PRACE GEOGRAFICZNE, zeszyt 104

Instytut Geografii UJ
Kraków 1999

Ewa Smolska

RIVER CHANNEL STRUCTURE IN A LATE GLACIATION AREA. AN EXAMPLE OF THE UPPER SZESZUPA RIVER (SUWAŁKI LAKELAND, NORTHEASTERN POLAND)

Abstract: The valley and the channel of the Szeszupa river are characterised following a field research. The origins of the valley are identified. The channel type is defined on the basis of lithological and structural features. They are conditioned by the location in the genetic type of the valley.

Key words: structure of the river channels, channel bed sediments, NE Poland.

1. Introduction

In late glaciation areas, many river valleys feature segments of different origin along their longitudinal profile. Primarily, these are melt water valleys and melt-out basins inter-connected with gap valleys. Longitudinal profile of both the valley bottom and the channel are not evened out. Slopes in the gap reaches have higher inclination than those in the other reaches. Individual parts of the valley-and-channel system have been transformed, to a varying extent, by the fluvial processes and conditioned by the glacial morphogenesis. Weak fluvial transformation can also be frequently observed (Starkel 1988).

Upper Szeszupa represents this kind of river valley. Its gap reaches are genetically linked with the activity of the river. The lows, of primarily melt-out origin, reveal, however, none of such activity or traces of it, and are filled with the material of non-fluvial origin (limnological, organic), into which the modern channel is cutting.

The dynamics of the Szeszupa channel were studied in two periods, 1986-1990 and 1994-1995. The research aimed at identifying the morphological features of the channel and the channel sediments in the longitudinal profile of the river on the one hand, and the course of fluvial processes in the particular genetic types of the valley, on the other. The dynamic types of the Szeszupa channel were determined according to the principles proposed by L. Kaszowski and K. Krzemień (1986).

2. The research area

Szeszupa river is the confluent of Niemen, located in Suwałki lakeland, which constitutes a part of the mesoregion of Lithuanian lakelands (Kondracki 1978). The study covered the upper Szeszupa channel system down to its opening into Pobondzie

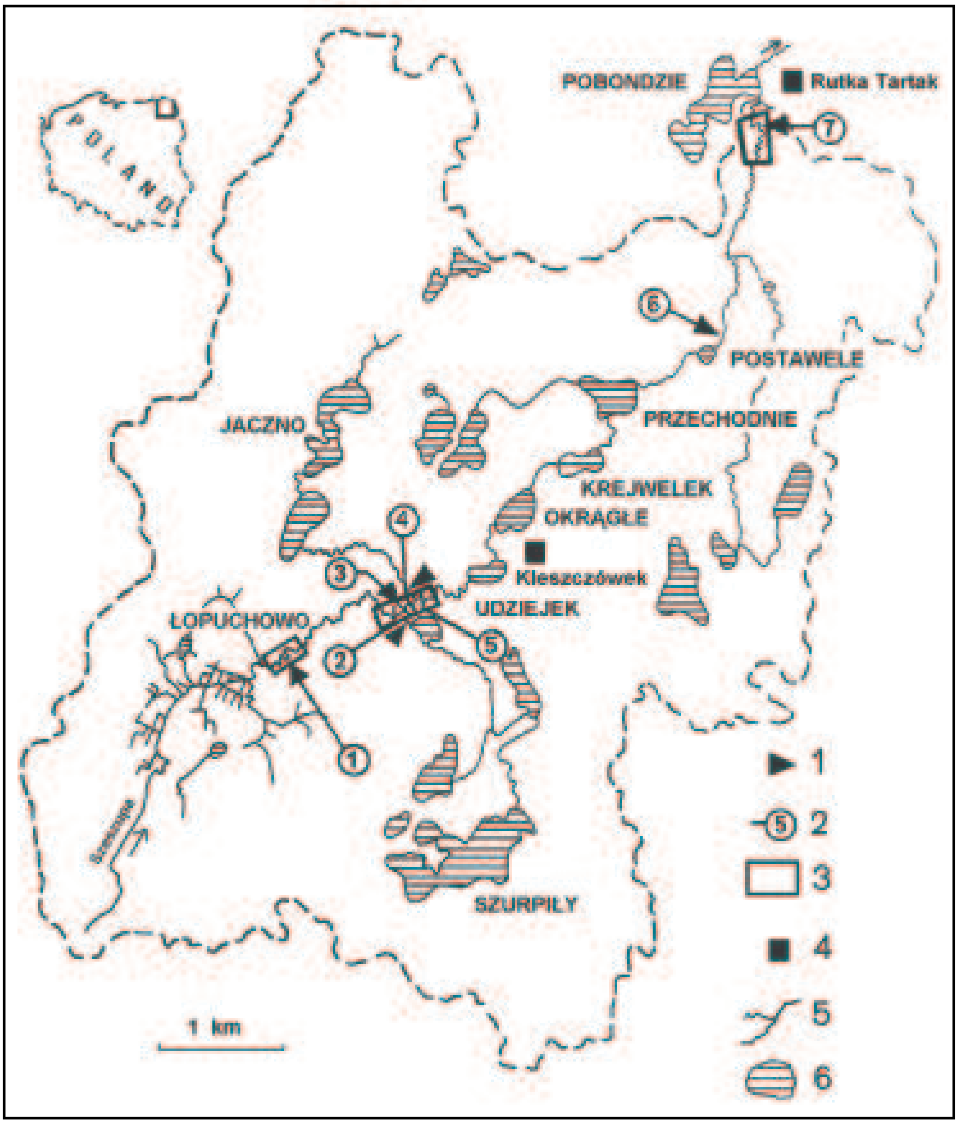

Fig. 1. Location of investigated area: 1 – water gauge points, 2 – numbers of hydrometric profiles, 3 – detail investigation areas, 4 – precipitation stations, 5 – rivers, 6 – lakes.

lake (Fig. 1). The river is 17.25 km long, the average channel slope reaches 3.2‰, and the sinuosity Si = 1.31.

The catchment area (73.2 km^2), includes the bottom of the extensive melt-out basin of Szeszupa river (Ber, Maksiak 1969; Ber 1982; Bogacki 1985) and the surrounding moraine uplands. The bottom of the basin is diversified, with land forms as: a ground moraine level, frontal moraine hills and ridges, eskers, kames, kame terraces, melt-out depressions of various dimensions and lake bowls, as well as river valleys.

The river basin is used agriculturaly. Arable land covers 43% of its area, permanent grasslands – 15%, and forests – approximately 25%. Lakes constitute a significant portion (6.3%) of the total area.

A characteristic feature of the upper Szeszupa valley is the alternating occurrence of narrow reaches with the slope gradient at 3.5-24‰, of gap origin, and wider reaches of melt-out origin or the melt water valleys where the slopes are much less steep, 0.5-2.8‰ (Fig. 2). Further down the river, below the Postawelek lake the valley turns into the meandering type, with slope inclination within 1‰.

In the gap stretches, the river channel is shallow (10-40 cm), gravel and sandy, in some places rocky, with numerous rapids and rather low thresholds (10-20 cm). The valley bottom is narrow (7-25 m), with its side slope inclination ranging between 9 and 24. This winding channel cuts into the valley slopes in many places.

Within the wider reaches of the valley, Szeszupa is somewhat deeper (30-80 cm), has a sandy bed and runs significantly. The slopes that surround the melt-out lows reach the gradient of 3-12°. The width of the bottom of the broader stretches ranges from 50 m in the melt-out of Udziejek to more than 1 km in the lake basin, where the river runs through five lakes in succession. The course of Szeszupa river has been regulated in the melt-out depression of Łopuchowo and in the lake basin. In the Udziejek melt-out basin, the river is meandering freely, with the average sinuosity reaching Si = 1.89 and even Si = 2.4 in places.

The nature of the river changes below the Postawelek lake – the bends are broader, the channel is deeper (exceeding 1 m), usually overgrown with aquatic vegetation. The width of the valley bottom and the flood terrace ranges between 100 and 500 m. In the upper part of this reach, where the river has been regulated, the cut-off bends are clearly distinguishable. In the lower part, the average sinuosity reaches 1.56.

There is one flood terrace along the whole lenght of the river valley.

3. Research method

During the years 1987-1989, standard hydrometric measurements were performed at seven transversal profiles of the Szeszupa channel with the aim to identify the dynamics of fluvial transport.

The relief of the entire upper Szeszupa channel system has also been mapped. This was achieved through the registration of the channel pattern, as well as the qualitative and quantitative description of landforms both and out of the channel. Special attention was paid to active incisions in the channel banks and in the slopes of the valley, as well as to the forms and microforms of the channel bed, which were regarded

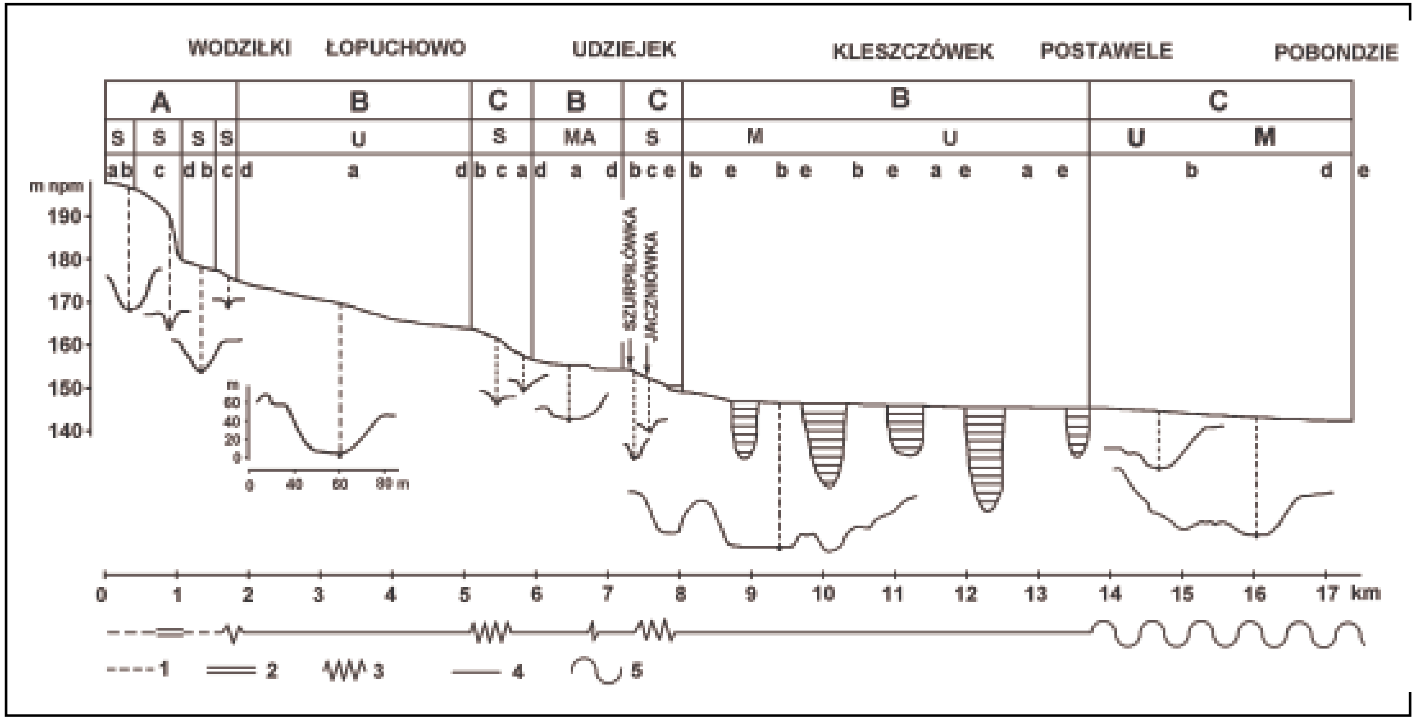

Fig. 2. The longitudinal profile of Szeszupa river and its structure: A – channel cut-out in boulder clay or in fluvioglacial sediments, with locally discontinuous alluvial cover in the bed; B – channel cut-out in peat and mineral-organic sediments with alluvial bed; C – channel cut-out in alluvial material, with locally discontinuous alluvial cover in the bed. The channel pattern: S – winding, M – meandering, MA – meandering, periodically anastomising. The dynamic types of the channel: a – stable redepositional, b-e – moderately stable with the following tendencies: b – lateral erosion, redepositional, c – weak lateral and bed erosion, transport – and – erosive, d – weak deposition and lateral erosion, redepositional, e – depositional (deltas). Fluvial subsystems: 1 – meltwater valley, 2 – incision valley (the slope of the ground moraine level), 3 – gap valley, 4 – valley with melt-out origin, 5 – wide valley of the meandering river.

as the indicators of the river transport and deposition activity. A seasonal geomorphologic mapping of the selected typical subsystems of the valley and the channel was also performed. Channel bank erosion measurements were conducted with reference to the established benchmarks. Similar approach was adopted in the measurement of the channel bed erosion/accumulation employing the steel rod method, and in the measurement of the geodesic profile for the periods indicative in the hydrological regime: the spring 1988 thaw spate, the July 1988 summer rain spates, and the low discharge period in September 1989. The measurements were repeated six years later, in the spring of 1994.

4. The hydrometeorological conditions of the study period

The hydrological system of Szeszupa – just as other river systems in the region – is moderately complex, with the supply coming from both ground water and precipitation (Dynowska 1971). The system is characterised by the occurrence of the largest spate in spring (the thaw spate) and the somewhat smaller spate in the autumn, usually in November (Byczkowski, Ciepielowski 1984; Bajkiewicz-Grabowska 1985).

During the research period, the highest spate occurred in spring of 1988 with more than a baneful discharge along the entire river course. The maximum discharge values ranged between 0.8 m^3s^{-1} in the upper part of the system analysed, and 2.4 m^3s^{-1} in the lower part. Such discharges occur 1.2 times in a year (Byczkowski 1975). The minimum discharges occurred typically in August and September, and were below 0.1 m^3s^{-1} in the upper part and approximately 0.4 m^3s^{-1} in the lower part of the channel system considered.

The mean annual air temperature was 6.5-8°C during the research period. The total annual precipitation ranged between 563 and 728 mm. The comparison of the weather conditions during the research period to the 1968-1986 period showed that the research period was average as regards precipitation, but warmer than average as regards air temperature. The research period featured short winters and thin snow cover.

5. The bed sediments of the channel

Channel bed sediments are characterised by a clear separation of the morphodynamic zones in the transversal profile of the channel; the current, the central bars, sidebars, and the alluvia appearing below various obstacles. The grain size composition analyses performed indicate the differentiation between sediments along the river course, both in the analysed transversal profiles of the channel in the current zone and in the zone of periodic accumulation, as well as dynamically (in particular measurement cycles).

The river current zone is characterised by a significant share of the gravel and, in places, also pebble size material ranging on average from 69.4 to 99.8% in the gap reaches, and from 50.5 to 76.6% in the reaches of the channel below the lake basin (Fig. 3). On the other hand, in the channel in the Łopuchowo and Udziejek melt-out

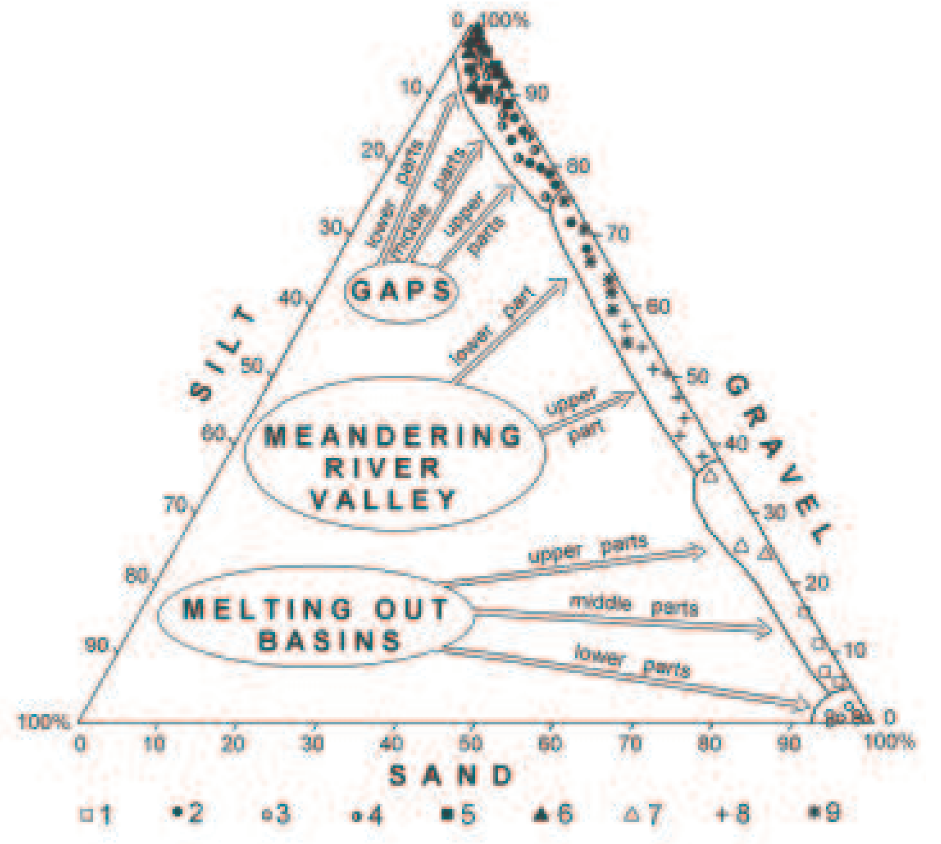

Fig. 3. Grain size composition of the Szeszupa channel deposits in the current zone:
1 – Łopuchowo basin, 2 – Łopuchowo gap, 3 – Udziejek, melt-out basin, 4 – Udziejek, upper part of the gap, 5 – Udziejek, middle part of the gap, 6 – Udziejek, lower part of the gap, 7 – lake basin (the estuary of river in the Gulbin Lake), 8 – Postawele, 9 – Pobondzie.

basins, there was a clear domination of the sand fraction (92-99%). Within the Szeszupa mouth reach opening into the Gulbin lake, the share of sands stood at 55-98%. The delta sediments were composed of sands (91-98%) as well. A very low share of silt was observed at all of the profiles within the river current zone (up to 4%; see Fig. 3). Such a distribution of grain size composition in the zone of the current is obviously linked to the distinct geomorphologic segments of the valley. The bed sediments of the channel in the gap valleys with significant slope values generally indicate the fact of washing out of the sand and silt material, with the coarser fraction being left in place. The sandy sediments, characteristic of the reaches between the gaps, come from the gap areas. This was confirmed by the drillings performed in the bottom of the melt-out depression in Udziejek which consisted of peat down to the depth of 2 m, followed by mineral-and-organic silts down to 3-3.5 m, which then turned into silt. The average thickness of alluvia in the channel of this reach was 60-70 cm. In the river current zone these alluvia are mainly sands. They could not have originated from the bed or lateral erosion.

Accumulation forms along the river course display a distinctly lower differentiation in the grain size composition (Fig. 4). In the gap reaches of the channel, the share of gravel in the median bars does not exceed 55%. It is only in the upper and the middle part of the gap in Łopuchowo that the share of gravel in median bars reaches 69%. Regardless of the hydrological situation (either following a spate or during an inter-spate period) two different material sizes could be differentiated. The coarser was

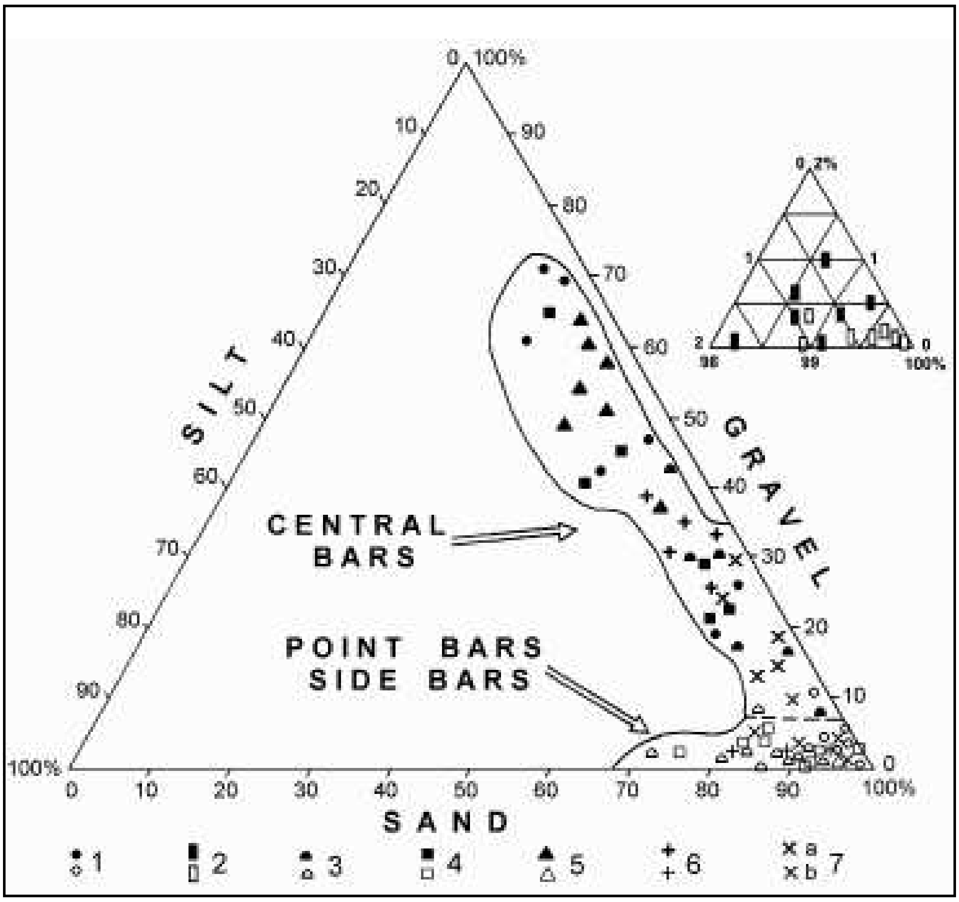

Fig. 4. Grain size composition of the Szeszupa channel deposits of median bars (a) and side bars and alluvia (b): 1 – Łopuchowo, 2 – Udziejek, melt-out basin, 3 – Udziejek, upper part of the gap, 4 – Udziejek, middle part of the gap, 5 – Udziejek, lower part of the gap, 6 – Postawele, 7 – Pobondzie

found in the median bars, while the finer, with a significant share of silt (up to 27%) – in the sidebars and in the alluvia in the lee of obstacles such as logs, boulders or median bars. The characteristic feature is the distinct difference in the structure of bars and alluvia in comparison with the river current zone. Only in the melt-out reach, the smallest difference between the fraction of the channel paving and the remaining ones was observed (see Figs. 3 and 4).

6. Channel forms

The dominating forms in the Szeszupa river channel are, bank incisions, side or bend bars, i.e. features typical for the winding rivers. There is a clear distinction of rapids (riffles) and pools along the longitudinal profile. An essential share of median bars and thresholds, especially in the middle parts of the gap valleys, is pronounced (Fig. 5).

The number of channel thresholds was the highest in the upper and middle parts of the gap valleys. The lower rubble thresholds – 10-20 cm, and the higher ones – 20-30 cm, are formed in the narrower segments of the channel, usually conditioned by the appearance of trees growing on the facing sides of the river. In the fluvial systems of a different origin permanent thresholds do not occur. Within the segments of the melt-out origin and the melt waters valley, the river was temporarily clogged after the spates with fallen trees, branches, etc., until the obstacles were gradually destroyed, usually within the period of 2-4 months.

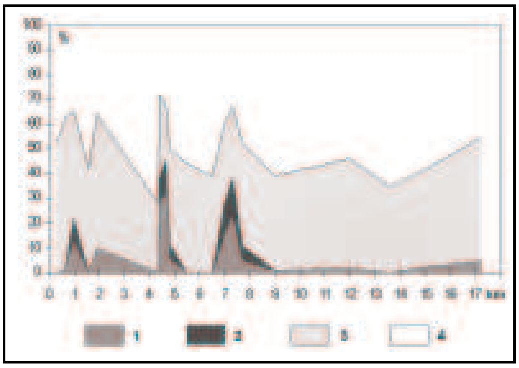

Fig. 5. Share of various channel forms along the Szeszupa river profile. Percentage shares of: 1 – rubble thresholds and rapids, 2 – potholes, 3 – incisions into the channel banks, 4 – bars.

Erosion marmites occur only below the thresholds and overflow channels. Median bars occur primarily in the gap valleys, especially in their middle and lower parts. Accumulation of material in the lakebound mouth reaches of the river is a typical feature of the Szeszupa river channel system. The largest deltas have formed at the openings to Gulbin and Pobondzie lakes.

7. Channel pattern

The Szeszupa river sinuosity is varied, ranging from 1.9 to 2.4, which is generally correlated with the valley slope gradient (except for the regulated reaches). The curvature radius of individual bends varies from 2 to 9 m's in the upper course and from 4.5 to 20 m's in the lower course of the channel system analysed.

Szeszupa river is typical in that the channel pattern changes during the baneful and higher discharges. Then, during some 10-20 days in a year, the channels-canals function whose bottoms are located somewhat above the bottom of the steady channel, and Szeszupa becomes locally a two-channel river. These channels are either of the overflow type or anatomising.

In the gap valleys in Łopuchowo and Udziejek the channels are of the overflow type, cutting through the necks of bends of loop-like shape with small radius of curvature – between 2.5 and 4 m. The overflow channels occur much less frequently on the outer side of the concave banks of the bends, especially where the concave banks are strengthened with growing trees and are hardly eroding (Fig. 6a). The radius of curvature of the channel formed is 2-3 m bigger than the radius of curvature of a Szeszupa bend. Some of the overflow channels form during one spate and cease to function soon after, but some remain in place for longer.

In the melt-out valley of Udziejek, an anatomising channel system functions during the spring thaw or autumn rain spates every year. A similar setting of the channel existed before regulation in the valley in the Łopuchowo melt-out depression.

Along the entire course of Szeszupa river the banks of the channel are well stabilised with vegetation, especially trees growing on both sides of the channel.

8. Channel structure

The following channel types have been identified following the application of the fundamental lithological and structural criteria (Kaszowski, Krzemień 1986):

A – cut out in the clay or in the fluvioglacial sediments, locally with discontinuous alluvial cover at the bed, winding,

B – cut out in peat and mineral-organogenic silt with alluvial bed, meandering and periodically anatomising,

C – cut out in the alluvial material, with alluvial bed, in places with discontinuous alluvial cover, winding or meandering.

Occurrence of the individual structural channel types is schematically shown in Fig. 2. Type B occurs only in one genetic valley type – the melt-out valley, while other structural channel types occur in several valley types. Type A channel occurs in melt water valleys, in the incision valley at the level of ground moraine. Type C channel occurs in the gap valley and in the wide meandering river valley.

The channel dynamics has been defined following a series of analyses concerning the intensity of the suspended and bed material transport, bed situation changes in the considered hydrometric profiles and the relaxation time. During the research period, the Szeszupa channel was in dynamic equilibrium and performed mainly the transport function. This was indicated by the preserved shape of the channel both in the cross-section and in the horizontal plan. The changes of the bed situation usually oscillated around one level and corresponded to temporary bed erosion, transport or accumulation,

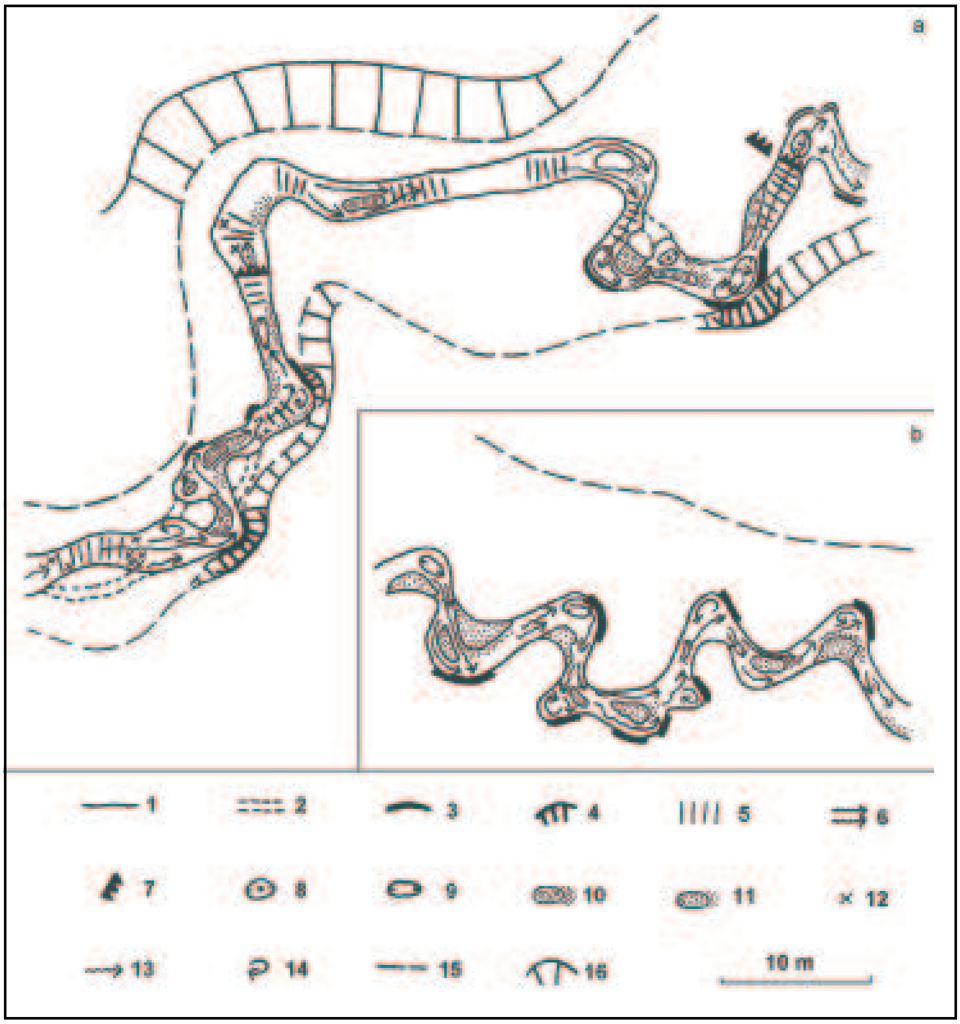

Fig. 6. Geomorphological sketch of the chosen channel segments in the middle part of Łopuchowo gap valley (a) and lower part of Udziejek melt out origin (b): 1 – channel banks, 2 – overflow channel banks, 3 – active channel bank incisions, 4 – active valley slope incisions, 5 – thresholds and rapids, 6 – riffles, 7 – potholes, 8 – pools, 9 – gravel and sand bars, 10 – sand bars, 11 – rocks, 12 – river current, 13 – back flow, 14 – range of flood terrace, 15 – valley slope

depending upon the intensity of discharge and assignment to a genetic valley type (Smolska 1996).

The relaxation time analysis showed that the main morphogenetic role during the research period was played either by the spring thaw spate or the autumn rain spate – the latter during the years, in which the snow cover was not adequate in winter. The bed pre-spate location recover time for the particular transversal profiles varied as follows:

1) 6-10 months, and even in up to 2 years within the middle and upper parts of the gap valleys subsystems (the bed erosion in the channel in the middle fragments of the gap valleys and in the valley on the slope of the ground moraine was observed only locally),
2) 4 months in the lower part of the gap valleys,
3) approximately 8-12 weeks in the valley of the melt-out origin,
4) approximately 6 weeks in the wide valley of the meandering river.

The results of the relief mapping of the channel showed a clear domination of the lateral erosion over the bed erosion and accumulation in the gap valleys and in the upper parts of the valleys in melt-out depressions. In the Szeszupa channel located in the valley of melt-out origin, especially in its lower part, a domination of accumulation was observed, related to the supply of material from the gap located upwards and to the impediment to the outflow of the material transported toward the next gap. In meltwater valley and in the wide meandering river valley, lateral erosion and accumulation of the material on the point bars, and locally on the riffles in the form of alternate bars were observed.

The role of the rain-related spates for the relief was limited – the river channel would return to the previous state after 2-3 weeks (of the inter-spate period). Lateral erosion or accumulation dominated in the upper and middle parts of the gap valleys. In the lower parts of gaps accumulation could be clearly observed in the channel. During the short, but abundant rainfalls of the summer season the advantageous transportation conditions within these segments lasted only up to a dozen hours and this period was insufficient for the amount of the material supplied to be transported to be brought down the river in its entirety. Thus, median bars emerged. Within the valleys of melt-out and melt waters origin, there were numerous incisions of the banks and simultaneously accumulation of bars and alluvia. Additionally, the in the wide meandering river valley the Szeszupa channel was characterised by the dynamic equilibrium, weak lateral erosion, as well as bed erosion in the current zone, and accumulation of the material in the point bars.

During the periods between floods any unevenness in the bed along the whole length the river was evened out through the bar and riffle erosion and the filling of potholes pools. The morphological effects of these periods would disappear after just one small spate of the rain falls season.

Both the lesser spates and the inter-spate periods had a clear effect of reversing of any changes in the riverbed resulting from the thaw spate. Lateral erosion along the course of Szeszupa river was not very intensive. The maximum rate amounted to approximately 60 cm during 6 years, and it usually did not exceed 20 cm.

The following dynamic types of the channel were identified along the course of Szeszupa river (see Fig. 2):

a) a stable channel with the redeposition function, and the moderately stable channel with the tendency to:

b) lateral erosion, also with the redeposition function,
c) weak bed and lateral erosion, with the transport-and-erosion function,
d) weak deposition and lateral erosion, with the redeposition function, and
e) the depositional one in the deltas.

On the basis of the analysis of the lithological-structural and dynamic features of the Szeszupa river channel, the fluvial subsystems were identified by the genetic type of the valley. The characteristic quality of each of the systems distinguished is the appearance of a definite structural type of the channel or its dynamics.

In the fluvial subsystem of the meltwaters valley a stable and locally moderately stable channel of type A is found. It is a winding, locally meandering channel, with the average sinuosity of Si = 1.28-1.41. This channel is cut out in the fluvioglacial sediments. The channel bed is covered in alluvium, which disappears only locally in the current zone and at the rapids – there are sands and gravel in the bed, with a share of larger size material. The width of the channel is similar along the bends and the straight segments: 1.5-2 m. The channel is cut out to the depth of 40-60 cm. The setting of the channel middle size forms corresponds to the channel type (type 12 according to Schumm 1981). The primary forms are side and point bars, riffles or rapids, as well as pools. Within the bends, the convex banks of the channel are incised, and only infrequently the slopes of the valley are incised.

The A type channel occurs also in the fluvial subsystem of the ground moraine level slope, but it is moderately stable there, with a tendency towards the lateral and depth erosion. The channel is cut out in the boulder clay, with a distinctive feature of the irregular rubble thresholds and shallow potholes. The narrow bottom of the valley, in places limited just to the channel, facilitates the supply of material for the fluvial transport from the slopes of the valley. The characteristic feature of the type A channel, occurring in the two subsystems, is the development due to just one cycle: straight channel → winding channel (Ferguson 1987). We do not observe here the well-developed loop-shaped bends, or the cut-off meanders on the flood terrace.

The fluvial subsystem of the valley with the melt-out origin, Szeszupa has a B type meandering, periodically anatomising channel. The characteristic feature of the channel pattern is the relatively regular course and occurrence of bends with short radius ranging between 2 and 10 m. Some of those have developed into loop-shaped bends. Locally, the smaller meanders develop along the bends (see Fig. 6b). This type of the channel corresponds to the type 13, and periodically to type 14a, according to S.A. Schumm (1981). This channel reach is stable, only locally moderately stable, with a tendency to a weak lateral erosion and deposition. It is cut out in peat and mineral-organic silts down to the depth of 1-1.5 m. The channel bottom is covered with alluvia. The setting of the channel medium-sized forms corresponds to the setting of the meandering channel – there are point bars, riffles and pools. In the upper and lower segments of the subsystem considered there are, locally, median bars. The channel is characterised here by its wider bends. It is visible particularly well in the upper and lower parts of the valley in the melt-out of Udziejek, where the channel is twice as wide in the bends as in the straight reaches (see Fig. 6b). During the low discharge periods the bend bars are cut through with the canals-chutes and we observe locally two or even three currents. During bankfull and higher discharges the anatomising channel functions as well.

In the fluvial subsystem of the gap valleys, the moderately stable C type winding channel occurs, with a tendency for lateral and depth erosion. The feature of the type C channel is its irregular course: side by side with the straight segments there are meandering fragments. The bends with a bigger radius of curvature develop smaller bends whose radius are between 2.5 and 9 m. Some of the bends have developed into the loop shaped bends and there are also cut-off meanders on the flood terrace. The C type channel has developed due to two cycles: straight channel → winding or meandering channel with large bends → winding or meandering channel with smaller bends (Ferguson 1987). The channel has been cut-out in the alluvia down to the depth of 0.5-1 m. The channel bed is covered with an alluvial cover of varied thickness ranging from a few of centimetres to 0.5 m. In the channel reaches with thresholds, rapids and a strong current zone, periodically, in numerous places alluvia do not occur. Instead, boulder clay is being washed away there in the form of rocky material with the diameter exceeding 10 cm. In the middle and lower sections, one notices chaotic distribution of forms with respect to the setting of the winding channel, and particularly in the middle part – their significant variation (see Fig. 6a). Along the bend bars and pools there are also rubble thresholds and rapids, and locally potholes. The width of the channel changes, it is bigger in the bends and smaller over the straight stretches. Similarly, the channel is wider in the rapid zone or in the zone of median bar accumulation. During the bankfull discharges the overflow canals are formed and function.

The C type channel also occurs in the subsystem of the wide valley of the meandering river. The setting of the medium-size forms corresponds to the meandering pattern of the channel. Bar accumulation at the riffles can be observed periodically. There are very few rapids. The main difference with respect to the channel of the fluvial subsystem of the gap valley is in the dynamics – the channel here is stable and moderately stable, with a tendency towards a weak lateral erosion.

In the case of the C type channel, it is very difficult to establish what is the corresponding type in the classification of S.A. Schumm (1981) – it can be described as an intermediary type between the types 8 and 13.

In the late glaciation area, separate subsystems appearing along the river course of Szeszupa's type are constituted by the lake stretches. The studies conducted in the Gulbin lake mouth reach allow the statement that this was an accumulation reach, and that the respective process was not limited to the very delta, but periodically covered also the bottom of the channel directly above the river mouth.

The course of the fluvial processes and the changes in the relief of the channel indicate that in the period 1986-1995 the channel was in dynamic equilibrium, with meandering being the main component process. The channel performed the transport function. The characteristic feature was periodical deposition and then redeposition of the deposited material. The tendencies to weak channel bed erosion in the channel in the middle stretches of the gaps and to weak deposition in the lower segments of the melt-out basins, as well as to accumulation in the mouths of the river (deltas) at the openings to the lakes, occurred only locally.

9. Conclusions

River valleys in the late glaciation areas are typified by the appearance of the segments of different origins in their longitudinal profile. These origins refer to the incision valley, the valley of the melt waters, the melt-out depression, the gap valley, and the wide meandering river valley. The genetic type of the valley is decisive mainly for the valley's width and slope, as well as for the nature of the formations appearing in the bottom. Such a differentiation of the morphological and lithological features in the longitudinal profile of the valley has distinctly conditioned formation and dynamics of the fluvial system.

Three lithological-structural types of the river channel may be observed along the course of Szeszupa river: A – the ones cut out in the boulder clays or in the fluvioglacial sediments, with locally discontinuous alluvial cover in the bed, B – those cut out in peat and in mineral-organogenic silts with alluvial bed, and C – those cut out in the alluvial material, with alluvial bed, and with locally discontinuous alluvial cover. In the particular fluvial subsystems these types differ by their sinuosity and the dynamics of fluvial processes.

The channel of Szeszupa river is stable and moderately stable. The weak lateral erosion is conditioned by high cohesion of the sediments in which the channel is cut out, while the weak bed erosion – by the gravel-and-stone formations of the washed out boulder clay and the fluvioglacial sediments. The channel mainly performs the transport function. It is characterised by the periodic deposition of the material and then its redeposition.

References

Bajkiewicz-Grabowska E., 1985, *Stosunki wodne* [w:] *Województwo Suwalskie*, Studia i Mat.1, OBN Białystok, IGiPZ PAN, Warszawa.

Ber A., 1982, *Marginal zones and deglaciation during the North Polish Glaciation in the Suwałki-Augustów Lakeland*, Biul IG, 343.

Ber A., Maksiak S., 1969, *Formy marginalne i formy martwego lodu w zagłębieniu Szeszupy na Poj. Suwalskim*, Biul. IG, 220.

Bogacki M., 1985, *Budowa geologiczna i ukształtowanie powierzchni* [w:] *Województwo Suwalskie*, Studia i Mat.1, OBN Białystok, IGiPZ PAN, Warszawa, Białystok.

Byczkowski A. i in., 1975, *Studia hydrologiczne w dorzeczu rzeki Szeszupy*, cz. III., typescript, SGGW AR, 1-45.

Byczkowski A., Ciepielowski A., 1984, *Stosunki hydrologiczne w województwach białostockim, łomżyńskim i suwalskim*, Gosp. Wodna, 4, 99-102.

Dynowska I., 1971, *Typy reżimów rzecznych w Polsce*, Zesz. Nauk. UJ, Prace Geogr., 28.

Ferguson R.I., 1987, *Hydraulic and sedimentary controls of channel pattern* [w:] K. Richards (red.), *River channels-environment and process*, Blackwell Oxford, 129-158.

Kaszowski L., Krzemień K., 1986, *Metody typologii koryt rzecznych*, Zesz. Nauk. UJ, Prace Geogr. 67, 7-23.

Kondracki J., 1978, *Geografia fizyczna Polski*, PWN, Warszawa.

Schumm S.A., 1981, *Evolution and response of the fluvial system. Sedimentologic implications*, Soc. of Econ. Paleontologists and Mineralogists, Spec. Publ. 31, 19-29.

Smolska E., 1996, *Funkcjonowanie systemu korytowego w obszarze młodoglacjalnym na przykładzie górnej Szeszupy (Pojezierze Suwalskie)*, Wyd. WGiSR UW.

Starkel L., 1988, *Historia dolin rzecznych w holocenie*, Wszechnica, PAN, Ossolineum, Wrocław, 87-107.