Changes of the Vistula river course and development of the flood plain in the border zone of the South-Polish uplands and Middle-Polish lowlands in historical times

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Abstract: The results of geomorphological research on the terraces of the Vistula valley have been compared with archaeological and historical evidence in this area and also with evidence of climate changes in the area of Poland. In the early Medieval times (the Medieval Warm Period), the river had a narrow channel with well-developed small meanders. This period was divided into two stages: an earlier (6th - 10th centuries) which was relatively dry and a later (11th - 13th centuries) which was relatively wet. In the first stage, the river flooded only occasionally and the favoured flood settlement. In the transitional times (11th - 15th centuries), more frequent floods started to endanger the settlements in this area; however, the meanders of the river were not significantly altered at this time. In the Little Ice Age (from the second part of the 16th to the 19th centuries) the frequency of floods was so great that the river changed its course in some channel sections and the channel itself changed from a meandering into braiding type; its width increased greatly at that time. This trend has increased considerably since the beginning of the 19th century, consequent upon climate changes and the development of agricultural land use of the Vistula catchment. To protect the fields from the floods, special protection embankments were built; the river responded in what is now the flood plain. The relationship of this plain to Medieval flood plains created by meandering river is discussed.

Key words: meandering river, braiding river, Medieval flood plains, modern flood plain, warm Medieval times, Little Ice Age

Introduction

The work concerns the area of the middle Vistula between Zawichost and Kozlówka. Between Zawichost and Puławy, it belongs to the belt of South-Polish uplands, and, between Puławy and Kozlów, it belongs to the belt of Middle-Polish lowlands (Fig. 1). In the valley floors of both sectors, settlement has been well developed since the earliest Medieval times (6th - 10th centuries). Artefacts may be thus used in analysing the character of the river and its course. Historical facts and sources are known since the 11th century; they are most prolific in the Sieciechów section of the lowland valley, i.e. the area of the Wieprz confluence with the Vistula.

Certain artefacts and historical evidence have been used in the analysis of geological-geomorphological results of flood plain investigation in both sectors of the Vistula. Changes of the river course and flood plain which have taken place since the 6th/7th centuries have been compared with the evidence of climate change trends in the second post-glacial climatic optimum (warm Medieval times) and the Little Ice Age.

The earliest Medieval times i.e. first stage of the warm Medieval period

The earliest Medieval times in the area of Poland provided a climate favourable for human activity. According to Kosiba (1962), this was the period of the "second post-glacial climatic optimum". In the West European literature it is called "a period of warm Medieval times" (Lamb, 1974). From a hydrological point of view, it should be divided into two sub-periods: the first - drier, and the second - wetter. Evidence of the dryness of the first sub-period is found not only in palaeogeographic research in Poland (Ralska-Jasiewiczowa & Stankel, 1983; Niewiarowski, 1995; Stankel et al., 1996) but also in the studies of the dune areas in West Europe (Heidinga, 1984) and in the hydrological relationships in the Dniepr catchment in East Europe (Rauer et al., 1983). The results of investigation in Central America (Hodell et al., 1995) may even show that it was a climatic trend on a global scale.

In this first, drier sub-period of warm Medieval times, an intensive development of agricultural development took place in the flood plain of the Vistula valley, and in the Chodel Basin in particular. In this Basin, the valley floor is the widest in the whole Vistula gap through the belt of the South-Polish uplands.
section of the Vistula river meanders course. However, the river sand according to Sill, Kowalczyk (1994), was located on the flood plains of the Medieval meander development may be distinguished in this area (Fig. 5). It should be emphasised that the dimensions of Medieval meanders in both sections are very similar, as do the discharge in the Opole Lubelskie section and Góla section (above the Węprz confluence) was then and is now virtually identical.

The distribution of the settlement shows that the meanders of the Vistula from the earlier stage are usually drier, rather less conspicuous and more often used now as pasturage. In contrast, the meanders from the later stage contain numerous abandoned channels filled with water which can be clearly distinguished on a topographical map (Fig. 4). The character and dimensions of the meanders from both stages are similar. The best developed (i.e. those in an advanced phase of meandering) have a curve radius of 0.3-0.5 km. Based on cartometrical measurements, the width of the channel is about 0.1 km. The meanders of both phases comprise a valley floor zone about 2 km wide between Góla and Stęczyca (Fig. 5).

The historical data show that the river channel with the meanders of the older stage probably existed until at least the end of the 11th century. Chronicles of war events from 1093 show that Sieciechów, an important administrative centre of a vast settlement area in the floor of Vistula valley (Dąbrowski, 1974; Kowalczyk, 1994), was located on the left bank of Vistula on a higher flood plain (Fig. 6). The importance of this centre was also determined by its location at an important trade route from Great Poland to Kievan Ruthenia. A crossing of the river in 1093 was not only provided by the old earthwork in Sieciechów, but also by a small defensive site. Where later, in the 12th century, a Benedictine monastery, Sieciechów Abbey, became established (Wisniewski, 1958) (Fig. 5).

The second stage of warm Medieval times and the transitional period to the Little Ice Age

Sieciechów earthwork with its Benedict monastery, situated on both banks of the river, flourished in the 12th - 14th centuries. The importance of the river crossing at this important trade route increased. At that time, Sieciechów was the seat of a castellan who was a manager of one of the main administrative units of the Sandomierz duchy. The Benedict monastery was an important economic centre which was associated with numerous villages in the Vistula region (Wisniewski, 1958).

In the 14th century, the first evidence of an increase in the frequency and intensity of the river floods appeared and, as a result of these, the village of Świecieća, situated 3 km SSE of Sieciechów, was completely destroyed; a new village, Klasztorna Wola, has replaced it. Also destroyed was...
the village of Brześć, situated 5 km NNW of Sieciechów, (Winiarski, 1958). A church in Regów Stary, which was built in 1390 on the upper floodplain of the Vistula, was also destroyed by floods and, at the end of the 15th century, a new church was built beyond the limits of flooding on a terrace of the river in Regów Nowy (Winiarski, 1913). At the beginning of the 15th century, the town of Sieczya was so badly flooded that, in 1442, it was re-built in a more elevated location (Kurzyp, 1989).

The increase of flood intensity probably determined part of the change of the Vistula course in the 14th-15th centuries. Earlier, it flowed from Goląb westward towards Stawczyn and Sieciechów but, since the 15th century, it flowed northward towards Borowa and Kępice (Fig. 5). However, the characters and parameters of the new channel were similar to those of the old one. The changes of the Vistula course was therefore the result of a natural migration of meanders. Further, it may be assumed that the hydrological regime of the Vistula did not change significantly; the increase of climate humidity and the role of floods must have been moderate.

The increase of flood frequency and the change of the river course caused a deterioration of the river crossing at Sieciechów and the administrative function of this setting also decreased. The seat of the castellan was transferred to Sieczya (Kowalczyk, 1994) at the confluence of the Wiprz and the Vistula and located on the terrace to protect it from floods (Figs. 5 and 6).

Between the second part of the 14th and the end of the 15th centuries, the climatic condition of the economy was less favourable than that of the early Medieval times (11th-13th centuries). At the beginning of the 14th century, the climate cooled; this caused an increase of food prices. By extension, it has been assumed that the cooling of the area of Poland lasted until the second half of the 15th century; in turn, this was interpreted as the first phase of the Little Ice Age (Maruszczak, 1987a, 1994). The results of the analysis of the Vistula run changes between Goląb and Sieczya suggest that the geomorphological effects of this phase were more pronounced than those observed in the economy. It may be assumed, therefore, that this was a transitional period from warm Medieval times to the Little Ice Age. Despite the changes of its course which resulted from flood frequency increase, the Vistula still had the form of a meandering river on a vast floodplain and, in the section adjacent to the confluence with the Wiprz, the Vistula alluvial floor was 8 km wide (Fig. 6).

The Little Ice Age

According to Western European data, the Little Ice Age lasted from the middle of the 16th century to the second half of the 19th century (Lamb, 1984). During this time, two distinctive cold phases, each lasting about 180 years may be distinguished (Maruszczak, 1987a, 1994).

At the beginning of the first cold phase, in the last decades of the 16th century, there must have been a considerable increase of flood size and frequency in the Vistula valley (Girga & Stopczewski, 1965). During one of the larger floods, probably in 1593 or 1595, Vistula changed its course and, in Borowa (north of Goląb), it shifted to the confluence section of its right bank tributary, the Wiprz. This is evidenced by historical facts: until 1583, river crossings and harbours were located on both the Vistula and the Wiprz; in 1595 these were located only on the Vistula (Kurzyp, 1989). As a result, the river course between Borowa and Sieczya was shortened by 50% (Fig. 5).

This considerable change in the course of the Vistula and the much-increased bottom erosion in the section between Borowa and Sieczya probably initiated a change of the meandering channel into one which was braided. This was conditioned by a long cold period which lasted till the end of the 17th century and it must surely represent the main phase of the Little Ice Age which is known to have culminated in the middle of the 17th century; this phase is easily identified on a plot of flood price changes (Maruszczak, 1994, p. 120). At about this time, the Vistula changed into a braided river with an unstable and multi-branch channel, the floods from which were increasingly frequent. The large floods which have occurred since the middle of the 17th century have caused much damage and considerably limited any economic activity on the flood plain. After the 16th century, hardly any villages were left in the Vistula valley floor between Puławy and Kozienice despite the fact that the average population density increased 5 times in the period 1580-1980 (Maruszczak, 1987b). In the Sieciechów section of the flood plain, i.e. between Goląb and Sieczya, only one village, Borek, was settled after the 16th century. It originated at the end of the 17th and beginning of the 18th centuries above the meander abandoned when the river cut its new course to the confluence section of the Wiprz.

The second cold period of the Little Ice Age started in the first part of the 18th century and its culmination (the climatic optimum) occurred in the first decades of the 19th century. The Vistula floods became especially dangerous and geomorphologically-active at this time because the river came to transport ever-increasing products of soil erosion.

This increase of soil erosion was undoubtedly caused by the considerable increase of plough land area which was necessary to fulfill the needs of a growing population in the Vistula catchment and by cultivation of root crops (such as potatoes and sugar beet) which became very popular at the end of the 18th and beginning of the 19th centuries (Szumanski, 1982; Maruszczak, 1987b). This increase of erosion products, especially the suspended load transported by the river, accelerated its capacity to cause devastation and the course became a multi-branch or braided system (Falkowski, 1982). Numerous small islands and channel bars built from alluvial-originated in the channel. They favoured winter freezing which resulted in the development of ice-jam on some river sections, thereby causing dangerous local floods. On 1 April 1845, an ice ridge in Sieczya created a river level which was actually higher than that caused by one of the largest summer floods recorded, that in 1744. In 1852 and 1854, large ice jams caused considerable damage to plough land and changes to the Vistula channel over a 10 km-long section below the Wiprz confluence (Kurzyp, 1989).

The flood hazard was so serious that it was considered necessary to construct protective embankments in Sieczya as early as in the 1760s. On a larger scale and in the longest sections, more flood embankments were built in the first decades of the 19th century. e.g. in the river section from Goląb to Borowa and from Sieciechów to Kozienice; these are shown in the former topographical maps (Fig. 4). The construction of the embankments had the effect of limiting the possibilities of river course changes and, along its braiding channel, a modern floodplain about 1-2 km wide started to develop. On the map dating from the first part of the 19th century, this plain is distinguished and described as "fresh sand deposits" (Figs. 3 and 4). Contour lines of present large-scale topographical maps reflect many abandoned sections of braiding channel within this plain. Two older Vistula flood plains, i.e. a lower and an upper, contain numerous traces of river channels with small meanders.
The modern flood plain, as contained between flood embankments, in the section from Pulawy to Kozienice often rises above the level of the upper flood plain (Fig. 61, II). Despite this, it is distinguished on many geomorphological and geological maps (not very logically) as the "lower flood plain" (Zakrzewski, 1986). Only within the section between Goląb and Stęgny is it situated below the level of Holocene flood plains. This is one of the consequences of both erosion of the Vistula channel, which was caused by shifting of Vistula river into a confluence section of the Wieprz at the end of the 16th century. In contrast, the Holocene flood plain is usually situated above the level of the Holocene flood plains. The flood plain built from the Vistula valley flood plains is of a meandering type. In turn, the historical flood plain contains numerous traces of meandering channels despite the fact that they have been cultivated for a long time.

In the earliest Medieval times (6th - 11th century), the Vistula river between Pulawy and Kozienice, was represented by a well-developed meandering channel; this indiction was of a relatively dry climate in which the river did not flood very often. These conditions favoured agricultural land use of this broad, Holocene flood plain which contained fertile and cultivable alluvial soil and variety of terrestrial and water habitats. The upper levels of the flood plain i.e. those beyond the limit of flooding, were eminently suitable for settlement. Sieciechow became the economical and administrative centre of this Vistula settlement region and it served to protect the river crossing along the important trade route from Great Poland to Kievian Ruthenia. This crossing was even more important in the early Medieval times (12th - 14th centuries), when, owing to a more humid climate, the discharge of the Vistula river became greater. A comparison of the lowland and upland sections of the valley suggests that a typical, meandering channel development in Neolithic and Bronze times was ubiquitous in the valley extensions. In the river gap section, where the valley floor is shallower than 3 km, well-developed meanders did not occur. The importance of this becomes obvious, if one considers the stream gradient which is more or less the same in both the narrow and wide parts of the valley, e.g. Zawichost-Kamięcin (relatively narrow valley) - 0.285%, e.g. in the valley floor between Pulawy and Kozienice, i.e. historical flood plains, contains numerous traces of meandering channels despite the fact that they have been cultivated for a long time.

Conclusions

1) In the earliest Medieval times (6th - 11th century), the Vistula river between Pulawy and Kozienice, was represented by a well-developed meandering channel; this indiction was of a relatively dry climate in which the river did not flood very often. These conditions favoured agricultural land use of this broad, Holocene flood plain which contained fertile and cultivable alluvial soil and variety of terrestrial and water habitats. The upper levels of the flood plain i.e. those beyond the limit of flooding, were eminently suitable for settlement. Sieciechow became the economical and administrative centre of this Vistula settlement region and it served to protect the river crossing along the important trade route from Great Poland to Kievian Ruthenia. This crossing was even more important in the early Medieval times (12th - 14th centuries), when, owing to a more humid climate, the discharge of the Vistula river became greater.

2) It seems likely that similar conditions for agricultural development and settlement occurred in this area earlier, i.e. in the Subboreal phase of Holocene. As evidence of this, numerous Neolithic and Bronze Age artefacts have been found near Opole Lubelskie in the river gap section of Vistula through South-Polish uplands between Zawichost and Pulawy. Preliminary analysis of these sites shows that they were also associated with a meandering river, as in the earliest Medieval times, in the early Medieval times (Zakrzewski, 1986). In addition, the development of the river floor is similar to that of the lowland section between Pulawy and Kozienice. A comparison of the lowland and upland sections of the valley suggests that a typical, meandering channel development in Neolithic and Bronze times was ubiquitous in the valley extensions. In the river gap section, where the valley floor is shallower than 3 km, well-developed meanders did not occur. The importance of this becomes obvious, if one considers the stream gradient which is more or less the same in both the narrow and wide parts of the valley, e.g. Zawichost-Kamięcin (relatively narrow valley) - 0.285%, e.g. in the valley floor between Pulawy and Kozienice, i.e. historical flood plains, contains numerous traces of meandering channels despite the fact that they have been cultivated for a long time.

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