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EVOLUTION OF THE FLOODPLAIN LEVELS OF THE DANUBE AND THEIR PRINCIPAL BEARINGS ON THE GEOGRAPHY OF AGRICULTURE

Institute of Geography of the Hungarian Academy of Sciences

Theoretical and Methodological Problems No 8.

Budapest
1966

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Most of the middle basin of the Danube is occupied by the alluvial plains of the Danube, the Tisza and their tributaries. On the vast former floodplains along the rivers there flourishes an intensive agriculture. In the course of evolution of the economic activity of human society, it was along the rivers that society influenced earliest and most profoundly upon the evolution of a natural landscape. The floodplain is one of the most active zones of the relief, owing to repeated inundations, catastrophic floods, rapid displacement and effacement of the river beds. Active natural processes and progressive human activity tend to accelerate landscape evolution in the intrazonal regions of the floodplains. The present-day level of organization of society requires that these causes underlying the rapid changes, natural and human, be disclosed one by one in their interactions as well.

In the course of the physiographic study of the Hungarian section of the Danube valley we have closely scrutinized also the natural evolution of the floodplain levels, the natural laws by which the process is governed, as well as the principal consequences of flood control, river regulation and agricultural influence (Pécsi 1959, Somogyi 1960). Lack of space forbids, however, to enumerate here more than the most general results of these studies.

Constitution and evolution of the floodplain levels
of the Danube

The Hungarian section of the Danube, longer than 400 kilometres, is accompanied on both sides by a floodplain, narrow locally, but fairly broad, in general. Thin floodplain can be divided into three easily distinguished types (Pécsi 1959):

1. The vast alluvial fan of the Danube in the Little Hungarian Plains (floodplain of deposition).

2. The intramontane section of the Danube in the Hungarian Mountains (valley and meander terraces – a largely erosional floodplain).

3. The Danube section of the Great Hungarian Plains, where alluvial fans and floodplains with meander terraces are interwoven in space and time (rhythmical erosional-depositional floodplain).

1. – The alluvial fan of the Danube in the Little Hungarian Plains hardly differs from its surroundings, as it has coalesced with the floodplains of the tributaries. The slope of the floodplain surface is greatest here in the entire Hungarian section (about 20 to 40 cm per kilometre). Before flood control, this part of the alluvial fan frequently witnessed displacements of the main Danube bed, shifts in flow direction, meanderings of lateral branches, formation of new branches and filling up of old ones. As a result of these processes, the floodplain is crisscrossed by more or less fully filled or waterlogged oxbows, depressions limited by natural levees, etc.

This is the typical relief of the so-called low floodplain, which is in its turn overtopped by 1 to 2.5 metres by the so-called high floodplain level of the alluvial fan. In the Little Plains section the high floodplain does not exceed the zero level of the river by more than 5 to 6 metres, i.e. it is inundated by the highest waters of the greatest floods. The seasonally repeated medium-high floods cause a rapid minerogenetic filling (silting up) of the depressions of the low floodplain level, whereas farther off the main bed the organogenic filling of derelict beds is also encountered. In the river beds themselves one finds a filling of sand and gravel, whereas the flood covering the entire floodplain spreads a cover of 0.5 to 1.5 m of sandy loessy silt. (Fig. 1).

The beginnings of the evolution of the alluvial fan in the Little Plains date back to the Pleistocene (Riss glacial phase). Holocene and late Pleistocene deposits, largely of gravel, are encountered in superposition as well as in lateral succession. (Fig. 2). The ancient riverbeds filled with silt and clay, penetrating into the sandy and gravelly body of the floodplain to a depth of 1 to 2.5 m, may considerably influence the movement of ground water. Namely, the level of the river between the levees may for protracted periods be as high as, or higher than the floodplain level beyond the levees. In such cases the gravelly and sandy base of the floodplain becomes saturated with high-pressure ground water and in places where the silty cover above the aquifer is thin (mostly on the flanks of the oxbows dissecting the surface), there are upsurges of water and the depressions and oxbows get filled. (Fig. 3). Underseepage in the aquifers under the levees has already resulted in catastrophic inundations of the protected areas.

2.- In the intramontane section, the second type of floodplain is characterized by narrow meander terraces or terrace isles formed by the resection of meanders. In these sections the low floodplain level tends to be incorporated in the present-day bed, and the high floodplain level is preserved but in the form of fairly narrow sickle-shaped rags. The floodplain levels are sharply terminated by the flank of the first terrace above flood level. (Fig. 4).

Fig. 4 shows the floodplain to be dominated by erosion, with the bases and surfaces, respectively, of the floodplain levels being incised below the first terrace above flood level. Both the latest Pleistocene (II/a) and early Holocene (I) terrace constitute low steps above the present day high floodplain level, while in the case of the floodplain of deposition the river-laid deposits occur in the normal, stratigraphic succession, or at most beside each other. The narrow intramontane floodplains are covered in their entirety by the highest floods, but the recession of the floods is also much more rapid than in the foregoing case.

3.- From a morphogenetic point of view, the third type of floodplain characterizes the Danube section in the Great Hungarian Plains. It is essentially a combination of the above two types in space and time. South of Budapest, the erosional-depositional floodplain in the Great Plains reaches over into Jugoslavia, having an overall length of more than 200 km and an average width of 25 to 30 km. The Great Plains type of floodplain bears in the broader vicinity of Budapest elongate isles flanked by living and dammed-up river branches. These isles bear in their turn late Pleistocene terrace isles. The marginal band of the floodplain likewise has a fringe of late Pleistocene terraces. At the same time there occur Holocene deposits also in the alluvial-fan type of succession, that is, above or beside the late Pleistocene deposits. A schematic profile of the Danube floodplain in the northern reaches of the Great Plains is given as Fig. 5. Among the relief forms of the floodplain, one encounters besides those described under 1 - also numerous shallow but spacious oval depressions.

In the broad floodplain of the Danube in the Great Plains one may observe among others a type of parameander which is not a product of the meandering of the former Danube beds. Locally this form is called a "vein"; it is a channel which conducted the flood waters of the river towards the deeper, marginal regions of the floodplain. The beds of these meandering "veins" are flanked by narrow levees standing out 2 to 3 metres above the mean level of the low floodplain. (Fig. 6). The parameanders crisscrossing the floodplain constitute a honeycomb structure of ill-drained or drainageless flat basin-shaped depressions. In them, temporary salt and soda lakes came to existence in the times before flood control. Their drainage frequently left over flats covered with salty or alkali soils or poor quality meagre swampy meadows. Their intensive utilization is contingent upon up-to-date methods of soil amelioration and ground-water control.

In the southern part of the Great Plains, floods of the Danube as high as 8 to 10 m were fairly frequent in the olden time and may still have considerable duration. Deposition of suspended load was intense all over the floodplain, now being restricted to the zone between the levees. The relief of the floodplain is fairly smooth, although most of it was repeatedly reworked by the river in the course of the Holocene.

Principal relationships between regime, load and constitution of the floodplain

In the before-outlined three distinctive types of floodplain the relative altitude of the low and high floodplain level, respectively, is in a close correlation with the levels of the medium, high and highest floods of the river. In the alluvial-fan type floodplain in the Little Plains, the highest level of the Danube is 5 to 6 m above zero, and so is the level of the high floodplain. In the southern part of the Great Plains, where floods of 9 to 11 metres above zero level may stay on for weeks owing to the gentle slope of the bed, the level of the high floodplain attains 9 to 10 metres above zero level. It is here that the mantle of silt and sandy silt is thickest.

The floodplain levels (improperly called floodplain terraces) of the Danube valley plain were and still are the results of erosion and deposition by the floods of various height and duration of the river. The various floodplain levels are, in consequence, essentially syngenetic forms with no substantial age difference between them, although in alluvial-fan type valley sections late Pleistocene and early Holocene deposits may occur side by side with younger sediment, and the older formations may have been repeatedly reworked in the course of the divagations of the river.

A detailed analysis of the riverbed profiles and of the geological profiles across the floodplain permitted to draw certain conclusions of fairly general validity as to the mechanics and nature of deposition in the floodplain. In its actual bed, the Danube erodes kettle-shaped depressions having a maximum depth of 8 to 10 metres below zero level, only to fill them up with sediment at a subsequent stage. The kettles, rhythmically spaced along the bottom of the bed, are displaced in the direction of flow. Now taking into consideration also the lateral displacement of the bed one sees how the sediments could have been reworked to a depth of about 10 metres in the whole floodplain area. The coarsest sediment was invariably deposited in the kettles proper, whereas in the bed above lowest water, the sediment became increasingly finer with the finest, suspended load having been deposited in the form of fine sand, floodplain silt and loessy silt all over the floodplain, as high as 5 to 9 metres above zero level. (In present times, high floods of the Danube tend to carry a suspended load of about 1000 g/cu. cm. Most of the mean annual amount of some 10 million cu. m of suspended load is moved in flood times, and most of it is deposited in the floodplain after the flood.) The result is a deposit, 15 to 18 metres thick, of fine sediment spread in the course of the younger part of the Holocene, when the Danube has already assumed its present regime and mechanism. (Fig. 7). The floodplain deposits of the Danube include two grain size classes. The one is the coarse gravel and sand of the deep bed and of the kettles; the other is the finer sand and silt of the shoal parts of the bed and of the floodplain proper.

This general outline of the floodplain profile may locally be substantially complicated by an involved network of filled-up dead branches and oxbows, as has been illustrated on Fig. 7.

Evolution of the floodplain levels and its relations to society

The regulation of the Danube, the flood control works and levees have had a double influence on the evolution of the floodplain. Firstly, the floods have been contained in a narrow zone and thus given the possibility of a more rapid abatement, and the meanderings of the bed, the rapid shifts of the banks, the formation of oxbows, etc. have been checked. Thus, the seasonal activity of the river in the vast floodplain beyond the levees came to an end; the evolution of the relief has since been governed there by human influence, by pedogeny and to a smaller scale by cryogenic sedimentation. Secondly, since flood control annual high waters, mostly of considerable duration, have largely enhanced the modelling activity of the river in the flood zone between the levees. In the extreme, this may have resulted in serious underseepage, saturation of the levees, upsurges of water beyond the levees and formation of waterlogged depressions which in their turn have influenced the evolution of vegetal associations and soils in the former floodplain. Since the flow is quicker, particularly at times of flood, the quantity

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of minerogenic sediment deposited in the flood zone is less than before. Nevertheless, the depressions of the meanders dammed up naturally or artificially between the levees are very rapidly being filled up by silt owing to frequent inundations by muddy waters. Although this process started hardly more than a century ago, it has reached - as proved by the scrutiny of ancient maps and by observations in the field - widely different stages in different places.

1. Artificially dammed-up meanders, communicating by underseepage with the main bed. Intense mineral and organic sedimentation generally results in considerable reduction of the ancient bed, with parts of it being laid dry at low water, in spite of the existing morphological and hydrogeographic link with the main bed. Type of the "living" oxbow lake (Fig. 8).

2. In the course of sedimentation, stagnant oxbow lakes may have developed in the beds of ancient meanders. In them, the reed-and-sedge associations may flourish so much as to cover up all the water surface, ib which case the marsh stage sets in (Fig. 9).

3. Dry meanders, isolated from the main bed, have generally completely been swamped by floodplain vegetation and have largely been incorporated in the low floodplain level. Morphologic links with the actual main bed are very scarce (Fig. 10).

4. Filled-up dry parameanders. In the course of evolution of the meanders, the main meanders left behind arcuate bands of lateral meanders. The filling up of these has reached a stage when all that is left of them is a gentle arcuate depression a few metres across. Beyond the leveees, where these depressions have even more thoroughly been levelled by agriculture, their existence is only proved by the elevation of the ground water table or by peculiar colourations of the soil as seen on aerial photos.

5. The type of swampy meanders far off the main bed is the result of a different process of evolution. In those reaches where the floodplain is sufficiently broad so that most of the suspended load is deposited at times of flood close to the main bed, the vicinity of the bed is elevated against the marginal parts of the floodplain. In this case there may occur swamp-covered meanders and depressions along the margins of the flood area. In them, meadow and swamp type soils are formed under the influence of a marsh and swamp vegetation. This process is most typical beyond the levees, in the cut-off meanders

and long dead branches far off the main bed (Fig. 6).

The larger part of the floodplain is situated to-day outside the levees, where flood control has slowed down the natural filling up of meanders and straight lateral branches and thus preserved their outlines. As the groundwater movement in the floodplain area has also substantially been affected by flood control, most meanders, etc. have dried up much sooner than would have been the case within the levees. The natural evolution outlined in the above points did not take place beyond the levees except in the large meanders or lateral branches which are seasonally filled with stagnant waters (Fig. 11). Oxbow lakes outside the zone of inundations are fairly rare nowadays. Most of the meanders in such positions have been invaded by agriculture. This has put an end to their natural evolution, substituting it by a man-controled process. However, in order to correctly plan and carry out this transformation of nature in the present and in the future, the teachings of the process of natural evolution must constantly be kept in mind.

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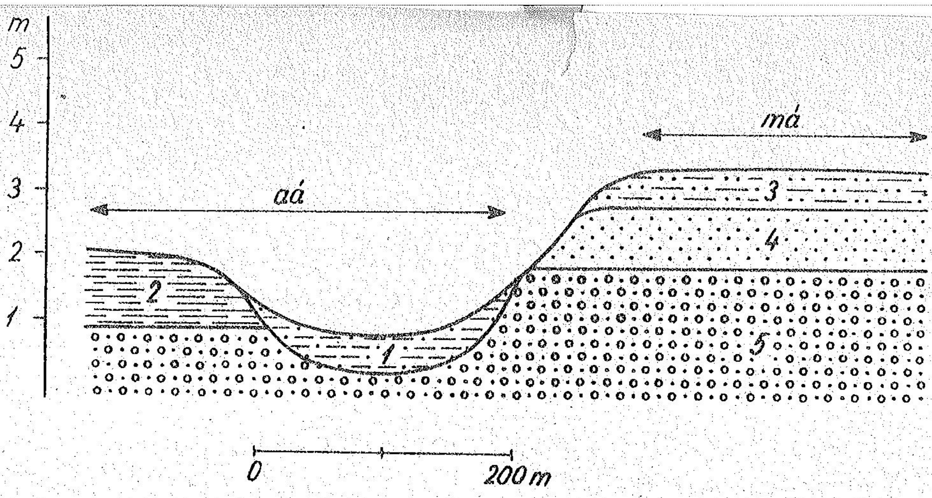

Fig. 1 Structure of the low and high floodplain.

1 - grey sandy silt, 2 - yellowish grey silty clay, 3 - yellow sandy silt, locally clayey, 4 - fluvial sand, 5 - fluvial gravel, sandy gravel; aá - low floodplain, má - high floodplain.

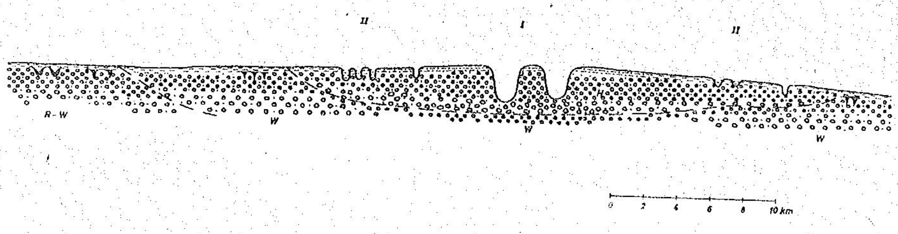

Fig. 2 Sketch profile of the floodplain-level alluvial fans of the Danube in the Little Hungarian Plains.

I - main beds with shoals, superimposed under the influence of the regular inundations of their surroundings; II - meandering lateral beds, H - Recent gravel - alluvial fan redeposited by the meandering beds, W - Würm gravel, with traces of cryoturbation, R-W - gravel of the Riss and of the Riss-Würm interglacial with younger and older forms of cryoturbation.

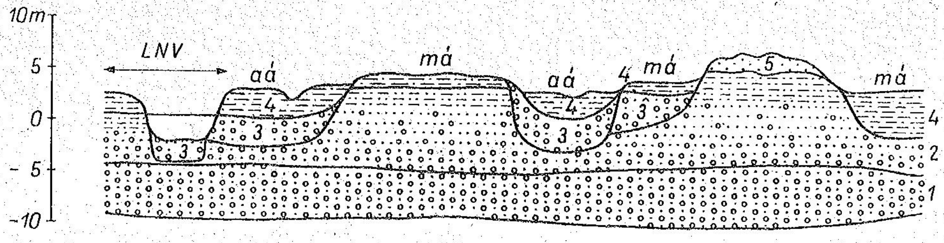

Fig. 3 Type of the floodplain level in the subsiding sections and on the alluvial fan.

1 - late Pleistocene gravel and sand, 2 - early Holocene gravel, 3 - young Holocene riverlaid deposit, 4 - floodplain silt, silty sand, 5 - wind-blown sand, riverbank dune; aá - low floodplain, má - high floodplain, LNV - level of highest floods.

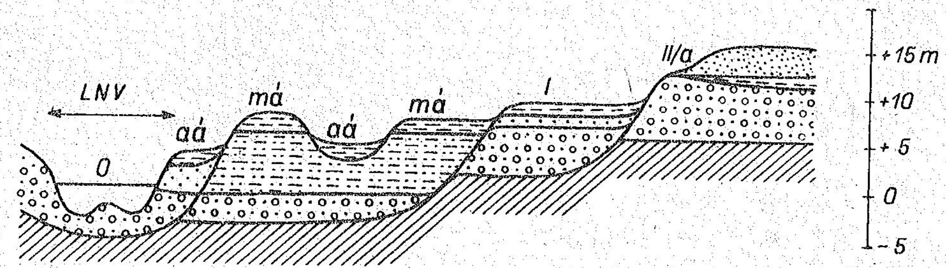

Fig. 4 Floodplain levels and low terraces in the mountainous sections of the river valley.

LNV - level of highest floods, aá - low floodplain level, má - high floodplain level; I - early Holocene terrace (first terrace above flood level); II/a - terrace formed at the end of the late Pleistocene.

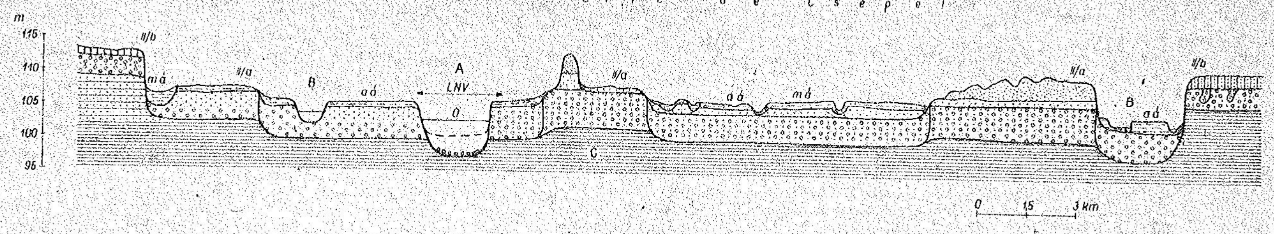

Fig. 5 Type of the floodplain levels of the Danube south of Budapest.

aá - low floodplain level, má - high floodplain level, LNV - level of highest floods, A - main bed of Danube, B - oxbow of Danube, C - Pliocene clay; II/a - terrace of the end of the late Pleistocene; II/b - Würm terrace.

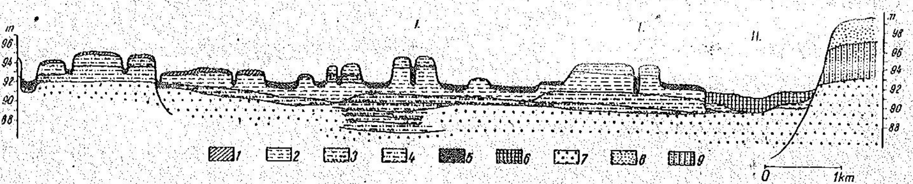

Fig. 6 Type of river flats with alkali soils surrounded by parameander levees in the floodplain of the Danube in the Great Hungarian Plains.

I - parameanders and their natural levees; má - high floodplain level, aá - low floodplain level; II - oxbow near the margin of the floodplain, filled with turf and covered by a swamp vegetation; 1 - meadow soil, 2 - river-laid loessy silt, pale yellow, 3 - sandy loessy silt, pale yellow, 4 - silty sand, 5 - swamp clay, meadow clay, salt and soda clay, clayey soil, 6 - peat, muck, 7 - fluvial sand, 8 - wind-borne sand, 9 - loessy sand, sandy loess.

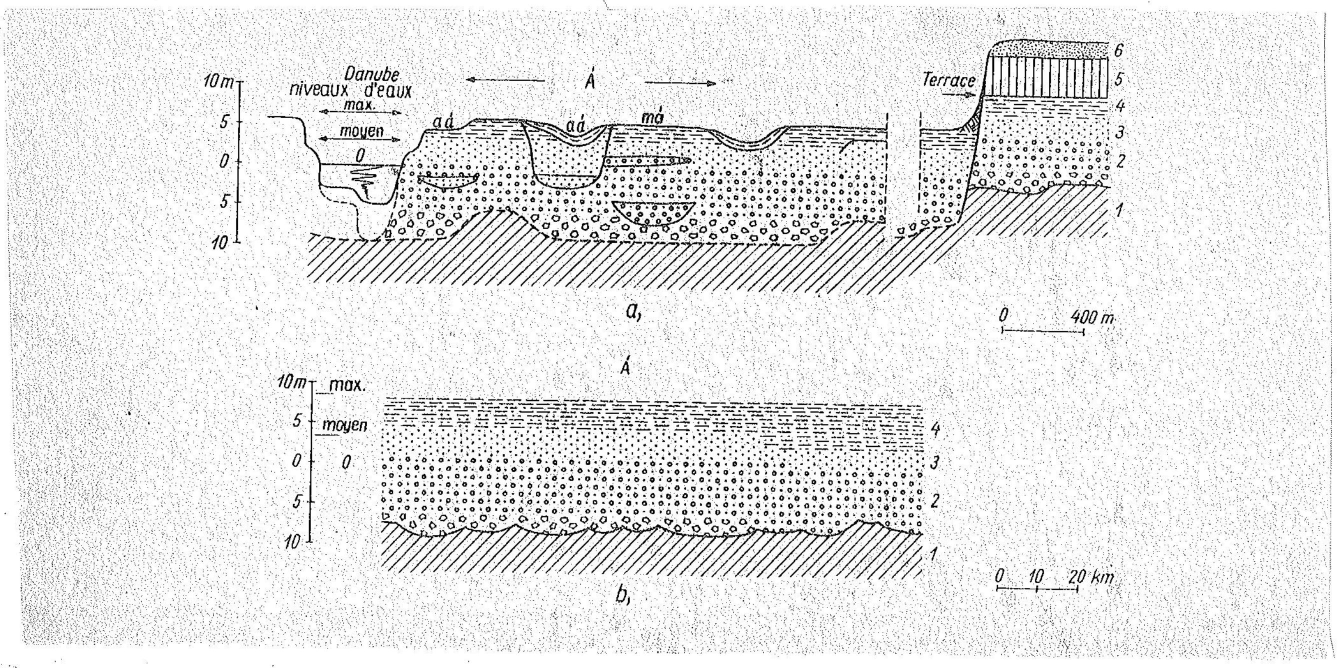

Fig. 7 Sketch profile of the floodplain deposits of the Danube.

a - longitudinal section of the bed, b - cross section of the bed; 1 - bedrock, 2 - graded gravelly deposit, passing into finer varieties upward, 3 - fluvial sand, 4 - fluvial sandy silt, silt, some clay, 5 - loess, 6 - wind-blown sand; Á - floodplain, aá - low floodplain, má - high floodplain, LNV - level of highest floods, KÖV - mean water level, 0 - zero water level.

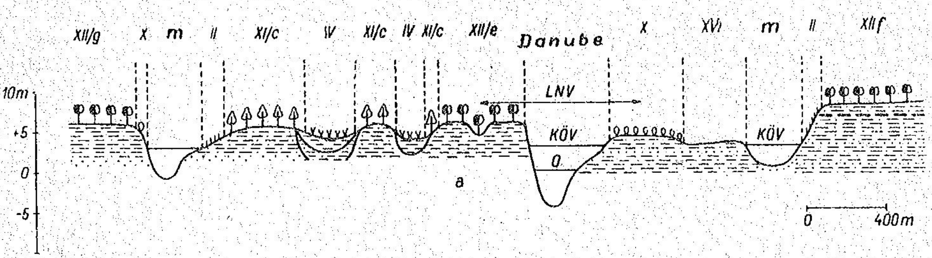

Fig. 8 Filling up of an artificially dammed-up meander within the levees.

m - oxbows connected by ground water to the river, R - meadow soil buried by floodplain silt; II - convex bank, rapidly silting up, Nanocyperion level of the low floodplain; IV - ephemeral oxbow lake, levels of Caricetum acutiformis ripariae and Scirpeto Phragmitetum; X - level of Salicetum triandrae; XI - of salicetum albae fragilis; XII - high floodplain covered by the vegetal association of Ulmetum hungaricum.

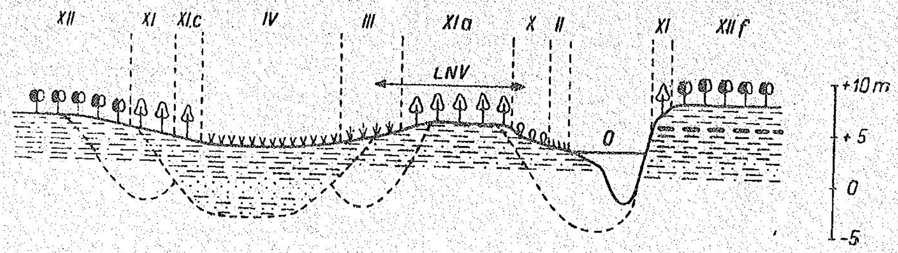

Fig. 9 Isolated oxbow lake and the swampy state of its filling up.
O - isolated oxbow.

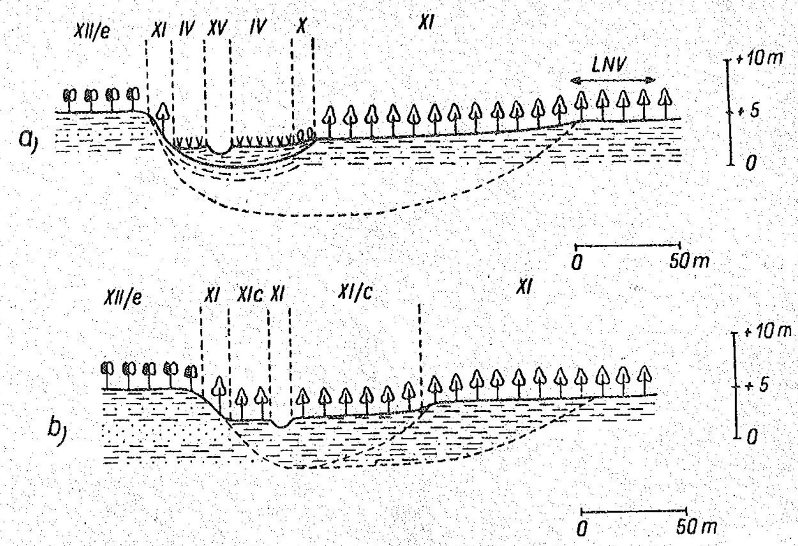

Fig. 10 Type of isolated dry oxbow.

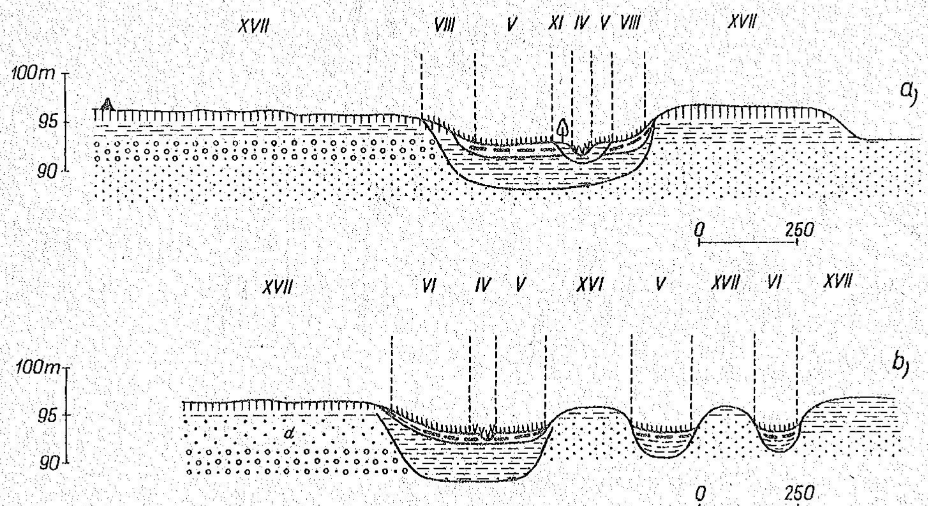

Fig. 11 Phases of the filling up of isolated oxbows and meanders outside the flood-control levees.

a - dry meander, occasionally covered with filtrating waters,
b - dry meander and minor parameanders covered by humid meadows, locally also by salt and soda flats, some of them tilled.

To Figs. 9 - 10 - 11

II - level of Nanocyperion
III- Caricetum acutiformis-ripariae, ephemeral or permanent swamps
IV - Caricetum acutiformis-ripariae level
V - swamp meadow (Agrostidetum)
VI - humid meadow (Festucetum pratensis)
VIII - green pastureland (Loliate-Cynodontetum)
X - Salicetum triandrae (willow shrub) zone
XI - Salicetum albae fragilis zone
XII- Querceto-Ulmetum hungaricum zone
XV - periodically water-covered area