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Correlation of genetic and morphometric types of Šventoji River catchment relief (north-east Lithuania)

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The Šventoji is a river of the Baltic Upland. The catchment of the Šventoji is teardrop-shaped up to 50–60 km wide, and 160 km long. Most of the catchment is situated in the Aukštaičiai Upland and the Western Aukštaičiai Plateau. The surface of the catchment was formed by Quaternary ice sheets that deposited a moraine layer 100–200 m, the thick topographic relief dating to the late Nemunas (Weichselian) Glaciation phases. The eastern part of catchment was formed in the East Lithuanian Phase, the middle part in the South Lithuanian Phase and the western part in the Middle Lithuanian Phase. The catchment surface is composed of three different genetic relief types: the ice-marginal deposits of the East Lithuanian Phase, represented by small hills; the middle part of the Šventoji catchment, transected by a few ice-marginal ridges of the South Lithuanian Phase which form small hills; and the western part of the catchment is transected by a few asymmetric ridges of the Middle Lithuanian Phase. The eastern part dominantly comprises ice-marginal deposits with glaciolacustrine and glaciofluvial intercalation; the middle part comprises variable glaciolacustrine, basal moraine and ice-marginal deposits; the western part by basal moraine and ice-marginal deposits.

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Key words: Šventoji catchment, relief genesis, morphometric types of relief.

INRODUCTION

The Šventoji is a river of the Baltic Upland. It and its main tributaries drain the western edges of the upland. The catchment of the Šventoji is teardrop-shaped of prolonged drop, up to 50–60 km wide and 160 km long. Most of the remaining basin is situated in the Aukštaičiai Upland and the Western Aukštaičiai Plateau, whereas part is in the Nemunas middle course and the Neris lower course plateau.

The Šventoji catchment includes a few other orographic units: the Aukštaičiai Upland (Zarasai, Utena and Molėtai segments), the West Aukštaičiai Plateau (Širvintos and Svedasai segments) and the Middle Lithuania Lowland (Nemunėlis, Lėvuo and Nevėžis segments) (Figs. 1 and 2). The surface of the Šventoji catchment has been formed by the latest Pleistocene ice sheets, which deposited 100–200 m of glacial and glaciofluvial deposits. In some areas they occur at 220–240 m a.s.l. These hilly areas, cover only one quarter of the Šventoji catchment (Basalykas, 1965). The hills are dissected by river valleys, glacial channels and other negative forms of different size and height. The Zarasai segment has the most complicated relief, the relief of other parts of the Aukštaičiai Upland and Plateau being simpler.

A great number of lakes is another distinctive feature of the Šventoji catchment. Long narrow, winding and comparatively deep they are arranged in a chains and often are composed of intersecting channels. Evidence of periglacial river valley history suggests that the recent Šventoji flows from the Sartai Lake through an ancient valley. The periglacial lakes played the greatest role in relief formation at the end of the glaciation. Their level sometimes reaches 130 m a.s.l. The Šventoji accounts for the arrangement of tributaries counter position of right and left tributaries.

DATA

The relief of the catchment was formed in the late Nemunas (Weichselian) phases. The eastern part of the basin was formed in the Eastern Lithuanian Phase, the middle part in the Southern Lithuanian Phase and the western part in the Middle Lithuanian

Fig. 1. Area of investigations

Phase. There are conspicuous differences in the genesis of the relief of the Šventoji basin. The basin surface is composed of 3 different genetic belts (Fig. 2). The eastern part is dominated by ice-marginal deposits, with parts underlain by glaciolacustrine and glaciofluvial deposits.

The eastern belt was formed by the Siesartis-Virinta glacier stretching from Anykščiai and across Kurkliai, Žemaitkiemis, Lyduokiai. According to Basalykas and Dvareckas (1968) the Kurkliai depression, filled with sands and encircled by part of the old Šventoji valley, is today used by the Judinys River. The surface of the morainic plain around Kurkliai is complicated. The kames (zvoncy) distributed north-east of Kurkliai towards the Nevėža Lake and Storiai have been described by Mikalauskas (1985). The central part is dominated by glaciolacustrine basal moraine and ice-marginal deposits.

The belt of ice-marginal deposits, extending from Anykščiai through Viešintos, Migoniai as far as Šepeta bog, has been formed by the Anykščiai glacier lobe. This morainic belt is 5–6 km wide and composed of three chains dissected by

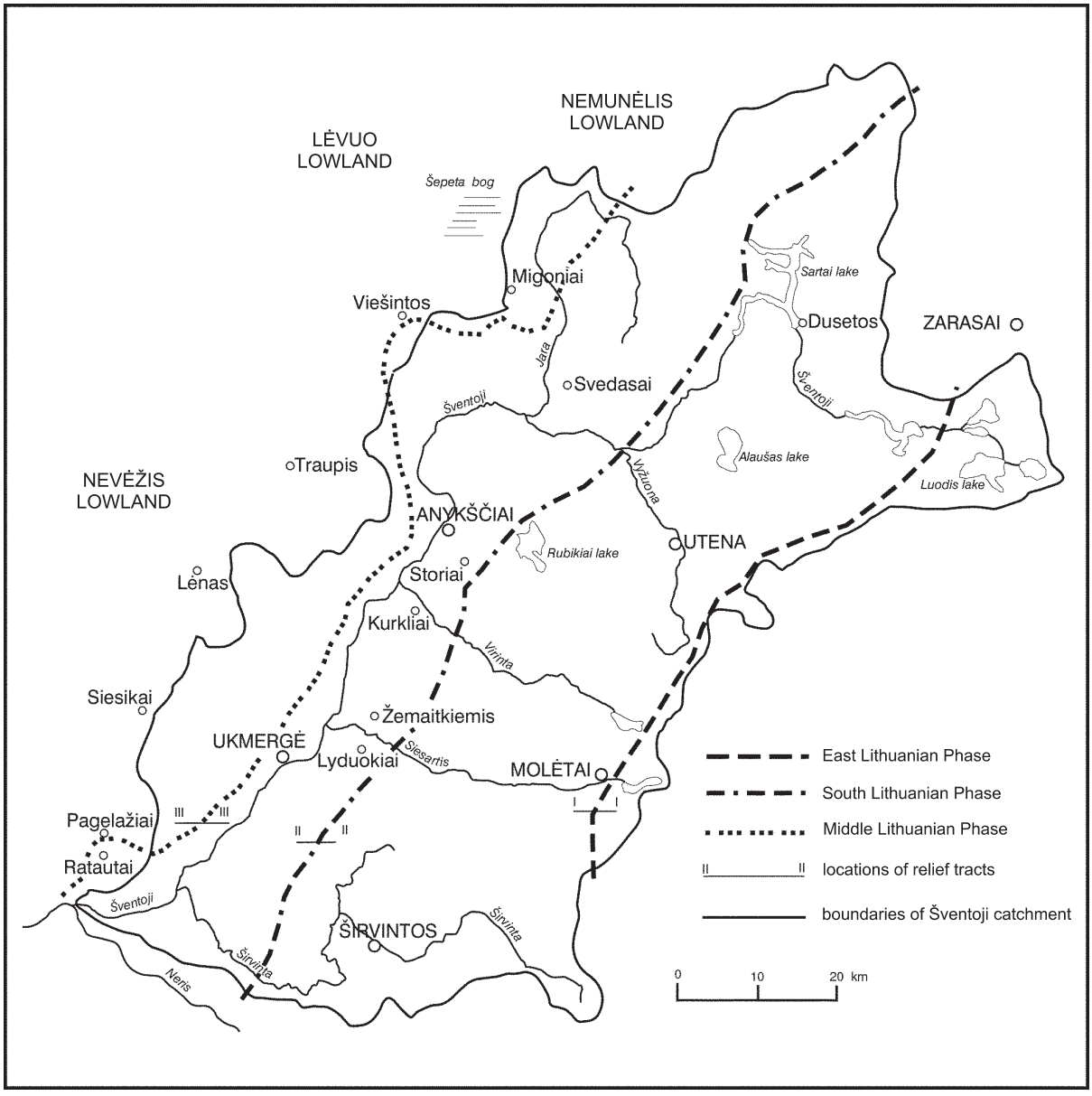

Fig. 2. Boundaries of ice-marginal deposits

thermokarst depression and old valley segments. The other morainic belt was formed by the Sartai and the Vyžuona glacier lobe, its altitude varying from 85–90 m. It includes the depression formed by a glacier side lobe: the Traupis plain separated from the rest of the Nevėžis plain by Siesikai-Lėnas interlobe morainic deposits and encircled to the south by the Ratautai-Pagela iai morainic arc. The Traupis plain includes plains transformed by thermokarst and having no fluvial deposits.

In some recent work (Guobytė *et al*., 2001; Geomorphological …, 2001) it has been suggested that the belt of East Lithuanian (Aukštaičiai) Phase ice-marginal deposits runs through the Virinta River valley from Kurkliai towards Daugeliškis; this suggestion needs further substantiation.

METHODS

Studies of river catchments such as, the Šventoji basin under consideration, may be analysed for different purposes and employing different techniques. For example, one study of experimental geomorphology (Schum *et al*., 1987) contains an analysis of catchment morphology and dynamics, whereas the catchment itself is taken as the key geomorphological unit, characterised as a certain type of drainage network. In Poland, mountain river channel types have been studied by 22 researchers (see summary data table describing the valley types and giving criteria for grouping the valleys in Kaszowski and Krzemień, 1999). On the basis of valley genesis, channel form and dominant processes, Falkowski (1991) distinguished: juvenile river with a valley modeled by erosion; juvenile river, with a valley modeled by deposition; mature free rivers with meandering or braided channel patterns; mature restricted rivers with limited horizontal as well as vertical displacements of the channel. The methods applied include environmental catchment analysis. This method includes the following procedures:

— selection of typologically significant environmental characteristics;

— classification of catchment geomorphology types based on the geomorphological and geological similarity/dissimilarity analysis of the remaining environmental characteristics and their effect on fluvial processes;

— identification of morphodynamic channel types in relation to the catchment types determined.

In contrast to this method which normally requires a subdivision of channels, catchment environment analysis results in determination of channel system types (Kaszowski and Krzemień, 1999). In this study we described the morphometric-genetic structure of the Šventoji catchment, which as a rule influences morphodynamics of the river channel.

According to Efremov (1949) the spatial distribution of relief, i.e. "relief geometry" is subdivided into morphography and morphometry. Morphography concerns analysis and systematisation of relief and its elements based on geometrical methods. Morphometry deals with the measured characteristics of relief types and forms as well as their elements. It uses kinetic terms (velocity, acceleration, shift gradients, *etc*.) for description and depiction of results. Relief geometry investigates stable developing relief. Both types of study constitute quantitative geomorphology and serve as an introduction to relief dynamics or dynamics geomorphology (Zaborski, 1931). Simonov (1998) described morphometry not only as a measuring technique but also as a key element of the geomorphological concept. Morphometric analysis includes identification not only of forms, the boundaries between them and their types, but also of morphosystems and their expression on the earth's surface. It has been also demonstrated that theoretically there are up to 32 000 relief types.

Morphometric analysis provides not only formal geometric data but also data on relief genesis and dynamics (Berliant, 1999, Česnulevičius, 1999). Its distinctive feature is that morphometry operates with derived indices, enhancing the reliability of morphometric models. Still another aspect is the employment of statistical data in morphometric calculations, considerably reducing the necessity for time-consuming measurements (Berliant, 1999). The applied aspects are important, because the coefficient of relief segmentation, determined on the basis of topographic data, determines factors such as levels of soil erosion, natural forests-cover and even agricultural yields (Shepilov, 1990).

RESULTS

The ice-marginal deposits of East Lithuanian Phase, situated in the eastern part of the basin, are composed of a few terminal moraine ridges. These ridges have asymmetrical slopes: distal slopes are gentle and longer than proximal slopes. Investigation of morphometric parameters is based on relief modelling (Kairiūkštis *et al*., 1983). The East Lithuanian Phase ice sheet limit deposits are represented by small hills (Figs. 3–5, Table 1). The middle part of Šventoji basin is transected by a few ice-marginal ridges of the South Lithuanian Phase, composed of medium-sized hills with asymmetrical slopes. The ice-marginal deposits in the western part of the basin are composed of large and medium-sized hills. The slopes are also slightly asymmetrical but the distal slopes are shorter and steeper, than the proximal ones. This is accounted for by the proximity of the Šventoji valley (erosion) and the smoothing effect of short-lived glaciolacustrine basins at the foot of the proximal slopes of the Middle Lithuanian Phase marginal deposits.

The relief of glaciolacustrine and glaciofluvial formations in the eastern part of the Šventoji basin is represented by medium-sized hills. Surface incisions appeared as a result of subsequent thermokarst and erosion processes, which were particularly active at the foot of the Aukštaičiai Upland.

The glaciolacustrine and basal moraine deposits in the middle part of the Šventoji basin mostly form gently undulating to flat plains. Flat plains are more frequent among the glaciolacustrine deposits, whereas the more undulating plains related to basal moraine deposits.

The basal moraine deposits in the western part of the basin form flat swampy plains, merging into the contiguous Nevėžis basin.

The valleys of the Šventoji and its main tributaries are deep and steep-sloped, within a small area of hilly relief. In the east-

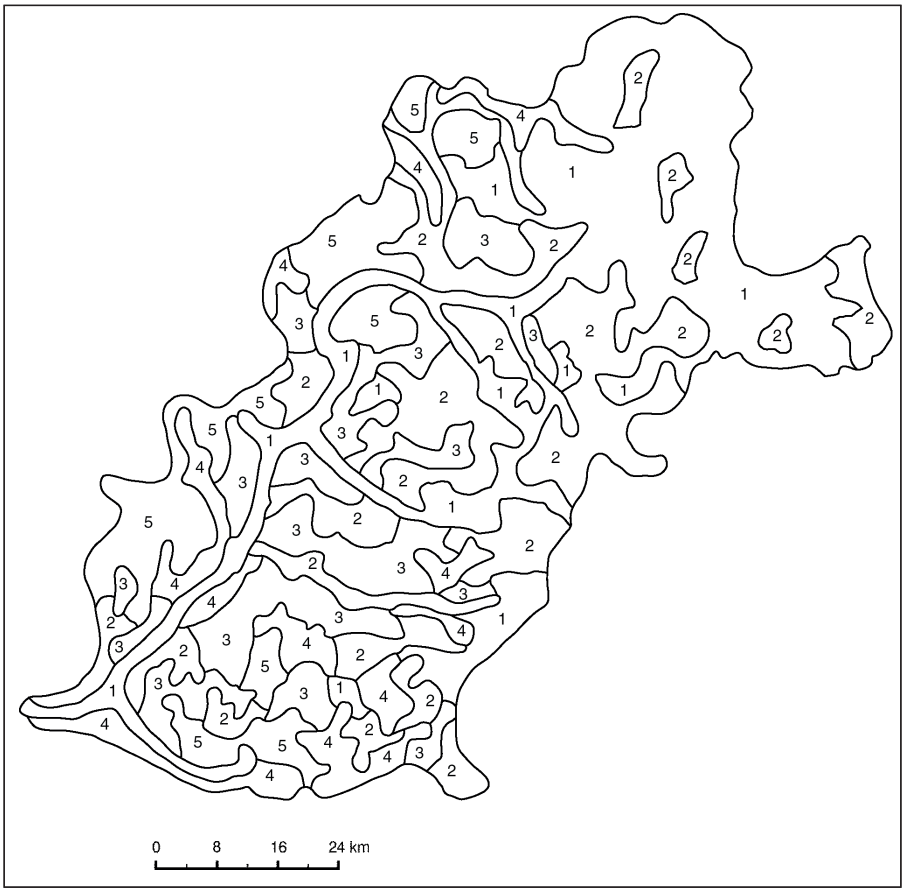

Fig. 3. Distribution of morphometric landform suites of the Šventoji basin relief

1 — small hills (1–3 types in Table 1), 2 — medium hills (4–6 types), 3 — large hills (7–9 types), 4 — undulating plains (10 type), 5 — flat plains (11 type)

ern part of the basin this fluvial relief joins the small hills of the ice-marginal deposits of the Eastern Lithuanian Phase.

DISCUSSION

Morphometric and genetic landform suites of the Šventoji catchment are interpreted as expressions of glacigenic and epigenetic processes. Attempts were made to determine the link between the genetic and morphometric types as a relative expression of process intensity. Half of the catchment relief is flat and other half is hilly, reflecting the conditions glacial and postglacial relief development. Thus, morphometric and genetic landform suites and their mutual relations contribute to our knowledge about deglaciation, in particular at the level of mesoforms.

CONCLUSIONS

1. The Šventoji catchment surface is composed of 3 different genetic tracts of relief: eastern, central and western. The

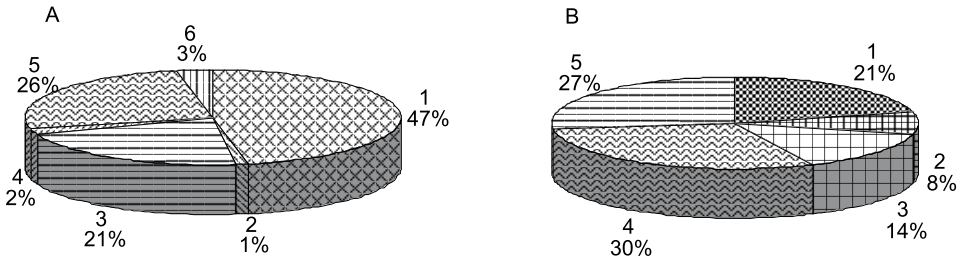

Fig. 4. The distribution of genetic (A) and morphometric (B) landform suites of the Šventoji basin

A: 1 — aeolian, 2 — fluvial, 3 — ice-marginal, 4 — glaciolacustrine, 5 — ground moraine, 6 — glaciofluvial formations; B: 1 — small hills, 2 — medium hills, 3 — large hills; 4 — undulating plains, 5 — flat plains

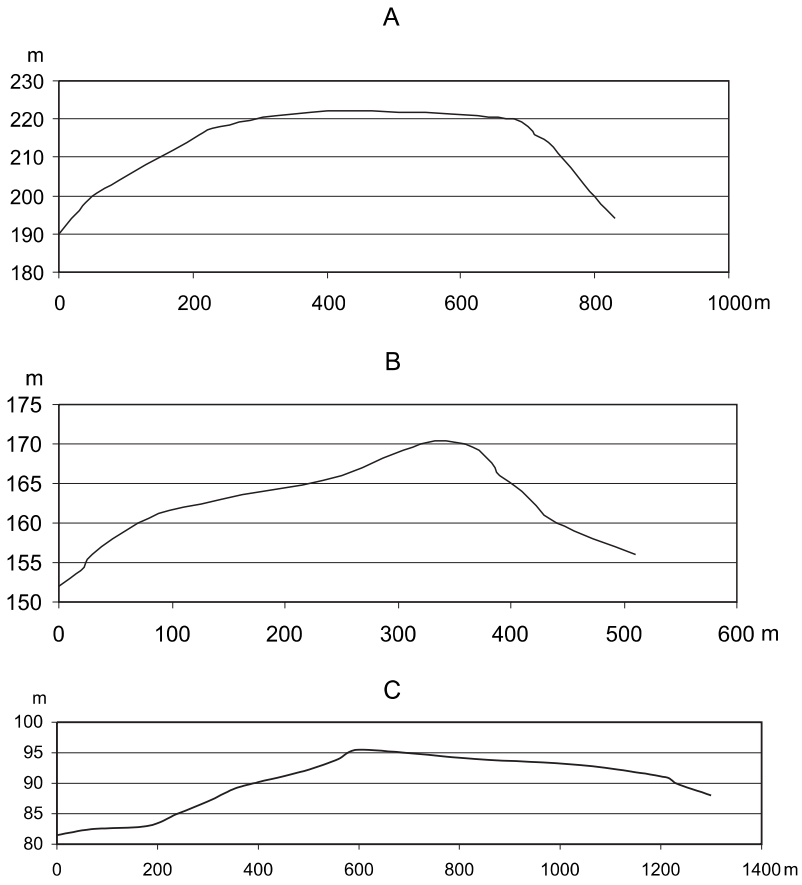

Fig. 5. Slopes from the limits of different ice sheets

A — East Lithuanian Phase, B — South Lithuanian Phase, C — Middle Lithuanian Phase; for location see Figure 2

Table 1

Morphometric classification of landforms

Size of landforms		Height (depth) of landforms		
		Low or shallow (to 10 m)	Medium (10–20 m)	High or deep (over 20 m)
Small (mound, hill, ridge, hillhorn, swell, tericon, bank, sink hole,basin, lobe, ravine, gully, pool, valley, gutter, channel, gully)	slope length [m]	2–50 1*	50–100* 2*	over 100 3*
	slope inclination [°]	over 7	over 7	over 7
	size of forms [ha]	1	3	10
Medium (hill, ridge, hillhorn, basin, kettle,ravine, pool, valley, gully)	slope length [m]	50–100 4*	100–200 5*	over 100 6*
	slope inclination [°]	3–7	3–7	3–7
	size of forms [ha]	3	15	30
Large (hill, ridge, hillhorn, kettle, ravine, valley, gully)	slope length [m]	20–50 7*	20–50 8*	over 100 9*
	slope inclination [°]	1–3	1–3	1–3
	size of forms [ha]	15	50	100
Wave	waves height up to 5 m, slope inclination 1–3°			10*
Flat	surface inclination less than 0.5°			11*

* — indices of landform types

eastern part is predominated by ice-marginal deposits with glaciolacustrine and glaciofluvial intercalations; the central part, by glaciolacustine, basal moraine and ice-marginal deposits; the western part, by ice-marginal deposits.

2. Different genetic relief types are composed of different landforms. The ice-marginal deposits are dominated by medium-sized hills; the glaciolacustrine deposits, by undulating plains; the glaciofluvial deposits, by medium-sized hills; the basal moraine by flat plains and the fluvial formations, by steeper valley slope. The ice-marginal deposits of the Šventoji catchment have asymmetrical slopes. The distal slopes are longer and lower than the proximal slopes.

3. Notwithstanding different approaches to this field of geomorphology, termed relief geometry and its variability, the approach we suggest can be obviously helpful in investigations of stable relief and of its changes. Generally, this work is based on catchment environment analysis, which has been supplemented by individual calculations for the Šventoji catchment morphometric-genetic structure analysis. The morphometric-genetic structure of the Šventoji catchment makes possible judgements about the scale and mature of post-glacial processes.

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