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Sedimentology of clastic intertill deposits studied in Dovainonys and Rokai outcrops, Central Lithuania

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A detailed structural, textural and compositional research of clastic intertill sediments in the Dovainonys and Rokai outcrops in Central Lithuania was carried out with a sedimentological analysis of bedding, grain size and geochemical composition of sediments in both outcrops. The deposit bedforms and composition are presented as a result of deposition in different environments of sedimentation. Sediment differences of glaciodeltaic and nonglacial fluvial environments are discussed on the successions of lithofacies revealed. The sedimentation of intertill deposit sequence in the Dovainonys site was related to the formation of glacigenic delta of trinomial structure with developed deltaic topsets, foresets and bottomsets in the proglacial basin. The sedimentation of intertill deposits in the Rokai sediment sequence was related to the nonglacial fluvial sedimentation in a river of meandering character. The lower amount of CaO, MgO, Na_2O, MnO and P_2O_5 in nonglacial intertill sediments in comparison with proglacial ones is related to a higher sediment geochemical maturity.

Key words: Pleistocene sedimentology, intertill deposits, sediment structure, grain size, geochemistry, lithofacies, glaciodeltaic and fluvial sedimentation, sediment geochemical maturity, Lithuania

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INTRODUCTION

A major part of the Quaternary deposit sequence in Lithuania is comprised of glacigenic deposits. Therefore investigation of glacigenic deposits has been always of main importance in the region. It resulted in an abundance of geological data characterising the Quaternary deposit sequence (Baltrūnas, 1995, 2002; Gaigalas, 1995a, b; Šinkūnas, Jurgaitis, 1998a; Гайгалас, 1984 and others). Accumulation of the bulk of intertill deposits took place during the ice melting of continental glaciations just before each interglacial. The largest thickness of intertill sandy deposits reaching 50 m or even 100 m is related to bedrock depressions filled with ice meltwater deposits (gravel, sand, silt or clay), and ice marginal forms evaded erosion by later glaciers. However, glacial erosion seems to modify the intertill deposit thickness in general which rarely exceeds 20 m, especially in lowlands were 10 m are not exceeded. Nevertheless, the intertill outwash and glacial-lake sediments related to glacial ice melting during the glacial climate shift to interglacials are widely spread in all the territory of Lithuania except its northern part which was eroded by glaciers repeatedly.

The clastic sediment features for indication of sedimentation pattern of the intertill deposits were established out during the previous investigations

(Barzdžiuvienė et al., 2000; Blažauskas et al., 1998a, 1998b, 2000; Jurgaitis ir kt., 2002; Jurgaitis, Šinkūnas, 2000; Kučinskaitė, 1998; Paškauskaitė, 2002; Šinkūnas, 1998; Šinkūnas, Jurgaitis, 1998a, b; Šinkūnas, Jurgaitis, 1999; Šinkūnas ir kt., 2001). These investigations were based on classification of the environments of sedimentation by K. Brodzikowski and A. J. Van Loon (1987, 1991) and carried out according to the genetic classifications of glaciofluvial deposits proposed by Lithuanian researchers (Jurgaitis, Juozapavičius, 1989; Šinkūnas, Jurgaitis, 1999). However, a conception of the deposit features indicating the sedimentation conditions is still of urgent necessity, especially for the identification of organic less clastic material sedimentation in a nonglacial environment. So the research on sediment sequences of the Rokai and Dovainonys outcrops also represents one of the starting points toward the understanding of such sediment features.

INVESTIGATION SITES AND METHODS

The investigation sites are the sediment sequences of the Rokai and Dovainonys outcrops situated in the central part of Lithuania near the Kaunas city (Fig. 1). The Rokai outcrop is located on the right bank of the Jiesia River, a left tributary of the Nemunas River, near Rokai (54°50′43″N, 23°56′07″E) place, and the Dovainonys outcrop is at a distance of about 20 km on the north-eastern bank of the Kauno Marios Reservoir on the Nemunas River (54°49′51″N, 24°13′58″E). The surrounding area is the Kaunas–Kaišiadorys glaciolacustrine plain spread in front of the marginal formations of the Middle Lithuanian phase of Last Glacial ice retreat and covered with varved clay (Kazakauskas, 2000).

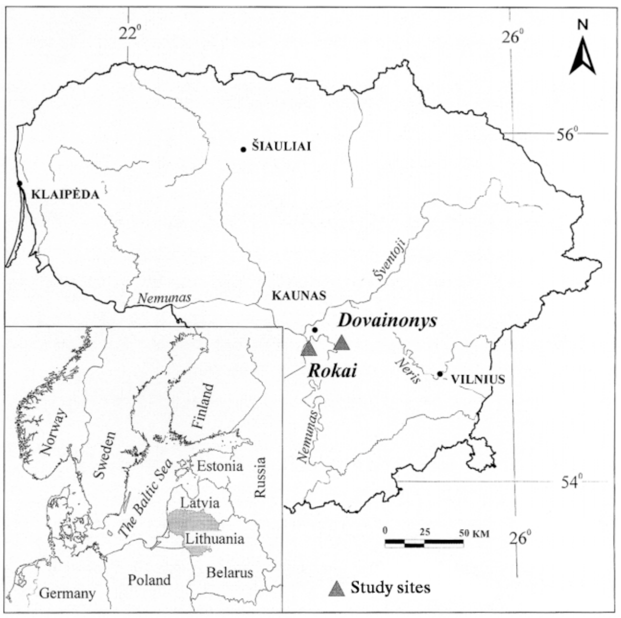

Fig. 1. Location of Rokai and Dovainonys outcrops
1 pav. Dovainonių ir Rokų atodangų geografinė padėtis

The stratigraphy of Pleistocene deposits in the Jiesia valley was studied by many researchers. In 1982, wood remains found in the lowest part of the Rokai sediment sequence were dated by the ^{14}C method. The sediments were dated back to the beginning and end of the Middle Nemunas (Weichselian) age (Gaigalas, 2001). Later the sediments of the Rokai sequence were subjected to optically stimulated luminescence (OSL) studies. The OSL dates showed a good correlation with radiocarbon ones and the same Middle Nemunas age. So, intertill sediments of the Rokai outcrop were assigned to the Middle Nemunas Interstadial and interpreted as lacustrine-alliuval (Gaigalas, Hütt, 1995; Gaigalas, 2000). O. Kondratienė and V. Riškienė (Кондратене и Ришкене, 1983) published the results of biostratigraphical examinations according to which plantfossils had been found only in the upper part of the Rokai intertill sequence. They supposed that sand strata were formed in periglacial tundra conditions during the Last Glaciation, most probably in Middle Nemunas time. After T. Kazarceva's detailed biostratigraphical investigation (Гайгалас и др., 1987), three stages of the Middle Nemunas flora evolution were distinguished in the sediment sequence (Gaigalas, 2001). A quite different conclusion was drawn about the sediment origin from the results of its chemical composition. Only a silt interlayer was indicated as accumulated in a lake or river floodplain environment, while the rest part of the sandy sequence was discussed as indicating an aeolian sand drift in periglacial conditions (Satkūnas, Grigienė, 1996).

Z. Malinauskas (Малинаускас, 1991) investigated the structure and composition of sediment sequence in the Dovainonys outcrop, interpreting the sedimentation conditions of intertill deposit as glaciofluvial related to ice melting during the last stages of the Last Glaciation.

Sedimentological analysis of the bedding, grain size and geochemical composition of sediments in both outcrops was implemented as a method of investigation during the present study. The type of bedding and deposit structure were described during fieldwork. Sandy sediments were sampled for grain size and geochemical studies from each bed at depth intervals depending on the bed thickness. A set of 19 sieves was used for grain size measuring. The grain size data obtained were characterized by calculating particle size, such as mean (X, mm), maximal (C, mm) and median (Md, φ) diameters and parameters of sorting – Trask's coefficient (S_O, mm), standard deviation (S, mm) and relative entropy (Hr). Parameters of grain size distribution were obtained after a statistical treatment of sediment sieving data by SIETAN compute program compiled at Institute of Geology and Geography in Vilnius after G. F. Rozhkov and V. D. Kulikov (Рожков и др., 1973; Рожков и Куликов, 1975). The ACME laboratory in Canada carried out the geochemical analysis of sandy sediment samples for the main component oxide composition. The subdivision of sediment sequences into lithofacies was complemented by data statistical cluster analysis using the CONISS algorithm built into TILIA program (Grimm, 1991). To analyze the character and degree of geochemical differences of sediments, Principal Component Analysis (PCA) was carried out using the computer programs CANOCO 4 for ordination and CANODRAW 3.1 for plotting (Jongman et al., 1995; Ter Braak and Šmilauer, 1998). Sediment samples must be projected perpendicularly to the vectors of chemical components in PCA biplot while reading the ordination diagram.

RESULTS

Dovainonys outcrop

Sediment bedding. Bed of greyish brown till of lithofacies VII up to 10 m above water level is covered with fine yellowish brown sand of lithofacies VI (Fig. 2). In the lowermost part of the bed, horizontally laminated fine-grained sand and silt occur. The lower half of the bed consists of yellowish brown horizontally laminated silt and brown varved clay (silt and clay with distinct lamination and thick laminas). Laminas differ in colour and grain size and are 1.5–2.5 cm thick. Fain- and middle-grained sand, horizontally laminated, occurs in the uppermost part of lithofacies VI.

Lithofacies V^c consists of light yellow fine-grained sand, massive and current climbing ripple-laminated (ripple height 3–4 cm, width 10–30 cm) and horizontally laminated in the uppermost part. The sand bed is overlain by middle- and coarse-grained sand with gravel, trough cross-bedded in the lower part of lithofacies V^b, with an interbed of light yellow fine-grained horizontally and current ripple-laminated sand. Laminated lenses of trough cross-beds are up to 0.4 m thick and 1.5–3 m wide; the dip direction of cross-bed foresets ranges from 200° to 300°. The upper part of the lithofacies is composed of sand with gravel; its structure is dominated by a decimeter-thick large-scale planar-parallel cross-bedding. Light yellow middle- and coarse-grained sand with gravel, horizontally and sub-horizontally laminated, comprises lithofacies V^a. On the top of it, a light yellow fine-grained current ripple-laminated sand of lithofacies IV underlies a bed of brown till with gravel and pebbles. An interlayer, about 30 cm thick, of brownish yellow silt of disordered structure occurs at the bottom of the sand bed. The till bed underlies a bed of varved clay (brown clay and yellowish grey silt, horizontally laminated) of lithofacies II, with lamina thickness up to 5 cm, covered with subsurface yellow fine-grained sand of massive structure.

Grain size. The sandy sediments of lithofacies VI are comparatively well sorted (S – 0.31, Hr – 0.63, S_o – 1.09) and are the finest (X – 0.11, C – 0.35, Md – 2.32) in all the intertill sediment sequence (Fig. 3). Sandy sediments of lithofacies V^c are nearly of the same sorting as of lithofacies VI (S – 0.25, Hr – 0.64, S_o – 1.09) and comparatively fine: X – 0.17, C – 0.25, Md – 1.80. The sediments of lithofacies V^b and V^a are the coarsest in the intertill sequence with the mean (X) – 0.27, maximal (C) –

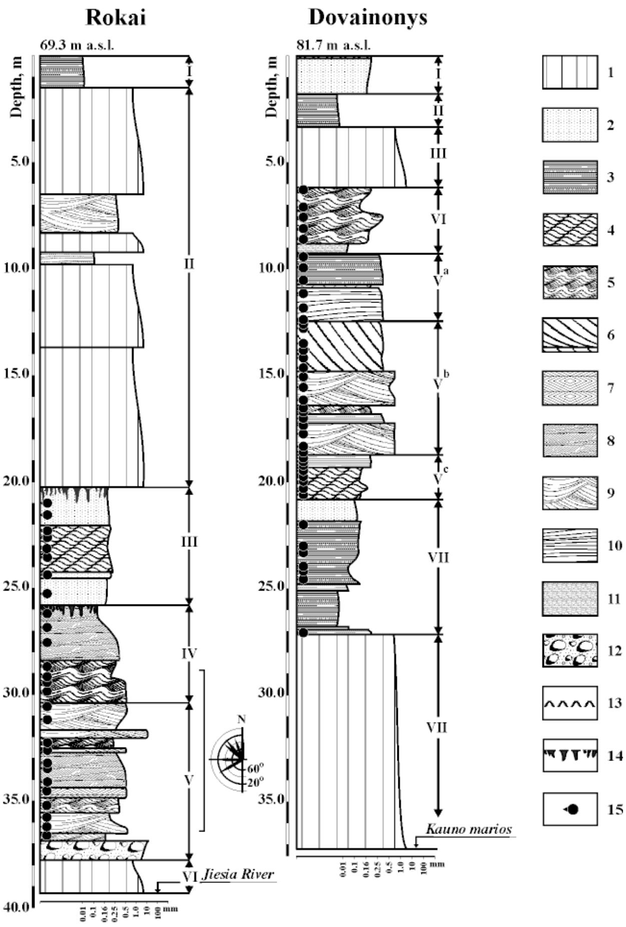

Fig. 2. Sediment sequences of Rokai and Dovainonys outcrops: *1* – till, *2* – sand of massive structure, *3* – horizontal lamination, *4* – wave ripple-lamination, *5* – current ripple-lamination, *6* – large scale planar-parallel cross-bedding, *7* – tabular cross-bedding, *8* – wedge-shaped cross-bedding, *9* – trough cross-bedding, *10* – sub-horizontal bedding, *11* – sediments of disordered structure, *12* – gravel, pebble and boulders, *13* – soil, *14* – ice-wedge casts, *12* – sampling sites

2 pav. Rokų ir Dovainonių atodangų nuogulų pjūviai: *1* – moreninis priemolis, *2* – masyvios tekstūros smėlis, *3* – horizontalus sluoksniuotumas, *4* – bangavimo ruzgų sluoksniuotumas, *5* – tekėjimo ruzgų sluoksniuotumas, *6* – stambus įkypas sluoksniuotumas, *7* – lygiagrečiai įkypas sluoksniuotumas, *8* – pleištiškai įkypas sluoksniuotumas, *9* – kryžmiškai įkypas sluoksniuotumas, *10* – subhorizontalus sluoksniuotumas, *11* – sujauktos tekstūros nuogulos, *12* – žvirgždas, gargždas ir rieduliai, *13* – dirvožemis, *14* – ledo pleištų žymės, *12* – mėginių paėmimo vietos

0.52, median (Md) – 1.42 and X – 0.29, C – 0.60, Md – 1.35 mean diameter values, respectively. The sediments are well sorted, nearly of the same sorting degree as the underlying deposits. According to the mean values of maximal (C – 0.45) and mean (X – 0.22) diameters, the sediment grain size of lithofacies IV has nearly similar rates as intermediate ones of all the intertill sediment sequence studied. However, the grain size parameters show a slightly poorer sorting (Hr – 0.70, S – 0.36, S_o – 1.13) of sediments in comparison with all the sequence.

Geochemical composition. The average composition of sediment main oxides in the intertill sequence of the Dovainonys outcrop is the following: SiO_2 – 87.76%, Al_2O_3 – 3.06%, Fe_2O_3 – 0.53%, MgO – 0.62%, CaO – 3.0%, Na_2O – 0.45%, K_2O – 1.39%, Sr–239.0 ppm, Zr – 67.0 ppm and Ba – 97.0 ppm. The sandy sediments of lithofacies VI contain the lowest amount of SiO_2 (84.2%) and the highest quantities of CaO (3.4%), MgO (1.0%), Fe_2O_3 (3.8%), Al_2O_3 (3.8%), Zr (200.75 ppm), Sr (77.5 ppm) and Ba (290.2 ppm). The sediment composition of lithofacies V^c–V^a is quite similar. The average chemical composition of these lithofacies is as follows: SiO_2 – 88.76%, Al_2O_3 – 2.84%, Fe_2O_3 – 0.42%, MgO – 0.48%, CaO – 2.87%, Na_2O – 0.45%, K_2O – 1.27%, Ba–233.0 ppm, Sr – 64.7 ppm, Zr – 53.2 ppm. However, sand in lithofacies V^c contains higher amount of K_2O (1.46%), Zr (85 ppm), Ba (243.5 ppm), the lowest amount of CaO (1.9%) and the largest of SiO_2 (up to 90.1%).

Sandy sediments of lithofacies IV contain the lowest amount of SiO_2 (84.2%). The quantities of other components are: Zr – 200.75 ppm, Sr – 77.5 ppm, Ba – 290.2 ppm, CaO – 3.4%, MgO – 1.0%, whereas the amounts of Fe_2O_3 (3.8%) and Al_2O_3 (3.8%) are the highest in all the intertill sequence.

Rokai outcrop

Sediment bedding. The bed of bluish grey till of lithofacies VI at about 1.6 m above water level is covered with middle and coarse-grained sand beds of lithofacies V. The sand is trough, tabular and wedge-shaped cross-bedded and current ripple-laminated in lenses with scattered limonite pigmentation and admixture of organic matter. Lenses are up to 3 m wide and 20–50 cm thick with a dip direction of cross-bed foresets ranging from 180° to 360° (Fig. 2). The middle part of the lithofacies is composed of yellowish, greyish white fine and very fine sand. The basal horizon up to 1 m thick, composed of mixtured pebble, gravel and boulders, underlies the sand beds.

The lower part of lithofacies IV consists of a white middle-grained sand bed, current ripple-laminated

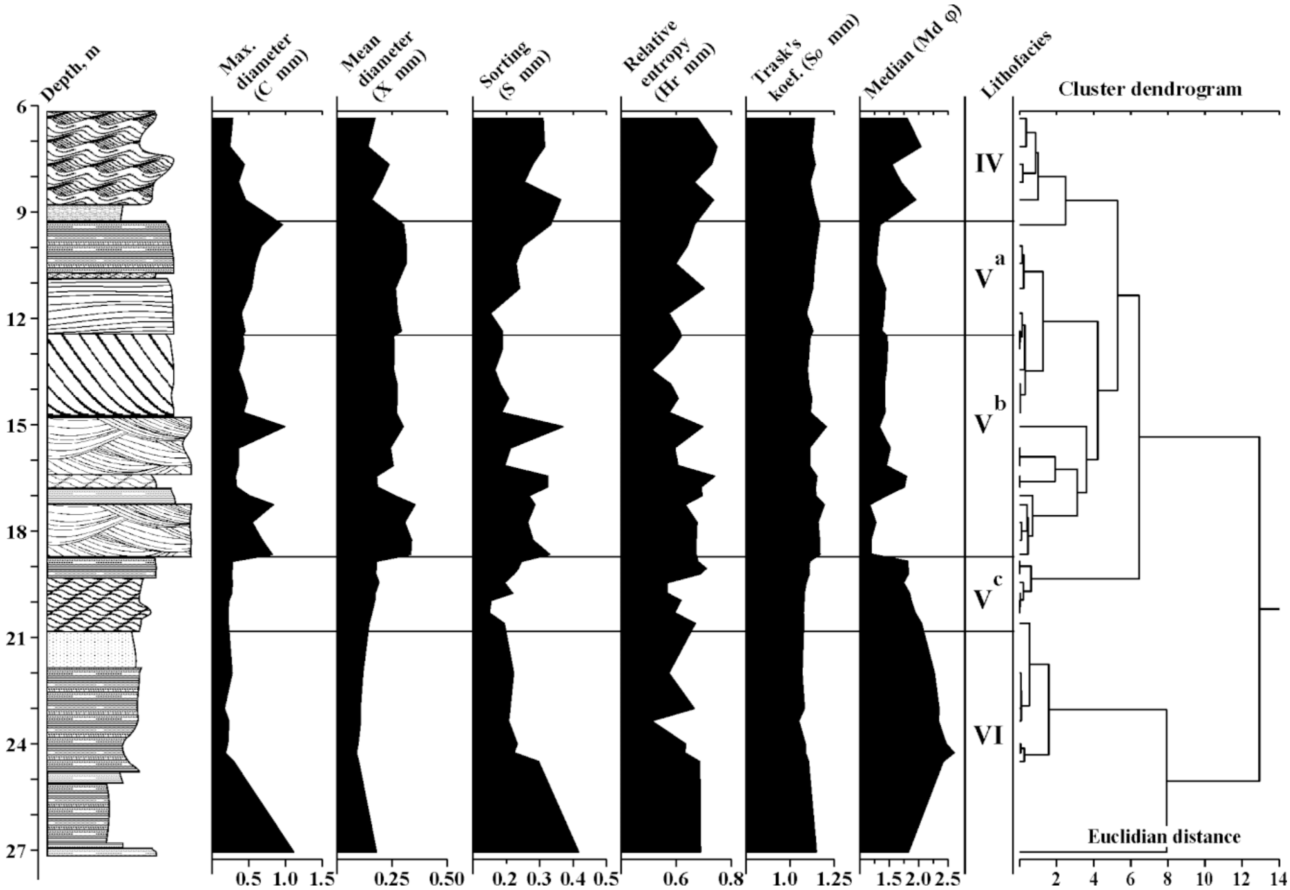

Fig. 3. Variation of grain size parameter values in sediment sequence of Dovainonys outcrop. Lithology as in Fig. 2
3 pav. Granuliometrinių parametrų kaita Dovainonių atodangos nuogulų pjūvyje. Litologiją žr. 2 pav.

with rare gravel in the lowermost part. The dip direction of ripple foresets is 340°. The upper part of the lithofacies consists of sand, wedge-shaped cross-bedded, with thin lenses of coarse sand. Cryoturbations and ice-wedge casts up to 50 cm deep are observed in the upper part of the bed.

Greyish white, yellowish brown and grey various-grained sand of massive structure occurs in the uppermost and lowermost parts of lithofacies III. Light wave ripple-laminated interbedding of various-grained sand and silty sand with lamina thickness of 1–5 cm occurs in the middle part of the lithofacies. Cryoturbations and ice-wedge casts up to 40 cm deep are observed in the upper part of the bed. The intertill deposits are overlain with yellowish grey, brown and reddish brown till beds with dark grey sub-horizontally laminated silt and fine cross-bedded sand interbeds in the upper part. The till beds are covered with subsurface bed of varved clay.

Grain size. The mean grain size parameters of the Rokai intertill sediments do not show big grain size differences. Sandy deposits in all the sequence are comparatively well-sorted (S – 0.43, Hr – 0.70, S_o – 1.17) and mostly fine-grained (C – 0.69, X – 0.23, Md – 1.62). However, the mean grain size parameters of lithofacies IV (C – 0.73, X – 0.27, Md – 1.47) represent coarse sediments.

Geochemical composition. Sediments of the Rokai outcrop contain higher average amounts of SiO_2 (up to 95%) and Zr (111 ppm) and lower amounts of Al_2O_3 (2.1%), Fe_2O_3 (0.4%), MgO (0.12%), CaO (0.34%), Na_2O (0.39%), K_2O (1.15%), Sr (45.2 ppm), Ba (217.2 ppm) (Fig. 4) in comparison with the Dovainonys intertill deposits. Sediment samples of lithofacies V contain the highest average amounts of Al_2O_3 (2.41%), Fe_2O_3 (0.46%), MgO (0.15%), CaO (0.41%), Na_2O (0.4%), Ba (235.63 ppm), Sr (48.13 ppm) and the lowest amounts of SiO_2 (94%) and Zr (103.7 ppm) in comparison with all the sequence. The composition of lithofacies IV is represented by the largest content of Zr (133 ppm) in all the outcrop. The other chemical components are presented in the same quantities as in lithofacies III containing the highest quantity of SiO_2 (up to 95.8%) and the lowest amounts of Al_2O_3 (1.8%), CaO (0.24%) and MgO (0.07%).

CONCLUDING REMARKS ON DEPOSIT SEDIMENTATION

The deposition of till occurring in the upper parts of both outcrops is related to the Last Glaciation. It is also evident that there is a possibility to correlate the intertill sequences studied, however, only in terms of the same glacial–interglacial cycle. Moreover, the differences of sediment bedding and composition imply the different environments of sedimentation of intertill deposits in the Rokai and Dovainonys sites.

The fine-grained horizontally laminated sand, silt and varved clay of lithofacies VI in the Dovainonys outcrop (Fig. 2) can be only related to lacustrine sedimentation. Furthermore, the differences in colour and grain size of varved clay laminas raise a strong initial presumption of a glaciolacustrine environment. The sediments are characterised by a rhythmical horizontal (varved) structure and by the finest grain size. This structure associates with seasonal sedimentation in a relatively deep proglacial basin (Gruszka, 2001; Winsemann et al., 2004). "Varves" as pairs of thin layers of sediments as a rule are composed of one band of sandy silt, while the second one is darker and composed of very fine clay particles. The glaciolacustrine sediments of deep palaeobasins as a rule are preserved better because of a bigger thickness of the deposit beds.

Sand of a massive and current climbing ripple-laminated structure in lithofacies V^c indicates a change of sedimentation pattern. Such structure to form

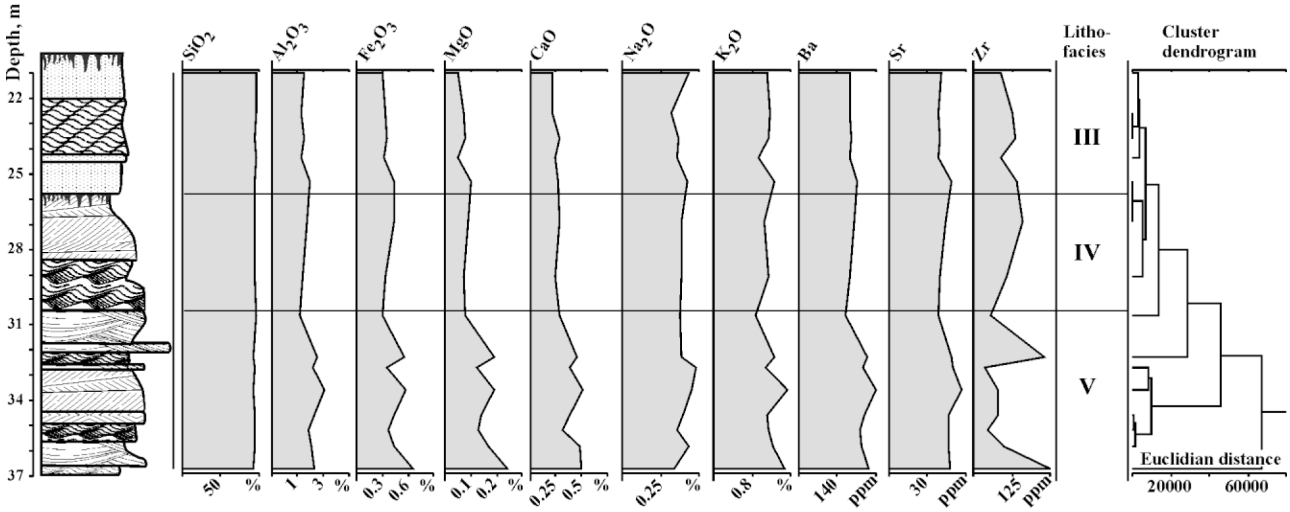

Fig. 4. Variation of geochemical composition in sediment sequence of Rokai outcrop. Lithology as in Fig. 2.
4 pav. Nuogulų geocheminės sudėties kaita Rokų atodangoje. Litologiją žr. 2 pav.

requires a higher sediment load supported by a flow of particular velocity (Brodzikowski et al., 1997). These sediments according to their structure are typical deltaic bottomsets. The presence of delta is confirmed by the following sequence of lithofacies, where lithofacies V^b, with its sediment structure expressed by large-scale planar-parallel cross-bedding, represents a subaqueous grain flow and debris avalanches in deltaic foresets causing a highly constructive progradation of the steep delta slope. Lithofacies V^b consisting of coarser sand with sub-horizontally laminated gravel represents a deltaic topset sedimentation (Deynoux et al., 2005). Deltaic sedimentation could occur in terminoglacial or proglacial subenvironments where ice meltwater streams entered a dammed small lake and a sedimentation shift from glaciolacustrine to glaciodeltaic lithofacies took place. However, such trinomial structure with developed deltaic topsets, foresets and bottomsets is more usual for large deltas formed in quite big proglacial basins.

The initial process of strong erosion is implied by fluvial type channel lag deposits represented by a mixture of pebble, gravel and boulders at the bottom of lithofacies V in the Rokai intertill sediment sequence. Trough, tabular and wedge-shaped cross-bedded and current ripple-laminated successions of lithofacies are characteristic of fluvial sedimentation (Zielinski, Gozdzik, 2001). The meandering character of the river is expressed by the occurrence of fine-grained interbeds whose thin layering is consistent with the overbank sedimentation (Gibbard, Lewin, 2002). The cryoturbations, occasionally associated with ice-wedge casts at several levels occurring in these units, point to the presence of continuous permafrost. Such lithofacies succession in the Rokai outcrop implies a nonglacial environment of fluvial sedimentation. Moreover, the nonglacial environment of sedimentation is clearly reflected by the compositional maturity of sediments.

Fluvial sedimentation in glacial and periglacial environments due to climate warming during the glacial-interglacial shift was quite intensive. During the interglacials, the surface was sheltered by vegetation, and organogenic sedimentation prevailed. However, rather thick sequences of sandy sediments seam to be related to the end of glaciation when the processes of erosion where very intensive. Sediment transport and weathering in the nonglacial environment created a sediment composition of higher maturity expressed in fining, rounding and chemical weathering of clastic material which caused an increase of quartz content in the deposits.

Results of statistical principal component analysis (PCA) display a very good positive correlation among the components CaO, MgO, Na_2O, MnO, P_2O_5, etc. (Fig. 5). Furthermore, deposits from the Dovainonys outcrop have quite a high content of components mentioned above. The content of CaO, MgO, Na_2O, MnO and P_2O_5 related to minerals less resistant to weathering was decreasing during the redeposition of sediments in the periglacial environment and continued to decrease in the nonglacial environment. In the nonglacial intertill deposits of the Rokai outcrop, the content of these components is notably reduced, with a simultaneous increase of silica. So, the geochemical composition of clastic intertill deposits can serve as a reliable indicator of a nonglacial environment of sedimentation.

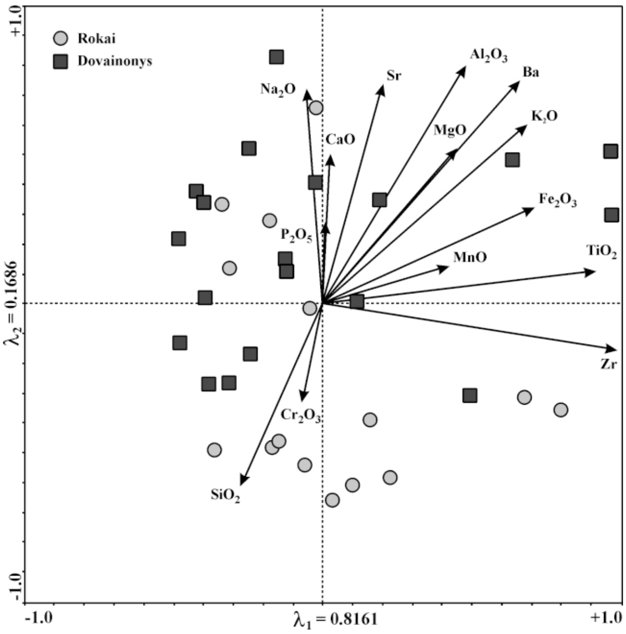

Fig. 5. Biplot of principal component analysis (PCA) carried out for deposit geochemical samples of Rokai and Dovainonys outcrops

5 pav. Rokų ir Dovainonių atodangų nuogulų geocheminės sudėties mėginių statistinės pagrindinių komponentų analizės (PCA) diagrama

CONCLUSIONS

The features of sediment bedding and composition show different environments of sedimentation of intertill deposits in the Rokai and Dovainonys outcrops. The sedimentation of intertill deposit sequence in the Dovainonys site is related to a large proglacial basin where the glacigenic delta of trinomial structure with developed deltaic topsets, foresets and bottomsets was formed. The sedimentation of intertill deposits in the Rokai sediment sequence composed of trough, tabular and wedge-shaped cross-bedded and current ripple-laminated successions of lithofacies is related to nonglacial fluvial sedimentation in the river of a meandering character. Nonglacial intertill sediments of the Rokai outcrop are notable for the lower content of such components as CaO, MgO, Na_2O, MnO, P_2O_5 and a simultaneous increase of silica in comparison with the Dovainonys proglacial sediment sequence.

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References

Baltrūnas V. 1995. Pleistoceno stratigrafija ir koreliacija. 179 p.

Baltrūnas V. 2002. Stratigraphical Subdivision and Correlation of Pleistocene Deposits in Lithuania. Vilnius: Geologijos institutas. 74 p.

Barzdžiuvienė V., Šinkūnas P., Jurgaitis A., Satkūnas J. 2000. Problems of Pleistocene Sedimentation in the Middle Neris Palaeobasin. *Litosfera*. ***4***. Vilnius. 36–45.

Blažauskas N., Jurgaitis A., Šinkūnas P. 1998a. Sedimentation of Quaternary Sandy Deposits in South Lithuania. *Litosfera*. ***2***. Vilnius. 87–100.

Blažauskas N., Jurgaitis A., Šinkūnas P. 2000. Svėdasų–Andrioniškio dubumos smėlingų nuogulų sedimentacijos sąlygos. *Litosfera*. ***4***. Vilnius. 46–53.

Blažauskas N., Kisielienė D., Stančikaitė M., Kučinskaitė V., Šeirienė V., Šinkūnas P. 1998b. Late Glacial and Holocene Sedimentary Environment in the Region of Ūla river. *Geologija*. ***25***. 20–30.

Brodzikowski K. and Van Loon A. J. 1987. A Systematic Classification of Glacial and Periglacial Environments, Facies and Deposits. *Eath-Sci. Rev*. ***24***. 297–381.

Brodzikowski K., Van Loon A. J. 1991. Glacigenic Sediments. *Developments in Sedimentology*. ***49***. Oxford: Elsevier Sci. Publ. 674 p.

Brodzikowski K., Van Loon A. J., Zielinski T. 1997. Development of a lake in a subsiding basin in front of the Saalian ice sheet (Kleszczow Graben, central Poland). *Sedimentary Geology.* ***113***. 55–80.

Deynoux M., Ciner A., Monod O., Karabiyikoglu M., Manatschal G., Tuzcu S. 2005. Facies architecture and depositional evolution of alluvial fan to fan-delta complexes in the tectonically active Miocene Koprucay Basin, Isparta Angle, Turkey. *Sedimentary Geology.* ***173***. 315–343.

Gaigalas A. 1995a. Characteristics and Genesis of Lithuanian Tills. Glacial Deposits in North-East Europe. J. Fhlers, Kozarski and P. Gibbard (Eds). Rotterdam–Brookfield: A. A. Balkema. 137–149.

Gaigalas A. 1995b. Glacial History of Lithuania. Glacial deposits in North-East Europe. J. Fhlers, Kozarski and P. Gibbard (Eds). Rotterdam–Brookfield: A. A. Balkema. 127–136.

Gaigalas A. 2000. Correlation of 14C and OSL dating of late pleistocene deposits in Lithuania. *Geochronometria*. ***19***. 7–12.

Gaigalas A. 2001. Viršutinio (vėlyvojo) pleistoceno stratigrafija ir geochronologija. *Akmens amžius Pietų Lietuvoje*. Vilnius. 14–23.

Gaigalas A., Hütt G. 1995. OSL dating of the Merkinė (Eem) Interglacial (in Jonionys) and Nemunas Glaciation (Rokai Section) in Lithuania. *PACT **50***: *Landscapes and Life*. 59–69.

Gibbard P. L., Lewin J. 2002. Climate and related controls on interglacial fluvial sedimentation in lowland Britain. *Sedimentary Geology.* ***151***. 187–210.

Grimm E. C., 1991. TILIA and TILIA GRAPH. Illinois State Museum, Springfield, USA.

Gruszka B. 2001. Climatic versus tectonic factors in the formation of the glaciolacustrine succession (Belchatow outcrop, outcrop, central Poland). *Global and Planetary Change*. ***28***. 53–71.

Jongman R. H. G., Ter Braak C. J. F., Van Tongeren O. F. R., 1995. Data Analysis in Community and Landscape Ecology. Cambridge University Press, Cambridge. 299.

Jurgaitis A., Blažauskas N., Šinkūnas P., Daunoravičius N. 2002. Ūlos upės slėnio nuosėdinės dangos. *Litosfera*. ***6***. Vilnius. 40–47.

Jurgaitis A., Juozapavičius G. 1989. Genetic Classification of Glaciofluvial Deposits and Criteria for their Recognition. Genetic Classification Of Glacigenic Deposits. Rotterdam. 227–242.

Jurgaitis A., Šinkūnas P. 2000. Quaternary Sedimentology of Lithuanian Sandy Deposits. *Quaternary International*. ***63–64***. 67.

Kazakauskas V. 2000. Kauno-Kaišiadorių limnoglacialinio baseino nuosėdų storis, paklotinis paviršius ir litofacijos. *Geologija*. ***32***. 46–56.

Kučinskaitė V. 1998. Kvartero nuogulų sedimentacijos seka Buivydžių atodangos pjūvyje. *Litosfera*. ***2***. Vilnius. 166–170.

Paškauskaitė J. 2002. Some Sedimentological Aspects of Intertill Deposits in Rokai Outcrop. *Litosfera*. ***6***. Vilnius. 123–128.

Satkūnas J., Grigienė A. 1996. The Rokai outcrop. *Correlation of stratigraphic events of Upper Pleistocene in Central and Peripheral parts of the Last Glaciation*. Vilnius. 49–51.

Šinkūnas P. 1998. Relation between the texture and composition of Quaternary deposits and their sedimentary environment. *PACT **54***: *Environmental History and Quaternary Stratigraphy of Lithuania*, 231–238.

Šinkūnas P., Barzdžiuvienė V., Jurgaitis A. 2001. Sedimentologiniai nuogulų aspektai Daumantų ir Vetygalos atodangose. *Litosfera*. ***5***. Vilnius. 67–79.

Šinkūnas P., Jurgaitis A. 1998a. Ledyninių nuogulų litologija ir sedimentacija. Vilnius: Academia. 71.

Šinkūnas P., Jurgaitis A. 1998b. Glacigeninės sedimentacijos tyrimų litogenetiniai aspektai. *Geologija*. ***23***. 99–105.

Šinkūnas P., Jurgaitis A. 1999. Kvartero darinių skaitmeninio modeliavimo problemos. Lietuvos mokslas: Geomokslai. Vilnius. 138–153.

Ter Braak C. J. F., Šmilauer P. 1998. CANOCO Reference Manual and User's Guide to Canoco for Windows: Software for Canonical Community Ordination (version 4). Microcomputer Power (Ithaca, NY USA). 352 p.

Winsemann J., Asprion U., Meyer T. 2004. Sequence analysis of early Saalian glacial lake deposits (NW Germany):

evidence of local ice margin retreat and associated calving processes. *Sedimentary Geology*. ***165***. 223–251.

Zielinski, T. and Gozdzik J. 2001. Palaeoenvironmental interpretation of a Pleistocene alluvial succession in central Poland: sedimentary facies analysis as a tool for palaeoclimatic inferences. *Boreas*. ***30***. 240–253.

Гайгалас А. 1984. К морфолитогенетической классификации гляцигенных грунтов Литвы. *Geologija*. ***5***. 88–98.

Гайгалас А. И., Арсланов Х. А., Банис Ю. Ю., Казарцева Т. И., Тертычная Т. В. 1987. Радиоуглеродные датирование позднего плейстоцена и архелогических памятников на теретории Литовской ССР. *Новые данные по геохронологии четвертичного периода*. Москва. 88–97.

Кондратене О., Ришкене М. 1983. Ледниковая флора в долине р. Еся. *Палинология в геологических исследованиях Прибалтики и Балтийского моря*. Рига. 54–57.

Малинаускас З. 1991. Строение и состав межморенных комплексов плейстоцена Литвы. Вильнюс: Мокслас. 128 с.

Рожков Г. Ф., Ипатова З. Н., Колобразов О. В., Стайсон Р. Н., 1973. Дробный ситовый гранулометрический анализ. *Литология и полезные ископаемые*. ***6***. 121–134.

Рожков Г. Ф., Куликов В. Д. 1975. Методика автоматической обработки результатов дробного ситового анализа. *Труды ВНИГРИ*. ***372***. 94–127.

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DOVAINONIŲ IR ROKŲ (CENTRINĖ LIETUVA) ATODANGŲ KLASTINIŲ TARPMORENINIŲ NUOGULŲ SEDIMENTOLOGIJA

S a n t r a u k a

Remiantis struktūros, tekstūros ir geocheminės sudėties detalios analizės Dovainonių ir Rokų atodangose rezultatais interpretuotos atsidengiančių tarpmoreninių klastinių nuogulų sedimentacijos sąlygos. Tekstūra ir geocheminė sudėtis rodo, kad vienoje ir kitoje atodangoje slūgsančių nuogulų kaupimasis vyko skirtingose aplinkose. Dovainonyse nuogulų sedimentacija yra susijusi su dideliu prieledyniniu ežeru, kuriame susidarė trinarė delta su išsivysčiusiomis apatinės, priešakinės ir viršutinės jos dalių litofacijomis. Rokuose atsidengiančių nuogulų kryžmiškai, lygiagrečiai ir pleištiškai įkypai sluoksniuotos bei tekėjimo ruzgomis išreikštos tekstūros susidarymas siejamas su sedimentacija, vykusia meandruojančios upės slėnyje neledyninėje aplinkoje. Neledyninėje aplinkoje perklostytų tarpmoreninių nuogulų geocheminė sudėtis Rokų atodangoje nuo Dovainonių atodangos prieledyninės deltos nuogulų skiriasi gerokai mažesniu CaO, MgO, Na_2O, MnO, P_2O_5 kiekiu ir atitinkamai didesniu SiO_2 kiekiu.

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СЕДИМЕНТОЛОГИЯ КЛАСТИЧЕСКИХ МЕЖМОРЕННЫХ ОТЛОЖЕНИЙ, ИЗУЧЕННЫХ В ОБНАЖЕНИЯХ ДОВАЙНОНИС И РОКАЙ В ЦЕНТРАЛЬНОЙ ЛИТВЕ

Р е з ю м е

По результатам детального анализа структуры, текстуры и геохимического состава интерпретированы условия седиментации кластических межморенных отложений, изученных в обнажениях Довайнонис и Рокай. Текстура и геохимический состав указывают на различные условия седиментации отложений в указанных обнажениях. Седиментация отложений в Довайнонис связана с присутствием приледникового озера, в котором образовалась дельта трехчленной структуры с развитыми литофациями нижней, средней и верхней ее частей. Текстура межморенных отложений в обнажении Рокай, представленная косой слоистостью различных типов и неоднородным течением, указывает на седиментацию в долине меандрирующей реки в неледниковых условиях. Геохимический состав отложений, переотложенных в неледниковых условиях, отличается пониженным количеством CaO, MgO, Na_2O, MnO, P_2O_5 и соответственно повышенным количеством SiO_2.