The evolution of fluvial systems in the Upper Vistulian and Holocene in the territory of Poland

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Abstract: The location of Polish territory at the junction of a shield-platform, Hercynian and Alpine Europe creates the possibility of studying a great diversity in the evolution of fluvial systems. As well as the climatic change from periglacial to temperate, an important role was played by the drainage of the whole territory towards the north and by the blocking of valleys by the advances of the Scandinavian ice sheet. Studies of the evolution of fluvial systems started at the end of the 19th century, but detailed investigations initiated in the 1970s provided a good background for stratigraphic and paleogeographic reconstructions. In the territory of Poland, several W-E oriented zones of various sequences and trends of evolution have been distinguished. In the southern and middle parts of extraglacial Poland climatic changes are registered in the erosional and depositional sequences. These are especially well expressed in the valleys of mountain rivers which show changeable flood frequency and different tectonic tendencies. In the upland and lowland zones, there is a very distinct phase of continental climate. In the zone of the last glaciation, systems of ice marginal streamways were developed in association with a new superimposed valley pattern, composed of transversal gaps and young, expanding fluvial systems. The periglacial episode was reflected in the valley floors in the zone of older ice sheet advances. During the Litorina transgression, a wide belt was submerged, but this sea level rise is not reflected in any obvious evolution of the valley reaches upstream.

Key words: fluvial system, Upper Vistulian, Holocene

Introduction

Poland occupies an area at the junction of three main tectonic units of the European continent: the NE part of the Fennoscandian Shield and Russian Platform, the western region of Hercynian horsts and grabens and the southern, Alpine zone of young mountains and foredeeps. The whole territory slopes to the north, so the main direction of drainage is towards the Baltic depression. This belt, less than 1000 km wide, was exposed to the Upper Quaternary climatic fluctuations and a N-S shift of the morphoclimatic zones responsible for the repeated appearance and decay of the periglacial zone as well as for advances and retreats of the Scandinavian ice sheets. There is no doubt that, on the vast European lowlands, the W-E directed fluctuations of degree in cold-intensity were also accentuated.

Therefore, regarding the evolution of the fluvial systems on Poland’s territory we may expect their diversity in a south-north transect reflecting all these external factors as well as with the internal growth of the catchments and the decline of gradient towards an unstable base level.

History of research

It is now over one century ago when Żarębczyński (1894), Lomnicki (1903) and Friedberg (1903) recognized two various Upper Pleistocene and Holocene alluvial fills in the upper Vistula basin and its lower course. Jentsch (1901) and Keilhack (1904) studied the retreat of the last ice sheet and the formation of ice marginal streamways. During the inter-war period the group of terraces in the Middle Vistula valley was related to supposed ice retreat (Lencewicz, 1927). Their number was multiplied in the gap of Lower Vistula which was filled after ice retreat from the Pomeranian marginal zone (Galon, 1934, 1953). In the upper reaches Klimczakowski (1948, 1967) assumed a Vistulian age for the alluvia filling the valley floors, while they are buried by Holocene overbank loams.

Detailed mapping in the post-war period (both geomorphological and geological) brought new evidence. The loess-covered terrace (or dune-structured sandy one in southern Poland) has been associated with the last cold stage (Jahn, 1957; Laskowska-Wysoczna, 1971) and several fills of late Vistulian and Holocene age were discovered in the valley floors (Starkel, 1969). In the Caspianian, the interfingering of fluvial and solifluction slope deposits was used as an indicator of
elaborated the concept of the transformation of river channel patterns from braided to meandering, as well as with environmental changes during the late Vistulian.

In the 1970s, the number of sites dated by radiocarbon and palynological methods increased rapidly. Parallel alluvial fills of Vistulian age (Mamakowa & Starkel, 1974) as well as Holocene age (Ralska-Jasięwieczowa & Starkel, 1975) were documented. Later, several international projects started (among them IGCP-158) which surveyed hundreds of kilometres of valley reaches and yielded hundreds of radiocarbon and other dates which indicated that the stratigraphy has been in need of revision and enabled extensive palaeogeographic reconstructions to be made. From these, we can state complex palaeogeographic studies along the Vistula valley (Starckel, 1990) and detailed investigations of the Holocene age (such as those by the Author, Starkel, 1968). In the additional valleys, detailed studies of the age of the terrace sequence were undertaken, enabling the formation of new dates (Jersak et al., 1987; Štefek, 1987) and climatic fluctuations during the cold stage (Franko, 1988; Surensen, 1996).

In the coastal zone, the sea level fluctuations were investigated (Mojski, 1990; Florcz, 1991). Most results relating to the Vistulian-Holocene transition are summarised in the volume related to the IGCP project 253 - Termination of Pleistocene (Starkel & Gumiński, 1995; Torkowska, 1995; Mojski, 1995, and others).

**Areal distribution of various factors in the evolution of fluvial systems**

The following factors discussed below are considered in the evolution of the fluvial systems:

1. The size of catchment and the longitudinal profile of valley floors and river channels;
2. The characteristic changes, reflected in variations of the hydrological regime and sediment load;
3. The advance and retreat of the Scandinavian ice sheet;
4. The last advance and retreat of the Scandinavian ice sheet;
5. Differences in neotectonic movements;
6. Anthropic factors (fluctuations of the newly formed Baltic Sea).

The last advance and retreat of the Scandinavian ice sheet

Before 45% of Polish territory was covered by the last ice sheet between ca 22 and 14 ka BP, River valleys were blocked by ice, rivers were diverted from their courses and, together with meltwater, were flowing to the west, following ice marginal streams (Galton, 1988). Together with ice melting (deepening, incision incision), new areas became free of ice and a new drainage pattern started to be organised under the periglacial climate (Kozerski, 1983, 1995). Later, this pattern became reorganised during the melting of ice blocks and the progressive amelioration of the climate. Differences in neotectonic movements

In the evolution of some regions, the tectonic factors may be important. During times of periglacial climate in its role was affected by extended slope degradation and seasonal

overloading of rivers (Starkel, 1968). The tendency of mountain regions to uplift and submergence of depocentres to subside may be reflected in a trend towards erosion or aggradation (Liszowski, 1982). In the lowland areas, the existence of glacial rebound is difficult to prove, due to its superposition on other isostatic trends (Bryczkowski, 1986).

**An eustatic factor (fluctuations of the newly formed Baltic Sea)**

The Baltic Sea was preceded by the Baltic Ice Lake, the level of which is considered to be more than 80 m below its present level. The Yoldia transgression started from ca 80 m a.s.l., a submontane depression, the South Polish Uplands (400-600 m a.s.l.) and the Baltic basin (1-50 m a.s.l.) (Starkel, 1968). The formation of the Baltic Sea started from a point between 4500 and 4000 years ago. Coastal flat areas were submerged. This shortening of river courses promoted new conditions for the development of deltas (Mojski, 1990).

**Anthropic factors, appearing in the Neolithic**

Forest clearance started in the Neolithic, primarily on a local scale, then on a regional scale (Starkel, 1968). Changes in the rate of overbank deposition, course-setting of sediment and, finally, in the last centuries, the transformation in the channel pattern (Klimeszk & Starkel, 1974; Starkel, 1995). However, this is not a main subject of this paper.

**Regional differentiation in the evolution of fluvial systems**

The combination of various factors caused a regional differentiation in the evolution of fluvial systems which has been discussed several times by the Author (Starkel, 1968, 1977, 1979, 1990, 1994, 1995b, 1953; Fig. 3).

**Upper mountain reaches**

In the mountains, the channel gradient (slope) depends on various factors and in the mature wide Carpathian and Sudetic valleys it fluctuates between 2 and 10%. The tectonic tendency and lithology of bedrock are very important. The aggradation during the cold stage, reflected in the interfering of slope and fluvial sediment with a distinct erosional break during the interglacial periods is a common feature. This is registered by overbank sediments with dated organic intercalations (Klimaszewski, 1971; Starkel, 1968). In reaches which have a rising tendency e.g. in the transversal gaps of the Danajec (Frohlich et al., 1972) or Wisłok (Zuchwieck, 1987), several steps were cut in alluvium and then in bedrock which reflect late-glacial and Holocene phases of incision. In the subsiding Orawa - Nowy Tang Basin, this destruction started long before the last Vistulian. Organic deposition started on an erosional step during the Bölling interstadial (Klimaszewski, 1967). Peatbogs located in the abandoned channel have been recognized in the Upper San valley at Tarnawa. Three distinct flood phases, two in the form of overbank deposits during the Younger Dryas and between 8.7-7.8 ka BP and the third one as a submergence during early Sub-Boreal have also been identified (Ralska-Jasięwieczowa & Starkel, 1975).

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organic sediments, the Plock Basin - upstream of maximal extend of last ice sheet

TH-4 W6jeik, - palaeochannel gravels, 1987; Klimek, 1992). The South-Polish late Lanzonian, 1995a; Knyliec. sands, 1995a; Knyliec. gravels, Oswil{eim the Uplands represent the youngest also been generally recognised, two fills being dated 30 loss. sands from the Younger Dryas

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Foothill reaches

In the wide belt of the Carpathian Foothills the older Vistulian terrace is buried by the loess or solifluction sediments (Starkel, 1974; Starkel, 1995a), deep pre-late Vistulian incision (Klimek, 1992) and several Holocene fills (Alexandrowicz et al., 1981). This reach shows a distinct tendency towards deepening and narrowing of the floodplain.

The trend opposite to aggradation was recognised in the subsiding Osiwiec Basin in the foreland of the Silesian Beskid (Niedzialekowska et al., 1985).

1) Wide valley floor (5-10 km) with a well developed loess terrace, remnants of a lower sandy level with dunes and a floodplain which has several fills and a distinct tendency to avulsions. As a result, wide fragments of valley floor with abandoned systems of palaeochannels from the Younger Dryas (Kalkic, 1991), late Atlantic (Starkel et al., 1991) or early Subboreal (Kalicki et al., 1996) have been preserved. The avulsions were typical also in the earlier times, which is indicated by islands of higher terraces separating two younger valley (cf. Starkel, 1990). The outlet of the Raba river (Gebica, 1993) possessed similar landforms.

2) In case of narrower gaps, as for the Vistula reach in the Cracow Gate or the gap of the Middle Vistula across the South Polish Uplands, the river energy due to confined meandering was manifested in the vertical variations. Therefore, in both valley reaches, the channel deposits represent the youngest members and, on the narrow benches, overbank deposits separated by fossil soil horizons are preserved (cf. Rutkowski, 1987; Pozarzyński & Kalicki, 1995; Fig. 3 f).

3) A sequence of alluvial fans at the mountain front, with two distinct upper pleniglacial terraces, 15 m high, younger than 28 ka BP, and 10-12 m high with a braided pattern (Mamakowa & Starkel, 1974; Starkel, 1995a), deep pre-late Vistulian incision (Klimek, 1992) and several Holocene fills (Alexandrowicz et al., 1981). This reach shows a distinct tendency towards deepening and narrowing of the floodplain. The trend opposite to aggradation was recognised in the subsiding Osiwiec Basin in the foreland of the Silesian Beskid (Niedzialekowska et al., 1985).

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Fig. 4. Longitudinal profile of the Vistula valley (Starkel, 1990).

1 - mean river level profile, 2 - terrace levels, 3 - overbank deposits from last ice sheet advance, 4 - pleniglacial terrace with late glacial dunes, 5 - interpleniglacial terrace covered by loess.

Fig. 3. Selected generalised cross-sections of river valleys in the Vistula catchment.

1 - Wisłoka valley at the Carpathian foreland (after Starkel, 1995b), 2 - Vistula valley at the Grobla forest - the western part of Sandomierz Basin (after Starkel et al., 1991), 3 - Vistula valley in the narrow gap across the South-Polish Uplands (after Pozarzyński & Kalicki, 1995), 4 - Vistula valley in the Plock Basin - upstream of maximal extend of last ice sheet (after Floré et al., 1987).

1 - bedrock, 2 - gravels, 3 - sands and gravels, 4 - sands, 5 - palaeochannel fills, 6 - overbank loams, 7 - organic sediments, 8 - loess, 9 - section sands, 10 - fossil soil horizons.
The South-Polish Uplands
Most of the upland rivers drain directly either to the Vistula or the Oder. Their width differs, according to their glacial history and tectonic tendencies, and their preglacial courses may be buried to several decametres below the present river (Glewiska, 1972; Mrazuszczak, 1972). In areas built from chalk and with a thick loess mantle, complex fluvo-devalual-colluvial bodies dated either to interpluvial (Harasimuz, 1991) or to the kataglacial phase of the upper pluvial (Jersak, 1976; Jersak et al., 1992; Saperszysyn, 1996) are very common. In the valleys with thick reservoirs of glacial fluvial sands their reworking under permafrost conditions was very active and extensive sandy fills are observed in their lower reaches (Jersak and Sendroby, 1991; Buzaczynski, 1994). The late Vistulan or early Holocene organic deposits in the valley floors indicate earlier intensive erosion (Snieszko & Dwucet, 1995). This was followed by Holocene aggradation, which accelerated after forest clearances (Snieszko, 1985).

A slightly different picture is observed in the limestone areas where, after the Late Vistulan, erosion followed over localities. The deposition of calcareous tufa was interrupted during phases with frequent flood episodes (Rutkowski, 1991; Pautz et al., 1988; Czarnowski, 1988).

The Lowland periglacial zone (extra-glacial)
This zone, 100-250 km wide, was glaciated in its northern part during the penultimate Warta advance. In this zone, large transversal valleys (Vistula, Bug, Oder, Warta, Prosna) and smaller river pattern may be distinguished. The first are easily recognised in the Warsaw Basin, where the staircase of terraces was earlier associated with the retreat phases of the last Scandinavian ice sheet (Rozyczki, 1967), then with lataglacial climatic oscillations (Baramuiezka & Koneck-Belley, 1987) and later the pre-EpE (c.14.5 ka BP) erosion downstream of Warsaw was documented by overbank deposits underlying the terraces on the first overflood terrace which have been dated at 14.5 ka BP (Manikowska, 1985).

In the Prosna valley, Romsck (1988) recognised the dissection of the higher terrace (with midoacid dates between 28 and 26 ka BP) which preceded an erosional phase which coincided with the maximum of the glacial advance and then aggradation about 18.5 ka BP. During the late Vistulan up to the Younger Dryas, the Prosna created large palaeomeanders, which indicate a 5-fold increase in bankful discharge (Romsck & Myczynski, 1989). During the Holocene lateral migration, several generations of smaller meanders were created.

In the smaller valleys of the Lodz region, the role of the Vistulan valley formation depends on the nature of the transformation of the previous river pattern formed after the retreat of the Warta ice sheet. Many closed depressions were incorporated into the uniform valley system (Klatkowa, 1989). Detailed studies of periglacial sediment have shown that, after the post-interpluvial aggradation, a phase of strong aeolian activity followed with the formation of a gravel pavement and, later, during the late Vistulan, deposition turned to erosion again (Manikowska, 1985, 1995; Turkowska, 1988, 1995).

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Fig. 6. Two ways of "expanding" river valleys in the zone of last deglaciation (after 20 ka BP).
A - Expanding downstream (e.g. Vistula, Oder): a - growing length in time (later transgression), b - expansion of floodplain controlled from upstream.
B - Tributary valley expanding "upstream", controlled by low base level: c - backward growth of river in zone of older phases, d - backward growth in zone of Pomeranian phase, e - formation of uniform floodplain in zone of older phases, f - formation of floodplain in the zone of the Pomeranian phase.

After a slight aggradation during the Younger Dryas, distinct episodes of fluvial activity about 8.5, 5.5 - 4.5 and 3.5 - 3.0 ka BP were recorded (Turkowski, 1988; Kamiński, 1993).

Ice marginal streamways - underfit streams
In northern Poland a system of ice marginal streamways (pradolina) developed, followed by the main phases of the ice retreat (Galan, 1967, 1968). After detailed studies in West Poland several new phases were recognised (Kozarski, 1988). The existence of only one streamway in the east is a common feature; in the west, their "avulsions" developed due to fast retreat from the marginal zones of Leszno (20 ka BP), Poznań (18 ka), Chodzież (17.2 ka), Pomeranian (15.2 ka) and Gardno (13.2 ka) were created (Kozarski, 1988). Some parts of these wide floors were gradually dissected (as in the case of Toruń - Elblag wedge pradolina; Kozarski, 1962) and sometimes became active up to the Bölling (like the Warta south of Poznań - Kozarski et al., 1988). Thermokarst probably played a considerable role in their lateral development. This was assumed by Jahn (1975) and later supported by Kozarski (1995) and his team (Antczak, 1986) after discovery of ice wedge casts and frost cracks connected with expansion of permafrost over the deglaciated south areas of the limit of the Pomeranian phase. Later, these floors were overgrown by peat. The peat accumulation started in the Allerod and totally fossilised the floor of the Biebrza pradolina near the interfluve between the Vistula and the Narew Basin (Zurek, 1975). This part represents a classical underfit stream. The short-lived narrow pradolinas drained at present by the Glogówka and Bachorza streams at the Vistula - Warta interfluve have a similar character (Andrezewski, 1955; Wiśniewski, 1982).

New datings from the Baltic Sea floor (cf. Mojski, 1995) and the Gardno phase (Romsck & Borówka, 1994) indicate that the age of the marginal zones must be increased and Kozarski (1995), in his last paper, accepts the age of the Chodzież phase as being about 17.7 ka, older than 16 ka for the Pomeranian phase and about 14.5 ka BP for the Gardno phase. The most northern pradolina of Bölling or Alleröd age is submerged under the Baltic Sea (Mojski, 1990).

The large transverse valley of the Vistula river
Following the ice retreat, the water of all rivers draining the southern periglacial zone as well as that accumulated in the ice dammed lakes (Warsaw Basin) formed the gaps across the marginal zones and, step by step extended their courses towards the Baltic depression (Fig. 2). In several transverse reaches systems of terraces are found, up to 10-12 in number, which reflect this pronounced incision (Galon, 1934). Several authors have made efforts to correlate these steps along the Lower Vistula and tributaries (Galon, 1967), but only the dating and correlation of the 3-4 lowest ones has proved possible (Röškó, 1968; Drozdowski & Berglund, 1976; Tomczak, 1987). As concluded by Wiśniewski (1982, 1987; also see Starkel, 1990), the correlation of higher terrace levels based on altitude is useless because these levels are all associated with transformations of different reaches during deglaciation (Fig. 4).

In the lowest course, incision probably continued until the beginning of the Holocene, when the low water level of the Yoldia Sea started to rise from 80 metres. Fluvial deposits of early Holocene age are recorded below the Vistula delta (Mojski, 1990). The construction of the Vistula delta started from 7 ka BP jointly with the Litorina transgression. The Holocene evolution of the Lower Vistula valley is controlled more and more by the hydrological regime of the upper and middle part of the basin. This means that the phases of Subboreal and Subatlantic aggradation and channel abandonment are synchronous with those identified in the Subcarpathian Basins (Florek et al., 1987; Tomczak, 1987; Starkel, 1990).

Detailed studies of the divergence of the Middle Warta valley (to the west of the pradolina, north of the Poznań gap) have shown that the transformation from braiding to meandering followed in the early Bölling stage, and the next change towards small meanders and a narrowing of the floodplain coincided with total reformation at the beginning of the Holocene (Kozarski et al., 1988; Kozarski, 1991). But even here in a lowland valley, the formation of abandoned meanders coincided with wet phases before 8, 4 and 2.5 ka BP.

Fig. 5. Evolution of the Vistula valley in longitudinal profile during last 30 ka (after Starkel, 1990, modified).
1 - erosion by braided river (Eh), 2 - aggradation by braided river (Ab), 3 - erosion by meandering river - large meanders (Em1), 4 - erosion with some aggradation by anastomosing or straight river (E-A), 5 - accumulation after by meandering river - small meanders (Am), 6 - anastomosing one (A-E), 7 - deltaite deposits (Ad), 8 - ice dammed lake, 9 - sea, 10 - ice sheet (modified after Kozarski, 1995), 11 - former outflow directions (westward along pradolina and southward over outwash plate), 12 - terrace of permanent, 13 - turn of deposition during flood phase, 14 - channel avulsion.
The tributaries of Vistula river in northern Poland

In their evolution, tributary valleys show a close association with the main valley. Therefore, the incision during the deglaciation fluctuated between 20 and 50 metres (Galon, 1953; Niewiarowski, 1968). A detailed study of several tributaries by Andrzejkowski (1994) has shown various mechanisms of evolution which relate to the previous origin of valley segments (sandur plain, ice marginal streams, subglacial streamways), which later were incorporated in one system. In several valleys with a low gradient, even the late Vistulian transitional phase, with its large palaeomeanders, is still visible.

In the evolution of these valleys, their first phases of transformation just after the deglaciation are very important. Under a cold periglacial climate in the southern part of the Pomeranian marginal zone, winter freezing was combined with the formation of icings which were recorded on the outwash plain in the shape of oriented depressions (Kozarski, 1975). The melting of dead-ice blocks continued until the Alleröd period when most of the lakes were formed, especially in subglacial channels (cf. Kozarski, 1995). Many of the small lakes are still not fully incorporated into the fluvial system. The larger ones, located in subglacial depressions and draining to the palaeolakes, show a tendency to overgrowth by peat (Niewiarowski, 1994).

The river valleys in the coastal zone

In this belt, which is up to 100 km wide, and which drains to the Baltic Sea, all valley patterns are superimposed on the meltout depositional relief created during the deglaciation of the Pomeranian and Gardno phases between 16 and 14 BP. Most of the valleys are composed of fragments of different genesis including various fluvial deposits, e.g. the Radunia valley near Gdańsk (Koutaniemi and Rachocki, 1981). A very low level base during the late Vistulian and early Holocene created the conditions for erosional advances upstream but also with time the floodplain with either higher or lower flood frequency. The evolution of fluvial systems in the Upper Vistulian...

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Sources of material supply and nature of fluvial transport in post-glacial agricultural-forested catchment (the upper Parsęta river, Poland)

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Abstract: Understanding the character and temporal variability of fluvial transport is of fundamental importance for the qualitative and quantitative description of contemporary fluvial systems. In the present study certain features of fluvial transport are regarded as markers which indicate the way the denudation system of a catchment operates. On the basis of mapping carried out along the upper Parsęta channel, only a small part of the catchment was found to take part in the supply of suspended material to the river channel. The occurrence and intensity of processes active in the supply of sediment for transport in the Parsęta channel depends largely on lithology, channel morphology, conditions of water flow, hydrogeological conditions, and vegetation. These factors are modified by the activity of man and animals. Variations in the transport of sediments along the upper Parsęta result from differences in lithological sources, which, in turn, are associated with other environmental factors which determine the rate of water circulation.

The figures for the transport of sediments obtained in this research confirm the regularity with which dissolved material is overwhelmingly predominant in the fluvial transport of Pomeranian rivers. The changing environmental conditions in the catchment, and also the seasonal development of its plant cover, are reflected in the way the river flow is sustained and, in the fluvial regime, is expressed as the amount of material leaving the catchment system. The three periods of denudational activity which have been distinguished on the basis of differences in their fluvial transport regimes, reflect the seasonal efficiency of denudational processes in the catchment. The seasonal variations in the fluvial transport in the upper Parsęta provide insight into the development of the present-day relief of the young-glacial area of West Pomerania.

Key words: fluvial transport, source of material, solute load, sediment load, post-glacial catchment

Introduction

In the contemporary denudation system of West Pomerania, fluvial transport plays a fundamental role by carrying away material from erosion and denudation in the catchments. A detailed analysis of fluvial transport provides a good indicator of relief evolution, including soil leaching and erosion. The character of the fluvial transport is also a good indicator of change in the landscape structure of a region. In the present study, the subject of the investigation was the upper Parsęta catchment, which is regarded as representative of the post-glacial zone of West Pomerania and the Polish Plain. Systematic investigations of modern morphogenetic processes in the upper Parsęta catchment have been carried out since 1981. Since 1 November 1985, daily measurements have been taken in the profile which closes the upper Parsęta catchment (at Storkowo); this catchment is regarded as an independent denudation system.

The programme of research in the upper Parsęta catchment is based on methodological assumptions derived from Cholley’s concept of a denudation system (Tricart, 1960) and BertallanfTy’s (1964) systems theory. They have provided the basis for the conception of geosystem operation, as formulated by Kostrzewski (1986, 1993). The following, already established regularity is the basic assumption of this investigation: the kind and amount of material flowing through the measuring point reflect current geomorphological processes taking place in the river channel and catchment (Gregory & Walling, 1973; Schumm, 1977, Richards, 1982; Froehlich, 1982; Knittig, 1984; Zwoliński, 1989).

The basic objective of the research conducted in the upper Parsęta catchment is the understanding of the operation of the geo-ecosystem of a lowland river in the conditions of climatic change and various forms of human impact. The aims of the present investigations include:

1) an evaluation of the controls, pattern and intensity of fluvial transport, which are reflections of the denudation processes occurring in the upper Parsęta catchment system, i.e. mainly soil erosion and leaching.

2) an analysis of variations in the physico-chemical properties of solutes and solids in the upper Parsęta channel as factors controlling the variability of fluvial transport and determining its role in the contemporary denudation system of the catchment.