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Sedimentology and geomorphology of overbank flows on meandering river floodplains

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ABSTRACT

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Along floodplains there occurs an ordered sequence of geomorphic events during floods. The following sequence occurs for individual flood events: (1) the rise of floodwater and of groundwater, (2) the inundation of the floodplain; (3a) adjustments of the overbank flow pattern to the floodplain environment; (3b) the flood peak; (4) the initial fall of floodwaters and changes in the overbank flow pattern; (5) a gradual cessation of the overbank flow; (6a) infiltration, evaporation and a wave-like motion of stagnant water; and (6b) postflood transformation under subaerial conditions. Field observations support this model for meandering rivers in the Polish Lowland.

Introduction

It is generally accepted that coarser channel deposits (lateral accretion deposits) and finer overbank deposits (vertical accretion deposits) participate in floodplain construction. It is difficult to state, in general, which of the two types of deposits dominates in floodplain sedimentary environments because varying climatological and physiographical factors determine the frequency and magnitude of overbank floods (Baker, 1977). Present-day surfaces of a floodplain are of course modified by overbank flows, causing vertical accretion of overbank deposits, and thus a general rising of the surface (Klimek, 1973; Wolman and Leopold, 1957). However, there is an apparent discrepancy between the horizontal energy distribution and deposit delivery within a floodplain (Lewin, 1978), and the erosional and depositional effects of overbank flows measured vertically.

Many recent papers point out the importance of overbank deposits in the construction of a floodplain (e.g., Blake and Ollier, 1971; Gomez and Sims, 1981; Lewin, 1981; Nanson and Young, 1981; Stene, 1980; Zwoliński, 1985a). Overbank deposits are most abundant in the middle and lower reaches of rivers. The main reasons for enhanced overbank sedimentation in these locations are: decreasing river slope, slow lateral movement of channels, rising baselevel, high frequency and magnitude of overbank flows, and human activity. The first three are connected with the general tendencies of such rivers (Bridge and Leeder, 1979; Kozarski and Rotnicki, 1977, 1978; Leopold et al., 1964; Schumm, 1977).

General descriptions of the floodplain environment, including vertical accretion processes, so far are rather general (Allen, 1965, 1970; Collinson, 1978; Gradziński et al., 1976; Happ, 1971; Knighton, 1984; Leopold et al., 1964; Lewin, 1978; Pettijohn et al., 1972; Reineck and Singh, 1973; Selley, 1976; Schumm, 1977; Schanzer, 1965; and Walker and Cant,

TABLE 1

Comparison of flood phases according to various sourses

<table>
<tr><th>SOURCE</th><th colspan="12">FLOOD PHASES</th></tr>
<tr><td rowspan="2">MCKEE ET AL. (1967); INTERMITTENT BIJOU CREEK</td><td colspan="8" rowspan="2">1. Phase of rapid flow;
horizontal stratification characteristic of the upper stream regime</td><td colspan="4">2. Waning phase</td></tr>
<tr><td>2a. Climbing ripple lamination, convolute structures, festoon bedding, scour surfaces</td><td colspan="3">2b. Receding waters may rework coarse sediments deposited earlier</td></tr>
<tr><td>ALLEN (1970); MEANDERING RIVERS MODEL</td><td colspan="4">1. Spilling of flood water from the main channel into empty flood-basins</td><td colspan="4">2. Filling up of flood-basins to a stage where sustained flow down the floodplain is possible</td><td colspan="2">3. Emptying of flood-basins</td><td colspan="2">4. Drying out of flood basins and modification of the newly deposited sediment</td></tr>
<tr><td>GUPTA AND FOX (1974); MEANDERING PAIUXENI RIVER</td><td colspan="2">1. Rapid rise of floodwaters</td><td colspan="6">2. Floodwaters overtop banks and adopt a straighter course</td><td colspan="2">3. Floodwaters return to the channel</td><td colspan="2">4. Low-flow stage</td></tr>
<tr><td rowspan="2">BAY (1976); POINT BAR; MEANDERING MISSISSIPPI RIVER</td><td colspan="7">1. Rising phase</td><td rowspan="2">2. Phase of maximum velocities; horizontal lamination</td><td colspan="2" rowspan="2">3. Waning phase;
trough cross-stratification</td><td colspan="2" rowspan="2">4. End phase;
clay drapes;
parallel lamination</td></tr>
<tr><td colspan="6">1a. Ripple drift lamination</td><td>1b. Convolute lamination</td></tr>
<tr><td>LEWIN ET AL. (1979); LEWIN AND HUGHES (1980); QUALITATIVE MODEL; DYVI, SENCE AND TEIFI RIVERS</td><td>1. Low water channel</td><td>2. Unvegetated bars and secondary channels</td><td>3. Groundwater rise and areas directly connected to channel via bank breaches</td><td>4. Higher parts of bars and breaches feeding more low relief areas</td><td>5. Bankfull promotes more rapid filling by overbank spilling and slows down the rate of stage rise in the channel</td><td>6. Internal transfer processes extendings area of inundation</td><td>7. Floodplain filling; ponds begin to deepen rather than extend</td><td>8. Whole valley flooded; further increments lead to higher flow velocities and depths</td><td>9. River stage falling allowing overbank returns</td><td>10. Once below bankfull rate of recession depends on the efficiency of transfer processes and ebb channels to empty floodplain</td><td colspan="2">11. Isolated disconnected ponds left in topograpic lows to dry by infiltration and evaporation</td></tr>
<tr><td>ZWOLINSKI (1985); LOWLAND MEANDERING PARSĘTA RIVER</td><td colspan="4">1. Inundation of the floodplain</td><td colspan="4">2. Adjustments of the flow pattern to the floodplain morphology;
flood peak</td><td>3. Initial fall in water level and discharge; changes in adjustments to the flow pattern</td><td>4. Gradual recession of flow on the floodplain</td><td>5a. Decantation in depressions</td><td>5b. Postflood transformation of sediments & forms</td></tr>
<tr><td>THIS PAPER; LOWLAND MEANDERING RIVERS</td><td colspan="2">1. Channel- and groundwaters rise; erosive modification of floodplain edges (bank erosion)</td><td colspan="2">2. Inundation of the floodplain; erosion and redeposition of older sediments; accretion of counterpoint bars, natural levees and meander sand covers</td><td colspan="3">3a. Adjustments of the overbank flow pattern to the floodplain environment (morphology, vegetation, etc.); erosion wanes; transport remains dominant; accretion and deposition of many facies; counterpoint bars, redeposited older terrace deposits, natural levees, meander sand covers, crevasse splays, terrace channels, terrace ribbons, sand shadows, deltaic & alluvial cones, meander scroll ridges, oxbow-lakes & swamps, slack water deposits</td><td>3b. Flood peak; erosion on the decline; wide-spread transport; total sedimentation in many forms</td><td>4. Initial fall of floodwaters; changes in the overbank flow pattern; decay of erosion; transport undergoes reduction; maximum intensity of deposition</td><td>5. Gradual cessation of floodwaters; transport ceases with time; final deposition; erosive modification of the newly-deposited forms</td><td colspan="2">6. Qualitative changes in hydrological & geomorphic processes
6a. Decantation & wave-like motion of stagnant waters in depressions
6b. Post-flood transformation in subaeral conditions</td></tr>
</table>

1979). These give only the basic outline of the morphological and the sedimentary nature of floodplains. On the other hand there has recently appeared a number of papers describing various details from the valley floor. A review of these publications may be found elsewhere (Zwoliński, 1986a). It seems necessary now to determine in more detail the depositional environment of this important fragment of the fluvial system.

The purpose of this paper is to present a possibly widely applicable morphological and sedimentary classification of vertical accretion deposits which accumulate along a floodplain. The basic research was carried out in 1979–1982 in the Parsęta River drainage basin. It included observations of overbank flows, geomorphological mapping, deposit sampling for laboratory analyses, and investigation of sedimentary structures. Detailed results of the study have been published in earlier papers (Gonera et al., 1985; Zwoliński, 1980, 1982, 1985a,b, 1986b,c). The recognized regularities have been verified also on other rivers in northwest Poland.

Previous models

The first synthesis was given by Allen (1970) who distinguished four stages in the flood cycle of meandering rivers. Separate outlines were also presented by Gupta and Fox (1974), Lewin et al. (1979), Lewin and Hughes (1980), and Zwoliński (1985a). Among the models now presented in Table 1, the flood inundation model is most significant here. It was proposed by Lewin and co-workers to describe different floods and different types of floodplains. In this model, flood phases from five to seven are considered to be separate. This assumption seems to have been made in haste as according to the observations made on the Parsęta River; these three phases occur simultaneously with the inundation period, overlapping both in time and space. Nevertheless, the precisely defined hydrological assumptions of this model (see also Hughes, 1980) make it adequate for extension by morphological and sedimentological features.

For comparison, Table 1 is augmented by two classifications of flood phases based on investigations of sedimentary structures of overbank deposits which are given by McKee et al. (1967)* and Ray (1976). Ray's phases correspond particularly well with both our empirical and theoretical results. However, it should be stressed that the description of the stages determined on the basis only of sedimentary structures is practically useless as far as the floodplain morphology is concerned. The models presented in Table 1 reveal one strong common characteristic; there do occur substantial morphogenetic changes during subsequent flood phases. These changes, caused by climato-hydrological factors, are reflected in the functioning of geomorphic processes, whose morphological and sedimentary implications are seen in form and deposit records, made during the flood wave, when it is falling and after total cessation of flowing waters on the floodplain.

Overbank deposition on floodplains

Hydrological analyses of observed overbank flows, as well as geomorphic processes and their morphological and sedimentary effects, indicate that there occurs an ordered sequence of floodplain events (Zwoliński, 1986c). This sequence is a response to the tendency of the same processes to repeat in space and time. The following sequence of hydrological and morphogenetic events occur during a flood with single peak for lowland meandering rivers in the temperate climatic zone (Fig. 1).

Phase 1: Rising of water stage and bank modification

In this phase occurs the rise of floodwater in the river channel and the associated rise of

*Although for floodplain of intermittent stream.

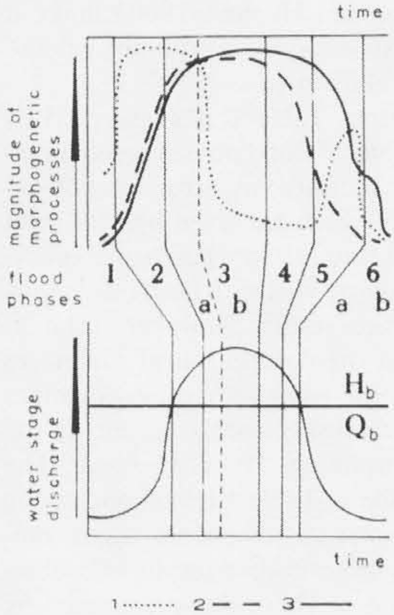

Fig. 1. Magnitude of main morphogenetic processes on a floodplain in relation to hypothetical flood phases. *1*=erosion, *2*=transport, *3*=accumulation, H_b/Q_b= bankfull stage and/or discharge.

groundwater within the floodplain. Bank erosion also occurs. The erosional processes prepare the channel banks for efficiently overflow of flood waters and conveniently transport of the alluvial material from the river channel onto the floodplain. Flood waters flow into chutes and meander scroll swales located in lower parts of the floodplain. Towards the end of this phase counterpoint deposits start accumulating on bends with low curvature ratio.

Phase 2: Floodplain inundation and initial deposition

Now occurs bankfull stage in the river channel, followed by inundation of the floodplain surface by floodwaters. Erosion takes place in breaches, crevasses and chutes. Redeposition of older terrace sediments within chutes and terrace channels also occurs. Mud balls may appear. Deposits continue to accumulate in the form of counterpoint bars. Initial deposits are delivered onto the floodplain surface. Changes occur in the transport type from suspension in the river channel to traction and/or saltation on the floodplain, but the finest particles still remain in suspension. Natural levees are built-up, especially on vegetated banks. Their sedimentary structures are not always clearly visible, but often include horizontal lamination. Meander sand covers are deposited at the upstream ends of bends. Laminar bedding of these covers can be found at large distances from the river channel. An increase of load capacity implies a decrease of the role of erosive processes.

Phase 3: Flood peaks and widespread transport and deposition

This phase is divided into two subphases (3a and 3b). At first, there occurs adjustments of the overbank flow pattern to the floodplain morphology. The role of erosion is in inverse proportion to the adjustments of the floodwaters to the floodplain environment. A gradual cessation of erosional processes and simultaneously progressive deposition takes place. Transport processes are prevailing. Crevasse splays are formed on distal ends of eroded crevasses on the outer side of natural levees. Deposits of these forms are usually of graded bedding, sometimes horizontal lamination, less frequently of small scale cross-bedding. Depending on the floodplain conductivity, jets and trickles do occur, and consequently, jets lead to the formation of terrace ribbons with a characteristic braided pattern and tripartite bedding: (1) structureless; (2) horizontally stratified (sometimes also small scale cross-bedding), and (3) structureless. Intensive deposition takes place in the terrace channels which are upholstered by fresh deposits, and consequently, they are predisposed to total transport of the next delivered deposits. There is maximum intensity of the counterpoint sedimentation.

The second subphase occurs during the precise flood peak and maximum effect of floodplain inundation. The moment of morphodynamic equilibrium between erosion, transport, and accumulation is correlated with the beginning of the flood peak. At the same time, the overbank flow pattern has finished with its organization. Almost complete cessation of erosive processes is observed. Transport over the whole floodplain surface remains dominant, especially along terrace channels, chutes, and terrace ribbons. There are favourable conditions for transportation of the largest amounts of alluvial material carried to the farthest parts of the floodplain. Proportional to increased distance from the river channel is a successive decrease of the size and amount of transported and accumulated sediment. On the floodplain fringes, slack-water deposits may be deposited. In shallow floodplain hollows are formed alluvial cones whose bottom set is of inclined bedding, and the inclination of laminations decreases towards the cone surface which is sometimes covered by a horizontally laminated set. In deeper hollows deltaic cones are accumulated. They are composed of microdelta cross-bedding deposits. Silt and clay deposits accumulate within oxbow-lakes and swamps. Occurrence of sand bodies around their borders is an evidence of sand sedimentation (sediment occlusion). Behind obstacles on the floodplain surface, such as trees or shrubs, sand shadows are created. Their length and width depend on the size of the obstacle. These forms are indicative of local current direction even if their deposits are structureless. Deposition of structureless sand deposits also occurs on the tops of meander scroll ridges. The organogenic material is incorporated in various alluvial covers. The whole flood period is advantageous for the growth of gyttia and peat. Towards the end of this phase the period of building-up of counterpoint bars draws to a close.

Phase 4: Falling of water stages and high intensity deposition

The initial fall of floodwaters causes changes in the overbank flow pattern. They are recorded as different directional sedimentary structures in top sets of alluvial deposits. Whereas the structures of bottom sets generally correspond with the longitudinal axis of the valley or the local directions of water flow, the structures of top sets indicate a transverse or oblique overbank flow in relation to the valley axis. The directions of these structures refer to overbank returns. The amount of material delivered from the river channel is decreased. The reduction of transport processes is accompanied by maximum intensity of accumulation within almost all terrace forms, and particularly within crevasse splays, alluvial and deltaic cones, sand shadows, terrace channels, chutes, oxbow-lakes and swamps. Erosion practically ceases. After the initial stage of flood water falling, evidence appears recording the highest level attained (such as plant detritus and anthropogenic refuse hanging on shrubs).

Phase 5: Cessation of overbank flow and final deposition

The gradual decline of overbank flow is a result of overbank returns and outflow via ebb channels. Quantitative changes in the operation of geomorphic processes can be seen. Transport processes undergo reduction with time as a result of the depletion of alluvial deposits able to undergo transportation, and the decrease of river power, particularly the velocity and thickness of outflowing water. Accumulation processes strongly depend on the transport activity and they are most intensive within terrace ribbons, alluvial and deltaic cones, terrace channels, chutes, meander scroll swales and meander sand covers at the downstream end of the bend. Deposition is rather intensive, but it ceases with time. Because of the quick character of sedimentation, deposits are usually structureless. Sometimes there are local examples of a small scale cross-bedding or horizontal lamination. Outflowing waters which are unloaded have erosive capacity which modify or even initiate erosion of previously deposited newly-formed alluvial covers and ebb channels. A total return of flood waters to river channel signifies the end of all geomorphic processes connected with flowing waters.

Phase 6: Post-flood transformation of overbank forms and deposits

Depending on the category of geomorphic processes, the post-flood transformation phase can be subdivided into two subphases. This division, however, is not in time terms, because these subphases can appear simultaneously in two more or less neighbouring parts of the floodplain. The first subphase comprises the morphogenetic activity of stagnant waters, the other refers to geomorphic processes taking place in subaerial conditions.

In regard to the first, stagnant water occurs in floodplain hollows and meander scroll swales, within oxbow-lakes and swamps, and in some parts of terrace channels and chutes. There, decantation of the finest mineral particles and organic matter takes place. Tranquil sedimentation of these deposits may be disturbed by water wave motion caused by wind. Erosive wave wash produces micro-cliffs and water level marks. The end of this subphase is marked by the termination of stagnant water through evaporation and infiltration. All fluctuations in the decline of these local water bodies are denoted by water level marks and rill marks.

Following these events, or coeval to them at different locations, subaerial geomorphic processes occur. These are responsible for translocations within surface layers of newly-deposited alluvium, and thus at least partial transformation of alluvial suites within the floodplain. Drying of silt deposits is associated with the appearance of mud flakes and desiccation cracks. Dried sand covers and mud veneers are easily windblown or carried away as a result of raindrops falling. The stability of those deposits is disturbed by animals crossing surfaces and/or entering the accumulative forms. Also, during a period of several weeks, upward and lateral successions of grasses and plants disturb the accumulated deposits. Man-made marks (foot traces, wheel marks) are also noticed. All these events imply disturbances in the structural pattern of flood cyclothems, especially in the surface layers.

Summary

The relative intensity of the main fluvial morphogenetic processes: erosion, transport and accumulation, depend on the distinguished flood phases (Fig. 1). The occurrence and duration of particular phases as well as the progress of the curves shown in the figure may vary. They in turn depend on the nature and course of floods. What is most striking is the crossing of the curves in phase 3 and phase 5 of the overbank flow. It follows mainly from the nature of erosive processes which are of local and little importance during the peak flow and immediately after it. The crossing of the erosion, transport and accumulation curves in flood phase 3 indicates a relatively dynamic equilibrium state of these processes. This point defines the final movement of the adjustment of the overbank flow pattern to the floodplain environment. However, the location of this point in the diagram may, of course, vary. It is linked mainly with the beginning of peak flow.

The accumulation curve, in turn, is dominant almost throughout the whole flood period. Thus, on the basis of field observations, a synopsis of the duration and intensity of sedimentation of overbank deposits in different alluvial bodies within the floodplain have been proposed (Table 2). These forms correspond to sedimentary facies distinguished according to morphogenetic criteria (Zwoliński, 1982, 1985a). The diagram shows a conspicuous domination of the deposition processes in respect to differentiation, spreading and intensity in phase 3 and phase 4. Therefore, these

TABLE 2

Duration and intensity of sedimentary processes for floodplain facies in relation to the flood phases

FACIES \ PHASES	1	2	3		4	5	6	
			3a	3b			6a	6b
Counterpoint bars	-+0	000000	000	00+	+--			
Redeposited older terrace deposits		00000	0++	+--				
Natural levees		0000	+++	+++	------			
Meander sand covers		0000	+++	+++	----++	0000--		
Terrace channels		-+	000	+++	+++000	00++-0	0+-	
Chutes		--	---	+++	000000	00+--0	0+-	
Organogenic deposits[1]		-	---	+0+	++++++	----		
Crevasse splays			000	000	0000++	--		
Terrace ribbons			000	---	----++	000++-		
Sand shadows			-+0	000	00++++	++-		
Deltaic & alluvial cones[2]			-++	000	000000	00++--	+-	
Meander scroll ridges			-+	000	+-			
Oxbow-lakes & swamps			0	000	00++++	-----0	0+-	
Slack-water deposits			-	000	00++++	----+0	000	
Meander scroll swales				---	--++++	++++00	0+-	
Decantational deposits[3]					---	++++++	000	
Post-flood transformation deposits							-+-	000

1 — PLANT DETRITUS: broken plants, boughes, twigs, cones, leaves; WHOLE FLOOD PERIOD IS CONDUCIVED TO ACCRETION OF GYTIA AND PEATS
2 — IN FLOODPLAIN HOLLOWS
3 — IN FLOODPLAIN HOLLOWS AND FLOOD-BASINS

SCALE OF INTENSITY: 000 - HIGH; +++ - MEDIUM; --- - LOW

two phases can be regarded as the most effective period of the overbank flows on a floodplain.

Discussion of some model modifications

Tresholds and system variables

The overbank formation of a floodplain operates as a system of processes of cyclic erosion and sedimentation (Lewin, 1981; Wolman, 1967). In this context, these processes can be treated as repeating geomorphic tendencies of river activity over a certain time scale. It follows that the proposed model is dependent on the activity of intrinsic thresholds (Schumm, 1977) existing in the fluvial system. Naturally, modifications in the functioning of the model are possible within the permissible range of intrinsic thresholds. The main variables causing alterations in the operation of the model are listed in Table 3. Some of these are discussed by Annenskaya (1982), Bridge and Leeder (1979), Chernov (1983), Chorley (1973), Hickin (1981), Knighton (1984), Perry (1981), Richards (1982) and Schumm (1977). These studies show that intrinsic variables control certain phenomena and enter in various inter-relationships in the river channel and on the floodplain. Particular overbank flows may react individually to the range and magnitude of those variables. The most important factors determining these processes are hydrologic (resulting from the climate), hydraulic, and the morphologic characteristics of the river channel and a drainage basin.

In recent years human activity has been ascribed a growing role among the modifying variables. There are a number of papers (Brown, 1982; Butzer et al., 1983; Costa, 1975; Froehlich, 1975; Gregory, 1987; Gupta, 1982; Lewin, 1981; Lewin et al., 1979; Park, 1981; Walesh and Videkovich, 1978; Williams and Wolman, 1984; Wolman, 1967) which demonstrate that considerable changes have taken place in the functioning of fluvial systems and their subsystems in urbanised and deforested areas.

A qualitative and unexpected change in the cyclic processes forming a floodplain relief can

TABLE 3

Variables modifying floodplain formation

Climatic conditions	Precipitation Temperature Seasonal and annual variability Melting of snow cover
Hydrology	Types of tributaries Nature of pre-flood period Nature and operation of floods Number of flood peaks Horizontal extent of floods
Time scales	Duration of floods Seasonality of floods Rate of bank erosion and/or incision Rate of alluviation
River channel morphology	Order of river Longitudinal profile Hydraulic geometry Sinuosity of channel Lateral planation Avulsion
Pre-flood terrace morphology	Valley slope Flat and/or diversified surfaces
Hydraulics of water flow	Hydrodynamic conditions in river channel Transport of suspended particles Conductivity of floodplain Adjustments of overbank flow pattern Hydrodynamics of overbank flows Including depth and velocity
Processes in drainage basin	Storage Mechanical denudation Overland flow Washdown
Supply of available sediments	To river channel To floodplain
Anthropological activity	River management and flood-control Deforestation and afforestation Structure and changes of land use Urban development

take place with a gradual increase of the activity of extrinsic thresholds such as neotectonics, climatic fluctuations, changes of the base level, or high-magnitude floods. Then, the system of progressive erosion and sedimentation activated by these thresholds may lead to changes in the river channel pattern, and consequently, to changes in the present-day formation of a floodplain (see e.g. Gupta, 1983).

In the context of threshold analysis, the problem of the persistence of morphological (Anderson and Calver, 1977) and sedimentary (Zwoliński, 1985a) records of high-magnitude floods within a floodplain should also be mentioned. The effacement of flood traces can occur in a relatively short time scale, particularly in phase 6b of the proposed model. Thus can floodplain surfaces rapidly recover (see also Wolman and Gerson, 1978). Therefore, one must take into account the potential possibilities of preserving of forms and deposits when reconstructing fluvial systems palaeogeographically. This opinion was shared by Young and Nanson (1982) who stated that the main determinator of the river terraces formation had been the exceeding of critical values of intrinsic thresholds in the depositional environments of floodplains during Pleistocene and Holocene.

Hydrological, morphological, and sedimentological records: the Parsęta River

The hydrological nature of a flood determines the range of overbank flow effects on a floodplain. Also, the effectiveness of overbank flows is dependent to a high degree on the duration and quality of the period immediately preceding the flood. If an overbank flow is preceded by several months of low or mean water levels, its erosive and accumulative productivity is very high. Such a situation was observed in March, 1979 along the Parsęta (Zwoliński, 1980, 1985a).

In the case of a period of continuing high water levels, the flood's effect is limited to inundation of the floodplain with a possible slight morphological touch-up and/or a thin mud veneer. This is consistent with Froehlich (1975, 1982) and Wolman and Leopold (1957): lower concentrations of suspended material is associated with longer term high discharges. It is closely related to the exhaustion of the available suspended particles (Webb and Walling, 1984). A flood of a low morphological and sedimentary effectiveness preceded by high-water levels occurred in July 1980 along the Parsęta. The possibility of occurrence of a quasi-unproductive overbank flow is allowed by the model of overbank accumulation described by Gonera et al. (1985).

A special case of unproductive inundation of a floodplain is the submergence of its surface (especially the floodplain basins) by groundwater as an effect of their filtration caused by a high-water level or a bankfull stage in a river channel. Such floodwater cannot overflow natural levees whose relative height is larger than top edges of the channel banks. The effects of this inundation are practically invisible.

It must be admitted that the presented model of overbank formation of a floodplain operates differently when the flood has more than one peak flow. Then, successive peak flows can bring about changes in the morphological and sedimentary effects of the first culmination. The results of the successive flows grow weaker and weaker, and less and less distinct on the floodplain surface. In March 1981, a snowmelt flood along the Parsęta consisted of two culminations separated by a 16-day period of falling waters. The first peak deposited numerous and thick sand covers, the other caused a slight wash of the previously deposited covers in some places, forming a thin clay veneer in others.

Conclusion

Field observations suggest that the presented model finds a satisfactory confirmation in the style of floodplain architecture within valley floors of a number of meandering rivers of the Polish Lowland. An illustration of the regularities in the distribution and development of sedimentary processes and their effects is an idealised depositional model of a floodplain (Fig. 2). Its original version was proposed by Gonera et al. (1985). That model distinguishes four morphodynamic zones associated with different types of overbank sedimentation, resulting from the circulation of energy and matter within a floodplain.

In the direct neighbourhood and very close to the river channel there is *zone I*, showing the highest lithological and morphological variability. It is dominated by alluvial sand covers differentiated morphogenetically. The shape, size, distribution and extent of these covers depend on many factors, the main ones being the morphology of the floodplain and the hydraulics of the overbank flow. The distinctness of this zone is often disturbed by different contiguous or overlapping depositional forms. The great variety of forms determines the necessity to investigate this zone in detail in order to understand this complex sedimentary environment.

In *zone II* there are mainly mud covers and clay veneer resulting from slow water flows or stagnant waters. They usually occupy the largest areas of the floodplain basins along their proximal side.

The distal side of these basins belongs to *zone III* which practically contains no depositional products. Within this zone there occur very slow flows transporting the finest (colloidal) particles as well as stagnant waters with decantational material.

The areas in the vicinity of the valley bluffs or higher river terraces, as well as the highest surfaces of a floodplain, are only inundated during extremal and catastrophic floods. This is *zone IV*. In this zone one expects to find only slack-water deposits.

This depositional model of a floodplain reflects the fact that an increase of the distance from the river channel involves also a decrease in the amount and diameter of particles being transported (Allen, 1970; Hughes and Lewin, 1982; Kesel et al., 1974; Lewin, 1978; Šifrer, 1978). Therefore, depending on the hydrodynamic conditions of floods and the existing floodplain relief, the widths of successive

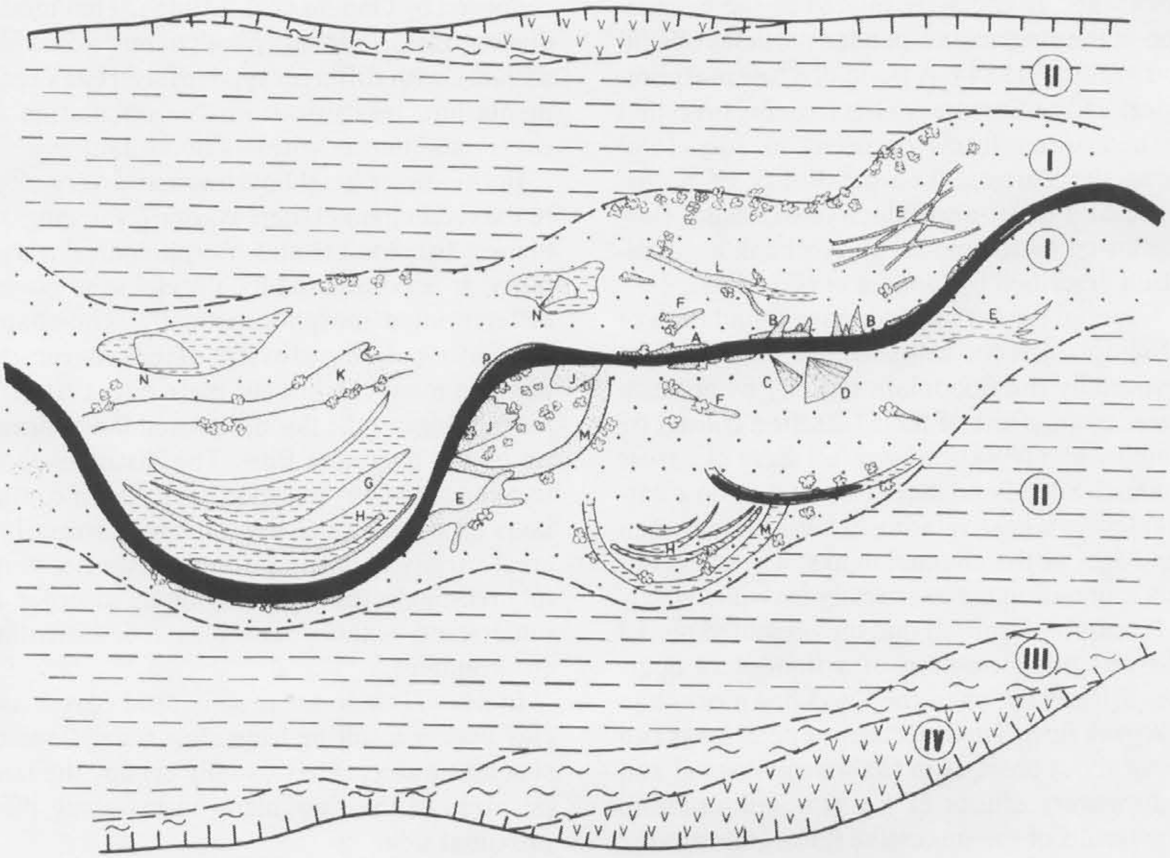

Fig. 2. Idealised depositional model of a floodplain. A = natural levees, B = crevasse splays, C = deltaic cones, D = alluvial cones, E = floodplain ribbons, F = sand shadows, G = meander scroll ridges, H = meander scroll swales, J = meander sand covers, K = chutes, L = terrace channels, M = oxbow-lakes, N = floodplain hollows, P = counterpoint bars. I–IV are successive depositional zones (explanations in text).

zones, particularly the first three zones, can be very different. Depending on the hydrological regime of the river, the number of zones in the general model may be reduced to only one.

Present knowledge of the modern sedimentary environment of a floodplain does not expressly pronounce for both counterpoint and slack-water deposits. Associating counterpoint deposits with vertical accretion deposits may look controversial because so far they have been regarded as solely lateral accretion deposits (Carey, 1969; Nanson and Page, 1983; Page and Nanson, 1982; Witt, 1979). Yet is has been demonstrated that, after a period of a constructive flood, counterpoint deposits constitute a new segment of a floodplain (Zwoliński, 1986b). Slack-water deposits present a slightly more complicated problem because as yet, much is known about their presence only within the sedimentary record (e.g., Baker, 1983; Patton et al., 1979). Baker (1983) questions the possibility of long term survival of these deposits in the temperate zone because of the lack of long-term stability for alluvial channel cross-sections. This, however, does not mean that they should not be included in the two presented models which exemplify the present-day floodplains.

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