltviller Tuff; NDZ: Niedereschbacher Zone

For the determination of the age of the "Mosbacher Humuszonen" sequence, only luminescence dates are available (fig. 2). The material from the OMHZ had ages from 65 to 70 ka. Probably this zone belongs to stage 5 of the oxygen istope stratigraphy. If that is correct, than we have not two interstadials (5a and 5c) in stage 5, but three.

Above the Mosbacher Humuszonen we find some meters reworked material from the underlying strata. It is overlain by the lower brown section of the "Niedereschbacher Zone" (SEMMEL 1968: 30). The upper, grey and very sandy section of this zone is covered by reworked loess material.

South of the described profile, a delle had eroded into the reworked loess. Later, this narrow valley was filled with the youngest Würm loess. Within this loess, we find several "Naßböden" (tundra gley soils) and the "Eltviller Tuff" (SEMMEL 1967).

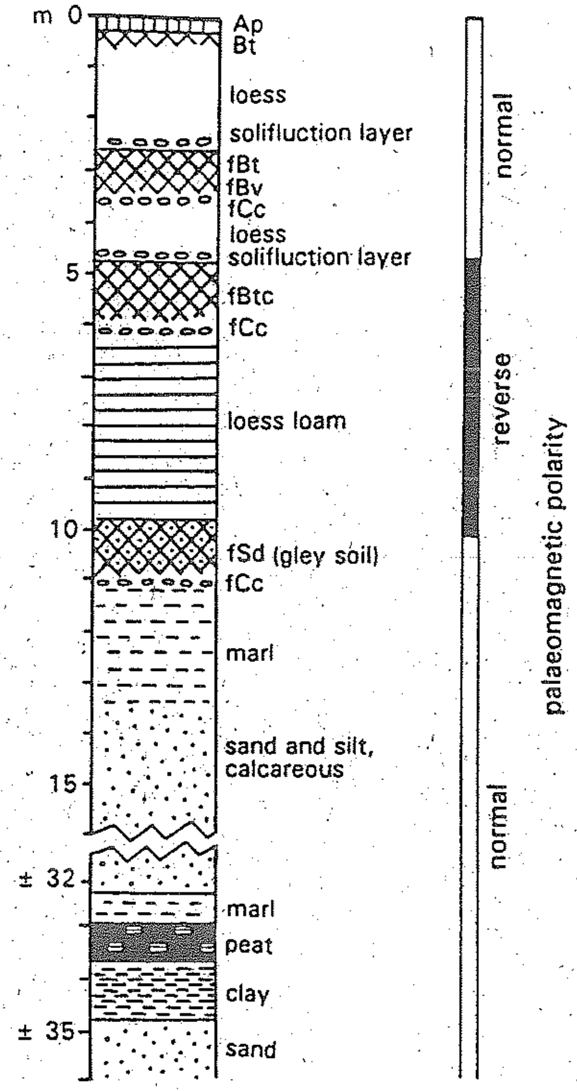

Fig. 5: Profile of the Pre-Würm sediments

The deeper part of the quarry offers above Miocene limestone the following profile (fig. 5): White, carbonate-free Pliocene sands are overlain by a layer of clay with peat. It contains polle of the Reuver. Below and above this peat we find calcareous sediments with a conchylia fauna with Late-Pliocene species (GEISSERT 1983: 79). The calcareous sediments testify changes of the heavy mineral and clay mineral contents (SEMMEL 1983). Whereas the underlying, white sand contains almost exclusively stable minerals, with a dominance of kaolinite in the intercalated clay layers, the typical rhenish heavy mineral spectrum with garnet and epidote maxima is found in the calcareous sediments. The clay here consists of kaolinite, of illite and of montmorillonite.

On top of these sediments, which show throughout a normal magnetic polarity, follows a very strongly developed gley soil with red and grey mottling. Within this soil, reverse magnetization is encountered for the first time (FROMM 1987: 12).

The gley soil reaches a thickness of 1 m. At its base and on top of it, big calcareous concretions are found. The content of clay is about 50 %, in the unweathered marl only about 40 %, but there is no difference concerning the quality of the clay minerals (kaolinite, illite, montmorillonite). In the gley soil the quantity of montmorillonite is higher. In comparison with that the quartz content increases in the soil, whereas the orthoclase content decreases. Plagioclase is missing. But there are possible influences from the loessic material on top. Such material reaches in fissures the deepest parts of the soil.

Above the gley soil follows a brown, clayey loam. Its finer matrix seems to be a mixture of weathered marl, loess loam and residues of argillic B-material. The low content of CaCO3 (3.4 %) is secondary. About 40 % of coarse silt and the increase of garnet and hornblende may represent the loess material. The older loesses, or rather loess loams, generally have higher clay contents than the younger loesses of the Rhine-Main area.

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Stop 4: Kärlich clay pit

Theme: **The Middle Pleistocene Loess/Palaeosol sequence of section Kärlich**

Guides: **Wolfgang Boenigk[1] & Manfred Frechen[2]**

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Topics: Tertiary clay, fluvial deposits of rivers Rhine and Moselle including the Matuyama/Brunhes magnetic boundary, Middle Pleistocene loess stratigraphy, Quaternary tephrochronology, Palaeolithic finds.

Access: Motorway A61, exit Kruft, direction of Andernach, exit B9 direction of Koblenz, exit Weißenthurm/Kärlich, up the hill in direction of the church, first street to the right, follow sign Tongrube Kärlich to the right.

Geological setting: The Kärlich section is situated within the Neuwied Basin (fig.1) which is part of the Rhenish Massif. The basin is an area of subsidence since the Palaeogen, exhibiting a terrestrial record from the marine Lower Oligocene through the terrestrial Pliocene and followed by Quaternary fluvial terraces of the rivers Rhine, "Rhein", and Moselle, "Mosel", loess and loess derivatives. The volcanic activity of the East Eifel Volcanic field began during the interglacial (oxygen isotope stage, OIS 15) which tops Unit F at the Kärlich site (BOENIGK & FRECHEN 1998 and in press). The Quaternary volcanism coincides with increasing rates of uplift, as evidenced by the terrace stair case of the river Rhine. At section Kärlich maar-like eruption centers and its pyroclastic deposits are exposed. The section at Kärlich is one of the most important localities in Germany where Pleistocene fluvial deposits as well as loess and loess derivatives intercalated by tephra horizons are exposed. Based on recent geological investigations the stratigraphy of the sediment sequence

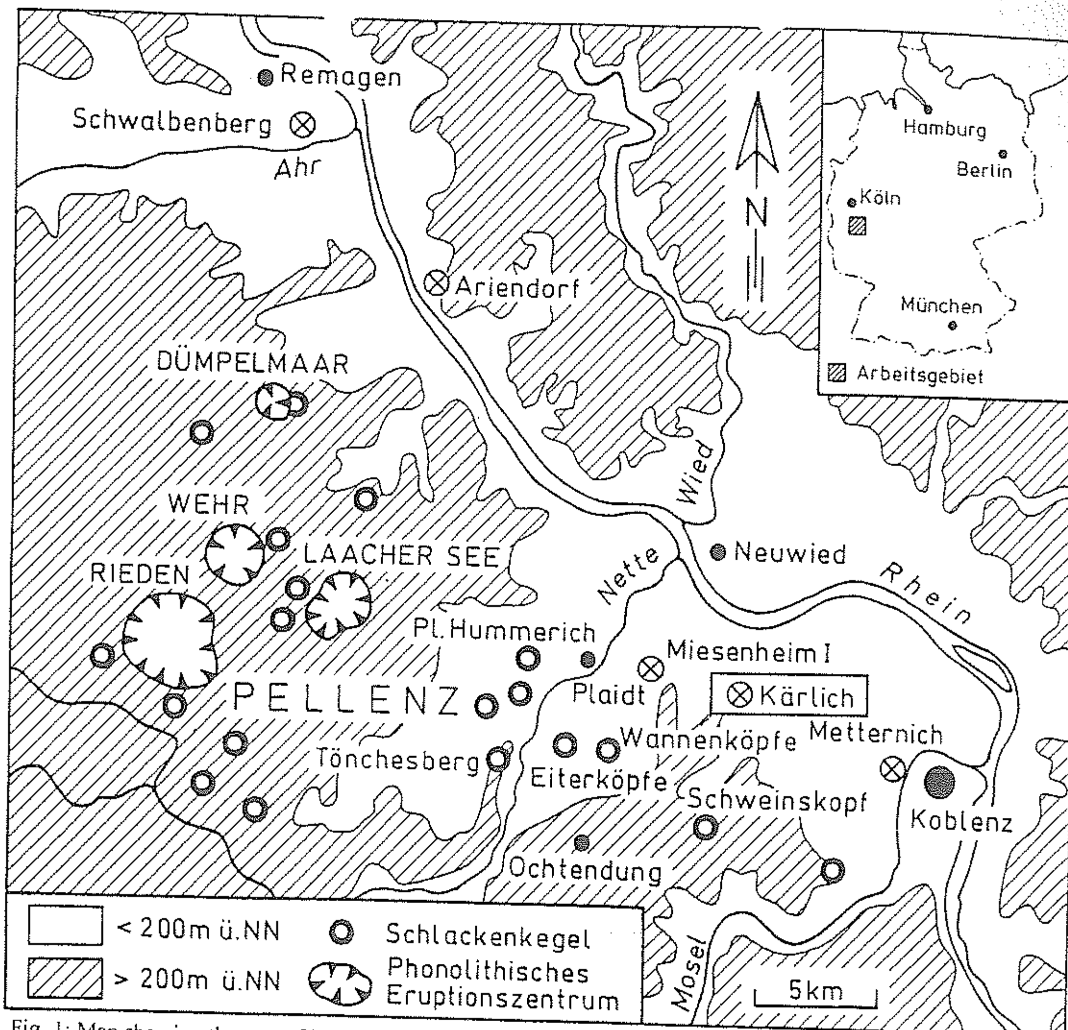

Fig. 1: Map showing the area of interest and the location of the section at Kärlich in the Neuwied basin, Germany

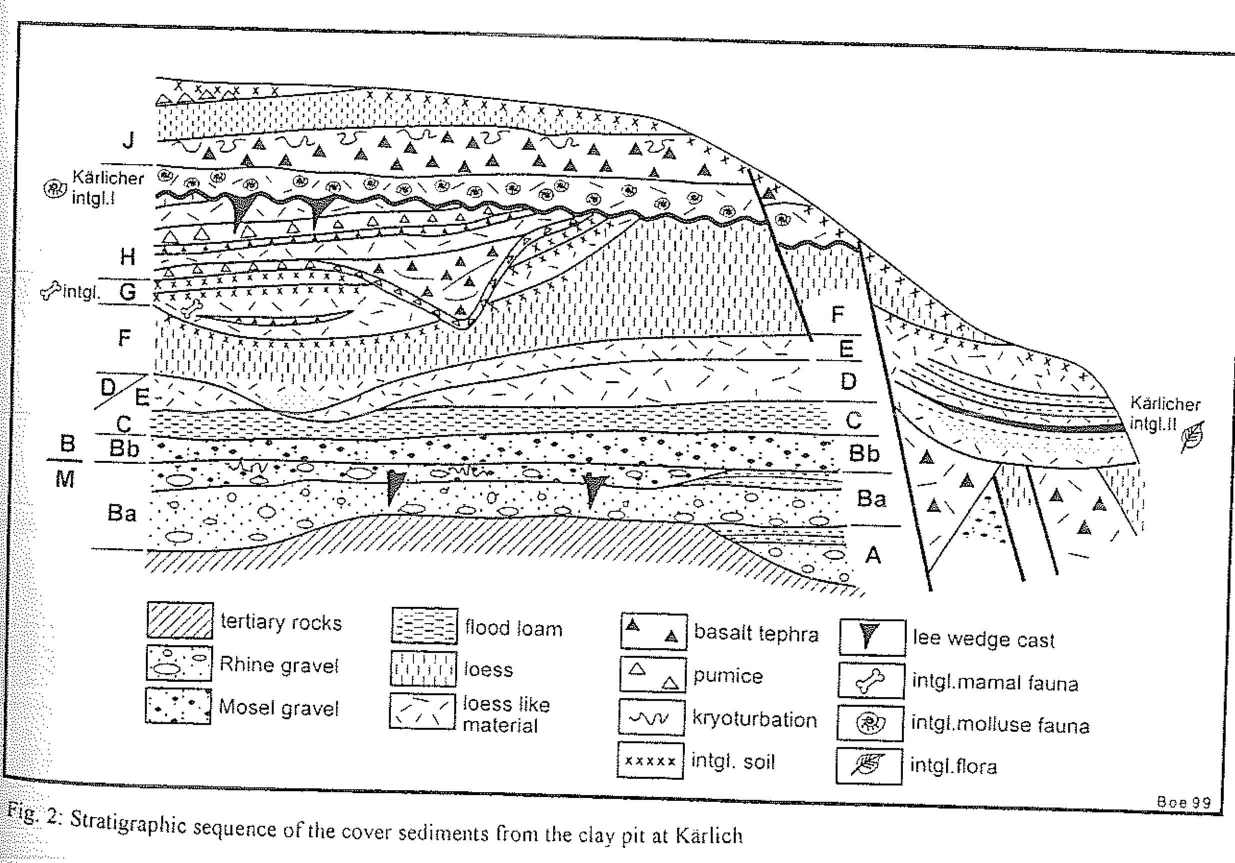

Fig. 2: Stratigraphic sequence of the cover sediments from the clay pit at Kärlich

stage $\delta^{18}O$	vulkanische Minerale	Mittelrhein Kärlich			Mittelrhein Miesenheim I	Mittelrhein Ariendorf	Terrassen	Niederrhein BOENIGK 1995 ergänzt	Niederlande ZAGWIJN 1985 verändert	
1			Parabraunerde	Holozän	Parabraunerde	Parabraunerde		Holozän		
			Löß	Glazial	Löß	Löß-Decke III	jüngere ältere	j		Weichselian
			Parabraunerde	Interglazial		Parabraunerde	Niederterrasse	NT äb Weezer Interglazial		Eemian
			stadiale+interstad. Flora	Glazial		Löß-Decke II	untere	äa		Saalian
		J	Seeabl.m.Flora	Kärlicher Intergl.II		Parabraunerde		MT IV b Kempen-Krefelder Intergl.		Holsteinian ?
	viel Pyroxen		Brockentuff			Löß-Decke I	mittlere	a		
				Kärlicher Intergl.I		Ariendorfer Intergl.	Mittelterrasse	MT III b Frimmersdorfer Intergl.		Holsteinian ?
12		H	Löß,Eiskeile			kaltzeitl. (Schotter)		a		Elsterian
			Bims u. Basalttuff	Glazial	Bims u. Basalttuff	mMT		b		
13			Parabraunerde	Interglazial	Interglazial	warmzeitl.		MT II Niederaußemer Intergl.		Intergl. IV
			Parabraunerde				obere	a MT I	Lingsfort-Beds	Glazial C
	viel braune Hornblende	G	Intergl.Fauna							
			Arvicola				Unterstufe jüngere Hauptterrasse	HT IV ?		
		F	Parabraunerde	Interglazial						Intergl. III
16	sehr wenig vulkanische Mineralien		Erosion Mimomys					HT III	Rosmalen-Zone	Glazial B
			Löß	Glazial		jHT Schotter	Jüngere Hauptterrasse	HT II	Weert-Zone	
		E	Bodenbildung						Woensel-Zone	Intergl. II
		D C	Bodenbildung Fließerde Hochflutlehm					Hauptterrasse Folge	Sterksel Formation	
19	B	B	Hochflutlehm Schotter,Eiskeile	Interglazial Glazial						
20	M		Hochflutlehm							Glazial A Intergl. I ? "CROMERIAN"
			Schotter Driftblöcke							
		A	Hochflutlehm Schotter	Interglazial				HT I	Sterksel-Zone	Leerdam Interglazial ?

Table 1: Pleistocene stratigraphy of sequences from the Middle and Lower Rhine Area and the Netherlands.

and the regional stratigraphic correlation have to be reinterpreted (tab.1). Our investigations indicate that:

1. The correlation of Unit "Abschnitt A" with the Jaramillo event is under discussion. It is likely that Unit A is younger and hence, correlated with the Bavelium complex.
2. The Quaternary volcanism of the East Eifel Volcanic Field began during the interglacial which tops Unit F. However, the volcanism of the West Eifel Volcanic Field began much earlier, most likely during the Matuyama chron.
3. There are no further subunits in Unit G, as proposed by Razi Rad (1976), indicated by a dominance of brown hornblende in the heavy mineral spectra for all sediments.
4. Unit H is subdivided into Unit H-lower part and Unit H-upper part by a marked unconformity.
5. The "Kärlich Interglacial" has to be subdivided into the Kärlich Interglacial I from below "Brockentuff" (phreatomagmatic maar-like deposits) and Kärlich Interglacial II from above the tephra layer. The two interglacials are separated by at least one cold phase or interstadial.

The sequence of section Kaerlich was investigated in detail by BRUNNACKER et al. (1969). In more recent times systematic multidisciplinary investigations of the present exposures provided new insight into the Middle Pleistocene stratigraphy of the area of interest. The geological investigations were carried out by BOENIGK & FRECHEN (1998, in press), floral and palynological remains were studied by BITTMANN (1991, 1992), the micromammals were investigated by KOLFSCHOTEN et al. (1990 and in press), tephrochronological aspects by BOGAARD et al. (1989) and BOGAARD & SCHMINCKE (1990) and the archaeological finds by VOLLBRECHT (in press) and GAUDZINSKI et al. (1996).

Quaternary fluvial deposits (fig.2)

The Tertiary sediments are cut by a significant hiatus.

Unit A

Channels had been incised into the Tertiary sediments ("Knubbletten") indicating a fluvial activity of the Rhine system. The heavy mineral spectra indicate these sediments as Lower

Pleistocene deposits of the River Rhine by the high percentage of epidot. BOENIGK & FRECHEN (1998 and in press) pointed out that the fluvial sediments include sediments from the river Moselle as evidenced by the presence of pyroxene, an indicator for the volcanic activity of the West Eifel volcanic Field. Palaeomagnetic investigations indicate a reverse magnetization (KOCI et al. 1973, BOENIGK et al. 1974; FROMM 1987) of the fine-grained material whereas the coarser grained material shows a normal magnetization. A tooth of *Hippopotamus sp.* was described by BRUNNACKER et al. (1980). The sedimentological investigation indicate a meandering fluvial activity, the faunal remains indicate interglacial conditions at the time of deposition.

Unit B

The 8 m thick sediments of Unit B consist of four fluvial accumulation phases intercalated by flood loam and gleyish soils. The sequence starts on top of a discontinuity marked by coarse blocks at the base.

The lower most parts consist of older Rhine gravel, which is separated from the upper Moselle gravel by a horizons including Rhine and Moselle gravel. The Matuyama/Brunhes boundary was determined between the Rhine and Moselle deposits; above the Rhine/Moselle gravel all sediments show a normal magnetization. The fluvial record of section Kärlich is shown in table 1. Cold climatic indicators, frost wedges, cryoturbation features and drift blocks, are only described for the mixed gravel of the Rhine/Moselle deposits. The flood loam is an indicator of more moderate, interstadial (?) climate and environment conditions.

Loess and loess derivatives

Unit C-D-E

Reworked loess-like sediments and solifluction horizons. The sequence is intercalated by weak soil horizons. Aeolian sediments are missing. Micro and macrofauna and snail assemblages contain interglacial and glacial species indicating a reworking of the sediments. The sequence is characterized by several erosion/accumulation cycles and weak soil formation.

Unit F

Homogenous reworked loess and loess, which is intercalated by aeolian and reworked sand (Rhine material, Pleistocene) and gravel (Kieseloolite terrace) at the base of Unit F. The sand lenses are of fluvial origin in the lower part and aeolian origin in the upper part. The loess deposits are intercalated by several tundra gleys ("Nassboden") and a strong brown soil. The heavy mineral spectra indicates the dominance of zirkone, epidote, garnet and hornblende. Volcanic heavy minerals are not present.

Unit F is characterized by a significant loess accumulation and hence, a glacial climate and environment is most likely. The mammals (BRUNNACKER 1971 and KOLFSCHOTEN & RICHTER 1998) indicate a cold-steppe.

Unit G

Unit G includes 7 m thick pedosediments and reworked loam, in which 5 cycles can be distinguished; at least 3 Bt horizons are intercalated.

The heavy mineral spectra are dominated by volcanic minerals with a dominance of brown hornblende. A mafic tephra horizon is intercalated in the pedosediments. Reworked loess and slope wash are indicators of open condition (open vegetation) and brown forest soils are indicators of interglacial climate conditions. An interglacial environment is also evidenced by mammal remains (BRUNNACKER 1971; KOLFSCHOTEN et al. 1990; KOLFSCHOTEN & RICHTER 1998). However, snail assemblages and micro mammals indicate a steppe vegetation as well.

The sequence is designated to represent an interglacial period including several climate changes to cooler temperatures. However, the soil formation on top of unit F and within unit G are so strong that a substantial amount of time is necessary to form such soils.

The transition from Mimomys in unit F to Arvicola in unit G (KOLFSCHOTEN & RICHTER 1998) also represents an extended time interval.

Unit H

The sediments of unit H are characterized by the dominance of clinopyroxenes in the heavy mineral spectra. Several intercalated tephra horizons, which were dated by $^{40}Ar/^{39}Ar$-single-grain dating indicate age estimates between 400 and 450 ka (BOGAARD & SCHMINCKE 1990). The sequence of unit H consists of several cycles of erosion and accumulation. The presence of loess, reworked loess, and frost wedges indicate a glacial climate. Several soil layers are intercalated. However, interglacial conditions are only evidenced by the top layer, defined as "Kärlich Interglacial I". BRUNNACKER et al. (1969) describes a brown forest soil below the maar-like tephra layer ("Kärlicher Brockentuff"). However, at present only the carbonate-rich C-horizon of the brown forest soil is exposed. A and B horizon were eroded resulting in a discontinuity, which separates unit H-lower part from unit H-upper part. Unit H-upper part, the sequence covering the "Kärlich interglacial I", consists of :

1. phase of erosion, resulating in the destruction of A and B horizon of the brown forest soil, representing a former interglacial
2. accumulation of reworked sediments including a fauna which is characterized by a dry-warm climatic snail assemblage
3. phase of a weak soil formation with intensive bioturbation
4. accumulation of a second layer of reworked sediments including snails of interglacial (forest) conditions
5. formation of a weakly gleyed horizon

Soil micromorphological investigations are in agreement with the field observations (BOENIGK et al. 1999). Thus, it is very likely that the sediments were deposited under late interglacial/early glacial conditions. A well-developed forest soil is missing.

Unit J

The sequence of unit J starts with maar-like pyroclastic deposits of the "Kärlich Brockentuff". Several maar-like eruption centers have been exposed and described in the Kärlich clay pit. Phlogopite crystals were dated by single-grain dating indicating an age estimate of 396±20 ka (BOGAARD & SCHMINCKE 1990), hence interglacial conditions and the presence of a brown forest soil would be most likely, if compared with the marine record (BASSINOT et al. 1994). More recent $^{40}Ar/^{39}Ar$ age estimates of phlogopite crystals from the "Kärlich Brockentuff" (BOGAARD 1997, unpublished) indicate an eruption age during the final part of OIS 11/early part of OIS 10. Such an interpretation has significant implications for the startigraphy of the Kärlich Seeufer site.

<u>The Kärlich Seeufer site</u>:

Lacustrine sediments were exposed on top of the reworked Brockentuff in a volcano-tectonic depression in the eastern part of the section at Kärlich. Immediately after the formation of the depression, hang sliding occured and gravel, loess-like sediments and finally volcanoclastic debris of the maar-like deposits were accumulated in the depression. Clay and silty mud

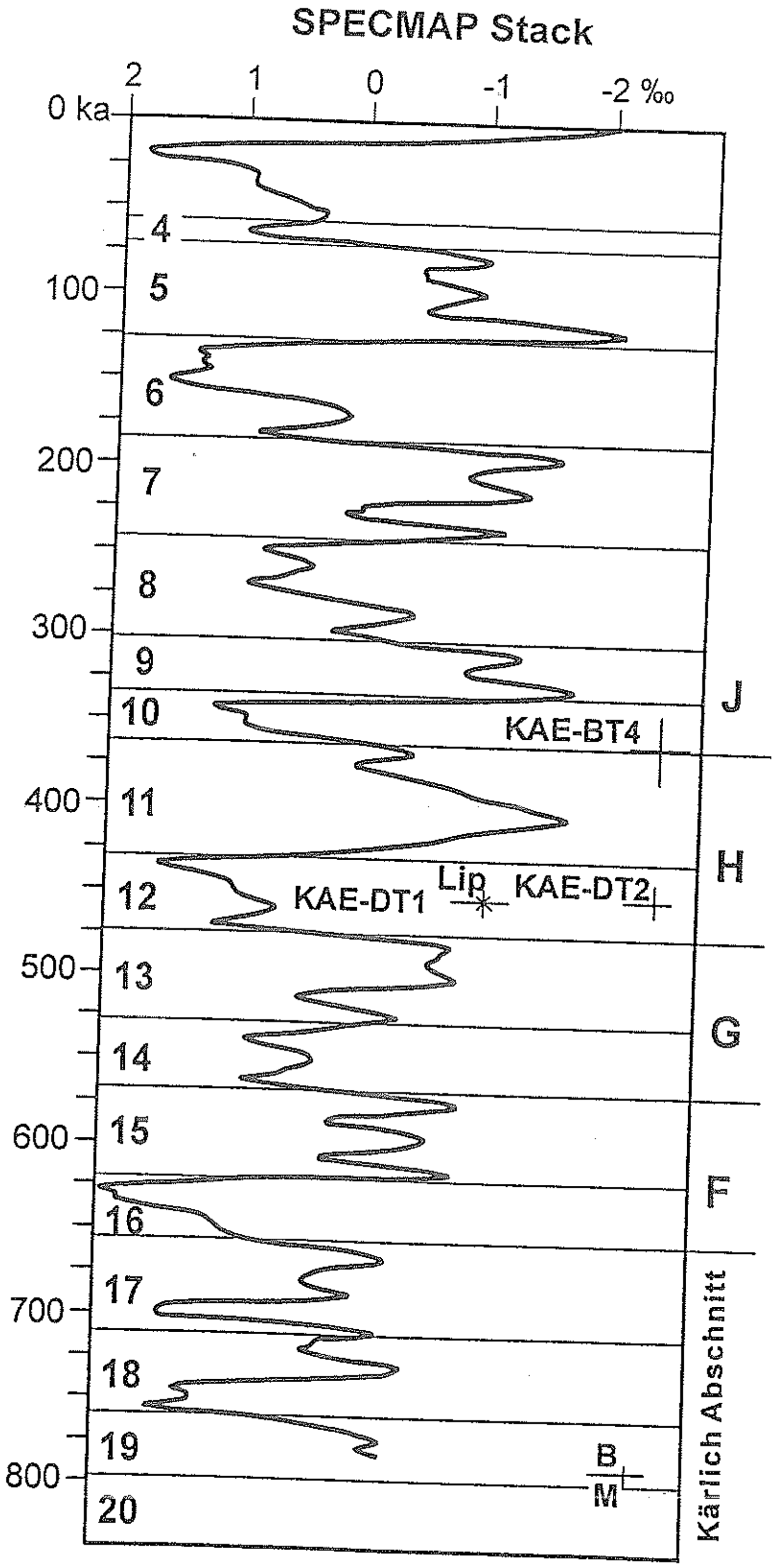

Fig. 3: Chronological results of the Kärlich site; SPECMAP curve after BASSINOT et al. (1994) and B/M boundery after TAUXE et al. (1996), Ar/Ar data from LIPPOLT et al. (1986), v. d. BOGAARD & SCHMINCKE (1988, 1990) and v. d. BOGAARD (oral presentation during the 1997 seminar „Quaternary of the Eifel Area", German Science Foundation).

indicate the existence of a shallow lake or swampy environment. In a period of surface stability the depression was filled with detrital organic-rich mud, which is finer towards the center and coarser towards the edge of the depression, developing into peat which includes an interglacial flora (BITTMANN 1992). The overlying sediments (layer d) consist of several layers of up to 2.4 m thick sandy debris flows at the edge of the depression. Fine-grained mud flows are the sedimentary equivalent towards the center of the depression. These deposits represent a short period of time when the surface was unstable, including a destruction of the vegetation cover. The debris flows yield the archaeological finds of Kärlich Seeufer (GAUDZINSKI et al. 1996). Above the debris flows, fine-grained sediments such as clay and silt were deposited including three organic-rich horizons, indicating a swampy environment with some open patches of water at the time of deposition.

On top of the uppermost organic-rich layer a significant change in sedimentation took place as evidenced by well-layered sediments rich in clay and up to 10 m thick well-layered clay-rich sediments, typical for slope wash.. Two gleyed horizons are intercalated in these sediments. Loess-like sediments cover the two soil horizons. The loess-like sediments are superimposed by a brown forest soil which is covered by loess. The Laacher See pumice and the Holocene brown forest soil terminate the sequence.

The lower part of the organic-rich sediments in the volcano-tectonic depression is designated to represent an interglacial deposits due to the floral remains (URBAN 1983; BITTMANN 1992). This interglacial is defined as "Kärlich Interglacial II" (BOENIGK 1995). The deposition of the debris flows are designated to represent the change from interglacial to tundra-steppe and tundra environment.

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