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2. The Holocene of the Former Periglacial Areas

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1. River Deposits

Until now there have been no descriptive reviews of the Holocene development of river valleys in the Federal Republic of Germany. This is mainly due to the fact that the Holocene development of complete river systems has not yet been investigated. Remarkably thorough and diverse studies, however, have been carried out recently on the Holocene development of shorter valley sections of several rivers in the area concerned, which lies between the greatest extend of the Alpine and Northern glaciations: on the middle course of the River Lech between Schongau and Landsberg (BRUNNACKER 1959 *, DIEZ 1968 *), on the River Isar in the area of Freising-Landshut (BRUNNACKER 1959, VIDAL et al. 1966, HOFMANN 1973), on the Danube in the region of Ulm, on the Lower Iller and on the Blau (GROSCHOPF 1961 *, B. BECKER 1971), on the Upper Austrian Danube in the basins of Eferding and Linz (KOHL 1968 *)[2]), on the upper Main between Bamberg and Kulmbach (SCHIRMER 1973), on the River Lahn at Gießen (MÄCKEL 1969), on the Rur between Düren and Jülich (SCHALICH 1968), and on the Upper Leine in the area of Göttingen (SCHEFFER & MEYER 1965, ROHDENBURG 1965*, WILLERDING 1960).

Additionally, there exist a great number of detailed studies from many rivers, mainly concerned with the uppermost parts of Holocene valley aggradations above the groundwater table. Lack of space makes it impossible to report the present state of research by describing individual studies or river sections. So in order to provide a survey, an attempt has been made to sketch coherently the historical evolution of river valleys, according to the present state of research, and by quoting significant evidence.

1.1 General Distribution and Characterization

The former periglacial area between the Alpine and Northern glaciations roughly coincides with the distribution of the German *Mittelgebirge* (uplands). It contains the greater part of the Rhine river basin, the upper drainage area of the Weser, and both the northern drainage area of the Upper Danube, and that extending into the northern Alpine Foreland.

The river deposits of the valley floor, containing the present floodplain, are mainly called *"Niederterrassen"-Sedimente* (Low Terrace sediments). The term *"Niederterrasse"* is applied by some authors merely in a morphologic-descriptive sense, that is, for terraces of the valley floor. Others attach to this term a morphologic-stratigraphic meaning, that is, terraces as surfaces on sediments of the last glaciation (Würm). Sometimes *"Untere Niederterrassen"* (Lower Stages of the Low Terrace), *"Vorterrassen"*

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*) Major studies, containing older literature. — The topographical situation see fig. 1 p. 294.

1) Lecture given on the Symposium on "Palaeogeographical changes of valley floors in the Holocene" of the INQUA "Commission for the Study on the Holocene" in Poland, at Zegrzynek near Warsaw, on the 20th of September 1972.

2) We would like to include the impressive results from the Upper Austrian Danube, as there exists no comparable research on the adjacent Lower Bavarian Danube.

(Fore-Terraces), „*Austufen*“ (Floodplain steps), etc. are separated from the Low Terrace surface. These surfaces, which are cut into the Low Terrace, are partly recognized to be of Late-Glacial, partly of Holocene age. Predominately sandy-loamy floodplain sediments, more rarely some gravels were ascribed to the Holocene. Only recently was it recognized that, in the case of many river courses, the so-called Low Terrace fill contains a fair amount of gravel of Holocene age.

Information about the stratigraphic relationships between the Low Terrace sediments of the Würm glaciation and Holocene sediments is available only in the case of a few rivers. A highly generalized evaluation for the river areas of the *Mittelgebirge* is presented as follows:

The surface of the Holocene deposits is incised into the Würm surface. The base of the Holocene accumulation, having a thickness of several meters, lies, in most of the observed cases, at the level of the lower part of the Würm gravel fill.

In the upper courses of rivers the Holocene river bed frequently occupies the width of the Würm river bed. Consequently there usually remain only sparse relics of Würm terraces on the valley flanks. Within the Holocene valley aggradation, gravel deposits, which can be differentiated chronologically, lie side by side at approximately the same level. In most cases they are covered by young floodplain loam, so that it is difficult to establish a morphologic differentiation for the Holocene gravel accumulation.

Whilst the Würm aggradation widens downstream, the Holocene aggradation maintains approximately the same width. Thus considerable benches of Würm terraces are preserved. The sequence of a Würm, Late-Würm, and Holocene terrace-fill presents itself in some places as a genuine staircase of terraces. Occasionally, even within the Holocene aggradation there exist terrace steps, which can be recognized morphologically.

This pattern is modified in different areas by tectonics (areas of subsidence or uplift), by the structure of the bedrock traversed (narrow valleys, widenings), and by the variation of the base level.

The Holocene river deposits within the river bed usually consist of sandy and loamy gravels and sands. Near river banks and in abandoned channels occur sediments rich in humic matter and organic detritus such as clay-muds and detritus-mud *(Mudde, Schlick)*. On the high-water floodplain a sandy, silty to clayey loam is deposited *(Auelehm)*. Sometimes it is calcareous, especially if there is a great amount of redeposited fresh loess. In the area of the rivers in the northern Alpine Foreland „*Auemergel*“ (floodplain marl) is deposited. Its lime content reaches 60—70 % (DIEZ 1968, HOFMANN 1973), which can be attributed principally to the till content and to the high percentage of carbonate rock in the total load of these rivers.

The Holocene age of these deposits can be — contrary to Würm and Late-Würm river sediments — determined by their frequently abundant plant debris *(Rannen*[3]), remains of roots, branches and leavels, peats), more seldom by embedded artifacts or fauna. Further distinguishing criteria are the more weakly developed soil formations on Holocene terraces, compared to those on Würm terraces (for example in the northern Alpine Foreland: BRUNNACKER 1959, DIEZ 1968, on the River Rur: SCHALICH 1968), and the already mentioned morphologic distinctions between the Holocene valley aggradation and Würm terraces.

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[3]) Subfossil tree-trunks, often with large branches or stumps of branches, often still with roots, toppled by undermining of the bank and usually embedded in the direction of flow. The term is applied in common usage, as well as in the geological literature of the Danube-Main area.

1.2 The Chronological Development of River Areas in the Holocene

a. Early Holocene

As far as fluvial processes during the transition from the Late-Glacial to Holocene can be understood, at latest by the Preboreal rivers began to dissect the Late-Glacial terrace deposits with channels and then, gradually restricted themselves to narrower river beds, where downcutting took place. Rarely thin beds of loamy gravel of this age are preserved but generally the surviving sediments consist of loamy-silty alluvium spread out over the Late-Glacial deposits (e.g. on the Rur: SCHALICH 1968, and on the River Lahn: MÄCKEL 1969). Whether the Early Holocene floodplain developing in this way was always formed on top of the Late-Würm terrace surface — as for the River Lahn — or whether it was formed at an erosion level within the Late-Würm terrace, still remains to be investigated.

The groundwater table in this Early Holocene floodplain lay, in general, close to the surface, so that these valley plains were often inclined to turn into fen. On parts of valley floors, where the groundwater table reaches the surface, or in lateral depressions of dried-up valley floors, which are additionally fed by phreatic discharge from the valley flanks, muds and peats have been developing since the Early Holocene.

At times their growth set in as early as the Preboreal. To quote but a few of the many relevant studies, together with their regional distribution: Upper Danube around Ulm and Upper Neckar drainage area (GROSCHOPF, most recently 1961*); on the Upper Rhine, the Bergstrasse river bed of the Neckar, abandoned by the Neckar during the Preboreal, which then took a direct course to flow into the Rhine at Mannheim (most recently KUPFAHL 1972*), on the middle Saar (ZANDSTRA 1954), on the Lower Rhine near Cologne (REHAGEN 1964), in the Hessian fault trough near Amöneburg (HUCKRIEDE 1965), on the Leine near Göttingen (KRETZMEYER 1949, cited in WILLERDING 1960). Here described are clayey, humic to peaty sediments, several decimeters in thickness, overlying older Würmian or Late-Würmian gravels or sands; these are called "*Basismudde*" (basal muds) (GROSCHOPF 1961) and "*Basistorf*" (basal peats).

Occasionally the formation of muds and peats began with the Boreal, for example on the Lower Rhine (REHAGEN 1964, HERBERHOLD 1968), or in the Lahn valley (HUCKRIEDE 1972). Where groundwater springs were present, even the more elevated Low Terrace surfaces began to develop fen and bog during the Early Holocene (e.g. in front of the Alpine Würm end-moraines on the Late-Glacial gravel plain of the Erdinger Moos: SCHMEIDL 1959, 134, on the Saar: ZANDSTRA 1954).

All the sediments mentioned may sometimes contain pieces of wood. They may be dated by means of pollen analysis, sometimes supported by molluscan faunas and by ^{14}C-dating; e.g. *Basismudde* on the northern border of the Schwäbische Alb: 9290 ± 190 BP (GROSCHOPF 1961).

Where groundwater, coming from calcareous drainage areas, reaches the surface — particularly in the South-German Jura, and on the outwash plains of the northern Alpine Foreland — *Alm*[4]) and *Dauch*[5]) are precipitated as well. Very rarely does the precipitation begin as early as the Preboreal, but, for example, in the Full-Glacial meltwater channel of the Memminger Ache, where the first precipitates of *Alm* appear, together with Preboreal peat formation (BRUNNACKER 1959). On a widespread scale, *Alm* and

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4) *Alm* ist between loose lime silt and lime sand, which is precipitated by discharge of calcareous groundwater (cf. VIDAL et al. 1966).

5) instead of the term "*Kalktuff*" (calcareous tufa) (cf. JÄGER 1965).

Dauch have only been developed since the Boreal (e.g. Schwäbische Alb: GROSCHOPF 1952, 1961), or since the Atlantic (Erdinger Moos: VIDAL et al. 1966) (cf. also chapter 2).

On dried-up floodplains, s o i l s have begun to develop since the Preboreal. In many areas these soils cap the shallow floodplain sediments of the Earliest Holocene (cf. above). These soils are dark and humic; they possess different names in specialist literature, frequently they are called "*Humushorizont*" (humus horizon). Typologically they can be classified as "*tschernosemartiger Auenboden*" (chernozem-like floodplain soil) (in MÜCKENHAUSEN's sense 1962), or as "*A u e n - F e u c h t s c h w a r z e r d e*" (wet chernozem of floodplains). They show transitions towards bog soils. The A_h-horizons reach a thickness of 5 decimeters.

The time of their formation can only be narrowed down: pollen analysis of the A-horizon (MÄCKEL 1969: River Lahn) indicates a time span stretching from the end of the Preboreal to the late Boreal. ^{14}C-datings of wood and humus give 7100 ± 110 PB (River Lahn: MÄCKEL 1969), 7380 ± 250 BP (Danube at Linz: KOHL 1968), 7980 ± 110 BP (Upper Main: SCHIRMER 1973). These dates indicate a Boreal to Early Atlantic age, but they need careful interpretation: they give an average — or in the case of more intensively reworked soils — a final age for the total period of soil formation; they can yield an even younger date where subsequent pedogenetic processes involve superimposed soils (cf. paragraph b). On the sides of the *Dauch*-filled Rosdorf valley depression near Göttingen, a *Feuchtschwarzerde* on loess extends downslope and continues below the *Dauch*, whose formation set in after the transition from the Preboreal to the Boreal (SCHEFFER & MEYER 1965). Consequently, the soil development had already set in during the Preboreal. Adjacent pits of the "*Ältere Linienbandkeramik*" (Older Danubian Ware culture), which were dug into fully developed *Feuchtschwarzerde* (SCHEFFER & MEYER 1965), and fragments of Older Danubian pottery, situated above this soil in the Leine valley (ROHDENBURG 1965), demonstrate that the complete soil development had already been in existence at the beginning of the Neolithic period (cf. also ROHDENBURG & MEYER 1968).

The main phase of the development of the *Auen-Feuchtschwarzerde* ranges, accordingly, from the Preboreal to the end of the Boreal, perhaps even including a part of the Atlantic.

The lateral change at this period of the Early Holocene from more elevated and drier habitats of the valley floors to moist depressions, channelways or marginal depressions, is reflected by the t r a n s i t i o n from *Auen-Feuchtschwarzerde* through boggy soils to peat (cf. HERBERHOLD 1968).

It is likely that a „*Lehmmudde*" (loamy mud), with plant remains, which was found in the Lahn valley at Marburg (HUCKRIEDE 1972), can be attributed to a moist depression of the Early Holocene floodplain. From its stratigraphic position, immediately beneath the floodplain loam, and by means of pollen analysis, this *Lehmmudde* can be dated to the late Boreal (^{14}C-dating: 6930 ± 60 BP). The depression was either flooded by high waters or by lateral discharge. At some distance downstream, towards Gießen, it is *Auen-Feuchtschwarzerde,* which covers widely this fossil floodplain there (MÄCKEL 1969).

b. Atlantic Stage

At all known localities the Early Holocene *Auen-Feuchtschwarzerde* is situated very close to the present surface, usually at a depth of 1—2 meters. In the Lahn valley it is covered — according to pollen-analytic data (MÄCKEL 1969: profiles 1 and 4) — by, at most, 2 meters of Atlantic and early Subboreal floodplain loam. This level was attained later only by mediaeval and modern floodplain loam. Also on the River Leine (ROHDENBURG 1965), and on the Upper Main (SCHIRMER 1973) the Early Holocene level is covered essentially by mediaeval and modern floodplain loam.

The development of an intensive, pseudogleyed brown weathering horizon (B_vS_d) below the humus horizon of the *Auen-Feuchtschwarzerde* on the Upper Main shows, further, that the Early Holocene level continued to exist for a long time under changed conditions — for example, a lower groundwater table, caused by increased downcutting of the river bed — probably even throughout the Atlantic stage.

A lowering of the erosional base and of water table in the valleys is also indicated by Atlantic loam and muds below the Early Holocene floodplain level, for example along the Lahn (Mäckel 1969: 151), and along the Saar (Zandstra 1954). By Atlantic times the erosion of the Saar had practically reached the base of the Pleistocene gravels. In the Lahn (Mäckel, profile 2, 3), and in the Upper Main valleys (Schirmer 1973) the base level of erosion is situated slightly higher.

Only in the case of the Lahn does Mäckel mention an Atlantic gravel accumulation. Its maximum thickness is 4 meters, and the inferred age is based on ^{14}C-dating (4100 ± 45 BP), and on a single pollen sample from a mud lens. The ^{14}C-dating, however, indicates a Subboreal age (cf. paragraph c), and it is quite possible that the mud material was reworked from the previously mentioned Atlantic floodplain loam into a younger gravel fill — a process frequently to be observed in Holocene gravels.

c. Subboreal Stage

The first certain indication of a change in fluvial regimes since the Early Holocene is provided by Subboreal gravel accumulations. According to the literature so far published, these gravel accumulations are the thickest and most frequent of the Holocene.

The gravel aggradation occurs in a very broad river bed, which had been widened by lateral erosion. The valley floor of the Early Holocene, together with the *Auen-Feuchtschwarzerde,* is preserved only in the form of narrow strips, mainly on the edge of wider sections of the valley.

In places, where the valley floor of the Early Holocene *Auen-Feuchtschwarzerde* can be recognized, it is not covered by gravel. That is to say, the accumulations are cut into it, as in the case of the Upper Main (Schirmer 1973), probably also of the Lahn [6]), and of the Danube near Linz (Kohl 1968). At Linz, the terrace concerned is called "*Oberes Hochflutfeld*" (Upper Floodplain), on the Isar it is called "*Pulling-Stufe*" (Pulling terrace) (Brunnacker 1959). In both localities the terrace is clearly incised into the Late-Glacial terrace level. The thickness of the aggradation on the Upper Main amounts to 2,5—3 meters, on the Lahn at a maximum 4 meters, on the Isar at least 4,5 meters, on the Danube near Linz at a maximum 9 meters.

On the other hand, Preboreal peat on the Danube near Ulm was covered by 4 meters of Subboreal gravel accumulation (Groschopf 1961), and, at some distance south-east of this locality, on the Kammlach, a Younger Dryas level is covered by at least 30 cm of Subboreal accumulation (German & Filzer 1964).

Further references to Subboreal accumulation are reported from Regensburg/Danube (Neweklowski 1964), Höchstädt/Danube (B. Becker 1971), and from the Rems (Eisenhut 1962) [7]).

Rather conspicuous is the abundance of *Rannen* [3]) in all the gravels mentioned. The chronology of the gravels was obtained by ^{14}C-dating of *Rannen,* and further, by dendrochronological correlation (B. Becker 1971) with ^{14}C-dated trunks. Only the Kammlach gravels mentioned were dated by means of pollen analysis. In some cases

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[6]) cf. chapter b, last paragraph.

[7]) cf. also the chapter on the Urnfield-period.

additional dates can be obtained through archaeological evidence; for example, near Ulm: Late Neolithic and Urnfield-period finds (GRAUL & GROSCHOPF 1952), on the Upper Main: numerous Late Neolithic and Urnfield-period finds (JAKOB 1956) [7]).

A compilation of current data on the Subboreal aggradation indicates that there are two periods of accumulation: one in the Late Neolithic, the other in the Bronze Age.

Whether the lack of records between these periods is the result of an insufficient number of observations, or whether it really marks two different phases of accumulation, or peaks of a single accumulation, remains to be shown by future studies.

The Urnfield-Period

As mentioned above the younger of the two Subboreal peaks is shown by the prehistoric records to continue into the Urnfield-period. SMOLLA (1954) has compiled information from areas, including those not dealt with in this article, where Urnfield finds are situated below fluvial accumulations. One of them, for example, is the aggradation of the *Märkter Terrasse* near Basle, in which a helmer from the Urnfield-period was found 3,5 meters below the surface (SCHMID 1950) [8]).

SMOLLA connects his findings, together with statements on slope changes and on the choice of location for settlements and burial-places, with the climatic deterioration at the turn of Subboreal/Subatlantic, as deduced by SERNANDER [9]) in 1926. This would signify a separate accumulation at the transition to the Subatlantic. As long as the gravels mentioned are dated only by single finds from the Urnfield-period, unsupported by further data or information on the surrounding Holocene frame, the possibility, that they lie within the sequence of late Subboreal accumulation cannot be ruled out.

d. Early Subatlantic Stage (Pre-Roman Iron Age)

From the oldest phase of the Subatlantic, only few data exist, which are concerned with the fluvial processes. Only on the Upper Main (SCHIRMER 1973) can a widespread accumulation, whose maximum thickness is 3,5 meters, be attributed to this period. It is situated at the same level as the Subboreal gravel, and it extends to immediately below the Early Holocene floodplain level. Three ^{14}C-dates from the lower, middle and upper part of the gravel aggradation fall between 2230—2470 BP; the dates, corrected by SUESS, establish an age between 800—400 BC.

Towards the Roman period the Main must have been downcutting, as the gravel surface is dissected by channelways, whose earliest deposits of muds contain rooted wood, datable by ^{14}C to the Roman period.

e. Roman Period

The information on Holocene fluvial processes during the Roman period is supported in particular by an abundance of cultural finds.

A separate gravel aggradation dating from the Roman period is found as part of a Holocene staircase of terraces, cutting through a fluvioglacial gravel plain in the foreland of the Würm end-moraine on the middle Lech near Epfach. The gravel aggradation, with a thickness of 2 meters, covered by 1,5 meters of river marl, can be shown to be restricted to the early Roman period up to the 4th century A. D., as there are Roman constructions in situ beneath it and above it (BRUNNACKER 1959, DIEZ 1968: 110).

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[8]) The author ascribes the gravel to the beginning of the Subatlantic.
[9]) cited in SMOLLA (1954).

Gravel aggradations, containing some ^{14}C-dated pieces of wood, but above all cultural finds from the Roman period, are familiar from various rivers. They originate from, for example, the alluvial fan of the Iller near Ulm (BRUNNACKER 1959, GROSCHOPF 1961), from the Isar near Landshut (HOFMANN 1973), from the Main near Bamberg (PESCHECK 1970), from the middle Saar (ZANDSTRA 1954), from the Lower Rhine (PETRIKOVITS 1960), from the Rur near Jülich (SCHALICH 1968), and from the Leine near Göttingen (WILLERDING 1960). Usually, however, these are isolated discoveries, well-provenanced only in certain cases. A gravel aggradation belonging to has not been separated. Consequently, all these records merely signify that the gravels, containing finds, are either from the Roman period or younger, for possibly the finds became embedded in the gravels at later times, as was shown by PETRIKOVITS (1959), for instance, with remains and finds from the Roman camp Vetera II.

The filling of an abandoned branch of the Rhine at Xanten in connection with the silting-up of Roman quay constructions at Colonia Traiana (PETRIKOVITS 1952) can be placed roughly within the period between A. D. 0 and the beginning of the 3rd century A. D. A silting-up of channels, cut into gravels from the Iron Age, which took place in the Roman period on the Upper Main (SCHIRMER 1973), has already been mentioned. Very similar channels, filled with loamy muds, were formed on Holocene gravels in the Leine valley near Göttingen (WILLERDING 1960). There the formation of mud, dated by pollen analysis, and on the Upper Main by ^{14}C, persisted from the Roman period up to the early Middle Ages, before the formation of floodplain loam set in.

Signs of the deposition of floodplain loam can be expected from Roman buildings which are still preserved *in situ* in river valleys. Most of these buildings are situated just out of reach of the present-day flood waters; some of them, such as the Roman citadels Wörth and Trennfurt on the western Main quadrangle (KESSLER 1962) are still within reach of flood waters. Others have been at least temporarily flooded since their construction, and are covered by a few meters of mud or loam. In addition to the examples from the Main quadrangle, parts of the Roman road between Koblenz and Andernach in the Neuwied basin (HIRSCHFELD 1881) [10]), a Roman grave, situated in a pre-Roman meander of the Rhine near Duisburg (HOPPE 1970), as well as a settlement predating the Colonia Traiana near Xanten (PETRIKOVITS 1952), should be mentioned. Only at the latter place can the inundations, which deposited 1,5 meters of flood loam — of the facies characteristically found close to river banks — be dated to approximately A. D. 20—50. At the other localities mentioned the Roman buildings merely provide a *terminus post quem* for the age of the loams.

The results demonstrate, however, that at the time of the construction of the Roman buildings, the river level must have been roughly as low as today, and that the high floods of subsequent periods, restricted by an increasing build-up of floodplain loam, were able to rise higher than in the Roman period.

f. Middle Ages and Modern Age

Floodplain loams are by far the most conspicuous formations of our river valleys in the Middle Ages and the Modern Age. At their base, however, mediaeval and younger gravels are found as well.

Not just in the Roman period, but in later times too, within the area of the fluvioglacial gravel plains of the northern Alpine Foreland and downstream, terrace steps in the form of a staircase of terraces were cut into the older Holocene terraces (BRUNNACKER

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[10]) cited in FUCHS (1960).

1959: Lech, Isar; DIEZ 1968: Lech; HOFMANN 1973: Isar). On the Isar, the older of two post-Roman steps, the *Dichtl-Stufe,* is dated to the 16th to early 17th century by a poplar trunk, which lay in the gravels at a depth of 1,5 meters. On the Rur also, two historical gravel aggradations appear. Their thickness, however, amounts only to a few decimeters: there, a modern gravel, containing cultural debris of the 18th and 19th centuries, is cut into a gravel, containing mediaeval potsherds, which can be explained by tectonic subsidence in the adjacent region of the *Niederrheinische Bucht* (SCHALICH 1968).

Here and in all other areas, gravels with a thickness up to a few meters, containing mediaeval and more recent cultural debris, mainly pottery fragments, are situated below the floodplain, which morphologically can hardly be differentiated. For example, on the Main (JAKOB 1956, BRUNNACKER 1958, KÖRBER 1962: 25, E. BECKER 1967: 15th century), and on the Regnitz (KUHN 1956). In most cases, however, the age of the cultural debris is rather ill-defined, and indicates, at any rate, only an upper age limit for the gravels.

Thus, it still cannot be shown whether there was any supraregional trend within the region of the *Mittelgebirge* towards particular phases of aggradation within this period. Alternatively, local events, such as the shifting and infilling of meanders may have given rise to such aggradation randomly in time and space. The six meander cutoffs on the Lower Rhine, which were formed, according to HOPPE (1970), at equal intervals over the period between 1200—1700 do not provide us with an answer. For meander cut-offs depend on the maturity of the meander and on flood peaks, which may occur at any time and under very different conditions (cf. HOPPE, p. 42). Data on the sudden acceleration of slowly developing meanders should be collected. This might help us to discern the time-pattern of such aggradations.

The recent valley floors consist of floodplain loam, generally with a thickness of 2—3 meters, but at times covering the older fluvial deposits to a much greater depth. The floodplain loam is usually situated above the groundwater table of the valleys, and it is most frequently to be found in valley exposures. Consequently, the younger loams are the most described Holocene deposits of our river systems.

The recent floodplain loams of valleys in the *Mittelgebirge* more or less fill up and level off the irregularities of the valley floor, which had remained after the activities of Holocene fluvial processes. Only the relief of the most recent lateral movement of rivers has not been evened out so far by these loams (cf. MÄCKEL 1969: 159). For the first time since the Early Holocene, this floodplain loam overlaps to a considerable extent the valley floor of that period, which is characterized by the *Auen-Feuchtschwarzerde* [11]), that is to say, it blankets the complete Holocene, partly even the Late-Glacial valley floor. Apart from predominately sandy-silty loams there are also areas of gravel and clay. Within a valley cross-section, a division into coarser-grained loams, which are deposited close to the river around the levées, and finer-grained loams, deposited at a greater distance from the river, around the marginal depressions, appears to be the rule (cf. e.g. ZANDSTRA 1954, VOLLRATH 1965).

Roman buildings *in situ* (cf. chapter e.) and Roman age finds on the floodplain (e.g. on the Mümling in the Odenwald: KESSLER 1962:40) are usually situated below this loam or in its lower part, thus marking the bulk of the loam as post-Roman.

In some river valleys, within the post-Roman floodplain loam an "older" and "younger floodplain loam" [12]) could be distinguished, which occur above as well as alongside each other, e.g. on the Upper Leine (most recently WILLERDING 1960*

11) cf. chapter b.

12) The terms are rather inadequate, as there are pre-mediaeval floodplain loams as well; cf. the previous chapters.

and ROHDENBURG 1965*), on the Lahn (MÄCKEL 1969), and on the Upper Main (SCHIRMER 1973). In the case of an overlap of the two loams, in the Leine and Main valleys a weak soil development took place on the older loam surface. Therefore, after the deposition of the older loam, parts of the floodplain must have been free from flooding, at least for a certain period of time, which indicates changed cnditions of discharge.

The deposition of the o l d e r l o a m began on the Leine, dated by pollen analysis (WILLERDING 1960), on the Lahn and on the Upper Main, dated by ^{14}C of pieces of wood *in situ,* in the early Middle Ages. On the Lahn the loam contained pottery from the 10^{th} and 11^{th} centuries. Cultural finds are numerous in other areas as well (e.g. Leine: HEMPEL 1956, Mümling/Odenwald: KESSLER 1962, 42).

The deposition of the y o u n g e r l o a m began on the Lahn (MÄCKEL 1969), as was proved by the ^{14}C-dating of a post with wickerwork, and by pottery, at the timespan from transition Middle Ages/Modern Age to early Modern Age. Consequently, there the younger loam belongs to modern times.

Possibly this bipartition reflects a connection with the suggested tendency towards erosion and accumulation in the river bed.

An ingenious demonstration of v e r y r e c e n t l o a m deposition was given by SCHALICH (1968). In the Inde valley, a tributary of the Rur, 3 meters of *"Jüngster Auelehm"* (very recent loam) were dated by their content of trace elements, namely zinc and lead, as well as by slag from the zinc-smelting at Eschweiler, which had been deposited since the second half of the 19^{th} century.

The deposition of loam still continues today. In the Neuwied basin, for example, one single flood in the year 1955 deposited 2 cm of sand on the floodplain; at banks, where the water had been dammed up, as much as 24 cm were deposited (FUCHS 1960).

The fact that the increased deposition of loam since the early Middle Ages is mainly due to anthropogenic influences, in particular forest clearances causing soil erosion, has been well appreciated in the specialist literature of the last twenty years. Earlier literature on this subject was reviewed by REICHELT (1953), more recent studies by JÄGER (1962) and MÄCKEL (1969).

1.3 Regional and Stratigraphic Survey, River Dynamics

In the northern Alpine Foreland Holocene valley development differed from that in the *Mittelgebirge.*

Observations on the rivers of the A l p i n e F o r e l a n d come chiefly from areas where gravel outwash plains lie in front of the Würm end-moraines, and from areas downstream from there. TROLL (most recently 1954) has described how these gravel plains were cut into by "trumpet valleys" *(Trompetentälchen)* during the Late-Glacial. These erosional valleys widen out and grow flatter downstream where alluvial cones were deposited. Basically these valley-forming processes of the Late-Glacial period continued, according to BRUNNACKER (1959) and HOFMANN (1973) during the Holocene. Thus the Holocene aggradations were deposited as a staircase of terraces with base levels cut through the Low Terrace even into the underlying bedrock.

By contrast, Holocene fluvial processes in the *M i t t e l g e b i r g e* r e g i o n are practically restricted to within the gravel fill of the Low Terrace. Staircases of terraces are rarely to be found or faintly indicated. Younger gravel fills are usually deposited at the same level as older ones, which makes their separation difficult.

In regions, where the formation of staircases of terraces took place, the age of these terraces can additionally be investigated by comparative differences in their soil development (BRUNNACKER 1959, DIEZ 1968, SCHALICH 1968, HOFMANN 1973).

A number of phases of accumulation and erosion, occuring since the Subboreal, are known from different areas. After a general Subboreal accumulation (possibly two-phase, Young Neolithic and Bronze Age) there are isolated indications of aggradation in the Iron Age, in the Roman period (especially in the northern Alpine Foreland), in the Middle Ages, and in the Modern Age. Authors agree generally that the Holocene aggradations consist more or less of eroded and redeposited Low Terrace sediments, into which the Holocene valleys and sediments were emplaced. In many cases it remains to be discovered, whether these aggradations occur along the whole course of river systems, or whether they are merely local, e.g. abandoned and filled-up meander fields, or caused occasionally by favourable local factors. It is possible that, with a more continuous range of data for the time since the Neolithic, more periods of aggradation will be recognized.

Beside the above mentioned alluvial cone formation in the rivers of the northern Alpine Foreland, there exist descriptions of local aggradations in the form of alluvial cones from places, where tributary valleys flow into the main valley, such as the alluvial cone of the Iller in the Danube valley near Ulm (most recently GROSCHOPF 1961), or the alluvial cone of the Wiese in the Rhine valley near Basle (WITTMANN 1961). In the latter case an alluvial cone of the tributary Wiese, which rises in the Black Forest, was spread downstream by the Rhine on to an erosional step of the Low Terrace (Field C, Märkter Terrasse). Upstream the surface of the alluvial cone is reported to merge into the above mentioned erosional step [13]). Also a change from a narrow to a wide valley is likely to favour the local formation of alluvial cones, e.g. in the basins of Eferding and Linz on the Danube (KOHL 1968).

In the preceding part of this paper it was in part possible to connect such local aggradations with general trends of accumulation. Only more investigations will prove, how far the Holocene fluvial processes were shaped by general or local factors.

The various interacting factors, which might have led to different causes of development in Holocene river valleys, e.g. particularly the importance of anthropogenic influence, are not discussed here. These very important factors, whose identification is ultimately the goal of this kind of research, have been frequently discussed in current literature (most recently e.g. by BRUNNACKER 1972*). The greatest deficiency, which has so far emerged, is the scanty amount of factual information concerning the Holocene inland.

Even the results gathered together in this article are only based, as well now be realized, on the studies of a few valley sections, and it is necessary to establish a denser network of observations. Hence this survey and the outline that follows should be considered simply as a draft for future work.

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Conclusion

The Holocene fluvial processes from the Danube region to the limits of the Northern glaciated area [14]) indicate, very schematically, that there are three successive trends:

1. During the early Holocene: deepening of the rivers into the glacial sediments from the closing stages of the Late-Glacial period onwards; the formation of a stable flood-

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13) For its dating cf. the chapter on the Urnfield-period.

14) The somewhat different conditions of the northern Alpine Foreland have been outlined in the first paragraph of this chapter.

plain, characterized by transitions from *Auen-Feuchtschwarzerde* to boggy soil *(Anmoor)* to peat and to muds. In the Atlantic erosion has cut through the Würm gravel fill, either largely or entirely.

2. From the Subboreal onwards a gravel fill was deposited in river beds, which had been greatly widened by lateral erosion. The aggradation does not quite reach the Early Holocene floodplain level, which is preserved only in fragments near the valley flanks. In some places floodplain sediments overstep the old floodplain.

Whether an early Subatlantic (Iron Age) aggradation, which is situated in a similar position to the Subboreal accumulation, continues the same trend, cannot be determined with certainty for the time being; a greater number of observations in different regions might answer this question.

3. By the Roman period at latest, the river bed reached approximately the erosional level of the Atlantic stage, and thus the recent level too, and at the same time began to grow narrower. Changes in the river course and a partly meandering river bed caused the shifting of gravels. Tendencies towards aggradation and erosion, seen in the northern Alpine Foreland, possibly exist in the *Mittelgebirge;* sufficient observations, however, are not to hand.

Since the early Middle Ages an increased deposition of floodplain loam set in, which was chiefly due to the clearence of forests. The deposits overstepped the Early Holocene valley floor, and again covered its complete width for the first time since its formation.

2. Calcareous Freshwater Deposits

During the Holocene, formations of *Dauch*[5]), *Alm*[4]), and *Seekreide* (lacustrine marl) were precipitated in drainage-basins rich in limestone — especially in the northern Alpine Foreland, in the South-German Jura, and in the *Muschelkalk*[15]) landscapes. Where they are closely connected with fluvial processes, they have already been referred to above.

Early precipitation of such sediments, during the Preboreal, was observed only at a few sites (BRUNNACKER 1959, 130). (For some possibly Late-Glacial precipitation cf. also GROSCHOPF 1952, 83). The precipitation of most of these calcareous freshwater deposits, however, began with the Boreal, e.g. on the southern and northern border of the Schwäbische Alb (GROSCHOPF 1952, 1961), in the Main valley near Würzburg (KÖRBER 1962, 144), in the Leine valley near Göttingen (KRETZMEYER 1949)[16]). After the latest onset of deposition during the Atlantic, in the Erdinger Moos (VIDAL et al. 1966), the peak of the lime precipitation was reached.

By the early Subatlantic at latest, the widespread, extensive precipitation of calcareous sediments practically ceased: in the Schwäbische Alb in the La Tène-period (KLEY 1952)[17]) up to the Imperial Roman times (KLEY 1963). Only an insignificant precipitation, limited to the upper courses of streams and springs, continues up till the present day.

In many cases, periodic interruptions of calcareous precipitation are indicated by settlement horizons stratified within these sediments. This can be observed especially well at the best-analyzed *Dauch*-occurrence of the region, the *Dauch* of Wittislingen on

[15]) Middle Triassic stage with limestones and marls.
[16]) quoted from SCHEFFER & MEYER (1965).

the southern border of the eastern Schwäbische Alb (SEITZ 1951, 1952, 1956, GALL 1971), but also in other places on the Alb (KLEY 1952)[17]), and on the Main (KÖRBER 1962, 144). They cannot necessarily be associated with contemporary fluvial events, but may be associated amongst other things with local processes, such as the building-up and destruction of cascade-forming Dauch-steps in valleys (cf. GROSCHOPF 1952, 75)[18]).

3. Hillwash and Soil-Creep Sediments and Deposits on Upper Courses of Streams

A knowledge of Holocene processes in the uppermost courses of tributaries and on the slopes of the drainage-basins is an essential prerequisite for understanding the environment and changes in Holocene valley processes. By means of pollen analysis, archaeological and ^{14}C-dating more data on denudational and accumulational processes on slopes and in hollows have recently become available.

Apart from slight slope movement in the early Holocene, there is an increasing amount of denudation and gully erosion, and consequently of the filling-up of depressions, which started with the first extensive agricultural activity and forest-clearance of mankind from the beginning of the Neolithic period.

Information about soil movement since the early Holocene can be found, for example, in BRUNNACKER (1958*), SCHEFFER & MEYER (1965), LÜNING, SCHIRMER & JOACHIM (1971). References to the intensification of such movement, predominately anthropogenic, since the Bronze/Iron Age are more numerous. Besides the references already cited, the studies of RICHTER & SPERLING (1967*), MACHANN & SEMMEL (1970*), HUCKRIEDE (1971*, 1972 a), and HABBE & MANN (1972) should be listed as examples of more recent literature.

All these studies are limited to closely restricted areas, characterized by local topographical conditions and local anthropogenic disturbance. Consequently, more general and wide-ranging treatments will not be considered here because of their hypothetic nature. In linking soil movements with fluvial processes it has, above all, to be taken into account that slopes and the upper courses of streams will react much more sensitively and immediately to activities, like forest-clearence and human settlement, than will the river dynamics. The latter will not be affected before an eventual build-up of activity on the slope areas, and of cause by climatic factors.

4. The Drifting of Aeolian Sand

Aeolian sand plains and dunes, which had been accumulating predominately during the late Würm Full-Glacial and the Late-Würm in low-lying basins and where valleys broadened out, became stabilized at the beginning of the Holocene by the spread of a closed vegetation cover. Removal of the vegetation cover (by forest-clearence, pastures, plaggen-cutting, or use as military training areas) led to a remobilization of the aeolian sands. Peats, plant remains, and cultural finds, which were buried by these drifts, demonstrate that within the area dealt with, repeated local drifting of aeolian sand has occurred from the Neolithic until the present, for example, in the Main valley (BRUNNACKER 1958), in the Upper Rhine valley (E. BECKER 1967, KUPFAHL 1972), and on the Lower Rhine (STAMPFUSS 1958/59, BRAUN and HINZ 1968)[19]).

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17) in: GROSCHOPF 1952.

18) A survey of the conditions and time of the formation of calcareous freshwater deposits for the Central European area is presented by JÄGER & LOŽEK (1968).

19) To mention only a few regional examples from the abundant specialist literature.

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