Annales Societatis Geologorum Poloniae (2000), vol. 70: 219–229.

ANASTOMOSING SYSTEM OF THE UPPER NAREW RIVER, NE POLAND

Ryszard GRADZIŃSKI[1], Janusz BARYŁA[1], Władysław DANOWSKI[2], Marek DOKTOR[1], Dariusz GMUR[1], Michał GRADZIŃSKI[3], Artur KĘDZIOR[1], Mariusz PASZKOWSKI[1], Roman SOJA[4], Tomasz ZIELIŃSKI[5] & Sławomir ŻUREK[6]

[1] *Institute of Geological Sciences (Cracow Research Centre), Polish Academy of Sciences, ul. Senacka 1, 31-002 Kraków, Poland; E-mail: ndgradzin@cyf-kr.edu.pl*
[2] *ul. Helclów 23, 31-148 Kraków, Poland*
[3] *Institute of Geological Sciences, Jagiellonian University, ul. Oleandry 2a, 30-063 Kraków, Poland*
[4] *Institute of Geography and Spatial Organization, Polish Academy of Sciences, ul. św. Jana 22, 30-018 Kraków, Poland*
[5] *Faculty of Earth Sciences, University of Silesia, ul. Będzińska 60, 41-200 Sosnowiec, Poland*
[6] *Geographical Institute, Pedagogic University, ul. Konopnickiej 15, 25-406 Kielce, Poland*

Gradziński, R., Baryła, J., Danowski, W., Doktor, M., Gmur, D., Gradziński, M., Kędzior, A., Paszkowski, M., Soja, R., Zieliński, T. & Żurek, S., 2000. Anastomosing system of the upper Narew river, NE Poland. *Annales Societatis Geologorum Poloniae*, 70: 219–229.

Abstract: The studied section of the upper Narew river is an example of an anastomosing system. It consists of a network of interconnected channels and interchannel areas covered with peat-forming rush and reed vegetation. The channels have low longitudinal gradient, are laterally stable, relatively deep, they have sandy bed and strongly overgrown banks. There are no natural levees built of clastic sediment. Straight-type channels dominate in the channel system. Meandering reaches lack discernible point bar topography. Vegetation plays an important role in the evolution of the anastomosing system of the Narew.

Abstrakt: Badany odcinek Narwi jest przykładem systemu rzeki anastomozującej. Składa się on z sieci rozdzielających się i ponownie łączących się koryt oraz z obszarów pozakorytowych, porośniętych rolinnością torfotwórczą. Koryta mają mały spadek, są stosunkowo głębokie i lateralnie stabilne, a ich brzegi są silnie zarośnięte. Większość koryt ma stosunkowo niewielką krętość, ale podrzędnie występują także odcinki kręte, typu meandrującego, pozbawione jednak dostrzegalnych łuków przyrostowych, charakterystycznych dla topografii odsypów meandrowych. Brak jest wyraźnie rozwiniętych wałów przykorytowych zbudowanych z materiału klastycznego. Roślinność odgrywa znaczącą rolę w rozwoju omawianego systemu.

Key words: anastomosing river, depositional system, Holocene.

Manuscript received 29 September 2000, accepted 18 October 2000

INTRODUCTION

The term *anastomosing river* has been used in its present sense for twenty years only (Smith & Smith, 1980). Apart from the previously known three major types of rivers – the braided, meandering and straight ones (Leopold & Woolman, 1957), the anastomosing rivers are now regarded as a separate group (see Rust, 1978; Knighton & Nanson, 1993; Nason & Knighton, 1996; Miall, 1996; Makaske, 1998). The latter also appear to represent a distinct depositional system, that has been little studied thus far.

The Narew is the best modern example of an anastomosing river in Poland. A selected part of this system has been studied by an interdisciplinary team since 1998. This paper presents a general description of the Narew river anastomosing system and preliminary results of studies on sedimentary processes operating within it.

GENERAL GEOLOGICAL AND GEOMORPHOLOGICAL BACKGROUND

The Narew river has its origin in Belarus from which it flows through NE Poland (Fig. 1). The middle course of the upper Narew is generally meridional. It flows there over Pleistocene sediments, up to 150 m thick, mainly glacial clays and glacifluvial sands. The upper part of these sediments is related to the Middle-Poland Glaciation.

The anastomosing section of the river, preserved in its almost pristine form, extends in the wetland area from Suraż to Rzędziany (Fig. 2). It is ca. 35 km long and lies within the

Fig. 1. The upper Narew river between Suraż and Tykocin. The channel network in the section downstream from Rzędziany is shown as before drainage works

Narew National Park (NNP). Until recently, the river was anastomosing for another 35 km downstream, but that part of the valley has been strongly altered by drainage works. Our studies have been carried out over a section ca. 20 km long, situated in the central part of NNP, mainly near Kurowo (Fig. 2).

Within the NNP area, the Narew river valley has a flat bottom. It is bordered by gentle slopes of low hills built mostly of glacial clays (Fig. 2). The width of the valley varies markedly from narrows of ca. 1 km to the so-called "basins" of 2–4 km.

A few available borehole sections demostrate that the valley follows a depression in the top of glacial clays. The depression is filled with a series of sands, 15–25 m thick, locally enriched in gravels (Churski, 1973; Banaszuk, 1996). The origin of this depression in not quite clear; it has been explained by presence of dead ice seperated from ice-sheet which slowly melted in the present-day "basins" (Falkowski, 1970). There is no direct evidence for the age of the mentioned sand series; it may be either of Late Pleistocene or Early Holocene age.

The valley bottom is almost completely covered with a few metres thick only layer of organic deposits, described as "peat" in the literature (Churski, 1973: Banaszuk, 1996), dated at Late Holocene (see Okruszko & Oświt, 1973).

Over the whole area of the NNP, from Suraż to Rzędziany, the river frequently branches and rejoins, creating a typical anastomosing pattern (see Figs 2, 3). The longitudinal gradient of the valley bottom is ca. 0.22 m/km, the gradients in transverse sections are minimal and difficult to measure.

CLIMATE AND HYDROLOGY

The studied area has a humid continental climate and it lies in the coldest part of north Poland. The average annual number of days with maximum temperature below 0°C is between 80 and 87 days, the average yearly precipitation is 550–560 mm. Rates of precipitation are highest in the June to August period.

The hydrological regime of the upper Narew features one period of water-level rise, related to snow melting in the spring and one period of low-water level, from July to October. The mean annual discharge of the river at the Suraż gauging station is 13.3 m^3/sec, the maximum recorded discharge being 250 m^3/sec.

The winter ice cover usually forms in the beginning of December and lasts until the middle of March. As a mean, it is ca. 30 cm thick.

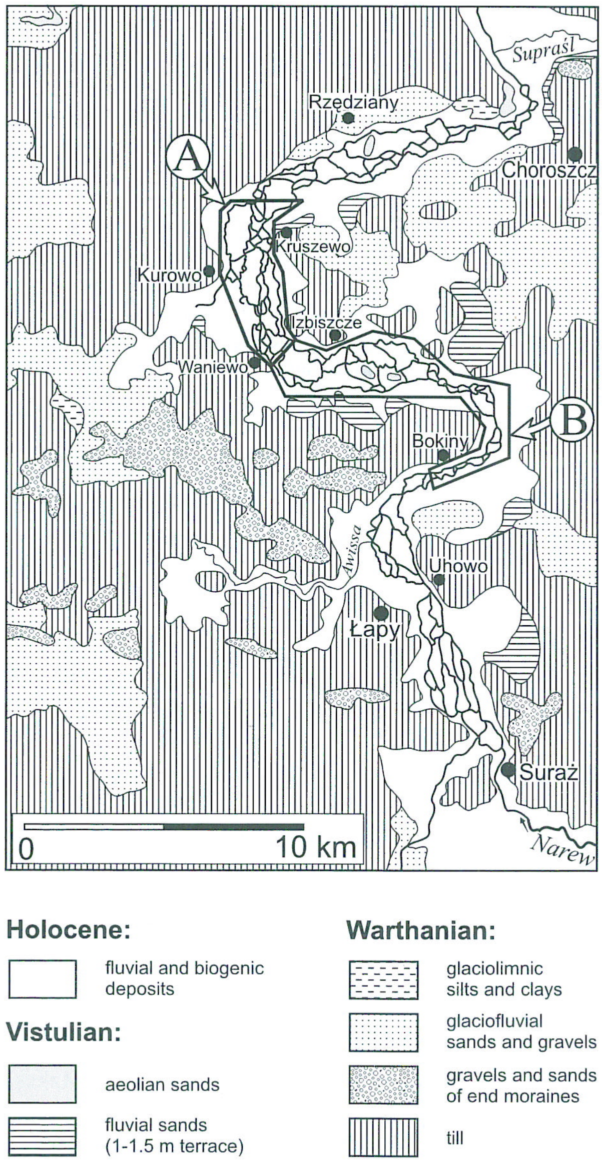

Fig. 2. Geological map of the middle section of the upper Narew valley (after Bałuk, 1973, simplified). A – area of detailed study; B – area of reconnaisance studies

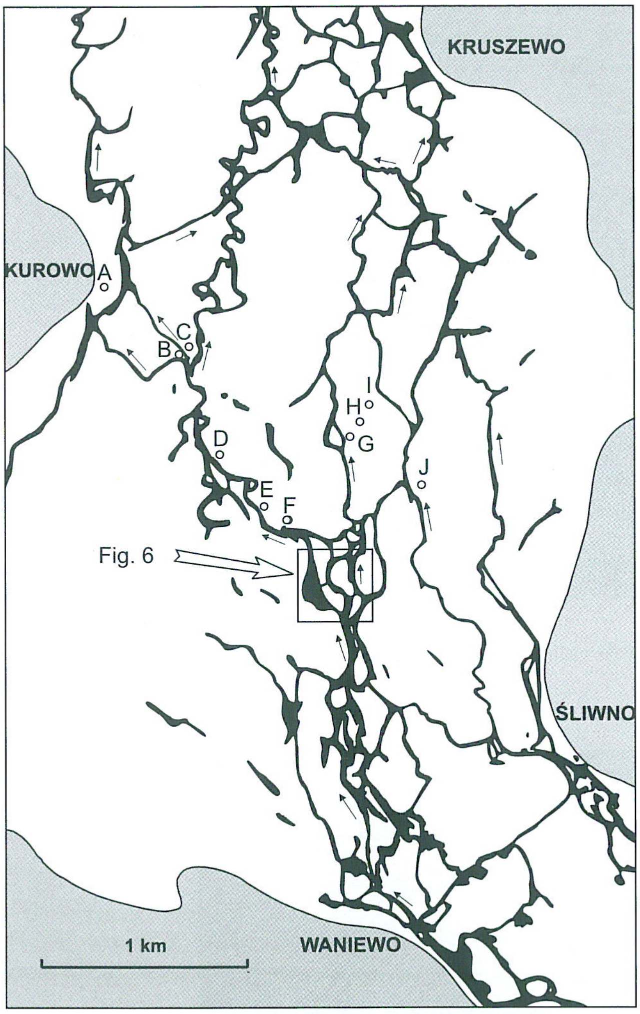

Fig. 3. The Narew valley between Waniewo and Kruszewo (cf. Fig. 2). Interchannel areas are white, elevations bordering the valley are grey; lettered points (A–J) correspond to locations of selected boreholes (cf. Figs 12, 13)

In the studied area, the surface of the interchannel areas is only slightly elevated over the mean water level, so the normal flow may be described as bankful discharge. The interchannel areas are often flooded for a few weeks or more when the water level rises.

METHODS

Our studies involved mainly sedimentological, but also botanical (J. Baryła), and hydrological (R. Soja) aspects of the river valley. Peat was studied by S. Żurek. Large inflatable boats were the main means of transport and a scuba diver supported investigation of channels. About 150 cores (up to 5 m long) were taken from the channel bottoms and from interchannel areas, using self-designed plexiglas-tube corer; 25 boreholes (up to 6 m deep) were made in interchannel areas using Eijkelkamp hand-auger set with peat-sampler. Additional samples of sediments with undisturbed structure were taken using wedge-shaped samplers and impregnated with epoxy resin (cf. Fig. 11; see Chudzikiewicz *et al.*, 1979).

Transverse sections of channels were usually made using traditional methods, and the longitudinal ones – using an electronic acoustic bottom profiler. Differences in altitude and water level over short distances were measured with an accuracy of up to 0.5 cm with a self-designed instrument. Specially adapted closed-circuit TV instruments were used for underwater observations.

Radiocarbon dating (17 analyses thus far) was done in the Institute of Geological Sciences of the Academy of Sciences of Belarus in Minsk.

Field work was carried out in June and September of 1998 and 1999, each time by a team of 10–14 people. Observations and photographs from the air were done from a helicopter, at elevations of 50 to 200 m.

CHANNEL NETWORK

The described anastomosing system consists of numerous channels interconnected in an irregular network. Nodes of this network are the places of bifurcation or coalescence of channels. The density of channels and the density of nodes differ between various fragments of the valley (see Figs 3–6). The distances between the nodes vary from a few tens to several hundred metres.

The network consists of channels of various size. Some of them show markedly larger dimensions and higher discharge than the others, and may thus be considered the main channels. Their course, in most cases, is approximately parallel to the valley axis. The number of the main channels varies between the individual cross sections of the valley. Some of the main channels loose a major part of their water to the smaller channels, thus they gradually loose the attributes of a main channel. An opposite situation occurs if a main channel is formed by confluence of smaller ones.

Most channels show a relatively low sinuosity, though tight bends ocasionally occur. Some short sections of the channels resemble in shape regular meanders (see Fig. 3). Sporadically, there occur longer sections of high-sinuosity channels which follow a typical meandering course, however they lack a distinctive point-bar topography (Fig. 5). Such channels are often accompanied by oxbow lakes. The low-sinuosity channels (with sinuosity index <1.3) are described below as *straight* (cf. Makaske, 1998), and those of higher sinuosity – as *meandering* ones.

It should be stressed that a more precise determination of the sinuosity index (SI, *sensu* Brice, 1964) is possible only for the meandering channels, as only there axis of a meander belt can be determined. For the straight channnels, their axis may be determined only approximately and arbitrarily.

Fragments of abandoned channels of various length and shape (Fig. 3) are locally preserved at the valley bottom. They are partly or completely isolated from the active channels. Some parts of the channel network have a form of relatively shallow lakes, often of irregular amoeboid shapes.

Longitudinal gradient of water surface in individual channels is low, usually from 16.5 to 20 cm/km, depending

Fig. 4. A fragment of the dense channel-network in the middle part of the valley between Waniewo and Kurowo (cf. Fig. 6). In front, an overgrowing lake

Fig. 5. A fragment of highly sinuous main channel near Kurowo

on the channel sinuosity. Active channels are in most cases relatively deep, 5 to 35 m wide (Fig. 7). Their width/depth ratio usually falls between 2.5 and 10. The larger channels are typically 3–4 m, locally up to 6 m deep.

Cross sections of active channels are usually canal-like, steep-sided, with a flat bottom (Fig. 8). Such cross-sections are observed both along straight sections and at many bends. At some bends, the cross-sections are distinctly asymmetric, their convex bank sloping more gently. A precise determination of the channel margins is usually impossible because of the prevailing grill-like nature of the margins (see section Vegetation).

Only a few fragments of the channel network are not natural. These are, in the first place, short fragments cut-off through the meander necks in the main channels, probably made in order to facilitate local navigation or wood-rafiting in the past centuries. Largely artificial is also a canal that connects both sides of the valley near Waniewo, moreover two straight canals near Śliwno (see Fig. 3).

Maximum flow velocity observed in the active channels at a mean water level is relatively low. In the main channels it varies between 10 and 30 cm/sec, thus the stream power is generally low. Exceptionally high velocities, ca. 70 cm/s, were measured in two narrow, short channels that connect

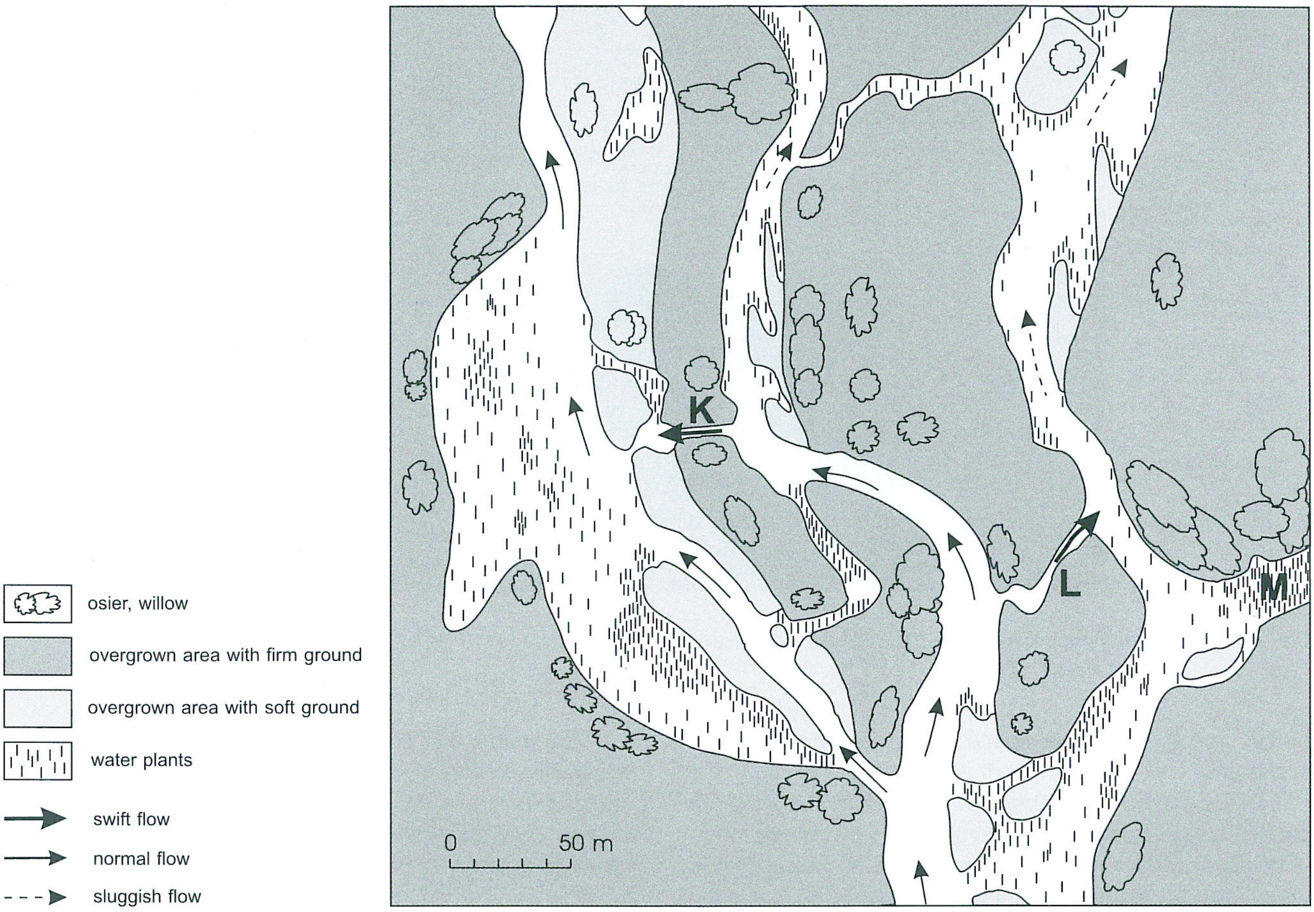

Fig. 6. Sketch-map of dense channel-network (for location, see Fig. 3). K and L – short channels described in text; M – plant jam

larger ones (see Fig. 6). Longitudinal gradient of water surface in these short channels is 0.13 cm/m. It should be also noted that both channels exist in their present shape at least from 1966.

INTERCHANNEL AREAS

The term interchannel areas is used herein in a broad meaning, encompassing not only the islands but also the other parts of the flat valley bottom, adjacent to its margins. These areas are densely vegetated marshy grounds, mostly covered with peat-forming rushes and reeds; they are being flooded at high water levels. Some fragments of the interchannel areas are so watery and spongy that they are accessible only when frozen.

Nowhere in the studied area have the authors found clearly marked natural levees built of clastic sediments. Strongly permeable "levees" composed of loose litter debris of reed, which profusely grows along the channels, are locally present. Only rarely they rise up to 15 cm above the water level in a channel.

VEGETATION

Interchannel areas are occupied mostly by rush and reed communities, dominated by common reed (*Phragmites australis*). Smaller areas are occupied by sedges *Carex elata* and *C. acuta* (= *C. gracilis*), canary grass (*Phalaris arundinacea*) and floating sweet-grass (mostly *Glyceria fluitans*). Locally, there occur small patches of osier community (*Salicetum pentadro-cinereae*) and single, arborescent willows. In some areas, rows of willow indicate limits of former areas exploited for crops of rushes. Subordinate are alder carr and dry-ground forest (*Tilio-Carpinetum*). The latter occupies isolated small hills in the valley bottom near Izbiszcze, rising to 6 m above the valley bottom; most likely these are stabilised dunes, older than peat.

No plants rooted in the bottom are present in active channels deeper than 2 m, though they are common in shallower channels with slack flow. The first species to settle in the course of a channel shallowing is arrowhead (*Sagittaria sagittifolia*) with tape-like leaves, then yellow water-lily (*Nuphar lutea* f. *submersa* – a form with submerged leaves). With further slowing of the current and shallowing of the channel, other species appear which are rooted in the bottom, suspended in water or floating on the surface. Many tens of species of water plants grow in the inactive or sluggish-water channels and in lakes. Individual sites differ

Fig. 7. A view of a main active reed-lined channel (reeds are ca. 3 m high)

in their species composition and belong to various plant associations.

Dense patches of floating plants are characteristic of the studied fragment of the valley bottom. They consist mostly of cowbane (*Cicuta virosa*) and great yellow-cress (*Rorippa amphibia*), accompanied by a few other species. The plants in the patches are not rooted in the bottom; they float freely as "floating islands". One of the main mechanisms producing such islands is winter freezing of plant patches into ice, setting free and drifting away during spring floods. A later stabilization of such floating islands favours formation of plant jams, which locally block the flow in the channels (Fig. 9).

The channel margins usually have a very specific character: they are here termed the *grill-like margins*. They are formed by a belt of reed whose stems grow from the channel bottom in water up to 1 m or less (Fig. 10B). Such a belt, where water flows between the stems, may be up to a few metres wide. Where the current slows down, a narrow, dense mat consisting of floating plants extends adjacent to the reed of the grill-like margin (Fig. 10C). This mat is formed of the same species that form floating islands and plant jams described above.

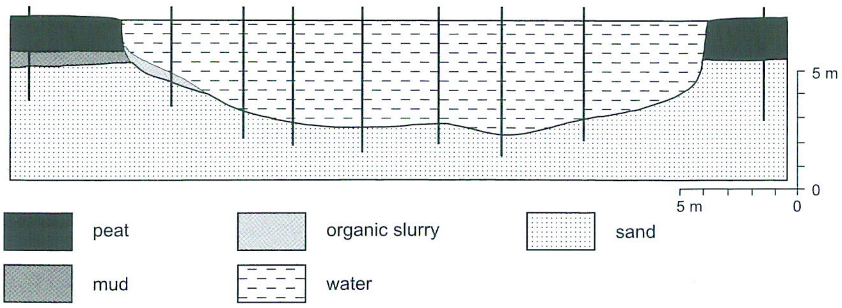

Fig. 8. Cross-section through a canal-like channel, boreholes marked with vertical lines

The plants that colonise the bars on the inner or outer banks of some bends, include: bur-reed (*Sparganium* sp.) and great yellow-cress (*Rorippa amphibia*) close to the channel, and grasses (*Agostis* sp., *Alopecurus* sp.) and rush (*Juncus* sp.) in drier places.

DEPOSITS

Predominance of sandy bedload is characteristic of the Narew river. Its suspended load, sometimes rich in organic material, is small. The beds of active channels are usually sandy. The sand varies in grain-size: it is mostly medium- or coarse-grained, moderately sorted, in some cases with an admixture of granule. Clasts of peat occur occasionally at the bottom of larger channels; the largest clasts are several tens of centimetres in size (see Figs 11 and 14). Where flow velocities are very low, a layer of dark, organic slurry and accumulations of larger plant debris form above the sandy bottom.

The sand deposited in channels usually is horizontally laminated or lacks mesoscopically discernible depositional structures. Locally present is large-scale cross-stratification, and in fine-grained sand also ripple lamination. Some sections include subordinate intercalations of dark-coloured fine-grained sand, often with a marked proportion of finer sediment, enriched in organic matter.

A few cm thick layer of dark slurry composed mainly of organic remains spreads over bottoms of lakes, relict channels and inactive fragments of channels. It is often underlain by a layer several centimetres thick of mud rich in organic material.

The interchannel areas are, as a rule,

Fig. 9. One of smaller channels with floating plant jam

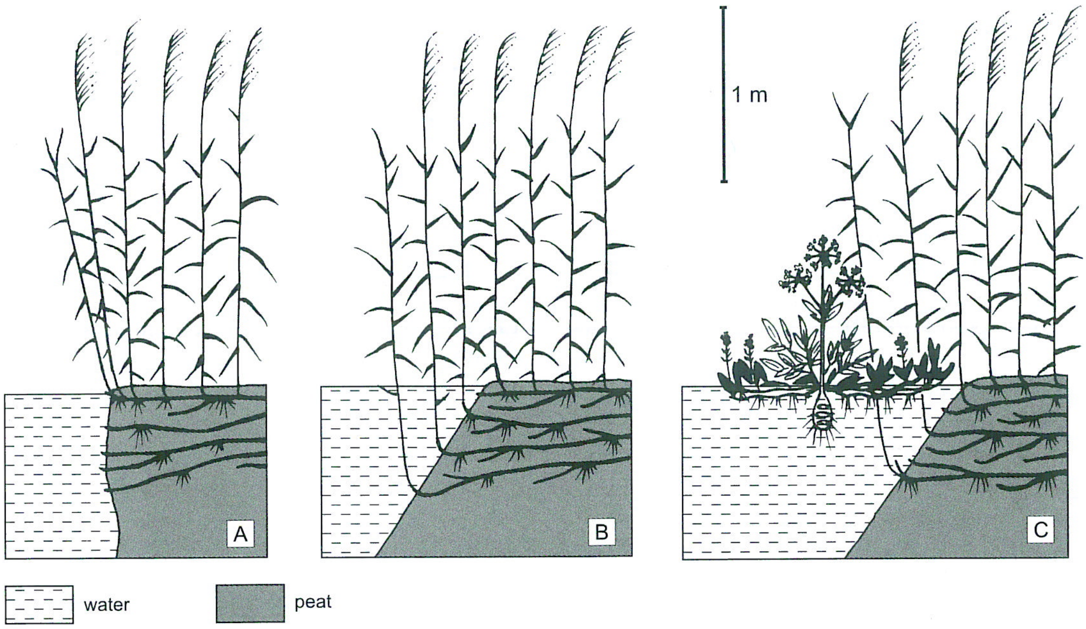

Fig. 10. A scheme of various types of bank overgrown with reed. **A** – reed stems not submerged; **B** – grill-like margin; **C** – grill-like margin with floating plant mat

directly underlain by a layer or organic-rich deposit. For the sake of simplicity, this layer is here termed the peat layer. It consists mainly of peat, usually rich in sand and finer clastics. The peat belongs to various types: mostly sedge peat and reed peat, less commonly – osier peat and sedge-reed one (see Fig. 12). Locally, the peat layer contains thin intercalations of sand or mud. The thickness of the described peat layer usually is between 1 and 2 m, only exceptionally exceeds 4 m (Fig. 13). Basal surface of the peat layer is uneven, in some cases even over very short distances.

The substratum of the peat layer was penetrated by drilling to various depths below the peat-layer base, from a few tens of centimetres down to 1.7 m. The sequence and lithology of the clastic sediments under the peat layer are different in each borehole. The most common sediment encountered directly beneath the peat is a several tens of centimetres thick layer of mud, often rich in organic debris, occasionally including subordinate intercalations of sand. This layer is underlain by sand, usually fine-grained, occasionally with subordinate thin intercalations of peat-like sediment or gyttja. The lowermost parts of some borehole sections show medium- and coarse-grained sand whose characteristics are similar to those of the channel deposits. In some cases such sands directly underlie the peat layer (Figs 12, 13).

Fig. 11. Channel sand from the bottom of a main channel, peat clasts in the upper part. Vertical sample taken using wedge-shaped sampler, impregnated with epoxy resin; scale in cm

SEDIMENT AGE AND SEDIMENTATION RATES

Radiocarbon ages of the basal parts of the peat layer, and of the directly underlying organic-rich muds vary widely within, mostly between 3,200 ± 90 BP and 1,340 ± 50 BP, locally even less. Only two dates are distinctly older: 7,080 ± 80 BP and 4,800 ± 300 BP. These dates indicate that accumulation of the peat layer began at different time in various parts of the valley, generally during the late Subboreal Period, and mainly in the Subatlantic Period.

Long-term sedimentation rates calculated for the inter-channel peat-layer range between 0.33 and 1.78 mm/yr, though most are bracketed within 1–1.5 mm/yr. These differences seem to be attributable to varying proportions of peat matter to clastic sediment, variations in rate of peat accumulation, and variable compaction rates of different types of peat.

LATERAL STABILITY OF CHANNELS

The actual channel network is very similar in planform to that recorded on old maps (the oldest, at a scale 1:84,000, based on a survey of 1886; the newer ones at 1:100,000 from 1915 and 1931). The apparent changes include disappearance of some channels, isolation of relic channels and diminishing of lake sizes.

More detailed comparisons are possible using a series of successive aerial photographs of the studied area, from 1966, 1980, 1989 and 1999, at scales 1:25,000 and 1:10,000: no change has been discerned in the position of channels, including the highly sinuous reaches; a progress is visible in overgrowing and isolation of inactive channels, and diminishing of the lake sizes.

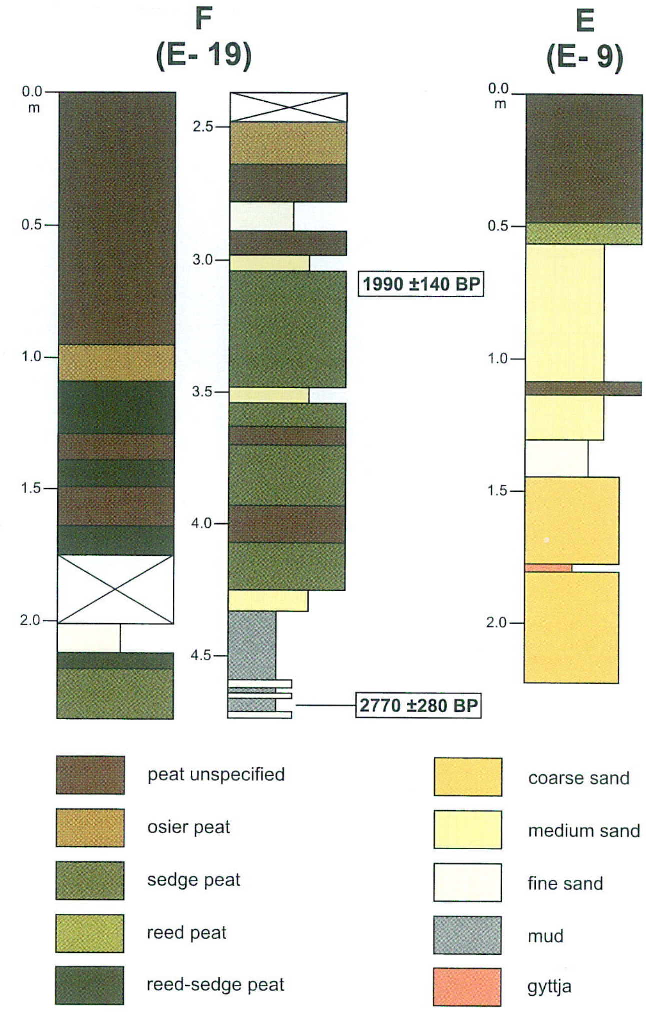

Fig. 12. Detailed logs of two selected boreholes (F and E). For location, see Fig. 3

There is no doubt that the lateral stability of the channels is directly related to the general lack of erosion at their banks. At the small gradient and low stream power, the submerged plants of the grill-like margins create a zone which strongly reduces the erosive power of the current. Another contributing factor is the low erodibility of the banks built of peat and covered with a mat of rhizomes and roots (see Smith, 1976).

On the other hand, presence of peat clasts on sandy bottoms of channels indicates that erosion of peat banks occurs, however occasionally. There are only a few places in the studied area (between Izbiszcze and Kurowo), where this happens. Such places are situated on outer sides of bends where the grill-like margin is poorly developed or absent. In such places our scuba diver found erosional niches in the submerged parts of the steep bank, extending up to 1.7 m into the bank (Fig. 14). Blocks of peat partly detached from the main mass and deflected from their original position were visible nearby, as well as loose blocks lying on the bottom. It may be supposed that the erosional retreat of the banks are being quickly restored by progradation of the rush and reeds towards the axis of the channel.

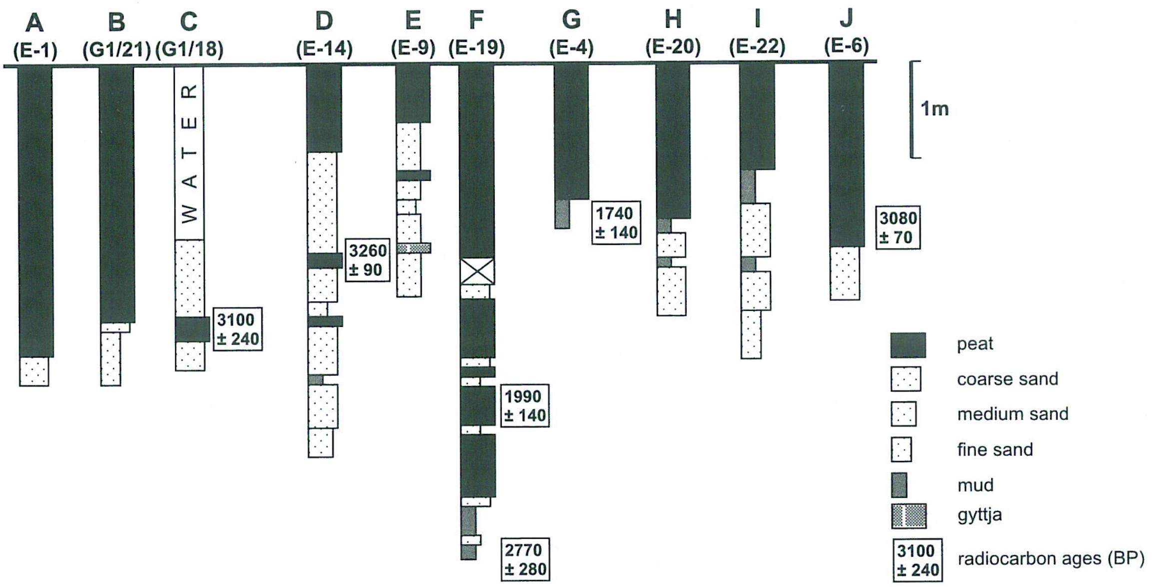

Fig. 13. Logs of selected boreholes. For location, see Fig. 3

AVULSION

A study of a series of air photographs of the investigated area from the last 34 years did not reveal any newly formed long sections of channels. A few new sections of channels which formed during that period are barely a few tens of metres long. They are situated between neighbouring smaller channels.

DISCUSSION AND CONCLUSIONS

The studied section of the Narew valley displays many characteristics considered typical of the anastomosing fluvial systems (cf. Knighton & Nanson, 1993; Miall, 1996; Makaske, 1998): the presence of a network of interconnected channels, low gradient, relatively deep and laterally stable channels, and general aggradation. The Narew differs, however, from most anastomosing rivers in its lack of natural levees built of clastic sediments; in this respect it is similar only to the Okawango (Stanistreet *et al.*, 1993).

(1) Similarly, as is the case with the other anastomosing systems, avulsion is the main cause of the existence and evolution of the Narew system, here described. The processes of avulsion are favoured by vertical aggradation and low gradient of the valley bottom (cf. Makaske, 1998), and flatness and small elevation of the interchannel areas over the mean water level in the channels. The principal triggers of avulsion in the Narew are plant jams in active channels (cf. Ellery *et al.*, 1995), possibly also ice-floe jams. Preferred sites for new channels are probably beaver or elk paths or others zones of less dense rushes and reeds.

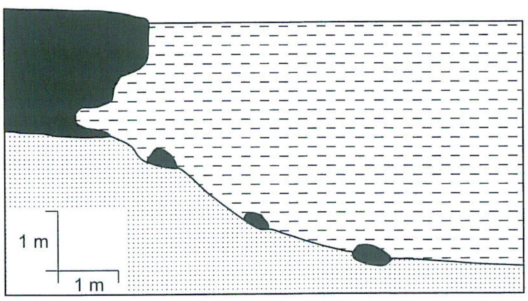

Fig. 14. An example of eroded peat bank

(2) Vegetation is also one of the factors of lateral channel stability in the Narew valley. It contributes to the growth of the layer of peat, relatively resistant to erosion. Additionally, vegetation on the channel banks forms a protective zone in the form of grill-like margins, it also invades channels, constricting them. Similar role is played by rushes in the Okawango delta (Stanistreet *et al.*, 1993; McCarthy *et al.*, 1996a, b).

(3) In our opinion, the development of the Narew anastomosing system is closely related to the growth of peat-forming vegetation in the valley. The sediment sequences and radiocarbon dates from the base of peat indicate that the accumulation of peat began at different times in different places of the valley bottom. It seems then, that the development of the anastomosing system was gradual and only during the late Holocene a dense network of channels had formed, similar in planform to the modern one.

(4) The anastomosing system of the Narew is dominated by low-sinuosity channels. The subordinate strongly sinuous, "meandering" reaches lacking any visible features of point bar topography, suggest that they may represent fragments of an earlier meandering fluvial system. These fragments became stabilised by the development of peat-forming vegetation and included into the anastomosing channel network.

(5) The Narew system is distinct from the examples of anastomosing rivers described in literature (cf. Nanson & Knighton, 1993; Makaske, 1998) by its predominance of bed load in the total load. It resembles with this respect the

Okawango where the presence of straight and meandering reaches is also ascribed to the influence of rushes (Stanistreet *et al.*, 1993).

(6) The relatively high rate of sedimentation in the interchannel areas is caused mainly by the accumulation of peat. The accumulation is accompanied by vertical accretion of channel sediments. The rate of this accretion is difficult to determine as all deeper channels are incised in older sands, similar to the modern channel deposits.

(7) Very rapid overgrowing of the lakes seems to be the result of increased supply of nutrients derived from fertilisers used in agriculture.

Acknowledgements

The study has been funded by State Committee for Scientific Research (grant No 6 PO4E 020 14, 1998–2000). Bogusław Deptuła, the Director of the Narew National Park and other members of the Park staff have rendered great help during the field work. Extremely helpful was the co-operation of Maciej Tomaszek as the scuba-diver. The authors thank also Piotr Banaszuk, Michał Banaś, Maciej Chilmanowicz, Piotr Gębica, Michał Gruszczyński, Jerzy Maciejczuk and Bolesław Wajsprych for their participation in the field work. Our technician Piotr Wal has made the necessary self-designed equipment. Iwona Bieleś and Józef Halama have rendered constant help during the field work. Special thanks go to Krzysztof Birkenmajer and Grzegorz Haczewski for their help in the preparation of the final version of this paper.

REFERENCES

Bałuk, A., 1973. *Geological map of Poland 1:200,000, sheet Łomża*. Wydawnictwa Geologiczne, Warszawa.

Banaszuk, H., 1996. *Palaeogeography, natural and anthropogenic transformations of the Upper Narew River valley* (In Polish, English summary). Wydawnictwo Ekonomia i Środowisko, Białystok, 213 pp.

Brice, J. C., 1964. Channel patterns and terraces of the Loup Rivers in Nebrasca. *U. S. Geological Survey Profesional Paper*, 442-D: D1–D-41.

Chudzikiewicz, L., Doktor, M., Gradziński, R., Haczewski, G., Leszczyński, S., Łaptaś, A., Pawełczyk, J., Porębski, S., Rachocki, A. & Turnau, E., 1979. Sedimentation of modern sandy delta in Lake Płociczno (West Pomerania), (In Polish, English summary). *Studia Geologica Polonica*, 62: 1–61.

Churski, T., 1973. Outline of geomorphology of swampy sector of the upper Narew valley (In Polish, English summary). *Zeszyty Problemowe Postępów Nauk Rolniczych*, 134: 11–30.

Ellery, W. N., Ellery, K., Rogers, K. H. & McCarthy, T. S., 1995. The role of *Cyperus papyrus* L. in channel blockage and abandoment in the norteastern Okawango Delta, Botswana. *African Journal of Ecology*, 33: 25–49

Falkowski, E., 1870. History and prognosis for the development of bed configurations of selected sections of Polish lowland rivers (In Polish, English summary). *Biuletyn Geologiczny Uniwersytetu Warszawskiego*, 12: 5–121.

Knighton, D. & Nanson, G. C., 1993. Anastomosis and the continuum of channel pattern. *Earth Surface Processes and Landforms*, 18: 613–625.

Leopold, L. B. & Woolman, M. G., 1957. River channael patterns; braided, meandering, and straight. *U. S. Geological Survey Profesional Paper*, 282-B: 1–85.

Makaske, B., 1998. Anastomosing rivers – form, processes and sediments. *Nederlandse Geografische Studies*, 249, 287 pp.

McCarthy, T. S., Ellery, W. N., Cairncross, B., Ellery, K. & Grobicki, T. S. A., 1988. Features of channel margins in the Okawango Delta. *Palaeoecology of Africa*, 19: 3–14.

McCarthy, T. S., Ellery, W. N., Rogers, K. H., Cairncross, B. & Ellery, K., 1986. The roles of sedimentation and plant growth in changing flow patterns in the Okawango Delta, Botswana. *Suid-Afrikaanse Tydskrift vir Weteskap*, 82: 579–584.

Miall, A. D., 1996. *The geology of fluvial deposits*. Springer, Berlin, 582 pp.

Nanson, G. C. & Knighton A. D., 1996. Anabranching rivers: their cause, character and classification. *Earth Surface Processes and Landforms*, 21: 217–239.

Okruszko, H. & Oświt, J., 1973. Natural characteristics of swampy upper Narew valley as a basis for its reclamation (In Polish, English summary). *Zeszyty Problemowe Postępów Nauk Rolniczych*, 134: 31–99.

Rust, B, R., 1978. A classification of alluvial channel systems. In: Miall, A. D. (ed.), *Fluvial Sedimentology. Canadian Society of Petroleum Geologists, Memoir*, 5: 187–198.

Smith, D. G., 1976. Effect of vegetation on lateral migration of anastomosed channels of a glacier meltwater river. *Geological Society of America, Bulletin*, 87: 857–860.

Smith, D. G. & Smith, N. D., 1980. Sedimentation in anastomosed river systems: examples from alluvial valleys near Banff, Alberta. *Journal of Sedimentary Petrology*, 50: 157–164.

Stanistreet, I. G., Cairncross, B. & McCarthy, T. S., 1993. Low sinuosity and meandering bedload rivers of the Okawangi Fan: channel confinement by vegetated levees without fine sediment. *Sedimentary Geology*, 85: 135–156.

Streszczenie

ANASTOMOZUJĄCY SYSTEM GÓRNEJ NARWI, NE POLSKA

Ryszard Gradziński, Janusz Baryła, Władysław Danowski, Marek Doktor, Dariusz Gmur, Michał Gradziński, Artur Kędzior, Mariusz Paszkowski, Roman Soja, Tomasz Zieliński & Sławomir Żurek

Omawiany odcinek górnej Narwi (Fig. 1, 2) dostarcza najlepszego w Polsce przykładu systemu rzeki anastomozującej i znajduje się w granicach Narwiańskiego Parku Narodowego. Rzeka płynie tutaj wieloma korytami, które rozdzielają się i ponownie łączą tworząc nieregularną sieć (Fig. 3–6). Składa się ona z koryt różnej wielkości i różnej krętości, których spadek jest nieznaczny. Oprócz koryt aktywnych występują koryta znajdujące się w różnych stadiach zamierania, a miejscami płytkie na ogół, zarastające jeziora. Charakterystyczną cechą aktywnych koryt jest ich stosunkowo duża głębokość w porównaniu z szerokością i przeważnie "kanałowy" kształt przekrojów (Fig. 8).

Płaskie obszary pozakorytowe, w tym liczne wyspy, wznoszą się jedynie nieznacznie nad poziom wody w korytach w warunkach przeciętnego stanu, a podczas wyższych stanów bywają zalewane na dłuższy czas. Obszary te są zabagnione i silnie zarośnięte roślinnością torfotwórczą, głównie trzciną i turzycami (Fig. 4–7). Podłoże obszarów pozakorytowych tworzy warstwa złożona w przewadze z utworów organogenicznych, głównie z torfów, zwykle silnie zapiaszczonych, zawierająca podrzędne wkładki osadów klastycznych (Fig. 12, 13). Warstwa ta, przeważnie o miąższości 1–2 m, sporadycznie do 4 m, rozwijać się zaczęła w różnym czasie w różnych miejscach doliny, na ogół począwszy od późnego subborealu, a głównie w subatlantyku (Fig. 12, 13).

Swierdzona lateralna stabilność koryt, charakterystyczna dla rzek anastomozujących, w przypadku Narwi tłumaczona jest przez autorów przede wszystkim warunkami hydrodynamicznymi (stosunkowo niewielkie prędkości, niska moc przepływu), obecnością torfów i maty korzeni oraz kłączy w brzegach, oraz pospolitym występowaniem "ażurowych" brzegów, które na skraju koryt tworzą strefę chroniącą brzegi przed boczną erozją (Fig. 7, 10).

W obciążeniu Narwi zdecydowanie dominuje materiał piaszczysty, klastyczna zawiesina odgrywa całkowicie podrzędną rolę. Dno aktywnych koryt jest piaszczyste, osady korytowe złożone są na ogół z średnio- i gruboziarnistego piasku (Fig. 11).

Rozwój anastomozującego systemu Narwi związany jest m.in. z warunkami generalnej agradacji, rozwojem pokrywy roślinności torfotwórczej i wielokrotnie zachodzącą awulsją. Bezpośrednimi przyczynami awulsji były przede wszystkim zatory roślinne (Fig. 9), a zapewne również zatory lodowe.