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Wolfgang Schirmer (ed.)

9

Rhein Traverse

Wolfgang Schirmer

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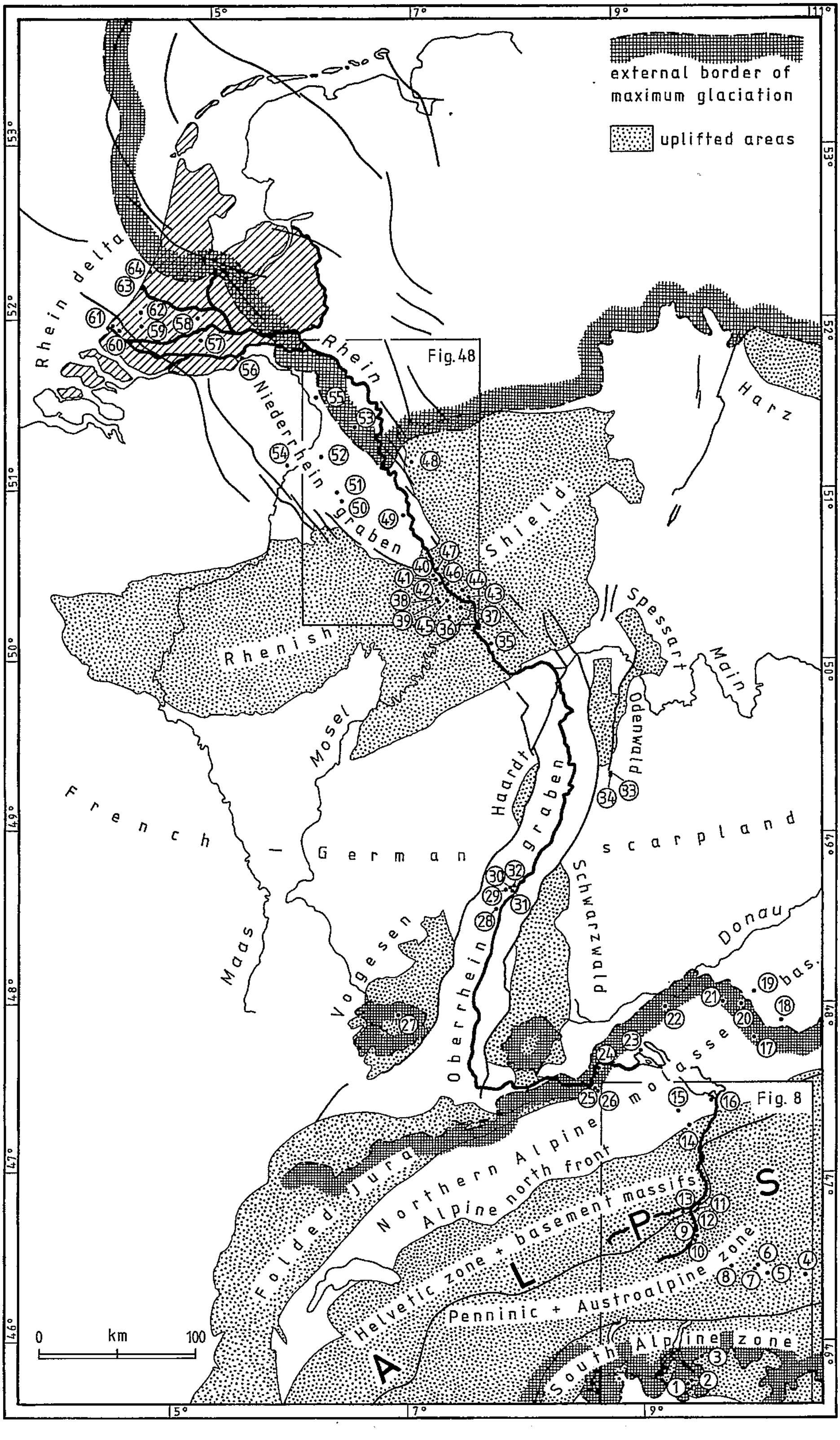


Fig. 1 All Stops (1–64) of excursion 9. Larger setting in Fig. 2. Detailed maps Figs. 8 and 48 marked as insets

Contents

Foreword

The Rhein traverse gives a survey of the Alpine glaciation, from its recent glaciers to the foreland glaciation, as well as of the joining periglacial area bounded by the Alpine glaciation and the southwestern border of the Northern glaciation. It follows the Rhein course with its history since Tertiary shaped by tectonics, climate and Alpine and Northern glaciation. It presents view into the origin of the valleys, the various valley forming processes, which created different terrace styles, view into the problems of subdividing loess piles alternating with tephra beds and fossil soils, into rockslides and delta environment. It presents glimpses of the primeval Rheinländer, the *Homo erectus heidelbergensis* and *Homo sapiens neanderthalensis*, of some highlights of the landscape, as the Loreley and the volcanic Eifel, as well as some cultural highlights. It passes all the seven European countries belonging to the Rhein catchment, Italy (I), Switzerland (CH), Liechtenstein (FL), Austria (A), Germany (D), France (F) and The Netherlands (NL).

Each Stop is headed by the international abbreviation of these countries followed by the respec-

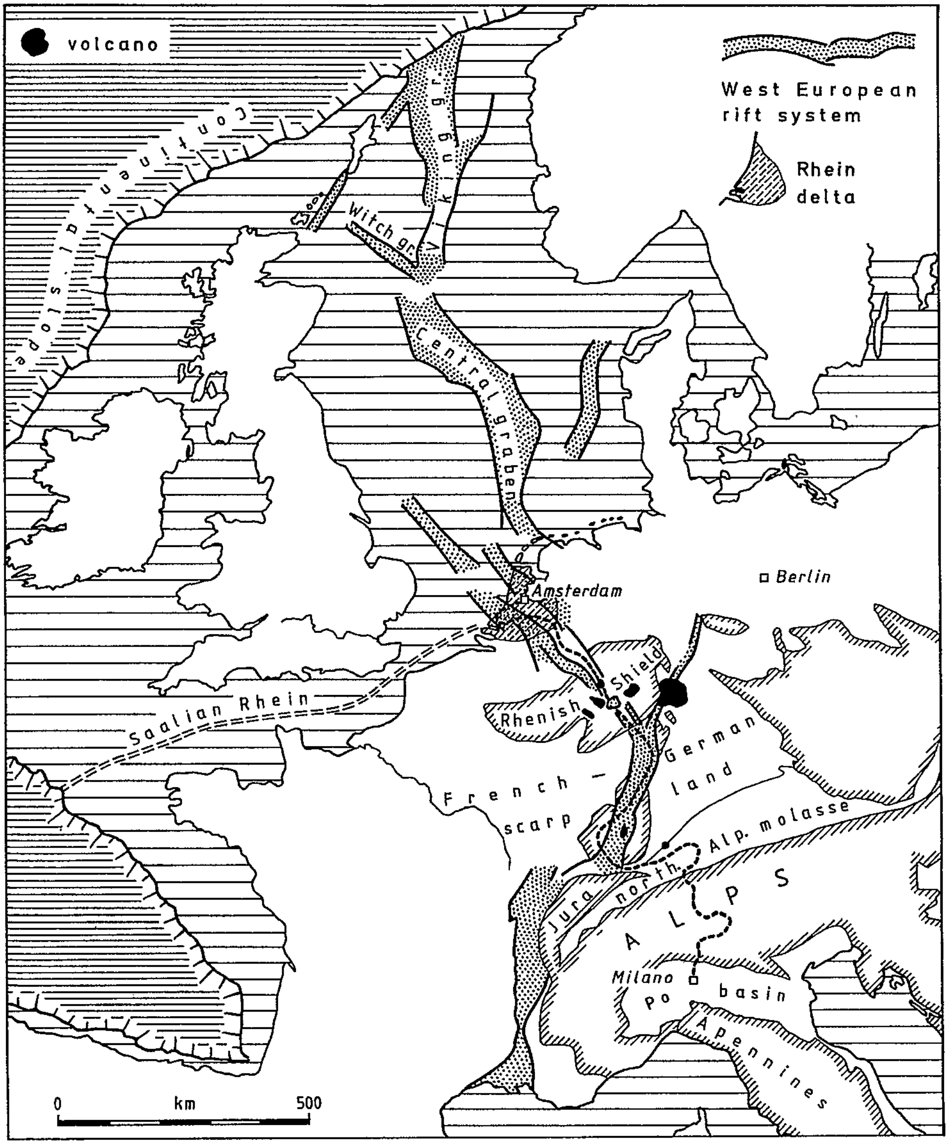


Fig. 2 Excursion route 9 in a larger geological setting

tive topographical map (TM), coordinates and elevation.

Thanks to all contributors for keeping company during field trips and preparing the contributions. Thanks to Ass. Prof. Dr. CHARLES MARTIN, Kansas State University, for reviewing parts of the English of this text. Thanks for much help to my student workers PETRA HORNUNG, GUÉNOLA KAHLERT, EVA IKINGER M. A. (drawings), ANNE HORMES, ROLF ZEDOW, to Dr. WULF HÜSKEN M. A. (typing and layout) and to my wife URSULA.

Introductory survey to the Rhein traverse

(W. SCHIRMER)

1. Brief earth history of the excursion area

The excursion passes the following eight tectonic, lithologic and morphologic units (Figs. 1 and 2):

8. Rhein delta
7. Niederrhein graben
6. Rhenish Shield
5. Oberrhein graben
4. French-South German scarpland
3. Northern Alpine molasse basin
2. Alps
1. Southern Alpine molasse basin (Po basin)

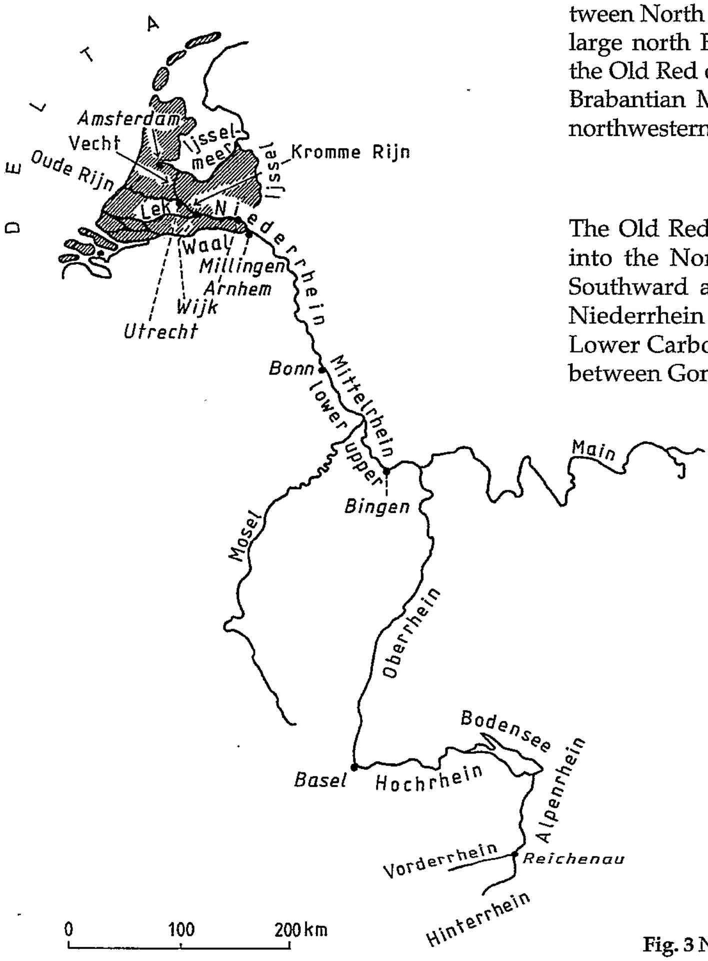


Fig. 3 Names of the different Rhein river sections

For the names of the different Rhein river sections see Fig. 3.

This eight units reflect the geological history of Europe since the Precambrian.

Pre-Variscan time

In places there are socles of the Variscan fold belt exhibiting pre-Variscan metamorphosis. These socles are attributed to the late Proterozoic Cadomic (= Assyntic) resp. to the late Caledonian orogeny (Silurian-Lower Devonian). The Caledonian orogeny was effected by closing the Iapetus ocean between North America and Europe. It resulted in a large north European-north American continent, the Old Red continent (Laurussia). Part of it is the Brabantian Massif, which forms the core of the northwestern Rhenish Shield.

Variscan era

The Old Red continent extended from the north into the North Sea including the Rhein delta. Southward a geosyncline was joining from the Niederrhein through the Po basin (Devonian-Lower Carboniferous). Carboniferous collision between Gondwana and Laurussia created the

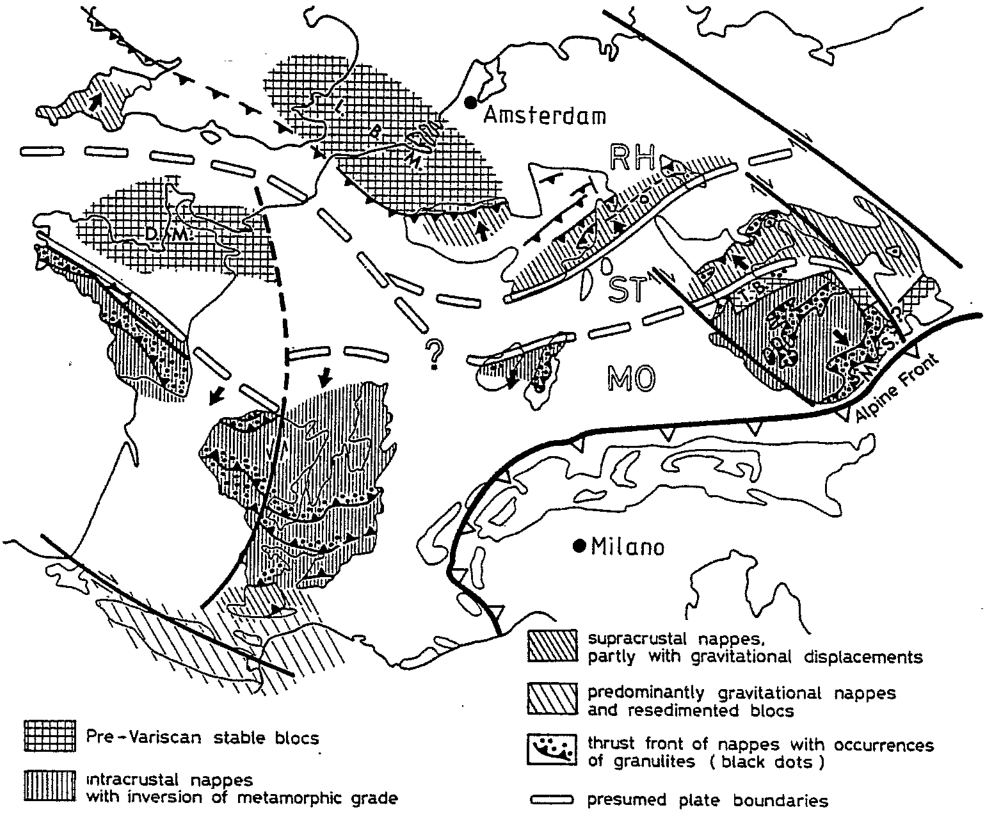


Fig. 4 Variscan belt of Central Europe. RH – Rhenohercynian Zone; ST – Saxothuringian Zone; MO – Moldanubian Zone; L.B.M. – London/Brabant Massif (Caledonian); D.M. – Domnoneo-Mancellian (Cadomian) and Icartien (Lower Proterozoic); T.B. – Tepla/Barrandean (Cadomian); M.S. – Moravo-Silesian (Cadomian) (modified from BEHR et al. 1984: 16)

Variscan fold belt (Fig. 4). Since Upper Carboniferous the fold belt became terrestric with molasse stade. The northern, extern molasse basin develops to a continuously subsiding trough (Saxonian basin), which is nowadays the north-central European lowland including the southern North Sea. Variscan remnants are visible in the Alpine socle, Schwarzwald, Vosges, Odenwald, Spessart, Haardt, Rhenish Shield and Harz (Fig. 1).

Alpidic era

From Permian on, two basins, the Saxonian basin and the Tethysian Alpine basin are growing and enlarging in extent and depth. In between, the German uplands vary from islands within an epicontinental sea to land masses. Since Permian/Triassic, the West European rift system (WER) (Fig. 2) starts to open between Scotland and Norway to procede like a zipper towards south.

By Middle Triassic, rifting and opening of the **Tethysian** ocean starts reaching its climax during Jurassic. It exhibits the following zonation (Fig. 5):
Helvetic trough: miogeosyncline at the European versant,
Penninic trough: eugeosynclinal deep sea with a mid ocean ridge,
Austroalpine trough: southern miogeosyncline,
South Alpine trough: southern miogeosyncline at the African versant.

The succeeding crustal shortening (Fig. 6) between Africa and Europe summits in three climax stades:

1. Around boundary Lower/Upper Cretaceous (eo-Alpine phase)
2. Eocene – Lower Oligocene (meso-Alpine phase)
3. Oligocene – early Pliocene (neo-Alpine phase)

Simultaneously with the meso-Alpine phase the WER cut from the southern North Sea through the central European upland, thus creating the Niederrhein graben, the small Mittelrhein basin (in the midst of the Rhenish Shield) and the Oberrhein graben (Figs. 2 and 7). During the Middle Oligocene this graben rift system became to a far extent marine connecting the Alpine with the northern lowland sea.

From the Upper Oligocene on **uplift** starts both

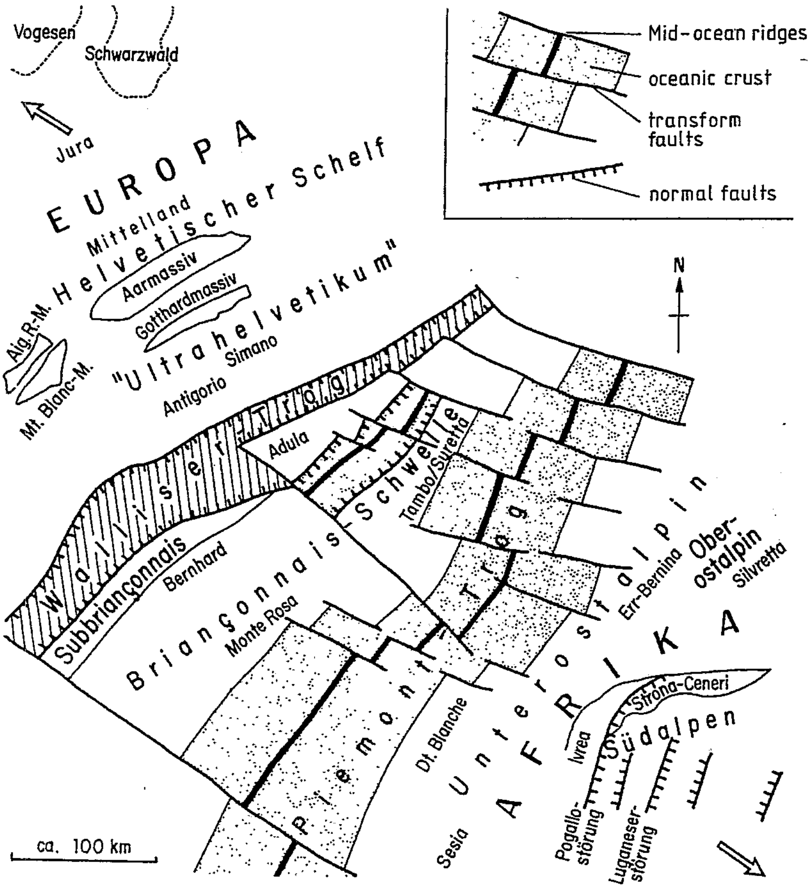


Fig. 5 Trough pattern of the Jurassic Alpine Tethys (modified from Labhart 1992: 153)

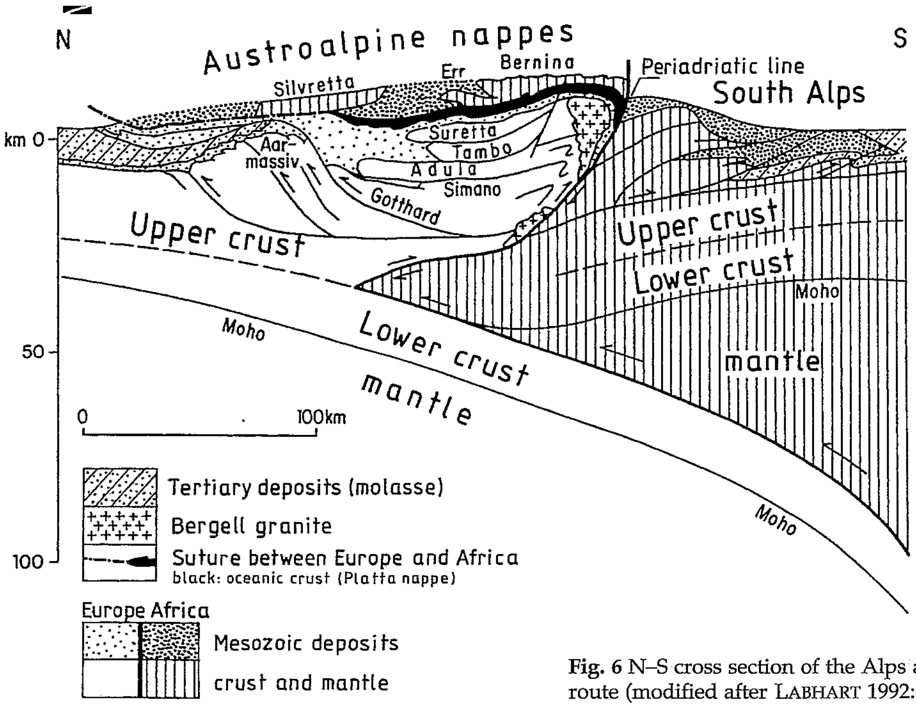


Fig. 6 N–S cross section of the Alps along the excursion route (modified after Labhart 1992: 158)

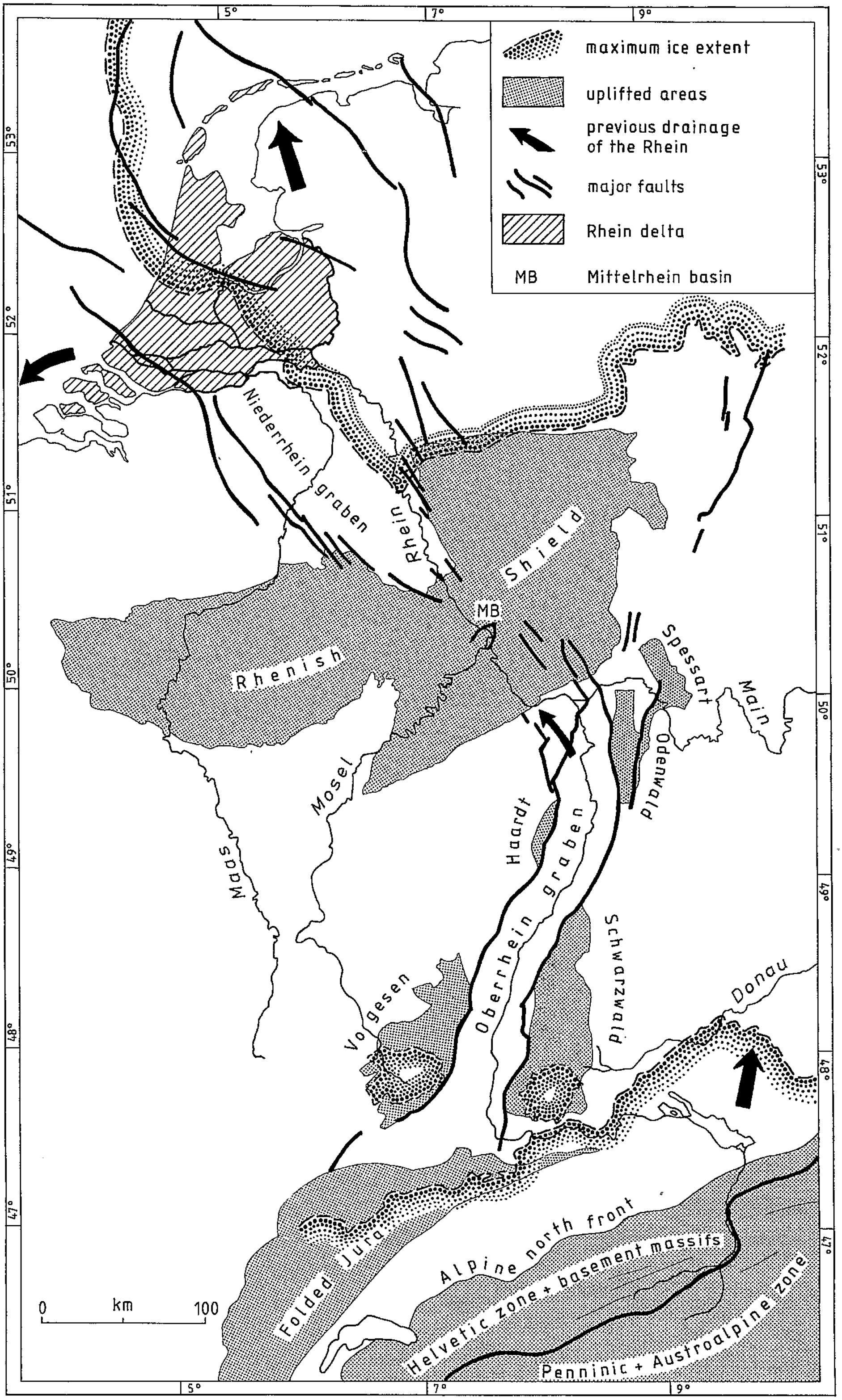
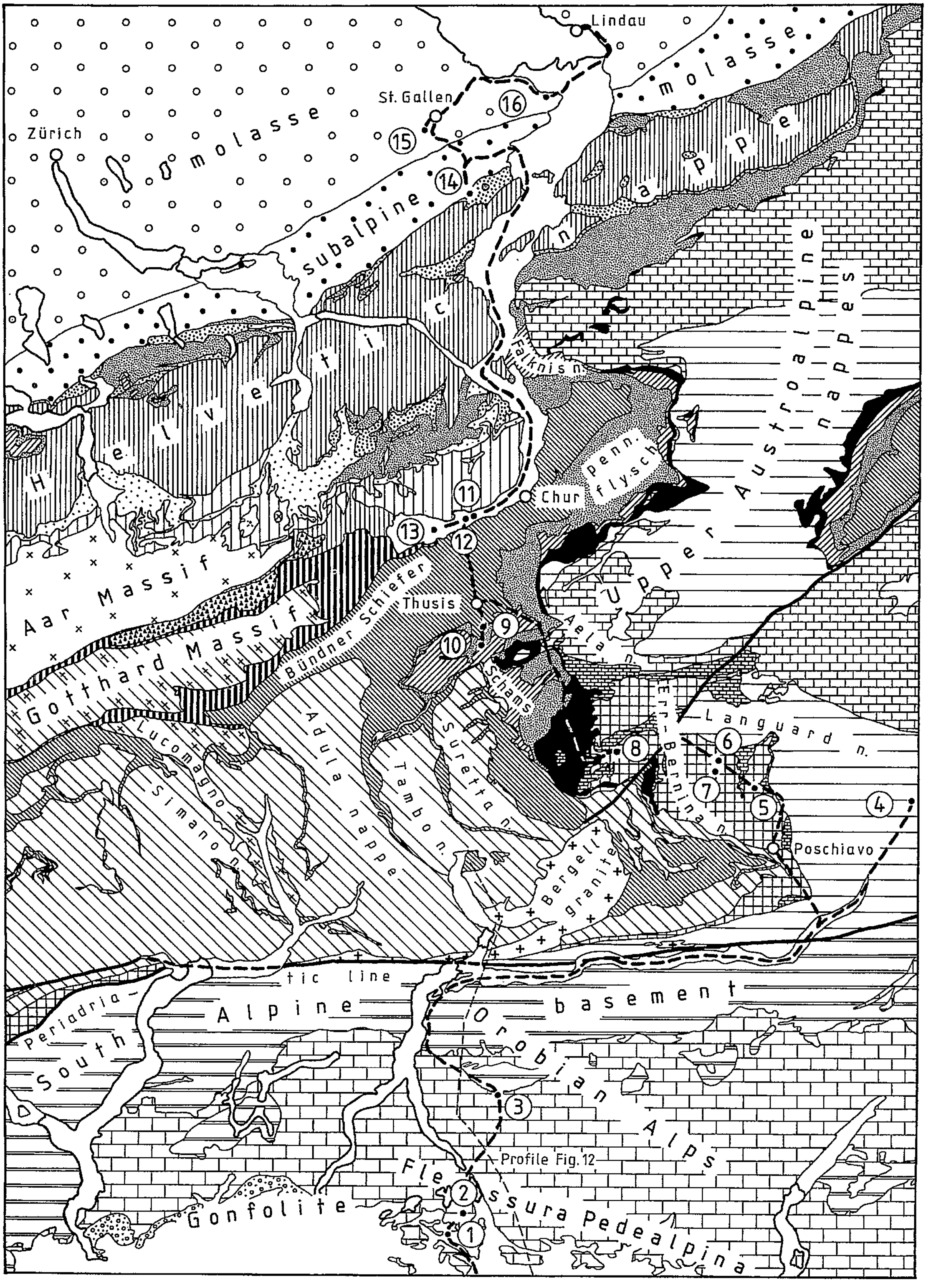


Fig. 7 Course of the Rhein controlled by the Western European rift system (WER) and the Alpine and Northern glaciation (modified from SCHIRMER 1994: 187)


Lindau
molasse
St. Gallen
⑯
Zürich
molasse
⑮
⑭
subalpine
nappe
Helvetic
Upper Austroalpine nappes
Falknis n.
penn. flysch
Chur
⑪
⑬
⑫
Aar Massif
Gotthard Massif
Bündner Schiefer
Thusis
⑨
⑩
Aela n.
Schams
Err-Bernina n.
Languard n.
⑧
⑥
⑦
⑤
④
Poschiavo
Lucomagno
Simano n.
Adula nappe
Tambo n.
Suretta n.
Bergell granite
Periadriatic line
South Alpine basement
Orobian Alps
③
Profile Fig. 12
Flessura Pedealpina
Gonfolite
②
①

in the Alps and in central Europe. As consequence, the WER became terrestric between Upper Oligocene and Lower Miocene, the northern Alpine molasse basin after Lower Miocene. The southern Alpine molasse basin fell shortly dry during the Messinian salinity crisis (end-Miocene) when the Mediterrranean was isolated from the Atlantic ocean and evaporated highly. At that time the south Alpine rivers created deep valley incisions, the predecessors of the recent valleys. Thus, a succeeding early Pliocene transgression pierced even into the exits of the south Alpine valleys. During the later Pliocene the Po plain became terrestric. The Niederrhein graben was gradually filled by the Rhein delta. The coast line started in the Upper Oligocene at Bonn and entered, migrating gradually northward, the recent Rhein delta (Figs. 1–3) at the beginning of the Quaternary. This Rhein delta depositional stack encompasses a highly complete Neogene and Quaternary sequence (Fig. 87).

The tectonic action was accompanied by rich **volcanic** activity. The Jurassic central Alpine (Penninic) rifting devised a thick ophiolite complex formed to the later Platta nappe (Figs. 5 and 8). From Upper Cretaceous up to modern times the European platform north of the Alps was effected by strong volcanism creating large volcanic landscapes as the Hegau and Kaiserstuhl (Figs. 2 and 37) effected by an Upper mantle pillow below the southern Oberrhein graben, or the Westerwald, Siebengebirge and Eifel (Figs. 2 and 55) caused by a crustal thinning below the Mittelrhein.

2. History of the Rhein catchment

With the uplift of the WER an oldest Rhein was born in the Rhenish Shield draining to the north (Brohl-Rhein) (Fig. 9). Another one drained the Oberrhein graben from south to north. During the Lower/Middle Miocene they joined to one Rhein system (Kaiserstuhl-Rhein). Promoted by uplift of the Western Alps and by vaulting of the southern Oberrhein graben, the Rhein enlarged its catchment towards south. Its head area lay since mid-Miocene around the Kaiserstuhl, since Plio-Pleistocene in the Alpine foreland, since early Lower Pleistocene in the Alps via Aare river system. Since late Lower Pleistocene it encroached the Alpenrhein system that was draining to the Donau before.

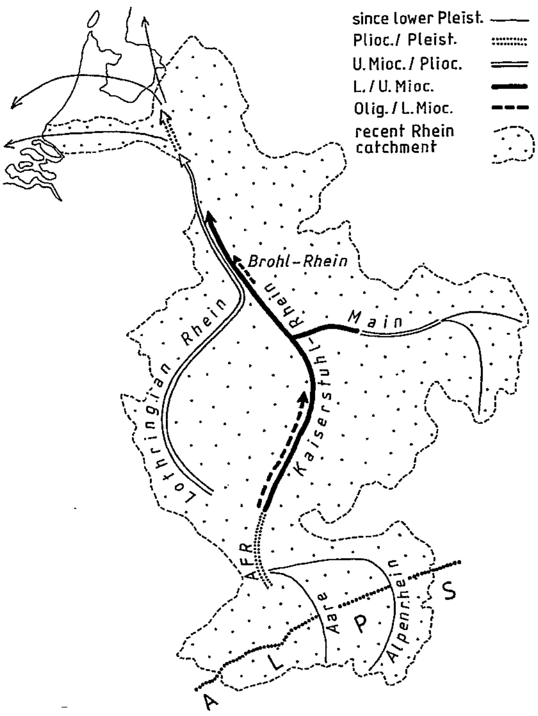


Fig. 9 Expansion of the Rhein course. AFR = Alpine foreland Rhein

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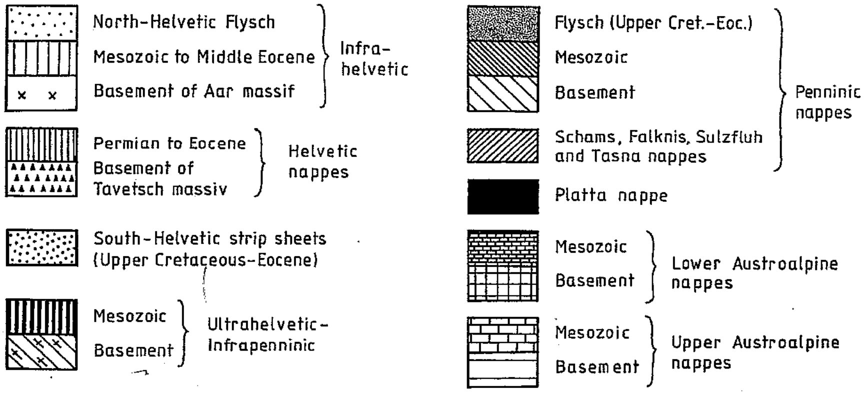
Fig. 8 Tectonical units of the Alps between Bodensee and Lago di Como covering the Alpine Rhein catchment (drawn on the basis of the Tektonische Karte der Schweiz 1:500,000; 2. ed., 1980)



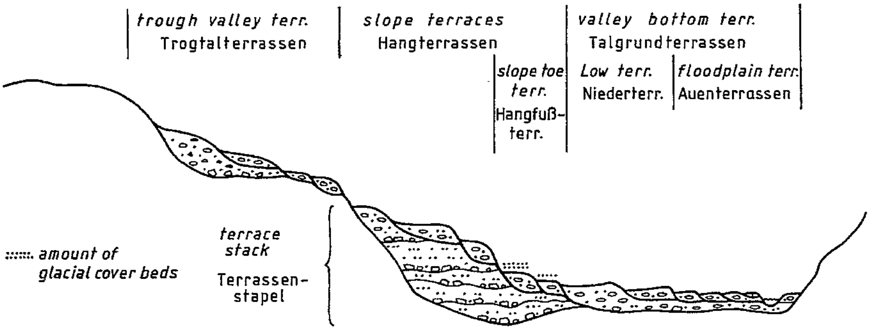


Fig. 10 Scheme of terrace texture of some upland rivers

3. History of valley-shaping in the uplands

It can roughly be outlined by a seven-membered story:

1. During the Tertiary, evident since the Eocene/Oligocene, an enormous valley incision took place. In places the Tertiary share of valley incision can be larger than that of the Quaternary. The result is a trough-like valley deepened into the land surface; it is wider than that of the Quaternary (trough valley terraces) (Figs. 10, 46 and 47).
2. During Pliocene/early Lower Pleistocene, rivers formed large meanders within this trough valley.
3. During the course of the Lower Pleistocene in larger upland areas strong tectonical uplift forced these meanders to incise, in places down about to the recent river level (entrenched meanders).
4. Late Lower Pleistocene to early Middle Pleistocene: Due to prevailing tectonic subsidence rivers pile up thick aggradations of some ten meters in height equalizing the preceding incision to a certain rate (terrace stack).
5. Mid-Middle Pleistocene: Rivers dissect their depositional stack indicating new widespread tectonical uplift. Thereby they form a terrace staircase as result of alternating erosion and aggradation (valley slope terraces).
6. Late Middle Pleistocene: Since the antepenultimate glacial period rivers form a gentle staircase in the lower part of the valley (slope toe terraces).
7. Upper Pleistocene to Holocene: Rhythmical fluvial deposition, since the Late Würmian prevailing lateral accretion in the valley bottom (valley bottom terraces) (see Stop 29).

4. Alpine and Northern glaciation

Although the Rhein is the only river touching both the Alpine and the Northern glaciation (Figs. 1, 7 and 11), up to now it did not succeed to connect both.

In Lombardia there are hints for a late Pliocene glaciation (cf. contrib. BINI). Likewise plateau gravel in the northern Alpine foreland interpreted as Biberian glaciation may root in the Pliocene (cf. contrib. ELLWANGER). The Biber and Donau glaciations are represented only by plateau gravels, the so-called 'Deckschotter' complex. The Günz and Mindel glaciation complex comprises at least five glacial periods, that are represented by glacigenic deposits as well as the fluvioglacial plateau gravel complex, the 'Deckenschotter' (cf. contrib. ELLWANGER and GRAF). According to magnetostratigraphical evidences this complex is of Matuyama age.

A strong morphotectonic event separates the Mindelian from the Rissian complex. The latter encompasses three glacigenic sequences (Older, Middle and Younger Rissian) separated by interglacials, the following Würmian two glacigenic sequences (Lower and Upper Würmian) (cf. contrib. ELLWANGER).

Undoubtly the Weichselian glaciation in the north corresponds to the Upper Würmian in the south. The Saalian glaciation complex in the north corresponds to the Middle and Younger Rissian in the south. The Elsterian glaciation (of normal magnetic polarity) may correspond to the Older Rissian; both are overlain by the typical Holstein interglacial in the north and the Samerberg-II-'Holstein' type in the south (Fig. 87). On the other hand in Thüringen and Niedersachsen MANIA (1994: 56) describes the Elster and Saale glaciation as being separated by three interglacial and two glacial periods.

5. Shape of the Rhein course

The Rhein course is generally determined by the West Eurpoean rift system (WER) (Fig. 2). The Rhein started being a river within this system, drained at first within this system into the North Sea and encroached the Alps by means of this rift. Thus, the Rhein is a rift river.

However, its recent head area is positioned

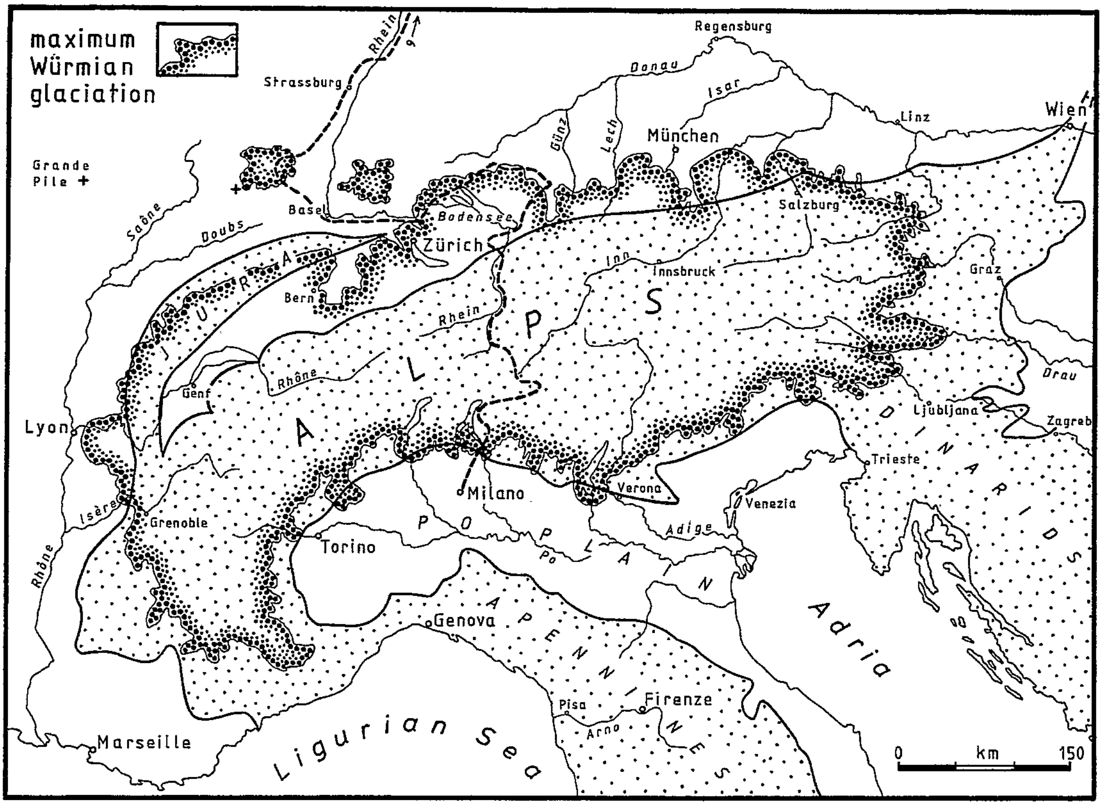


Fig. 11 The Alps during the maximum Würmian glaciation (modified from Ehlers 1994: 10)

outside this rift, and its delta bends westward off this rift (Fig. 7). These deviations were effected by both the Alpine and the northern glaciations. When the Alpenrhein glacier, draining to the Donau so far, entered the former Rhein-Donau divide in the Randen area between the Bodensee and Basel (Figs. 31 and 33) the meltwater spilled over to the Rhein. As the Rhein level is much deeper there (250 m) than that of the Donau (400 m), by the glacier retreat the whole Bodensee glacier basin and its feeder, the Alpenrhein, used this new drainage way. Hence, the Alpenrhein glacier drained during the very climax of later glaciations for a short while to the Donau when it climbed the Rhein-Donau divide in the northern and eastern part of the Bodensee basin.

In the north the first big glaciation (?Elster) formed an ice barrier across the North Sea by connecting the Scottish and Scandinavian ice shields. Thus, the Rhein was forced to bend westward in front of the ice barrier and to drain through the English Channel into the Atlantic ocean getting the Themse und Seine as tributaries (Fig. 2). With the Saalian glaciation this new course has been consolidated. A succeeding southward trend of the delta is still ongoing affected by the tidal activity that is controlled by the Channel (cf. Schirmer 1994: 187).

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Po plain and Southern Alps

(R. Bersezio)

The Po Plain subsurface

On the basis of the geophysical interpretation a magnetic basement (crystalline rocks and Permo-Scythian sediments), Mesozoic carbonates and a Cenozoic-Quaternary foredeep basin fill can be separated. The foredeep successions developed in the common Alpine-Apenninic foreland area, building two huge clastic wedges, up to 10 km thick, whose deposition was controlled by the emplacement of the South Alpine and Apenninic thrusts. The succession of the South Alpine margin represents the South Alpine molasse (Menard 1988).

The structural framework of this area is characterized to the north by the south-verging thrusts of Southern Alps, sealed by the uppermost Miocene-Pliocene sediments, and to the south by the north-verging Apenninic thrusts. These two thrust systems face a common foreland, along the axis of the Po plain. Subsidence patterns of the Po plain foredeep were therefore determined by the emplacement of the two opposite thrust belts. The tectonic load of the Apenninic thrusts is responsible for the latest subsidence/uplift history of the Po plain area, postdating the Alpine evolution and influencing the drainage patterns.

The Southern Alps

The central part of Southern Alps in Lombardia, consists of a fold and thrust belt comprising a northern E–W trending strip of basement rocks and sedimentary successions generally younging southwards (Fig. 8). In outcrops, the Variscan basement and the Triassic units form the Orobian Alps and the Prealpine belt, while the Jurassic-Tertiary units belong to the border chain corresponding to the Flessura Pedealpina (Desio 1929) and to the southernmost relieves at the border of the Po plain. The Flessura Pedealpina tectonic step lowers the Rhaethian-Lower Cretaceous successions of about 2 km southwards (Schonborn 1992). The youngest and more external foothill area of the chain is buried beneath the Po plain basin fill (Pieri & Groppi 1981; Cassano et al. 1986), and has been called Milano belt by Laubscher (1985) (Fig. 12).

The Periadriatic Lineament (Linea Insubrica)

It is a steeply north-dipping and east-west trending fault zone (Figs. 8 and 12) that in pre-Alpine to neo-Alpine times accomodated large dextral strike-slip movements (60 km since the early Miocene) (Laubscher 1971). Considerable dip-slip displacements (Schmid et al. 1989) resulted in southward upthrusting and backfolding of the north-alpine greenschist to amphibolitic grade metamorphic nappes over the southalpine units. The latter underwent only very low-grade metamorphism during the Alpine deformation.

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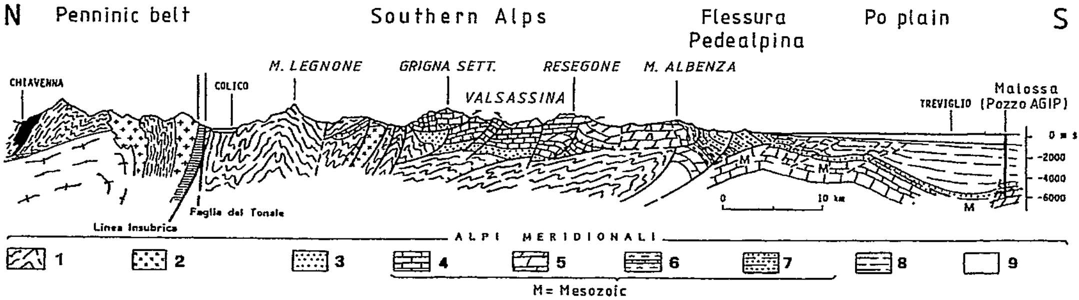

Fig. 12 Interpretative geological cross section of the Lombardian Southern Alps between the Adda and Brembo Rivers (location of the geological cross-section in Fig. 8). After Cita et al. [eds.] 1991: 51, modified. 1) South Alpine basement; 2) Variscan intrusives; 3) Permian clastics; 4) Lower-Middle Triassic carbonates; 5) Upper Triassic carbonates; 6) Jurassic syn- to post-rift succession; 7) Cretaceous succession; 8) Tertiary sediments; 9) Quaternary deposits

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Glacial deposits and morphology in the pre-Alps of Lombardia

(A. BINI)

Verbano (Lago Maggiore) end-moraine system

The first evidences of glacial expansion occur in Valle della Fornace SW of Varese and have been ascribed to the Late Pliocene (isotope stages 96–100?) by means of paleomagnetism and palynological dating (UGGERI et al. 1994). The areal extension reached by this glacier is unknown. The glacial inventory of the Lago Maggiore area reveals seven different geologic units within the end-moraine system. These units can be related to seven glaciations, separated by interglacials (DA ROLD et al. 1994). The youngest one belongs to isotope stage 2 (Fig. 13). The other units range in age from Early Pleistocene to Late Pleistocene (> 30,000 yr BP).

Adda end-moraine system

The Adda glacier splits into several tongues (Fig. 14) which caused the Faloppio, Como, Lambro and Lecco end-moraine systems. This end-moraine system consists of fewer glacial units than the Verbano one. This difference may be ascribed to a different degree of isostatic uplifting and neotectonic deformation. The Verbano area was subject to intense neotectonic deformation from the Late Pliocene up to the present. This phenomenon caused the uplifting of the piedmont sector, which acted as a major barrier for each subsequent glaciation (BINI et al. 1993). Because of the tectonic evolution, the ancient bodies were not completely buried by

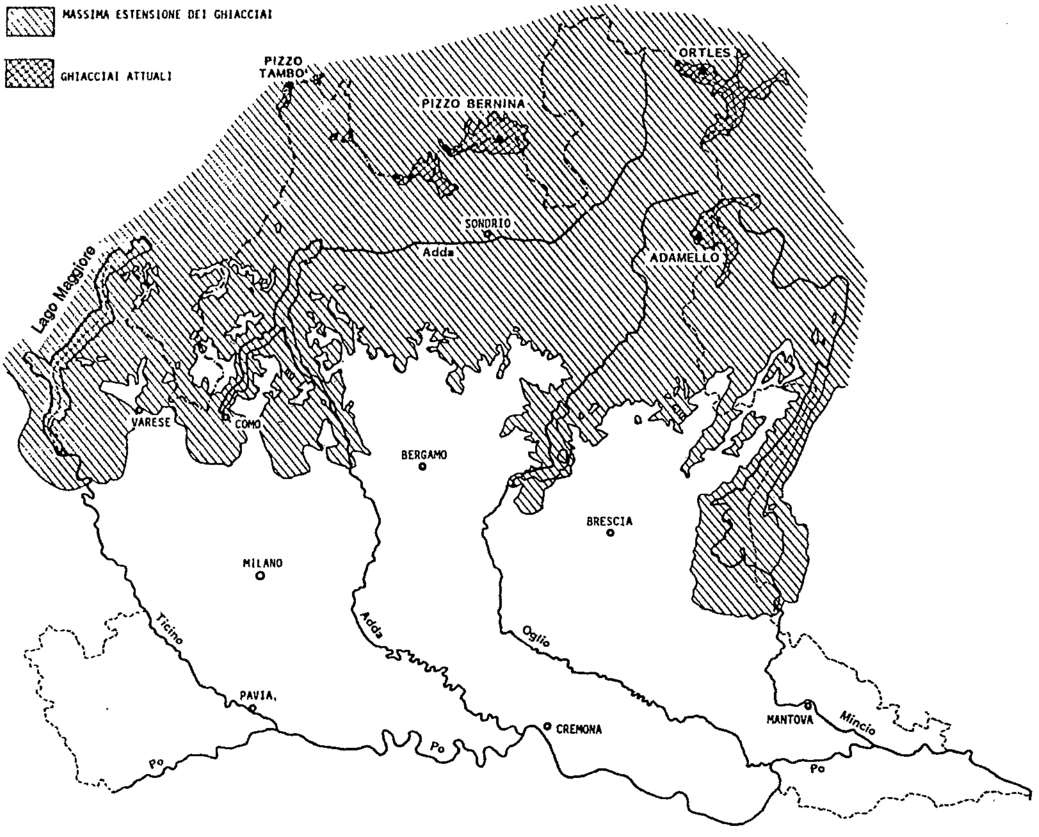

Fig. 13 Schematic map showing the maximum glacial extension in Lombardia (from OROMBELLI, in CITA et al. 1991: 55, modified)

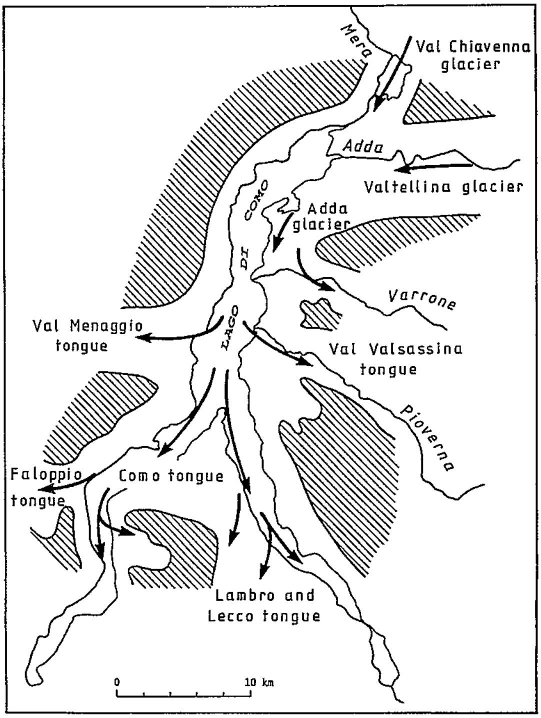

Fig. 14 Schematic map showing the Adda glacier in the central sector of Lago di Como (from GAETANI & BINI, in CITA et al. 1991: 210, modified)

the more recent sediments, as it was the case for the Adda end-moraine system.

All the end-moraine systems exhibit cemented gravels (so-called ceppo) of Late Pliocene – Early Pleistocene age.

The last glacial expansion

Its sediments are named the Alloformazione di Cantù in the end-moraine systems of the Adda glacier. It corresponds only in part to the Würm auct. Consequently, the areal extension of the last glacial expansion is not as large as it was believed to be in the past (Fig. 13).

In the Como end-moraine system it is possible to recognize two minor phases of glacial advance which occurred during the general glacial retreat.

In the course of the deglaciation phase, wide and shallow (5 to 10 m deep) marginoglacial and proglacial lakes formed in the Lambro and Como end-moraine systems. When the glacier retreated behind Bellagio, these marginoglacial lake waters gradually flowed into the Lecco branch marginoglacial lake, located 58 m below. Part of the waters crossed a fluvioglacial plain which stretched between the glacier to the N and the mountain slope to the S. Another part flowed below the glacier (SACCHI 1993). This model is contrary to the sudden and catastrophic drainage event hypothesized by previous authors (BINI 1987).

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The Adda glacier basin (South Alps)

Turning at the end of the freeway (Usmate) to the state road towards Lecco there is a cliff which limits a terrace consisting of fluvial conglomerates (ceppo) and strongly weathered, ancient glacial deposits. Passing a high plain, which consists of ancient fluvioglacial deposits exhibiting loess cover, we will reach the first rocky hillocks and moraines of the Lecco end-moraine system near Merate. From Calco in western direction the road runs along the valley of Rovagnate. This valley joins the Lambro end-moraine system area to the Lecco end-moraine zone. During the last glacial expansion, a lateral branch of both the glaciers transflowed into the valley, but did not reach the anastomotic stage.

Entering Rovagnate we pass a huge moraine belonging to the Lambro end-moraine system. It encloses a broad lacustrine plain with the following depositional sequence:

- laminated clay and silt lacking organic matter (top)
- fossiliferous marls bearing molluscs
- peat (^{14}C ages range from 10,620 ± 60 yr BP through 4,780 ± 80 yr BP)
- laminated sand and silt
- gravel and sand (bottom)

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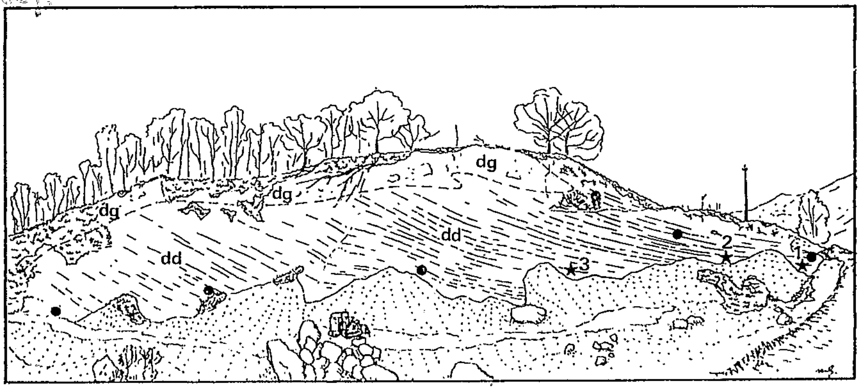

Fig. 15 View of the delta-moraine of Insiraga-Cologna
dd = foresets; dg = till. Black asterisks = logs (after GNACCOLINI & OROMBELLI, 1976)

= section

Stop 1: Cologna

I – TM 50: sheet 097 Vimercate,
R 52687, H 506655, 300 m a. s. l.

During the retreat from the maximum position, at Rovagnate, a lake was fed by meltwater of the delta (dd in Fig. 15). The overlying till (dg) is related to a little readvance of the glacier (OROMBELLI & GNACCOLINI 1978).

Stop 2: Villa Vergano

I – TM 50: sheet 097 Vimercate,
R 52934, H 507010, 666 m a. s. l.

Location on top of the terminal moraine of the last glacial maximum advance (Alloformazione di Cantù). The glacier came from the Lecco branch of Lago di Como, splitted into two parts at Monte Barro forming the two end-moraine systems of Lambro (west) and Lecco (east). The two tongues anastomosed at the col of Galbiate, which can be seen to the north. Some of the hills to the west consist partly of bedrock (flysch), others are true moraines. Between these hills there is a broad plain which bounds the lakes of Annone, Pusiano and Alsèrio. The maximum last glacial expansion stopped at these hills. The plain with the lakes of Pusiano (258 m) and Alsèrio (260 m) is the result of glacial retreat that stopped a little above the rocky cliff at Annone. After the complete drainage of this lake the lake of Annone (226 m) developed only in a subsequent stade of glacial retreat. Thus, the lakes of Brianza formed as a consequence of both the characteristics of the substrate and, to a lesser extent, glacial deposition. Consequently, these lakes should not be considered as intermoraine lakes.

Pollen sequences of Lago di Annone and Lago del Segrino
(L. WICK)

Lago di Annone (226 m a. s. l.) and Lago del Segrino (374 m a. s. l.) are situated in the Insubrian region, an area characterized by relatively warm temperatures and high precipitation.

The pollen diagram (Fig. 16) shows a steppe vegetation dominated by *Artemisia* and Gramineae during the early Late Glacial, followed by an initial stade of reforestation with *Juniperus, Salix,* and *Hippophaë*. The expansion of *Betula* dated to 13,690 yr BP and the development of an open birch forest correspond with a sediment change from silt to lake marl. At about 12,300 yr BP *Pinus sylvestris* expanded, and the forests became denser. Due to the situation of the investigation area close to the glacial refuges *Quercus, Tilia,* and *Ulmus* immigrated during the Allerød. At the beginning of the Younger Dryas the thermophilous trees disappeared, and *Betula, Artemisia,* and other heliophilous herbs became more frequent. Mixed oak forest and hazel expanded very quickly at the beginning of the Holocene; somewhat later *Abies* and *Alnus* became important, too. There is very little human impact recorded in the pollen diagram before ca. 2,000 yr BP. Major vegetation changes happened during the Roman settlement and the Middle Ages. At this time the cultivation of *Castanea sativa* and *Secale* became important, and great parts of the oak forests below 800–1000 m a. s. l. were cleared.

Valsassina

The sedimentary succession between Lecco and Bellano has been deposited from the Permian to the Triassic. The most characteristic features of the landscape in Valsassina are carved in Ladinian carbonate platform facies. Today, Valsassina is hanging over Lake Como both to the N (Bellano) and to the S (Lecco).

The evolution of the valley can be described as follows: In Valsassina the Pioverna, which now flows northwards, used to flow to the south through the Canyon di Balisio down to Lecco. The fluvial deposits of this evolutionary stage are identified by the conglomerates of Ponte della Folla,

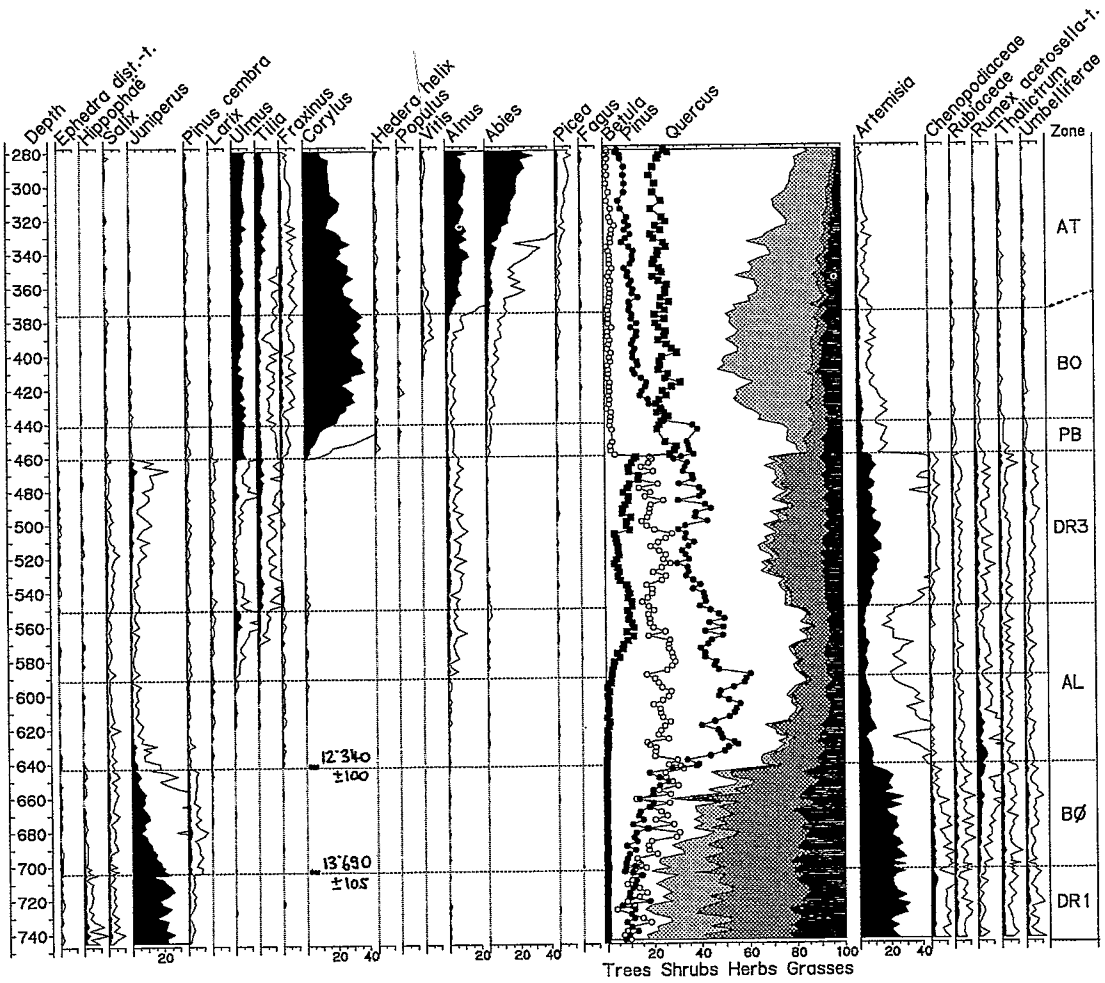

Fig. 16 Pollen diagram of Lago di Annone: Late Glacial and early Holocene (Anal. L. WICK 1994)

which predate the glacial expansions. This phase was followed by several glacial expansions, during which the glacial stream drained the waters to the south. Glacial and fluvioglacial deposits filled the Balisio canyon and the valley below. On top of the deposition of the now cemented alluvial fan in the Basilio pass region occurred. During the Lower and Middle Pleistocene, tectonic dislocations caused the deviation of the Pioverna flow direction from south to north. The drainage Balisio to Lecco became a fossil valley. During the glacial expansions two tongues of the Adda glacier entered Valsassina both from Bellano and from Lecco, leaving a small sector ice-free in between.

Trip from Lecco to Barzio

Lecco is located on alluvial fans. The Gerenzone valley exhibits fluvial conglomerates, slope conglomerates and tillites. These deposits are overlain by till and marginoglacial lacustrine sediments, which record several episodes of glacial expansion. Just before entering Ballabio fluvial conglomerates of the south orientated paleo-Pioverna are quarried. Overlying fluvioglacial deposits present structures indicating a reversal flow direction. The topping till pertains to the Alloformazione di Cantù. The moraine at Ballabio belongs to the Last Glacial.

The area of Canyon di Balisio (Dolomia Principale) and Colle di Balisio is a fossil valley. The latter is the highest elevation reached by an ancient alluvial fan formed by the Pioverna. Before entering the Conca di Barzio the conglomerate of Ponte della Folla is visible.

Stop 3: Fucine

I – TM 50: sheet 076 Lecco,
R 53517, H 508938, 620 m a. s. l.

Along the dirt road lateral to the bridge, massive dolomites of the Ladinian Formazione di Esino, the dark grey, bioturbated limestones of the Carnian Calcare Metallifero Bergamasco, and the red and green sandstones, siltites and shales of the Carnian Arenarie di Val Sabbia are exposed. In the abandoned quarry, the Quaternary Fucine unit crops out.

The Quaternary succession begins with horizontal beds composed of sands and gravels, which were deposited in a fluvial plain by N–S trending braided streams. Most of the clasts are of local provenance, however, part of them were transported from Valtellina. Consequently, the gravels were deposited after one or more glacial expansions. Note that the conglomerates of Conglomerati di Ponte della Folla, which were also deposited by N–S trending currents, are exclusively composed of clasts of Valsassina provenance and, therefore, predate the glacial expansions.

The gravels are overlain by the proximal sediments of a proglacial delta, consisting of SW-dipping massive banks of conglomerates and gravels, which exhibit weathered clasts and intercalated yellow sands. The gravels are predominant in the lower part of the bank, whereas the sands are more common towards the top. Distal deltaic deposits and clays outcrop in other quarries.

The Fucine unit identifies deltaic sedimentation in a lake which developed in front of a glacier terminus. The palynologic analysis of lacustrine deposits yielded a Lower Pleistocene age. The glacier was located to the north and its meltwater flowed to the south. The northward deviation of the Pioverna current had to occur at a later time.

Northwards we cross tha Valtorta Fault, where Permian red conglomerates (Verrucano) join the Ladinian, massive, grey Calcare di Esino.

Beyond Introbio, to the left, the Pizzo della Pieve cliffs are formed by the Calcare di Esino. To the right you will see the metamorphic and igneous rocks of the basement, as well as the Troggia waterfalls, which had been described by the great Leonardo da Vinci.

The Valsassina bottom, up to Ponte di Tartavalle, consists of eroded alluvial and proglacial lacustrine deposits. From the bridge, the road goes down along the canyon cliffs, which are cut into the 'Gneiss chiari' up to Bellano. From Bellano onwards, along the Lago di Como shore, only the 'Gneiss chiari', Scisti dei Laghi and pegmatites of the crystalline basement crop out.

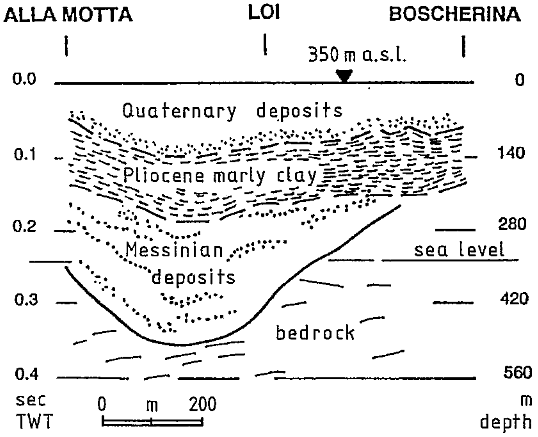

Fig. 17 Geology of the seismic profile of Valle della Motta (modified after FELBER 1993)

Origin of the Prealpine valleys and lakes

Seismic profiles carried out in the lakes (FINCKH 1978) and through the valleys demonstrated that the Prealpine valleys and lakes are deep, buried valleys (886 m below sea level for Lago di Como at Argegno and 500 m below sea level for Verbano at Piano Magadino) which were subsequently filled by sediments and shaped by glacier erosion. This sedimentary fill consists of basal continental conglomerates, Early Pliocene marine sediments, Plio-quaternary glacial and fluvioglacial deposits on top (BINI 1994; FELBER et al.) (Fig. 17). In the major valleys which had been only partially glacialized (as Valseriana and Valbrembana), there are wedges of Pliocene marine deposits along a several kilometer-long belt located at the margin of the plain (BRAMBILLA & LUALDI 1986; RIZZINI & DONDI 1978).

It derives that the Prealpine valleys have not been formed by the erosive action of glaciers. BINI et al. (1978) correlated the development of these valleys with the Mediterranean desiccation event, which took place in the Messinian (HSÜ et al. 1977). In this perspective, the major morphologic features of the Prealpine landscape would be inherited from the Tertiary (BINI et al. 1994; FELBER et al.).

Stop 4: The 1987 Val Pola rock avalanche
(G. CROSTA)

I – TM 50: sheet 041 Ponte di Legno, R 6043, H 51376

The Val Pola rock avalanche, occurred on July 28, 1987 in Valtellina (2500 km^2 drainage area) and caused 27 casualties. The area presents the typical features of a glacial valley, with steep flanks and with more recent fluvial morphology and deposits. It is placed within the Austroalpine nappe, formed by igneous and metamorphic rocks. In particular, gabbros and diorites (Gabbro di Sondalo) outcrop mainly in the lower part of the slope while paragneiss and amphibolite (Cristallino del Tonale) are found in the upper part, close to the landslide crown area. The structural settings are mainly influenced, on a regional scale, by the overthrust of the Grosina Unit on the Tonale unit and by a well developed set of N–S discontinuity set, parallel to the main valley axis. Along the slope, two E–W faults (Val Pola and M. Zandila fault) were in correspondence of the main creeks limiting the landslide area to the North, while minor faults strike NW–SE and NNE–SSW. Geomechanical field surveyings revealed a higly fractured rock mass and joint sets with dip direction N–S, E–W, ENE–WSW, NNW–SSE (post glacial rebound). An old quiescent landslide was already recognizable.

The 1987 catastrophic event, occurred between July 15 and 20, was characterised by abundant rainfalls (on average 200–300 mm, with peak values of 600 mm in the Orobic area) that induced flooding (estimated discharge at Sondrio: 1600 m^3, 1200 ha were flooded and 3460 people evacuated) and landsliding (soil slips, debris avalanches, large rotational and planar sliding, etc.) all over the Valtellina and alpine areas. In 24 hours 130 mm felt in Upper Valtellina and 190 mm between July 17 and 19, with the freezing point stable at more than 4000 m of altitude for all the antecedent period and during the entire event. Sediment yield and mass transport within the Val Pola caused the growth of a huge fan and the damming of the valley bottom on July 18. The impounded water of the Adda river covered a 266,000 m^2 in about one day before to overtop the fan and then reducing almost to an half the impounded area. The general slope failure took place on July 28 at 7:23 a. m., involving about 34 Mm^3. The rock avalanche spread in three possible directions, upslope on the opposite valley side (270 m), downhill (1550 m) and uphill (2200 m) along the valley bottom. In particular, the material that moved upstream mixed itself with the impounded water and precede by a large muddy wave, oscillating between the valley flanks, splashing them up to 100 m above the valley bottom and destroying four villages. At the same time, the material mounted on the opposite valley flank moved laterally, in part generating two vortex-like structures, and in part falling downhill as large debris flows and avalanches. Almost 40 seconds took to complete the whole event, according to witnesses and seismic recordings.

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Central Alps

(W. SCHIRMER)

Four km after the border Italy/Switzerland the route passes the **rockslide** of **'Motta di Meschino'** near Miralago. A rock mass of 0.15 km^3 (HEIM 1932: 116) from the western valley flank, named Giümelin, mostly consisting of granite, is dated to the late Würmian between the Bühl and Steinach stades (BURGA 1987: 20). By blocking the Poschiavino valley, the rockslide formed Lago di Poschiavo. As the rockslide glided 270 m upslope the opposite valley flank, the recent river cut a new gorge at the slide side (HEIM 1932: 137).

Leaving the Poschiavino valley towards the

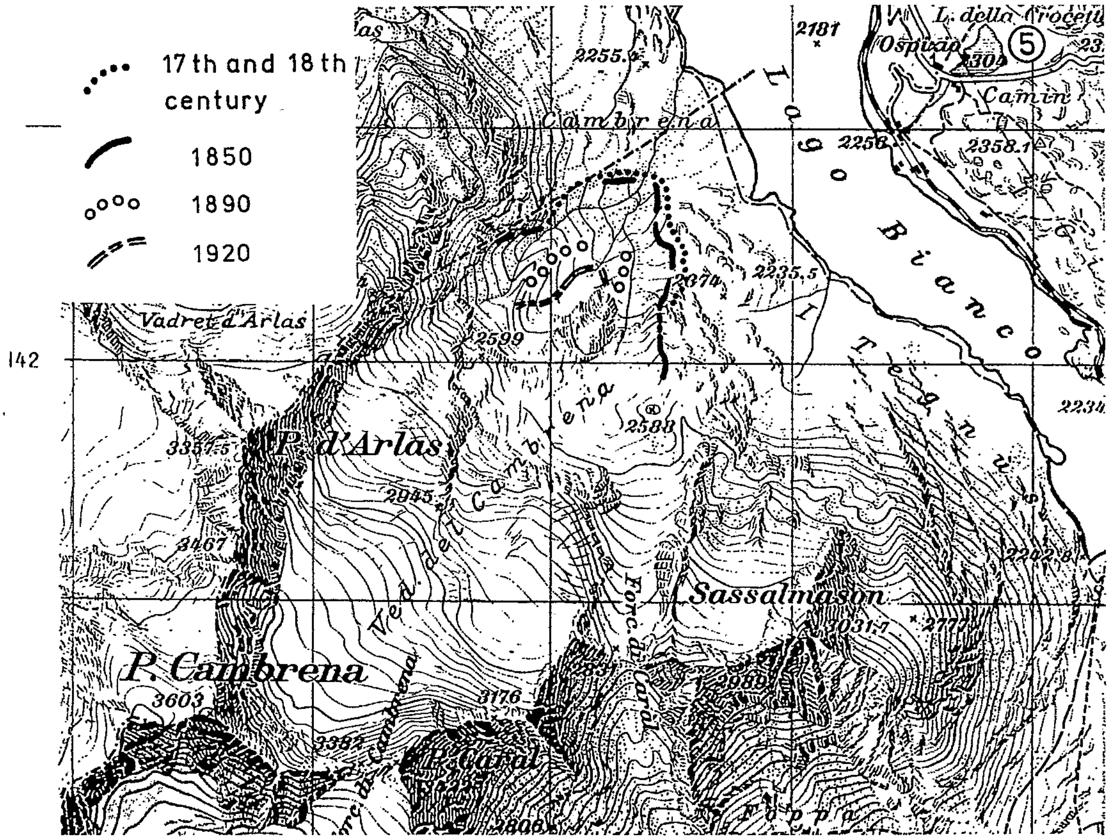

Fig. 18 Cambrena glacier and its geographical setting (after Landeskarte der Schweiz 1:50,000, 269 Berninapass and Beeler 1977: Fig. 6). = Bernina pass

Bernina Pass after La Rösa, the **Gessi hill** with its striking light colours is visible to the north. Its name and colours come from Triassic rocks including dolomite and gypsum (gypsum = Italian: gesso). It is part of the Mesozoic cover of the Lower Austroalpine Bernina nappe dipping to east below the overthrusting Upper Austroalpine crystalline Languard nappe.

Stop 5: Bernina Pass (2323 m a. s. l.)

CH – TM 50: sheet 269 Berninapass,
R 799.06, H 143.25

Divide between the Po and the Donau (Danube) catchment area. Roche moutonnée landscape. Tectonically the area lies within the Lower Austroalpine crystalline basement of the Bernina nappe which is overthrusted in the east by the basement of the Upper Austroalpine nappes (Fig. 8). A strip of Mesozoic cover of the Bernina nappe (Piz Alv series) is visible to the west by its light rock colours (Alv from Latin: albus = white) that are effected mostly by Triassic dolomite. It represents a recumbent syncline opening to the west, preserved between two crystalline lobes of the Bernina nappe, the Stretta lobe in the east and the Bernina lobe in the west.

The scenic view to the southwest presents Piz Cambrena (3603 m) crowning the large Cambrena cirque and glacier (Fig. 18). In front of the glacier snout the well formed and fresh terminal moraine of 1780 and 1850 is visible (Beeler 1977: 162, 176). Below the Cambrena summit, northwards through Piz d'Arlas, a light alkali granite stands out against darker metamorphic shists of the summit and darker rhyolite of the deeper northern flank.

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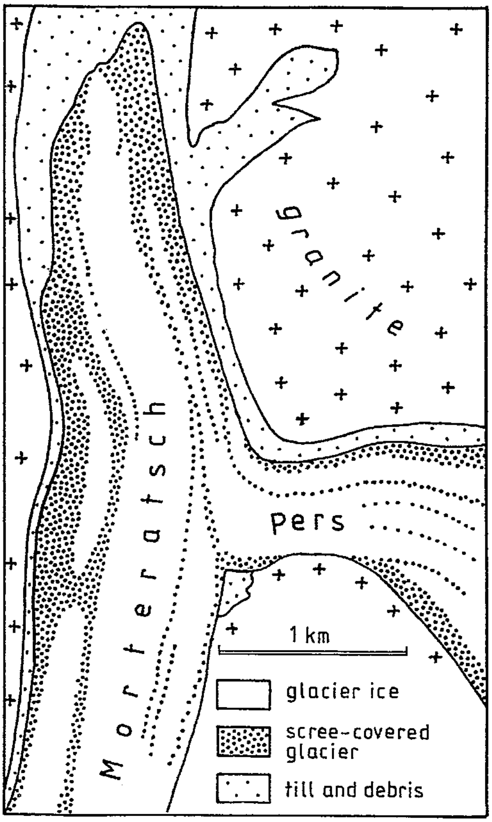

Fig. 19 Morteratsch and Pers glacier in the northern Bernina area

Downvalley Val Bernina on the left hand good prospect of the Cambrena glacier and its foreland, on the right hand of the Mesozoic Alv series.

Stop 6: Montebello

CH – TM 50: Sheet 268 Julierpass,
R 792.35, H 148.15, 1950 m a. s. l.

Scenic view to the Bernina massif and the Morteratsch glacier. The glacier basin is framed at its western flank by Piz Bernina (4049 m), at the eastern by the Bellavista crest (3922 m). The whole massif surrounding the glacier basin consists of predominantly acid plutonic rocks, representing the Variscan crystalline basement of the Bernina nappe. The steep walls seaming the glacier tongue, which are free of vegetation, are the lateral moraines of the 1850 glacier stade. The dark, debris-rich lateral parts of the glacier result from lateral moraines and merging medial moraines of the glacier hinterland (Fig. 19).

One km after Stop 6 junction to Morteratsch. From the parking area a 1 km walk to Stop 7 and further 2 km to the glacier snout along a glacier trail with the signs no. 1–15 (cf. MAISCH et al. 1993).

Stop 7: Morteratsch glacier

CH – TM 50: sheet 268 Julierpass,
R 792.25, H 147.1, 1920 m a. s. l.

The trail reaches upvalley (at sign 3 of the glacier trail) a humble, forested ridge, the terminal moraine of the Little Ice Age glacier stades. A borrow pit at its inner flank exhibits a section with four superimposed podsol soils (Fig. 20).

The first three podsols under the surface are very small developed sometimes incompletely preserved. The fourth podsol from top (f 3) is the strongest one. Its humus yielded a ^{14}C age of 1,150 ± 50 yr BP (MAISCH et al. 1993: 14), that is 860–980 cal AD (using STUIVER & BECKER 1993). After this first podsolization the morainal ridge was affected by three further glacier advance events of similar extent during which the external slope of the ridge was supplied by a thin depositional mantle. The three depositional phases are separated each by a period of podsol formation. The 1857 glacier stade is represented by a track of boulders joining the internal side of the morainal ridge.

Since 1857 the glacier retreated from this place 2 km towards the recent snout exposing an area of 2.9 km² (MAISCH et al. 1993: 131). This young glacier foreland exhibits a well developed glacier inventory that can be studied along the trail to the glacier snout: E. g. pioneer vegetation; sheep-back formed roches moutonnée (around sign 8) with striae, crag-and-tail forms and chatter marks; enlargement of the lateral moraines where on the eastern slope a ravine feeds the glacier with debris.

Among the glacial and fluvioglacial pebbles and boulders occur striking petrographic types:

1. Plutonites: biotite granite with green or white feldspar, amphibole-biotite granite with blue feldspar (typical Bernina granite), chlorite granite with red feldspar (compare the reddish Alvier granite massif in the north), amphibole quartzdiorite, rarely gabbro and dunite.
2. Metamorphites: biotite gneiss, biotite-amphibole augengneiss, chlorite gneiss with porphyric quartz phenocrysts.

Approaching the glacier snout its morphology

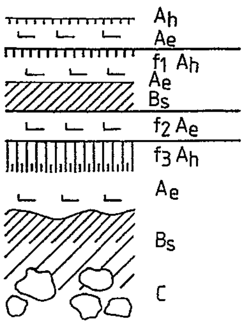

Fig. 20 Podsol profile on top of a terminal moraine in the Morteratsch glacier forefield (not to scale)

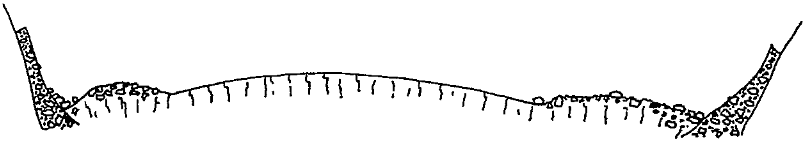

Fig. 21 Cross section of Morteratsch glacier snout flanked by the 1850 terminal moraine

exhibits three ridges (Fig. 21). The middle one is the most active part of the ice with less debris; amongst its ablation till there are good glacier tables. The lateral ridges represent upglacier lateral and medial moraines (see Fig. 19). As the ice has been protected from melting by a thick scree mantle they form longitudinal ridges. The glacier snout often exhibits good inclined share planes.

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The route joins the Engadin (Inn valley) and upvalley passes St. Moritz. Between St. Moritz and Silvaplana the craggy Bergell granite massif is visible in the upvalley background. It is one of the rare Alpidic plutons, whereas the plutonites passed on this route originate from the Variscan era.

In Silvaplana towards Julier Pass. 5 km west of Silvaplana, in the Alp Julia (R 777.5, H 149.3), on the south side a well developed meadow-covered moraine of the Egesen stade (Younger Dryas) embraces the recent brook that drains the Lagrev glacier, which cannot be seen from the street.

Stop 8: Julierpaß (2284 m)

CH – TM 50: sheet 268 Julierpass, R 775.8, H 149.3

Divide between the Donau and Rhein catchment area. This notch is situated in the so-called Julier granite, a biotite granite with green feldspar. Some blocks of biotite-amphibole diorite come from the summit of Piz dellas Colonnas in the south. The rocks represent the Variscan crystalline basement of the Err-Bernina nappe. Because of its green feldspar that is unique in the Rhein catchment, the Julier granite serves well as indicator of the ice movement. Two Roman columns beside the street witness the old history of this pass.

At the end of the lowermost hair-pin bend the route descends through the Lower Austroalpine nappes into the Penninic nappe area, here the Platta nappe (rich in ophiolite). The valley is called Sursés (Rhaetian = above the crag). It is passed by the Julia River. Down to Mulegns pure ophiolite landscape. Near Savognin at the eastern side on top Lower Australpine nappe, with a klippe (Piz Toissa) on the western valley side, at Crap Ses (Triassic dolomite crag) crossing the Julia in a local synclinal structure.

At Tiefencastel the Sursés valley is rectangularly cut by the gorge of the Albula River, but it continues to north in the Lenzerheide valley, which runs straight towards the Alpenrhein, thus representing a very old and high Rhein valley. Following the Albula gorge (called Schyn) the route passes the Schams nappes into the Adula nappe with the deep-sea deposit of the Bündnerschiefer that are cut in many places by deep gorges.

The headwaters of the Rhein

The headwaters of the Rhein lie within western Grisona (Graubünden) (Fig. 22). Among twelve

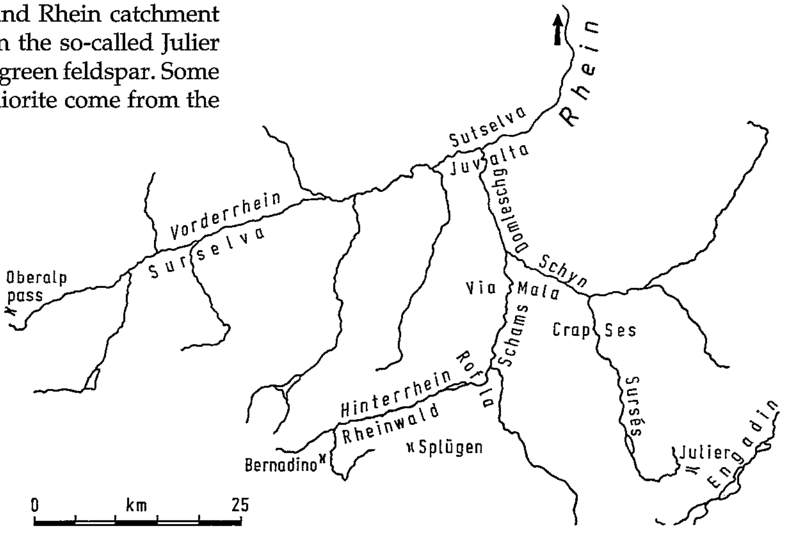

Fig. 22 Headwaters of the Rhein in Grisona (Graubünden)

Fig. 23 Vision of Via Mala gorge (W. SCHIRMER 1994)

bigger feeders the Vorderrhein and Hinterrhein are the main sources merging at Reichenau to form the Alpenrhein. Both Vorderrhein and upper Hinterrhein run parallel to the Alpidic foldbelt, i. e. in tectonical b direction. An exception is the lower Hinterrhein. It follows the tectonical c direction making way for the High Penninic and Austroalpine nappe stack. The western rim of this nappe stack forms a south-north running line, thus separating the Western from the Eastern Alps. This is the very line which controls the south-north running course of the lower Hinterrhein and the downstream succeeding Alpenrhein (Fig. 1).

In its lower course the Hinterrhein valley is subdivided into three gorges (Rofla, Via Mala, Juvalta) and two basins in between (Fig. 22).

Stop 9: Via Mala

CH – TM 50: sheet 257 Safiental, R 753.7, H 169.9

Offering the main connection between the Bodensee area and Milano, the Hinterrhein as an old trade-route has as its worst obstacle the Via Mala ('bad way'). In a narrow gorge of 5 km length and up to 600 m depth are exposed nothing but grey, steep walls sometimes leaving a horizontal clearence of only a few meters (Fig. 23). The gulch is cut into Bündnerschiefer (schistes lustrés), slates to phyllites that are interbedded at this place by more solid silici-carbonaceous layers. Belonging tectonically to the infra-Penninic nappes they are of Cenomanian age. By contrast the joining Schams and Domleschg basins lie in more argillic slates. At Stop 9 the walls of the gorge exhibit the Bündnerschiefer with excellent buckled folds and white calcite and quartz veins.

Close to the southern end of the scale that leads down to the gorge, a former gorge of the Rhein is visible, few meters wide and now refilled by gravel. It demonstrates that the Rhein at a former stade could not find again its own gorge. This could happen during a glaciation period when subglacial streams filled up the gulch. Thus, the former gorge might have been active during an interglacial period.

The Via Mala exposes roads and bridges of different ages from 1473 up to modern times. At its northern exit the ruin of Hohenrätien (12th–14th century) crowns the gorge.

JÄCKLI, H. (1967): Reichenau–Domleschg–Thusis–Via Mala–Zillis. – In: Schweizer. Geol. Gesellschaft [ed.]: Geologischer Führer der Schweiz, 8: 786–789; Basel.

Stop 10: Zillis. Romanesque church of St. Martin.

CH – TM 50: sheet 257 Safiental, R 753.4, H 166.75

South of the Via mala gorge within the Bündner Schiefer is a small basin called the Schams. It is the first basin on the Hinterrhein at well habitable altitude (ca. 950 m) and is bracketed by narrow gorges of the river (Fig. 22). Here in Zillis we find the old and beautifully painted church of St. Martin. It is the uppermost of a long chain of St. Martin churches along the Rhein and one of the most exciting. The church was founded upon Roman ruins dating from about 500 AD. The modern building dates to 1140 AD and is in the Romanesque style. The main attraction is the painted wooden ceiling which dates about to the 12th century and is the only and oldest work of this style preserved today. The 153 pictograms narrate the life of Christ, of St. Martin and the story of the Apocalypse. The wild and grotesque animals, symbols of the evil, refer to the latter (Fig. 24). This style of painting resembles book illuminations. Post-Romanesque renovations include the Gothic choir built in 1509.

Fig. 24 Apocalyptic figure of St. Martin in Zillis (1140 AD)

The Flims-Tamins rockslide area

(W. Schirmer)

The largest rockslide area of the Alps (70 km²; Abele 1970: 345) lies in the Vorderrhein/Alpenrhein valley along a tectonic line where Penninic Bündnerschiefer are overthrusting the Aar Massif with its Helvetic autochthonous sediment cover (Permian to Cretaceous). The bulk of the rockslides roots at the northern margin of the valley (Fig. 25). It consists of the Flims rockslide (9 km³; Abele in press), the Tamins rockslide (1.5 km³; Pavoni 1968: 500) as well as the smaller Domat and Chur rockslides. Their background is a slope-parallel dipping of Malmian limestone beds towards the valley. The south dipping limestone (10–40°) was undercut by the Vorderrhein glacier and river, thus triggering the rockslides. Additionally, on the southern versant of the Vorderrhein valley three smaller landslides from the Bündnerschiefer area and the Mesozoic of the Gotthard Massif have slidden upon the Flims rockslide. The two big rockslides, Flims and Tamins, slid into a groundwater-saturated valley fill. This fill consisted of gravel and floodplain deposits, the latter with cryoturbations as well as rannen (remnants of trees, see Stop 12). By this sudden impact the valley fill was mobilized and turned into a slurry. Consequently its corpus became completely reorganized: By perfect destruction of the primary bedding and gravel orientation coarse components sank into the deeper part, finer components were positioned in the upper part. Its maximum thickness attains 60 m near Bonaduz (Staub 1910: 14; Jordi 1986: 71). The whole mass is topped by an even surface with an elevation of 50 m above the modern Rhein and thus called Bonaduz Terrace (Gsell 1918: 186). The Bonaduz gravel extends (Fig. 25) from the junction of Vorderrhein and Hinterrhein upvalley both rivers, 14 km at the Vorderrhein and 13 km at the Hinterrhein.

Pavoni (1968: 497) uses the term 'Gesteinsbrei' for the Bonaduz gravel. Abele (in press) describes this new sediment to be a debris flow. As it lacks a flow direction and related features of a gravity flow I suggested the term impact slurry (Erschütterungsbrei) (Schirmer 1994: 14). For other opinions concerning the origin of the Bonaduz gravel see Abele (1970) and Schirmer (1994: 14).

A point of discussion is that of the event sequence of the different rockslides. Concerning the Flims rockslide, Heim (1883: 300) at first ascribed the whole rock mass to one single event. However, already Hartung (1884: 185) infers a composite rockslide mass. Recent drillings exhibiting fossil soils and morainal material within the rockmass indicate a composite rockslide mass (Nabholz 1987: 28).

Age of the rockslide: Beginning with Heim (1883: 307) till deposits and erratics have been found topping both the rockslides and the Bonaduz gravel (Fig. 25). This glacier advance is assigned to the so-called Chur stade (Staub 1938: 69),

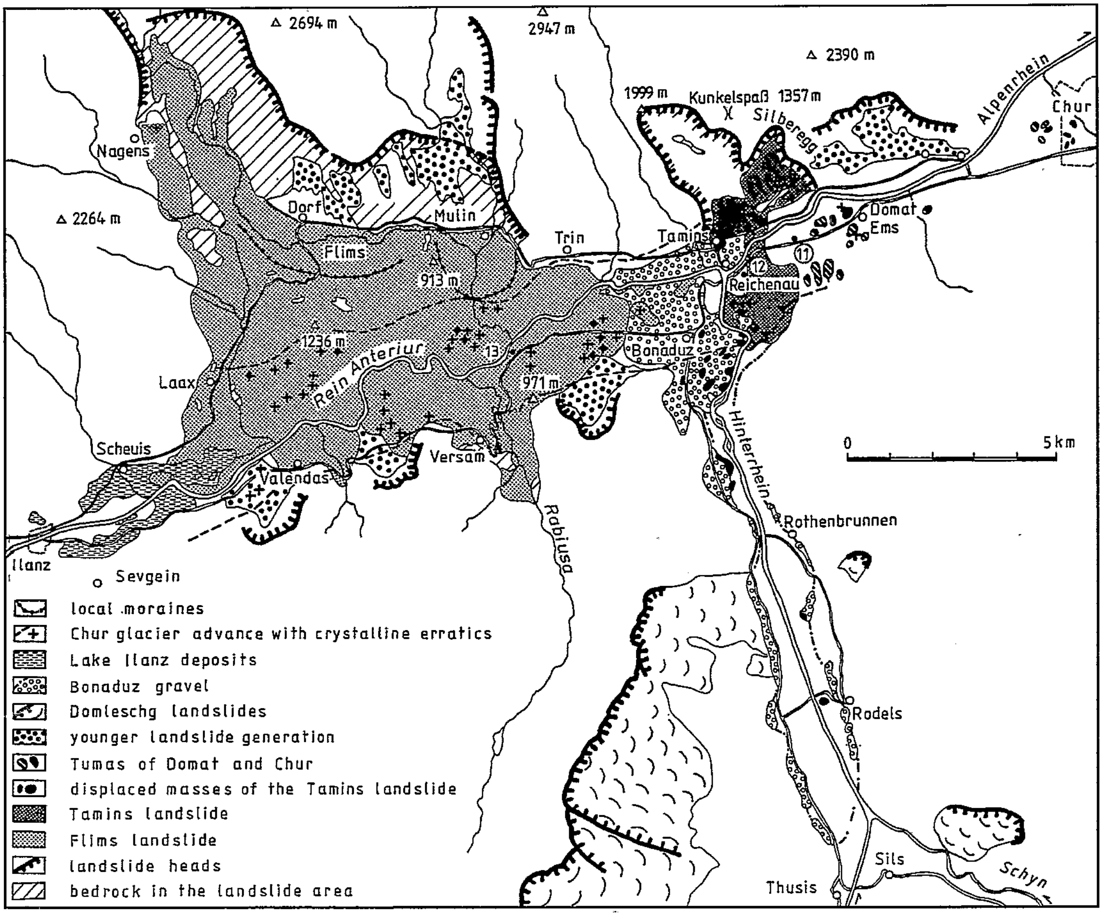

Fig. 25 Flims-Tamins rockslide area (SCHIRMER 1994: 15)

which is a late Würmian retreat stade between Bühl and Steinach, prior to 13,000 yr BP (JORDI 1986: 65, 67). Thus concerning the age of the Flims and Tamins rockslides, during the last decades all authors agree on a late Würmian age starting with the maximum Würmian glacier retreat and followed by succeeding minor rockslides up to modern times. But, if the nature of the fossil soils, as mentioned by NABHOLZ (1987), is true, the main Flims rockslide should be of pre-maximum Würmian age (SCHIRMER 1994: 14). As consequence the role of the Chur stade has to be considered anew.

Stop 11: Domat/Ems. Panoramic view of the rockslide area

CH – TM 50: sheet 247 Sardona,
R 752.0, H 188.4, 598 m a. s. l.

Downvalley in the east there rises a couple of small hills within the valley plain partly habitated by the town Domat/Ems. The hills have the local name Toma (lat. tumulus = grave hill). In former times these hills were regarded as being old barrows. Therefore the Grisonic name Domat was given for the town. The toma are rockslide masses originating from the Calanda mountain that can be seen to the northeast.

To the north and northwest the head scarp of the Tamins rockslide is well visible. Upstream, to the west, its debris masses block the valley forming a forested dam across the valley named Ils Aults (lat. altus = high). Beyond Ils Aults the Hinterrhein and the Vorderrhein merge to the Alpenrhein, which cuts Ils Aults in a small gorge. In the western background the area of the Flims rockslide is visible.

Stop 12: Gravel pit of the 'Kieswerk Reichenau, Calanda Beton AG'

CH – TM 50: sheet 247 Sardona,
R 750.9, H 187.6, 660 m a. s. l.

In the gravel pit the Bonaduz gravel is exposed. In former times huge Malmian limestone boulders were found at the base of the gravel (ZIMMERMANN 1971: 168). It is an unsorted gravel in a sandy, silty, slightly loamy matrix. Bedding is absent. Clods of flood sediment up to several meters large are floating within the gravel; their original bedding is well preserved but indicates a complete disorientation of the clods up to vertical turn. In places flood loam clods exhibit intercalations of cryoturbated beds. About 20 m below the surface an external mould of a ranne surrounded by adherent flood loam was found embedded in the gravel (SCHIRMER 1994: 15).

Crossing Tamins and Reichenau the bridge to Bonaduz passes the Vorderrhein just at the junction with the Hinterrhein. Climbing up the Bonaduz Terrace the way to Versam and Ilanz follows the top of this even terrace towards west till

Stop 13: Ruinaulta, the Vorderrhein gorge piercing the Flims rockslide

CH – TM 50: sheet 247 Sardona,
R 745.3–5, H 185.5– 186, 780 m a. s. l.

It is difficult to stop along this scenic but narrow route. Park carefully!

To the north the head scarp of the Flims rockslide is visible. From there the whole area down to the river is rockslide mass that mostly consists of debris of white Malmian limestone. The walls along our scenic route show Liassic slates (autochthonous cover of the Gotthard Massif) in the northern part and rockslide debris towards the south, most conspicuously visible at a jut tunnelled by the street.

Turn in front of the Rabiusa bridge to take the way back downvalley the Alpenrhein.

ABELE, G. (1970): Bergstürze und Flutablagerungen im Rheintal westlich Chur. Versuch einer Chronologie der Bergstürze von Flims, Reichenau/Rhäzuns und Ems. – Der Aufschluß, **21** (11): 345–359; Heidelberg.

— (in press): Rockslide movement supported by the mobilization of groundwater-saturated valley flour sediments. – Z. Geomorph.

GSELL, R. (1918): Beiträge zur Kenntnis der Schuttmassen im Vorderrheintal. – Jber. naturforsch. Ges. Graubünden, N. F., **58** (1917/18): 127–202, Taf. 1–3; Chur.

HARTUNG, G. (1884): Das alte Bergsturzgebiet von Flims. – Z. Ges. Erdkunde zu Berlin, **19**: 161–194, Taf. 4; Berlin.

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SCHIRMER, W. (1994): Flims rockslide area and Bonaduz gravel. – In: SCHIRMER, W. [ed.]: Glacier and debris flow activity in the Alps – excursion guide: 13–16; Düsseldorf (Dept. of Geology Univ.).

STAUB, R. (1938): Altes und Neues vom Flimser Bergsturz. – Verhandl. schweizer. naturforsch. Ges., **119**: 60–85; Chur.

STAUB, W. (1910): Die Tomalandschaften im Rheintal von Reichenau bis Chur. – Jber. geogr. Ges. Bern, **22**: 1–28, Taf. 1–4; Bern.

ZIMMERMANN, H. W. (1971): Zur spätglazialen Morphogenese der Emser Tomalandschaft. – Geogr. Helv., **26** (3): 163–171; Bern.

Retreat stades of the Würmian glaciation

(O. KELLER)

The Würmian Rhein-Linth glacier system has been reconstructed in different retreat stades (Figs. 26 and 27) defined as ice-marginal complexes. The reconstruction is based on moraine ramparts, levels of outwash plains, ice-marginal drainage and glacial morphological horizons. The local glaciers of the Alpine front mountains have been correlated with the foreland glaciation by using ice contacts, ice-dammed lakes, drainage paths and intermediate outwash plains.

During the maximum position, the ice of the Rhein-Linth system covered an area of 16,400 km^2 and comprised a volume of 6,150 km^3.

Trip Chur–Bodensee: The course of the **Alpenrhein** valley follows the general direction S–N. Exactly observed, it is built very complicated and shows a lot of valley types: isoclinal, transverse, longitudinal, cross, rift valley. It is filled by glaciolacustrine and fluvial sediments up to 600 m. During a short period of the Late Glacial the Bodensee occupied the whole Rhein valley as far as Chur.

The **Stoss pass** (950 m a. s. l.; Fig. 28) is a valley-floor divide. The high-lying valley of Gais is cut at the pass. Already prior to the Würm maximum, the Rhein glacier overflowed the Stoss pass from the E. During the **maximum stade**, the ice surface had risen to an altitude of 1200 m a. s. l. Due to pollen analyses it is known that the Stoss pass has been free of ice since the oldest Dryas.

The ice-marginal deposits of the Sitter glacier in the **stade of Stein am Rhein** (W/S) are preserved 150–200 m above the valley bottom of Ap-

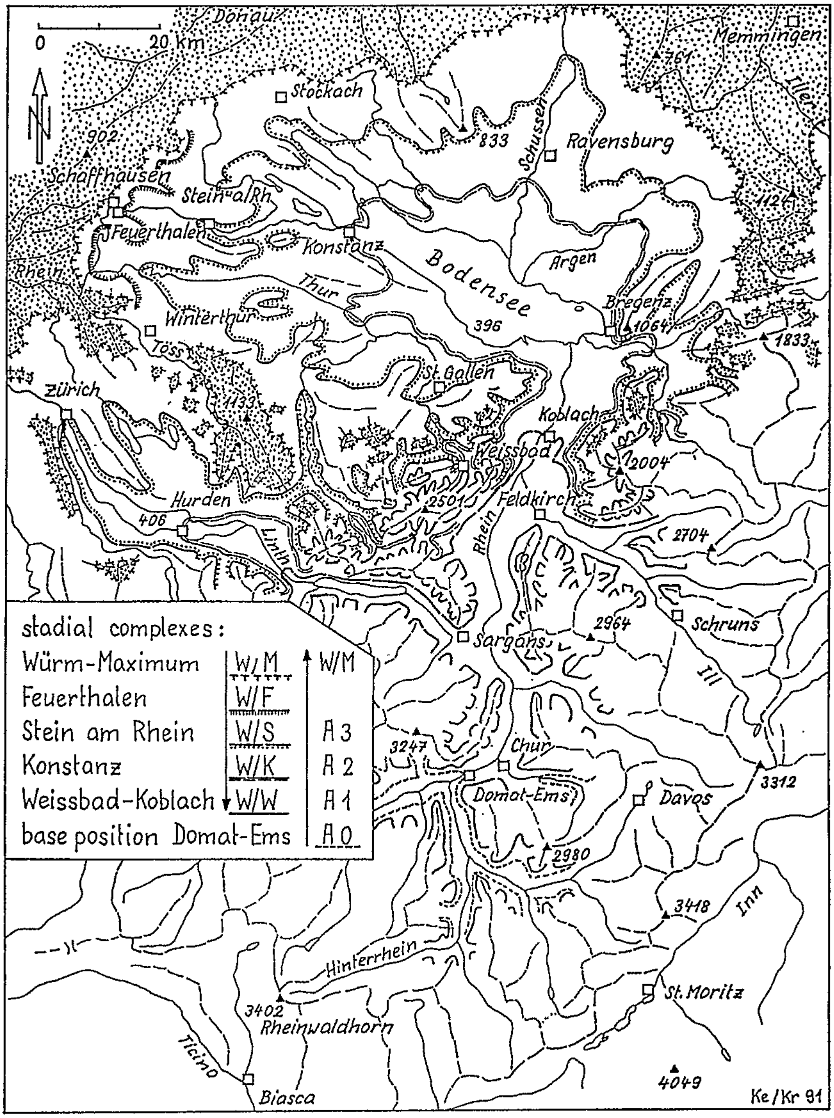

Fig. 26 Ice marginal complexes of the Würmian Rhein-Linth glacier

penzell. This glacier received ice supply from the Rhein glacier of the Alpenrhein valley over the Stoss and Eggerstanden passes. Therefore it could advance to the region of St. Gallen, where it met the Bodensee-Rhein glacier (St. Gallen tongue). During the **stade of Konstanz** (W/K), the Sitter glacier built up a lot of moraine ramparts. It was now independant as it is shown by an intermediate ice-dammed lake near Eggerstanden.

Stop 14: Schwarzenegg, 4 km SE of Appenzell

CH – TM 50: sheet 227 Appenzell,
R 751.9, H 241.5, 960 m a. s. l.

High Würmian glaciation on the border of the Alps and the first Late Würmian advance of local glaciers in the Weissbad stade (Fig. 29):

This place is lying directly on the tectonic border of the Alps. The view into the fold bundle of the Alpstein (Säntis Mountains) is very impressive. The three main valleys of the accumulation area of the High Würmian Sitter glacier join just below Schwarzenegg. After the Konstanz stade the glaciers melted back into the interior valleys of the Alpstein. The overdeepened basin of Schwende filled with a finger lake. As till-covered lacustrine deposits prove, the following first late glacial advance of the local Schwendi glacier reached

Weissbad, what means an increase of length of 50 % (Weissbad stade W/W). This advance of local glaciers is indicated in all Alpine front mountains of the Rhein-Linth area between Mythen (Kt. Schwyz) and Hochgrat (Allgäu).

Towards St. Gallen, in the region of Stein, the route several times crosses moraine ramparts and melt-water channels of the Stein am Rhein stade of the Sitter glacier. S of St. Gallen the road follows a wide melt water valley of the Bodensee-Rhein glacier (Fig. 28).

Stop 15: Haggen, 3 km SW of the City of St. Gallen

CH – TM 50: sheet 227 Appenzell,
R 743.8, H 252.2, 760 m a. s. l.

The detachment of local glaciers from the Bodensee-Rhein foreland glacier after the Würmian maximum (Fig. 28):

At this point, the ice stream network of the Bodensee-Rhein foreland and the Appenzell Prealps reached an altitude of 1000 m a. s. l. Then, during the younger High Glacial, the mountain region became successively ice-free. The tongues of the Sitter and the Urnäsch glacier separated from the Bodensee-Rhein glacier in the Stein am Rhein stade in this area (Fig. 28). A series of ice-marginal ramparts, melt-water channels and outwash terraces allows to reconstruct the processes of separation.

Trip St. Gallen – Bodensee. The high-lying valley of St. Gallen is filled with deposits of the retreat stages of the Bodensee-Rhein glacier. Fan terraces of the Goldach sit on the slopes above the Bodensee. They have been induced by the melting glacier. The molasse mountains in the region of Heiden, the so-called Appenzeller Sporn, are characterized by forms of glacial polishing because of the narrow outlet channel of the Rhein glacier.

Stop 16: Walzenhausen, 100 m above the village

CH – TM 50: sheet 218 Bregenz,
R 763.2, H 257.7, 720 m a. s. l.

Geological history of the Bodensee; the Rhein delta during the last 2000 years (Fig. 30):

The basin of the Bodensee is remarkably deepened into a wide upland at about 700 m a. s. l. In the older Quaternary, the Rhein still flowed over this high-lying region to the N as a tributary of the Donau. The early foreland glaciations (Donau?, Günz, Mindel) caused an overflow of melt water to the deep-lying Aare system. This event was the beginning of the fluvial and glacial excavation of the Bodensee basin. Today the bedrock floor of the lower Alpenrhein valley lies 200 m b. s. l.

The postglacial Bodensee was born at about 16,000 yr BP, when the Rhein foreland glacier melted back from the ice margin of the Stein am Rhein stade. The lower Alpenrhein valley became ice-free 14,500 years ago. At the end of the Würm glaciation at 10,000 yr BP the front of the Rhein delta was situated between Altstätten and Dornbirn. Coast lines of the Bodensee and the growth of the Rhein delta since the Roman age are marked in Fig. 30.

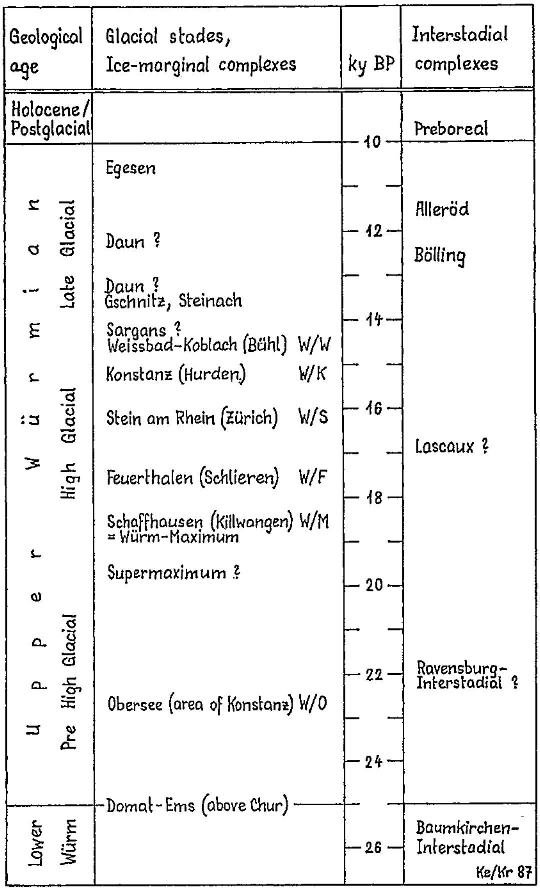

Fig. 27 Chronology of the Upper Würmian (Rhein-Linth)

Keller, O. (1988): Ältere spätwürmzeitliche Gletschervorstösse und Zerfall des Eisstromnetzes in den nördlichen Rhein-Alpen (Weissbad-Stadium/Bühl-Stadium). – Phys. Geogr., **27 A**: 241 p., **B**: 291 p., 2 Krt.; Zürich.

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— (1994): Entstehung und Entwicklung des Bodensees, ein geologischer Lebenslauf. – In: Maurer, H. [ed.]: Umweltwandel am Bodensee: 33–92; UVK, St. Gallen.

Keller, O. & Krayss, E. (1993): The Rhein-Linth-Glacier in the Upper Wurm: A model of the last alpine glaciation. – Quaternary International, **18**: 15–27; Oxford.

Krayss, E. & Keller, O. (1989): Die eiszeitliche Reliefentwicklung im Bodenseeraum. – Vermessung, Photogrammetrie, Kulturtechnik, **89** (1): 8–12, 5 fig.; Baden-Dättwil.

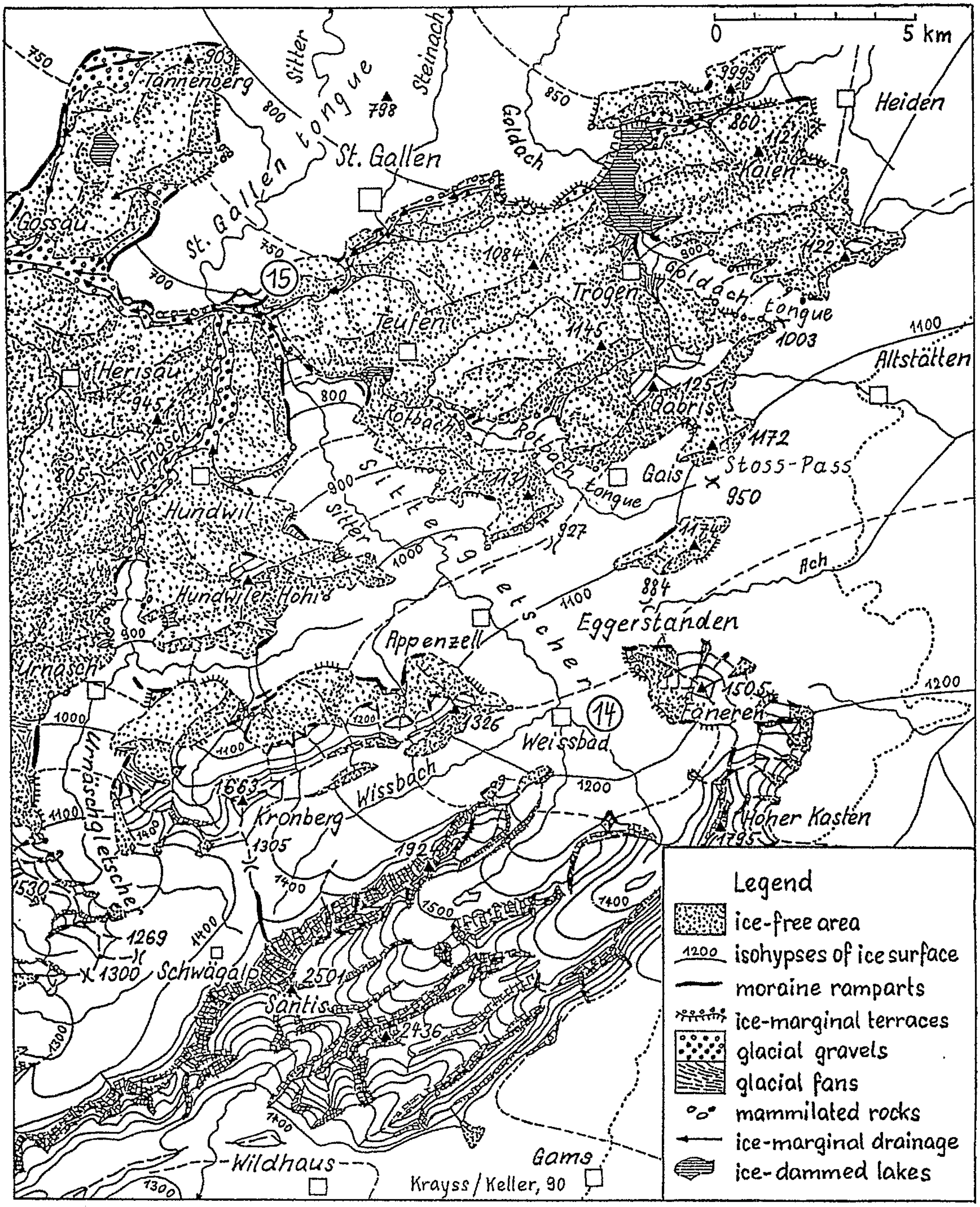


Fig. 28 Würmian glaciation of the Appenzell region. Ice-marginal complex of Stein am Rhein

SCHLÜCHTER, C. (1988): The deglaciation of the Swiss Alps: A paleoclimatic event with chronological problems. – Bull. Assoc. Franç. étude Quaternaire, **88** (2/3): 141–145; Paris.

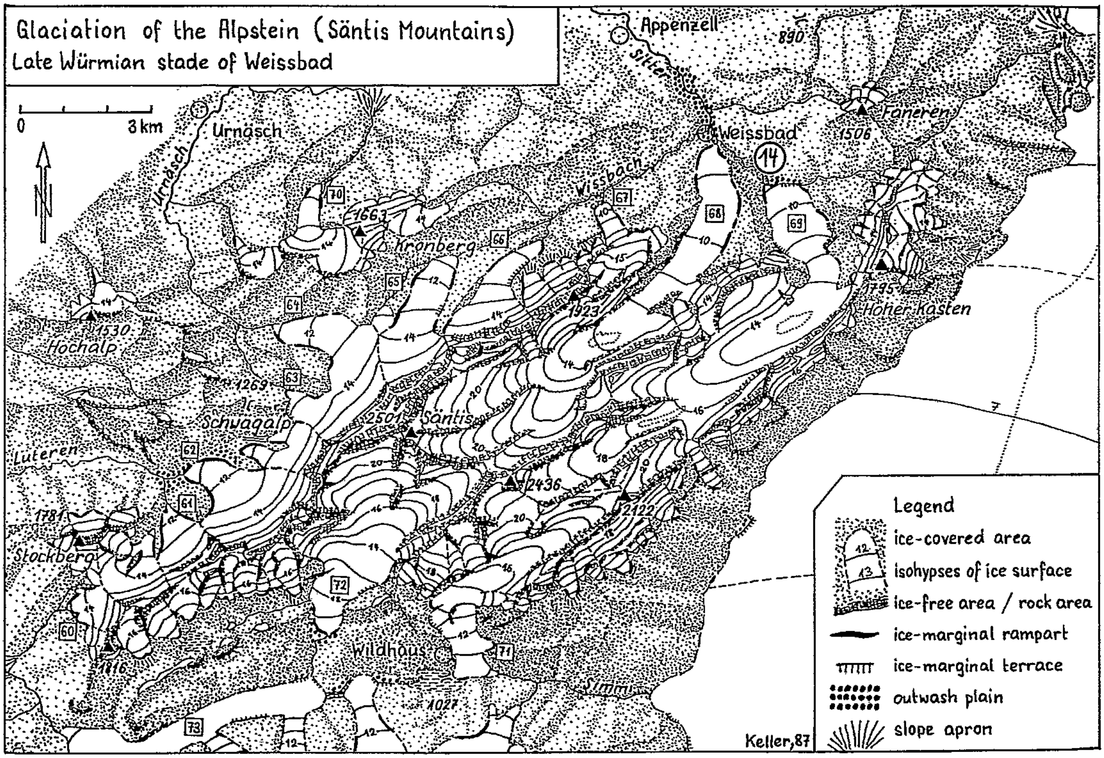


Fig. 29 Weissbad stade

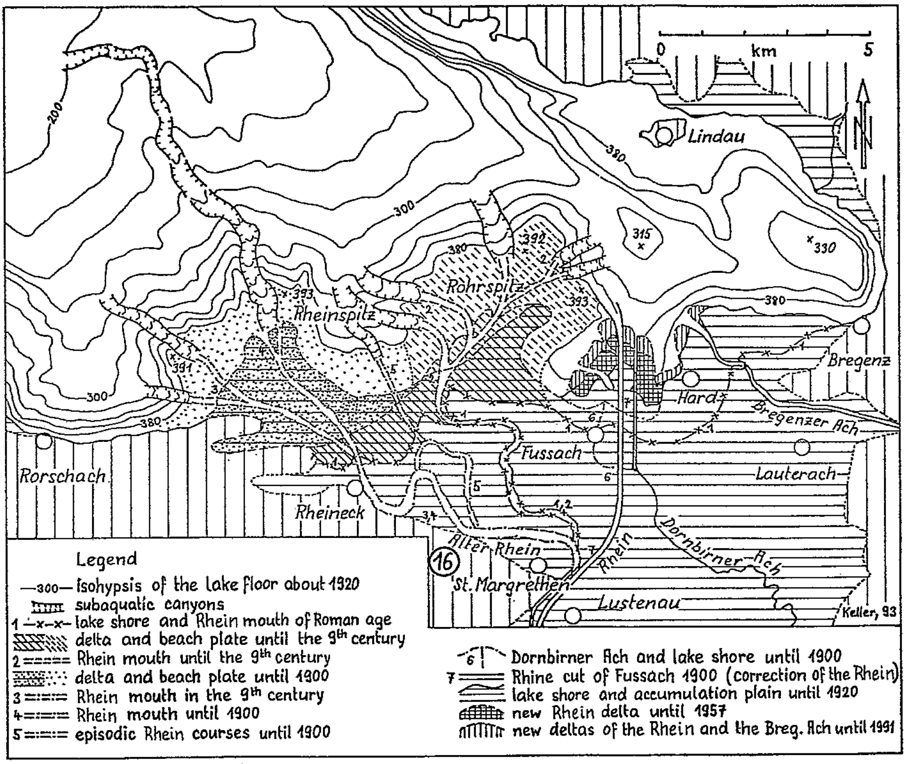


Fig. 30 Eastern Bodensee and Rhein mouth system since the Roman age

Rhein foreland glacier
(D. ELLWANGER)

The most significant elements of this area are glacial basins of various size (Fig. 31). Main element is the depression of the Bodensee basin s. l. Its northern edge acts as watershed between the rivers Rhein and Donau. It appears further subdivided by more or less deeply incised branch basins. They are often but not always elongated parallel to the former ice flow direction and illustrate the general spreading of the foreland ice mass. In addition, there are two directions where basin structures appear even more concentrated: the Bodensee basin s. s. towards NW, and the Schussen basin complex towards NNE. They both reflect regional tectonic directions.

Within the basins, glacial and glacio-lacustrine deposits are of considerable thickness. In the Bodensee basin s. s., they reach down below sea level. Even in minor branch basins, deposits often exceed 100 m.

The various morainal and meltwater landforms between the basins are positioned according to the general morphological framework given by the basin structures:

Within the Bodensee basin s. l., the bedrock surface is generally dipping towards the Alps, thus slowing down the advancing glacier. The moraine landscape embraces radially orientated drumlin fields in the more proximal part of the depression,

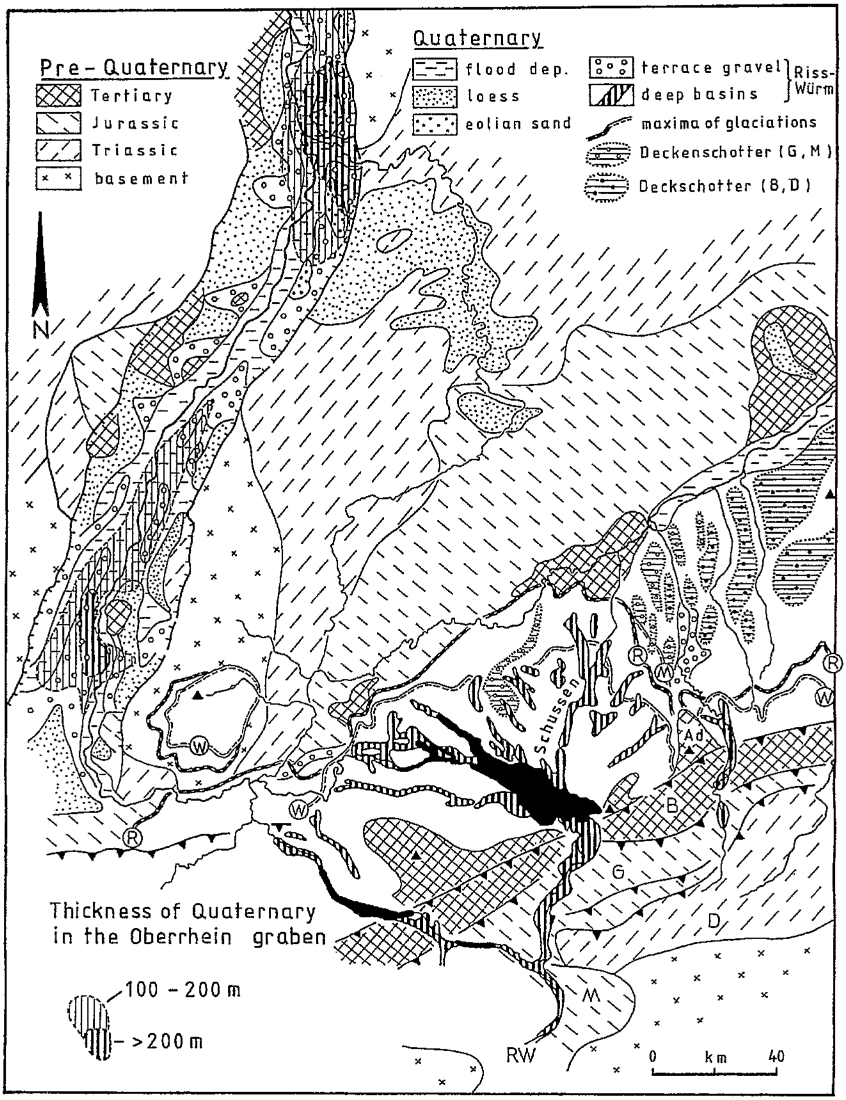


Fig. 31 Geological map of the Oberrhein-Bodensee area with Rhein foreland glaciation: W = Würm, R = Riss, M = Mindel, G = Günz, D = Donau, B = Biber. Ad = Adelegg Mountain

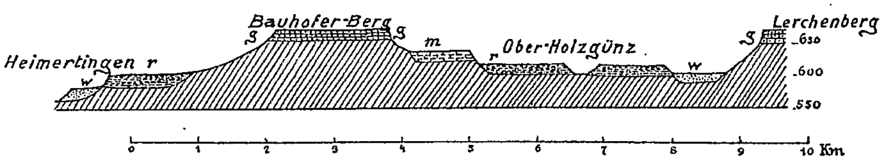


Fig. 32 Cross section at Grönenbach (PENCK & BRÜCKNER 1901: 31). Hatched = Miocene. g = Günz, m = Mindel, r = Riss, w = Würm

and transverse moraine ridges in more distal position (terminal moraines). The basin and its surroundings implicate the following preliminary stratigraphy:

- Riss-Würm complex: 5–6 glacial periods separated by 5 warm periods (Middle and Late Pleistocene, Brunhes epoch)

— Main hiatus, morphologic (tectonic?) event

- Deckenschotter complex = Günz, Mindel: > 5 glacial periods, (early Pleistocene, Matuyama epoch)

— Main hiatus, morphologic (tectonic?) event

- Deckschotter complex = Biber, Donau (?Pliocene–eo-Pleistocene, ?Gauss–Matuyama epoch)

— Main hiatus, morphologic (tectonic?) event
Miocene molasse

Stop 17: Main moraine ridge of the Würmian maximum near Herlatzhofen

D – TM 25: sheet 8226 Leutkirch West,
R 35753, H 52957, 746 m a. s. l.

Overview from the top of the main moraine ridge ('Äußere Jungendmoräne') which embraces the large Bodensee-Rhein glacial basin.

The ridge consists of a complex of moraine walls, also push moraines. It is up to 2 km wide and can be followed, with little interruptions, in the order of 10 km, oblique to the former ice flow direction as derived from subglacial streamlined landforms.

The ridge often acts as or lies close to the watershed between the rivers Rhein and Donau. The Rhein glacier basin and also part of the ridges contain deposits from older glacial advances. This has been proved for the basin sequences by palynology and for the ridges by fossil soil intercalations. It follows that the ridge acting as watershed is of polyglacial origin.

Stop 18: Cross section Grönenbach

D – TM 25: sheet 8127 Grönenbach,
R 3590–3600, H 5306, 700–775 m a. s. l.

Cross section of the four gravel terraces serving as type region of the classical Alpine glacial system: Günz, Mindel, Riss, Würm (PENCK & BRÜCKNER 1901/09). Central element is the valley bottom of Würmian age ('Memminger Feld') (w in Fig. 32) which is subdivided by late glacial terraces. In the west, the 'Zeller Feld' (r) is partly only somewhat higher than the Würmian level and illustrates the Rissian unit. On a higher level, the 'Grönenbacher Feld' (m) represents the Mindelian glaciation. In the east the uppermost terrace, called 'Böhener Feld', represents the Günzian unit (g in Fig 32).

The situation illustrates that the Alpine stratigraphic system was originally based on a strictly morphostratigraphic definition. Later investigations of various methods are often discussed in the context of this classical framework.

PENCK, A. & BRÜCKNER, E. (1901/09): Die Alpen im Eiszeitalter. – 3 Bde., 1199 p.; Leipzig (Tauschnitz).

Stop 19: Viewpoint near Eichbühl

D – TM 25: sheet 7925 Ochsenhausen,
R 35728, H 5324, 650 m a. s. l.

This Stop illustrates the terrace with the highest elevation attributed to the Donau glaciation. There are no permanent sections where the deposits could be shown. The sequence as known from drillings consists of three main layers:

(3) Gravel dominated by dolomite pebbles of the Northern Limestone Alps (Donau glaciation)
(2) Fine-grained layers containing a mollusc fauna which is considered to be of Tiglian age (det. MÜNZING);
(1) Gravel containing up to 30 % crystalline pebbles (Biberian). Its composition is similar to the uppermost Alpine molasse gravel of the nearby Adelegg mountain.

It is stressed that up to now no Biberian and Danubian glacial deposits are known. In contrast the younger deposits this Deckschotter deposits are tectonically uplifted and tilted.

Stratigraphically, the Donau gravel nearby is covered by interglacial deposits of Tiglian age (1.8 m yr). The material of all gravel units is derived from different catchment areas (see Fig. 31).

ELLWANGER, D., FEJFAR, O., KOENIGSWALD, W. VON (1994): Die biostratigraphische Aussage der Arvicolidenfauna vom Uhlenberg bei Dinkelscherben und ihre morpho- und lithostratigraphischen Konsequenzen. – Münchner geowiss. Abh., **A 26**: 173–191; München.

Stop 20: Glacial basin of Füramoos

D – TM 25: sheet 7923 Saulgau Ost,
R 35658, H 53174, 680 m a. s. l.

The basin of Füramoos is situated in the distal part of the 'Riss' moraine landscape. The sequence starts with 'Deckenschotter' deposits followed by various glacial deposits, which are considered to represent Riss advances. In the basin of Füramoos, they are followed by lacustrine deposits containing three different interglacial periods.

The upper two interglacial periods represent palynologically the St. Germain period and the Eemian. The lowermost resembles to the 'Pfefferbichl' period (perhaps redeposited, disturbed), which is supposed to be intercalated between the Middle Rissian and the Younger Rissian glaciation. Together with drillings in neighbouring basins within the Rhein foreland glacier, the following sequence of basin fill has been evidenced:

* Upper Würmian glacial advance
Stadial & interstadial phases
Fagus warm period (St. Germain)
* Older Würmian glacial advance
Eemian interglacial period
* Younger Rissian glacial advance
Warm period (Pfefferbichl type?)
* Middle Rissian glacial advance (= Doppelwall-Riss)
Warm period, complex? (Samerberg-II-'Holstein' type)
* Older Rissian (complex?) glacial advance

Stop 21: Würm supermaximum at Ingoldingen, gravel pit a&b

D – TM 25: sheet 7924 Biberach Nord,
R 3554, H 53205, 570 m a. s. l.

The site is situated just outside the maximum Würmian morainal ridge. There are more or less proximal meltwater deposits with a diamicton layer intercalated. The latter was micromorphologically analysed and has been identified as subglacial till (det. VAN DER MEER). This indicates that at least this Würmian advance went beyond the maximum Würmian morainal ridge.

Stop 22: Gravel pit of Bittelschieß

D – TM 25: sheet 7921 Sigmaringen,
R 35173, H 53184, 650 m a. s. l.

The pit exposes a typical sequence of the classical Rissian glacial complex.

Older Rissian sensu SCHREINER 1989

The sequence starts with up to 8 m massive, horizontally bedded fluvial gravel, followed by 2–3 m better sorted and finer but still fluvial material and topped by a fossil soil. It is followed by further 1–2 meters of well sorted gravel, and then by 4 meters of laminated fines that contain the 'Samerberg-II' ('Holstein') interglacial pollen spectrum (det. BLUDAU).

The base of the sequence documents the decreasing meltwater activity of an early advance of the Riss complex (Older Rissian). The weathering horizon and the pollen sequence both indicate interglacial conditions. Thus, within the early Rissian complex one or two warm periods ('Holstein') occur.

Middle Rissian = Doppelwall-Riss sensu SCHREINER 1989

The sequence continues with up to 12 m fluvial gravel (proximal meltwater deposit). It is followed by 1–3 m diamicton, and may have been deposited as subglacial till. The sequence ends with up to 25 m of unsorted gravelly and boulder-rich deposits, sometimes topped by another diamicton (=subglacial till) of various thickness. It indicates that proglacial meltwater activity was followed by deposition in an subglacial and finally supraglacial environment. It represents the middle part of the Rissian complex ('Doppelwall-Riss'). This unit is topped by a fossil soil with a decalification up to 20 m.

Towards the northern part of the pit, large parts of the Middle Rissian sequence are glaciotectonically disturbed and deformed to ridges and depressions, thus indicating the final Middle Rissian glacial readvance. A loess soil sequence of the interridge depressions show that after termination of the Middle Rissian, at least another 2–3 climatic cycles occurred.

SCHREINER, A. (1989): Zur Stratigraphie der Rißeiszeit im östlichen Rheingletschergebiet (Baden-Württemberg). – Jh. geol. Landesamt Baden-Württ., **31**: 183–196; Freiburg i. Br.

Stop 23: Gravel pit Meichle & Mohr, Radolfzell-Markelfingen

D – TM 25: sheet 8219 Singen,
R 34997, H 52905, 445 m a. s. l.

The pit lies in a kame terrace position. The sequence starts with lacustrine deposits (fines and waterlain till) known from drillings. They are followed by gravels and intercalations of diamiction and few fines and sands. On top, there are various layers of diamiction. The surface exhibits a weak drumlin morphology.

Various dikes and veins cut the gravel. They consist of the underlying lacustrine material. The intrusion happened when the gravel was permafrozen, probably during a readvance phase. There are also sill and dike intrusions from above consisting of fine grained material of small subglacial pools. They intruded when frozen blocks of the gravel were pushed down in flow direction of the ice.

ELLWANGER, D. (1992): Lithology and stratigraphy of some Rhine glacier drumlins (South German Alpine foreland). – Geomorphology, 6: 79–88; Amsterdam.

— (1994): Observations on drumlinized till in the Rhine glacier area (South German Alpine foreland). – In: WARREN, W. P. & CROOT, D. G. [eds.]: Formation and deformation of glacial deposits: 115–125; Rotterdam (Balkema).

HABBE, K. A. (1989): On the origin of the drumlins of the South German Alpine foreland. – Sediment. Geol., 62: 357–379; Amsterdam.

Hochrhein

Stop 24: Rhein Falls near Schaffhausen

(W. SCHIRMER)

CH – TM 50: sheet 205, Schaffhausen,
R 688.1, H 281.5, 360 m a. s. l.

In this area the Rhein has to cut the southeast dipping Malmian limestone platform in obsequent direction (Fig. 33). Moreover, the northwest facing limestone scarp, the Randen, was a rampart for the western lobes of the Rhein foreland glaciers. They never succeeded in passing it (Figs. 31 and 33).

After the Mindel glaciation, due to strong tectonic uplift, the deep Singen-Klettgau furrow was formed as the oldest deeply incised Rhein valley of this area.

Consequently, during the following Riss glaciation periods this furrow functioned as spillway for the meltwaters of the Rhein foreland glacier (Fig. 33). During the Old and Middle Rissian glaciation this furrow has been filled by a 130 m thick gravel stack. During the Middle Rissian glaciation the entrance of the Klettgau furrow was debris-blocked. Hence the Rhein changed roughly to its modern course (Rhein Falls furrow). Here it had to carve its channel through weak marls of molasse beds down into Malmian limestone. During the maximum Würmian glaciation this steep-walled channel was filled again. By the early deglaciation the Rhine was meandering on top of the glacial aggradation. Smoothly cutting down, at the level of the contact molasse marl above Malmian limestone it met its former channel that crossed its way rectangularly at Neuhausen. By removing the soft gravel fill of the old furrow the Rhein Falls started to form. Thus, the Rhein Falls mould the former old left channel rim. The falls have a width of 150 m and a height of 20 m. The exposed rocks are reef limestone (Kimmeridgian, Upper Jurassic).

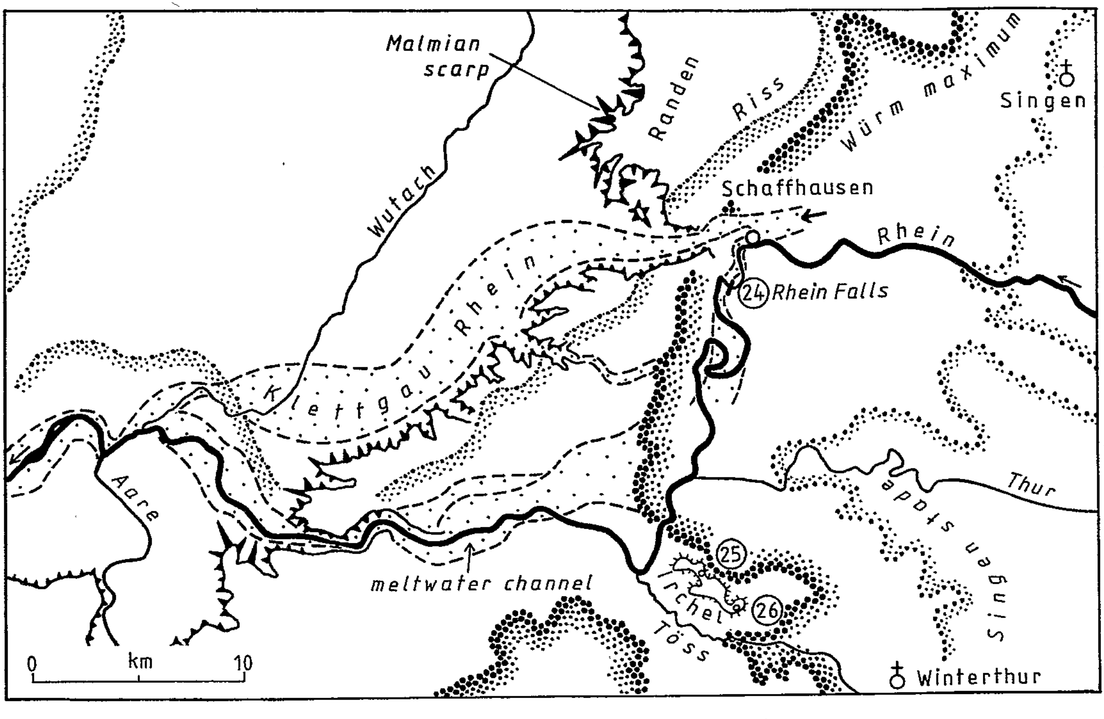


Fig. 33 Terminal moraines along the Hochrhein (compiled from various sources)

HOFMANN, F. (1989): Geologie des Rheinfalls (Exkursion B, Teil 1, am 28. März 1989). – Jber. Mitt. oberrhein., geol. Ver., N. F., 71: 27–33; Stuttgart.

KELLER, O. & KRAYSS, E. (1993): The Rhine-Linth glacier in the Upper Wurm: a model of the last alpine glaciation. – Quaternary International, 18: 15–27; Oxford.

SCHREINER, A. (1992): Einführung in die Quartärgeologie. – 257 p.; Stuttgart (Schweizerbart).

Irchel Gravel series

(H. GRAF)

The early Pleistocene of Switzerland is represented by sequences of sandur deposits. Perhaps even the Upper Pliocene is included. These sequences of mainly gravelly sediments define in morphostratigraphic terms the 'Ältere Deckenschotter' (Older Plateau Gravel), which used to be correlated with the 'Günz' glaciation. Recent investigations (GRAF 1993) have shown that the Ältere Deckenschotter comprises at least four stacked cold-warm cycles. It is followed by a Middle Deckenschotter and three series of Younger Deckenschotter. The latter evidenced by revers magnetic polarity to be of Matuyama age (FORSTER & SCHLÜCHTER, unpubl.).

These Ältere Deckenschotter deposits are preserved as rather small relics. Correlation between them is still not well established due to two reasons: First, several glacier systems, different in petrography, were involved in the formation of the deposits. Second, neotectonic events lifted the relics differentially.

According to the classical scheme the sandur deposits of the Deckenschotter are developed as staircase. Here, however, superimposed sandur sediments of different glaciations form the morphostratigraphic unit of the Ältere Deckenschotter. This means that during the Pleistocene, times of minor tectonic activity caused sediment stacking. Periods with intensified crustal uplift caused strong erosion and the formation of gravel-terrace configurations fitting to the classical morphostratigraphic scheme.

The Irchel hill is situated 15 km south of the Rhein Falls (Fig. 33). The bottom part of the Irchel is composed of generally sandy molasse deposits of Upper Miocene age topped by a stack of Ältere Deckenschotter of mainly gravelly sediments (Fig. 34). Their pebble spectra differ significantly in the amount of crystalline rocks, quarzite and dolomite. The oldest unit, the 'Lower Irchel Gravel', is overlain by the 'Intermediate Irchel Gravel'. In the east a channel was eroded into the Intermediate Irchel Gravel and filled with the 'Irchel Dolomite Gravel'. Its pebble spectrum is characterized by a very high content of dolomite pebbles. The 'Upper Irchel Gravel' tops the succession as well as the Irchel hill. According to the pebble spectra the 'Walensee-Rhein-Glacier' was responsible for the formation of the Irchel Gravels. Since no glacigenic deposits are known, the glacier might not have reached the Irchel itself. Paleoflow of the meltwater streams was mainly directed to the north-west. Only the Irchel Dolomite Gravel reflects a paleoflow direction to the north.

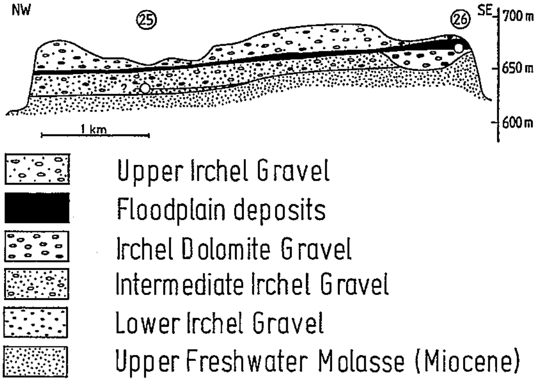


Fig. 34 Section of the early Pleistocene deposits of the Irchel

In certain places the glaciofluvial sediments are topped by overbank deposits. Some of them yielded mollusc shells which reflect a mainly warm climate.

Stop 25: Gravel pit 'Irchel Ebni' SW Gräslikon

CH – TM 50: sheet Baden,
R 687.025, H 267.575, 640 m a. s. l.

A small gravel pit exhibits the contact between the Lower and Intermediate Irchel Gravel (Fig. 35). The base of the Quaternary deposits lies just a few meters below the bottom of the pit. The basal part of the Lower Irchel Gravel contains boulders of considerable size. Therefore the presence of a glacier in the vicinity of the site is probable. The sediments represent a fining upward sequence, which terminates in a fine-grained channel fill. The channel fill deposits and in some parts the gravel underneath are affected by multiphase pedogenic alterations. The most important features for the reconstruction of the paleoclimate of the time in question are pedogenic calcite precipitates, which are indentified as mature caliche. This implies that the Lower and Intermediate Irchel Gravels are separated by an interglacial period.

Stop 26: Hasli, N Dättlikon

CH – TM 50: sheet Baden,
R 688.950, H 265.550, 670 m a. s. l.

Irchel Dolomite Gravel is overlain by a complex succession of floodplain deposits and mostly grav-

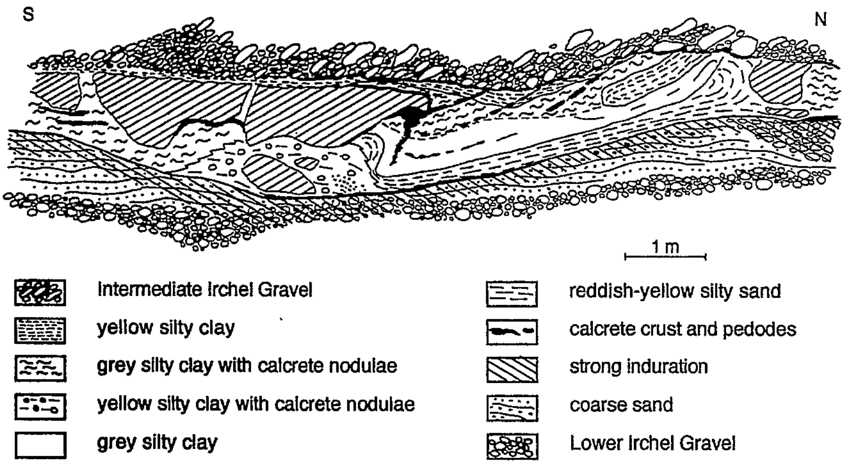


Fig. 35 Gravel pit east of 'Irchel Ebni' (bottom part): deformed channel fill sediments with mature caliche at the boundary Lower to Intermediate Irchel Gravel

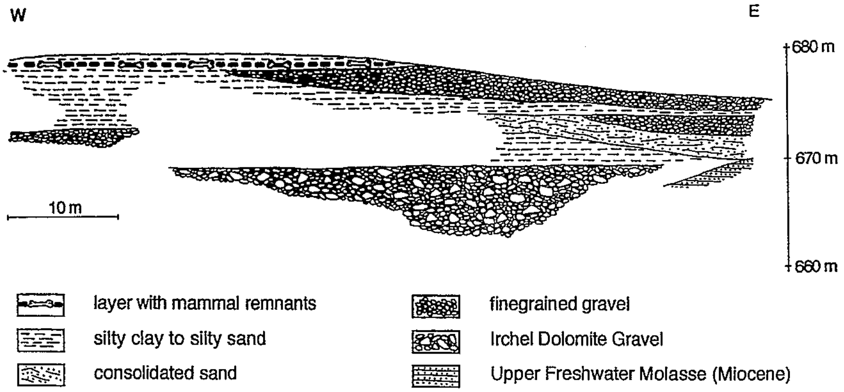


Fig. 36 Section 'Hasli': Floodplain deposits and channel fills above the Irchel Dolomite Gravel

elly channel fillings (Fig. 36). In the upper part of the section the overbank deposits yielded mammal remnants, especially tooth fragments. Research on the mammal teeth and of paleomagnetic investigations is going on. For the first time there might be a chance to approach an age of the Ältere Deckenschotter of Switzerland.

GRAF, H. (1993): Die Deckenschotter der zentralen Nordschweiz. – 187 p., 135 Abb., 16 Tab.; Diss. ETH Zürich; Zürich.

The Oberrhein graben and its borders
(W. SCHIRMER)

The Oberrhein graben is part of a West European continental rift (Figs. 1 and 2). A mantle diapir intruding since the Upper Cretaceous below the southern part of the Oberrhein graben (Fig. 37) with culmination in the Kaiserstuhl area is responsible for the extreme uplift of the graben shoulders of this area (Schwarzwald 1492 m and Vosges 1423 m), responsible for the graben itself (since Eocene) and for the Kaiserstuhl volcanism (Lower Miocene). The opening of the graben started in the Middle Eocene in the south and proceeded towards the north. In the Middle Oligocene the whole graben acted as a small marine furrow combining the sea of the northern Alpine molasse basin and the northwest European sea. It was the last time when Central Europe was dissected by the sea from north to south. In the Upper Oligocene the southern part of the graben rose from the sea. The northern part became terrestric during the Lower or Middle Miocene. During the Pliocene the main uplift of the graben and its shoulders started. The consequence is a recent elevation of the graben bottom of 400 m a. s. l. in the south (Sundgau) and 100 m a. s. l. in the north. Thus, the graben is draining to the north. The northern inclination of the Oberrhein graben may be due to the rise of the Western Alps. The northward graben tilting started by the Middle Oligocene, the time of the first uplift of the Alps from the sea. The Pliocene was the next time of enormous uplift of the Western

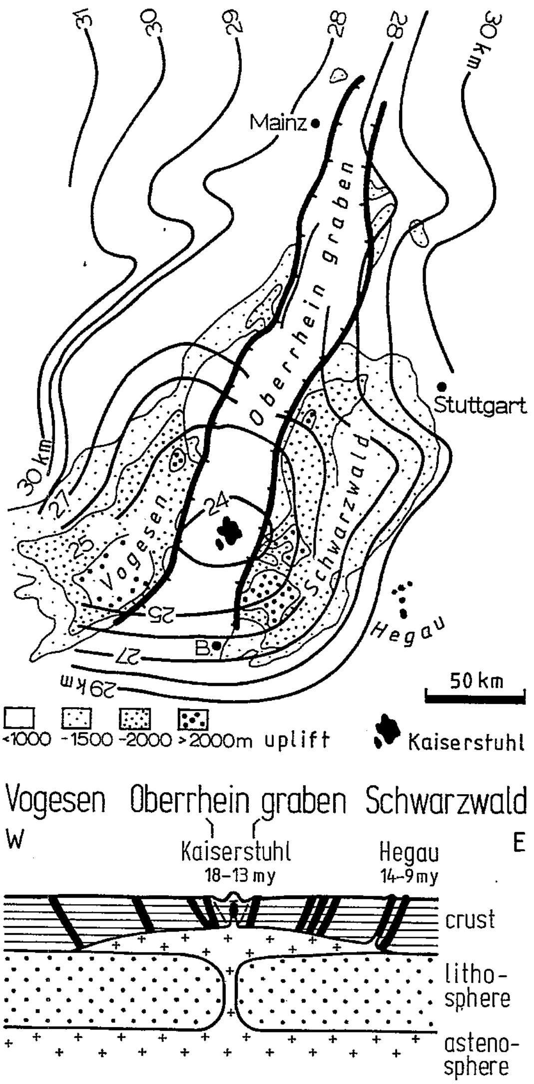


Fig. 37 Mantle diapirism below the southern Oberrhein graben. Top: Contour lines of the mantle-crust boundary and uplift rates of the graben shoulders. Bottom: Mantle diapir and volcanism during Miocene (modified from GEYER & GWINNER 1991: 215, 260)

Alps. Hence the Western Alps exhibit the maximum elevation of the Alps (Fig. 38). Coincidental with this Alpine uplift, the Jura Mountains were folded during the Pliocene. Consequently, it is not accidental that the Rhein catchment is the only one amongst all Alpine drainage basins draining to the North Sea. All other parts drain along the molasse basin axes parallel to the Alpine mountain belt. In case of the Rhine catchment an extreme uplift of the Western Alps together with the West European rift zone caused the unique draining rectangularly off the Alps (Fig. 38).

The Oberrhein graben fill consists of up to 3000 m of Tertiary deposits (near Mannheim) and up to 300 m of Quaternary deposits (near Heidelberg) (Fig. 31). According to drillings, the Quaternary encompasses a stacked Pleistocene. Close to Strassburg its lower quarter are sands and silts of local provenance (Kaiserstuhl Rhein) of palynologically Lower Quaternary age. The upper three quarters are gravel of Alpine provenance (Alpine Rhein) (BROST & ELLWANGER 1991). The Holocene, on the other hand, is filled into the Würmian as it is the case on all rivers outside the graben area. As the Holocene is an example of an interglacial it can be concluded that likewise during the general stacking trend of the Pleistocene, erosional periods were intercalated causing stratigraphical gaps within the vertical stack of the Oberrhein graben.

BROST, E. & ELLWANGER, D. (1991), mit Beitr. von BLUDAU, W. & ROLF, C.: Einige Ergebnisse neuerer geoelektrischer und stratigraphischer Untersuchungen im Gebiet zwischen Kaiserstuhl und Kehl. – Geol. Jb., E **48**: 71–81; Hannover.

GEYER, O. F. & GWINNER, M. P. (1991): Geologie von Baden-Württemberg. – 482 p.; Stuttgart (Schweizerbart).

The Vosges/Vogesen

The Vosges are the western part of the vaulting Schwarzwald-Vosges dome that was uplifted by the Oberrhein mantle diapir and dissected by the Oberrhein rift valley (Figs. 7 and 37). They are part of the Variscan fold belt (Fig. 4). They consist predominantly of eugeosynclinal deposits as shales and basic volcanites (young Proterozoic to Lower Carboniferous). Towards the middle Carboniferous folding activity, deposition of greywacke and flysch facies prevail. During the later Carboniferous, late-orogenic acid plutonism in-

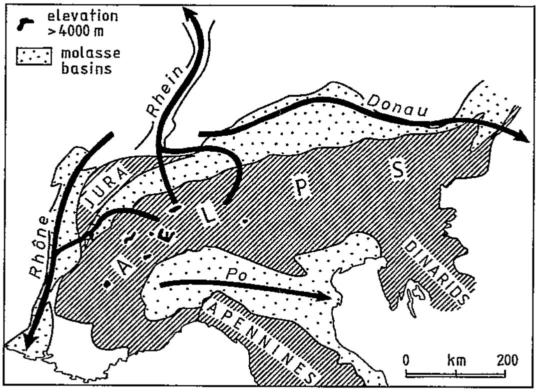


Fig. 38 Drainage pattern of the Alps. The Rhein solely drains radially, the other rivers axially to the fold belts and molasse basins

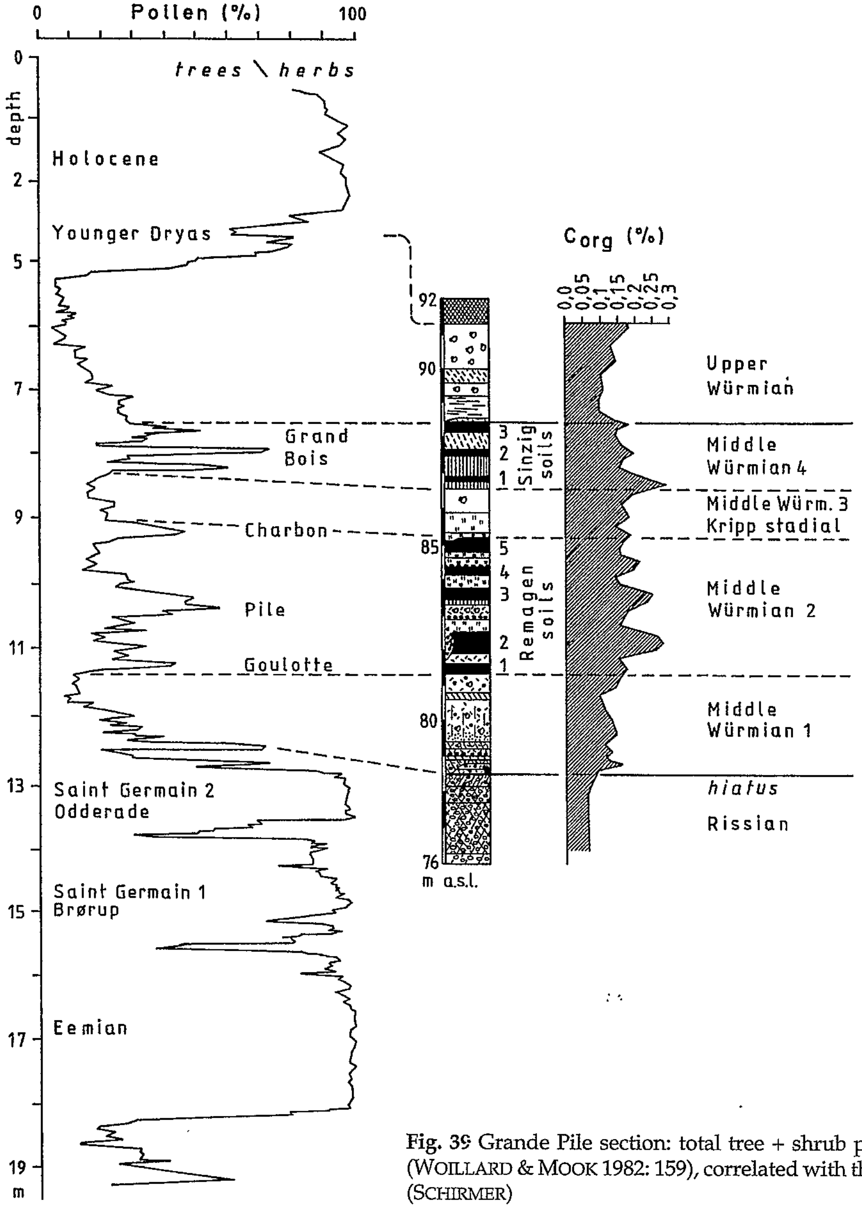


Fig. 39 Grande Pile section: total tree + shrub pollen versus herb pollen (WOILLARD & MOOK 1982: 159), correlated with the Schwalbenberg section (SCHIRMER)

trudes, mostly as granite. Denudation gives rise to thick clastic fill of the Permian molasse basins at the northern and southern Vosges rims. From the Mesozoic on, the whole Variscan complex was buried under a thick epicontinental mantle of Triassic and Jurassic beds. Cretaceous mantle diapirism vaulted up the big Schwarzwald-Vosges dome (Fig. 37). Simultaneous denudation uncovered the dome down to the deeper Variscan socle. The subsiding Oberrhein graben dissected the dome into the Schwarzwald and Vosges massifs. Quaternary erosion and repeated glaciation (Fig. 11) moulded the mountains to its recent form.

Stop 27: Crest of the Vosges/Vogesen near Rainkopf Mountain

F – TM 50: sheet XXXVI/19 Munster,
R 946.4, H 344.7, 1304 m a. s. l.

The crest of the Vosges is composed prevailingly of Carboniferous greywacke and granite. As a consequence of the graben subsidence the mountain range is asymmetric, steeply descending to the graben, gently declining to Lothringen/Lorraine. Its higher parts were glaciated leaving imposing cirques filled by more or less boggy lakes.

The Rainkopf (biotite granite) is surrounded by

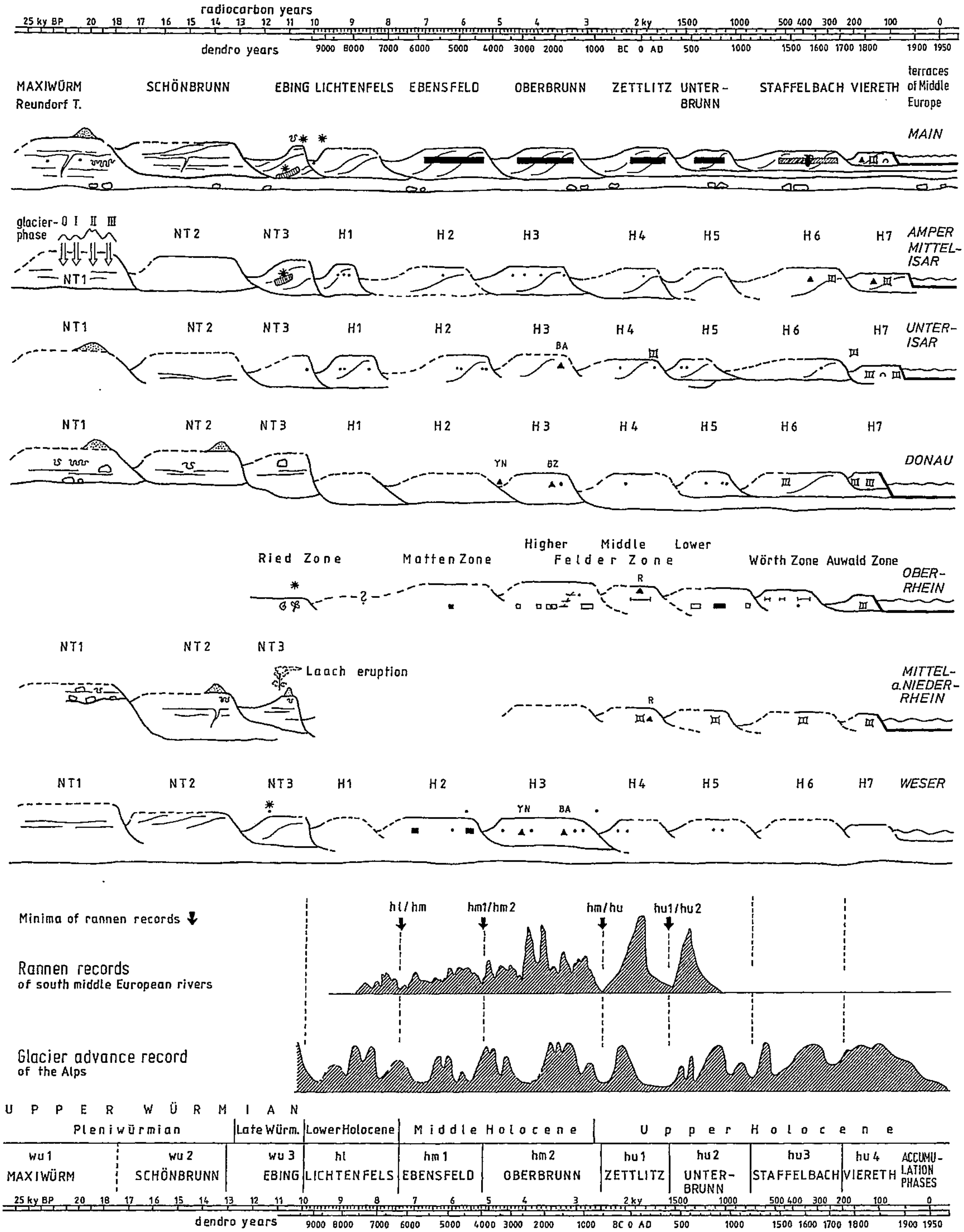


Fig. 40 Phases of increased deposition on Middle European rivers since the Pleniwürmian compared with rannen records from river deposits and glacier advance phases in the Alps (SCHIRMER 1994)

three imposic cirques, the east-draining Altenweiher and the west-draining Lac de Blanchemer and Etang de Machey. The names of the cirques evidence the boundary between the German and French language following the crest. Old bench marks are preserved with D and F as well as conspicuous battle trenches that are being overgrown both by vegetation and the European idea.

The Etang de Machey revealed a Preboreal to Boreal pollen sequence after WOILLARD (1975: 32). In the southwestern part of the Vosges a peat bog filling a glacier depression of pre-Eemian age became famous, the **Grande Pile** – famous for its continuous pollen record of the last 140,000 years (Fig. 39) (WOILLARD 1978, BEAULIEU & REILLE 1992).

Remarkable therein are two interglacial-like periods, called St. Germain 1 and 2, succeeding the Eemian and being separated by short cold events (Melisey I and II). It is still in dispute whether these warm periods correlate with the northern Brørup and Odderade interstadials (as realized in Fig. 39) or precede them. Another conspicuous feature is the coincidence of the Middle Würmian warm peaks not only with the ocean records (WOILLARD & MOOK 1982) but also with the loess-soil sequence of the Schwalbenberg section (Stop 40) (Fig. 39).

BEAULIEU, J.-L. de & REILLE, M. (1992): The last climatic cycle at La Grande Pile (Vosges, France). A new pollen profile. – Quat. Sc. Rev., **11**: 431–438; Oxford.

WOILLARD, G. M. (1975): Recherches palynologique sur le Pléistocène dans l'est de la Belgique et dans les Vosges Lorraines. – Acta Geographica Lovaniensia, **14**: 118 p., 7 fig., 40 diagr.; Louvain-la-neuve.

— (1978): Grande Pile peat bog: A continuous pollen record for the last 140,000 years. – Quaternary Res., **9**: 1–21.

WOILLARD, G. M. & MOOK, W. G. (1982): Carbon-14 dates at Grande Pile: Correlation of land and sea chronologies. – Science, **215**: 159–161; Washington, D.C.

Stop 28: Strassburger Münster/ Cathedral of Strasbourg

Brief history of Strassburg

16 AD at the place of a Celtic settlement foundation of the Roman castrum Argentoratum
355–498 AD the German speaking Franconians conquer Elsass/Alsace and give the town the new name Stradiburc (later Strassburg)
1180 foundation of the Münster, finished 1439 (late Romanesque to Gothic)
1210 GOTTFRIED VON STRASSBURG writes his epos 'Tristan and Isolde'
1621 Foundation of the University
1681 LOUIS XIV conquers Strassburg and adds it to France with the name Strasbourg
1870 The Germans reconquer Elsass; 1918 again French, 1940 German, 1944 French
1949 Strassburg becomes center of the European Union

Holocene river development of the Oberrhein graben

The Oberrhein graben presents the Holocene river activity in the same manner as it is found all over central Europe. The central Europe terrace system of the valley bottom consists of three Würmian and seven Holocene terraces (SCHIRMER 1991a: 153; 1991b; 1993; 1994) (Fig. 40). Seven terraces of them are exposed in the Lower Elsaß/Alsace north of Straßburg/Strasbourg (SCHIRMER & STRIEDTER 1985; STRIEDTER 1988; SCHIRMER 1988; 1994). As Figs. 41 and 42 demonstrate the river shifted from the western rim of the valley bottom towards the center, thus depositing rhythmically one terrace body besides the other: so-called row terraces (SCHIRMER 1983: 28). Each terrace body of the terrace row consists of channel deposits, flood deposits and a typical soil formation. Due to the deposition of the terrace bodies from the Late Würmian up to the last century, their soils are decreasing in weathering intensity from luvisol to calcaric regosol (pararendzina) (Fig. 42). Thus, they are indicator soils for their terrace deposits below.

Stop 29: Gravel pit Gambsheim-Steinwald

F – TM 25: sheet 3815 est, Bischwiller,
R 1006.5, H 127, 128 m a. s. l.

This pit is the type locality for the Matten zone (Ebensfeld Terrace of the central Europe terrace system) (Figs. 41 and 42). Matten means meadow (note the same root!). Topographic maps of some decades ago indicate pure meadow farming in this floodplain zone.

The gravel excavated from below the groundwater table contains numerous rannen 16 of which dating dendrochronologically from 5,150 BC to 5,000 BC. An oak ranne from the gravel top or the base of the flood deposit has a ^{14}C age of 4,430 ± 65 yr BP. Consequently the deposition of the flood sediment starts in the Subboreal period. The flood deposit mantle, 1.3 m thick, contains two flood sediment units separated by a floodplain soil. The lower unit (0.75 m) is topped by a black fluvic phaeozem (pseudochernozem), the upper one (0.55 m) by a luvisol that continued developing under steadily forested conditions up to modern times. Its B_t horizon permeates the fossil A of the pseudochernozem. This soil type, luvisol with fossil phaeozem, is a reliable indicator soil for the Matten zone, that represents the Ebensfeld Terrace.

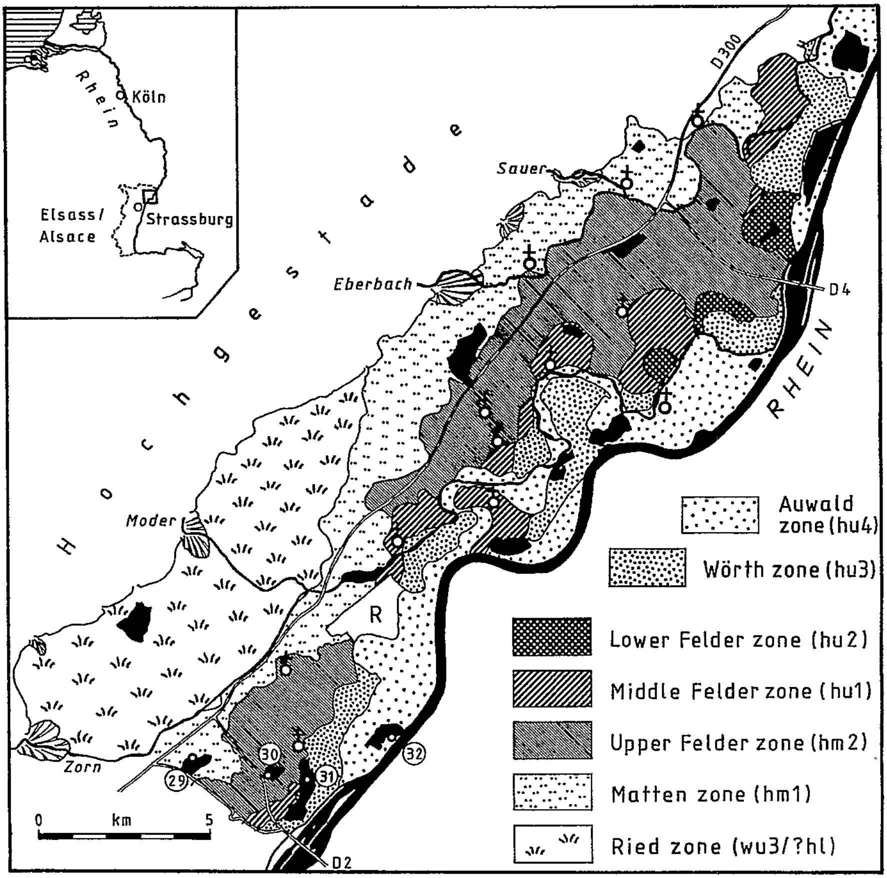


Fig. 41 Late Glacial and Holocene floodplain terraces north of Strassburg (mapped by W. SCHIRMER and K. STRIEDTER)

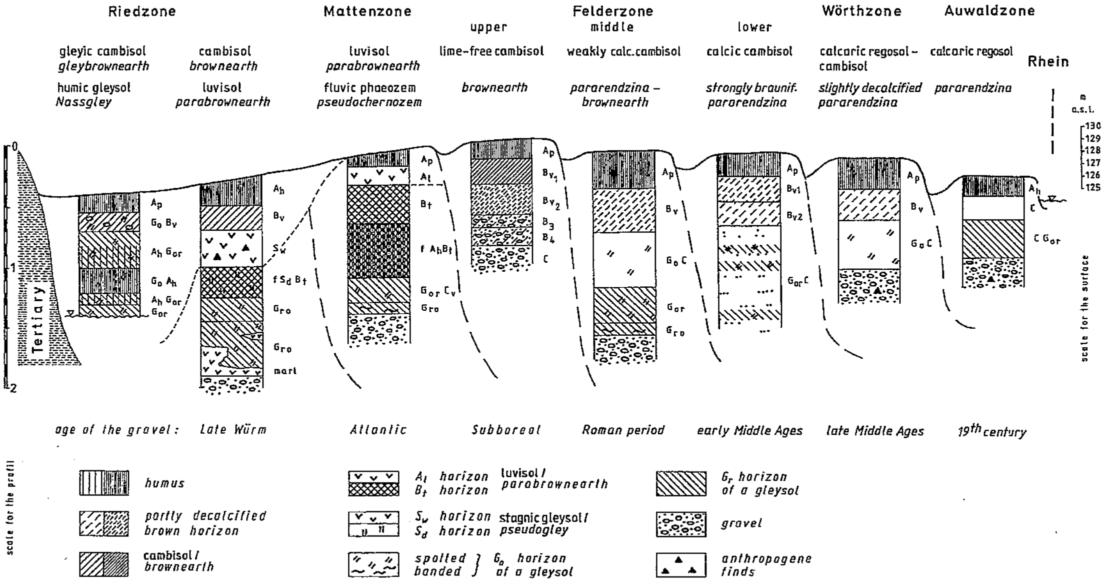


Fig. 42 Soil sequence of the floodplain terraces in the Oberrhein plain north of Strassburg. FAO soil system: normal letters; German soil nomenclature: italics

Stop 30: Gravel pit Gambsheim-Gräbelstücke

F – TM 25: sheet 3815 est Bischwiller,
R 1009.1, H 126.5, 128 m a. s. l.

This pit is the type locality for the Upper Felder zone (Oberbrunn Terrace). Felder zone means field zone (note the same root!), arable land. The Felder zone is the strip of land situated highest within the Oberrhein valley bottom. Consequently, it was settled first (villages with the suffix -heim). Even nowadays it bears the highest concentration of villages and traffic veins.

The gravel below the groundwater bears three levels of rannen:

- 8 m below the surface 3,030 ± 55 yr BP
- 12 m below the surface
- 17 m below the surface 3,600 ± 55 yr BP

Thus, the gravel is of Subboreal age. Besides a certain stacking trend there is hint of depositional rhythmicity even within the Oberbrunn reworking phase. Its flood-sediment mantle of 0.7 m thickness bears a strong cambisol with a decalcification depth of 0.7 m. Also this soil functions as indicator soil for the Upper Felder zone. All younger zones adjoining riverward bear calcaric regosols of riverward diminishing grades.

Stop 31: Gravel pit Offendorf

F – TM 25: sheet 3815 est, Bischwiller,
R 1010, H 126, 126 m a. s. l.

This pit is the type locality for the Wörth zone (Staffelbach Terrace). Wörth means island. It presents places of land surrounded by abandoned river channels with stagnant or slowly running water. The whole zone is often completely flooded and consequently used for seasonal meadow farming. By rectification and dyking of the Rhein (1825–1879) the Wörth zone was cultivated and even used for arable farming.

The gravel below and above the ground water contains numerous medieval ceramics, a mill stone and rannen with chop marks traces at the base of the trunk. The 1 m thick flood sediment on top bears a calcaric regosol slightly decalcified (A horizont 12 %, C horizont 18 % $CaCO_3$) – again an indicator soil for the Wörth zone.

Stop 32: Port d'Offendorf

F – TM 25: sheet 3815 est, Bischwiller,
R 1013, H 128.5, 125 m a. s. l.

The place of the recent boat harbour was in the eighties a gravel pit serving as the type locality for the Auwald zone (Viereth Terrace). Auwald means riverine forest. In the 19th century before the rectification of the Rhein, this zone was part of the branching Rhein with densely forested islands (Köpfe = heads) in between and often flooded. Nowadays it is used as riverine forest and sometimes even for farming.

A small pit (easy to excavate at any higher place within the forest) exhibits an A horizon of 10 cm thickness above fresh fine sandy flood sediment. Shallow augering displays this flood sediment of some two meters above the gravel. Farther to the north the gravel contains brickstone of the 19th century.

The lime content of the C horizon is 19–23 %. In the A horizon it diminishes from base to top to 14 % – evidence for a slight decalcification of the calcaric regosol.

SCHIRMER, W. (1983): Die Talentwicklung an Main und Regnitz seit dem Hochwürm. – Geol. Jb., **A 71**: 11–43; Hannover.

— (1988): Holocene valley development on the Upper Rhine and Main. – In: LANG, G. & SCHLÜCHTER, C. [eds.]: Lake, mire and river environments during the last 15,000 years: 153–160; Rotterdam (Balkema).

— (1991a): Bodensequenz der Auenterrassen des Maintals. – Bayreuther bodenkundl. Ber., **17**: 153–186; Bayreuth.

— (1991b): Breaks within the Late Quaternary river development of Middle Europe. – Aardkundige Mededelingen, **6**: 115–120; Leuven.

— (1993): Der menschliche Eingriff in den Talhaushalt. – Kölner Jb., **26**: 577–584; Berlin.

— (1994): Valley bottoms in the late Quaternary. – Z. Geomorph., Suppl.-Bd. [in press]

SCHIRMER, W. & STRIEDTER, K. (1985): Alter und Bau der Rheinebene nördlich von Straßburg. – In: HEUBERGER, H. [ed.]: Exkursionsführer II: Unterelsaß (Rheinebene N Straßburg), Lothringische Vogesen: 3–14; Hannover (Deutsche Quartärvereinigung).

STRIEDTER, K. (1988): Holozäne Talgeschichte im Unterelsaß. – Inaug.-Diss. Universität Düsseldorf: 235 p., 4 Krt.; Düsseldorf. [Maschinenschr.]

Stop 33: Neckar meander of Mauer

D – TM 25: sheet 6618 Heidelberg Süd,
R 348597, H 546784, ca. 195 m a. s. l.

As explained more extensively in the 'Introductional' survey, item 3, during the Tertiary an essential valley forming process took place. In the case of the lower Neckar about two-thirds of the valley incision is of pre-Quaternary age, one-third of Pleistocene age. During the early Lower Pleistocene some upland rivers formed large meanders in a wider valley, here to be found at the level of roughly 100 m above the modern valley bottom. Our place is the external point of such a meander of 6 km amplitude, the so-called Mauer loop (Fig. 43). Due to following strong tectonic uplift these meanders incised – in case of the Mauer loop into the Middle Triassic Muschelkalk and Lower Trias-

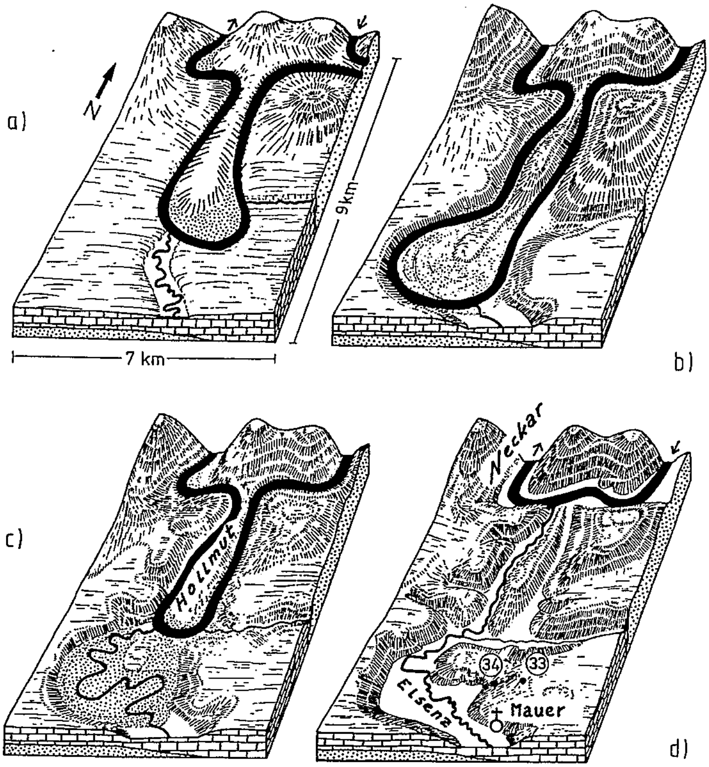


Fig. 43 Deposition of the Mauer sands by a Neckar loop (modified after SCHWEIZER 1982: 150)

sic Buntsandstein – down to the recent river level. From late Lower Pleistocene to early Middle Pleistocene, due to general subsidence of a large upland area, this incision was partly filled by a fluviatile aggradation of some ten meters. In the case of the Mauer loop a presumably 50 m thick stack has been preserved. Within this fluviatile pile the lower jaw of *Homo erectus heidelbergensis* has been found. During the mid-Middle Pleistocene the rivers dissected this stack again indicating a new widespread tendency of tectonical uplift. During this dissection the Neckar cut off the Mauer loop promoting the small Hollmut spur from a right-bank to a left-bank hill (Fig. 43).

SCHWEIZER, V. (1982), unt. Mitarb. von KRAATZ, R.: Kraichgau und südlicher Odenwald. – Sammlung geol. Führer, **72**: 203 p.; Berlin, Stuttgart (Borntraeger).

Stop 34: Sand pit Grafenrain – type locality of *Homo erectus heidelbergensis*

D – TM 25: sheet 6618 Heidelberg Süd,
R 34 85 61, H 54 67 98, ca. 145 m a. s. l.

The sand pit abandoned in 1962 has been investigated recently by diggings and drillings for research purposes (BEINHAUER & WAGNER 1992). The general section (Fig. 44) presents above Middle Triassic carbonate rocks (Muschelkalk) roughly 50 m of Quaternary deposits composed of 35 m of Neckar river sediments topped by 15 m of loess. The fluviatile stack displays three fluvial rhythms each starting with channel deposit and ending with flood deposit. The three flood deposits are decalcified from above each to different degree. The lower channel sediment exhibits gravel, the two upper ones gravely sand (lower Mauer sands and upper Mauer sands). The flood sediment of the third rhythm is followed by four loess layers each ending with a B_t horizon.

The middle fluviatile rhythm with the lower Mauer sands contains scattered, mostly isolated faunal remnants, amongst them the lower jaw (Fig. 45) of *Homo erectus heidelbergensis* – proof of fluvial reworking of the material. Main mammals are (v. KOENIGSWALD in BEINHAUER & WAGNER):

Insectivora: *Talpa minor, Talpa europaea*
Primates: *Homo erectus heidelbergensis*
Rodentia: *Apodemus* sp., *Microtus arvalis-agrestis, Arvicola cantiana, Pliomys episcopalis, Castor fiber, Trogontherium cuvieri*
Carnivora: *Canis lupus mosbachensis, Ursus stehlini, Ursus deningeri, Hyaena arvernensis, Panthera pardus sickenbergi, Panthera leo fossilis, Felis (Lynx) issidorensis, Felis* cf. *silvestris, Homotherium* sp.
Proboscidea: *Elephas (Palaeoloxodon) antiquus*
Perissodactyla: *Equus mosbachensis, Stephanorhinus*

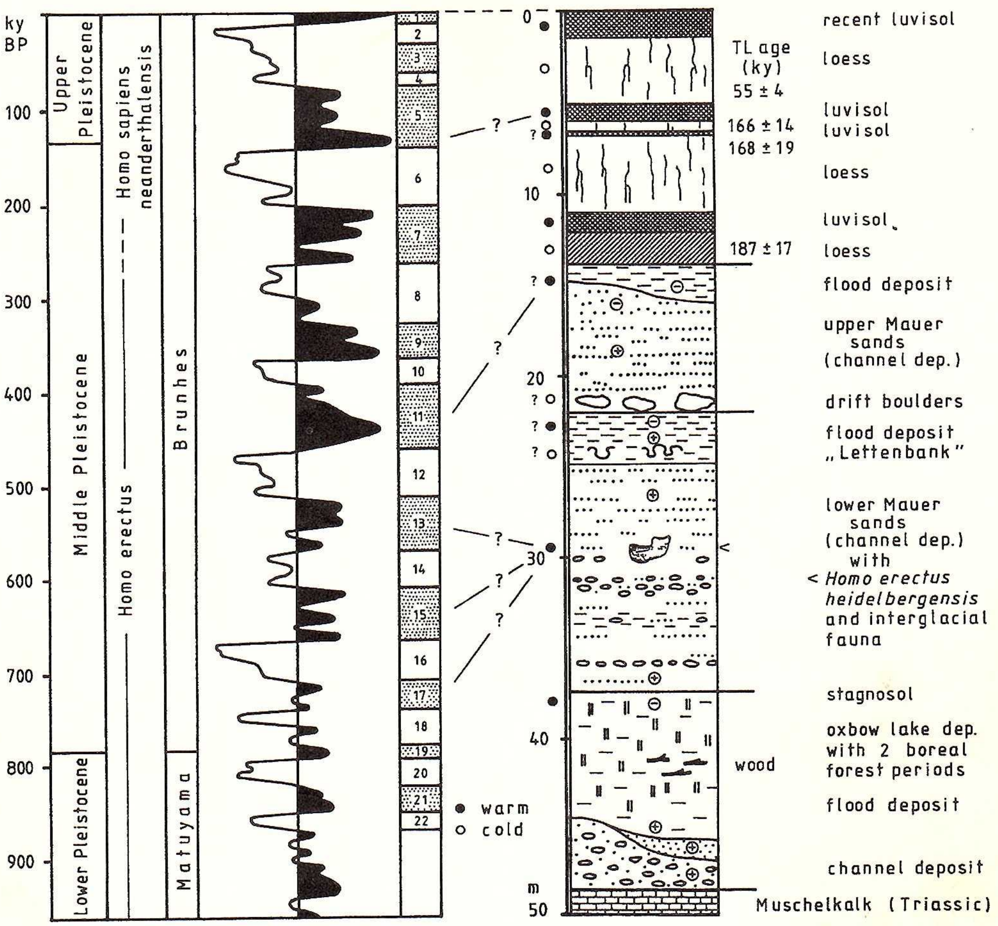


Fig. 44 Grafenrain section (compiled after BEINHAUER & WAGNER 1992). + = carbonaceous, - = non-carbonaceous

hundsheimensis

Artiodactyla: *Sus scrofa priscus, Hippopotamus amphibius antiquus, Alces latifrons, Cervus elaphus acoronatus, Capreolus suessenbornensis, Bison schoetensacki.*

Ecologically, this fauna indicates interglacial conditions. A tusk of *Elephas* has been dated by U/Th at a minimum age of 300 ka. The fauna itself points to an older Middle Pleistocene interglacial period. The whole profile is paleomagnetically normal (Brunhes epoch). With respect to comparable localities (Main river) the loess mantle is incomplete. Additionally, the nature of the smallest fossil soil, whether it represents an independent interglacial or not, is open. Moreover, the fluvial stack may be incomplete. Dissecting the Middle Pleistocene fluvial stack the river left a staircase as a result of alternating erosion and aggradation. Each of these aggradational terraces is underlaid by a socle of the fluviatile stack. Thus, the top rhythm of the fluviatile Grafenrain stack may be one of the terraces cut into the stack.

All in all, the lower Mauer sands can be attributed to the earlier Middle Pleistocene. Thus, *Homo erectus heidelbergensis* is still the oldest human fossil of Central Europe.

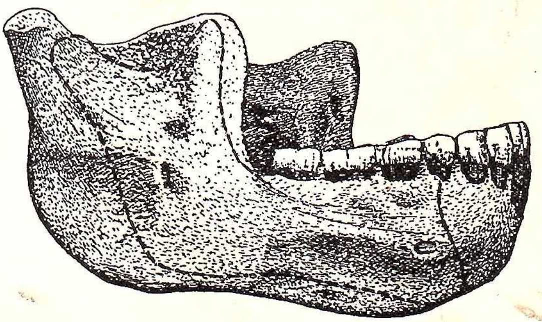


Fig. 45 Mandible of *Homo erectus heidelbergensis* (SCHOETENSACK 1908) found in 1907. Interrupted line: Lower jaw of recent man (modified after STEINMANN 1917: 83)

BEINHAUER, K. W. & WAGNER, G. A. [eds.] (1992): Schichten von Mauer – 85 Jahre *Homo erectus heidelbergensis.* – 192 p.; Mannheim (Braus).

STEINMANN, G. (1917): Die Eiszeit und der vorgeschichtliche Mensch. – Aus Natur und Geisteswelt, **302**, 2. Aufl.: 105 p.; Leipzig.

Mittelrhein and Niederrhein Bay

(W. SCHIRMER)

The style of both valley reaches is predominately informed by their tectonic history: uplift of the Mittelrhein area and both subsidence alternating with uplift of the Niederrhein Bay.

The **Mittelrhein** is the valley reach where the Rhein pierces the Rhenish Shield, the so-called Rheinisches Schiefergebirge (Figs. 1, 2 and 7). This Rhenish Shield has been rising since Upper Carboniferous / Permian, mostly functioning as inland, island or coastal area. The Mittelrhein valley is antecedent: During the existing Rhein course the Rhenish Shield arose. Consequently, the Rhein had to cut in, forming the terrace staircase with the famous romantic gorge (Figs. 46 and 47).

The **Mittelrhein Basin** (Fig. 48) separates the Mittelrhein into an upper and lower Mittelrhein

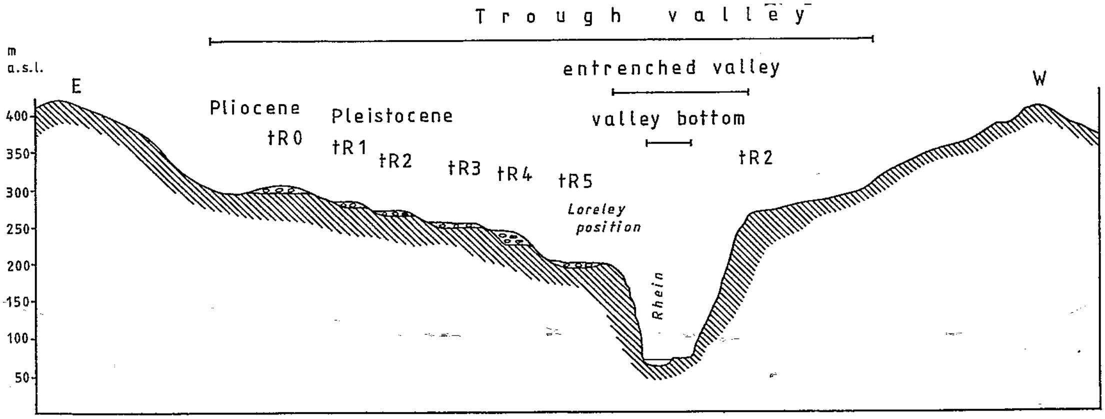


Fig. 46 Schematic cross section of the upper Mittelrhein valley in the Loreley area (based on the terrace record of SEMMEL 1977; 1989); exaggeration 5 ×

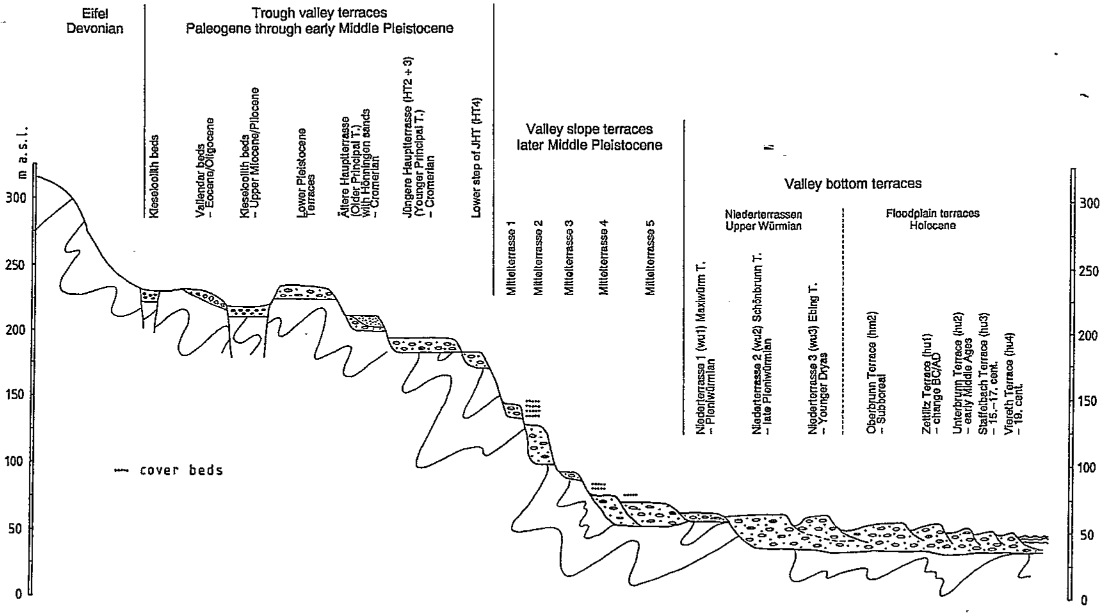


Fig. 47 Schematic cross section of the lower Mittelrhein valley and adjacent areas (modified from SCHIRMER 1994: 185)

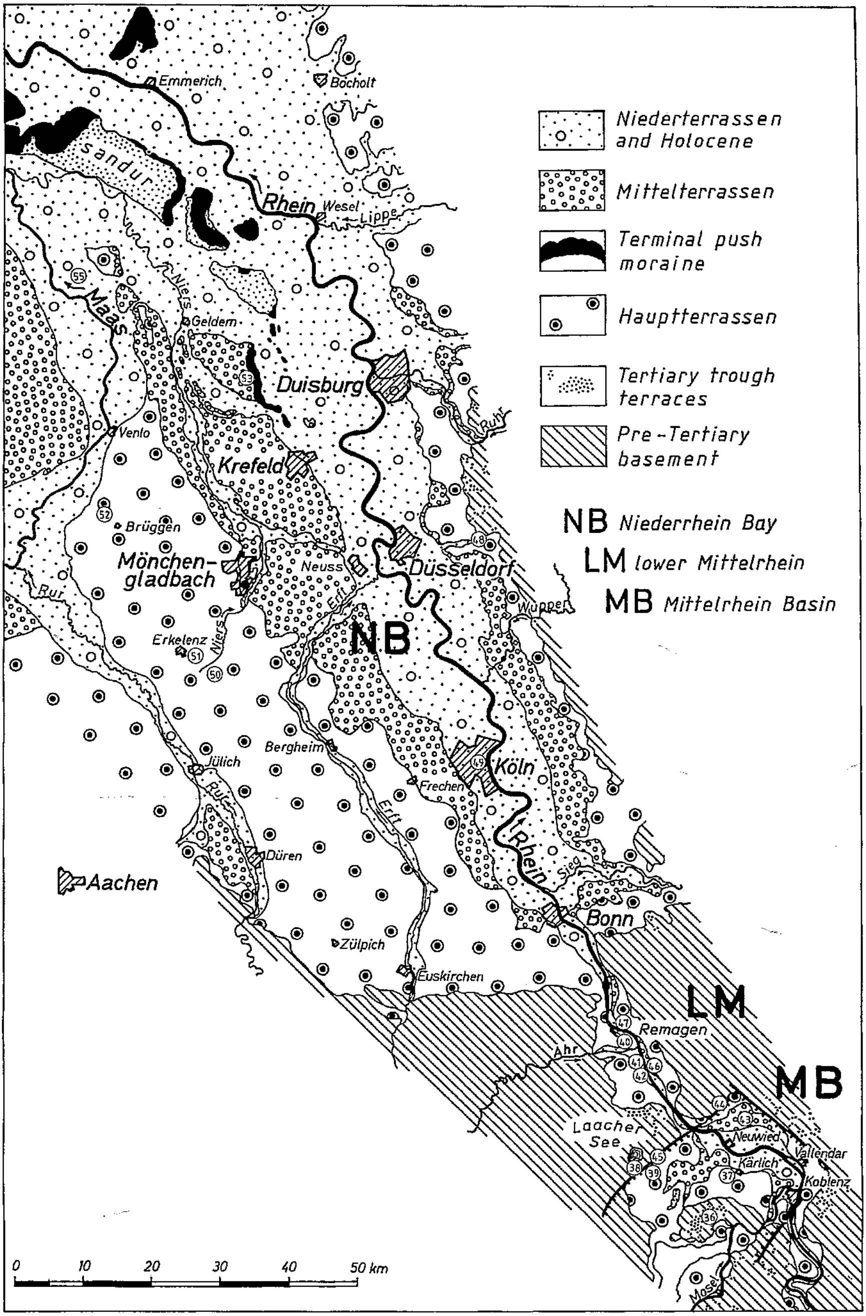


Fig. 48 Mittelrhein Basin, lower Mittelrhein and Niederrhein. River terraces and Stops 36–53 and 55 (based on Quitzow 1959: Beil. 1)

section (Fig. 3). This subsiding tectonic basin exhibits a depositional stack ranging from an Lower Oligocene marine basis through terrestric Pliocene with hiatuses. Hence follows a terrace stair case of the Rhein and Mosel displaying minor vertical distances than that outside the basin. Rich volcanic activity accompanied the tectonic movements (Figs. 49 and 55).

The **Niederrhein Bay**, as a graben, marks the place where the WER pierces from the north into the Rhenish Shield (Figs. 1, 2, 7 and 68). Subsidence of the Niederrhein graben is documented by a sedimentary stack starting with an Middle/Upper Oligocene marine fill passing over a brackish Miocene with 100 m thick brown coal beds into terrestric delta deposits of the Rhein and Maas of Pliocene and Lower Pleistocene age (Fig. 69). Since early Middle Pleistocene due to prevailing uplift,

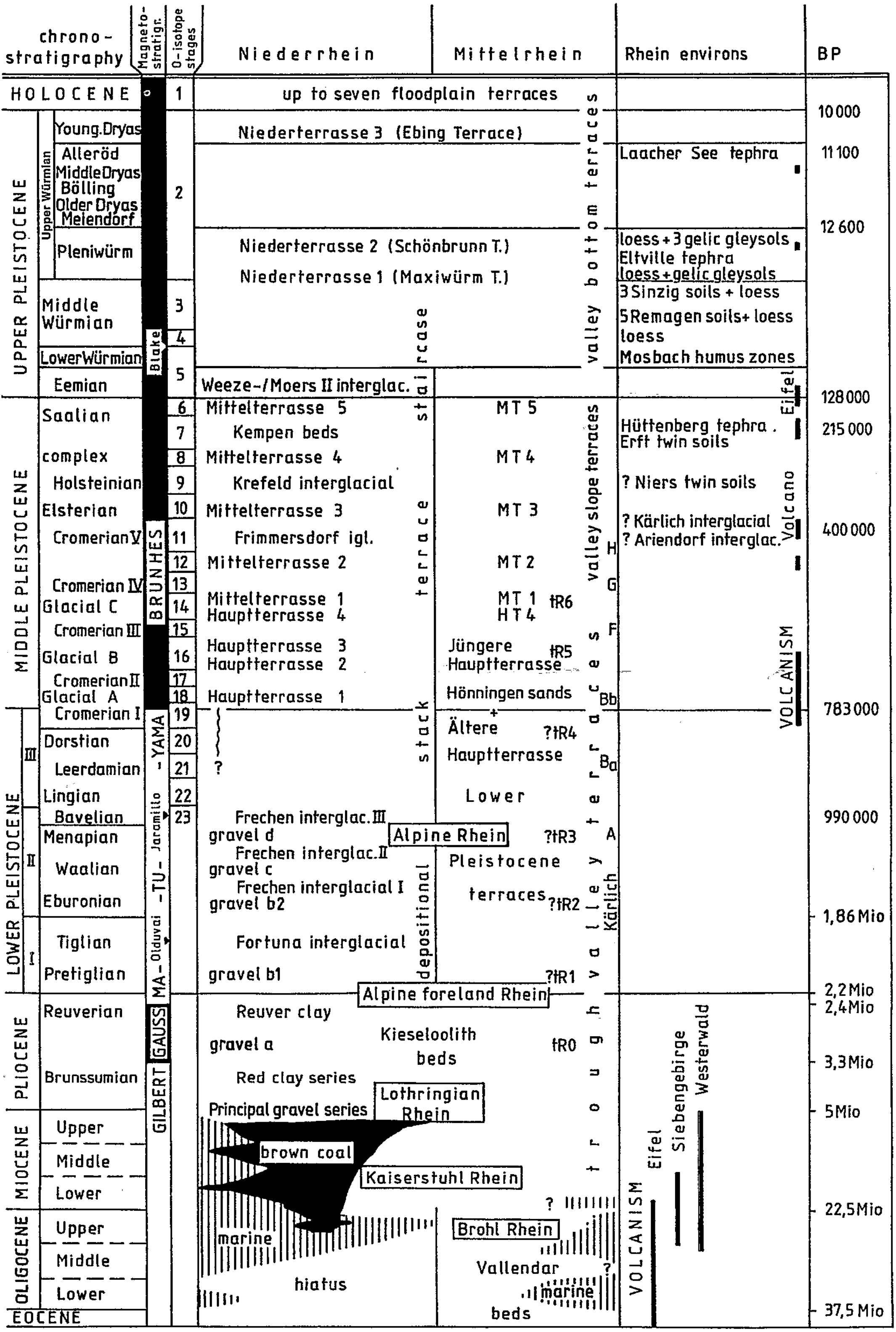


Fig. 49 Stratigraphical table of the Mittelrhein/Niederrhein area

the Rhein cuts its depositional stack forming a terrace stair case. Towards north-west the Quaternary depositional stack piles up to 500 m thickness close to Amsterdam (ZAGWIJN & DOPPERT 1978: 584). Thus, the Niederrhein graben area encompasses one of the most complete terrestric Neogene and Quaternary sequences of Europe (Fig. 49) (cf. ZAGWIJN 1985; 1992).

To Fig. 47: Within the entrenched valley of the Mittelrhein as well as the Niederrhein Bay, up to now four Mittelterrassen has been known. However, in the area of Köln the lowest one can be split up into the MT 4 with two fossil luvisols on top and the MT 5 with one fossil luvisol on top. Likewise on the river Main the same terrace configuration as the MT4/MT5 of the Rhein has been found recently (SCHIRMER, unpubl.).

QUITZOW, H. W. (1959): Hebung und Senkung am Mittel- und Niederrhein während des Jungtertiärs und Quartärs. – Fortschr. Geol. Rheinl. u. Westf., **4**: 389–400, Taf. 1–4, Beil. 1; Krefeld.

SCHIRMER, W. (1994): Der Mittelrhein im Blickpunkt der Rheingeschichte. – In: KOENIGSWALD, W. V. & MEYER, W. [eds.]: Erdgeschichte im Rheinland. Fossilien und Gesteine aus 400 Millionen Jahren: 179–188; München (Pfeil).

ZAGWIJN, W. H. (1985): An outline of the Quaternary stratigraphy of the Netherlands. – Geologie en Mijnbouw, **64**: 17–24.

ZAGWIJN, W. H. (1992): The beginning of the ice age in Europe and its major subdivisions. – Quaternary Science Reviews, **11**: 583–591; Oxford.

ZAGWIJN, W. H. & DOPPERT, J. W. CHR. (1978): Upper Cenozoic of the southern North Sea Basin: palaeoclimatic and palaeogeographic evolution. – Geologie en Mijnbouw, **57**: 577–588; Den Haag.

Upper Mittelrhein

(W. SCHIRMER)

Stop 35: Loreley, Patersberg-Rheinblick

D – TM 25: sheet 5812 St. Goarshausen,
R 340868, H 555848, 230 m a. s. l.

Along the Mittelrhein (Fig. 3) the Rheinisches Schiefergebirge is composed of solely Lower Devonian beds: slates, sandstone and some quartzite intercalations. An alternation of anticlinoria and synclinoria molds this Variscan socle (Fig. 50). The Loreley rock consists of south dipping sandy shales and quartzites of the Lower Emsian that crossed also the Rhein as riffles offering danger for shipping. Later the riffles were removed by blasting.

The cross-section of this upper Mittelrhein valley presents a three-membered shape (Fig. 46): a through valley up to 6 km wide and 100 m deep cut into the peneplain of the Schiefergebirge, a narrow entrenched valley up to 1 km clearence and a very small valley bottom. The trough valley houses a terrace staircase up to seven steps (tR0–tR6; in Fig. 46 only six) that dates from the Pliocene (tR0) through the early Middle Pleistocene (SEMMEL 1977). The terrace forming the platform of the Loreley rock is the tR5 terrace, the so-called Jüngere Hauptterrasse (Younger Principal Terrace) (Cromerian Complex) (Fig. 49). The entrenched valley, formed during the later Middle Pleistocene, contains the Mittelterrassen that are rarely preserved. The valley bottom embraces the Niederterrassen and Holocene floodplain terraces.

The ancient 'Lureley' rock got its name from its

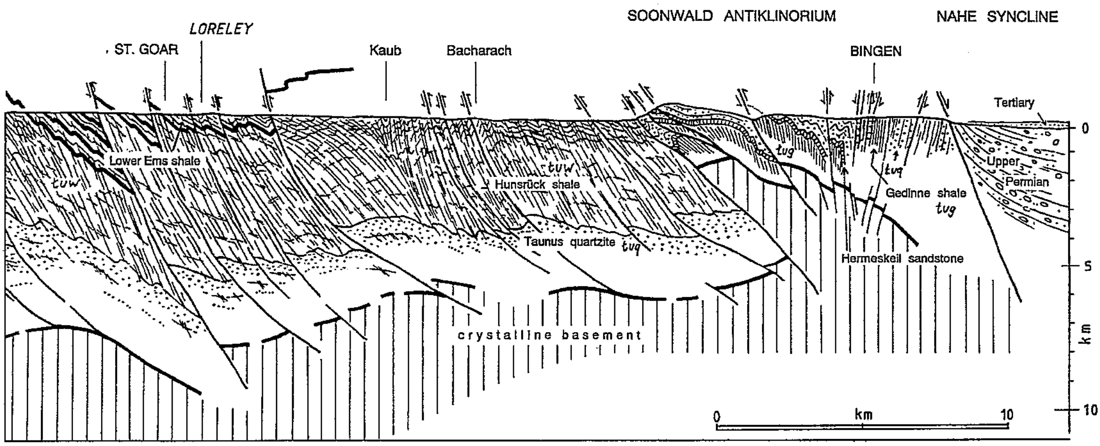


Fig. 50 Longitudinal section of the upper Mittelrhein valley. Lower Devonian: Lower Ems shale – Hunsrück shale – Hermeskeil sandstone – Gedinne shale (MEYER & STETS 1975: tab. 1, modified)

excellent echo (echo rock). In 1801 the grand Romantic poet Clemens von Brentano created the famous Loreley, a female being who changed – in the eyes of different poets – from nixie to a girl enticing the shippers by her singing thus endangering them to collide with the riffles.

Meyer, W. & Stets, J. (1975): Das Rheinprofil zwischen Bonn und Bingen. – Z. deutsch. geol. Ges., **126**: 15–29, Taf.1–2; Hannover.

Semmel, A. (1977) in: Bibus, E. & Semmel, A.: Über die Auswirkung quartärer Tektonik auf die altpleistozänen Mittelrhein-Terrassen. – Catena, **4**: 386–396; Gießen.

— (1989): Field Trip G3: Geomorphology of the upper Middle Rhine valley. – geoöko-forum, **1**: 317–318; Darmstadt.

Mittelrhein Basin and lower Mittelrhein

(W. Schirmer)

Stop 36: Dreitonnenkuppe, Kieseloolith-Terrasse (Siliceous Oolite Terrace) (uppermost Miocene to Pliocene)

D – TM 25: sheet 5610 Bassenheim,
R 25998, H 55774, 315 m a. s. l.

In the western part of the Mittelrhein Basin the morphologically highest position besides the Quaternary volcanoes is formed by the Kieseloolith Terrace. It is the oldest well-tracable gravel bed of the Rhein system.

The gravel up to 10 m in thickness consists of small well-rounded pebbles (medium-sized in a sandy matrix). The pebbles represent mostly quartz, some quartzite and silicified rocks. Amongst the latter occurs the siliceous oolite facies (Fig. 51). Moreover, small crinoid fossils can be found. The heavy mineral spectrum shows tourmaline, zircone, rutile and staurolite for a total of more than 50 %. This characteristic indicates a strong selection by weathering before and during the deposition. Succeeding the deposition the gravel was weathered by a deep red soil.

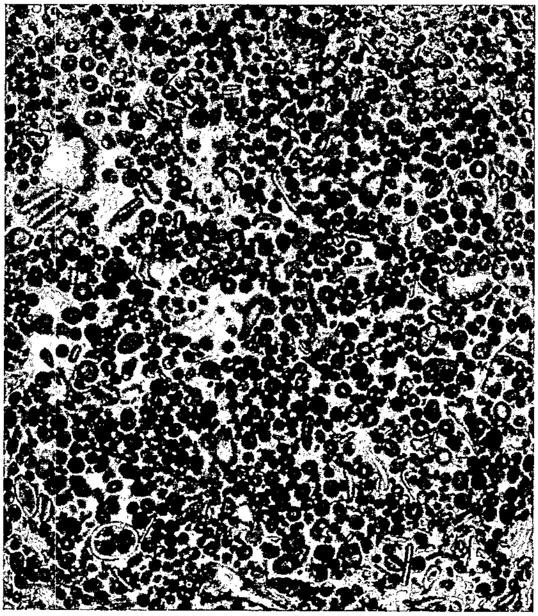


Fig. 51 Kieseloolith (siliceous oolite) pebble from the upper Miocene-Pliocene Kieseloolith beds. Lateral width: 20 mm

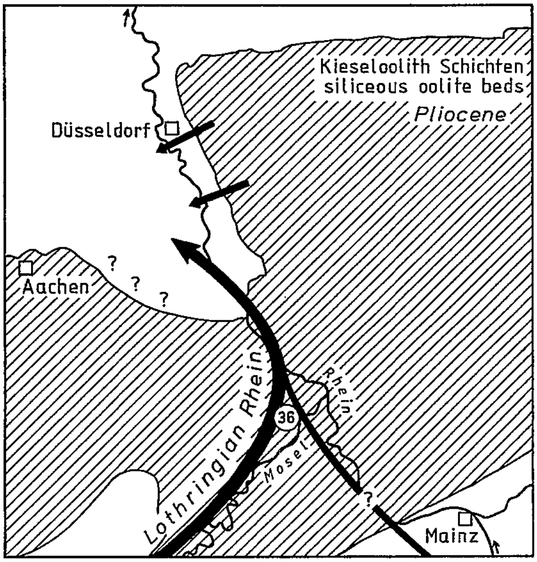


Fig. 52 The Lothringian Rhein (Upper Miocene-Pliocene) within the Rhenish Shield (modified from Boenigk 1981: 251)

The parent material of the siliceous oolite and the fossils come from Middle Triassic and Jurassic beds that occur upstream in the Mosel area of Lothringen. As the gravel facies of this river system differs between the Upper Mittelrhein and the Mosel, and as on the Niederrhein prevails that of the Mosel (Boenigk 1981: 242) it follows that a primeval Rhein came from Lothringen via Mosel and may have received the virtual Rhein as a tributary in the Mittelrhein Basin (Lothringian Rhein) (Fig. 52).

Below the gravelly Kieseloolith beds in places there follow Vallendar gravel and Lower Oligocene clay, marl and sandstone (Maifeld beds) preserved in the tectonical basin position. The gravel is topped by a periglacial surficial mantle with ice wedges.

BIBUS, E. (1990): Pliozäne Kieseloolithterrassen südwestlich vom Karmelenberg (Lonniger Höhe). – In: SCHIRMER, W.: Rheingeschichte zwischen Mosel und Maas, deuqua-Führer, **1**: 38–41; Hannover.

BOENIGK, W. (1981): Die Gliederung der tertiären Braunkohlendeckschichten in der Ville (Niederrheinische Bucht). – Fortschr. Geol. Rheinl. u. Westf., **29**: 193–263, 2 Beil.; Krefeld.

Stop 37: Clay pit of Kärlich

D – TM 25: sheet 5610 Bassenheim,
R 25045, H 55842, 200 m a. s. l.

The Kärlich section (survey in SCHIRMER 1990) is the most exciting one of the Rheinland with a research history ongoing since 1913. The rough vertical sequence is the following:

ca. 22 m	loess mantle with tephra layers
ca. 10–14 m	Pleistocene fluvial gravel complex (Hauptterrassen/Principal Terrace complex)
————	major unconformity
2 m	brown Lower Miocene clay
2 m	green and grey trachytic pyroclastic bed (22.8 ± 0.6 m yr, Upper Oligocene)
6–13 m	Upper Oligocene dark blue clay, which is exploited
ca. 50 m	Lower Oligocene green Maifeld beds

Concerning the Pleistocene strata (Fig. 53), the **gravel complex** presented within the last 30 years a stack of **three fluviatile series**: A, Ba and Bb, each starting with gravel at the base and ending with flood deposits on top. Each series is topped by a fossil soil which is more or less preserved.

The loess/tephra mantle exhibited **seven loess units** (C/E, F, Ga, Gb, H, Ja, Jb) each ending with a B_t horizon of a luvisol. This soil is regarded as a soil of interglacial type. Additionally, unit G yielded an interglacial fauna, and soils and sediments topping the loess unit H are accompanied by an interglacial flora and fauna (Kärlich interglacial).

In 1995 not all of this strata, observed during the course of thirty years, will be exposed.

Important data for the section are:

▷

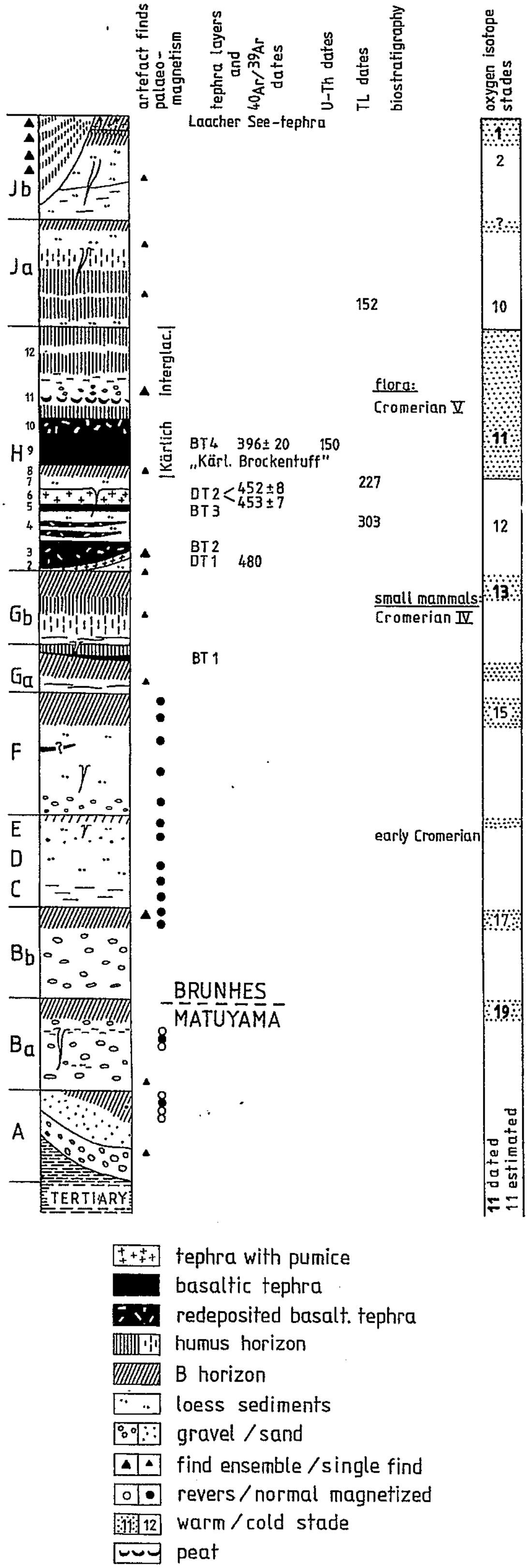


Fig. 53 Loess-tephra mantle of the clay pit Kärlich (not to scale) with stratigraphical data. Bold numbers of oxygen isotope stades are based on the given data, normal numbers are suggestions (modified from SCHIRMER 1990: 61)

The Matuyama/Brunhes boundary is bracketed between gravel unit Ba and Bb. Thus, eight glacial periods pile in the section above the Matuyama/Brunhes boundary. This seemed to be a continuous sequence of the Middle and Upper Pleistocene that normally consists of eight glacial periods. However, some datings and stratigraphical evidences disagree with it. The flora of the Kärlich interglacial (see contrib. BITTMANN) points to a young Cromerian interglacial, and a $^{40}Ar/^{39}Ar$ age of the Kärlicher Brockentuff fits to the O-stage 11 (a continuous profile would attribute the interglacial of unit H to stage 7, that is of Holstein age or obviously younger). Consequently, between the Matuyama/Brunhes boundary and unit H there are too many interglacial periods, and above H two interglacial periods are missing. Taking into consideration the evidence of twin soils which are two B_t horizons running tightly parallel a (buried) surface and are attributed to one interglacial period, the mere counting of B_t horizons must be dropped (for the Rheinland see SCHIRMER 1974: 39). To identify twin soils needs a long reach of observation, at least some hundred meters. However, in Kärlich most of the soils are wedging out after a distance of some decameters due to an undulated surface, as it may be compared in my drawing of the main wall of the pit in BRUNNACKER et al. 1969. (Concerning the problem of twin soils compare Stop 51).

Remarkable features of the Kärlich section:

Unit A exposed the oldest artefacts (choppers) of the Rhein area. In unit E small-mammal bones point to early Cromerian. In unit Gb *Arvicola terrestris cantiana* together with *Pliomys* points to the Cromerian interglacial IV (V. KOLFSCHOTEN 1988: 137). Unit H bears besides the flora and fauna artefacts of probably *Homo erectus* (KRÖGER et al. 1991).

BRUNNACKER, K., STREIT, R. & SCHIRMER, W. (1969): Der Aufbau des Quartär-Profils von Kärlich/Neuwieder Becken (Mittelrhein). – Mainzer naturw. Arch., **8**: 102–133, 1 Beil.; Mainz.

KOLFSCHOTEN, T. VAN (1988): The evolution of the mammal fauna in the Netherlands and the Middle Rhine area (Western Germany) during the late Middle Pleistocene. – Diss. Rijksuniv. Utrecht: 157 p.; Utrecht.

KRÖGER, K., BOGAARD, P. VAN DEN, BITTMANN, F. & TURNER, E. (1991): Der Fundplatz Kärlich-Seeufer. Neue Untersuchungen zum Altpaläolithikum im Rheinland. – Jb. röm.-germ. Zentralmuseum Mainz, **35** (1988): 111–135, Taf. 14–17; Mainz.

SCHIRMER, W. (1974): Mid-Pleistocene gravel aggradations and their cover-loesses in the southern Lower Rhine Basin. – IGCP project 73/1/24: Quaternary glaciations in the northern hemisphere, report no. **1**: 34–42; Prague (INQUA).

— (1990): Kärlich – Forschungsstand 1990. – In: SCHIRMER, W. [ed.]: Rheingeschichte zwischen Mosel und Maas. – deuqua-Führer, **1**: 60–67; Hannover (Deutsche Quartärvereinigung).

The Kärlich interglacial: palaeobotanical investigations

(F. BITTMANN)

Palaeobotanical investigations of the 'Kärlich Interglacial' (Unit H 11–12 in Fig. 53) revealed six periods with 14 PAZ (pollen assemblage zones) in the pollen diagrams (BITTMANN 1992 and in press) (Fig. 54):

1. period of QM (Quercetum mixtum, PAZ 1–3): This period was characterised by mixed oak forests under optimal climatic conditions.
2. period of *Carpinus* and QM (PAZ 4–7): At the beginning of the period representing the late phase of the interglacial the hornbeam became the dominant tree. In the course of PAZ 6 the cooling of the climate began. Boreal forests and fen vegetation spread out.
3. period of *Pinus* (PAZ 8)
4. Mülheim I Stadial (PAZ 9–10): tundra vegetation dominated the landscape.
5. Kettig Interstadial (PAZ 11): climatic conditions improved, so *Quercus* and *Corylus* could expand a little.
6. The Mülheim II Stadial (PAZ 12–14): tundra vegetation existed in the surrounding area. The boundary between PAZ 13 and 14 is marked by an abrupt change in the sediment (loess) and climate (cold steppe conditions).

Stratigraphic position

The pollen sequence is typical for the warm stages of the Cromerian Complex. Consequently, an Eemian or Holsteinian age can be excluded. Among the Cromerian sites known so far, the Kärlich sequence shows a good agreement only with the second part of the Cromerian interglacial from Bilshausen, Lower Saxony (MÜLLER 1992), but palaeontological investigations in the Kärlich clay-pit (VAN KOLFSCHOTEN 1990) support an age younger than the Cromerian IV Interglacial of Dutch chronology (the hitherto youngest Cromerian interglacial; ZAGWIJN 1985). Thus, the Kärlich Interglacial is regarded to be younger than the Cromerian IV and older than the Holsteinian and may be named Cromerian V Interglacial.

BITTMANN, F. (1992): The Kärlich Interglacial, Middle Rhine region, Germany: vegetation history and stratigraphic position. – Veget. Hist. Archaeobot., **1**: 243–258; Berlin.

— (in press): Vegetationsgeschichtliche Untersuchungen an mittel- und jungpleistozänen Ablagerungen

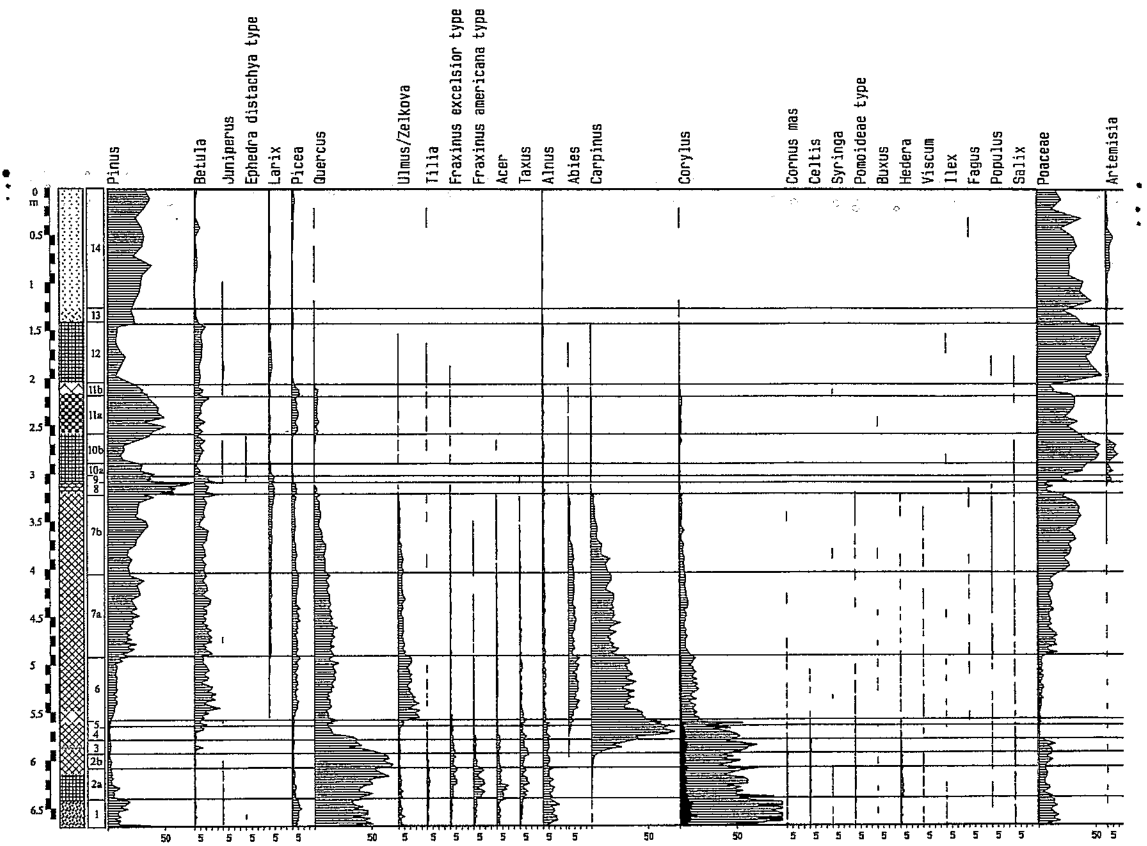


Fig. 54 Percentage pollen diagram (Profile D/E in unit H) from the Kärlich clay pit. A total terrestrial pollen sum less *Corylus* is used. Only the more important pollen curves are shown

des Neuwieder Beckens (Mittelrhein). – Jb. röm.-germ. Zentralmuseum Mainz.

KOLFSCHOTEN, T. VAN (1990): The evolution of the mammal fauna in the Netherlands and the Middle Rhine Area (Western Germany) during the Late Middle Pleistocene. – Meded. Rijks Geol. Dienst, **43**: 3–69; 's-Gravenhage.

MÜLLER, H. (1992): Climate changes during and at the end of the interglacials of the Cromerian Complex. – In: KUKLA, G. J. & WENT, E. [eds.]: Start of a Glacial. – NATO ASI Series, **13**: 51–69.

ZAGWIJN, W. H. (1985): An outline of the Quaternary stratigraphy of the Netherlands. – Geol. en Mijnbouw, **64**: 17–24.

Quaternary volcanism of the Eifel

The Eifel volcanism is part of a volcanic activity spread largely in tectonically uplifted blocks of central Europe. The volcanic activity of the Rhenish Shield started in the late Eocene simultaneously with increasing uplift of the shield. Due to uplift thinning of the lithosphere together with partial melting of mantle material is postulated as causing the volcanism (RAIKES & BONJER 1983: 315). Eo-

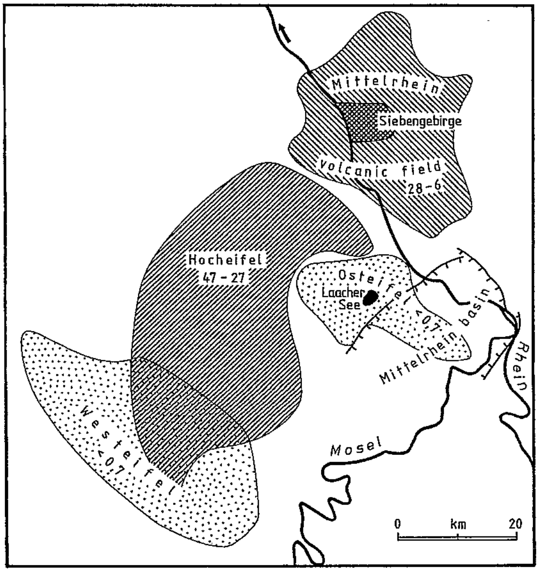


Fig. 55 Volcanic fields of the Eifel/Mittelrhein area (modified after VIETEN 1994: 146)

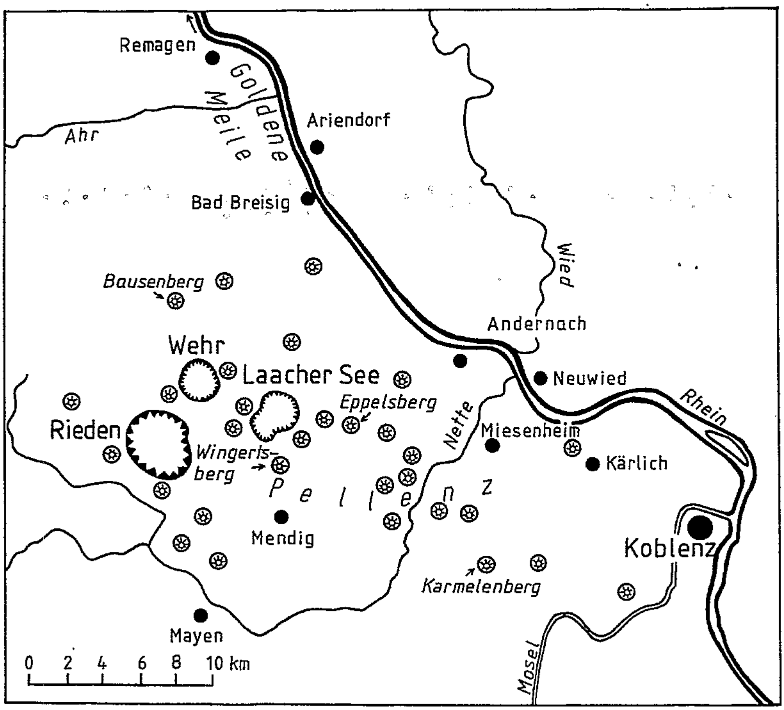


Fig. 56 East Eifel volcano field

cene, Oligocene and Quaternary are climax stages of the Eifel volcanism (Fig. 49).

The volcanic fields of the Eifel show a rough NW–SE orientation fitting to the NW–SE compression of the recent stress field (Fig. 55). The Osteifel volcanic field of about 120 volcanic centers started its activity towards the end of the Lower Pleistocene (Fig. 49) and is still going on. Its most spectacular devises are:

1. Tephra beds intercalated in Quaternary deposits of central Europe and serving as tephrochronological marker horizons (see Stops 37, 41, 42, 45 and 51).
2. Volcanic scoria cones representing unique landmarks in the East Eifel volcanic area (Fig. 56) (see Stop 44).
3. Its youngest and best preserved eruption, that of the Allerødian Laacher See volcano (Stops 38 and 39), plombing an extended area in the vicinity, and spreading an ash layer over large areas of Europe (Fig. 57) (Stop 41).
4. An impregnation of eolian and fluviatile deposits by the respective volcanic mineral spectrum.

BOGAARD, P. VAN DEN & SCHMINCKE, H.-U. (1985): Laacher See Tephra: A widespread isochronous late Quaternary tephra layer in central and northern Europe. – Geol. Soc. of America Bull., 96: 1554–1571.

RAIKES, S. & BONJER, K.-P. (1983): Large-scale heterogeneity beneath the Rhenish Massif and its vicinity from teleseismic P-residuals measurements. – In: FUCHS, K., GEHLEN, K. VON, MÄLZER, H., MURAWSKI, H. & SEMMEL, A. [eds.]: Plateau uplift. The Rhenish Shield – a case history: 315–331; Berlin (Springer).

VIETEN, K. (1994): Vulkanismus im Tertiär und Quartär. – In: KOENIGSWALD, W. V. & MEYER, W. [eds.]: Erdgeschichte im Rheinland: 137–148; München (Pfeil).

Stop 38: Laacher See volcano

D – TM 25: sheet 5609 Mayen,
R 258995, H 558642, 300 m a. s. l.

The Laacher See is a crater lake of barely 2.5 km diameter. Its level is at 224 m, its base at -50 m a. s. l. The eruption happened around 11,000 yr BP, during the Allerødian interstadial, in midst of a couple of young Pleistocene scoria cones the relics of which are surrounding the present lake basin. The eruption obviously used the place of an older crater belonging to the framing young Pleistocene volcanism. The form of the lake of two intermittent circles (Fig. 57) indicates a change of the vent. The southern crater was used during the Lower Laacher See tephra, the northern since the Middle Laacher See tephra (see Stop 39). Recent activity is restricted to weak gas production close to the eastern bank of the lake (CO_2 derivable from the earth mantle due to high $^3He/^4He$ ratio; SCHMINCKE et al. 1990: 155). Until 1152 the lake was larger. In the 12th and 19th century monks of the cloister Maria Laach lowered the lake level by more then 6 m, draining it by a tunnel at its southern bank in order to yield more arable land (FRECHEN 1976: 154).

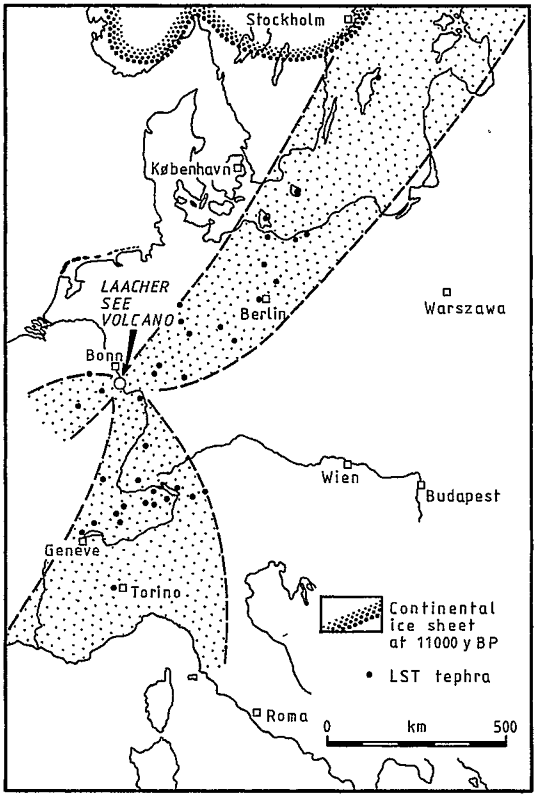


Fig. 57 Laacher See tephra in central Europe (modified after v. d. Bogaard & Schmincke 1985: 1554)

The hauyn-phonolitic magma has its chamber at a depth of 2–5 km. About 5 km^3 dry rock mass has been thrown out spreading over central Europe (Fig. 56). The eruption is mostly of Plinian type and therefore estimated to have happened within a few days. As I found recently, the Laacher See eruption took place by two events, the second being separated from the first by a time-lag of some years or a few decades of years. Thus, the following stratigraphical sequence of the Laacher See eruption is inferred here:

Meile tephra
Breisig interruption
Pellenz tephra
Mendig soil
} Allerød period

The first event produced the major part of the Laacher See tephra, Pellenz tephra, named after its thickest occurrence in the Pellenz (Fig. 57). The second event produced a much smaller tephra amount well exposed in the Goldene Meile, burying there the Breisig flora (see Stop 41). The Meile tephra may correspond to the highest part of the Upper Laacher See tephra of Schmincke's subdivision (see Stop 39).

Frechen, J. (1976): Siebengebirge am Rhein – Laacher Vulkangebiet – Maargebiet der Westeifel. Vulkanologisch-petrographische Exkursionen. – Sammlung geol. Führer, **56**: 209 p., 5 Beil., 3. Aufl.; Berlin, Stuttgart (Borntraeger).

Schmincke, H.-U. (1994): Vulkanismus im Laacher See Gebiet. Exkursion der Geologischen Vereinigung und Deutschen Vulkanologischen Gesellschaft 10. – 12. 6. 1994. – GV Exkursionsführer, **1**: 59 p.; Kiel.

Schmincke, H.-U., Bogaard, P. v. d. & Freundt, A. (1990): Quaternary Eifel volcanism. Excursion 1AI. Workshop on explosive volcanism, August 27 to September 2. – 188 p.; Mainz.

Stop 39: Laacher See tephra pit of Wingertsberg

D – TM 25: sheet 5609 Mayen,
R 25906, H 55846, 320 m a. s. l.

The Wingertsberg scoria cone belongs to the group of late Pleistocene volcanoes surrounding the Laacher See volcano. Positioned in a distance of one km off the Laacher See crater, it is covered by a thick Laacher see tephra (LST) mantle (cf. Schmincke et al. 1990: 131). The tephra pit exhibits the following sequence (thicknesses varying):

Ca. 40 m	phonolitic Laacher See tephra (Allerødian, ca. 11,000 yr BP) subdivided into:
4.5 m	ULSTL = Upper LST: laminated
9 m	ULST = Upper LST: dark surge breccias, dunes, flows
ca. 13 m	MLST = Middle LST: striped fallout flow deposit
12 m	LLST = Lower LST: light, fallout
1 m	BLST = basal LST: greenish fine-grained ash, initial phreatomagmatic eruption
0.2 m	Mendig soil: calcaric regosol (Allerødian)
0.5 m	loess (Upper Würmian)
	tephritic lava and tephra of a scoria vulcano (penultimate glaciation to Eemian)

The surface of the scoria exhibits periglacial reworking activity with ice wedges. On top of the small loess bed a weak soil has developed consisting of a humic A horizon (pararendzina = calcaric regosol). Together with the soil, scattered rannen of an Allerødian forest have been preserved as root remnants and stumps of trees upright towering into the Laacher See tephra for a few meters and of a diameter up to 20 cm. The basal fine-grained ash of the Laacher See tephra contains imprints of leaves.

An indicator mineral for the Laacher See pumice is the blue hauyne (up to a few mm ∅). Notable

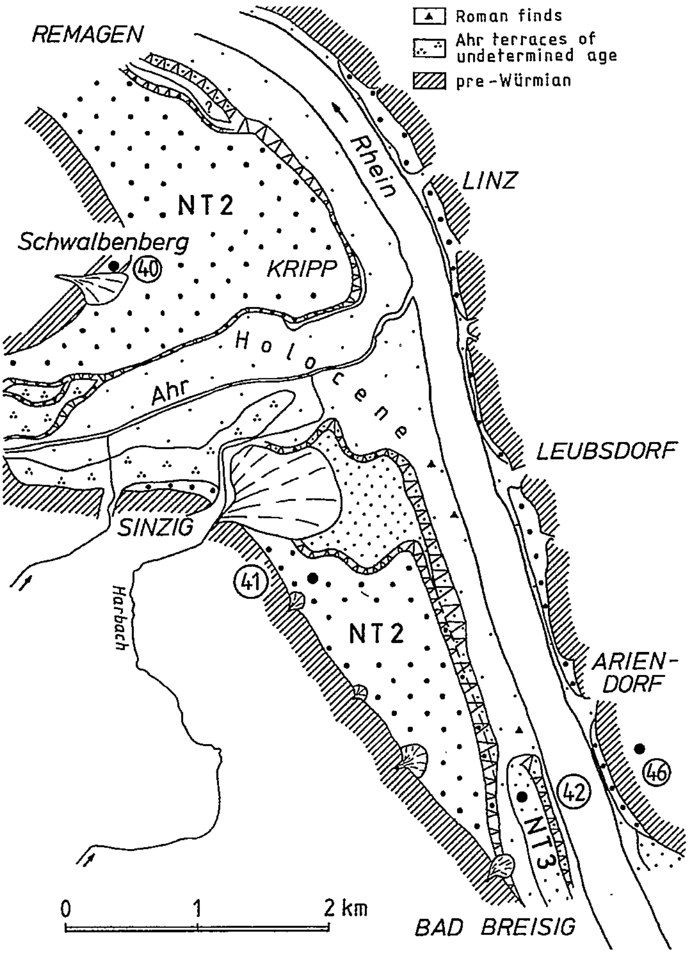


Fig. 58 Terrace map of the Goldene Meile (Golden Mile) (modified after SCHIRMER 1990: 95)

for the tephra are single bombs, the darker lapilli layers rich in xenoliths (abundant Palaeozoic slate), fine-grained bands of ignimbrite horizons in the MLST. These small horizons represent an overbank facies of some decameter thick ash flows filling those valleys that spread radially from the Laacher See. The ULST exhibits dune horizons (radial wind transport off the vent).

SCHMINCKE, H.-U., BOGAARD, P. V. D. & FREUNDT, A. (1990): Quaternary Eifel volcanism. Excursion 1AI. Workshop on explosive volcanism, August 27 to September 2. – 188 p.; Mainz.

The 'Goldene Meile' (Golden Mile)

It is a fertile basin of a German geographical mile (= 7.4 km) in length, 140 m deep incised into the climatically rougher trough valley of the Rhein. It has been formed at the place where the left tributary, the Ahr, pushed the Rhein towards its eastern valley slope. Protected by the gravel cone of the Ahr river, a small valley bottom – the Goldene Meile – extends on top of the Niederterrassen 2 and 3 and a couple of Holocene floodplain terraces (Fig. 58). The Mittelterrassen form small steps within the steep slopes of the entrenched valley between the level of the trough valley and the valley bottom (Fig. 47).

SCHIRMER, W. (1990): Die Goldene Meile. – In: SCHIRMER, W. [ed.]: Rheingeschichte zwischen Mosel und Maas. – deuqua-Führer, 1: 94–98; Hannover (Deutsche Quartärvereinigung).

Stop 40: Schwalbenberg/Remagen. Middle Würmian

D – TM 25: sheet 5409 Linz,
R 258824, H 560356, 92 m a. s. l.

This locality displays within a steep cut the 'Untere Mittelterrasse' (MT 4) of the Rhein topped by a fossil luvisol and a 13.5 m thick loess pile. This loess pile comprises a Middle Würmian section of appreciable vertical extension and fairly complete preservation (Fig. 59):

Middle Würmian 4 (Sinzig period): Interstadial complex with three calcic cambisols.

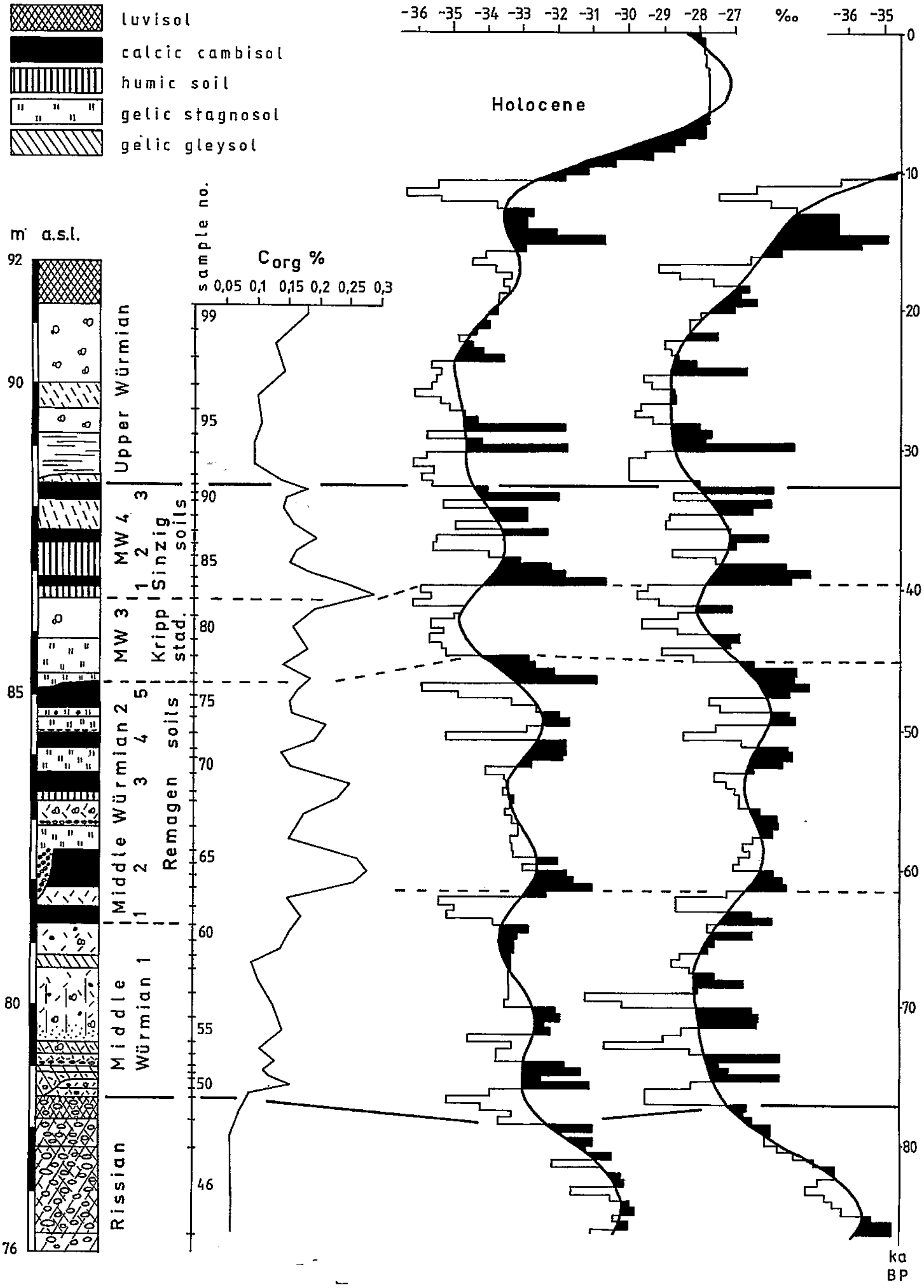


Fig. 59 Schwalbenberg section and its organic carbon content compared with δ18-O of the Dye 3 drilling (left) and Camp Century drilling/Greenland (right) (SCHIRMER 1991: 75, modified)

Middle Würmian 3 (Kripp period): Short stadial period with loess and basal gelic stagnic gleysol.

Middle Würmian 2 (Remagen period): Interstadial complex with five calcic cambisols.

Middle Würmian 1: Solifluctional loess, with gelic gleysols.

There is a significant correlation both to the Grand Pile section (Fig. 39) and to ice cores and deep sea cores (Fig. 59). The correlation is based not only on the loess-soil sequence but also on the rough thickness relationships, on the soil chemical and chronological data. Consequently, this correlation gives – besides that of the Grande Pile – further proof of the correlatability of terrestric and marine Quaternary deposits.

SCHIRMER, W. (1990): Schwalbenberg südlich Remagen. – In: SCHIRMER, W. [ed.]: Rheingeschichte zwischen Mosel und Maas. deuqua-Führer, 1: 105–108; Hannover (Deutsche Quartärvereinigung).

— (1991): Würmzeitliche Paläoböden am Mittelrhein. – 10. Tagung des Arbeitskreises "Paläoböden" der Deutschen Bodenkundlichen Gesellschaft vom 30.5.–1.6.1991 in Bonn, Programm und Exkursionsführer: 70–83; Münster, Bonn, Düsseldorf.

The Niederterrassen (Low Terraces)

As in whole central Europe, three Niederterrassen (NT) exist on the Rhein river (Figs. 47 and 49). On the lower Mittelrhein the NT 1 (Maxiwürm Terrace) lies on average 16 m above the river level, the NT 2 (Schönbrunn Terrace) 14 m, the NT 3 (Ebing Terrace) ca. 13 m.

The NT 1 has a small sandy flood sediment and is free of loess. The NT 2 has a thick fine-sandy, silty flood sediment. Within the reach of the Laacher See tephra fan there exist three flood loam strata separated by the Pellenz and the Meile tephra:

Upper flood deposit
Meile tephra
- Breisig soil and flora

Pellenz tephra/Middle flood deposit (lahar-like)
- Mendig soil and flora

Lower flood deposit
NT 2 channel sediment

The Goldene Meile area was only fed by the Meile eruption.

From the Mittelrhein basin downstream, both the NT 3 channel and flood sediment bear small pebbles and grains of Laacher See pumice.

SCHIRMER, W. (1990): Der känozoische Werdegang des Exkursionsgebietes. – In: SCHIRMER, W. [ed.]: Rheingeschichte zwischen Mosel und Maas. deuqua-Führer, 1: 9–33; Hannover (Deutsche Quartärvereinigung).

Stop 41: Gravel pit Schmickler, Sinzig (NT 2)

D – TM 25: sheet 5409 Linz,
R: 25898, H 550125, 64 m a. s. l.

The gravel pit lies in seam channel position of the Niederterrasse 2 (Schönbrunn Terrace) (Fig. 60). A V gravel with ice wedges and drift boulders indicates cold-climate depositional conditions. A thick floodplain-channel sand fill fits to the external terrace position. Loamy intercalations with drop soils indicate the continuation of the cold climate. Riverward beyond the pit, a flat channel of L gravel is cut into these deposits indicating a first meandering river. This whole channel facies is mantled by a 3.5 m thick fine-sandy to silty flood deposit.

Concentrating towards the upper part, it contains pieces of massive silty Laacher See tephra up to 30 cm Ø and swimming disorientated in the flood loam. It points to a lahar-like flood deposit that spreads over the NT 2 during or short after the Pellenz eruption. A break of at least several years within the Laacher See eruption sequence is indicated by a well-developed flora on top of this flood deposit (Breisig period). Then the Breisig flora was covered and preserved by the Meile tephra, the second event of the Laacher See eruption. The Meile tephra consists of an up to 60 cm thick tephra bed. Its lower part (15 cm) is of massive tuff, a fall-out facies, that contains the well-preserved Breisig flora. Its upper part (up to 45 cm) presents a fluvially reworked tephra. The Meile tephra is overlain by another 30 cm of flood deposit, that is topped by the Holocene fluvic luvisol.

SCHIRMER, W. (1990): Die Goldene Meile. – In: SCHIRMER, W. [ed.]: Rheingeschichte zwischen Mosel und Maas. deuqua-Führer, 1: 94–98; Hannover (Deutsche Quartärvereinigung).

Tephrobiology: The Breisig flora and fauna (G. WALDMANN)

The Laacher-See tephra contains the remains of broad-leaved plants and invertebrates preserved as imprints. The thanatocoenosis represents a local snapshot of the environment minutes before the eruption took place. The plant and animal community is a response onto the ecological conditions of the Allerødian interstadial.

Some of the more temperate species found in the Meile tephra at Sinzig and Bad Breisig are:

Plants: *Achillea millefolium, Bellis perennis, Campanula cf. rapunculoides, Convallaria majalis, Corylus avellana, Geum urbanum, Knautia arvensis, Lysimachia nummularia, Malva alcea, Pimpinella saxifraga, Primula veris, Quercus robur, Rhamnus catharticus, Rumex acetosa, Thalictrum flavum, Valeriana dioica, Verbascum cf. nigrum, Vicia cf. cracca, Viburnum opulus, Viola cf. odorata*

Animals: *Discus ruderatus, Lithobius* sp.

Judging by the spectrum of plant species detected, the environment was by no means inhospitable, from today's human point of view. Being alive, many species found in the tephra are edible. Early man no doubt appreciated good cooking. Some plants recorded produce soft fruit and nuts supporting the need of vitamins for human nutrition even today. Others can be used as a fibre source for basketry and knitting nets for collecting, transportation, fishing, trapping and hunting purposes as well. Shrubs and trees provide wood for weapons like bow and arrow and bark for tanning leather.

The use of plants was one of the presuppositions to make the highly mobile lifestyle of the 'Fe-

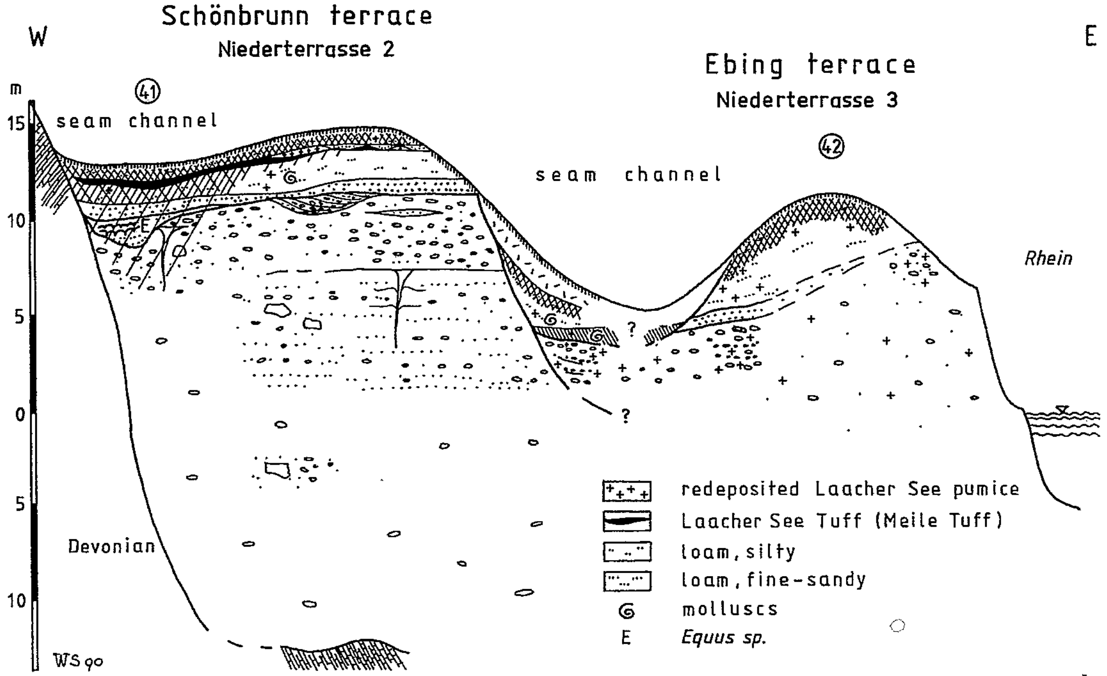


Fig. 60 Cross section of the valley bottom of the Goldene Meile (modified after Schirmer 1990: 96)

dermessergruppen' possible. A lot of plants listed content drugs and were perhaps important for medical care to treat diseases and wounds caused during hunting activity.

With high evidence it can be supposed the collecter-hunter-culture disposed of solid botanical knowledge. Poisenous plants that have been discovered might have been used in shamanistic celebrations.

It can be assumed that the importance of plants for the daily survival of the people within the Allerødian interstadial has been considerable underestimated so far.

The eruption of the Laacher-See volcano however destroyed a huge area within the Rhineland, being uninhabitable afterwards. The eruption even might have caused a natural and cultural hiatus for centuries.

Waldmann, G. (1994): Ein allerödzeitlicher Auenwald bei Sinzig/Mittelrhein. – In: Hoffmann, K. & Lange, J.-M.: Umwelt- und Quartärgeologie Mitteldeutschlands. 150 Jahre Inlandeistheorie in Sachsen. Kurzfassungen der Vortrags- und Posterbeiträge: 52 p.; Leipzig (DEUQUA).

Early Late Glacial pollen record of Miesenheim

(U. Schirmer)

The Allerødian interstadial, characterized by the macroflora given above as well as by the pollen flora in Fig. 61 marks the first reforested period of the Late Würmian. The spreading of the vegetation from the Würmian Pleniglacial to the Allerødian Laacher See tephra is well recorded by the Miesenheim pollen diagram (Fig. 61). At this locality (Fig. 56) a lake deposit starts with a thick Pleniwürmian loess fill fairly poor in pollen content. It continues with a Late Würmian sequence of alternating lime precipitation and organic intercalations (pollen diagram zone 1–3), followed by an early Allerødian peat (PDZ 4–5). The sequence is topped by the Laacher See tephra, which provides a reliable time marker. Even the preliminary results of the pollen record present a distinctly subdivided Late Glacial sequence:

PDZ 1 / Meiendorf interstadial

PDZ 1 reflects the situation of the late Meiendorf interstadial with *Betula* percentages already ranging from 10 to 50 (Ø 27 %). Most probably a certain share of shrub *Betula* is involved as the values of dwarf willow (cf. *Salix retusa*) are high and the pioneer shrubs *Hippophaë* und *Juniperus* are constantly present. *Artemisia, Helianthemum, Potentilla, Thalictrum* and *Polemonium coeruleum* are the more important nonarboreal pollen types. The radiocarbon age of a piece of wood dates this interstadial to 12,320 ± 90 yr BP (Hv 18,442).

PDZ 2 / Older Dryas Period

This period gives proof of a climatic deteriora-

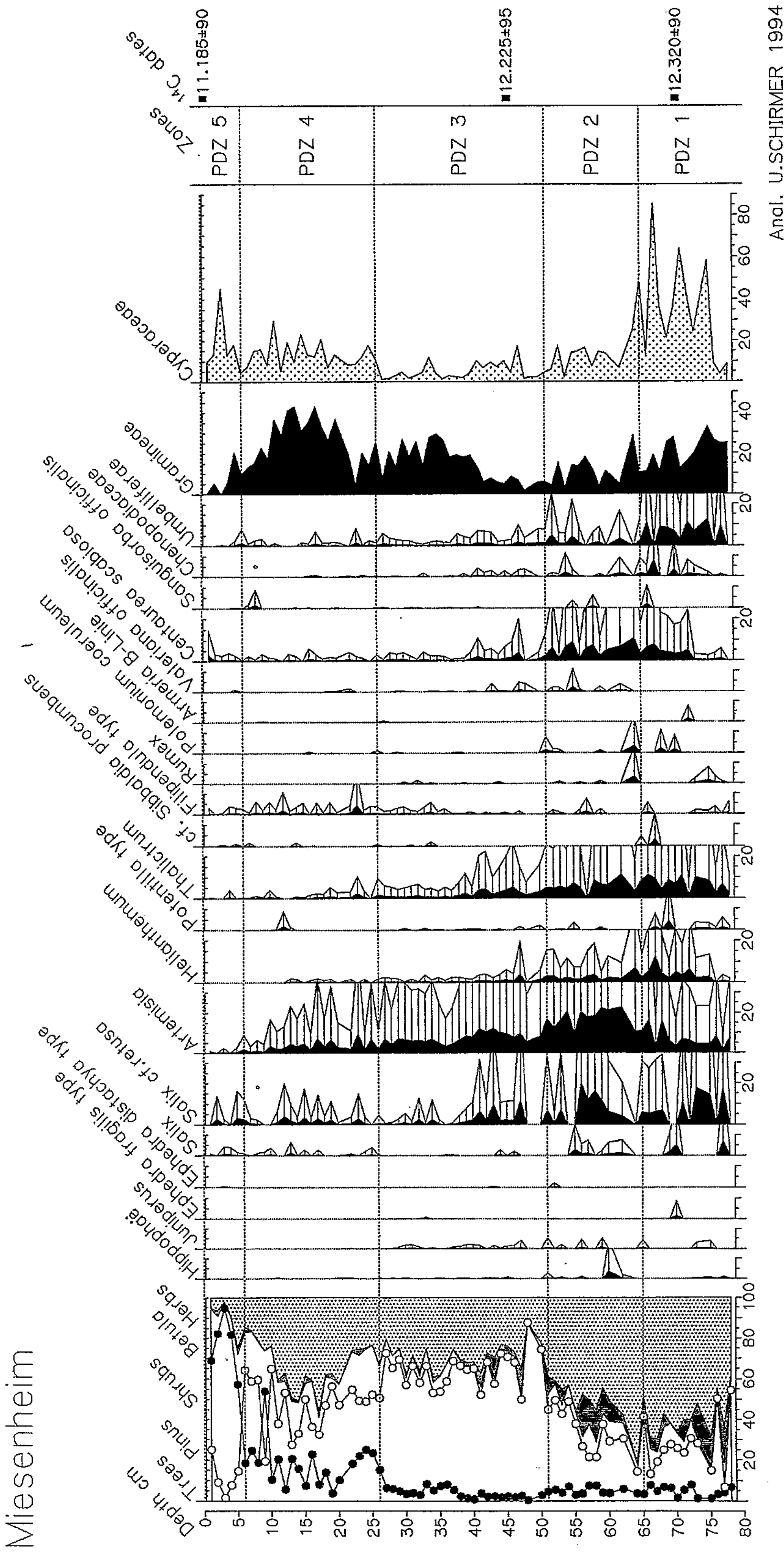


Fig. 61 Miesenheim – early Late Glacial pollen diagram (0 = 95,6 m a. s. l.; only pollen types concerning the stratigraphy are printed; Cyperaceae are excluded from the basic sum)

tion by its increase of nonarboreal heliophilous pollen types most of all *Artemisia* and *Thalictrum* which reach their absolute maxima. The increase of *Betula* and *Salix* may be caused by their shrub shares.

PDZ 3 / Bølling

This pollen zone features the full expansion of arboeal *Betula*. A radiocarbon date of wood places the *Betula* maximum to 12,225 ± 95 yr BP (Hv 18,443). The Late Glacial heliophyts decrease to the values of PDZ 1.

PDZ 4 / Allerød (*Betula* phase)

The pollen record shows the steady expansion of *Pinus* – with *Betula* still dominating – and the rapid decline of the heliophilous types.

PDZ 5 / Allerød (*Pinus* phase)

The highest part of the profile is characterized by the final expansion of *Pinus* which in most middle European pollen records precedes the event of Laacher See tephra. A radiocarbon analysis of wood dates the top of the profile to 11,185 ± 90 yr BP (Hv 18,444). This age fits perfectly to the presence of the topping LST.

Stop 42: Gravel pit Klee, Bad Breisig (NT 3)

D – TM 25: sheet 5409 Linz,
R 25914, H 55995, 60 m a. s. l.

The NT 3 (Ebing Terrace) rises to a similar level as the NT 2 (Schönbrunn Terrace) (Fig. 60). However, mostly it remains 1–2 m below the NT 2 level. Bearing reworked pebbles of Laacher See pumice throughout its terrace accumulation, the NT 3 evidences to be younger than Allerød. Exhibiting locally cold-climate indicators, it has to be placed into the Younger Dryas period, the last cold period of the Würmian glaciation.

Stop 43: Gravel pit east of Torney
(W. Schirmer & A. Ikinger)

D – TM 25: sheet 5511 Bendorf,
R 339375, H 559250, 120 m a. s. l.

As soon as the Laacher See tephra mantle is thinning to few meters off its eruption center, the Holocene soil formation penetrates through the whole tephra and sometimes beyond it into its bedrock pervading there the pre-existing and tephra-buried Mendig soil. In this case it is difficult to separate the Allerødian soil formation from the Holocene one. Thus a long scientific discussion is going on whether an A-C soil or an A-B-C soil would have developed during the Mendig soil period. Wherever the Mendig soil is not affected by later soil formation processes it presents a calcaric regosol (pararendzina) (Rohdenburg & Meyer 1968). Ikinger (1995) found that by damming of the pore solution on top of the Mendig soil, luvisol features developed on top of this fossil soil, in places within this soil and beneath in its protolith.

The section exhibited here presents the Holocene luvisol penetrating the Laacher See tephra (exploited as far as the basal few centimeters), the Mendig soil (calcaric regosol) and parts of the loess below it.

Ikinger, A. (1995): Bodenbildung unter Laacher Bims im Mittelrheinischen Becken. – Inaug.-Diss. Univ. Düsseldorf: 131 p., 4 Beil.; Düsseldorf. [Maschinenschrift]
Rohdenburg, H. & Meyer, B. (1968): Zur Datierung und Bodengeschichte mitteleuropäischer Oberflächenböden (Schwarzerde, Parabraunerde, Kalksteinbraunlehm): Spätglazial oder Holozän? – Göttinger Bodenkundl. Ber., **6**: 127–212; Göttingen.

Stop 44: Prehistoric Museum Monrepos

D – TM 25: sheet 5510 Neuwied,
R 250248, H 559492, 290 m a. s. l.

As department of the Römisch-Germanisches Zentralmuseum in Mainz, this museum of Pleistocene archaeology housing in the Schloß Monrepos works as place of investigation as well as museum for the Palaeolithic archaeology of the Mittelrhein area. The museum exhibits finds beginning with *Homo erectus*, 1 Mio years ago, through the time of *Homo sapiens neanderthalensis* (200,000–40,000 yr BP) peaking in the Magdalénien of Neuwied-Gönnersdorf (ca. 12,500 yr BP) with engraved slate slabs figuring picturesquely man and glacial fauna.

Bosinski, G. (1992): Eiszeitjäger im Neuwieder Becken. – Archäologie an Mittelrhein und Mosel, **1**, 3. Aufl.: 148 p.; Koblenz.

Stop 45: Eppelsberg volcanic scoria and lapilli cone

D – TM 25: sheet 5509 Burgbrohl,
R 259395, H 55859, 265 m a. s. l.

The Eppelsberg – as a typical example of the polygenetic scoria cones of the East Eifel – exhibits five eruption units (A–E) separated by unconformities (Schmincke et al. 1990: 112; Schmincke 1994: 26). These unconformities encompass periods of vulcanotectonical displacement and/or soil development. Within these units the rock composition turns from early tephrite to late basanite. The two basal units (A, B) represent initial maar phases with predominantly hydroclastic well bedded tuff deposits. The third unit (C) is the main Strombolian phase with eruption of lava that mainly appears as scoria breccias, short lava tongues and

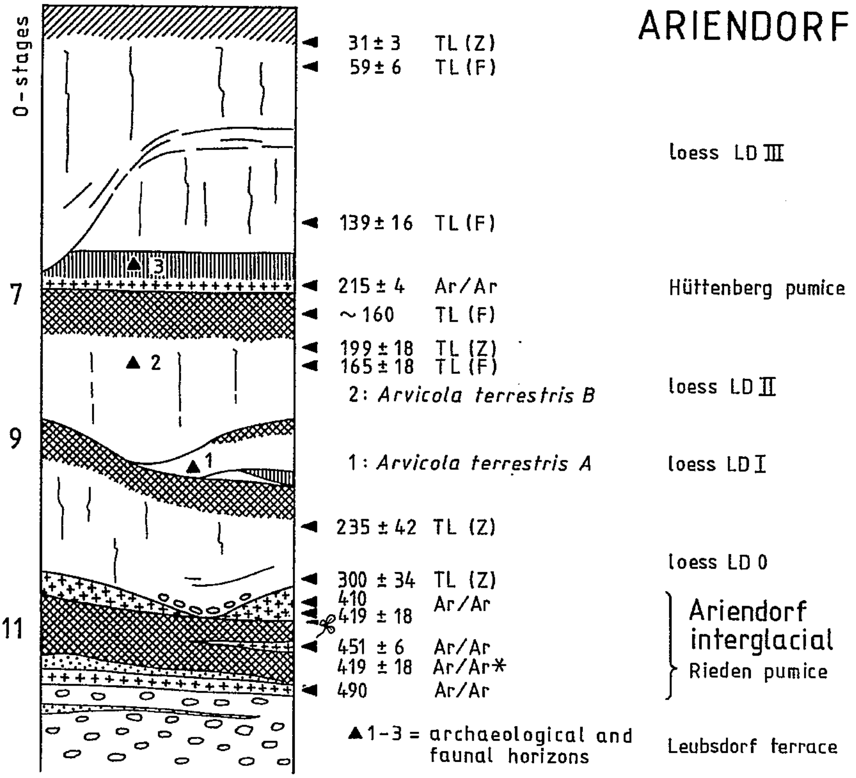


Fig. 62 Ariendorf section: cover series (compiled after V. D. BOGAARD & SCHMINCKE, FRECHEN, HAESAERTS and V. KOLFSCHOTEN in SCHIRMER [ed.] 1990: 112 f.). Ar/Ar = ^{40}Ar/^{39}Ar laser dates by V. D. BOGAARD & SCHMINCKE; * = step degassing age by LIPPOLT, FUHRMANN & HRADETZKY; F = TL dating by FRECHEN; Z = TL dating by ZÖLLER & STREMME

bomb breccias. They form the principal core of the scoria cone, its crater fill and adjacent wall. Units D and E indicate the late hydroclastic phase. They consist of stratified pyroclastic and hydroclastic tuffs and lapilli beds changing their colour from bed to bed. A conspicuous cambisol separating unit D from E embraces imprints of leaves, e. g. fern (SCHIRMER, unpubl.) – testifying to a longer hiatus between both hydroclastic phases. The scoria cone is capped by a loess layer and the Laacher See tephra.

During the first three eruption phases the crater maintained nearly the same position but, it changed the position within the cone during the late hydroclastic phases to places beyond the pit.

SCHMINCKE, H.-U. (1994): Vulkanismus im Laacher See Gebiet. Exkursion der Geologischen Vereinigung und Deutschen Vulkanologischen Gesellschaft 10.–12. 6. 1994. – GV Exkursionsführer, 1: 59 p.; Kiel.

SCHMINCKE, H.-U., BOGAARD, P. V. D. & FREUNDT, A. (1990): Quaternary Eifel Volcanism. Excursion 1AI. Workshop on explosive volcanism, August 27 to September 2. – 188 p.; Mainz.

Stop 46: Gravel pit Ariendorf

D – TM 25: sheet 5409 Linz,
R 25923, H 56000, 145 m a. s. l.

The pit displays a pile of 17 m loess with tephra (Fig. 62) above ca. 30 m gravel of a Mittelterrasse: Situation see in Fig. 58.

The loess pile exhibits four loess units (LD 0–LD III) separated by luvisols. According to the datings given in Fig. 62 loess unit LD III embraces the last two glaciation periods, and the first fossil soil from top is placed in O stage 7. The Ariendorf interglacial with a luvisol and a flora below the upper Rieden pumice layer is dated to O stage 11. As there are two luvisols and only one interglacial left between O stage 7 and 11, two of the four fossil luvisols within the loess pile may represent twin soils (compare Stop 51).

The Leubsdorf Terrace is attributed at minimum to the 5th glaciation BP thus representing the Mittelterrasse 2 (Fig. 47).

SCHIRMER, W. [ed.] (1990): Rheingeschichte zwischen Mosel und Maas. – deuqua-Führer, 1: 295 p.; Hannover (Deutsche Quartärvereinigung).

Stop 47: Erpeler Ley

D – TM 25: sheet 5409 Linz,
R 258820, H 560576, 55 m a. s. l.

The Erpeler Ley (190 m) belongs to the Oligo-Miocene Mittelrhein volcanism (Fig. 55). A basaltic vent fill is cut by the Rhein both on top, during the formation of the Hauptterrasse, and on its flank, during the formation of the entrenched valley. It is covered by gravel of the Jüngere Hauptterrasse. On the Rhein side it exhibits picturesque basaltic columns. Ley = rock (Rhenish dialect).

Ruins of a former railway bridge on both sides of the river bring to mind March 7, 1945. This day for the first time the allies encroached the eastern bank of the Rhein crossing this last preserved bridge along the river.

Niederrhein Bay

(W. Schirmer)

Gott, wie rühmen Dich
Berge, Fels und Klippen.
Sie ermuntern mich -
drum an diesem Ort,
o mein Fels und Hort,
jauchzen meine Lippen.

Joachim Neander

Stop 48: Neandertal – locus typicus of *Homo sapiens neanderthalensis*

D – TM 25: sheet 4707 Mettmann,
R 256652, H 567698, 80 m a. s. l.

The Neandertal belongs to the towns of Erkrath and Mettmann. It is drained by the Düssel river. Eleven km E of the center of Düsseldorf this valley pierces a syncline of upper Middle Devonian reef limestone for a distance of 750 m (Fig. 63). In former times there was a 60 m deep and narrow gorge rich in karst forms as caves, named 'Gesteins' (the rocks) (Figs. 64–65). After 1679 AD this valley was renamed 'Neandertal' (Neander valley) after the Protestant theologian and hymn poet Joachim Neumann (1650–1680) who graecized his family name to Neander. J. Neander liked to spend much time in this romantic valley and its caves. From 1850 on the idyllic limestone gorge fell a victim to limestone quarrying. In 1856 during quarrying, bones of a primeval man were found in the Small Feldhof grotto (Fig. 66). Johann Carl

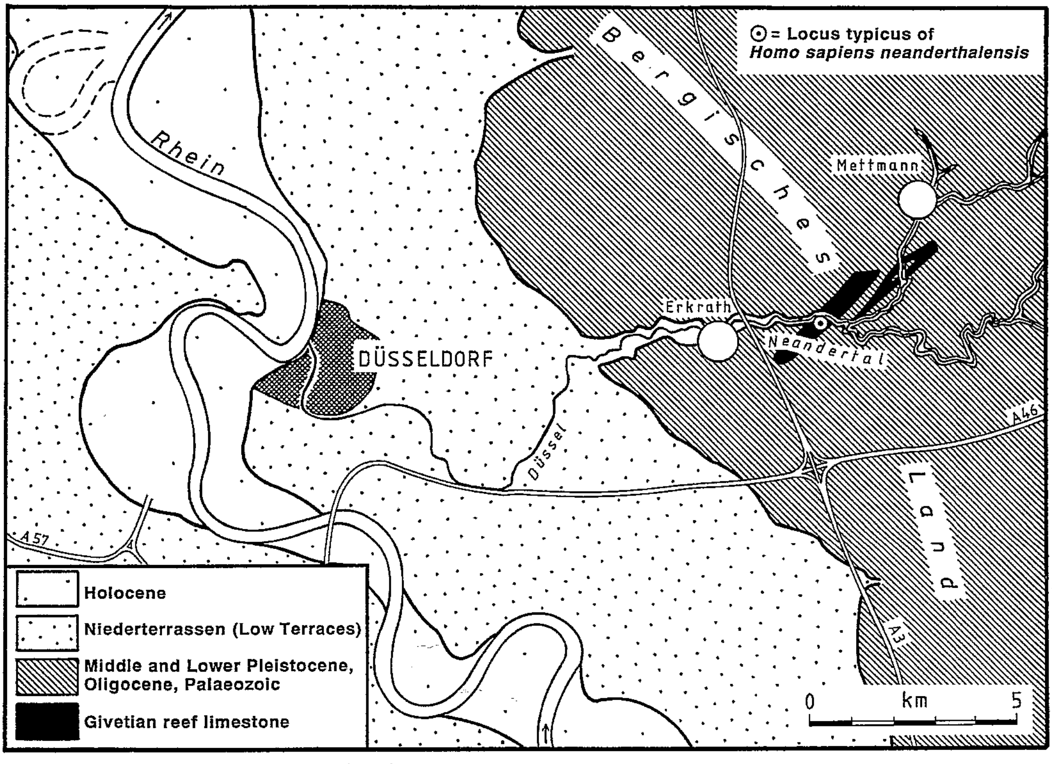


Fig. 63 Geological setting of the Neandertal

Fig. 64 The Neandertal gorge before quarrying (BONGARD 1835, after p. 60)

Fig. 66 Skull of the *Homo sapiens neanderthalensis* (KING 1864) (FUHLROTT 1859: Taf. 1)

FUHLROTT (1803–1877), teacher in (Wuppertal-) Elberfeld, was the first who recognized the importance of this find (FUHLROTT 1859). Later it turned out that *Homo sapiens neanderthalensis* (KING 1864) (Fig. 67) was widely distributed in the Old World. Especially in the craters of the scoria cones of the East Eifel volcanic field traces of Neanderthal man have been found. Stratigraphically the Neanderthal man ranges from the early penultimate glaciation through the Middle Würmian linked between *Homo erectus* and *Homo sapiens sapiens* (Fig. 44). But, whether *H. s. sapiens* has developed from *H. s. neanderthalensis* or not is under discussion. In any case, both occur together in space and time for a while during the Middle Würmian (ca. 80,000–35,000 yr BP).

The previous locus typicus has now become an overgrown quarry area. At the coordinates given

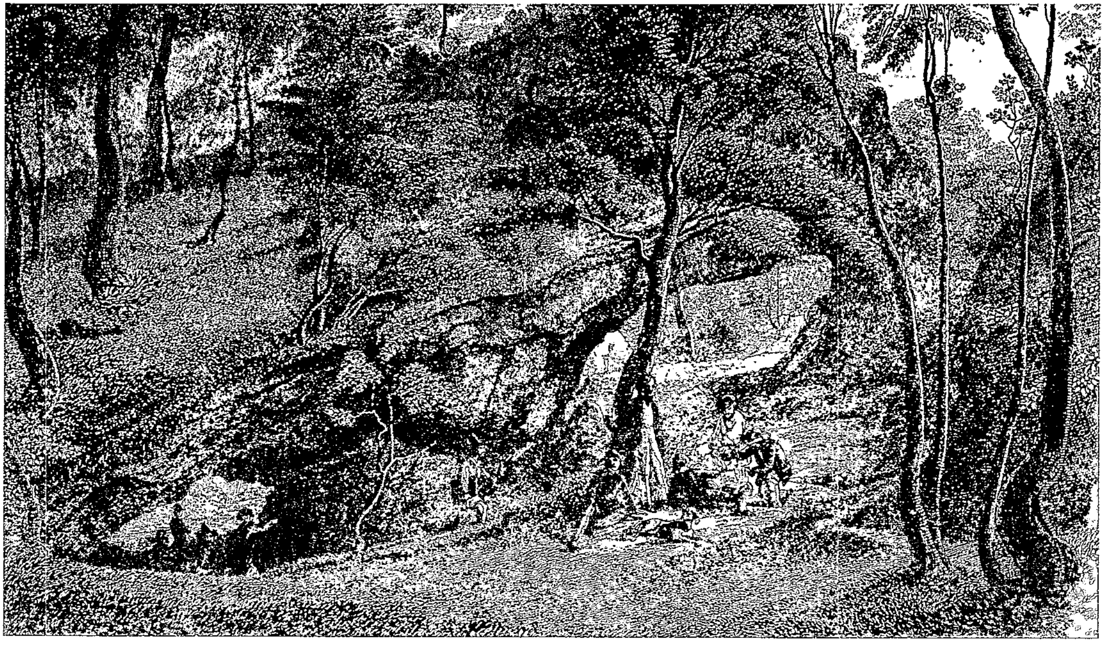


Fig. 65 The former Neander cave in the Neandertal gorge (drawing J. W. KRAFFT, steel engraving W. COOKE)

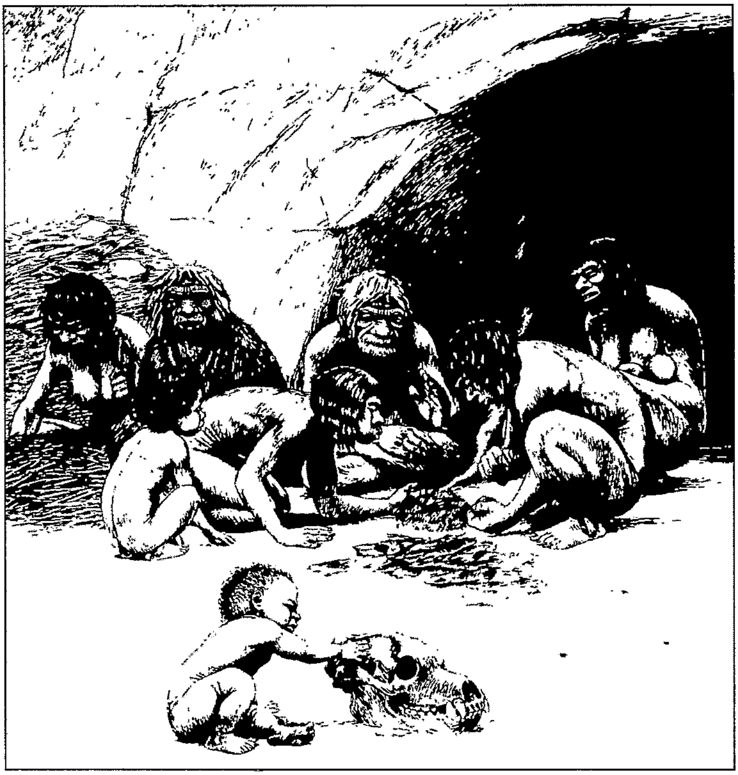


Fig. 67 *Homo neanderthalensis* scenery after Gerhard Wandel

above, a museum presents a small Neanderthal exhibition. A new large museum is under construction.

Bongard, J. H. (1835): Wanderung zur Neandershöhle. – 67 p.; unveränderter Nachdruck, original paperbacks nr. 4; Remscheid (Kierdorf).

Fuhlrott, C. (1859): Menschliche Ueberreste aus einer Felsengrotte des Düsselthals. Ein Beitrag zur Frage der Existenz fossiler Menschen. – Verhandl. naturhist. Ver. preuß. Rheinld. u. Westf., **16**: 131–153, Taf. 1; Bonn.

Stop 49: Kölner Dom/Cathedral of Cologne

Brief history of Köln

12 BC donation of the altar Ara Ubiorum by Roman officers in the area of the Germanic tribe of the Ubians

50 AD foundation of a town with the new name Colonia Claudia Ara Agrippinensium (Claudia = mother of emperor Nero). Capital of the Roman province Germania inferiore until 400 AD. (From 'Colonia' arose 'Köln'.)

355 AD first destruction by the Franconians, then taking possession

1164 bones of the Three Magi are brought from Milano

12th cent. biggest town of Germany (40,000 inhabitants)

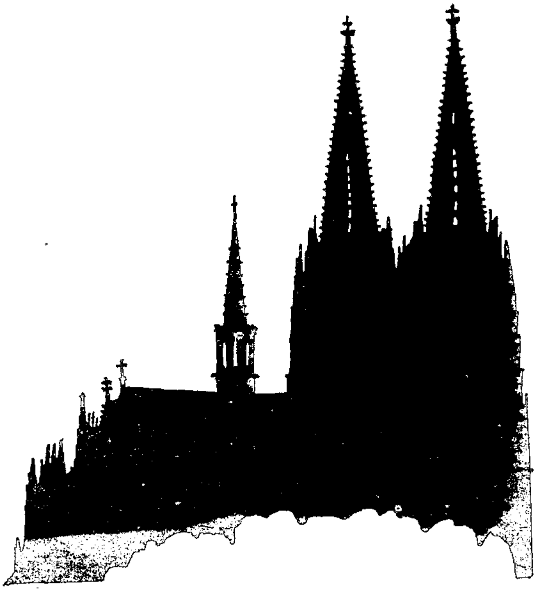
1248 foundation of the Kölner Dom, finished 1880 (see vignette)

1388 foundation of the University

1919 Konrad Adenauer major of Köln

1945 Köln destroyed by 96 %

now a bare million inhabitants.



Stop 50: Gravel pit Holzweiler

D – TM 25: sheet 4904 Titz,
R 25273, H 56573, 92 m a. s. l.

The large terrace plain at about 100 m elevation occupying the western part of the Niederrhein Bay is the continuation of the trough valley of the Middle Rhein. This terrace plain of the rivers Maas and Rhein, up to 40 km wide (Fig. 48), is built up by a stack of the Hauptterrassen complex (Principal Terrace complex).

The Hauptterrassen complex of the Niederrhein Bay is subdivided into four units HT 1–HT 4 that mainly differ by gravel petrography (Tab. 1). HT 1 and HT 2 are superimposed. With the deposition of the HT 3 a big break of the river regime arises, the break between the wide trough valley and the entrenched valley – in the Niederrhein graben between the wide terrace plateau and the valley trench restricted to the eastern side of the Niederrhein Bay. The HT 3 still is spread in the Erft basin (Figs. 68 and 69) but concentrates there to the tectonically subsiding parts. During this time the Ville ridge (Figs. 68–69) was rising in axial direction in the midst of the Niederrhein Bay. Consequently, the Rhein entering the Bay on its eastern side could not trespass this ridge any more. Hence being trapped on its eastern side it molded there the valley trench up to recent times. Whereas the terrace plateau presents a terrace stack the valley trench presents a terrace staircase. The HT 4 heads this terrace staircase.

Tab. 1 Quartz percentages (fraction 2–5 cm) within the different terraces of the Niederrhein Bay (after Schnütgen 1990: 140)

Pliocene		85 — 80
Lower Pleistocene		75 — 65
Hauptterrasse (Principal Terrace)	HT1	60 — 55
	HT2	55 — 45
	HT3	45 — 35
	HT4	55 — 45
Mittelterrassen (Middle Terraces)		45 — 30
Niederterrassen (Low Terraces)		ca. 30

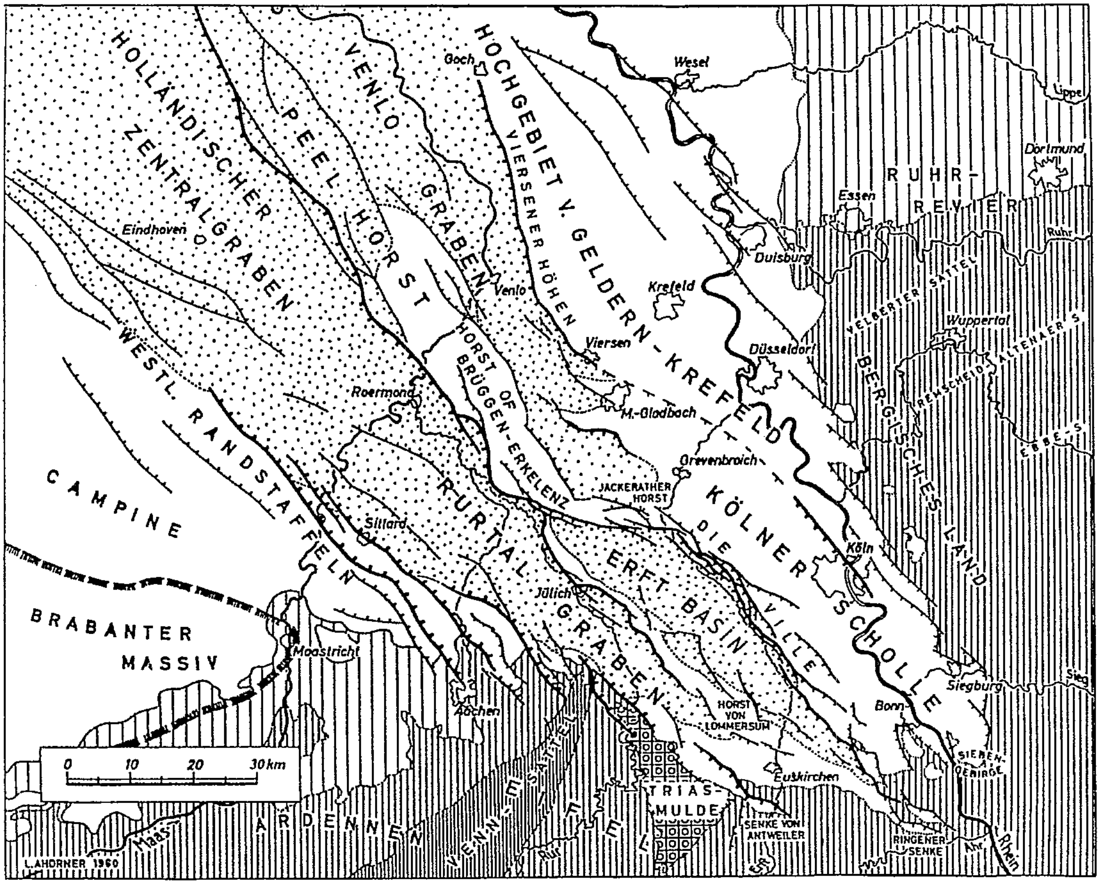


Fig. 68 Tectonical map of the Niederrhein Bay/Niederrhein graben (modified after Ahorner 1962: 28)

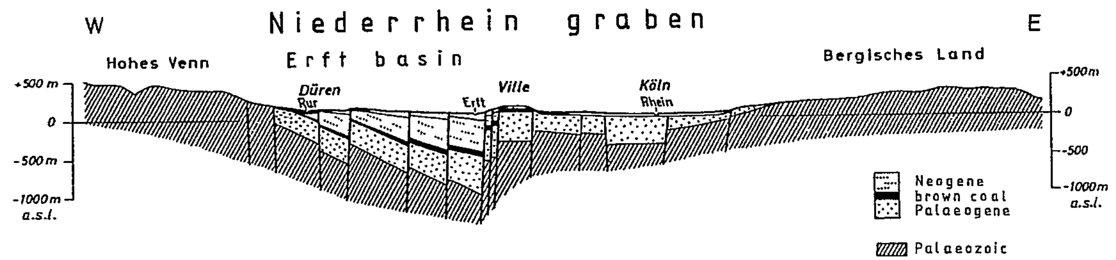


Fig. 69 Cross section of the Niederrhein graben (modified after AHORNER 1968: 152)

The gravel pit exposes a gravel stack of ca. 20 m (percentages after BOENIGK 1980: 24):

		quartz	flint
13 m HT 2	Rhein gravel and sand with drift blocks	46–53	0–2 %
5 m Lower Pl. II	Maas sand and gravel with drift blocks	28–43	7–19 %
2 m Lower Pl. I	Rhein sands and Maasgravel	67	+

The stack demonstrates the interfingering of the rivers Rhein and Maas in this apex area of the former Rhein-Maas delta.

AHORNER, L. (1962): Untersuchungen zur quartären Bruchtektonik der Niederrheinischen Bucht. – Eiszeitalter und Gegenwart, **13**: 24–105, Taf. 2–5; Öhringen/Württ.

— (1968): Erdbeben und jüngste Tektonik im Braunkohlenrevier der Niederrheinischen Bucht. – Z. deutsch. geol. Ges., **118**: 150–160, Taf. 4; Hannover.

BOENIGK, W. (1980): Holzweiler (altquartäre Rhein- und Maasschotter). – In: BRUNNACKER, K. [ed.]: Tagung der Deutschen Quartär-Vereinigung, Aachen 1980, Exkursion I: Mittel- und Niederrhein: 21–24; Köln.

SCHNÜTGEN, A. (1990): Holzweiler – Stratigraphie und flußgeschichtliche Entwicklung in der westlichen Niederrheinischen Bucht nach den Befunden von Schotteranalysen. – In: SCHIRMER, W.: Rheingeschichte zwischen Mosel und Maas. – deuqua-Führer, **1**: 138–143; Hannover.

Stop 51: Brickyard Erkelenz

D – TM 25: sheet 4904 Titz,
R 25244, H 56604, ca. 95 m a. s. l.

The subdivision of Quaternary terrestric sediment stacks by paleosoils works best in loess deposits. However, individual soils normally cannot be identified by inherent characteristics. An undebatable assignment of loess strata and interglacial soils to a certain glacial resp. interglacial period is difficult because of the following items:

1. Erosional unconformities within the loess units prevent dating by counting the soils and loesses downwards from the surface.
2. The interglacial nature of a soil, especially the luvisol, is often in dispute, especially when the soil is partly eroded.
3. Luvisols may occur as twin soils bound to one interglacial period. They have been described already by KUKLA (1961) from the Czech Republic, from the Rheinland by SCHIRMER (1974). Twin luvisols are running nearly parallel for distances of kilometers indicating that there was no major morphodynamic change of the landscape between them, but small increment of loess. Namely, molding of the landscape by erosional and depositional processes is one of the typical characteristics of a glacial period in the periglacial area. In small exposures the nature of twin soils may hardly be identified because of their similarity to single soils.

The brickyard pit Erkelenz exposes two sets of twin luvisols (Fig. 70). The Niers twin soils are horizontally topping the basal fluvial gravel. The Erft twin soils (SCHIRMER 1992), 10–11 m above, are smoothly dipping through the loess pile from south to north. Additionally, at the northern wall a single, younger luvisol is exposed. By counting from the top this soil has to be assigned at least to the last interglacial, the Erft twin luvisols at least to the penultimate interglacial, the Niers twin soils at least to the antepenultimate interglacial period. The same soil configuration occured in the brown coal open cast Frimmersdorf West, now excavated. There, the lower twin soils could be traced over a distance of 1.5 km, the Erft twin soils over 500 m (SCHIRMER 1974: 36).

The upper three luvisols are each capped by a small, light loess bed of eluvial character (A_l, S_w in Fig. 70), followed by a humic zone of early glacial habitus. The three loess units II–IV between the interglacial soils exhibit plenty of gelic gleysols (Nassböden = N). Units II and III are each subdivided by seven of them. Unit IV (Upper Würmian) exposes four of them, one below the black Eltville tephra and three above it. Their different character, that of a gleysol (NG) or that of a stagnic gleysol (NS), is useful for identifying a distinct individual

(SCHIRMER 1990). Some of them are tracable over hundreds of kilometers, as the tailed humic soil (A_hN_G) above the tephra. Moreover, this soil marks the first fossil surface running nearly parallel to the recent surface, unconformably cutting the older landforms. Other gelic gleysols are more local, sometimes even wedging out within the pit. Thus, gelic gleysols are of various stratigraphical value.

KUKLA, J. (1961): Quaternary sedimentation cycle. – Instytut Geologiczny, **34**: 145–154; Warszawa.

SCHIRMER, W. (1974): Mid-Pleistocene gravel aggradations and their cover-loesses in the southern Lower Rhine Basin. – IGCP project 73/1/24: Quaternary glaciations in the northern hemisphere, report no. **1**: 34–42; Prague (INQUA).

— (1990): Lösse und Paläoböden in Erkelenz. – In: SCHIRMER, W. [ed.]: Rheingeschichte zwischen Mosel und Maas. deuqua-Führer, **1**: 144–147; Hannover (Deutsche Quartärvereinigung).

— (1992): Doppelbodenkomplexe in Erkelenz und Rheindahlen. – In: Arbeitskreis Paläopedologie: Bodenstratigraphie im Gebiet von Maas und Niederrhein: 86–94; Kiel (Dt. Bodenkdl. Ges.).

Stop 52: Clay pit Brüggen-Öbel

D – TM 25: sheet 4702 Elmpt,
R 2511, H 56795, 60 m a. s. l.

The area of Brüggen and Erkelenz is situated upon the horst of Brüggen-Erkelenz (NL: Peel horst) (Fig. 68). It is flanked on both sides by the central part of the Niederrhein graben (Figs. 68 and 71). In this position the Tertiary and Lower Pleistocene is outcropping close to the surface. On the other hand the continuous uplift of this area caused a depositional sequence full of hiatuses in contrast to the graben sequences that are known by drillings.

The section Brüggen-Öbel (Fig. 72) exhibits a sequence of sands and gravel with two clay beds in between. The lower clay bed (clay I + II) is palynologically Reuverium B (Upper Pliocene) (ZAGWIJN 1960). The optical bipartition of the clay (I: dark brown, II: bluegreen with peat) evidences the boundary between a stable heavy mineral spectrum (Upper Pliocene Kieseloolith formation) and a spectrum of less stable minerals as garnet, epidote and green hornblende, that marks the Lower Pleistocene along the Rhein (BOENIGK 1970: 36). This latter spectrum is due to the encroachment of the Rhein upon the molasse deposits of the Alpine foreland (BOENIGK 1982: 174). The overlying gravel of a mixed Rhein-Maas pebble composition is not the earliest Pleistocene deposit according to Fig. 71. The following upper clay bed (clay V or van Eyck interglacial) is pollen-analytically of Tiglian C 3–4 age (ZAGWIJN 1963: 56) resp. Tiglian C 5–6 (URBAN 1979: 158). According to its heavy mineral content, it should be younger (BOENIGK (1970: 116).

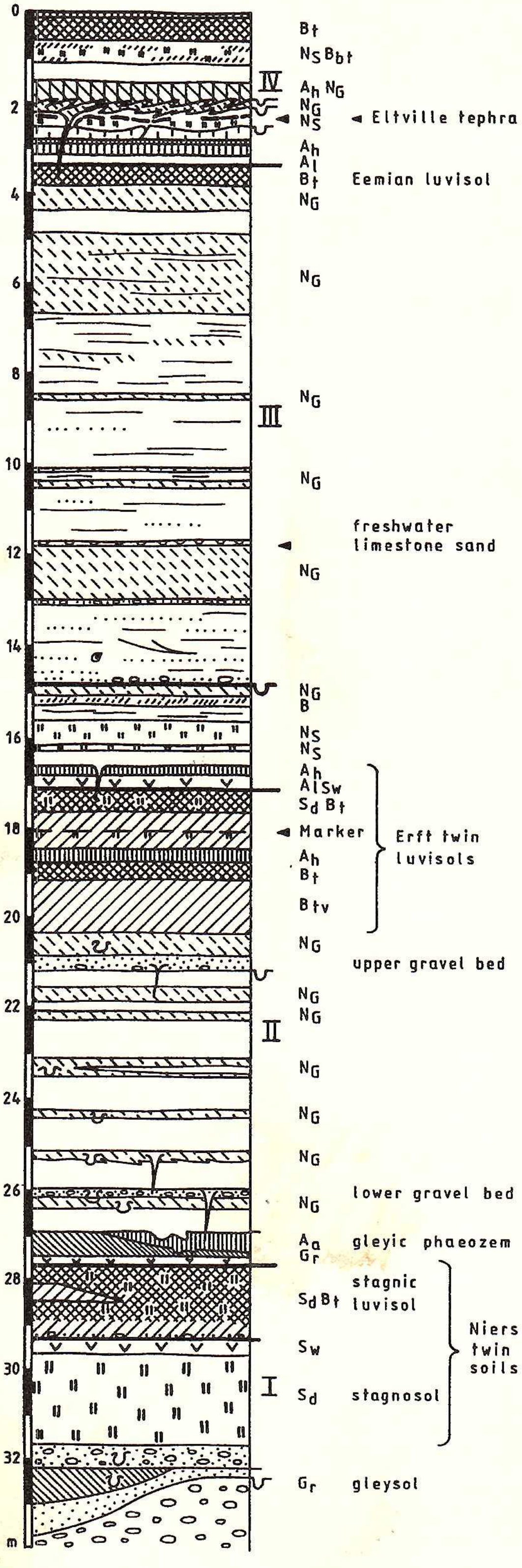


Fig. 70 Schematic section of the brickyard pit Erkelenz

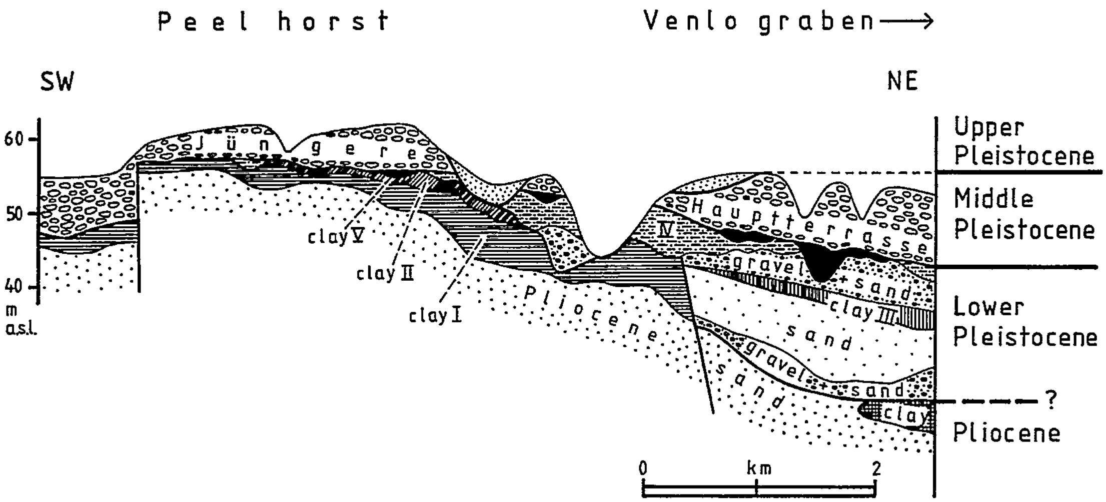


Fig. 71 Cross section of the Peel horst close to Brüggen (modified from BOENIGK 1970: 141)

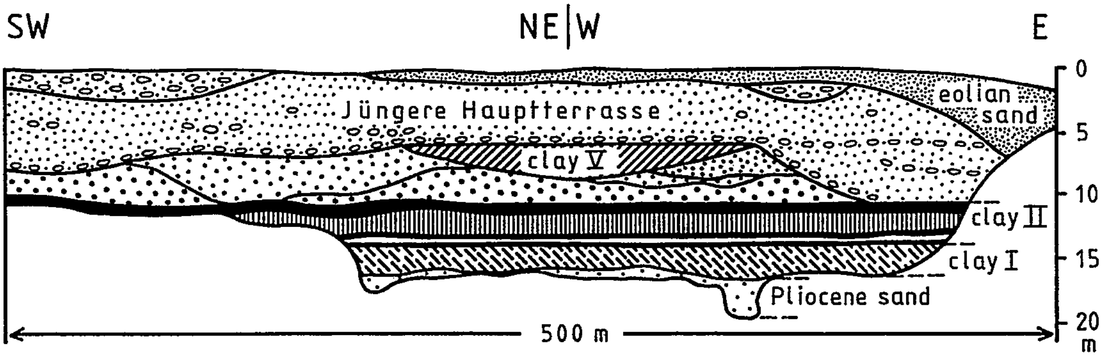


Fig. 72 Section of the clay pit Brüggen-Öbel (BOENIGK 1970: 35, modified)

BOENIGK, W. (1970): Zur Kenntnis des Altquartärs bei Brüggen (westlicher Niederrhein). – Sonderveröff. Geol. Inst. Univ. Köln, **17**: 138 S., 3 Taf.; Köln.

— (1982): Der Einfluß des Rheingraben-Systems auf die Flußgeschichte des Rheins. – Z. Geomorph. N. F., Suppl.-Bd. **42**: 167–175; Berlin, Stuttgart.

URBAN, B. (1979): Bio- und Magneto-Stratigraphie plio/pleistozäner Ablagerungen in der Niederrheinischen Bucht. – Acta Geol. Acad. Scient. Hungaricae, **22**: 153–160.

ZAGWIJN, W. H. (1960): Aspects of the Pliocene and Early Pleistocene vegetation in the Netherlands. – Med. Geol. Sticht., Ser. C-III-1 (5): 78 p.; Maastricht.

— (1963): Pollen-analytic investigation in the Tiglian of the Netherlands. – Med. Geol. Sticht., N. S. **16**: 49–71, pl. 2–3, encl. 4–6; Maastricht.

Stop 53: Schaephuysen Ridge

D – TM 25: sheet 4504 Kerken,
R 253276, H 570115, 73 m a. s. l.

The Rhein is the only river that touches both the Alpine and the Northern glaciation area (Fig. 7). Nevertheless, up to now it did not succeed to correlate the Alpine with the Northern glaciation by way of its river terraces.

The Schaephuysen Ridge is a 12 km long push-moraine ridge belonging to a long chain of push moraines ranging along the Rhein valley and being attributed to the Saalian glaciation (Fig. 73). When the Northern continental ice sheet reached the Rhein valley from the northeast, it scooped out the less frozen valley fill molding it to a frontal push moraine (Fig. 74). Consequently the interior of the push moraine consists of dislocated soft bedrock – fluvial deposits and even Tertiary marine sands – covered by scattered erratics.

In its western foreland a sandur dips towards the flat Aldekerk plate which is a Rhein terrace (Krefeld Terrace) of at least the penultimate glaciation period: The gravel of this terrace exhibits a full fluviatile series consisting of gravel, flood deposits and topping interglacial soil, the whole mantled by Würmian solifluctional loess of 1 m average thickness (SCHIRMER 1990: 156). As these terrace deposit cuts the joining sandur, a correla-

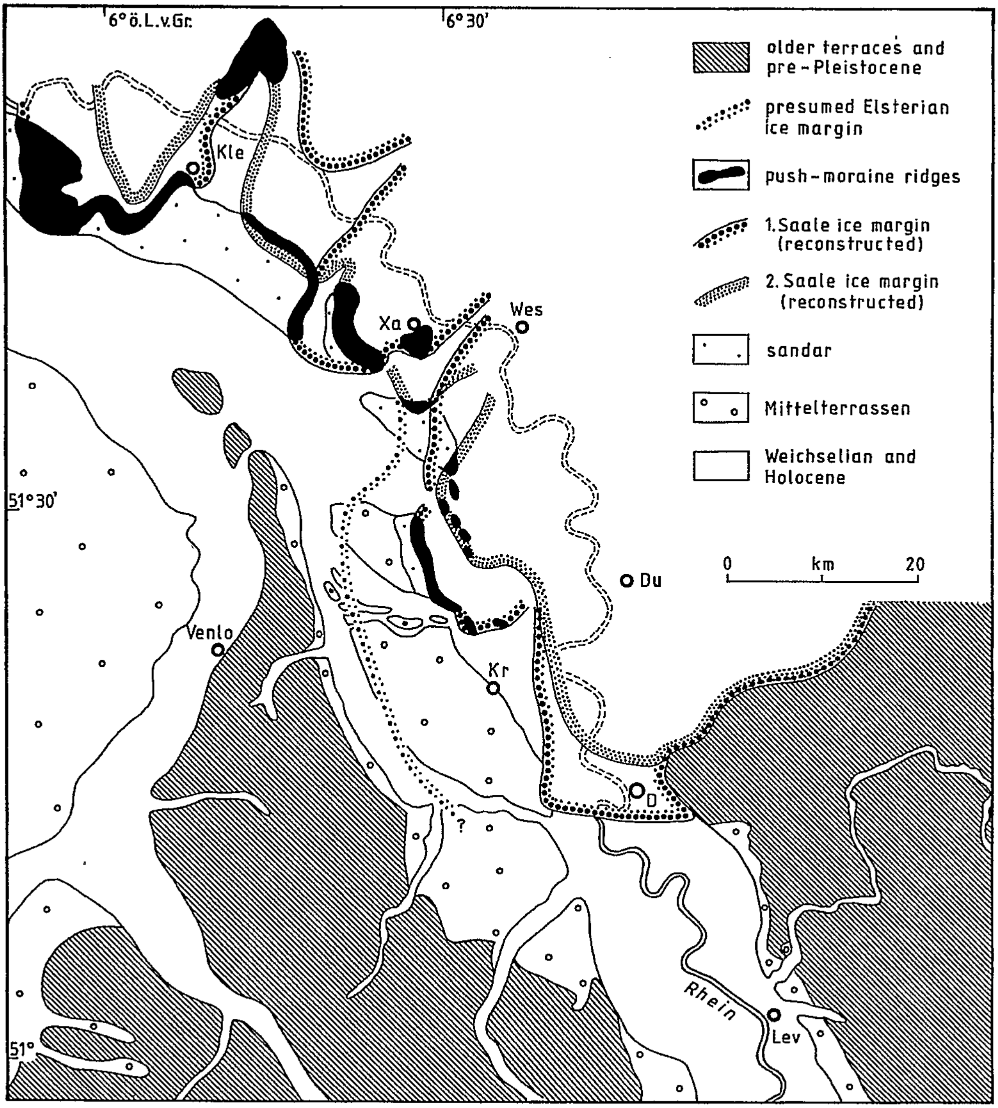


Fig. 73 Northern continental ice on the Niederrhein (compiled from figures of KLOSTERMANN 1985)

tion of this Krefeld Terrace with the ice-pushed ridge is not possible. A possible context of both is given in Fig. 74.

Considering the configuration in Fig. 74, it remains open whether the Saalian glaciation with the push moraines happened during the second or the third glacial period before today.

Moreover, it is still controversial whether the continental ice reached the Rhein during one, two or three glaciation periods (compilation in SCHIRMER 1990: 153). Prior to the conspicuous remnants of the Saalian glaciation, on the base of indefinite traces older glaciations are suggested, which are attributed to the Elsterian glaciation (Fig. 73) and the new proposed Angerian glaciation (THOME 1990: 297, 291).

KLOSTERMANN, J. (1985): Versuch einer Neugliederung des späten Elster- und des Saale-Glazials der Niederrheinischen Bucht. – Geol. Jb., **A 83**: 3–46; Hannover.

LANSER, K.-P. (1983): Die Krefelder Terrasse und ihr Liegendes im Bereich Krefeld. – Inaug.-Diss. Univ. Köln, 241 p.; Köln.

SCHIRMER, W. (1990): Stauchmoränen der Aldekerker Platte. – In: SCHIRMER, W. [ed.]: Rheingeschichte zwischen Mosel und Maas. deuqua-Führer, **1**: 153–164; Hannover (Deutsche Quartärvereinigung).

THOME, K. N. (1990): Inlandeisvorstösse in das Ruhrgebiet (nebst der Entwicklung einer spätglazialen Rheinrinne). – In: SCHIRMER, W. [ed.]: Rheingeschichte zwischen Mosel und Maas. – deuqua-Führer, **1**: 273–292; Hannover.

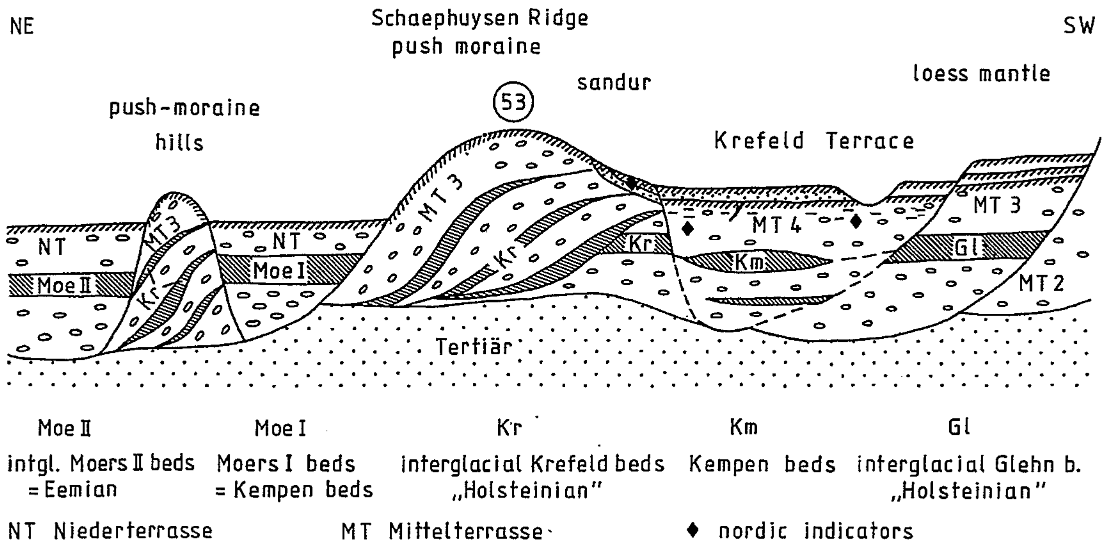


Fig. 74 Cross-section through the terminal moraine and its setting at the Niederrhein (combined from Lanser 1983: 120 and Schirmer 1990: 153). The climatic role of the Kempen beds is unknown

The Maas valley
(M. W. van den Berg)

Stop 54: Panheel – Late Pleniglacial

NL – TM 50: sheet 58 West,
R 189.00, H 355.00, 25 m a. s. l.

Cold-climate (26–12 kyr BP) overbank sequences of the river Maas, The Netherlands, matching the global climatic record Late Pleniglacial (26,000–12,000 yr BP, stage 2) overbank deposits in the Lower Maas basin in the SE Netherlands show a stacked series of 9 sequences of about 1 m thick each. Generally they consist of fine-sandy fluvial overbank deposits at the bottom, with increasing amounts of (wet) aeolian sandy intercalations towards the top, one consists of a sandy loam. The sequence boundaries are formed by sharp breaks in the grainsize and cryogenetic macrostructured marker-horizons and, in the top half of the section, by 'interstadial' soils.

In our interpretation, each sequence records a cycle of diminishing river activity, increasing eolian action and a gradual shift to a period of maximum coldness (ice-wedge casts). The maximum rate of environmental change occurs around the sequence boundaries where the structural deformation indicates thawing of permafrost. This sudden return to milder conditions is followed by flooding. The interstadial soils represent relative climatic optima. The changing sedimentary environments within the sequences and the punctuated and discreteness of the sequence boundaries favour an allocyclical, climatically driven origin. Tectonic subsidence is slower than foodplain aggradation, precluding an autocyclical origin.

Each sequence may represent the record of a minor climatic cycle, expressed in terms of discharge (Q+/-) and temperature (T+/-) (Fig. 75). The available time-controls suggest an average cycle duration of 1,600 years. Similar frequencies have been noted in the position of the front of the Laurentide ice-sheet in the temperature fluctuations and in the global dust record (Fig. 76).

Stop 55: Bosscherheide – Late Glacial

NL – TM 50: sheet 52 Oost,
R 204.00, H 399.00, 20 m a. s. l.

'The sandpit at Bosscherheide, on the east bank of the Maas (= Meuse), provides a detailed record of Late Weichselian palaeoenvironmental changes. The periglacial fluvial, and aeolian processes recorded in its sediments have been studied by means of pollen, macrobotanical and thin section analyses, sedimentological observations and radiocarbon datings. The data reveal a series of processes involving rapid environmental changes, which determined the termination of the Bølling–Allerød interstadial complex. At the transition from Allerød to Late Dryas, ca. 10,800 BP, large-scale floodings and deposition of suspension load took place. Prior to these floodings, a short period with (incipient) permafrost occurred. The aeolian sedimentation, leading to the formation of para-

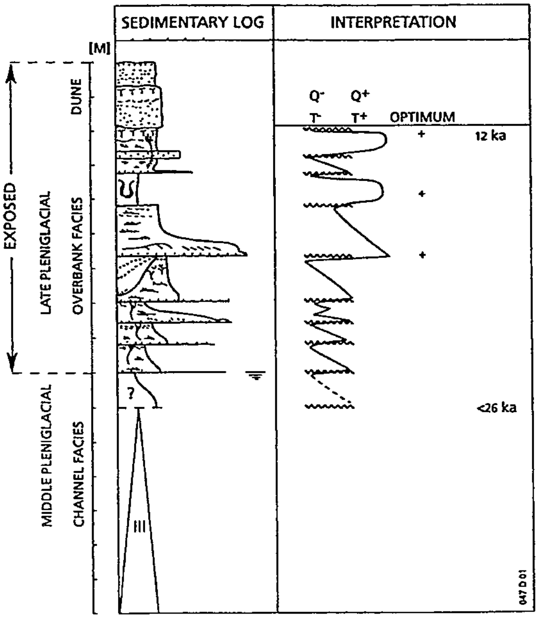


Fig. 75 Sedimentary log and grainsize variations of metre-scale fluviatile overbank sequences, exposed along the river Maas. Each sequence is composed of a number of flooding events, the sequence boundaries are interpreted to mark shifts from cold and low-discharge conditions to 'warm' conditions with reactivated fluvial activity. ^{14}C age-control is indicated

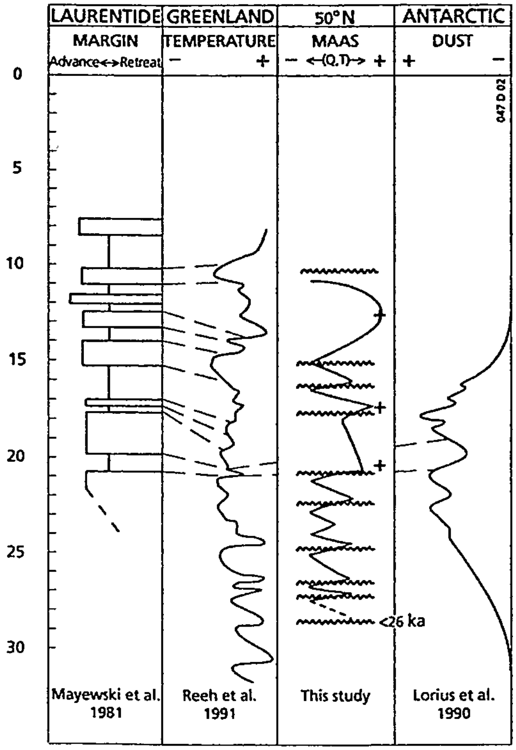


Fig. 76 Tentative correlation of Maas river overbank sequences with Arctic and Antarctic climatic-proxy data

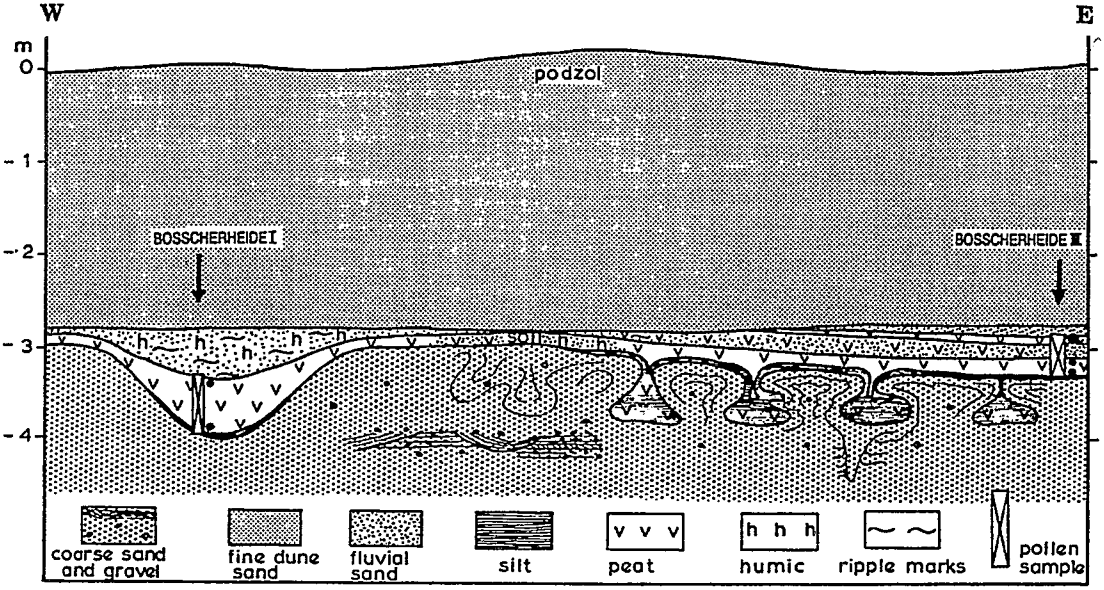


Fig. 77 Schematic profile of the exposures at Bosscherheide showing the location of the pollen samples. The black dots refer to the radiocarbon-dated levels: Bosscherheide I, top GrN 13379, 10940 ± 60, bottom GrN 13382, 12110 ± 70; Bosscherheide III: from top to bottom GrN 11568, 10500 ± 60; GrN 11569, 10880 ± 50 and GrN 12165, 11500 ± 50 BP (BOHNCKE et al. 1993: 195)

bolic dunes, took place mainly between 10,500 and 10,150 BP' (BOHNCKE et al. 1993: 193) (Fig. 77).

The gravelly sands underlying the Late-Glacial silts and peats are of river Maas origin. They are shallowly (a couple of meters) underlain by Maas/Rhein terrace-deposits of Late Saalian (deep sea stage 6) age. This superposition indicates a river-terrace intersection near the hinge-line of the North Sea basin.

BOHNCKE, S., VANDENBERGHE, J. & HUIJZER, A. S. (1993): Periglacial environments during the Weichselian Late Glacial in the Maas valley, the Netherlands. – Geol. Mijnbouw, 72: 193–210.

The Rijn-Maas delta in The Netherlands during the Holocene

(H. J. A. BERENDSEN)

The Holocene Rijn-Maas delta probably is the most extensively studied delta in the world. A database of 200,000 lithological borehole-descriptions, and about 300 ^{14}C dates, present at Utrecht University offers a unique opportunity to investigate lithological characteristics of various fluvial styles, both in space and time. At present 25 % of the data is available in a digital form.

The Weichselian subsurface in The Netherlands' Rijn-Maas delta consists of two terrace levels formed by braided rivers, that are now covered with Holocene deposits. The higher level has been named the 'Laagterras' (Low Terrace or 'Niederterrasse' in German). The approximately 1.5 m lower (younger) level is of Late Glacial age. The older terrace became covered with clay in the Bølling-Allerød interstadial, while the younger terrace is covered with Holocene clay.

During the Early Holocene rivers were incising, meandering streams, and no deposition occurred on the Pleistocene surface. From the early Atlantic onwards aggradation prevailed and the deep early Holocene river channels were gradually filled up. Further accumulation by meandering streams was induced by the rise of sea-level, which forced gradients of the rivers to decrease. New river channels formed through avulsion.

In the central-western part of The Netherlands anastomosing rivers could develop between approximately 6,000 and 4,000 yr BP. Rapid sea-level rise and a thick cohesive subsoil are considered a prerequisite for anastomosis. Near the northern and southern margin of the delta laterally migrating meandering rivers continued to exist, apparently as a result of the easily erodible, sandy Pleistocene subsoil. The anastomosing river system is characterized by stable channels filled with fine sand, intercalated in a peaty matrix, low gradients, low sinuosity, a high sedimentation rate, low width/depth ratios, and lithologically very complex crevasse splays. After 4,000 yr BP the anastomosing river channel system changed again to meandering as a result of the decreased rate of sea-level rise.

Stop 56: Heerewaarden

NL – TM 50: sheet 45 West,
R 154.75, H 425.00, 5–6 m a. s. l.

Observation: The former confluence of the Waal and Maas rivers near Heerewaarden.

Geological situation: The most recent fluvial sediments along the major rivers in The Netherlands make up the Holocene Betuwe Formation, that was essentially formed by meandering rivers. Sediments consist of channel deposits (sand, sometimes with gravel), natural levée deposits (silty and sandy clays), flood basin deposits (clay and peat), and dike breach deposits (sandy clay or sand).

Geomorphological history: Since water levels in the Waal were usually about two meters higher than those of the Maas, the Waal lost water to the Maas. However, the total Maas output had to flow back into the Waal river at the confluence further downstream. This caused continuing water-control problems in the nearby Bommelerwaard polder which suffered numerous dike breaches. Originally, three natural connections existed between the two rivers at the confluence near Heerewaarden. In 1904, a new course was dug for the Maas output (the Bergsche Maas) and a dam was constructed to separate the Maas from the Waal. These constructions effectively solved the water problems in the Bommelerwaard.

Stop 57: Noordeloos (Alblasserwaard polder)

NL – TM 50: sheet 38 Oost,
R 126.10, H 435.55, -1 m a. s. l.

The landscape: Anastomosing river deposits locally show up as small-scale ridges. The ridges are less than 1 m high and less than 100 m wide.

Cores will be shown of channel deposits of one of the anastomosing river systems (suction corer), flood basin deposits (auger and gauge) and crevasse-splay deposits. The coring equipment will be demonstrated.

Geological situation: The Middle-Holocene

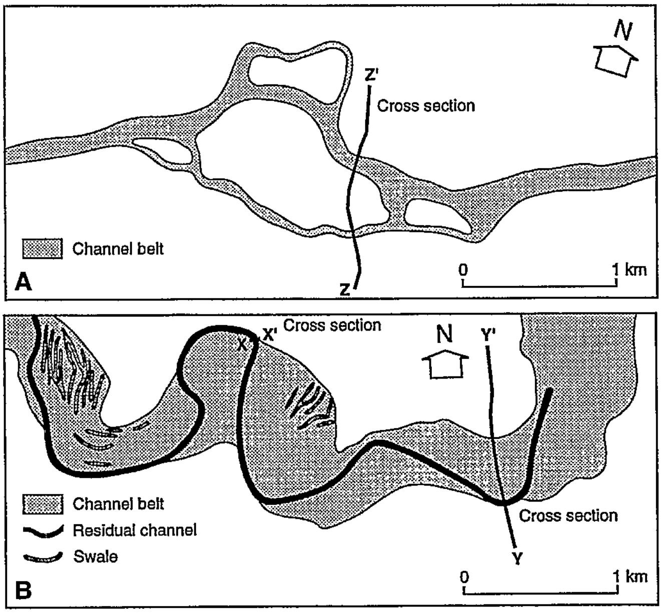


Fig. 78 A: Channel belt planform of an anastomosing fluvial system in the delta: the Schoonrewoerd system (TÖRNQVIST 1993)
B: Channel belt planform of a meandering fluvial system in the delta: the Stuivenberg system (BERENDSEN 1982)

anastomosing distributary system of the Rijn-Maas delta has developed during the Atlantic period (7,000–4,000 yr BP) in the perimarine part of the Westland Formation. Fig. 78 A gives an impression of an anastomosing river system in the Alblasserwaard polder: the Schoonrewoerd system (visited during the excursion). The area has been mapped with a borehole density of 60–100 boreholes/km². Crevasse density increases westward, while width/depth ratio of the channel belt decreases from 15 to less than 7.

Mechanisms for the development of anastomosing fluvial systems: A rapid sea-level rise induces a rapid ground-water rise and hence rapid vertical aggradation. This is a prerequisite for the development of anastomosing fluvial systems. A thick cohesive subsoil consisting of clay or peat inhibits lateral channel migration and enhances channel

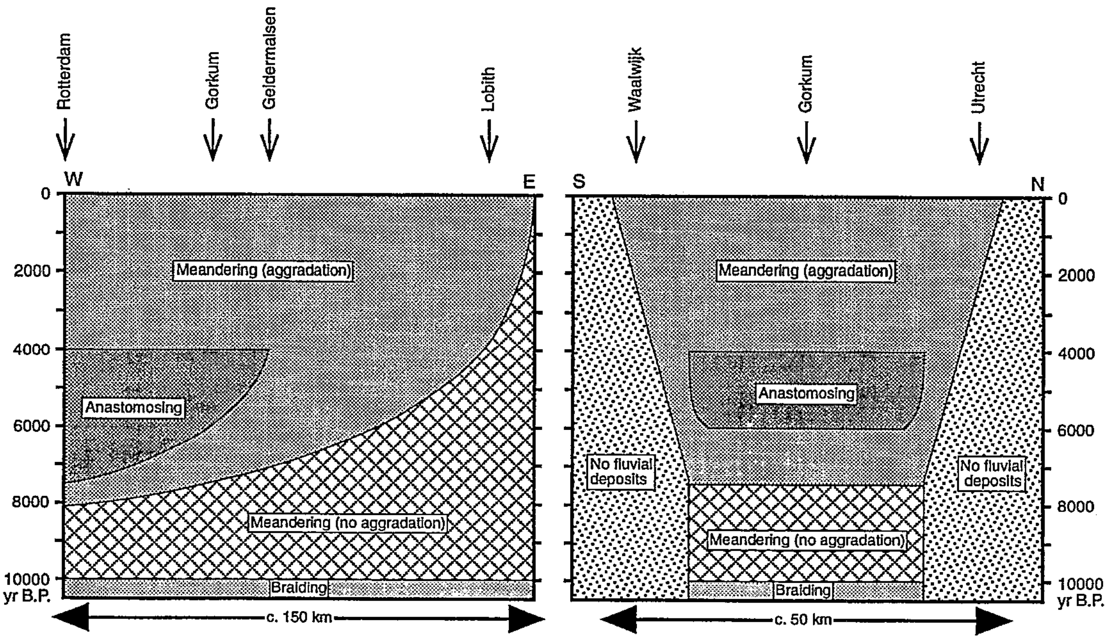


Fig. 79 Time-space model indicating the Holocene development of channel patterns in the Rijn-Maas delta (TÖRNQVIST 1993)

anastomosis. The requirements are an annual ground-water rise of over 1.5 mm, and an at least 3–4 m thick cohesive subsoil. These conditions were met in the central part of the delta, but not near the northern and southern margin were fine grained wind-blown sand occurs at shallow depth. The evolution of the Rijn-Maas delta during the Holocene may be seen as a reflection of climatic change at the Pleistocene-Holocene transition and relative sea-level rise, resulting in river patterns that varied both in time and space (Fig. 79).

Stop 58: Montfoort

NL – TM 50: sheet 38 Oost,
R 125.25, H 449.50, ca. 0 m a. s. l.

The landscape: pointbar and swale topography in the background, a clay/peat filled abandoned channel and a natural levee in the foreground can be observed.

Cores will be shown of all three elements.

Geological situation: At this location, the Holocene is about 5–6 m thick. It consists of alternating fluvial and organic deposits of the perimarine part of the Westland Formation. A 300 m wide, 6 m thick sand-filled meander belt is incised into the Pleistocene subsoil. The observed meandering river system is known as the Stuivenberg system (Fig. 78B). In the same area, the Lopiker system (Fig. 80) represents a transitional form between anastomosing and meandering. It only incidentally bifurcates, but its crevasse deposits resemble those of the anastomosing type.

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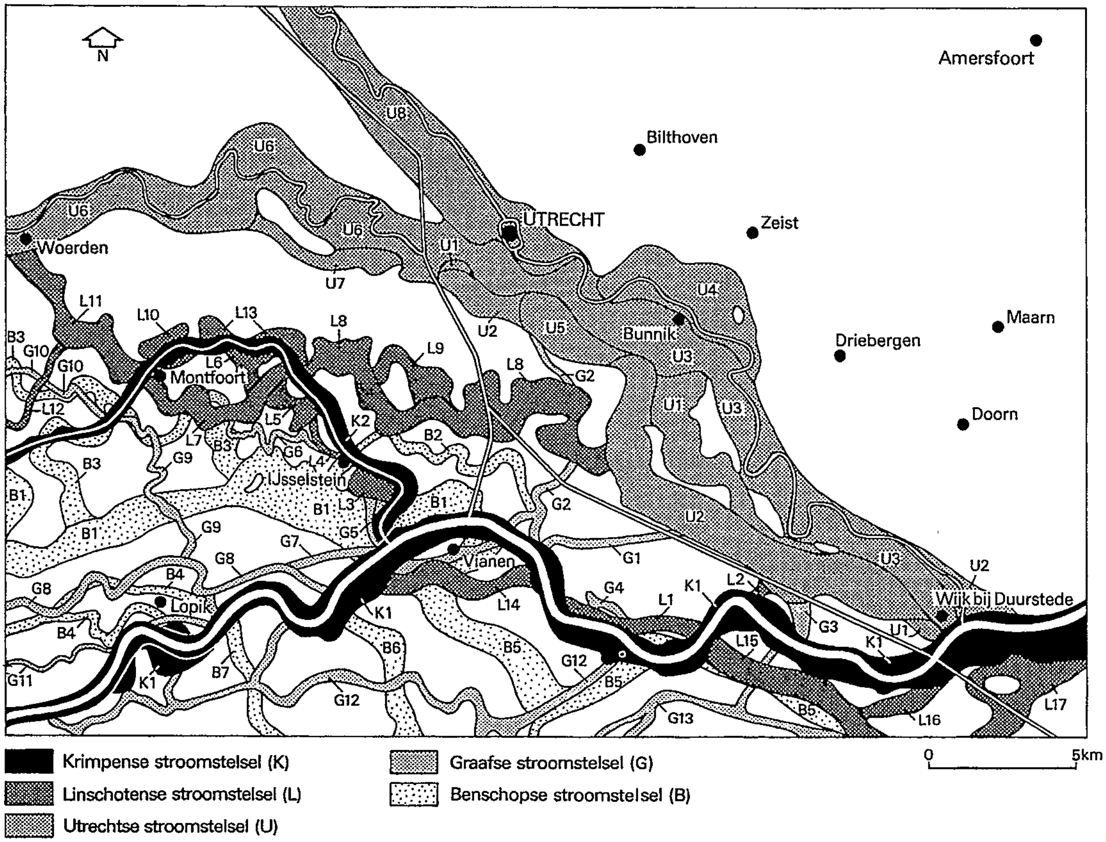
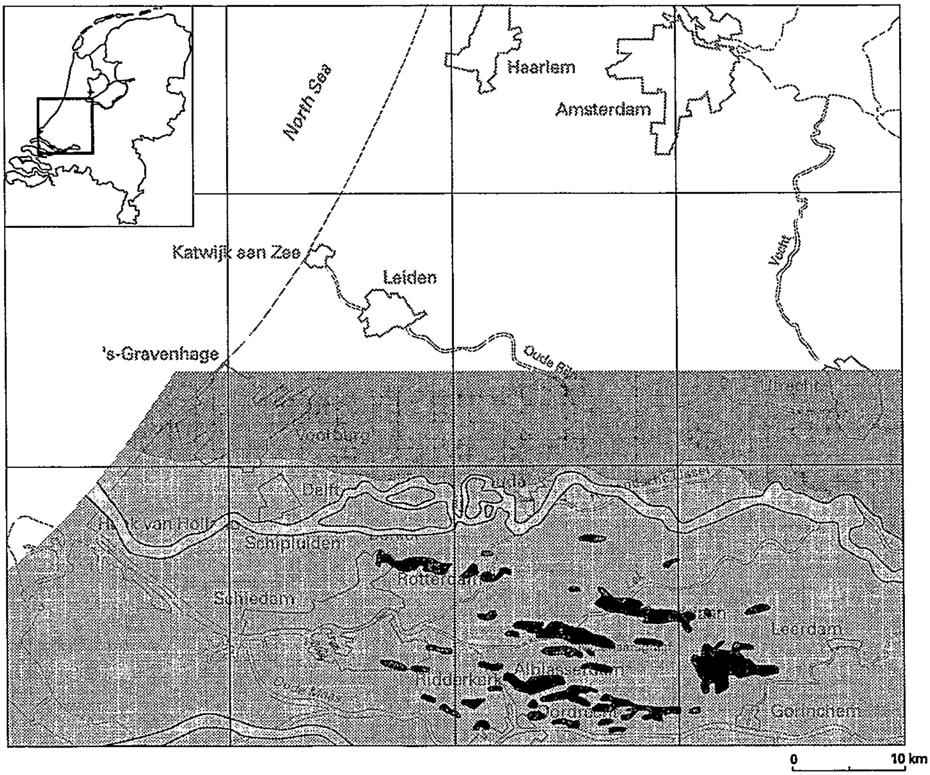


B3 Benschop river system	meandering	older than 5300 y B.P.
G8 Lopik river system	transitional	5000 - 4000 y B.P.
L7 Stuivenberg river system	meandering	4000- 3100 y B.P.
K2 Hollandse Ijssel	meandering	2000-800 y BP (dammed)

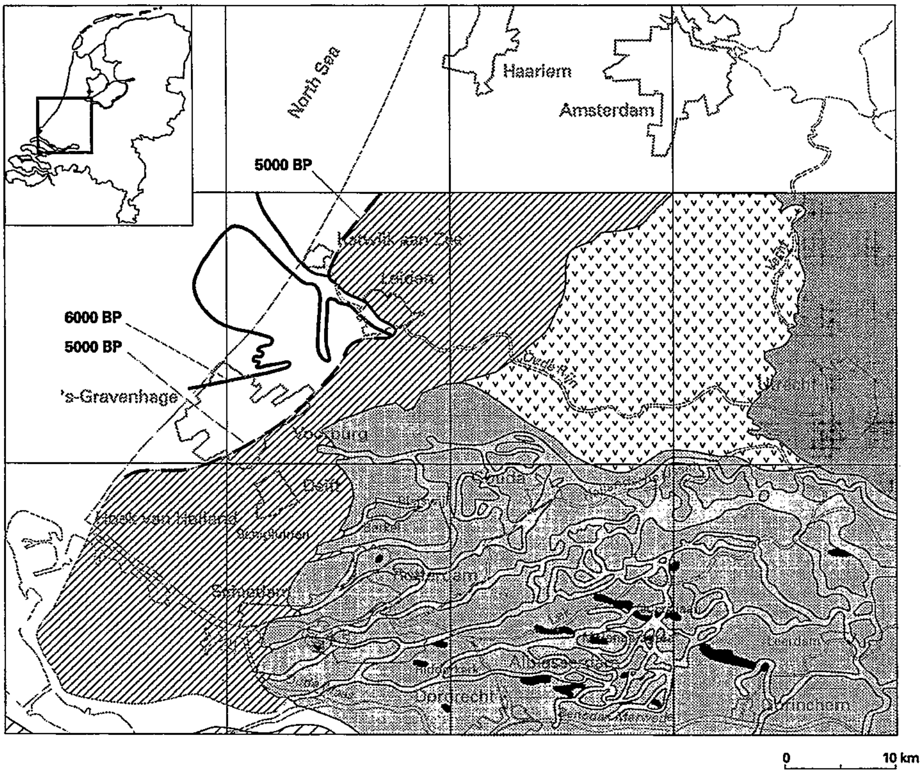
Fig. 80 River systems around Utrecht (BERENDSEN 1982)

c. 8500 - c. 6500 years BP



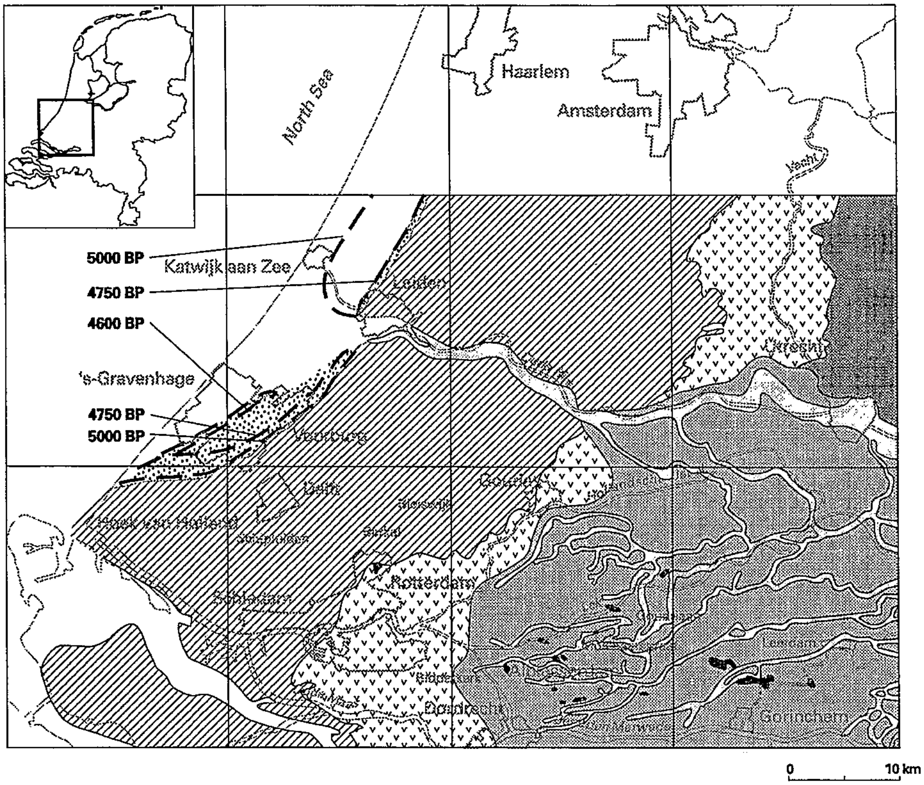
A

c. 6500 - c. 5000 years BP



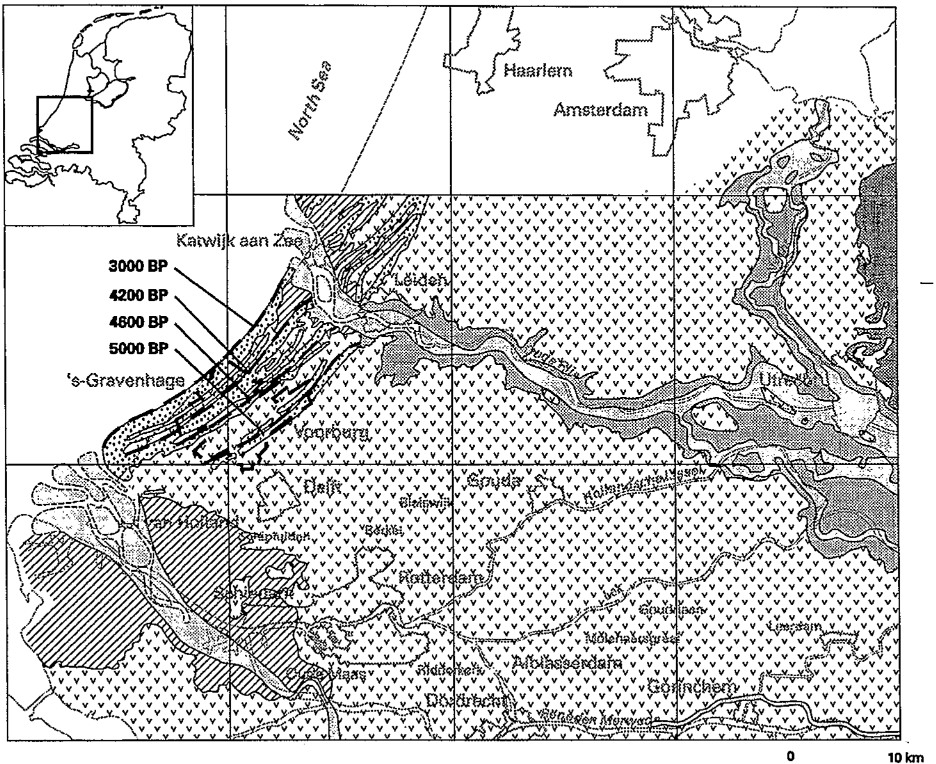
B

c. 5000 - c. 4600 years BP



C

c. 4600 - c. 2500 years BP



D

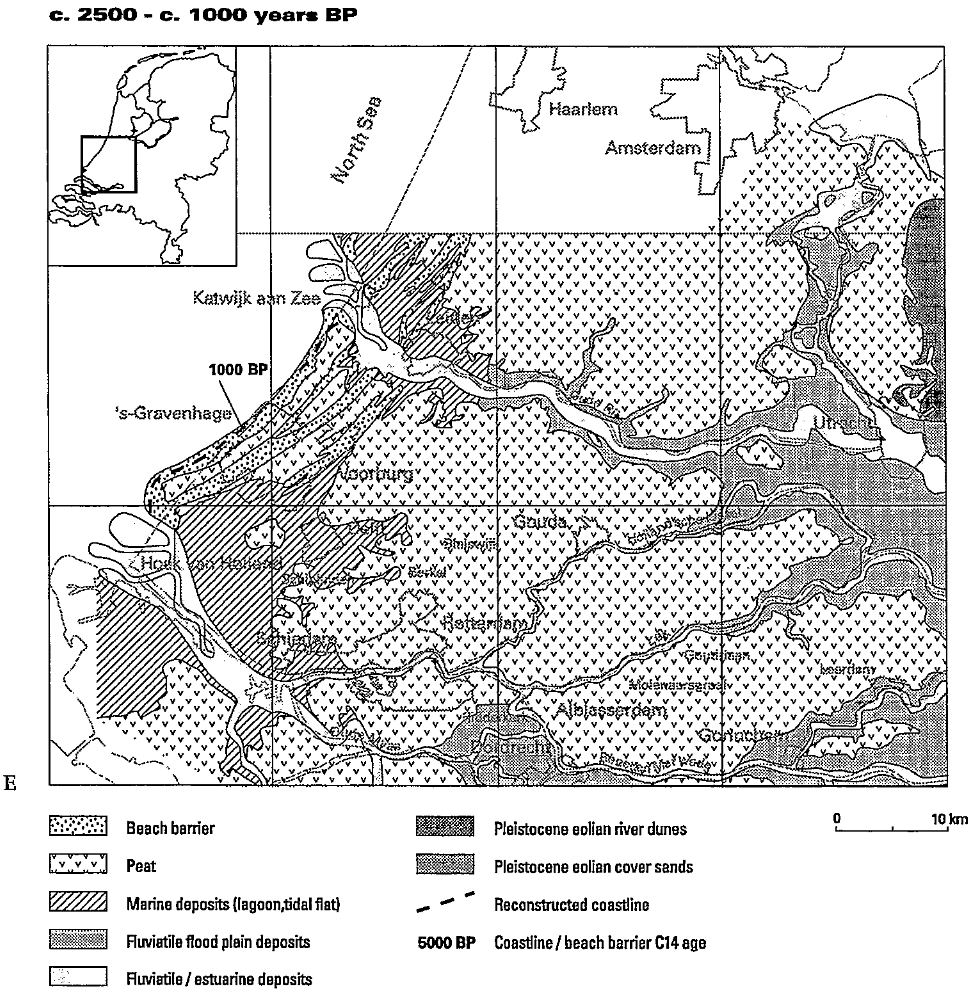


Fig. 81A-E Palaeogeographical development of the Lower Rijn system since the Late Glacial. (DE GROOT & DE GANS in press)

The lower Rijn delta
(W. DE GANS & T. DE GROOT)

The western part of The Netherlands is composed of a low-relief coastal plain with a width varying between 20–100 kilometers. Where Rijn and Maas flowed through this plain during the Holocene, a so-called perimarine area is located were fluvial sedimentation was influenced by sea level rise and marine deposition. As groundwater level in the coastal plain is high, exposures are rare. For mapping and research purposes data are obtained by means of (hand) drilling equipment.

From the mapping activities of the Geological Survey in the coastal zone it has become apparent that the Lower Rijn system evolved from:

- a braided system (until the early Late Glacial),
- an entrenched meandering system (about 11,000–8,500 yr BP),
- an aggradational meandering system (about 8,500–6,500 yr BP),
- an anastomosing system (about 6,500–5,000 yr BP),
- a new meandering system (about 5,000–2,500 yr BP) situated north of the preceding systems with the main branches Oude Rijn and Vecht and finally
- an anabranching system (about 2,500 yr BP to the present time), with many diversing channels.

The facies evolution of the system, starting about 7,000 yr BP, was related to the sea level rise and coastal development. The transformation around

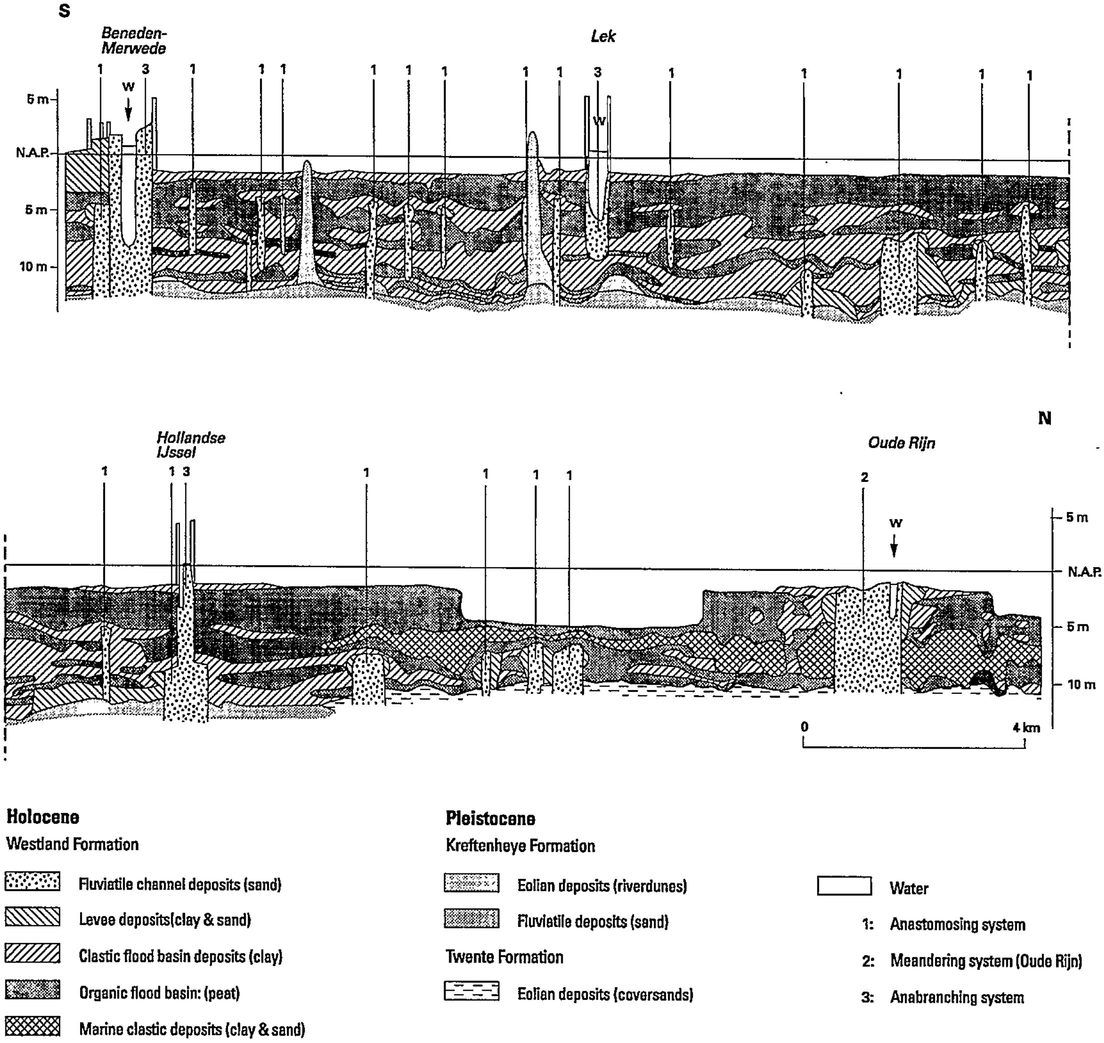


Fig. 82 Section showing the complex character of the perimarine deposits (DE GROOT & DE GANS in press)

5,000 yr BP from a retrograding 'open' tide-dominated coast to a prograding 'closed' and wave dominated coast with coastal barriers, and back again to a retrograding coastline from the Roman period on, was of major influence on the Rijn-Maas system.

The processes of facies changes of the lower Rijn system since the Late Glacial period and its relation to sea level rise and coastal development are shown in Fig. 81. The complex lithology of the perimarine area is demonstrated by Fig. 82.

Stop 59: Oude Leede. (Pleistocene and early Holocene fluvial systems)

NL – TM 50: sheet 37 oost,
R 89.1, H 443.8, -5 m a. s. l.

The Oude Leede section (Fig. 83) is located several kilometers west of Rotterdam. The section shows a Late Glacial/early Holocene backswamp/overbank clay bed from the Rijn-Maas system (at 16–18 m below NAP = Amsterdam ordinance datum) overlying Pleistocene Rijn deposits (Kreftenheye Formation).

The Pleistocene Rijn deposits are (with the exception of the overbank clay bed at the top) composed of sands. In the section these sediments are present between 19–39 metres below NAP. This sequence is interbedded by a layer of sands con-

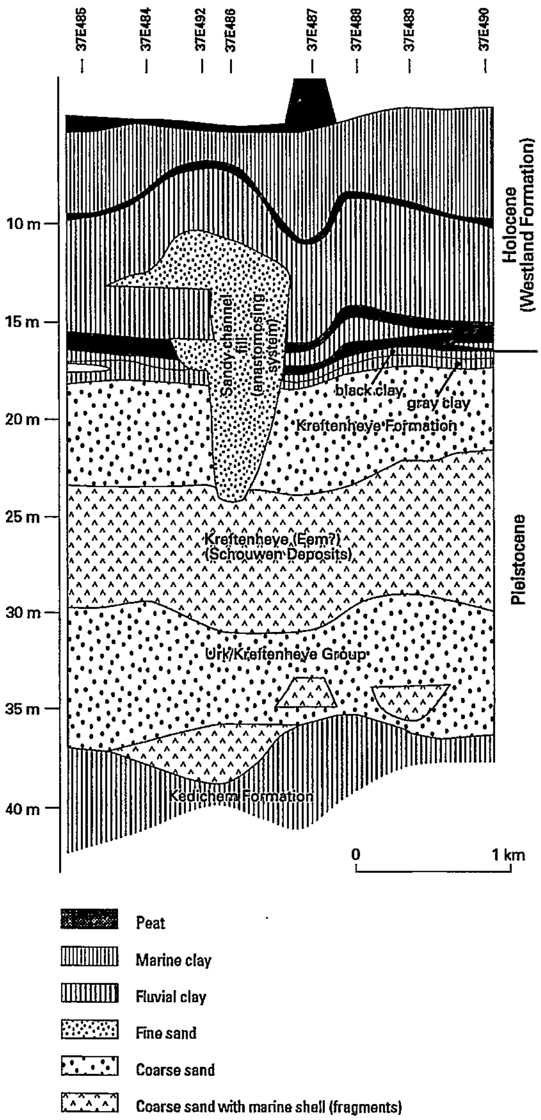


Fig. 83 Section Oude leede (explanation see text)

taining marine shells and shell fragments. This layer is generally interpreted as a marine deposit of late Eemian age on the bases of its malacological composition but now regarded as Weichselian fluvially reworked Eemian (see Stop 61).

A sandy channel fill is eroded into these Pleistocene Rijn deposits. The fluvial sedimentation in the channel was deposited in two periods. These two phases are also reflected in the surrounding fluvial overbank clay as it is intercalated by a peat bed. Deposition in the channel continued until a level of about 11 metres below NAP as the deposition in the channel was keeping pace with the rising sea level.

On the bases of the stratigraphic position the lower channel fill is correlated with the meandering phase of fluvial sedimentation in the Rijn system. The upper ('uplifted') channel fill is correlated with the anastomosed phase of fluvial sedimentation.

The fluvial system was covered by a marine/ lagoonal clay bed. The marine system is separated from the fluvial system by a thin peat bed. The undulating character of this peat bed is the result of differential compaction. On top of the lagoonal clay bed a peat bed was formed also, which, originally may have been over 6 meters in thickness. The peat layer at the surface has in general been excavated. The resulting lake has been reclaimed. As a result the landsurface is now situated at about 4–5 metres below NAP.

Stop 60: Storm-surge barrier in the Nieuwe Waterweg (Lower Rijn/Maas system)

NL – TM 50: sheet 37 west, R 71.0, H 442.0

The flood disaster of February 1. 1953, during which large parts of the south-western Netherlands were flooded, took the lives of over 1,500 people. Directly after the disaster, the Delta Project was started in order to strengthen the coastal defence line. At first it was decided that the Western Scheldt (entrance to the port of Antwerp) and the Nieuwe Waterweg (entrance to the port of Rotterdam) should remain open. However updated calculations in the early 1980s showed that the flood levels needed to be adjusted in order to meet the flood protection standards. Dikes would have to be stengthened even in the urban areas of Rotterdam, Dordrecht and Sliedrecht. In addition to the tremendous expenses involved, a great deal of demolition work would be necessary, to achieve the desired results.

As a concequence it was decided to build a storm surge barrier in the Nieuwe Waterweg (constructed in 1872 to make Rotterdam accessable by ship) just a few kilometres from the North Sea. This major project will be completed in 1996.

Stop 61: Hook of Holland (reworked Pleistocene marine deposits)

NL – TM 50: sheet 37 west, R 67.5, H 444.5

The 'Hook' of Holland is the present (man made) position of the Rijn-Maas outlet.

Underneath the Holocene coastal and marine sediments, Pleistocene Rijn deposits are found, predominantly composed of sands. Beds with marine shells and shell fragments (e. g. *Cerastoderme edule, Macoma baltica*) are intercalated between these fluvial deposits.

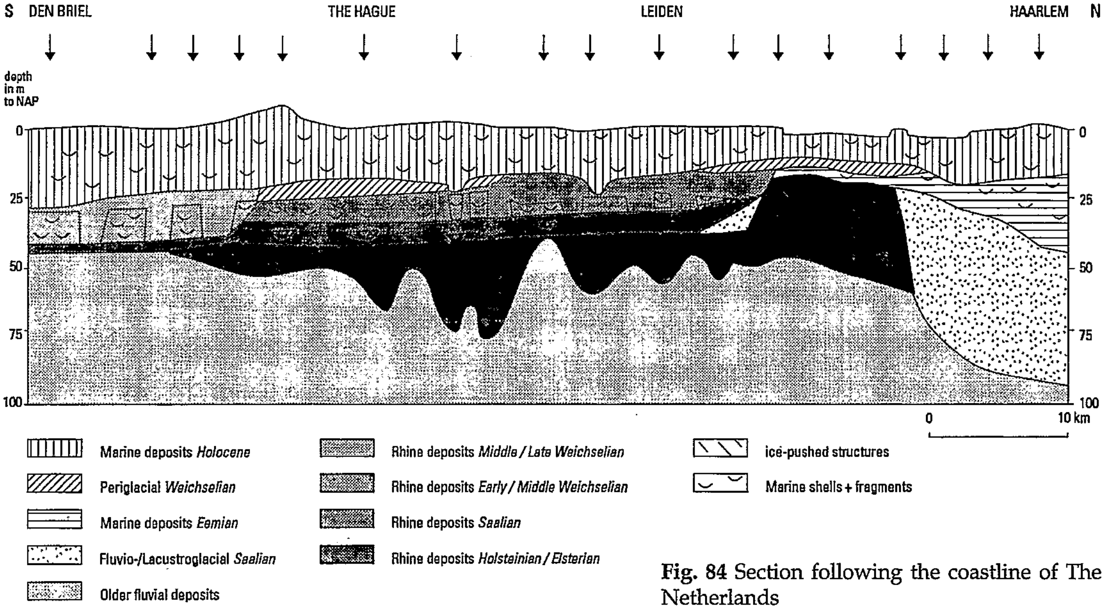


Fig. 84 Section following the coastline of The Netherlands

These beds of presumed marine origin were reworked by Rijn (and Maas) during glacial periods: the Eemian beds are fluvial reworked in the Weichselian; the Holsteinian beds during the Saalian etc. (Fig. 84). The large width of the Weichselian (and older) floodplains is tentatively explained as lateral shift of (braided?) channel systems due to thermal erosion under permafrost conditions.

Lacquer peels of the Pleistocene fluvial deposits with reworked marine shells (borehole Ockenburg) will be demonstrated.

Stop 62: Stompwijk windmills

NL – TM 50: sheet 30 oost,
R 88.6, H 455.0, -5 m a. s. l.

At Stompwijk, a row of 18th century windmills used in the reclaiming of the adjacent Driemans polder will be visited.

Stop 63: Katwijk (Oude Rijn system)

NL – TM 50: sheet 30 oost, R 87.5, H 469.7

The mouth of the so called Oude Rijn (Old Rhine) was located near Katwijk. This Rijn branch has been active between 5,000 yr BP and 1170 AD. The development of the Oude Rijn branch is depicted in Fig. 81.

It is assumed that between 5,000 and 4,600 yr BP a branch of the Rijn took a northern course and was connected with a tidal inlet. As a result an estuary was formed, which – during progradation of the coast – gradually evolved into a small delta before the Roman occupation of The Netherlands. From the Roman period on, erosion of coastline occurred and the delta was changed into an estuary again. Around 1170 AD the estuary of the Oude Rijn was silted up, followed by deposition of coastal dunes, which completely covered the outlet of the Rijn system. The present channel through the dune system was dug, after several failures, early this century.

Historically, the Oude Rijn was part of the Roman defence line (Limes). It is assumed that its westernmost fortification (Brittenburg) was situated on this delta, several kilometers from the contemporary Rijn outlet. The remnants of Brittenburg were last depicted in the 17th century (Fig. 85) when the remnants of this fortification were found on the beach near Katwijk. At present it is assumed that these remnants are situated as far as 500 meters off the beach.

Stop 64: Noordwijk (coastal system)

NL – TM 50: sheet 24 oost, R 92.9, H 479.8

The Holocene evolution of the coastal plain is largely controlled by the rate of sea-level rise on the one hand, and the supply of sediment on the other.

The mean rate of sea-level rise of over 60 cm/century prior to 6,000 yr BP, forced the coastal system, both barrier and back barrier basin, to shift rapidly eastward. The continous creation of accomodation space in the back barrier basin due to

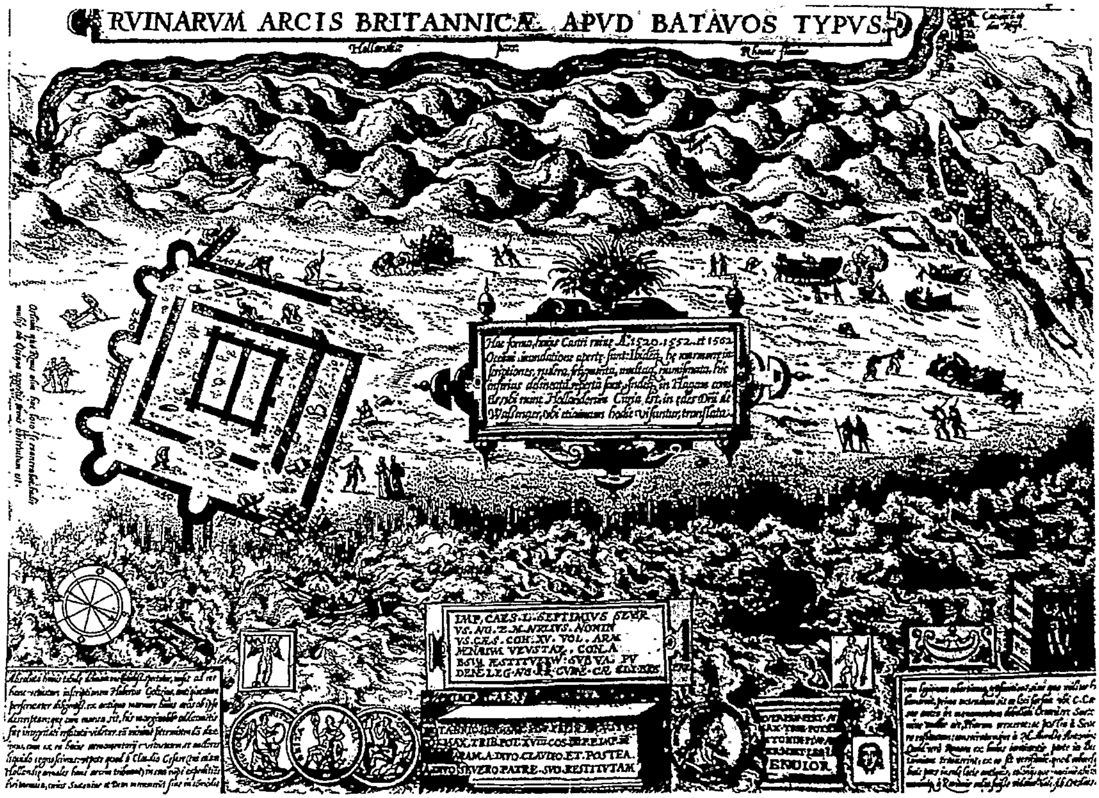


Fig. 85 Remnants of Brittenburg and the Oude Rijn branch near Katwijk (ABRAHAM ORTELIUS 1581)

sea-level rise outran sediment supply, with the result that in the distal parts of the tidal basin lagoonal conditions prevailed. Landwards these lagoons graded into reed swamps.

When sea-level rise decelerated to 15 dm/century between 5,000 and 3,000 yr BP, the balance between accomodation space and sediment supply reversed. As a result, the back barrier basins were filled and the tidal inlets closed. The barriers stabilized and, because of continuing sediment supply derived from adjacent headlands, ebb-tidal deltas and the relative shallow North Sea floor, the barrier of the coast of Holland prograded over a distance of 8–10 kilometers. It is estimated that only 10 % of the sand supplied to the coastal system came from the Rijn-Maas system.

As sea level rise continued, though at a lower rate, the back barrier basins changed into fresh water marshed with peat accumulation.

The prograded barrier sequence consists of

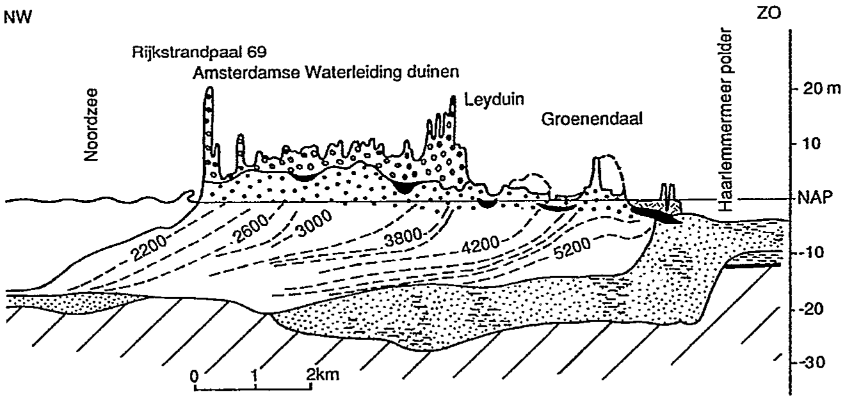


Fig. 86 Coastal section near Zandvoort with inferred ^{14}C time gradients (200 ^{14}C interval; not calibrated) of the Subboreal and Subatlantic beach barrier deposits (VAN DER VALK 1992)

barrier ridges and beach plains. In contrast to the ridges, beach plains lack or have very little aeolian sediments. The beach plains are broadests (up to 3 kilometers) and most common in the oldest part of the barrier sequence. Their origin is thought to be connected to the shallow bathymetry of the North Sea at the onset of progradation.

The western part of the barrier sequence is covered by dunes which are part of a much younger aeolian phase. These so-called Younger Dunes were formed after 900 AD. The cause of this aeolian phase is still little understood. Probably it is amongst others related to steepening and erosion of the shoreface (Fig. 86).

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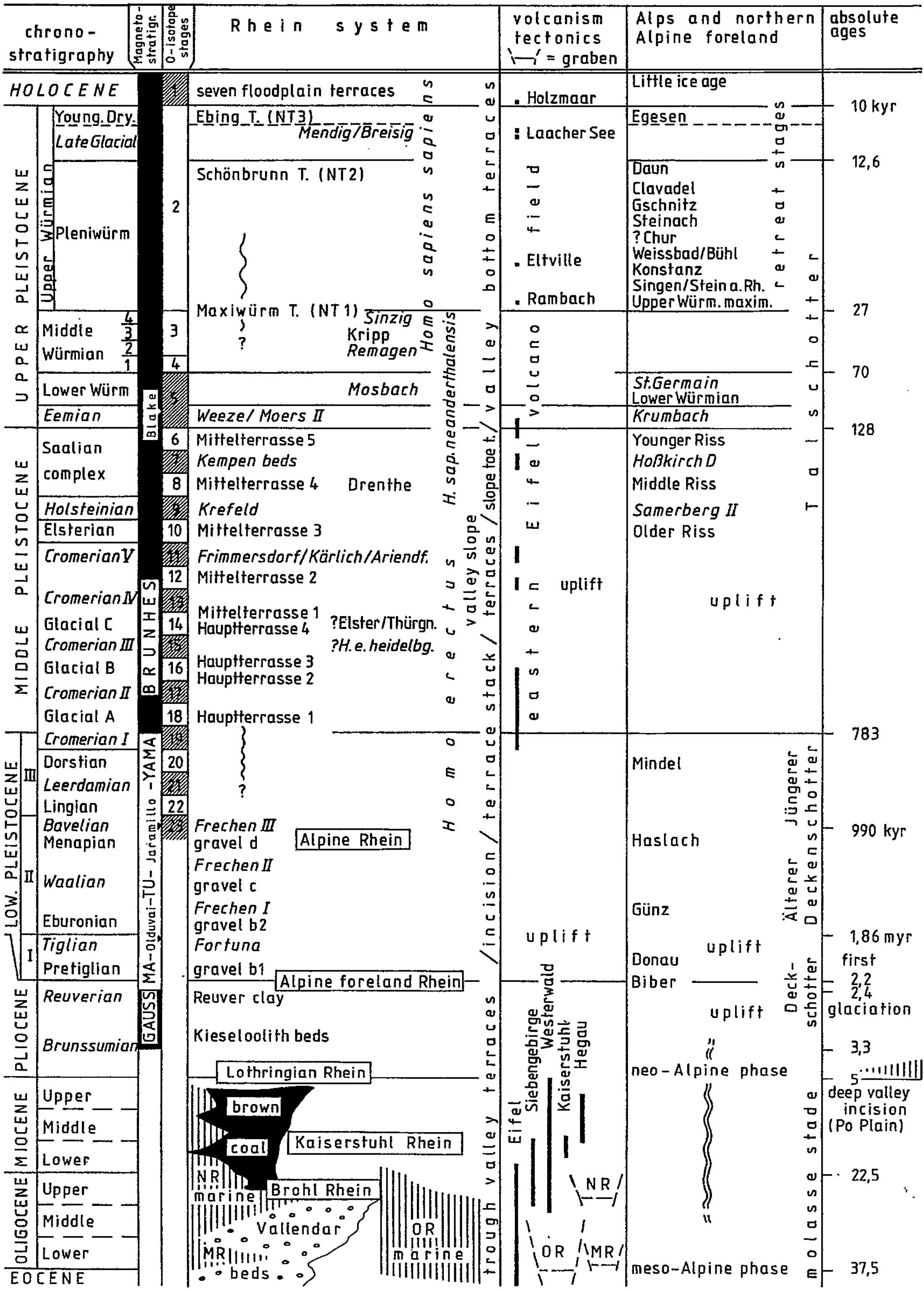

Fig. 87 Stratigraphy of the Rhein Traverse excursion area (OR = Oberrhein, MR = Mittelrhein, NR = Niederrhein)