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Late Pleistocene glaciofluvial sedimentation in Gariūnai–Pagiriai proglacial valley, SE Lithuania

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The results of studies of glaciofluvial sediments and their sedimentation in a proglacial valley in the northern part of SE Lithuanian outwash plain are presented. The aim of the study was to compare the features of sediments in the geomorphologically well expressed Gariūnai–Pagiriai proglacial valley with the rest part of the SE Lithuanian Sandy Plain in which the complexity of proglacial fluvial sedimentation was revealed during the resent investigations. The change of depositional structures of sandy sediments and grain size distribution in vertical sediment sequences was studied for lithofacies analysis. The studies carried out let to interpret the sedimentation conditions of deposits in the proglacial valley as a meandering stream of SE direction, which downstream turns SW and intersects the SE Lithuanian Sandy Plain composed of braided stream outwash sediments. Lithofacies of proglacial valley deposits were distinguished in the deposit sequences due to a qualitative sedimentological research. Mid-channel and side-channel bar deposits of the proglacial valley were described and conditions of their sedimentation were evaluated. It was interpreted that formation of glaciofluvial terraces in the proglacial valley took place in several stages under the changing mode of ice meltwater flow and the steady source of clastic sediment material.

Key words: Quaternary, SE Lithuania, glaciofluvial sedimentation, proglacial valley

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INTRODUCTION

Geomorphological research at the SE Lithuanian Sandy Plain was carried out by A. Basalykas, V. Dvareckas, L. Dicevičienė (Basalykas, 1955, 1965; Basalykas et al., 1984) as well as lithological studies and sediment structure analysis by A. Mikalauskas and A. Jurgaitis (Mikalauskas, 1964; Mikalauskas, Jurgaitis, 1975). Also the sedimentological investigations of proglacial glaciofluvial sediments carried out in Poland (Zielinski, 1989, 1992; Zielinski, Van Loon, 1999a, 1999b, 2000; Brodzikowski, Van Loon, 1985, 1991) by means of applied methodology let to reconstruct sedimentation conditions of sediments deposited in the studied proglacial valley. Recent studies (Blažauskas et al., 1998, 2007; Jurgaitis et al., 2002) of the deposits exposed in outcrops and quarries in SE Lithuania together with the analyzed geomorphological features confirmed the idea that proglacial glaciofluvial deposits are of the most importance in the development of the SE Lithuanian Sandy Plain. This area was probably one of the major areas in Lithuania where the intensive ice meltwater activity took place during the ice retreat of the last continental glaciation. Results of the recent research (Baltrūnas et al., 2007; Blažauskas et al., 2007; Jurgaitis et al., 2002)

displayed the complexity of proglacial fluvial sedimentation there.

The aim of this study was to compare the features of sediments in the geomorphologically well expressed Gariūnai–Pagiriai proglacial valley with the rest part of the SE Lithuanian Sandy Plain. The Gariūnai–Pagiriai proglacial valley joins the SE Lithuanian Sandy Plain with Baltija Uplands where the meltwater streams were originated. Therefore glaciofluvial deposits in the proglacial valley have some importance for the sedimentation history interpretations of the SE Lithuanian Sandy Plain. The studied sites (Fig. 1) are located mostly in the north-eastern part of the outwash plain where the area is rich in active quarries, particularly related to the proglacial valley. Due to present sand and gravel extractions the deposits are well exposed for detail examination, especially in Gariūnai (Fig. 2) and Pagiriai quarries.

METHODS

Sedimentological investigations of the sandur in North East Poland and deposits of proglacial meltwater valleys made by T. Zielinski (1989, 1992), the estimation of hydraulic parameters of palaeocurents (Blažauskas et al., 2000a) were taken into account during this study. Sedimentological methodology was approved when reconstructing the depositional process of the glaciofluvial delta in East Lithuania (Blažauskas et al., 2000b) and the sandur in the SE Lithuanian Sandy Plain (Blažauskas et al., 2000a, 2007).

It needs to be mentioned that this study deals with sandy and gravel deposits mostly. Therefore the sedimentation conditions and qualification of the flow regime are applied to these sediments and also such a phenomena as sand and gravel dunes

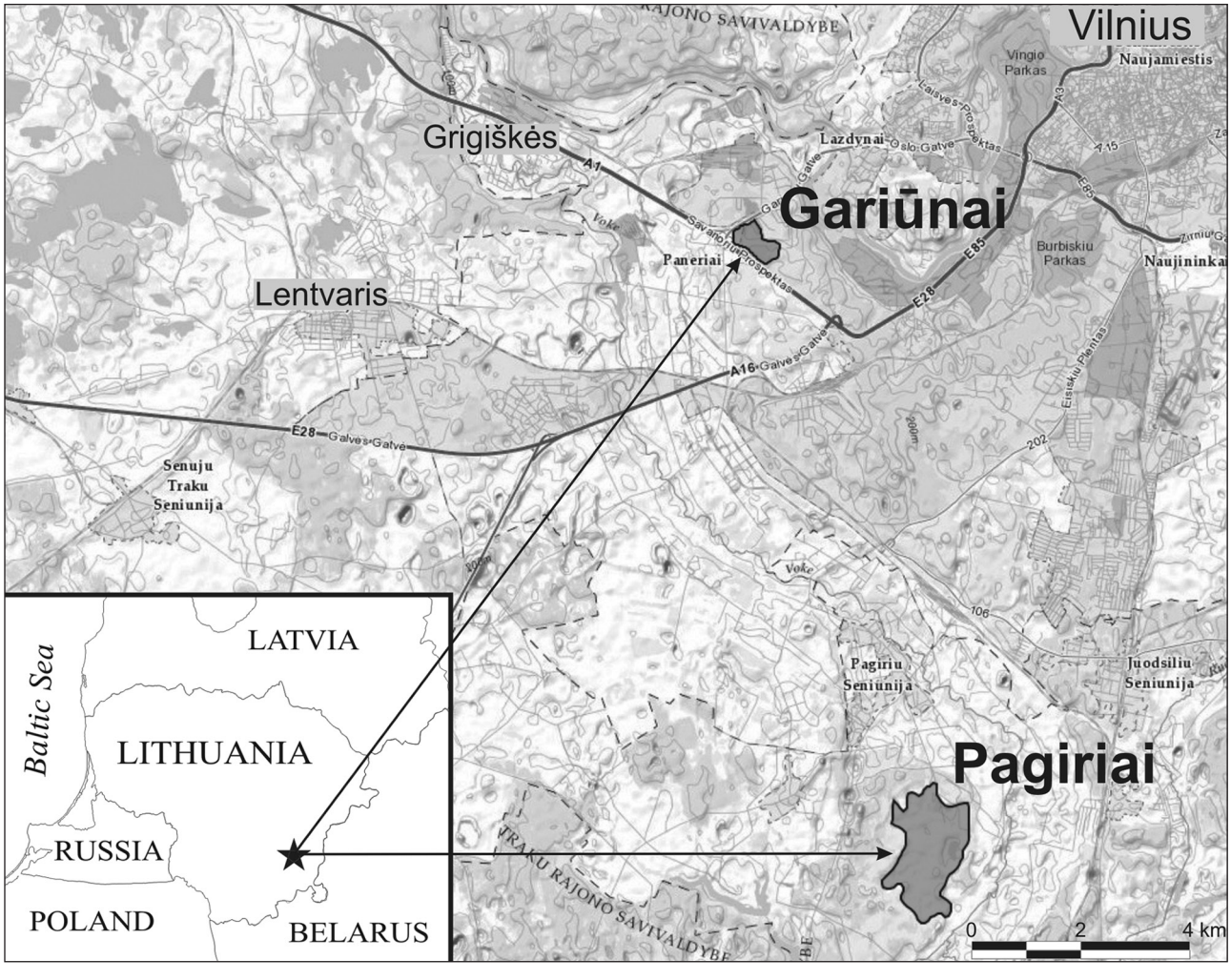

Fig. 1. Location of the investigated glaciofluvial deposit sites at Gariūnai and Pagiriai
1 pav. Ištirtų fliuvioglacialinių nuogulų telkinių padėtis Gariūnuose ir Pagiriuose

Fig. 2. Glaciofluvial sediment sequence at the Gariūnai quarry
2 pav. Fliuvioglacialinių nuogulų storymė Gariūnų karjere

and ripples were taken into account. The bedding type and lamina dip directions were examined in the field. These parameters were used to define the palaeoflow directions, to evaluate a hydraulic mode of the flow as well as to identify sedimentation phases of glaciofluvial deposits (Brodzikowski, Van Loon, 1985; Jurgaitis et al., 1982; Boothroyd, Ashley, 1975).

Sediment samples were analysed using a 19 sieve set to evaluate a grain-size distribution of the investigated deposits. Lithology of the sediments was defined and several statistical parameters (mean diameter, standard deviation, variance and asymmetry) were estimated with relevance to these analyses. Hydraulic parameters such as mean flow velocity and stream power were estimated by means of its qualitative evaluations. For this most useful was the pattern of sediments bedding, such us change of the bedding type of sandy and gravel sets, mostly trough and tabular cross bedding and subhorizontal stratification, the most common for all proglacial glaciofluvial facies.

LITHOFACIES

The transportation range of ice-released material from the ice front and substratum surface has influenced the depositional process, erosion and deformational patterns. Different lithofacies are able to be formed because of meltwater flow dynamics change in periglacial environment during various sedimentation phases (Brodzikowski, Van Loon, 1991). According to the same authors, proglacial subenvironment is considered as the part of periglacial environment where the buried dead-ice blocks, remnants of a period of greater ice extent, can be preserved in the subsoil. Lithofacies of the outwash plain, which is reached by the proglacial valley towards the southwest, are described there along with the lithofacies of the proglacial valley to analyse the differences in the sedimentation pattern.

Lithofacies of outwash plain

Lithofacies of the outwash plain in SE Lithuania are represented by the sandur, which was the area of rapid aggradation, crossed by braided streams which continually shifted their pattern and course causing simultaneously occurred local erosion and deposition. Depending on the distance from the ice margin, the deposits of proximal, middle and distal parts of the outwash plain as different facies in braid plain were distinguished in the SE Lithuanian Sandy Plain (Blažauskas et al., 2007) where outwash deposits are spread.

Deposits of the outwash plain proximal part earlier observed and described in the Serafiniškės sand and gravel quarry (Blažauskas et al., 2007) are represented by badly sorted subhorizontally laminated gravel and trough cross stratified sand and gravel sets. According to geometry measurements of trough cross stratified sandy beds, the sandy dunes were originated in slower and weaker flow, whereas the sheet like beds of coarse gravel represent an intensive flood phase of meltwater discharge under upper plain bed conditions (Rust, 1975). Also an accumulation of the low level longitudinal bars took place. However, the most intensive meltwater flow is represented by the flat sedimentation phase (Church, Gilbert, 1975; Mikalauskas, 1985) described as an antidune sedimentation phase. At this stage, flattening of the already deposited bedforms and sedimentation of subhorizontally or parallel laminated layers took place (Ruegg, 1977). The observed flow till or diamictic deposits of subaerial mass transport facies confirm the proximity of the outwash plain proximal part to the ice margin. Terminoglacial fans in NE Poland described by T. Zielinski and A. J. Van Loon (1999a, 1999b, 2000) have similar features as the proximal part of the outwash plain. The sediments in the proximal part are relatively coarse close to the ice margin and have a massive structure or not well expressed bedding in many cases. Quite different bedding type is common to braided stream channel deposits at the proximal part of the outwash plain. Three dimensional dunes causing trough cross stratified sand and gravel sets formed by high energy flow were widespread in them (Zielinski, Van Loon, 2003).

Lithofacies characteristics of the outwash plain middle part were studied earlier south of the studied area in the outcrops at lower reaches of the Ūla River (Jurgaitis et al., 2002) and sand and gravel quarries (Blažauskas et al., 2007). Trough cross stratified coarse sand and even subhorizontally stratified gravel along with ripple-laminated coarse silt were described. It was noted that sediments are obviously finer and have a notably smaller size of cross stratified beds than in the proximal part. The braided streams in the middle part of the braidplain had obviously lost their power and flow velocity. This was interpreted after the description of palaeoflow parameters of trough cross stratified sandy deposits. The sediment sequences of the outwash plain middle part are predominantly composed of the subhorizontally stratified sands deposited under sheet flood conditions. Such sediment features are described in present (Gomez et al., 1997) and ancient (Ruegg, 1977; Zielinski, Van Loon, 2003) outwash plains. Irregular shifting of sedimentation stages from high energy sheet flood to low energy braided stream flows accompanied by regular sediment supply have resulted in quite large sediment sequences composed of sand and gravel deposits. All these features show that braided streams in the middle part of the outwash plain had lost a considerable part of their power.

The distal part of the outwash plain is characterised by finest sediments. Sediment sequences described in the outcrops of the Ūla River upper reaches (Blažauskas et al., 2007) comprise fine sand and coarse silt sediments, predominantly current ripple laminated. Trough cross and subhorizontally stratified sand is very rare and is present only in thin beds indicating a very low flow velocity and mean stream power.

The drop of braided stream energy several times along the outwash plain profile resulted in the differences of the deposition pattern in different parts of the outwash plain producing the sediment sequences which have specific textural and structural features. Especially it concerns cross and ripple laminated sediments. Occurrence of sheet-like beds reflecting overbank sedimentation depended on occasional increase of the ice meltwater amount.

Lithofacies of proglacial valley

In some cases the ice meltwater is able to form distinctly canalized flows similar to recent single meandering channels or large scale multi channel braided rivers. The proglacial fluvial valley as a single meandering channel is under consideration in this case. The meandering stream sediments were characterised in order to more clearly distinguish them from the sediments of braided streams generally characteristic for sedimentation in outwash plains. Canalized glaciofluvial flows are often originated near the glacial ice margin in upper reaches of meltwater streams by their confluence (Zielinski, 1992) or directly influenced by catastrophical outburst of ice meltwater (e. g. glacial outburst floods described by Maizels, 1997). In our

study we deal with the deposits of the Gariūnai–Pagiriai proglacial valley of SE direction, which downstream turns SW (Fig. 3) and intersects the outwash plain further extending along the former glacial ice margin. According to the structure of the deposit sequence, bedding pattern and roughness of deposited sediments, it is possible to distinguish mid-channel and side-channel bar deposits.

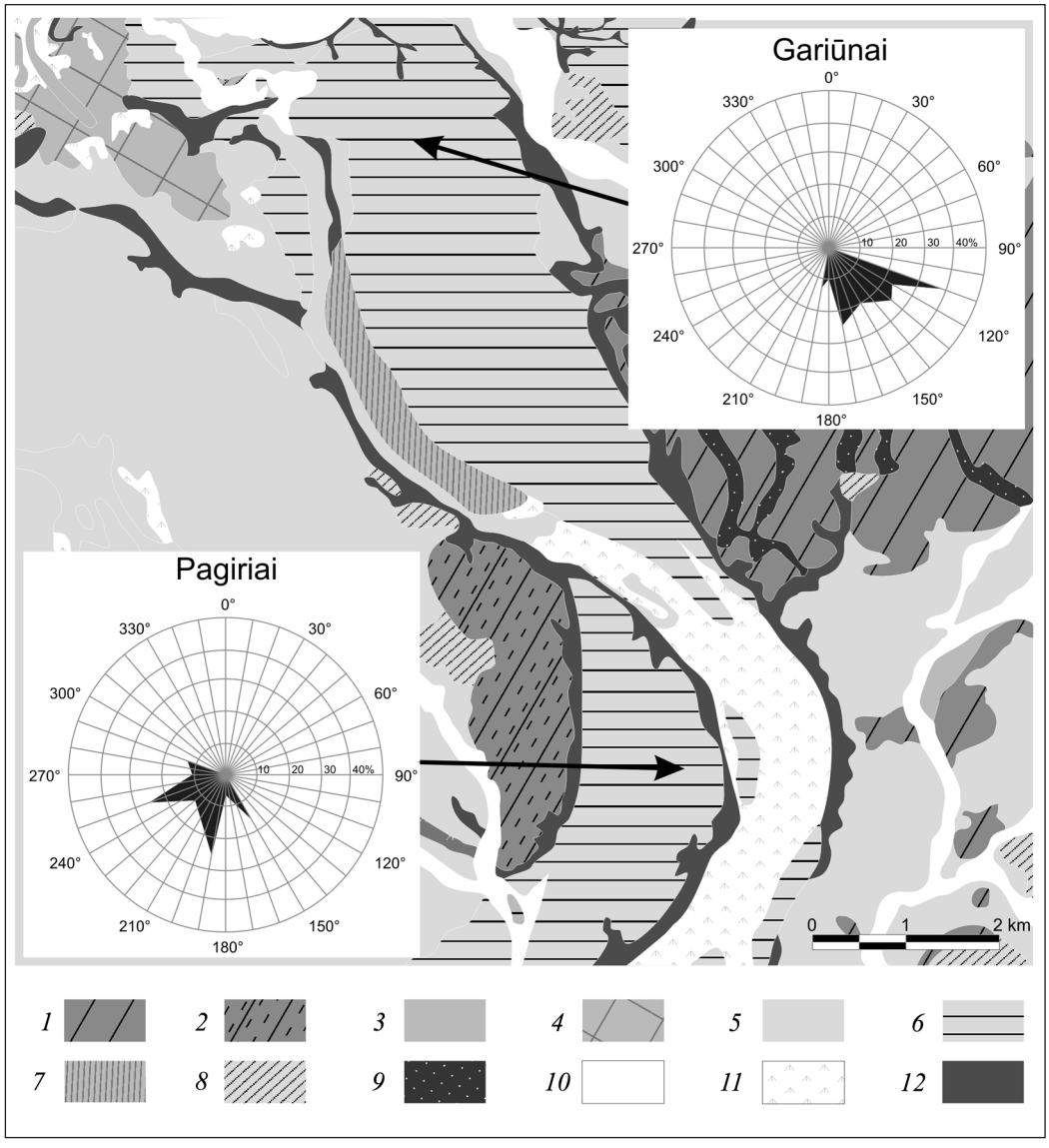

Fig. 3. Landform morphology of the investigated area and the rose diagrams of sediment lamina dip directions at Gariūnai and Pagiriai glaciofluvial sites: *1* – Middle Pleistocene landforms affected periglacially; *2* – eroded Middle Pleistocene landforms; *3* – basal till plains of the Last Glaciation; *4* – marginal formations of the Last Glaciation; *5* – outwash plains of the Last Glaciation; *6* – glaciofluvial terraces in the proglacial valley; *7* – erosional terraces; *8* – glaciolacustrine plains of the Last Glaciation; *9* – dry valleys; *10* – fluvial valleys; *11* – wetland plains; *12* – slopes

3 pav. Tyrimų ploto geomorfologija ir Gariūnų bei Pagirių telkinių fliuvioglacialinių nuogulų sluoksnelių polinkio krypčių rožės diagramos: *1* – periglaciališkai paveiktas vidurinio pleistoceno darinių reljefas; *2* – eroduotas vidurinio pleistoceno nuogulų paviršius; *3* – paskutiniojo apledėjimo pagrindinės morenos lyguma; *4* – paskutiniojo apledėjimo kraštiniai dariniai; *5* – paskutiniojo apledėjimo zandrinės lygumos; *6* – prieledyninio slėnio fliuvioglacialinės terasos; *7* – erozinės terasos; *8* – paskutiniojo apledėjimo limnoglacialinės lygumos; *9* – sausslėniai; *10* – fliuvialiniai slėniai; *11* – žemapelkių lygumos; *12* – šlaitai

The coarse mid-channel bar sediments were studied in both Gariūnai and Pagiriai quarries. Coarse sediments of large scale trough cross and tabular stratification as well as subhorizontally stratified gravely deposits were observed (Fig. 4). 1.1–1.7 m/s mean flow velocity and 17.4–60 N/m · s stream power were estimated in the Gariūnai gravel quarry (Blažauskas et al., 2007) for trough cross stratified sand beds with the lenses up to 0.7 m thick and 3–10 m long. The shifts from three dimensional dunes and transverse bar to flat gravely sheet like beds of low angle longitudinal bar sedimentation phase are observed in Gariūnai and Pagiriai sediment sections as well as badly sorted sediments point to high energy uneven flow conditions – quite typical for high energy proglacial streams (Zielinski, 1992). Subhorizontally stratified sheet-like gravel beds up to 2.5 m thick could be attributed to high discharge events, such as glacial outburst floods. Deposits of steadier flow were observed in the Pagiriai site. Subhorizontally stratified sheet like beds (Fig. 4B) refer to downstream progradation through vertical accretion of low longitudinal bars or gravel sheets (Zielinski, 1992). The described deposits are similar to the main channel deposits of the Weichselian sandur in NE Poland described by Zielinski and Van Loon (2003). These facts prove that these sediments were deposited in the part of the proglacial river with the most intensive flow and therefore refer to mid-channel bar deposition.

As side-channel bar deposits various bedding types of sandy sediments in Gariūnai and Pagiriai sand and gravel extraction sites were observed.

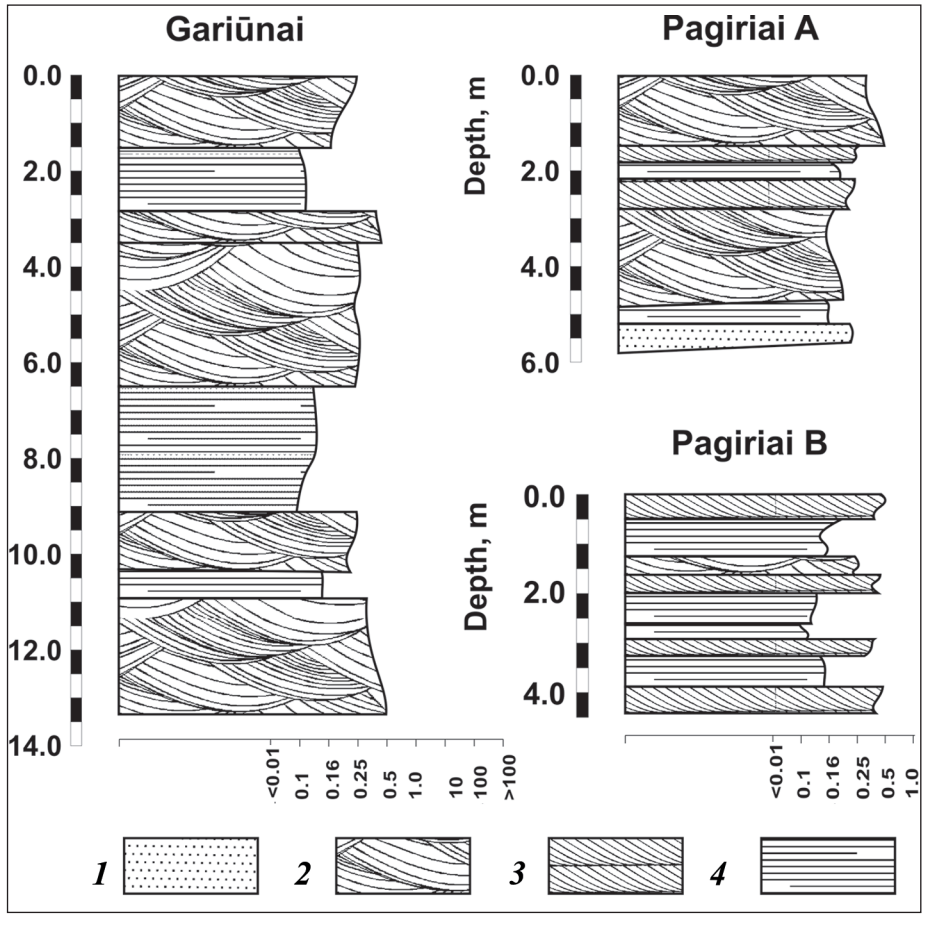

Fig. 4. Sedimentological logs of sediment sequences from the investigated deposits: *1* – sediments of massive structure; *2* – trough cross stratified sediments; *3* – tabular cross stratified sediments; *4* – subhorizontally stratified sediments
4 pav. Nuogulų sekų sedimentologiniai pjūviai ištirtuose telkiniuose: *1* – masyvios tekstūros nuogulos; *2* – kryžmiškai įkypai sluoksniuotos nuogulos; *3* – lygiagrečiai įkypai sluoksniuotos nuogulos; *4* – subhorizontaliai sluoksniuotos nuogulos

Beds of small thickness with long lenses of tabular and trough cross stratified sediments (Fig. 4A) were found. Subhorizontally stratified sandy sediment sequences well exposed in the Pagiriai site in some places are superimposed by current ripple laminated fine sediment beds and point-bar deposits showing lower palaeoflow velocity and stream power towards the margin of the channel and the meandering character of the proglacial river. Due to the decrease of the proglacial stream energy the deposition of sand is more frequent at the margin of the channel.

During the deposition in abundant water flow conditions transverse bars and three dimensional dunes were originated. Namely, a large scale of bedforms observed in the field is the representative feature for the proglacial river valley rather than for the outwash plain deposits described in this paper earlier. Subhorizontally stratified sand beds, related with the deposition characterised by high aggradation rates of transported material in a very shallow water flow are also rather thick in the proglacial stream valley. These sand beds can be accumulated by stream floods which periodically occur in irregular glaciofluvial water supply systems. If to compare sediment features from the Gariūnai site with the ones in the Pagiriai deposit by means of the change of the palaeohydraulic parameters, the slight weakening of the proglacial stream power and flow velocity downstream direction is obvious.

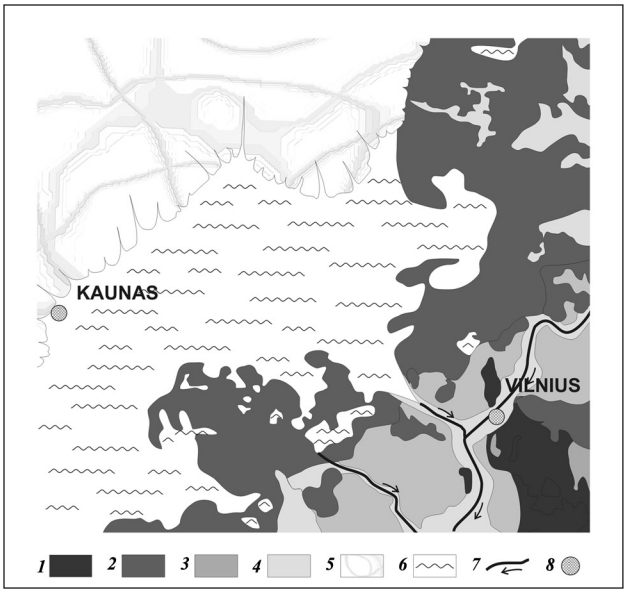

Fig. 5. Last Glacial ice retreat situation during the final stages of glaciofluvial sedimentation in Gariūnai–Pagiriai proglacial valley: *1* – Middle Pleistocene landforms; *2* – marginal formations of the Last Glaciation; *3* – outwash plains of the Last Glaciation; *4* – glaciofluvial proglacial valleys; *5* – glacier; *6* – proglacial lake; *7* – ice meltwater flow routes and directions; *8* – present town places

5 pav. Paskutiniojo apledėjimo ledyno atsitraukimo situacinė schema fliuvioglacialinės sedimentacijos Gariūnų–Pagirių prieledyniniame slėnyje baigiamuoju etapu: *1* – vidurinio pleistoceno dariniai; *2* – paskutiniojo apledėjimo kraštiniai dariniai; *3* – paskutiniojo apledėjimo zandrinės lygumos; *4* – fliuvioglacialiniai prieledyniniai slėniai; *5* – ledynas; *6* – prieledyninis ežeras; *7* – ledyno tirpsmo vandens tėkmės ir jų kryptys; *8* – dabartinių miestų vietos

SEDIMENTATION CONDITIONS

Sedimentation conditions of the glaciofluvial deposits in the Gariūnai–Pagiriai proglacial valley area were interpreted after the previous and present sedimentological research (Fig. 5). The investigated area was covered by several ice-lobes during the Last Glaciation. Melting glacial ice during the first degradational stage of the Last Glaciation has initiated the SE oriented glaciofluvial activity and sedimentation in front of the ice margin. Therefore, the sandur plain composed of braided stream sediments has been formed. It was observed earlier (Jurgaitis et al., 2002; Blažauskas et al., 2007) that two sedimentary covers of braided stream sediments, investigated in Ūla River valley outcrops, were deposited due to a repeated activation of the ice melting during the final degradational stage. Due to high aggradational rate in braided streams and abundance of provided material from nearby existed glacial ice a thick cover of sandy sediments was accumulated in the outwash plain. Change of the observed lithofacies in the sandur deposit sequence shows a characteristic pattern of sedimentation in braided streams, implying frequent shifting of sedimentation in the main and secondary channels as well as in the flooded plains.

Glacial ice melt during the final degradational stage of the Last Glaciation resulted in new activity of glaciofluvial sedimentation in the investigated area. The appearance of the second outwash belt northwestward from the first stage sandur accumulation is related with this glaciofluvial sedimentation stage.

After some retreat of the glacial ice margin from the marginal formations a relatively intensive outflow of ice meltwater has burst across them to the SE Lithuanian Sandy Plain originating a submarginal proglacial meandering stream (Fig. 5). High energy flow has eroded former relief forming the proglacial valley and deposited proglacial river sediments. A typical pattern of the sediment transport and depositional process in the meandering stream was confirmed by well expressed mid-channel bar deposits observed in the upper reaches of the proglacial flow (Gariūnai and Pagiriai sites) as well as side-channel bar deposits (e. g. point bar deposits) in several places in the Pagiriai site.

CONCLUSIONS

The glaciofluvial deposits of the Gariūnai–Pagiriai proglacial valley area are composed of outwash plain (braided stream) deposits and proglacial valley (meandering stream) deposits. The proglacial valley of SE direction downstream turning SW intersects the outwash plain further extending along the former glacial ice margin. Mid-channel and side-channel bar deposits are distinguished as lithofacies of the meandering proglacial valley. Large scale of bedforms is the representative feature for proglacial river deposits. The slight weakening of the proglacial stream power and flow velocity is present downstream in separate intervals of the proglacial valleys.

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VĖLYVOJO PLEISTOCENO FLIUVIOGLACIALINĖ SEDIMENTACIJA GARIŪNŲ–PAGIRIŲ PRIELEDYNINIAME SLĖNYJE PIETRYČIŲ LIETUVOJE

S a n t r a u k a

Straipsnyje pateikiami fliuvioglacialinių nuogulų ir jų sedimentacijos sąlygų prieledyniniame slėnyje Gariūnai–Pagiriai, esančiame šiaurinėje Pietryčių Lietuvos zandrinės lygumos dalyje, tyrimo rezultatai. Paskutinieji tyrimai rodo, kad Pietryčių Lietuvos zandrinės lygumos nuogulų sedimentacija vyko skirtingomis sedimentacijos sąlygomis, kurioms interpretuoti reikalingi detalesni sedimentologiniai tyrimai. Šio tyrimo tikslas buvo palyginti nuogulų, suklostytų geomorfologiškai gerai išreikštame prieledyniniame slėnyje, ypatybes su likusios Pietryčių Lietuvos zandrinės lygumos nuogulų charakteristika. Kaip pagrindiniai litofacijų išskyrimo tyrimo metodai buvo naudojama nuogulų granuliometrinės sudėties ir tekstūros kaitos vertikaliuose pjūviuose analizė. Tai leido prieledyniniame slėnyje suklotų nuogulų sedimentacijos sąlygas interpretuoti kaip būdingas meandruojančiam PR krypties srautui, kuris, pasisukdamas į PV, kerta Pietryčių Lietuvos smėlėtąją lygumą, sudarytą iš klaidžiojančių srautų suklotų zandro nuogulų. Atlikus kokybinius sedimentologinius tyrimus prieledyninio slėnio nuogulų sekose buvo išskirtos litofacijos. Tuo pagrindu buvo charakterizuotos prieledyninio slėnio vagos vidurinės ir šoninės dalių pylimų nuogulos ir įvertintos jų sedimentacijos sąlygos. Interpretuota, kad prieledyninio slėnio fliuvioglacialinių terasų formavimasis vyko keletu etapų esant kaičiam ledyno tirpsmo vandens srautui ir pastoviam nuotrupinės mineralinės medžiagos šaltiniui.

Raktažodžiai: kvarteras, Pietryčių Lietuva, fliuvioglacialinė sedimentacija, prieledyninis slėnis