Formation and architecture of the Quaternary glacial succession

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Šliaupa A. Formation and architecture of the Quaternary glacial succession. *Geologija.* Vilnius. 2003. No. 44. P. 31–37. ISSN 1392-110X.

The locis of persistent deposition and consequently increased thickness are confined to the areas of persistent subsidence and uplift during the Quaternary time. The succession is statigraphically more complete within this kind of structures. The areas showing less active neotectonic vertical movements represent plains, low-relief uplifts and have played an important role in the migration of the ice sheet. These areas were subjected to intense transportation and removal of the material. Only a thin cover has been preserved, mainly accumulated during the last glaciation. The boundaries of the minimum thickness in some way mark the zones of the high gradient of the neotectonic vertical movements. It is very likely that these areas were not subjected to maximum exaration, but represent the pathways of the most intense transit of the material. The composition and architecture of the Quaternary succession are closely related to the neotectonic structures and vertical movements of the earth's crust. The block-type architecture of the Quaternary succession is ascribed to activity of the tectonic blocks. Therefore, data on the Quaternary continental glacial, melt-water, lacustrine–alluvial and other deposits are essential for reconstruction of the evolution and character of vertical movements of the earth's crust during the Quaternary, as well as of the linear and areal neotectonic structures.

Key words: formation, glacial, deposits, bedrock relief, block-type

Received 17 March 2003, accepted 2 May 2003

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INTRODUCTION

The succession of the Quaternary continental sediments dominated by glacial and melt-water deposits represents a peculiar geological body. It is characterised by specific sedimentation conditions differing greatly from the other continental deposits. Their deposition and redeposition are closely related to the ice sheet and melt-water activity and bedrock relief.

RESULT

The main features of the bedrock relief are controlled by the geological-tectonic (neotectonic) structure. The thickness, composition and architecture of the Quaternary succession often show clear differences within particular neotectonic structures (Šliaupa et al., 1987). The formation conditions of the Quaternary continental succession are an important question. Studies of the deposits and relief of the last glaciation indicate that the glacial and melt-water deposits of increased thickness (50–100 m) are confined to the highs, whereas sediments are thin (5–15 m) within the plains. They thicken to 20–25 m and more in the depressions of the relief. The anomalous thickness is mapped also in the palaeoincisions. This correlation should be taken into account when considering the formation of the whole Quaternary succession. Particular genetic ty-

pes show different conditions of the distribution. For example, limnoglacial deposits are commonly confined to the broad plains-lowlands. Outwash plain (sander) and bottom moraine are also widely distributed. The end moraine and associating meltwater deposits are related to the uplifted forms of the relief, which makes a barrier for ice sheet propagation. The recognition of the genetic relationship of the whole Quaternary succession layers provides the possibility to effectively reconstruct the palaeogeographic-palaeotectonic conditions of its formation. We state that the loci of persistent deposition and consequently increased thickness are confined to the areas of persistent subsidence and uplift during the Quaternary time (Šliaupa, 1979; Šliaupa et al., 1987). The succession is statigraphically more complete within this kind of structures. The areas showing less active neotectonic vertical movements represent plains, low-relief uplifts and played an important role in the migration of the ice sheet. These areas were subjected to intense transportation and removal of the material. Only a thin cover was preserved, mainly accumulated during the last glaciation. The boundaries of the minimum thickness in some way mark the zones of the high gradient of the neotectonic vertical movements (Šliaupa et al., 1987). It is very likely that these areas were not subjected to maximum exaration, but represent the pathways of most intense transit of the material. Undoubtedly, before each glaciation there existed a rather thick succession of glacial, melt-water and interglacial deposits compatible to the rest structures left since the preceding glaciation. These deposits were readily removed in wide smoothed areas, incorporated into that ice sheet body and redeposited in more favourable places. The bedrocks seem to have been only slightly subjected to this process. This should be taken into account while considering the level of exaration of the sub-Quaternary rocks. I think that the main exaration of the pre-Quaternary bedrocks took place under the central part of the ice sheet, whereas the main part of the Baltic Sea area, Estonia, partly Latvia and Lithuania should be referred to as a zone of active transit of the material left by the preceding ice sheet and formed during the interglacial time, essentially in the Holstein and Eemian Sea. It seems that the continental ice sheet was still able to incorporate the material. The further from the centre of the ice sheet, the less pronounced this ability became. This might explain the growing completeness of the Quaternary succession from the north to the south.

The composition and architecture of the Quaternary succession allows to reconstruct the trend of the neotectonic movements. Northern Lithuania probably represented a low topography watershed before the first glaciations. The depressed lowland was inherited from the Neogene in eastern Lithuania, where intense accumulation of the lacustrine-alluvial sediments took place during the Daumantai preglacial time. Erosional processes dominated in the western territories, an intricate hydrographic network was established on the polygenic surface of the Neogene planation. This palaeogeographic situation, in other words, the character of the substrate of the Dzūkija ice sheet, predefined the distribution of the Dzūkija–Dainava intertill or Turgeliai interglacial deposits. They are rather widely distributed in the eastern part of Lithuania (Fig. 1). According to Z. Malinauskas (Малинаускас, 1991), clayey and fine-grained sandy deposits predominate. It can be therefore concluded that the territory of eastern Lithuania was on the lower topographic level than the rest considered territories during the Dzūkija and Dzūkija–Dainava times. These rest territories are covered mainly by the Dzūkija glacial deposits. The distribution of the Dainava–Žemaitija sediments (Malinauskas, 1991) points to changes in the palaeogeographic situation. Intertill or Butėnai interglacial deposits are more widely distributed in the west of Lithuania, likely indicating a subsidence of the western territories during that time. The downwarping of the earth's surface should be related to the

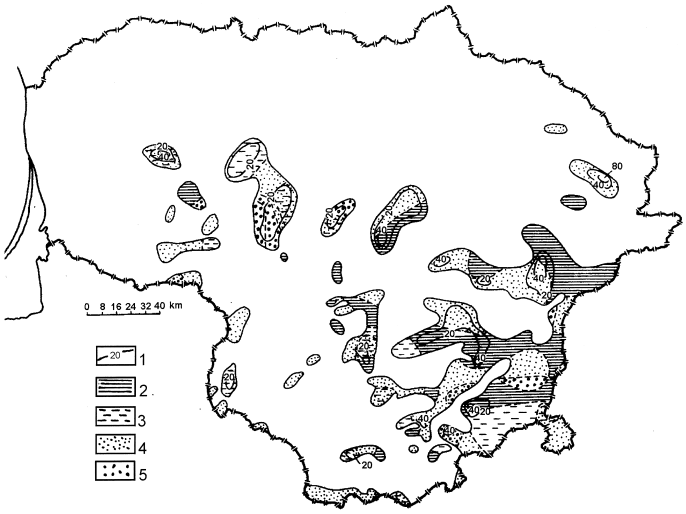

Fig. 1. Distribution, thickness and lithofacies of the Dzūkija–Dainava deposits (after Malinauskas, 1991): *1* – isopachs. Predominant composition: *2* – clay, *3* – silt-sand, *4* – sand, *5* – gravel-sand

1 pav. Dzūkijos–Dainavos nuogulų paplitimas, storiai ir litofacijų sudėtis (Малинаускас, 1991): *1* – izopachita; storymės vyraujanti sudėtis: *2* – molinga, *3* – aleuritinė – smėlinga, *4* – smėlinga, *5* – žvyringa

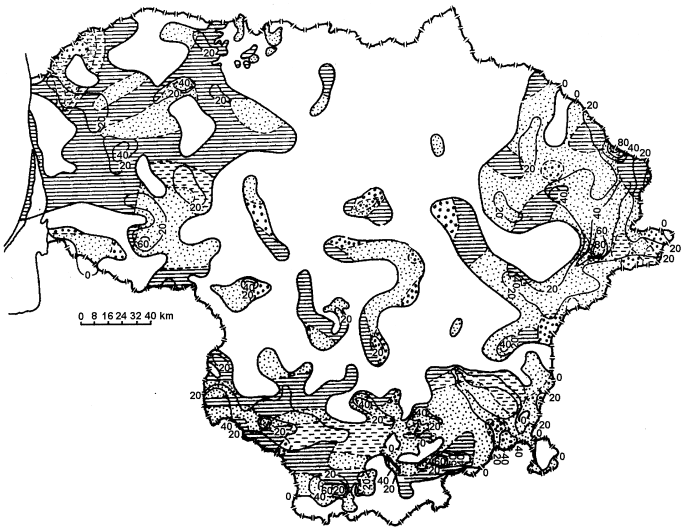

Fig. 2. Distribution, thickness and lithofacies of the Medininkai deposits (after Malinauskas, 1991). See Fig. 1 for legend
2 pav. Medininkų–Varduvos nuogulų paplitimas, storiai ir litofacijų sudėtis (Малинаускас, 1991). Sutartiniai ženklai 1 pav.

formation of the Baltic Sea depression. The subsidence continued during the Medininkai–Nemunas time, as the intertill or Merkinė interglacial deposits are more widely distributed in western Lithuania (Fig. 2). They are dominated by clayey sediments. The Nemunas intertill deposits show a similar distribution (Malinauskas, 1991), but they are dominated by sandy lithologies, which sometimes are of considerable thickness (up to 100 m). This is essentially typical of eastern and southern Lithuania, which evidences changes in the palaeogeographic conditions. It is possible that a tectonic uplift took place and provided favourable conditions for accumulation of thick melt-water sediments in the periphery of the ice sheet.

It can be concluded that the pre-glacial watershed of northern Lithuania remained stabile in terms of the absence of the intertill or interglacial deposits throughout the Quaternary time. Furthermore, this area is covered mainly by glacial deposits of the last glaciation, showing that this ancient watershed represented a zone of persistent transit of the glacial material. The advancing ice sheets removed deposits left by the preceding ice sheet. Outside the watershed the processes of accumulation of the glacial, melt-water and interglacial material prevailed, related to the active neotectonic subsidence or uplift.

The peculiar block type of the Quaternary succession is well reflected in abrupt changes of its thickness and composition. For example, a sharp change of the thickness is seen on the isopach map of the Quaternary cover of the Baltic area along the narrow Ventsipls–Kuldiga–Mažeikiai–Šiauliai–Panevėžys–Rokiškis–Stučka–Sigulda–Ciesis zone towards Pskov (Fig. 3). This zone coincides with particular segments of the Riga–Pskov, West Baltic, Mažeikiai–Vilnius and other faults. Beside the sharp changes of the Quaternary thickness, drastic changes of its composition occurred along the neotectonically active shear zones of the crystalline basement and faults of the sedimentary cover (Figs. 4–7). They are very distinct in the eastern part of Latvia (Fig. 5, 6). For example, the thickness of the Quaternary deposits is 120 m and more in the Vidzeme High, whereas they attenuate to 10–30 m in the adjacent North Vidzeme and East Latvian lowlands, where they are repre-

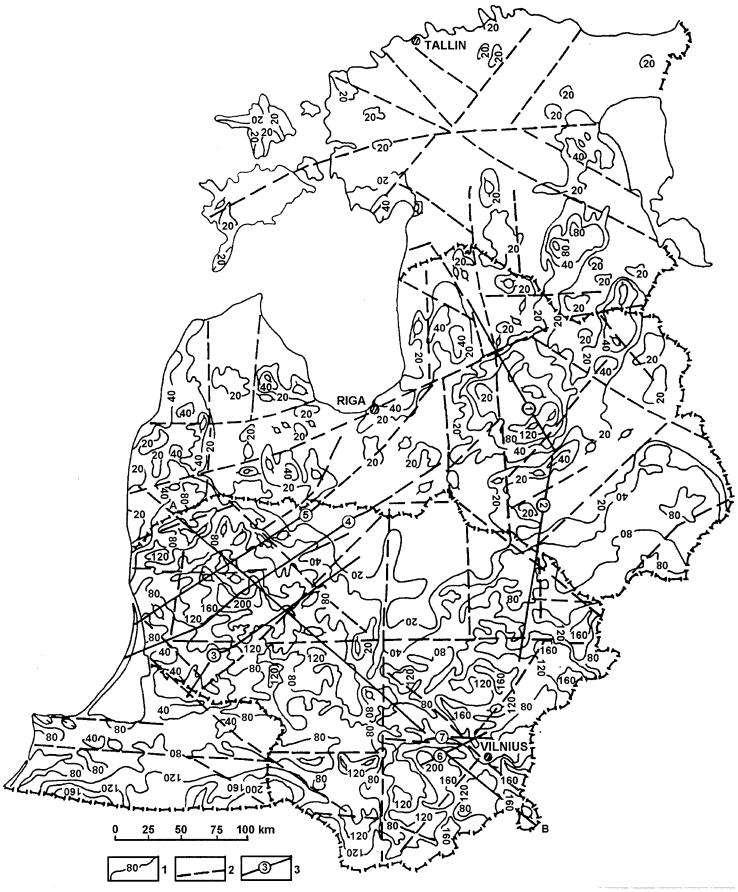

Fig. 3. Thickness of the Quaternary of the Baltic area (after Šliaupa et al., 1987): *1* – Quaternary isopachs, *2* – major faults of the crystalline basement and sedimentary cover (Puura (ed.), 1980), *3* – lines of geological cross-sections
3 pav. Pabaltijo kvartero nuogulų storių schema (Шляупа и др., 1987): *1* – kvartero nuogulų izopachita, *2* – kristalinio pamato ir nuosėdinės dangos pagrindiniai lūžiai (Пуура (ред.), 1980), *3* – geologinio profilio linija

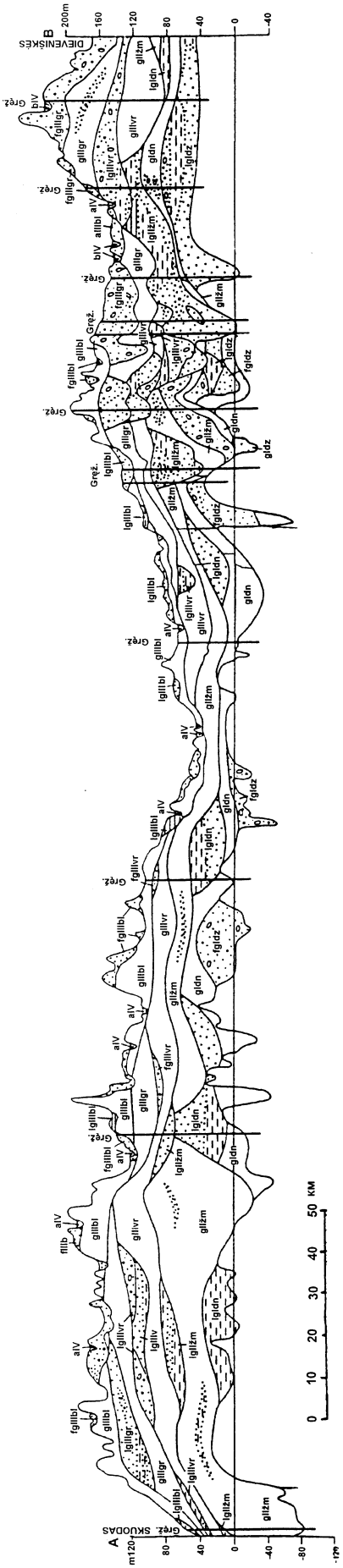

Fig. 4. Geological cross-section A–B (Geology of..., 1994)
4 pav. Geologinis profilis A–B (Lietuvos..., 1994)

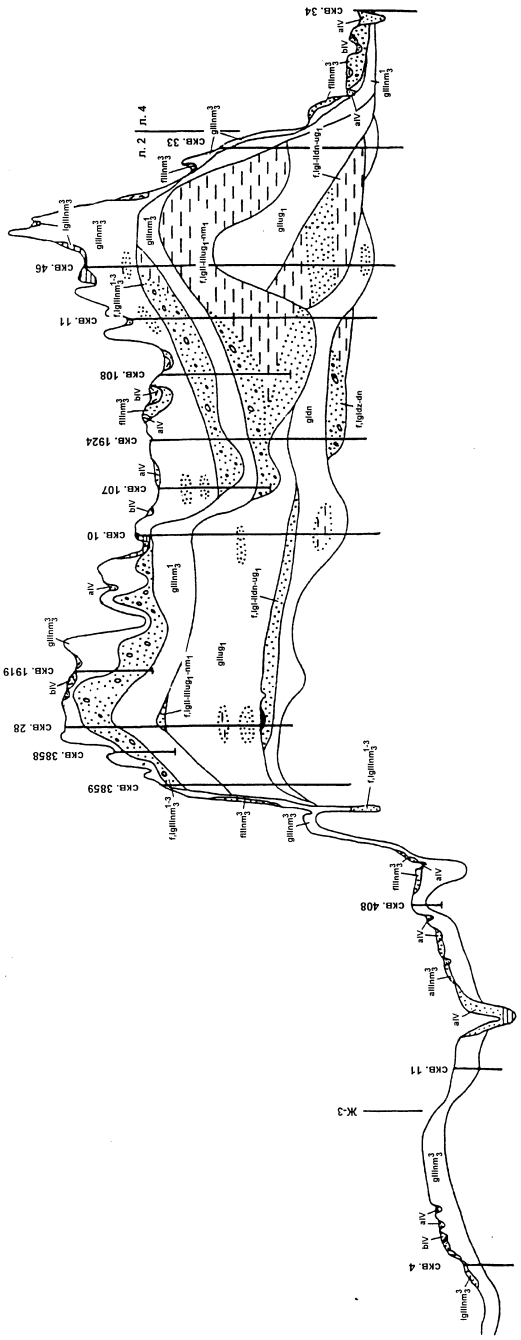

Fig. 5. Geological cross-section 1 (Vonsavičius (ed.), 1980)
5 pav. Geologinis profilis Nr. 1 (Вонсавичюс (ред.), 1980)

sented mainly by glacial sediments of the last glaciation. Quite often sharp changes in the composition are recognised that do not associate with any significant changes in the Quaternary thickness (Figs. 4, 7), such as domination of the intertill deposits suddenly giving way to till. For example, melt-water sediments prevail in eastern Lithuania, whereas glacial accumulation dominated western Lithuania (Fig. 7). These sharp lithological changes are usually confined to faults of the crystalline basement and pre-Quaternary sedimentary pile. It should be noted that these litholgical boundaries are often punctuated by pre-glacial and Quaternary palaeoincisions

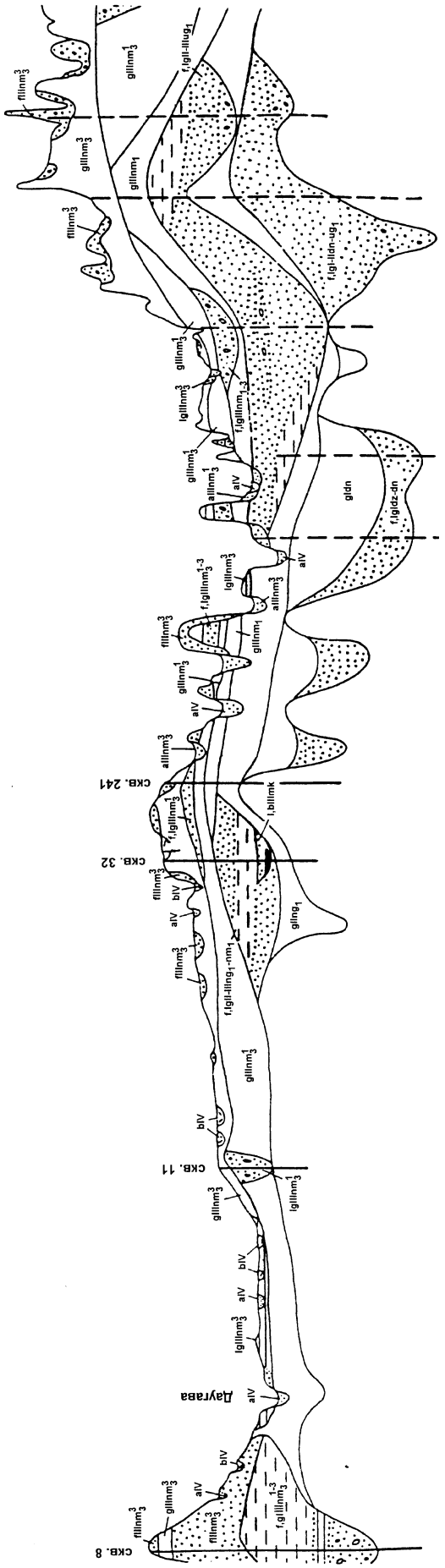

Fig.6. Geological cross-section 2 (Vonsavičius (ed.), 1980)
6 pav. Geologinis profilis Nr. 2 (Вонсавичюс (ред.), 1980)

(valleys). The block-type architecture of the Quaternary succession is distinct not only on the regional scale, but is also documented in the local areas. The Vidzeme and Baltic highs are examples of this phenomenon (Figs. 5, 6, 7).

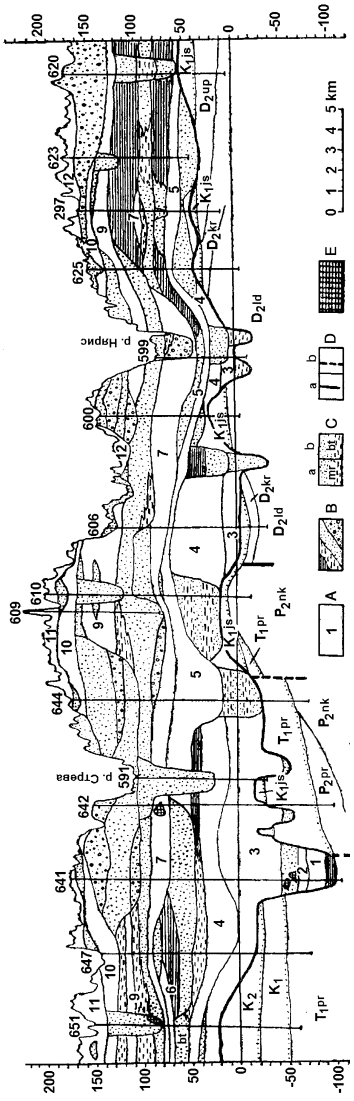

Fig. 7. Geological cross-sections 6, 7 (after Šliaupa, Bitinas, 1986). *A* – glacial deposits: *1* – Lower Dzūkija, *2* – Upper Dzūkija, *3* – Lower Dainava, *4* – Upper Dainava, *5* – Lower žeimaitija, *6* – Middle Žemaitija, *7* – Upper Žemaitija, *8* – Varduva, *9* – Daugai, *10* – Barčiai, *11* – Žiogeliai, *12* – Baltic; *B* – melt-water deposits; *C* – inter-Glacial deposits: *a* – Merkinė, *b* – Būtėnai; *D* – faults: *a* – proved and *b* – suggested; *E* – pre-Quaternary erratic blocks

7 pav. Geologiniai profiliai Nr. 6, 7 (Шляупа, Битинас, 1986): *A* – glacigeninės nuogulos: *1* – apatinės Dzūkijos, *2* – viršutinės Dzūkijos, *3* – apatinės Dainavos, *4* – viršutinės Dainavos, *5* – apatinės Žemaitijos, *6* – vidurinės Žemaitijos, *7* – viršutinės Žemaitijos, *8* – Varduvos, *9* – Daugų, *10* – Barčių, *11* – Žiogelių, *12* – Baltijos; *B* – ledynų vandens nuogulos, *C* – tarpledynmečių nuogulos: *a* – Merkinės, b – Butėnų, *D* – lūžiai: *a* – patikimi, *b* – spėjami, *E* – prekvartero uolienų luistai

Despite a complex structure of the individual layers of the Quaternary succession, clearcut differences are identified in their topographical position, which coincide with the well documented faults and structures of the crystalline basement and pre-Quaternary sedimentary cover (Fig. 7).

CONCLUSIONS

Based on the affore-described evidences, it should be concluded that the composition and architecture of the Quaternary succession is closely related to the neotectonic structures and vertical movements of the earth's crust. The block-type architecture of the Quaternary succession is ascribed to activity of the tectonic blocks. Therefore, data on the Quaternary continental glacial, melt-water, lacustrine-alluvial and other deposits are essential for reconstruction of the evolution and character of the vertical movements of the earth's crust during the Quaternary time, as well as the linear and areal neotectonic structures.

References

Lietuvos geologija. 1994. Vilnius. 448 p.

Вонсавичюс В. П. (ред.). 1980. Геологическая карта четвертичных отложений республик Советской Прибалтики. Масштаб 1:500 000. Ленинград.

Малинаускас З. 1991. Строение и состав межморенных комплексов плейстоцена Литвы. Вильнюс. 129 с.

Пуура В. А. (ред.). 1980. Геологическая карта кристаллического фундамента республик Советской Прибалтики. Масштаб 1:500 000. Ленинград.

Шляупа А. 1979. О связи рельефа и глубинных структур. Строение и рельеф Жямайтской возвышенности. Вильнюс. 5–17.

Шляупа А. И., Битинас А. Л. 1986. Тектоническая структура и строение четвертичной толщи в районе г.г. Вильнюс–Тракай–Электренай. Исследование ледниковых образований Прибалтики. Вильнюс. 104–113.

Шляупа А. И., Страуме Я. К., Каяк К. Ф. 1987. Особенности строения и развития четвертичной ледниковой формации Прибалтики. Тектоника, фации и формации запада Восточно–Европейской платформы. Минск. 193–204.

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KVARTERO LEDYNINĖS FORMACIJOS SUSIDARYMO YPATUMAI IR SANDARA

Santrauka

Kvartero žemyninių nuogulų kompleksas, kuriame vyrauja ledyniniai ir ledynų vandens dariniai, yra ypatinga formacija. Jos susidarymas siejasi su ledynų veikla ir ledyno guolio pobūdžiu. Ledyno guolio bruožus sąlygojo geologinė-tektoninė (neotektoninė) struktūra. Nustatyta, kad atskirose Pabaltijo neotektoninėse struktūrose keičiasi kvartero nuogulų storis, sudėtis bei sandara. Didesnio storio ledyninės ir ledynų vandens nuogulos kaupėsi nuolat intensyviai grimzdusiose ar kilusiose struktūrose. Tokių struktūrų kvartero nuogulų pjūviai yra pilnesni. Neotektoniškai silpnai aktyvūs rajonai sietini su lygumomis ar nedidelėmis pakilumomis, kuriomis slenkantis ledynas intensyviai nešė ar perklostė įvairaus amžiaus ir genezės nuogulas. Šias struktūras galima laikyti mineralinės medžiagos intensyvaus tranzito rajonais.

Analizuojant kvartero nuogulų storymę, nustatytas jos blokinis pobūdis, pasireiškiantis staigiais storio ar sudėties pokyčiais. Tokio staigaus pasikeitimo zonos paprastai sutampa su kristalinio pamato ar nuosėdinės dangos lūžiais. Blokinė kvartero nuogulų storymės sandara stebima tiek stambiuose regionuose, tiek ir nedideliuose plotuose. Sudėtingoje kvartero storymėje neretai galima pamatyti (geologiniuose profiliuose) atskirų horizontų staigius hipsometrinius pakitimus, kurie dažniausiai sutampa su prekvartero sluoksnių ar kristalinio pamato struktūros pokyčiais. Galima teigti, kad kvartero storymės blokinį pobūdį nulėmė žemės plutos blokiniai judėjimai. Storymės sudėtis bei sandara atskleidžia neotektoninių struktūrų formavimąsi.

Александрас Шляупа

ОСОБЕННОСТИ ОБРАЗОВАНИЯ И СТРОЕНИЯ ЧЕТВЕРТИЧНОЙ ЛЕДНИКОВОЙ ФОРМАЦИИ

Резюме

Комплекс четвертичных континентальных отложений, в составе которого преобладают ледниковые и водно-ледниковые образования, представляет собой особую формацию. Их накопление и переотложение были теснейшим образом связаны в первую очередь с ледниковой и водно-ледниковой деятельностью, а также с характером ложа ледника. Главные черты ложа ледника как рельефа земной поверхности были определены геолого-тектонической (неотектонической) структурой. На территории Прибалтики в пределах отдельных неотектонических структур изменяются мощность, состав и строение четвертичной толщи. Очагами постоянного накопления ледниковых и водно-ледниковых образований повышенной мощности являлись районы, постоянно и интенсивно погружавшиеся или поднимавшиеся за четвертичный период. В пределах таких структур имеются более полные разрезы отложений. Малоактивные в неотектоническом отношении районы представляли собой равнины, пологие поднятия и играли особую роль при продвижении ледников. В этих районах постоянно происходили более интенсивные перенос и вынос материала, т. е. они являлись зонами наиболее интенсивного транзита материала.

Анализ мощности и состава четвертичной толщи позволил выявить ее своеобразный блоковый харак-

тер, заключающийся в сравнительно резких изменениях мощности и состава толщи. Зоны резкого изменения состава толщи обычно наблюдаются в разломах кристаллического фундамента и в дочетвертичных слоях. Блоковый характер строения четвертичной толщи выявлен не только в крупных регионах, но и на небольших площадях. Несмотря на сложность залегания отдельных горизонтов четвертичной толщи, нередко в геологических разрезах просматриваются резкие изменения их гипсометрического положения, которые часто совпадают с известными линейными тектоническими нарушениями или структурами дочетвертичных слоев и кристаллического фундамента. Блоковый характер строения четвертичной толщи обусловлен блоковыми движениями земной коры. По составу и структуре этой толщи можно судить о ходе и направленности неотектонических движений.