Palaeoecological study on the Holocene valley development of the River Main, southern Germany

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Tree-ring studies carried out on subfossil oak trunk deposits within the Holocene valley fills of the River Main can reconstruct phases of increased fluvial activities. These phases have been dated on the base of two absolutely tree-ring dated chronologies and in addition by ^{14}C-datings of eleven floating tree-ring series of subfossil oaks.

Geological-pedological investigations reveal an alternation between increased and reduced fluvial activity during the Holocene.

Periods of increased gravel redeposition are dated by dendrochronology, and by ^{14}C and cultural findings. Increased fluvial activity becomes more frequent towards Modern Times with culminations in the Middle Atlantic, the Subboreal, the Iron-Roman Age, the Main Middle Ages till earliest Modern Times, and in the last century.

On the sequence of Holocene river deposits there developed specific soil types as indicators for the age of the river deposits since the Last Glacial.

Among other palaeoecological results an important finding is the correlation between tree-ring width, flood-loam sedimentation, and soil development.

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This report is the result of several years of joint investigation of Holocene river sediments and subfossil oak trunks buried in them in the valleys of southern Central Europe. The geological-pedological studies carried out by W. Schirmer should achieve an insight into the Holocene valley development and its dependence on the changing activity of the rivers. A prerequisite for this was the working out of an accurate stratigraphy of the Holocene river deposits. The tree-ring analyses of the subfossil oak-trunks (so-called *Rannen*) of the Main valley, carried out by B. Becker, is a subproject of the long-term task of constructing a complete tree-ring sequence of oak covering the Holocene. It is also intended that the correlation between the development of the Holocene riverine forests, and the characteristic palaeoecological changes of the flood plains, should be more closely examined.

That the focal point of interest within the river courses dealt with jointly by the authors is situated just on the upper and middle course of the River Main, is in one sense connected with the fact that, at this point, favourable exposure conditions prevail for the geological investigation. The gravel pits, from which trunks are continually being dredged out, lie in a close sequence along the valley and permit a close-set investigation of the sediments in cross-section and longitudinal profile. In Fig. 1 and Table 1, all gravel pits are listed from which subfossil trunk layers have been investigated. The geological investigations, however, are based on an even greater number of exposures. In several of the exposures, it is also possible to obtain an insight into the entire vertical profile of the valley fill, as at these localities the ground-water is pumped out down to the base of the gravel fill, to facilitate gravel quarrying.

The Main trunk layers are of importance for tree-ring analysis, too. They are situated broadly in the centre of the Danube, Rhine, and Weser river systems, within which several German tree-ring laboratories are working on subfossil oaks (e.g. Becker, Delorme & Schmidt 1977). Within this area, however, regional differences in the tree-ring patterns are already becoming inconveniently obvious. Crossdating

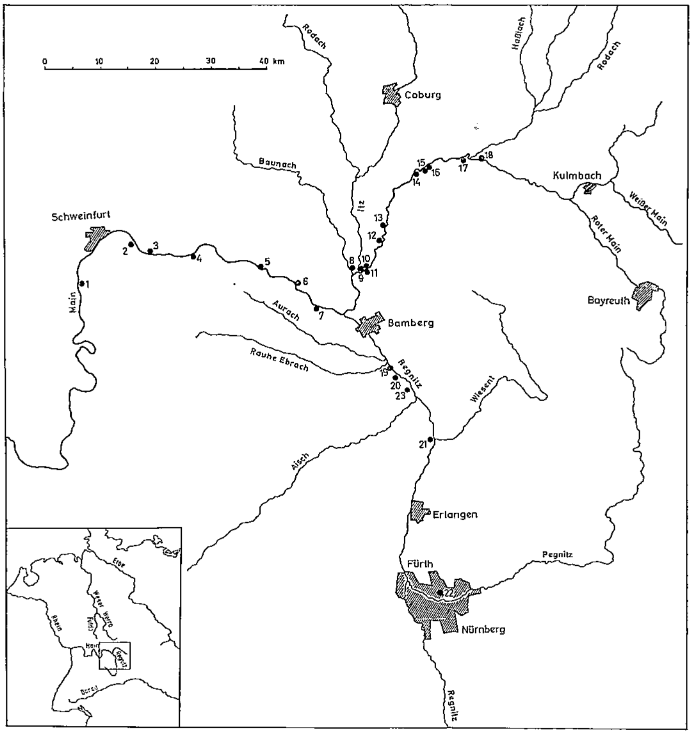


Fig. 1. Localites of subfossil trunk layers in the Main and Regnitz valleys.

of subfossil oak tree-ring patterns succeed over greater distances only through stepwise correlation of neighbouring river areas. Therefore the River Main served, for example, as a bridging member in the successful correlations of subfossil tree-ring series from the River Danube to the Fulda and Werra (Becker, Delorme & Schmidt 1977).

Local observations dealing with the Holocene valley of the Upper- and Middle-Main are available in over 50 publications. Statements which could contribute towards the knowledge of the Holocene valley development are to be found above all in Jakob (1956). Jakob gathered numerous observations about *Rannen* (subfossil tree-trunks) in the Main deposits around Bamberg. According to their height within the gravels, he distinguished two *Rannen* horizons. The origin of these horizons he interpreted in accordance with the ideas of Graul & Groschopf (1952) as catastrophic events during which riverine forests of former, lower situated valley floors were buried by gravels. An extensive statistical material gathered by him, consisting of historical records and cultural finds, accumulates statistically in definite periods. For this reason, Jakob believed he had found the cultural remains of gravel-covered valley floors and that the two *Rannen* horizons could be attributed to the end of the Burial Urn Age, about 800 B.C., and to the Middle Ages.

Körber (1962) delimited cartographically the Holocene valley-filling as 'later lower Low Terrace' in the entire Main valley. Later, on different map sheets, covering the Upper Main and Regnitz valley, this entity was subdivided into two to three terraces: a 'front terrace' (Early Holocene), a later Holocene terrace, and the 'valley filling' (in a sense of youngest alluvions) (Hoffmann 1970; Janetzko & Roloff 1970; Koschel 1970; Lang 1970). For determining these different Holocene terraces, these authors used Jakob's datings of the *Rannen* horizons, beginning with the end of the Subboreal, in various ways.

Principal features of Holocene valley development of the River Main

Tree-ring analysis of the subfossil trunk layers

Findings of buried trunks in our valley fillings must have been known for a long time as special names have been created for them.

Subfossil trees from river gravels in southern Germany are known as *Rannen* (e.g. Jakob 1956); in Upper Austria they are described as *Raner* (Neweklowski 1964). Most of these trunks buried in gravel and sand are oaks, *Quercus sessiliflora* SAL. or *Qu. robur* L. These two species unfortunately cannot be separated distinctly by their wood anatomy (see Huber, Holdheide & Raack 1941). Only in rare cases trunks of other riverine tree species have been found such as ash (*Fraxinus exelsior* L.), alder (*Alnus glutinosa* L.), elm (*Ulmus* sp.), poplar (*Populus* sp.), willow (*Salix* sp.), beech (*Fagus sylvatica* L.) and birch (*Betula* sp.). The subfossil oaks referred to in the following with the name *Rannen* attain diameters of up to one and a half metres. Their state of preservation after a several thousand year repose in ground-water is sometimes so good that today the wood is used for making furniture. The characteristic black colouring of the outer trunk sections, earning them the name *Mooreichen* (swamp oak), is due to a chemical reaction of the hard wood, which has

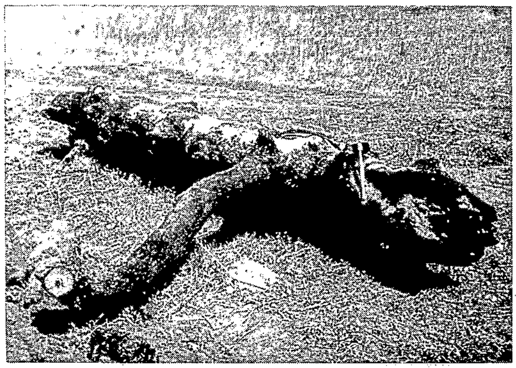


Fig. 2. Well preserved oak *Ranne* with branch. Gravel pit Breitengüßbach. Foto: W. Schirmer 3.5.73.

Table 1. Localities of Holocene *Rannen* layers on the Main-valley.

Number in the map	Locality	Total number of trunks	Workshop title of the layers
1	Heidenfeld	not yet processed	
2	Schonungen	15	Main 3, 10
3	Gädheim	21	Main 1, 2, 3, 4, 6, 16
4	Obertheres	23	Main 3, 5
5	Limbach	5	Main 1, 6, 8
6	Stettfeld	13	Main 1, 6, 7
7	Viereth	26	Main 4, 9, 11
8	Baunach	12	Main 1, 8
9	Breitengüßbach I	44	Main 1, 2, 4, 6, 13, 15
10	Breitengüßbach II	28	Main 2, 5, 6, 7, 13, 11
11	Unteroberndorf	16	Main 1
12	Zapfendorf	6	Main 1, 8
13	Ebensfeld	37	Main 1, 2, 3, 6, 8, 11, 13, 16
14	Hausen	7	–
15	Kösten	6	Main 10
16	Lichtenfels	6	Main 3, 5, 10
17	Trieb	43	Main 1, 8
18	Hochstadt	24	Main 1
19	Pettstadt	24	Main 1, 2, 5
20	Erlach	21	Main 1
21	Burk	17	Main 5
22	Nürnberg	4	Main 3
23	Altendorf	13	Main 2, 10

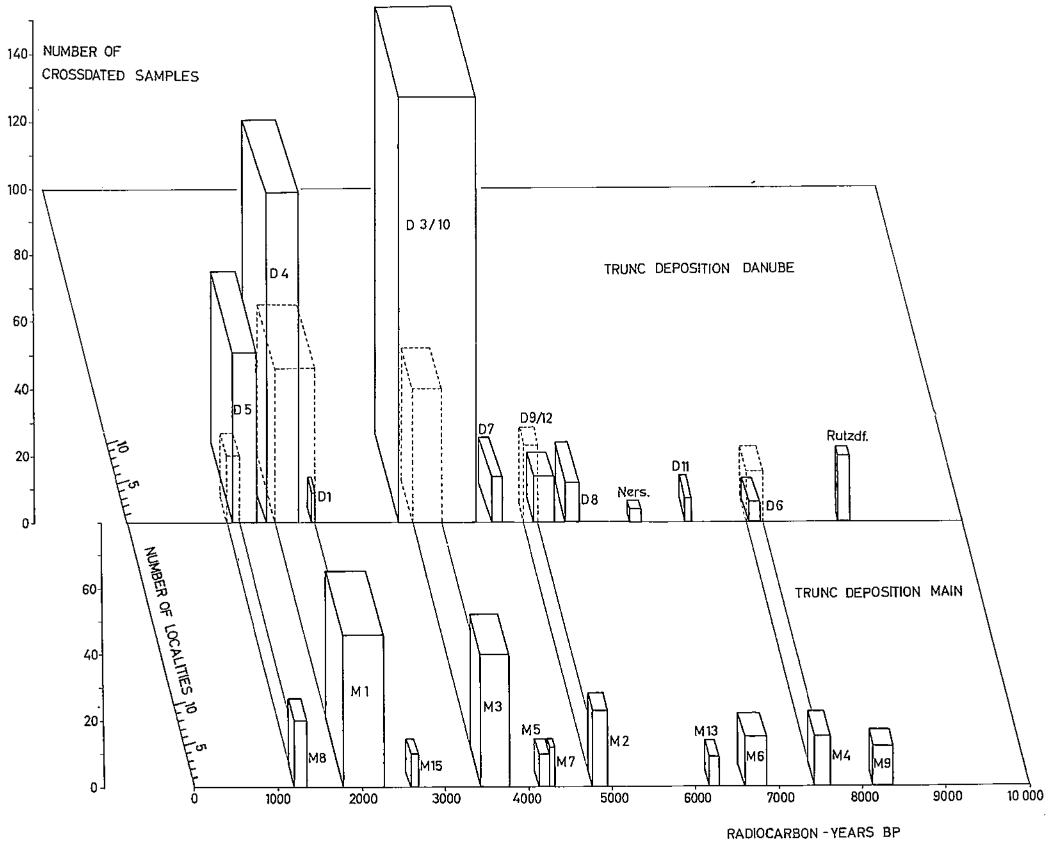


Fig. 3. *Rannen* deposits and their temporal heaping in the Main and Danube valleys. The blocks are constructed on base of the deposition-periods (x-axis), number of cross-dated trunks within each layer (y-axis) and number of localities (z-axis). Cross correlation between the Danube and Main valleys are shown by dotted blocks in the upper part of the diagram.

a high tannic acid content, with iron-bearing ground-water. We use the term 'subfossil' for the structure of these *Rannen* – whose organic substance is still fully preserved – in contrast to fossilized wood, whose original components have been changed, for example, by incoalation or completely replaced by silification.

The deposition of the subfossil trunk layers can be followed along the River Main by means of 213 dated oaks, the tree-ring patterns of which are correlated into 13 determined absolute or floating chronologies. In Fig. 3 the time sequence of death for the *Rannen* layers and their temporal heaps on the River Main and the River Danube are represented in a block diagram form. Table 2 gives additionally all important dates for the Main chronologies, and the terminology used there has also been retained in the text following the Table.

The deposition of eroded riverine forest was obviously a typical and widely spread occurrence during the Holocene valley history. Distinct phases of increased river-activity can be reconstructed by a significant clustering of cross-dated trunks. There does exist a remarkable coincidence of time interval and extent of the down-wash of riverine oaks on the Danube and Main. Nevertheless, the Danube valley, in view of its 640 analysed cross-sections, is considerably better covered than the Main,

Table 2. List of all hitherto dated subfossil trunk layers of the Main-valley.

Work-shop title	Total number of trunks	Dating of the entire tree-ring sequence	Dating of the deposition period	Localities (Table 1)	Total localities	Cross-correlation
Main 1	46	397 BC – 130 AD[a]	226 BC – 130 AD[a]	3, 5, 6, 8, 9, 11, 12, 13, 17–20	12	65.2[c]
Main 2	23	5219 –4759 BP	4936 –4758 BP	3, 10, 13, 19, 23	5	65.3
Main 3	40	3881 –3419 BP[b]	3767 –3419 BP[b]	3, 4, 13, 16, 22	5	64.9
Main 4	16	7753 –7420 BP	7614 –7420 BP	3, 7, 9	3	70.3
Main 5	10	4398 –4119 BP	4251 –4119 BP	4, 10, 16, 19, 21	5	68.3
Main 6	15	7016 –6591 BP	6848 –6591 BP	3, 5, 6, 7, 9, 10, 13	7	63.9
Main 7	12	4580 –4255 BP	4308 –4255 BP	6, 10	2	73.1
Main 8	20	420 AD– 711 AD	559 AD– 711 AD	5, 8, 12, 13, 17	5	61.7
Main 9	12	8518 –8120 BP	8358 –8120 BP	7	1	66.8
Main 10	23	4404 –4105 BP	4300 –4105 BP	2, 15, 16, 23	4	61.3
Main 11	9	8097 –7782 BP	7900 –7782 BP	7, 10, 13	3	64.5
Main 13	9	6480 –6160 BP	6279 –6160 BP	9, 10, 13	3	66.4
Main 15	10	2934 –2595 BP	2682 –2595 BP	9	1	69.2

[a] Dated absolutely by tree-rings.
[b] Calibrated ^{14}C-datings.
[c] Mean of the values of agreement of all cross-dated samples (%).

from which to date 274 samples have been evaluated.

The oldest Main *Rannen* layers date from Boreal and Early Atlantic Times. The successful cross-datings of the tree-ring patterns from these simultaneously (between 7650 and 7400 B.P.) washed-down trees on the Danube and Main provide first indications of the supra-regional course of the river-activities even during the Lower Holocene. A decisive change in the history of the valleys can be recognized from a significant increase in trunk numbers at the beginning of the Subboreal. Within a time span extending over some 400 years, trunks have been accumulated beginning at 5100 B.P. on the Danube and at 4900 B.P. on the Main, whose cross-dated tree-ring patterns once again cover the synchronous course on both rivers. The flooding and eroding forest sites along the valleys reached its first zenith during the period between 4160–3240 B.P. on the Danube (First main horizon according to Becker 1973 and 1977). This phase can be followed on the Main by means of 40 cross-dated subfossil oaks in 5 exposures, over the period 3750–3400 B.P.

Following the Bronze Age *Rannen* deposition, a phase of inactivity lasting over more than 1300 years probably occurred. From southern Central Europe there is only one single trunk layer on the Main known to us (M15 = 2680–2590 B.P.). With an average of 300 growth-rings the relatively great age achieved by these oaks implies a purely local interruption of an otherwise undisturbed riverine forest development within the valleys during this time.

About 220 B.C., a renewed phase of flooding began to destroy the riverine forest. This can be reconstructed dendrochronologically by means of 46 cross-dated trunks from 8 exposures along the Main-valley. The deposition of this *Rannen* layer, obviously the most important horizon of Holocene Main valley, extended over some 350 years between 220 B.C.–130 A.D. This period of enforced fluvial activity is simultaneously evident in the Main and Danube area (Second main horizon according to Becker 1973/77). Furthermore, the Iron-Roman Age tree-ring patterns have been dated absolutely, following their successful correlation with the ring-sequences of Roman oak bridges and wood remains of settlements in northern Switzerland and in the River Rhine area (Hollstein 1967; Becker 1977). The growth and death processes of all cross-dated trunks

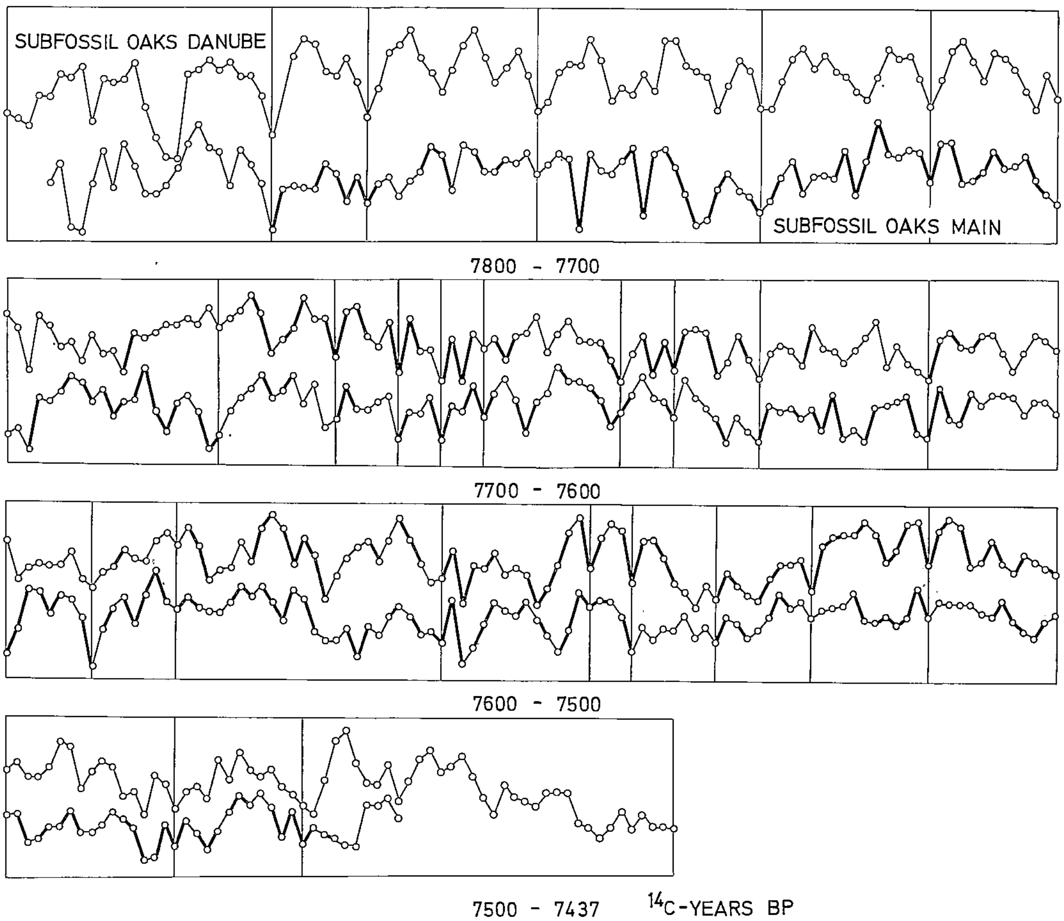


Fig. 4. Tree-ring pattern of the *Rannen* layers Danube 6 – Main 4 7800–7437 B.P. Signature-years (ring-width variations with a value of agreement of more than 80% within all cross-dated samples) are made plain by thick lines in the curves.

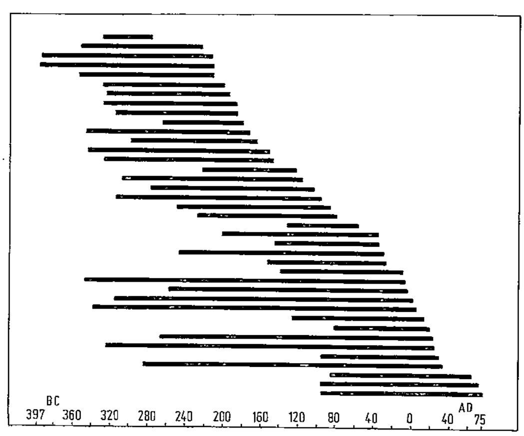


Fig. 5. Growth and death processes of the *Rannen* layer during the Iron-Roman Period in the Main valley. Each block shows one cross-dated trunk; growth starts on the left hand and ends on the right.

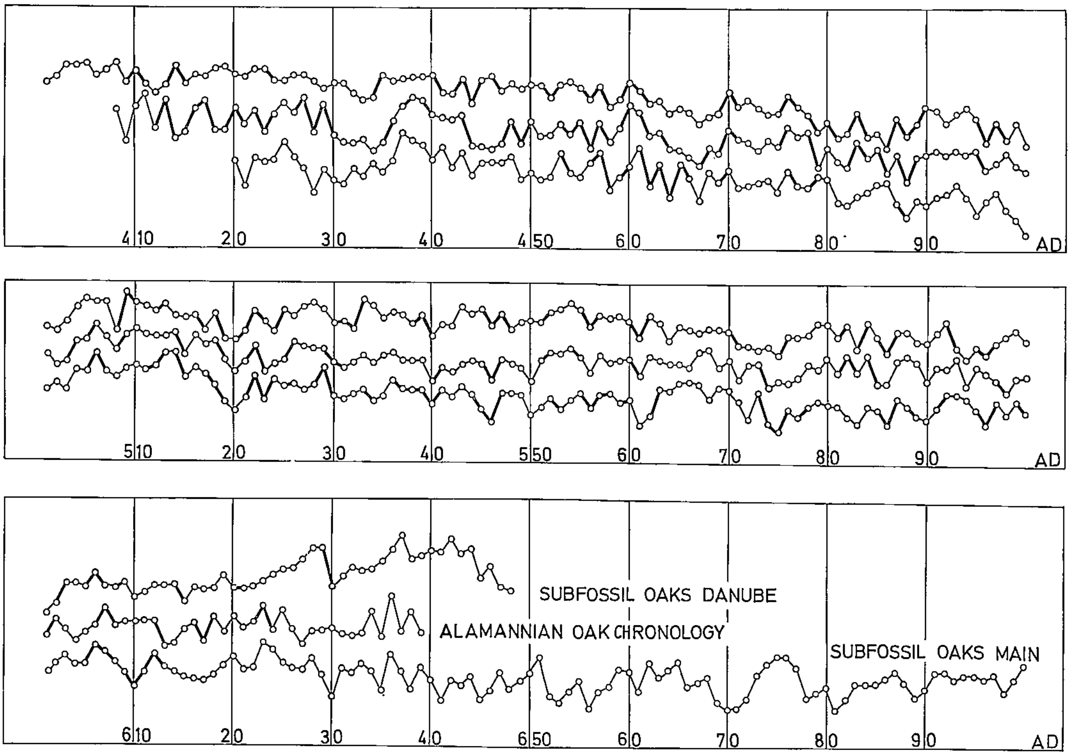


Fig. 6. Tree-ring pattern of Early Middle Ages riverine oaks as well as tree-coffins of the Alamannian Period. The master chronologies are plotted on the absolute time scale from 400–700 A.D. Signature-years are shown by thick lines.

are recorded diagrammatically over the absolute time scale in Fig. 5. Obviously the genesis of this layer is not to be explained by a single catastrophy which overflooded the oak-sites, but rather by a continuous deposition for more than three centuries. A final *Rannen* horizon was established in the Main valley in the Early Middle Ages. The trunks recovered, dating between 560–711 A.D., probably cover only the earlier section of a phase which began on the Danube in 350 A.D. and which led to the creation of the Third main horizon (Becker 1973, 1977).

Even more recent tree-ring data from the Main valley were used in buried Middle- and Late Middle Age pile constructions (Becker & Schirmer, in prep.). They reveal that since the beginning of the 13th century A.D., extensive river-bank building was undertaken in the valley plain to protect cultivated land.

Geological structure of the valley fill and Holocene valley development on the Middle and Upper Main

The Holocene valley fills in Central Europe reveal a geological structure which – corresponding to the orographical and hydrological conditions – differs slightly between the Alpine forelands, the Central Uplands, and the northern German Plains (see Schirmer 1973, 1974). According to this subdivision, the Main is a typical Central Uplands river. Its upper- and middle-course can be regarded as a region of uniform macroclimate which also is free of young tectonics. Therefore, disturbing local tectonic and local climatic influences are not to be expected from the results obtained.

In the valley ground there lies the gravel fill of the Würm Age Low Terrace. On those strips at the edge of the valley floor where its

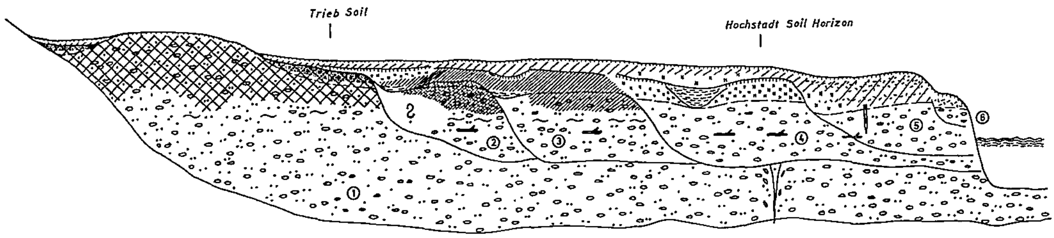


Fig. 7. Schematical cross section of the structure of the valley floor along the Upper Main River.

(1) Würm Age gravel ('Low Terrace') with ice-wedges; in special positions with Trieb Soil on its surface.
(2) Middle Atlantic Age gravel.
(3) Subboreal Age gravel.
(4) Iron-Roman Age gravel with Hochstadt Soil horizon on the top of its flood loam.
(5) Main Middle Ages to Modern Age gravel with pile constructions.
(6) Last century gravel.

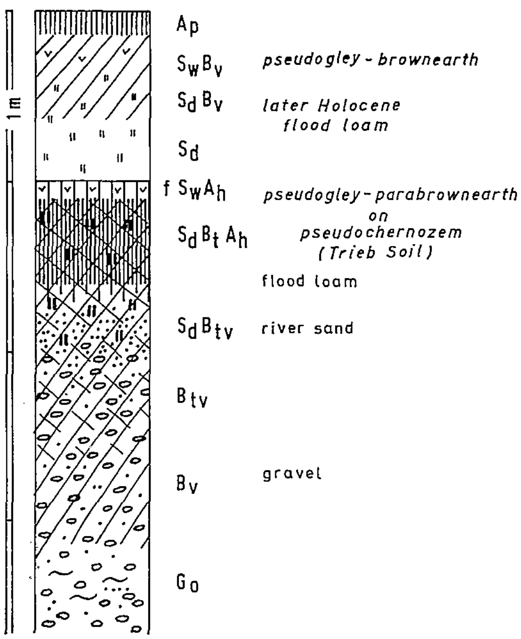


Fig. 8. Generalized section of the early Holocene valley floor with Trieb Soil. Legend see Fig. 7.

surface is still intact, it extends upwards to some ten metres above the present river level. Its thickness extends down to the river level or a little lower. The Holocene deposits are restricted to within this gravel fill: Their surface rises to 5 m above the present river-level. Their base does not extend down to the lower boundary of the Würm gravel, so that below the Holocene gravels Würm gravel is always preserved (see Fig. 7) (Schirmer 1977). Those parts of the Low Terrace which are not covered by Holocene gravels bear a deeply extending para-brown earth. (All soil types mentioned in the following text are floodplain soils, *Auenböden,* that is a soil with a gley horizon at the basis.) At a slightly lower surface covering Late-Glacial deposits a pseudo-chernozem has developed on a floodloam of 0.5–1 m thickness on average (see Fig. 8). Its humus substance revealed a ^{14}C-Age of 7980±110 B.P. (BN. 1801). This soil has been referred as Trieb Soil (Schirmer 1977). It is often present in the valleys of the Central Uplands region. Additional datings from different rivers are ranging in age from the Preboreal up to the Atlantic (see Schirmer 1973: 309).

A subsequent braunification of the pseudochernozem, which penetrates down into the underlying gravel, can be explained by a lowering of the previously higher situated groundwater table during the down-cutting of the river.

The earliest exposed Holocene gravel accumulation on the Main valley is dated by means of a *Rannen* layer to the Atlantic Period (M 13: 6279–6160 B.P.). The deposits have been exposed only rarely. Their thickness extends somewhat over 3 m (see Fig. 9). A 1–2 dm

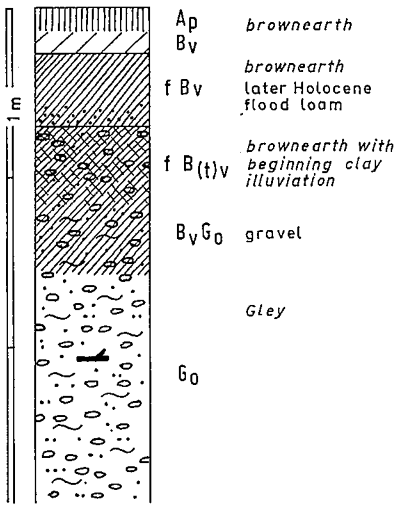


Fig. 9. Simplified section of the Atlantic gravel layer at Ebensfeld. Legend see Fig. 7.

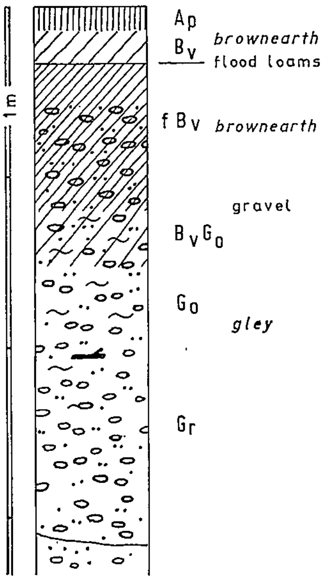


Fig. 10. Simplified section of the Bronze Age gravel layer at Ebensfeld. Legend see Fig. 7.

thick sandy flood loam, covered by later flood loam deposits, is probably the rest of a once thicker, later somewhat eroded flood sediment.

On flood loam and gravel a strong brown earth extending downwards to an average of 1.5 m has developed, which bears light traces of clay illuviation and firmly cements the gravel. Later flood loams are overlying this soil.

From other areas gravel deposits from the Atlantic Period are known only rarely, e.g. on the Erft to the West of Cologne (Schirmer, in prep.), where they were dated due to Banded Ceramic finds and finds from the Rössen Culture.

Since the beginning of the Subboreal, several gravel layers, closer in time to one another, were deposited in the Main valley. According to ^{14}C-dated *Rannen* layers (M2: 4800–4650 B.P. M7: 4290–4255 B.P. M5: 4250–4120 B.P.) they can partly be placed into the early Subboreal. More widely distributed are gravel bodies of the later Subboreal, about the Bronze Age. Nearby Ebensfeld, for example (see Fig. 10), such gravel crops up with a thickness of 4 m. It contains many *Rannen* from chronology Main 3 (sedimentation period 3750–3400 B.P.). Probably all hitherto discovered Subboreal gravel aggradations of the Main valley belong to a continuous accumulation phase, especially since *Rannen* findings on the Danube continually cover the period 4160–3240 B.P. All hitherto known facts concerning the structure of Holocene valley fills show unanimously that on other rivers in southern Central Europe Subboreal gravel deposits are also widely distributed (Schirmer 1973).

The Subboreal gravel of the Main valley shows in its upper part together with its overlying flood loam a strong brown earth. The braunification extends on average to a depth of 1.5 m, but is considerably less intensive than that on the Atlantic gravel. In the overlying beds even younger flood loams follow.

The river history apparently shows, at about the change from Subboreal to Subatlantic – in other words Late Bronze Age to Early Iron Age – a period of decreased fluvial activity. Gravel deposits from this period are known very seldom.

According to the observations to date, the most widely distributed Holocene gravel body on the Main originated during the Late Iron Age and the Early Roman Period. In pits No.

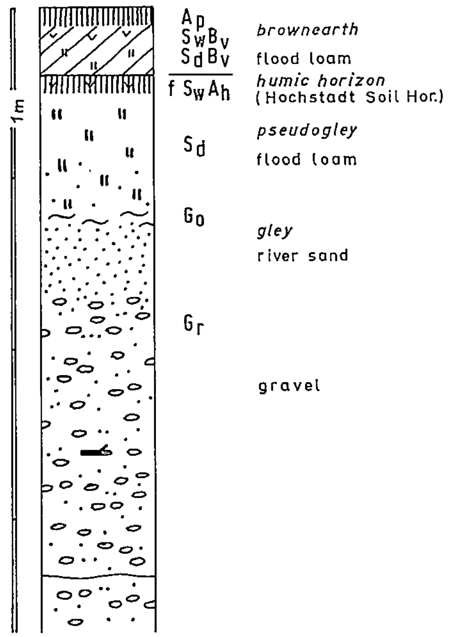


Fig. 11. Generalized section of the Iron-Roman Age gravel layer at Trieb and Hochstadt. Legend see Fig. 7.

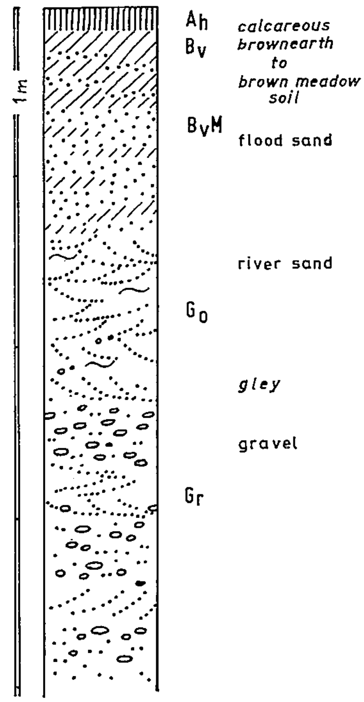


Fig. 12. Section of a Late Middle Ages gravel layer at Viereth. Legend see Fig. 7.

17 and 18 (Hochstadt and Trieb) it attained a thickness of up to 3 m above the Würmian gravel (Fig. 11). By datings of several *Rannen,* which all belong to the Main 1 chronology, a minimum time-span from 220 B.C. until 130 A.D. can be given for the gravel accumulation. In narrower valley sections of the Main, such as that above the mouth of the River Rodach, this gravel covers almost the entire width of the present-day valley. By dating the *Rannen* spread out over a larger area within this gravel it was possible to reconstruct the shifting of the river within the valley (see below).

The Iron-Roman Age gravel body is completed by an approximately 1.5–2 m thick flood loam deposit upon which a weak brown-earth has developed. A buried humus horizon (Hochstadt Soil Horizon) indicates the upper limit of this soil. It is covered by later flood loams. ^{14}C-determinations of the Hochstadt Soil Horizon obtained from charcoal which came from the deeper parts of the humic horizon (Hv 5564: 1440 ± 115 a B.P.), as well as from roots of this soil (Hv 5559: 1285 ± 130, Hv 4279: 1225 ± 85 a, Hv 4691: 1170 ± 60), spread over a period from 400–840 A.D., thus pointing in the main to the Early Middle Ages (Schirmer 1977).

A gravel redeposition dated, however, dendrochronologically by *Rannen* finds of the Main 8 chronology obviously must have occurred in the same span of time. As a spatial relationship of this trunk deposit to the Hochstadt Soil Horizon has not as yet been established and as considerable deviations possibly exist between tree-ring and radiocarbon ages, the exact time-relationship of the Hochstadt Soil Horizon and the Early Middle Ages trunk layer must still remain open.

The latest large gravel accumulation can be attributed to the main Middle Ages up to early Modern Times. So far as observations were possible, the base of this gravel layer which extends up to 4 m in thickness is always cut into older Holocene gravels, but never in Würmian gravel. The Middle Ages gravel contains no *Rannen*. However, ceramic finds (in some cases glazed), tools, and other culture finds provide datings as well as ^{14}C-data of wood remains ranging in time from approx. 1000 to approx. 1500 A.D. In addition, tree-ring data of gravel-covered oak pile constructions with cutting-dates from between 1205 and 1590 A.D. (Becker & Schirmer, in prep.) give evidence for the phase of deposition of this gravel.

The Middle Age gravel is overlaid by a flood loam which covers the valley plain to a great extent and even covers the flood plain of the Early Holocene (see Schirmer 1977). The soil on this flood loam is developed as an allochthonous brown soil with transitional features of an autochthonous soil formation of the brown-earth type (see Fig. 12). A young high-water bed has formed as a margin near the river that lies on average 2–3 m below the Holocene flood plains described so far. A gravel bed, shallow-situated, lies in its underground up to 1 m in thickness overlaying older Holocene gravels. This gravel contains cultural remains from the 19th century as well as examples of *Dreissena polymorpha* (Pallas), a shell that migrated into the Main in the previous century, showing therefore the young age of this deposit (see Schirmer 1977).

Survey of the Main valley development during the Holocene

Fig. 13 shows diagrammatically the development of the Holocene valley on the Upper- and Middle Main. The figure reveals that during the Holocene, periods of relatively fluviatile inactivity alternated with periods of increased fluviatile material redeposition.

The river activity of the ending Late Glacial stabilized during the Holocene. This is expressed by the formation of a pseudo-chernozem (Trieb Soil) upon the Early Holocene flood plain. From the Boreal Period onwards, oak trees near the river banks were eroded and deposited as *Rannen*. The significance of the Early Holocene trunk deposits in respect to the valley history of the Boreal and Early Atlantic cannot exactly be estimated from the present geological findings. After a strong gravel redeposition assignable to the Middle Atlantic Period, the geological findings indicate a relatively undisturbed valley development during the second half of the Atlantic. *Rannen* layers from this period are unknown.

From the beginning of the Subboreal the available findings show a continuously shortening rhythm of increased and reduced lateral erosion and gravel redeposition. Stronger redeposition tendencies occur during the Subboreal up to the Early Bronze Age, and during the Iron and Roman Age.

Whereas Early Middle Age-dated *Rannen* have not yet been connected with gravel deposits, widespread Middle Age gravel deposits and smaller Modern Age sediments could be followed in many sections along the valley.

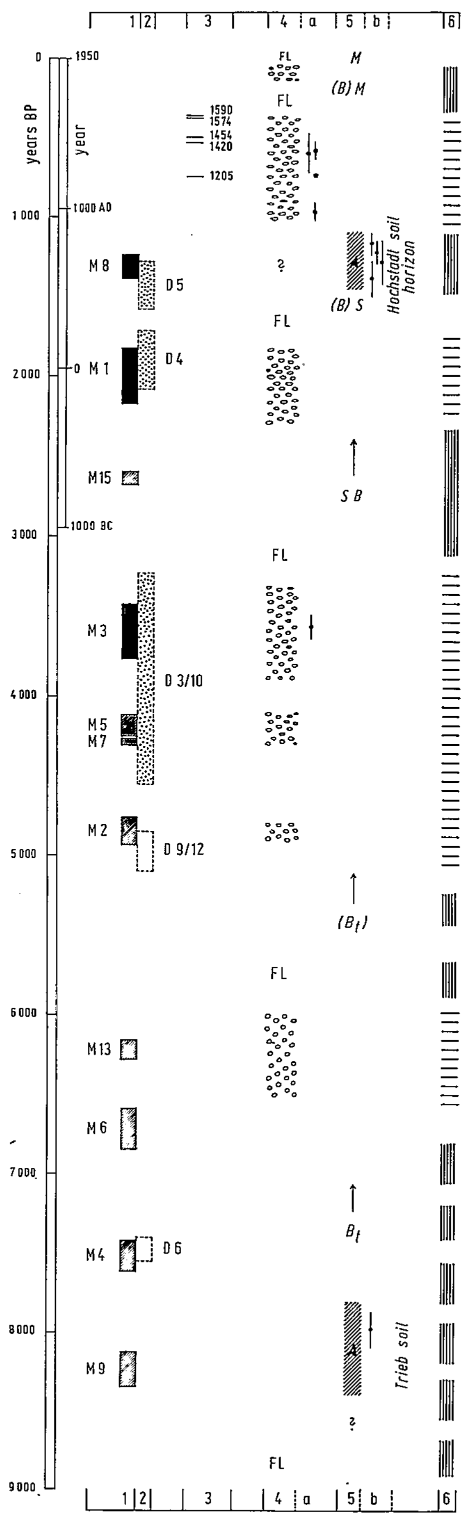
Detailed findings concerning the *Rannen* deposition and gravel accumulation

Tree-ring data interpretation from subfossil trunk layers applied to fluviatile processes

The tree-ring investigations of *Rannen* must in most cases be carried out on trunks which have been dredged out of the ground-water during gravel quarrying. Their original position within the gravel is therefore largely unknown. As already mentioned, in several exposures of the Upper Main valley the ground-water is lowered to the gravel base for gravel quarrying. In such exposures we could saw off a greater number of trees in situ, and by means of their tree-ring processing, we could obtain data concerning the stratigraphy and the formation of the Holocene valley sediments.

The transfer of the tree-ring data onto the spatiotemporal course of the gravel formation imposes the prerequisite that one can largely exclude the reworking of older trunks and their redeposition in younger gravel bodies. We examined this question in three gravel pits of the Upper Main valley (No. 11, 17, 18, Table 1), in which trunk-bearing faces of the Iron-Roman Age gravel, in some cases more than 100 m in length, are exposed down to the Würmian base. After four years of observation, no remains of older trunk-bearing Holocene gravel could be found anywhere in these pits. During this period the attempt was made to sample the dredged out *Rannen* as completely as possible. The evaluation of the findings gave the following result:

From the 54 tree cross-sections examined, 24 were cross-dated with the Iron-Roman Age *Rannen* layer (M1). From the remaining trunks



not a single sample could be correlated with the other tree-ring series from the Main. In consequence, during the course of the four year exploitation in the three exposures, no reworked tree was found. The non-cross-dated trunks represent the portion of samples within a *Rannen* layer that cannot be further processed because the number of growth rings for significant correlation lies either on or under the necessary limit (less than 100 tree-rings).

The probability of a renewed accumulation of *Rannen* that were exposed by erosion is likely to be very small. The depositing of uprooted trees, which for example one can see today on the River Isar in the 'Pupplinger Au' after pronounced high-water, occurs because following the recession of high-water, the trees are caught up on flat gravel banks or in shallow channels. Thereby the roots and larger branches which are buried quickly by underwashing, function as an anchor, with the result

Fig. 13. Diagram of Holocene valley development of the River Main.

Column 1

Black signature: felling dates of tree trunk layers Main 1 and 8 (dendrochronologically dated), Main 3 (corrected ^{14}C-age).

Hatched signature: felling dates of the tree trunk layers left (uncorrected ^{14}C-ages).

Column 2

Spotted signature: felling dates of the tree trunk layers Danube 4 and 5 (dendrochronologically dated), Danube 3/10 (corrected ^{14}C-age).

White signature: felling dates of the Danubian synchronous tree trunk layers left (uncorrected ^{14}C-ages).

Column 3

Felling dates of wood of pile constructions on the Main.

Column 4

Gravel bodies on the Main.

Fl=flood-loam sedimentation.
a =^{14}C-ages concerning the gravels.

Column 5

A =A_h-horizon; b=^{14}C-ages concerning the A_h-horizon. Soil development.

B =B_v-horizon; ( )=weakly developed.
B_t=B-horizon with clay illuviation; ( )=initial type.
S =Pseudogley.
M=Alluvial soil.

Column 6

Horizontal lines: periods of dominating fluvial activity.
Vertical lines: periods without remarkable fluvial activity.