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MAIN FEATURES OF THE DEVELOPMENT OF RIVER VALLEYS IN THE EAST BALTIC

Palaeohydrology

In the Baltic region the formation of river valleys is closely related to the deglaciation of the territory and to the development of the Baltic Sea under a considerable influence of glacioisostatic movements of the Earth's crust.

Alongside leading factors common to the development of river valleys, several regional and local differences have been established. First of all they are due to temporal differences in the development of the deglaciation of the territory, in the formation and dynamics of local lakes, in varied effects of glacioisostatic movements and in the development of the Baltic Sea. Let us deal in brief with the development of river valleys in different Baltic regions.

Deglaciation of the Baltic territory shows that in Lithuania the formation of river valleys started after the retreat of the glacier from the marginal zone of the South Lithuanian Stage about 16 000 years ago with the formation of some reaches of the Neris and Nemen valleys, along which meltwaters flowed into the big Vartava—Vilnius marginal valley (Fig. 1). In Latvia that development was primarily related to the retreat of the glacier of the North Lithuanian (Luga, Haanja) Stage about 13 000—13 200 years ago, although a reach of the Daugava valley connecting the glacial lakes of Polotsk and Nitsgale had been formed already during the retreat of the glacier of the Middle Lithuanian (Krestetski) Stage. In Estonia the development of river valleys started somewhat later, with meltwaters flowing along the marginal valley of the Võru—Hargla—Piusa into the basin of the Gauja River. This took place during the Otepää Stage about 12 600 years ago, when the Pihkva glacial lake was formed in front of the glacier margin. It may be said that all the main arteries of the river valleys in the East Baltic had been formed approximately by the beginning of the Alleröd, with the exception of some coastal areas, in West and North Estonia in particular. Thus the whole system of river valleys developed on the territory concerned in a relatively short time which covered about 4000 years.

Nevertheless, during that period (the Pre-Alleröd time) the rivers cut rapidly deep valleys in their basins, e. g. the Neman River — 40—60 m, the Neris — 60—80 m, the Daugava and Abava — 20—40 m, the Gauja — 40—60 m, and the South Estonian rivers down to 20—40 m which forms 65—75%, and in places up to 90% of the total depth of the valleys. This indicates that the fluvial processes were rather intensive at that time.

This scheme shows rather well that in the Baltic the effect of glacial lakes on the development of valleys increased from the south and south-east to the north and north-west. In the south, the meltwaters flowed mainly along the glacier margin or freely in the distal direction. For these reasons wide and deep ice-marginal valleys are more frequent

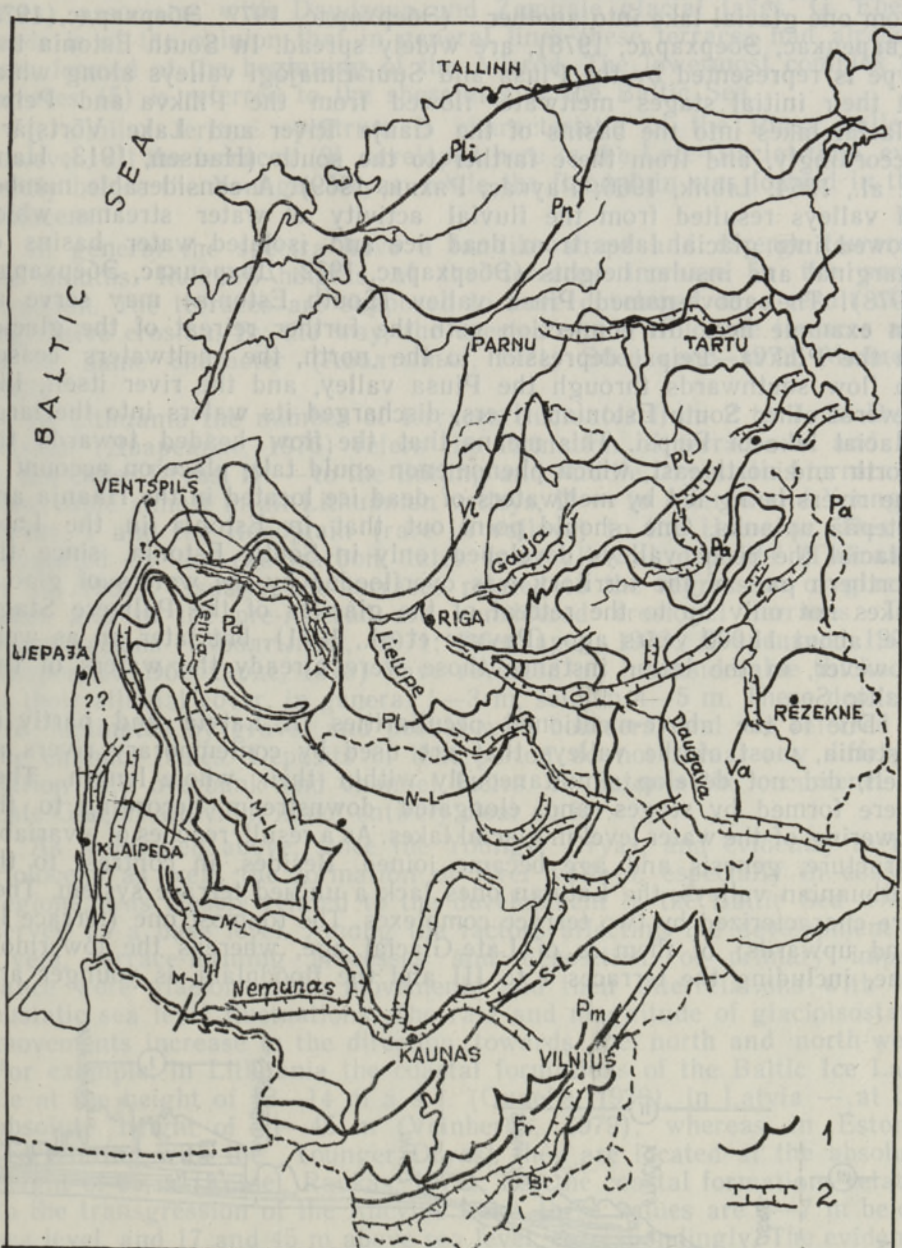

Fig. 1. Main marginal zones of glacier of the last glaciation and location of meltwater valleys in the East Baltic (after O. Aboltinš et al., 1974). *1* — marginal zones, *2* — meltwater valleys; Marginal zones: Br — Brandenburg, Fr — Frankfurt, Pm — Pomeranian, S-L — South-Lithuanian, M-L — Middle-Lithuanian, N-L — North-Lithuanian, Va — Vainodes—Gulbene, Pa — Pampalu, Pl — Pliene (Otepää), Vl — Valdemarpils (Sakala), Pn — Pandivere, Pli — Palivere.

in Lithuania. However, in North Lithuania, Latvia and Estonia a complicated system of glacial lakes, serving as a base level, was formed in front of the glacier margin. In Latvia and South Estonia this was favoured by specific glacial accumulation that led to the formation of insular heights (Latgale, Vidzeme, Otepää, etc.), with areas between them occupied by glacial lakes. Accordingly, in Latvia the valleys or reaches of the valleys which were formed due to the effect of meltwaters flowing from one glacial lake into another (Эберхардс, 1972; Эберхардс, 1975; Дварецкас, Эберхардс, 1978), are widely spread. In South Estonia this type is represented by the Piusa and Suur-Emajõgi valleys along which at their initial stages meltwater flowed from the Pihkva and Peipsi glacial lakes into the basins of the Gauja River and Lake Võrtsjärv, accordingly, and from there farther to the south (Hausen, 1913; Hang et al., 1964; Liblik, 1966; Раукас, Ряхни, 1969). A considerable number of valleys resulted from the fluvial activity of water streams which flowed into glacial lakes from dead ice and isolated water basins of marginal and insular heights (Эберхардс, 1972; Дварецкас, Эберхардс, 1978). The above-named Piusa valley (South Estonia) may serve as an example here. In connection with the further retreat of the glacier in the Pihkva—Peipsi depression to the north, the meltwaters ceased to flow southwards through the Piusa valley, and the river itself, like several other South Estonian rivers, discharged its waters into the large glacial lake of Peipsi. This means that the flow headed towards the north and north-east, which phenomenon could take place on account of the rivers being fed by meltwaters of dead ice located in the Haanja and Otepää uplands. One should point out that in Estonia in the Late-Glacial the river valleys developed only in South Estonia, since the northern part of the territory was overflooded by the waters of glacial lakes not only up to the retreat of the glaciers of the Palivere Stage, i. e. about 11 000 years ago (Раукас et al., 1971), but later on as well; however, in the latter instance those were already the waters of the Baltic Sea.

Due to the above-mentioned peculiarities in Latvia and partly in Estonia, most of the valleys that are used by contemporary rivers as well, did not develop simultaneously within their whole length. They were formed by stages and elongated downstream according to the lowering of the water level in glacial lakes. As a result, reaches of a variable structure, genesis and age became joined. Besides, in contrast to the Lithuanian valleys, the Latvian ones lack a unified terrace system. They are characterized by two terrace complexes. The topmost one (terrace IV and upwards) of them is of Late-Glacial age, whereas the lowermost one, including the terraces I to III and the floodplain, is younger and

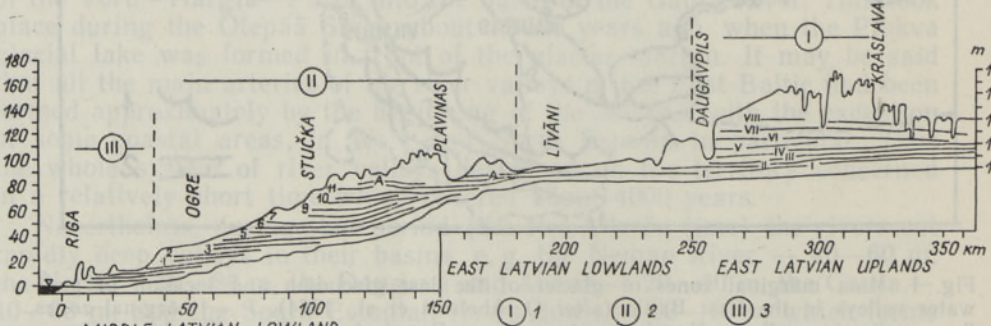

Fig. 2. Terraces of the Daugava River, Latvia. *1* — East Latvian spectrum, *2* — Middle Latvian spectrum, *3* — spectrum in the mouth area.

associates with the development of the Baltic Sea, since the stage of the Baltic Ice Lake, i. e. starting with the Younger Dryas (Аболтыньш, 1971; Эберхардс, 1972; Аболтыньш, Вейнбергс, Эберхардс, 1974; Эберхардс, 1975; Дварецкас, Эберхардс, 1978).

The Daugava River with its 3 terrace complexes will serve as a good example here (Fig. 2). The topmost complex (7 terraces) is related to the development of the Nitsgale glacial lake, the middle one (12 terraces) associates with Daudzeva and Zemgale glacial lakes. G. Eberhards is of the opinion that in general lines these terraces had already been formed at the beginning of the Alleröd. The lowermost complex of terraces (5) is referred to the shorelines of the Baltic Sea.

A similar terrace spectrum is characteristic of the Piusa valley; however, all the terraces (9) developed here in the Late-Glacial time, evidently before the Younger Dryas, while the floodplain was formed in the Holocene.

In general the spectra have a fan-like shape and diverge towards the mouths. Relative heights of the terraces increase in the same direction. The terraces are supposed to have developed as a result of a regressive erosion. By the way, the spectra of the Holocene terraces are of the same character (Аболтыньш, 1971; Эберхардс, 1972; Мийдел, 1967).

In Lithuania the number of terraces fluctuates from 2 to 7. B. Dvaretskas (Дварецкас, 1976) refers the formation of terraces V and IV to the Older Dryas, III — to the Bölling and Middle Dryas (this terrace is observable almost in all Lithuanian valleys, II — to Alleröd and Younger Dryas, I and the floodplain (rare in valleys) to the Holocene. This is supported by the radiocarbon dates from alluvial deposits (Гайгалас et al., 1981). Usually, the terraces related to the regression of glacial lakes and to the pre-Alleröd are considered erosional terraces. The investigations (Аболтыньш, 1971; Эберхардс, 1972; Дварецкас, 1976; Дварецкас, Эберхардс, 1978) have revealed an inconsiderable thickness of their alluvial cover, in general 1—3 m, seldom 4—5 m. These deposits are dominated by gravel and pebble with boulders, and are referred to the channel facies. Deposits of that period do not reveal any differentiation into overbank and channel facies. In Estonia the occurrence of Late-Glacial alluvium is not entirely clear so far.

As mentioned above, since the Younger Dryas, and evidently in the Holocene as well, the formation of river valleys, especially in coastal regions, was closely related to the development of the Baltic Sea which served as a base level. Among the factors affecting the development of rivers, terrace-forming processes and deposition, of primary importance were glacioisostatic movements and their interrelations with the eustatic sea level fluctuations. The rate and magnitude of glacioisostatic movements increase in the direction towards the north and north-west. For example, in Lithuania the coastal formations of the Baltic Ice Lake lie at the height of 13—14 m a. s. l. (Gudelis, 1979), in Latvia — at the absolute height of 44—45 m (Veinbergs, 1979), whereas in Estonia (correlating with the Younger Dryas) they are located at the absolute height of 65 m (Kessel, Raukas, 1979). For the coastal formations related to the transgression of the Ancylus Lake, these values are 6—7 m below sea level, and 17 and 45 m above sea level, correspondingly. The evidence obtained through the studies of the Estonian territory show a distinct decrease in the rate and uplift magnitude in space and time. In the Holocene, like in the Late Glacial, the rivers elongated according to how the sea retreated and the territory was freed of water. This process was most prominent in West Estonia, where the length of such seaborn areas might have exceeded 60 km. The magnitude of the elongation varied with

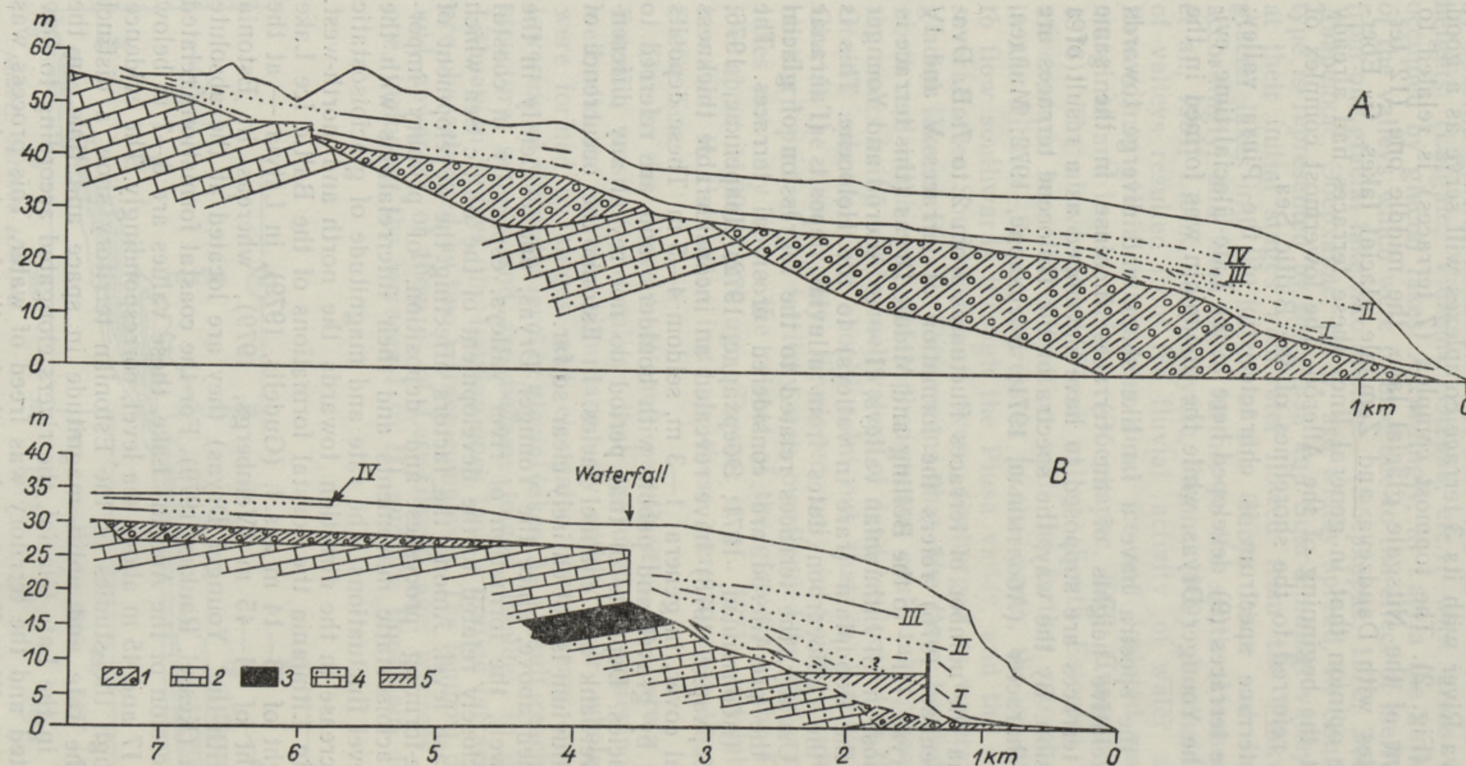

Fig. 3. Terraces of the Selja River (A) and Jägala River (B), North Estonia. *1* — till, *2* — limestones and dolomites, *3* — shales, *4* — sandstones, *5* — reservoir. Supposed age of the Selja River terraces: TI — Limnea Sea, phase LimIII (ab. 2500 yr. B. P.), TII — Littorina Sea, phase L III (ab. 5300 yr. B. P.), TIII — Littorina Sea, phase L II^b (ab. 6000 yr. B. P.), TIV — Ancylus Lake, phase A III (ab. 7500—8100 yr. B. P.). Supposed age of the Jägala River terraces: TI — Limnea Sea, phase Lim III, TII — Limnea Sea, phase Lim I (ab. 4200 yr. B. P.), TIII — Littorina Sea, phase L III, TIV — Ancylus Lake, phase A I (ab. 8200—8400 yr. B. P.).

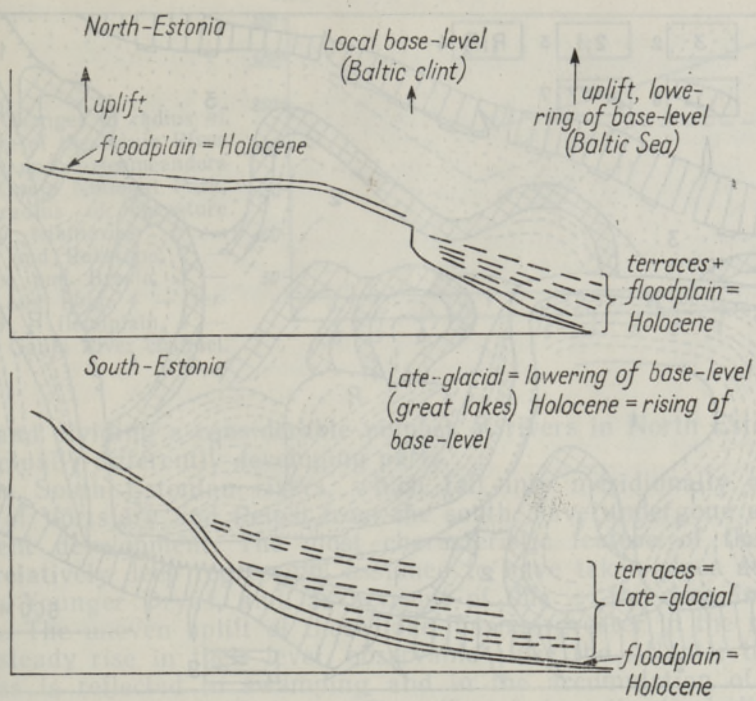

Fig. 4. Principal scheme of time — age relations of terraces and floodplain in Estonian river valleys.

different stages of the Baltic Sea, depending upon the slope gradient of the uprising sea bottom and the lowering of the sea level. In West Estonia the most prominent elongation is related to the regressions of the Baltic Ice Lake and the Littorina Sea.

As a result of the total uplift increasing to the north and north-west, the number of terraces grew in Baltic river valleys; due to that fact, the contemporary terraces vary in their relative height, number of order and geological structure (Fig. 3). For example, the number of terraces corresponding to the Baltic ancient basins increases from 2 in Lithuanian valleys to 7 in Latvia and 11 in North Estonia.

The dependence of the terrace structure upon the intensity of glacioisostatic movements and eustatic fluctuations is distinctly observable at the lower reaches of the Daugava River and in North Estonian rivers. According to G. Eberhards (1972) the estuarine part of the Daugava River yields 5 terraces well relatable to the levels of the Baltic Sea (Fig. 2). All these are mainly accumulational terraces with the thickness of alluvial deposits fluctuating from 6—12 m (terrace V) to 4—7 m (terrace II).

Except terrace V, overbank deposits prevail in the alluvium, and starting with terrace III (downwards) oxbow lake deposits, too. Recurrent changes in the base level starting with the Yoldia Stage, revealed through a frequent alternation of transgressions and regressions, led to the accumulation of a thick (up to 40 m) delta complex. It might be assumed that in the area of the Riga Gulf eustatic sea level those changes were of greater importance than in North and North-West Estonia, where the river terraces are extremely erosional. The thickness of the alluvial deposits is 1—2 m, seldom 3 m. The alluvium is mostly composed of channel deposits, the share of overbank sediments is incon-

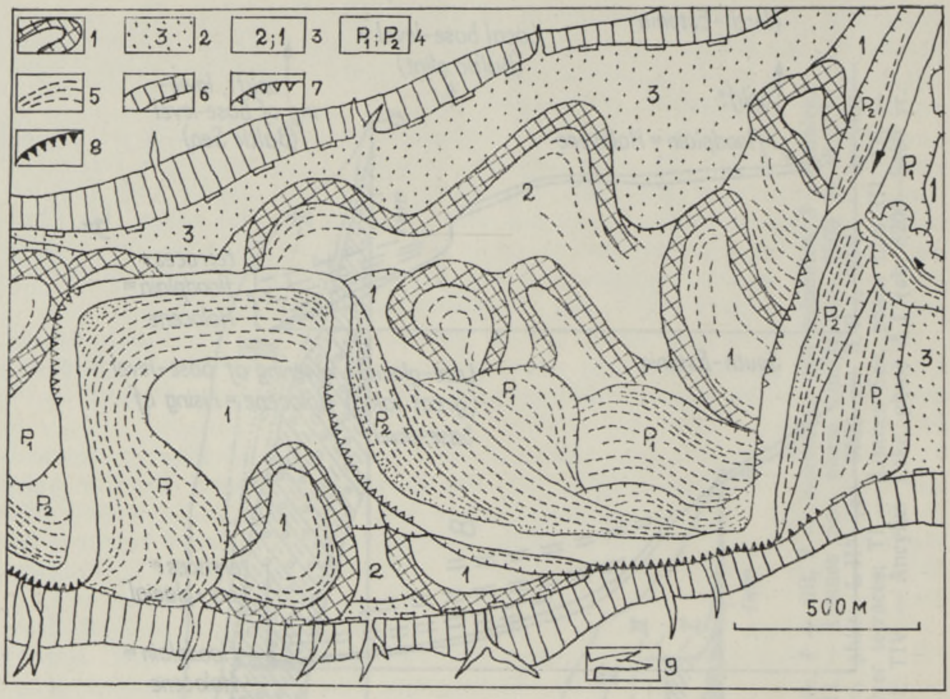

Fig. 5. The photo-geomorphological scheme of the Gauja River valley, near Cesis, Latvia. *1* — paleomeanders, *2* — terrace III with traces of braided river channels, *3* — low terraces with paleomeanders, *4* — floodplain (high and low level), *5* — point bars, *6* — valley slopes, 7, and *8* — active under-cut slopes in fluvial and non-fluvial deposits.

siderable, and the oxbow lake deposits are rare. Fluvial deposits are represented by relatively coarse material rich in pebble and boulders. All this gives evidence of a steady incision during the Holocene.

The terraces are in good agreement with the stages of the Baltic Sea (Fig. 3). Correlation of river terraces with shorelines of the Baltic Sea is the best method enabling to date the terraces, especially in Estonia, where the application of palynological and radiocarbon methods is complicated due to the limited distribution of oxbow lake deposits.

According to G. Eberhards (1972) the above-mentioned terraces of the Daugava River are of the following age: V—VII — the stages of the Baltic Ice Lake, related to the Younger Dryas; II — the first Littorina transgression with its maximum in the Atlantic time and I — young (3000 years ago).

In North Estonia almost every stage of the Baltic Sea has its corresponding terrace at least in one valley; however, there is not a single stage during which the terraces might have developed in all the valleys. It is supposed (Мийдел, 1967) that these terraces are unpaired and do not mark long-term stabilizations of the Baltic Sea level. They were formed in the process of incision.

The fluctuations of the Baltic Sea level gave rise to a wave of regressive erosion in valleys. In Latvia the regressive erosion covered as much as 15—25 km, sometimes 30—40 km (the Daugava River), and in some ancient valleys with low-resistance Quaternary deposits even more (the Gauja and the Salaca Rivers). In North Estonian valleys the effect of the sea level fluctuations was limited to smaller areas, about 10—15 km in length. A further advance to the south was obstructed by the Baltic Clint (Fig. 3), serving as a large local base level with numerous water-

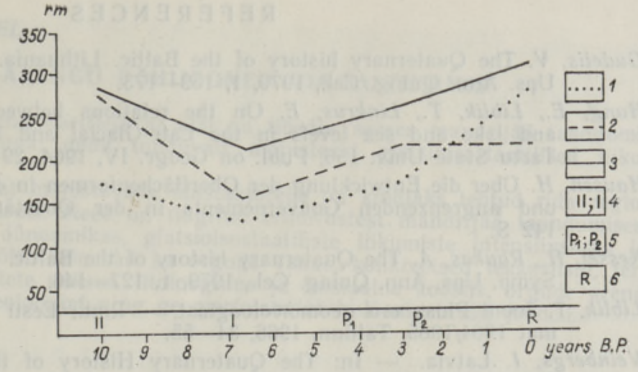

Fig. 6. Changes in radius of curvature of the Gauja River channel and paleomeanders in the Gauja National Park. Mean radius of curvature between tributaries: *1* — Jumara and Rakstupe, *2* — Rakstupe and Brasla, *3* — Brasla and Loja, *4* — terraces, *5* — floodplain, *6* — present Gauja River channel.

falls and dividing a considerable number of rivers in North Estonia into two actually differently developing parts.

The South Estonian rivers, which fall into meridionally elongated lakes of Võrtsjärv and Peipsi from the south, have undergone a slightly different development. The most characteristic feature of these lakes is a relatively deep regression, assumed to have taken place at the end of the Younger Dryas, and, as a result of this — the deep incision of rivers. The uneven uplift of those lake basins, greater in the north, led to a steady rise in their level, observable since the Atlantic time. This process is reflected in swamping and in the accumulation of deposits at the lower reaches of rivers. The alluvial deposits (including peat) are 10—13 m in thickness. This process is still in progress.

As one can see, the development of North and South Estonian river valleys has run in different ways. Those differences are summarized in Fig. 4.

The above-presented material shows that palaeogeographical analysis is rather complicated to perform for the purposes of the reconstruction of palaeohydrological changes on the Baltic territory. The main trend in valley development is characterized by down-cutting. For this reason, the intensive lateral shifting of channels was limited. And such features as point bars and oxbow lakes, typical of the meandering rivers with wide floodplains, are rare. However, the preliminary results obtained by G. Eberhards for the Gauja valley are rather promising. The materials on Latvia show that in some valleys the change from a braided to a meandering river channel took place in the Younger Dryas. The investigation of geometrical parameters of palaeomeanders in the Gauja valley demonstrates that the river channel changes were insignificant in time (Fig. 5). Our data indicate some changes in the radius of curvature, only (Fig. 6), decrease in radii in the first half of the Holocene; however, starting with the Subboreal time quite a reverse tendency is observed in young floodplains. This is explained by the increase in sediment load as a result of climatic changes and human activity. However, it has to be noted that this problem has been insufficiently studied so far. We hope that the elaboration of the project on palaeohydrological changes in the temperate zone for the recent 15 000 years will stimulate investigators to perform analogical studies in the East Baltic as well.

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JÕEORGUDE ARENGU PÕHIJOONED IDA-BALTIKUMIS

Jõevõrgu kujunemine ja areng käsitletaval alal on tihedas seoses mandrijää taandumisega ja Balti mere arenguga, mida tunduvalt mõjustasid glatsioisostaatilised liikumised.

Lisaks jõeorgude arengut mõjustavaile ühisfaktoreile on kindlaks tehtud rida regionaalseid ja kohalikke iseärasusi. Need on tingitud erinevustest mandrijää taandumises, jääjärvede kujunemises ja dünaamikas, glatsioisostaatiliste liikumiste intensiivsuses ja Balti mere arengus. Selle tõttu erinevad ka orgude vanus, konkreetsed tekkeviisid, terrasside arv ja tüübid, jõesetete paksus, litoloogiline ja fatsiaalne koostis, orgude areng ja mitmed teisedki nende geoloogiat ning geomorfoloogiat iseloomustavad jooned.

Г. ЭБЕРХАРДС, А. МИЙДЕЛ

ОСНОВНЫЕ ЧЕРТЫ РАЗВИТИЯ РЕЧНЫХ ДОЛИН В ВОСТОЧНОЙ ПРИБАЛТИКЕ

Формирование и развитие речной сети рассматриваемой территории тесно связаны с дегляциацией территории и развитием Балтийского моря в условиях значительного влияния гляциоизостатических движений. Несмотря на общность факторов в развитии речных долин установлены региональные и локальные особенности, обусловленные различиями в дегляциации, формировании и динамике ледниковых озер, интенсивности гляциоизостатических движений и развитии Балтийского моря. Следовательно, различаются возраст речных долин, их развитие, конкретные пути формирования, количество и типы террас, мощность, литологический и фациальный составы аллювиальных отложений, а также некоторые другие черты геологии и геоморфологии.