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Estimation of geochemical profile of soil and sediments in Lithuanian terrestrial and aquatic landscapes

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The distribution of chemical elements in soils and river bottom sediments of Lithuania's landscapes is analysed from the viewpoint of their formation period and absolute heights, assuming the prevalence of elements of natural genesis. On this basis, the distribution of four macro- (Ti, Zr, P and Mn) and eight microelements (Cr, V, Zn, Cu, Ni, Pb, Co, U) has been analysed. Their content was determined in samples taken from 4 (5) upland and 5 (6) lowland geomorphological regions formed 160–130 thousand years (Ašmena Upland as the relief of the penultimate Medininkai glaciation) to 25–13 thousand years ago (all other regions with the last glaciation relief forms). The prevailing upland altitudes range from 95–100 m (50–90 m in Linkuva Hill Range) to 260–290 m, while the lowland altitudes vary from 2–35 to 70–100 m above the sea level. There are eight soil groups of Level I observed in the above-mentioned geomorphological regions: Gleysols (GL), Albeluvisols (AB), Planosols (PL), Cambisols (CM), Leptosols (LP), Luvisols (LV), Arenosols (AR), and Histosols (HS). The grain size of these soils is characterised by eight deposit types: loam, sand, gravel, sand with sandy loam, sandy loam with loam, peaty loam, peat, and clay. The data show maximum contents of the elements studied in very fine dispersed river bottom sediments (with the exception of Lake Rėkyva containing minimum quantities). Contents of Ti, P, Mn, Cr, V (partly Zn) in the soils of upland areas increase going from the oldest and highest areas to the most recent and lowest upland regions. Contents of Cu, Ni, Pb, Co and U decrease in this direction. All these facts indicate intensive exogenous processes in relief development during a period over 120 thousand years, as well as a variety of chemical element migration (state) forms and migration extent for dissolved, colloidal or very fine-dispersed matter. Variations in element content are closely related to the soil groups and grain size. The distribution of the total content of elements shows their prevailing natural origin. The decrease in their content should be related to element-containing minerals and the intensity of their later migration, as well as to a possibly lower content of these elements in the initial moraines of the Last Glaciation versus that of the penultimate glaciation.

There is an uneven distribution of elements in the soils of lowland regions formed at the end of the Late Pleistocene. The increase of their content in bottom sediments of rivers draining these lowlands is especially obvious in the rivers formed in the lowland regions 1.5–2 thousand years earlier. Such distribution is due to element migration from upland soils rich in these elements to the lowland rivers and accumulation in bottom sediments.

Contents of elements in soils of different terrestrial landscapes are comparable to (or significantly lower than) those in the deposits of various origin and bottom sediments of the Kuršių Marios (Curonian) Lagoon and the Baltic Sea. Concentrations of elements in sediments of rivers draining these landscapes are slightly higher than in the Kuršių Marios, but lower than in the very fine-dispersed (pelitic) mud of the Baltic Sea. To assess the potential technogenous impact, when in the medium under study elements of natural origin prevail, comprehensive investigations on their migration (state) forms are necessary.

Key words: soil, bottom sediments, element distribution, geomorphological upland and lowland regions, terrestrial and aquatic landscapes

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INTRODUCTION

Lithuania's surface was formed 25–13 thousand years ago by deposits of the Nemunas Glaciation Grūda and Baltija phases. Only in southeast Lithuania its formation should be related to Medininkai Glaciation which is 160–130 thousand years older.

Different soils were forming above these Quaternary deposits (glacial, glacio-fluvial, glacio-lacustrine, alluvial and organic-peaty) of different age and origin. Natural exogenous soil-formation processes (sodding, podzolisation, gleying and bogging) caused formation of different genetic soil groups, whereas their grain-size composition determined their chemical composition. During the historical period, especially in the last 50 years, these soils were to different extent affected by technogenous factors, and their composition has possibly changed. If this is true, what was the extent?

A comparison of the ratios of natural and technogenous elements is given for profiles I–I, II–II and III–III crossing Lithuania in different directions from its northern and north-western margins to the southern, eastern and south-eastern borders (Fig. 1).

To make the profiles, the median quantities of elements in mono-element geochemical field maps to the scale 1:1000 000 (Kadūnas et al., 1999) have been used. According to the maps from the atlas (Lietuvos TSR ..., 1981) and a specified model (Belickas, Dėnas, 1999) the relief of the study profiles was depicted, as well as soil types (later called Level I soil groups) and grain size data were laid down. Thus, each characteristic relief alteration in the soil and river (lake) sediments was fixed by a median content of a corresponding chemical element. The data obtained in this stage were compared to the generalised data (Kadūnas et al., 1999). Computerised digital values of the relief and element content data were joined by curves and data on the dependence of element variations on the distribution of Level I soil groups in different geomorphological (relief) regions and river (lake) bottom sediments were obtained.

The profiles show regularities in element distribution for all 11 regions of Lithuania. Eight soil groups (of 12 distinguished in Lithuania) belonging to Level I are found in the profiles. The basic diagnostic features of Lithuania's soils are as follows: continuous hard rock, gleyic properties, stagnant properties, albeluvic tonguing, abrupt textural change, but they are not discussed at lenght in the present paper.

The soils are marked only at Level I, i. e. their denotations reflect the most typical genetic and macro-morphological features. We could compare such soils to the former genetic types of soils (TDV-96). First of all, the profiles were investigated in detail in the maps enlisted in the agricultural classification of soils (TDV-96), and later the denotations were changed according to the LTDK-99 classification Level I group names. The macro-morphologic diagnostic set given in the monograph by J. Mažvila, M. Vaičys and V. V. Buivydaitė (2006) was applied, as well as a table of equivalents between the old (TDV-96) and new (LDTK-99) classifications of Lithuania's soils was compiled.

Thus, the profiles contain eight groups of Level I soils: Gleysols (GL), Albeluvisols (AB), Planosols (PL), Cambisols (CM), Leptosols (LP), Luvisols (LV), Arenosols (AR), Histosols (HS). Smaller areas of Anthrosols (AT) are distinguished in the cities and their environs as well.

The grain-size composition of these soils is characterised by eight types of deposits: loam, sand, gravel, sand with sandy loam, sandy loam with loam, peaty loam, peat, and clay.

River and lake bottom sediments are represented by aleuritic and politic silt. The distribution of four macro-elements (Ti, Zr, P, Mn) and eight microelements (Cr, V, Zn, Cu, Ni, Pb, Co and U) has been analysed within this range of soil and bottom sediment composition.

In the present paper, soil chemical composition is given according to the geoecological conception that assumes prevalence of elements of natural origin, and fixing a possible local technogenous impact. Such approach has been confirmed by generalised geochemical investigations of aquatic landscapes (Pustelnikovas, 1998; Pustelnikovas et al., 2005) and some investigations into genetic types of Lithuanian soils (Baltakis, 1993; Kadūnas, 1998; Baltrėnas, Kaušis, 2006). This principle looks rather conclusive

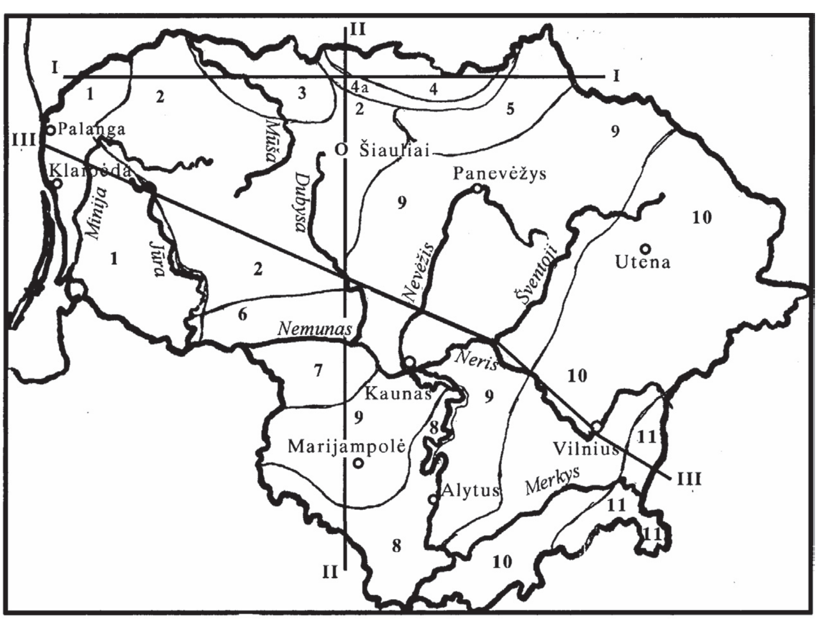

Fig. 1. Location of the investigated geochemical profiles studied.

Lines I–I, II–II, III–III – geochemical profiles of soil and river sediments of Lithuania.

Geomorphological (relief) areas: *1* – Coastal Lowland, *2* – Žemaičiai Upland, *3* – Venta Middle-Coarse Plain, *4* – Žiemgala Lowland, *4a* – Linkuva Hill-range, *5* – Mūša–Nemunėlis Lowland, *6* – Karšuva Lowland, *7* – Šešupė Lowland, *8* – Sūduva Upland, *9* – Middle Lithuanian Lowland, *10* – Aukštaičiai Upland, *11* – Ašmena Upland

1 pav. Geocheminių dirvožemio ir upių (ežero) nuosėdų profilių bei Lietuvos geomorfologinių (reljefo) rajonų schema.

I–I, II–II, III–III linijos – geocheminiai dirvožemio ir upių nuosėdų profiliai.

Paviršiaus reljefo rajonai: *1* – Pajūrio žemuma, *2* – Žemaičių aukštuma, *3* – Ventos vidurupio lyguma, *4* – Žiemgalos žemuma, *4a* – Linkuvos kalvagūbris, *5* – Mūšos-Nemunėlio žemuma, *6* – Karšuvos žemuma, *7* – Šešupės žemuma, *8* – Sūduvos aukštuma, *9* – Vidurio Lietuvos žemuma, *10* – Aukštaičių aukštuma, *11* – Ašmenos aukštuma also in a comprehensive mapping of soils (Kadūnas et al., 1999). Here, however, anomalous total quantities of elements in the urbanised landscapes are insubstantially attributed to human impact. Analogous approaches are also used in other works in the field (Radzevičius et al., 1997, 2004: Kadūnas et al., 2001). A purely bioecological approach recognizing dependence of chemical composition on human impact prevails in works related to pedology, landscape ecology, agro-biology and other fields (Pauliukevičius, 1986; Regiono ..., 1998; Šleinys, Rimšelis, 1993; Tyla, 1996; Lietuvos ..., 1998; Eidukevičienė, 2001; Eitminavičius et al., 2002). The authors of the present paper, disputing with the latter position, propose the natural approach – analysis of the quantitative and qualitative distribution of elements taking into account the age of glacial formations, variations in relief and soil types, and peculiarities of element migration.

1. CHARACTERISTICS OF RELIEF AND QUATERNARY DEPOSITS IN THE PROFILES

In order to reveal the regularities in the distribution of chemical elements, the process of relief formation, its changes and the prevailing soil groups formed under their impact should be known. These soils of different grain-size composition accumulate different chemical elements, the quantities of which reflect the probable spans of exogenous processes.

Profile I–I reflects the features of relief in the Coastal Lowland, Kuršas Upland, Venta Lowland and Žiemgala Lowland (Fig. 2). (The Coastal Lowland is described in Profile III–III.) The relief of this profile is drained by numerous rivers, including the Bartuva, Venta, Mūša and Nemunėlis.

The Kuršas Upland was formed by ice melting in Central Lithuania 14–14.5 thousand years ago (Baltrūnas, 1995; Gaigalas, 1995, 2001; Satkūnas, 1993, 1997). In Lithuania's area only the southern part of this upland, i. e. the northern slope of the Žemaičiai Upland, is situated. In the environs of Ylakiai, there is a ridge expanding along the southern margin of the upland. Southwards from this ridge, the main hills and plateaus of the Žemaičiai Upland occur. The surface of the Kuršas Upland is notable for a hilly relief with depressions and bogged morainic troughs (Guobytė, 2002). The prevailing height of the hills ranges within 120–140 m above sea level.

The Venta Lowland is notable for a flat 70–90 m high surface formed of morainic loam. In some places it is undulating, containing sandy loam covered with glaciofluvial and glaciolacustrine deposits. The latter ones are more frequent in the western part of the lowland. Single kames and eskers protrude above the flat surface of the lowland. At its eastern margin, there is the Linkuva Hill Range 10–15 m high, with its strata formed of morainic loam, sandy loam, as well as washed sand and gravel. Its age is c. 13–14 thousand years. The Venta Lowland is crossed by

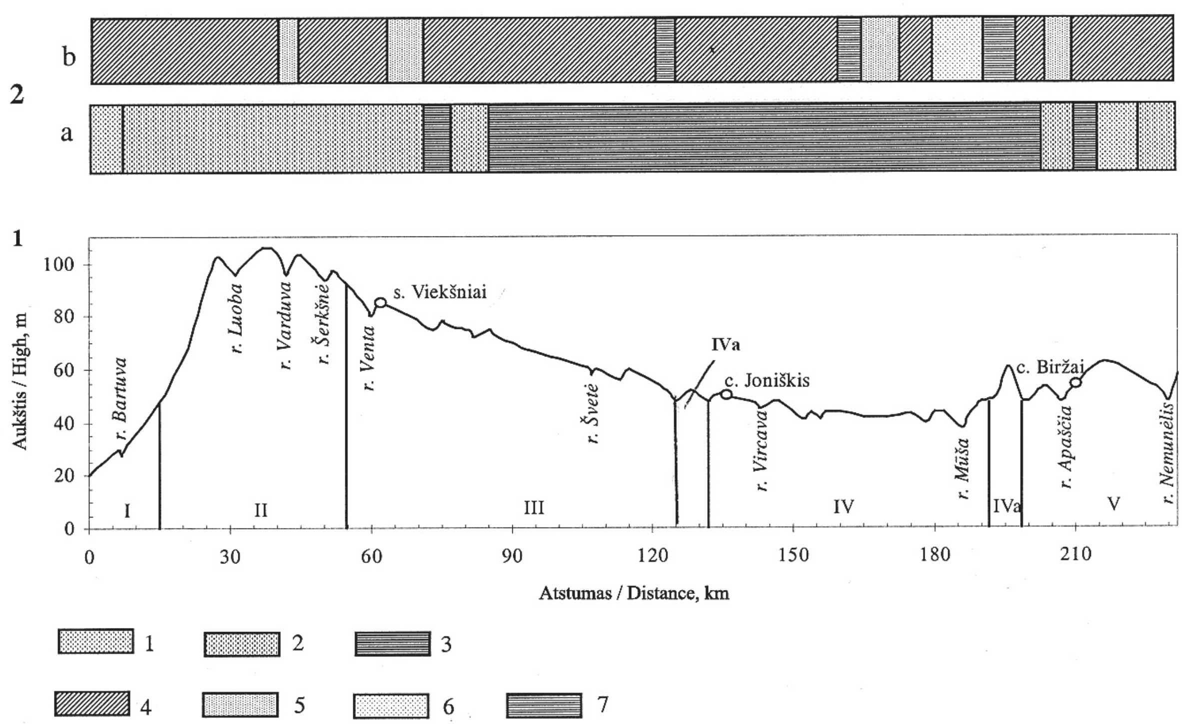

Fig. 2. Profile I–I of North Lithuanian relief from West to East (*1*) and distribution groups of soil (*2, a*) and their grain-size (*2, b*). Location of the profile see in Fig. 1. Districts of surface relief: I – Coastal Lowland; II – Žemaičiai Upland; III – Venta Middle-Coarse Plain; IV – Žiemgala Lowland; IVa – Linkuva Hill-range; V – Mūša–Nemunėlis Lowland. Groups of soil (*2, a*): *1* – Cambisols (CM), Gleysols (GL), Luvisols (LV); *2* – Gleysols (GL) and Cambisols (CM); *3* – Gleysols (GL), Cambisols (CM) and Luvisols (LV). Grain-size of soils (*2, b*): *4* – loam; *5* – sand; *6* – gravel; *7* – clay

2 pav. I–I Šiaurės Lietuvos paviršiaus profilis vakarų–rytų kryptimi (*1*), dirvožemio grupių (*2a*) bei granuliometrinės jų sudėties (*2b*) pasiskirstymas. Profilio padėtį žr. 1 pav. Paviršiaus reljefo rajonai: I – Pajūrio žemuma, II – Žemaičių aukštuma, III – Ventos vidurupio lyguma, IV – Žiemgalos žemuma, IV a – Linkuvos kalvagūbris, V – Mūšos-Nemunėlio žemuma.

Dirvožemio grupės (*2a*): *1* – rudžemiai (RD), šlynžemiai (GL), išplautžemiai (ID) ir balkšvažemiai (JI); *2* – šlynžemiai (GL) ir rudžemiai (RD); *3* – šlynžemiai (GL), rudžemiai (RD) ir išplautžemiai (ID). Granuliometrinė dirvožemių sudėtis (*2b*): *4* – priemolis, *5* – smėlis, *6* – žvyras, *7* – molis the impressive valley of the Venta River, the channel bottom of which is 46 m above sea level in the environs of Mažeikiai.

The eastern part of **the Žiemgala (Zemgale) Lowland** contains clay accumulated in the water of a large periglacial lake. The western part of its surface is covered with a layer of sandy loam. Its surface was formed at the time when the Linkuva Hill Range was forming and later when the ice shield was melting in the present area of Latvia. The valleys of the Mūša River and its tributaries add variety to its surface. Going farther from the Baltic Sea, the altitude curve in Profile I is gradually rising and reaches a 100-m height on the south-eastern slope of the Kuršas (Kursa) Upland. Then, going farther towards Joniškis, the curve is descending to c. 30 m in the Mūša River valley. From this lowest point, the curve rises again and exceeds 60 m in the environs of Biržai.

Profile II–II crosses the surface of Lithuania from north to south across the Venta and Žiemgala lowlands, as well as the East Žemaičiai Plateau, Šešupė Lowland and Sūduva Upland (Fig. 3). The rivers of Mūša, Kulpė, Dubysa, Nemunas and Šešupė are distinguished in this relief as the sedimentary matter accumulation basins.

The East Žemaičiai Plateau is a morainic plain with 15–25 m high hilly morainic ridges protruding above it. The surface of this plain lies 95–100 m above sea level. There are also some sporadic relief forms such as kames and small meltwater-formed deposit accumulations of sand and sandy loam. The NE and SW extending ridges are settled by loam and sandy loam. The Central Lithuanian Hill Range is located at the eastern margin of the plateau. The dating (Baltrūnas, 1995; Gaigalas, 2001; Satkūnas, 1993; 1997 et al.) shows their age to be c. 14–14.5 thousand years. This area of an impressive hilly morainic relief is notable for small hills and kames (Guobytė, 2002).

The Šešupė Lowland was formed in the place of a vast periglacial basin where large masses of fine-grained matter with clay admixture were settled during the melting of glaciers belonging to the South Lithuanian phase c. 15,000–16,000 BP. Its surface is flat and undulating, covered with a clay and sand layer. The height of its western and eastern parts is respectively 35–50 and 60–65 m above sea level. The sand in its eastern part is drifted by wind into dune massifs.

The surface of the plain is inclined towards **the Karšuva Lowland** where the prevailing heights are 20–40 m and 50–70 m, respectively, in its western and eastern parts. A belt of sand and pebble deposits extending westwards from Jurbarkas is typical of the lowland, its formation of being linked to the melting of an ice lobe of the South Lithuanian phase in the lower reaches of the Nemunas.

The Sūduva Upland, like other Baltic uplands, is notable for very prominent hilly zones, such as Rudamina, Seirijai and Gražiškės, the latter being the most picturesque hill range.

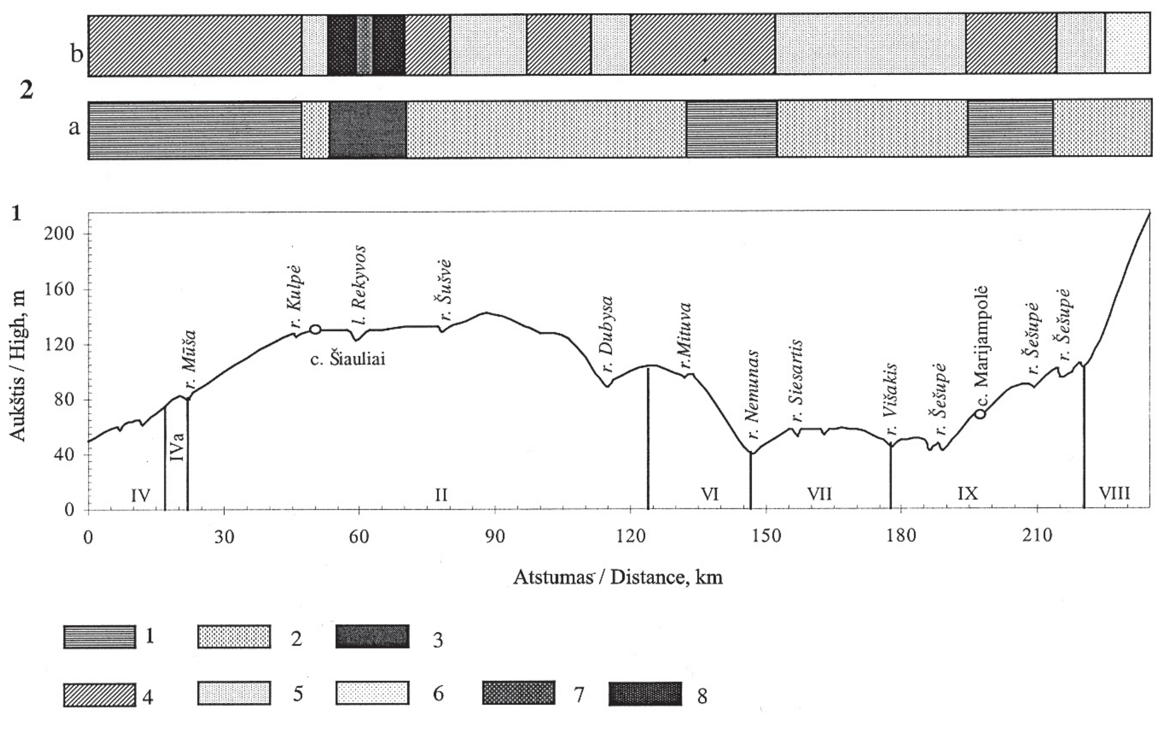

Fig. 3. Profile II–II of Lithuanian relief from North to South (*1*) and the distribution of soil groups (*2, a*) and their grain-size (*2, b*). Location of the profile see in Fig. 1. Districts of surface relief: II – Žemaičiai Upland; IVa – Linkuva Hill-range; IV – Žiemgala Lowland; VI – Karšuva Lowland; VII – Šešupė Lowland;VIII – Sūduva Upland; IX – Middle Lithuanian Lowland. Groups of soil (*2, a*): *1* – Gleysols (GL) and Cambisols (CM); *2* – Luvisols (LV), Gleysols (GL), Arenosols (AR) and Cambisols (CM); *3* – Histosols (HS). Grain-size of soils (*2, b*): *4* – loam; *5* – sand; *6* – gravel; *7* – mud of the lakes; *8* – peat

3 pav. Lietuvos paviršiaus reljefo II–II profilis šiaurės–pietų kryptimi (*1*), dirvožemio grupių (*2a*) bei granuliometrinės jų sudėties (*2b*) pasiskirstymas. Profilio padėtį žr. 1 pav. Paviršiaus reljefo rajonai: II – Žemaičių aukštuma, IVa – Linkuvos kalvagūbris, IV – Žiemgalos žemuma, VI – Karšuvos žemuma, VII – Šešupės žemuma, VIII – Sūduvos aukštuma, IX – Vidurio Lietuvos žemuma. Dirvožemio grupės (*2a*): *1* – šlynžemiai (GL) ir rudžemiai (RD); *2* – išplautžemiai (ID), šlynžemiai (GL), smėlžemiai (SD) ir rudžemiai (RD); *3* – durpžemiai (PD). Granuliometrinė dirvožemių sudėtis (*2b*): *4* – priemolis, *5* – smėlis, *6* – žvyras, *7* – ežero dumblas, *8* – durpės

The main features of the upland were formed by the glacier of the Baltic stage c. 16–17 thousand years ago. The glacier brought here and while melting left thick beds of morainic deposits reaching 200 m and 100–150 m in the Gražiškės and Rudamina hill ranges, respectively (Guobytė, 2002). The composition of the morainic matter varies greatly. Morainic loam beds with dislocations and morainic sandy loam with sand and pebble interbeddings are found here.

The highest hills in the Gražiškės reach over 260 m above sea level with abundant glaciofluvial and glaciolacustrine kames but rarer eskers. Kame terrace fragments were detected on the northern slope of the Rudamina Hill Range at 180–190 m. The lower places among the hills contain glaciolacustrine fine-grained deposits, and numerous troughs are bogged with peat beds of various thickness (Švedas, 1995).

Profile III–III, extending in the SE–NW direction, reflects all the key features of Lithuania's surface (Fig. 4). It crosses the Medininkai Upland of a more recent glaciation at the SE margin of Lithuania's area and then the Žemaičiai Upland and comes to its end in the Coastal Lowland. Therefore we describe the relief from the oldest to the youngest formations on the Baltic coast. Migration of sedimentary matter and chemical elements takes place here into many river arteries, including such rivers as Minija, Jūra, Dubysa, Nevėžis and Neris.

The main feature of **the Medininkai Upland** is its relief with abundant large hills and their high ridges extending in submeridional direction. They were formed during the Medininkai Glacial c. 130–160 thousand years ago (Satkūnas, Kondratienė, 1995). Hills in these large ridges reach 280–290 m above sea level. This is the highest hilly morainic relief in Lithuania. Based on the glacial deposits studied, a presumption can be made that this relief was formed within the marginal zone of the former glaciers. The hills were settled by various-grained sandy loam, sand, gravel, morainic loam and even fine aleurite matter. For a long time the morainic cover was affected by periglacial conditions and permafrost, therefore sandy loam prevails in the 3–5 m surface layer abundant in pseudomorphs, involutions and other traces of frost impact. The above-mentioned surface formations affect soil features and the distribution of chemical elements (Басаликас, Швядас, 1976). In this case, C_{carb} analyses showed migration of carbonates which had been carried away in some places or accumulated as new formations in other places. Variations of Fe valency forms should be mentioned as indicating the intensity of chemical processes causing reduction of some minerals. Mn, Ni, V, Cr migration with Fe compounds was found to reflect the degree of impact caused by hypergene processes on the primary rocks.

The Sudervė Hill Ridge is separated from the Dzūkai Upland by an old break-through valley of the Neris River. The prevailing

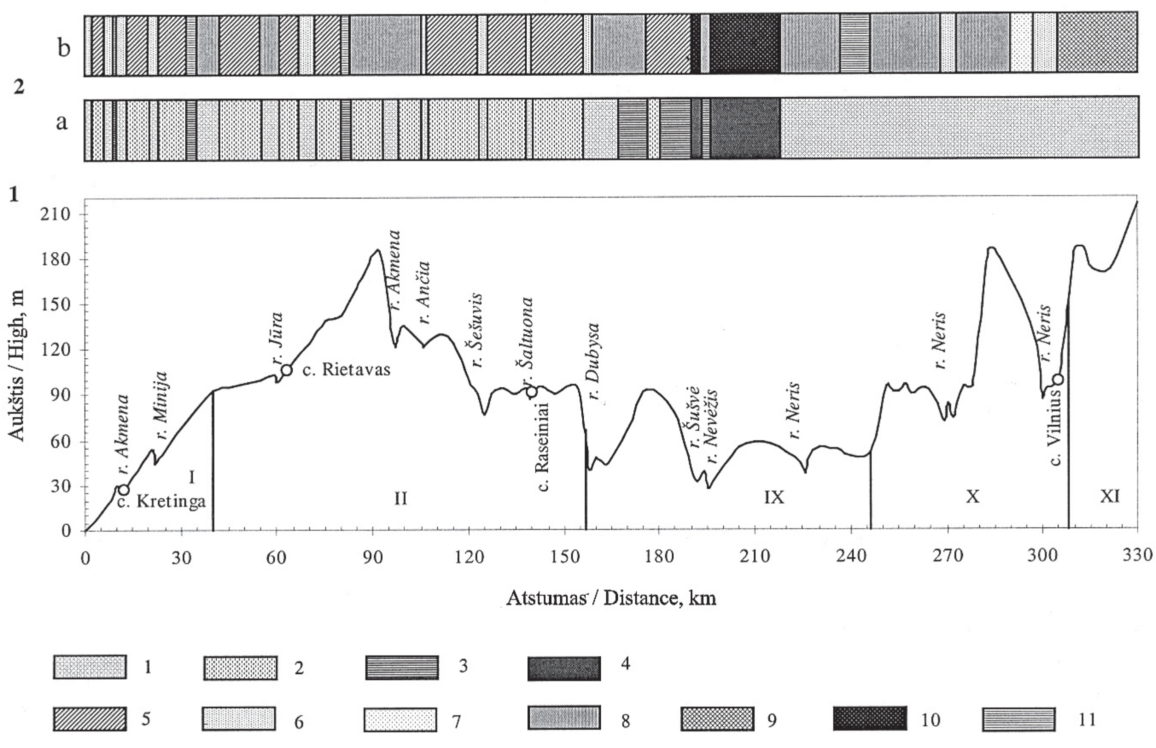

Fig. 4. Profile III–III of Lithuanian relief from Northwest to Southeast (*1*) and distribution soil groups of (*2, a*) and their grain-size (*2, b*). Location of the profile see in Fig. 1. Districts of surface relief (1): I – Coastal Lowland, II – Žemaičiai Upland, IX – Middle Lithuanian Lowland, X – Aukštaičiai Upland, XI – Ašmena Upland. Groups of soil (*2, a*): *1* – Luvisols (LV); *2* – Abbeluvisols (AB), Luvisols (LV) and Arensols (AR); *3* – Gleysols (GL); *4* – Histols (HS). Grain-size of soils (*2, b*): *5* – loam, *6* – sand, *7* – gravel, *8* – sand and sandy loam, *9* – sandy loam and loam, *10* – peaty loam, *11* – clay

4 pav. Lietuvos paviršiaus reljefo III–III profilis šiaurės vakarų–pietryčių kryptimi (*1*), dirvožemio grupių (*2a*) bei granuliometrinės jų sudėties (*2b*) pasiskirstymas. Profilio padėtį žr. 1 pav. Paviršiaus reljefo rajonai: I – Pajūrio žemuma, II – Žemaičių aukštuma, IX – Vidurio Lietuvos žemuma, X – Aukštaičių aukštuma, XI – Ašmenos aukštuma. Dirvožemio grupės (*2a*): *1* – išplautžemiai (ID); *2* – balkšvažemiai (JI), išplautžemiai (ID) ir smėlžemiai (SD); *3* – šlynžemiai (GL); *4* – durpžemiai (PD). Granuliometrinė dirvožemių sudėtis (*2b*): *5* – priemolis, *6* – smėlis; *7* – žvyras, *8* – smėlis ir priesmėlis, *9* – priesmėlis ir priemolis, *10* – durpingas priemolis, *11* – molis hill heights are 190–200 m and the thickness of glacial deposits ranges within 10–60 m. Beds of the Grūda (below) and Baltija (above) stages prevail (Guobytė, 2002). The age of the lower and the upper beds is, respectively, about 24–25 thousand and 16–17 thousand years. A 10–15 m high ridge in the Maišiagala environs is related to the limit the glaciers of the South Lithuanian phase reached. Their age is not determined, but, according to other dating, it might be about 15–16 thousand years (Baltrūnas, 1995; Gaigalas, 2001; Satkūnas, 1993).

The slopes of the Sudervė Hill Range are notable for a variety of relief forms, where, beside hills of different height, there are bogged depressions, hollows, valley outwash sites and glaciolacustrine plains.

The Neris Lower Course Plateau is a plain lying in the area of the lower reaches of the Neris and Šventoji rivers and showed off by a part of the Central Lithuanian Hill Ridge making the plateau relief diversiform. The absolute height of its lower part is 70–90 m and that of the ridge 110–125 m. Slightly swashed morainic hills in the area south of Musninkai are nicely showed off over the glacio-lacustrine plain background. The clay-rich plain has also deposits of various-grained sand and gravel. Fine aleuritic sand and clay with sand admixture occur, settled on the bottom of the former basin. The periglacial lake was formed at the time when the South Lithuanian glacier accumulated an impressive hill ridge that dammed the meltwater stream about 15.000 years ago.

The Nevėžis Lowland is located between two plateaus – West Aukštaičiai and East Žemaičiai – with the Nevėžis valley in its middle part being 24.1 m above sea level at Kėdainiai. The major part of the plain is covered by clayey and sandy deposits settled in glacio-lacustrine basins, as well as by ground moraine loam. Investigations in this area enabled to distinguish three morainic plain levels: the highest (70–80 m a.s.l.), the middle (65–70 m), and the lowest (50–65 m) (Микалаускас, 1969). The surface in its northern part has glacio-fluvial and old deltaic deposits. Its central part has the Šėta–Okainiai belt of eskers and kames. The Nevėžis Lowland was formed during a period when the Central Lithuanian phase glaciers were melting (14–14.5 thousand years ago).

The East Žemaičiai Plateau is a morainic plain with hilly massifs. Its main features had been formed 16–17 thousand years ago with prevailing heights of its surface ranging within 110–130 m a.s.l. There are also some sporadic relief forms, such as various-sized kames, morainic hills and meltwater-formed topography. Therefore, glacial deposits are varied in composition; however, sandy loam and sand prevail. The NE–SW ridges, composed of morainic loam, are showy on the plain surface.

The eastern part of the plateau contains an extension of the Central Lithuanian Hill Ridge as a belt of picturesque hills, small and medium-sized, with frequent kames.

The final stage of **the Žemaičiai Upland** started 24–25 thousand years ago when the last glaciers were retreating from Lithuania northwards. The interacting ice lobes moving from different sides formed an island-shaped upland (Kudaba, 1983) that rises over 150 m above the surrounding plains. The watershed hill massifs are located in its central part at 200–220 m a.s.l. The plateaus situated at its margins are significantly lower, and their height range in 110–130 m a.s.l.

The relief forms prevailing in **the Central Žemaičiai Hill Range** are large flat hills and kame massifs, the Šatrija, Medvėgalis and Girgždutė massifs being most impressive. The internal structure of hills is composed of morainic loam and sandy loam. Glaciofluvial kames and eskers are frequent. Steep slopes of ridges gradually turn into plateau plains. The slope descending towards Užventis is especially impressive (Kudaba, 1983).

The Tverai Hill Range is quite different. It is formed of small and medium-sized hills descending into the Rietavas Plain. The Central Žemaičiai Hill Range makes the most expressive part of the whole Žemaičiai Upland.

The West Žemaičiai Plateau is part of the Žemaičiai Upland that is cascading into the Coastal Plain and reaches the Rietavas Depression in its southern part. Its hilly surface contains morainic loam, with sandy loam prevailing. Nearby there is the Endriejavas Ridge. The western part of the plateau is hillier, and the surface layer of the hills represents the morainic matter with sandy loam.

The Coastal Lowland is a morainic plain with glacier margin formations at its surface. Such is the Coastal Morainic Ridge. The shores of the Baltic Ice Lake are marked by a swell of sand, gravel and pebble extending from Palanga towards Šventoji. Some authors think that the age of this Coastal Ridge might be related to the formation of the Linkuva Morainic Ridge, thus proposing to date its formation to about 13 thousand years B. P.

Another opinion is expressed by R. Guobytė (2002) who presented the latest data on deglaciation of Lithuania's area. Based on cosmogenic ^{10}Be dating data, she makes a conclusion that the age of Central Lithuanian and North Lithuanian morpho-glacial complexes is approximately the same: 13 520 ± 1191 and 13 641 ± 635 years, respectively.

2. DESCRIPTION OF SOIL GROUPS IN THE PROFILES

Profile I–I. Even 66%[1] of all soils are gley calcareous Cambisols (CM) and calcareous Gleysols (GL). They occur in the central and eastern parts of the profile, i. e. in the lowlands of Venta and Žiemgala (Fig. 2.2a).

Loamy and sandy loamy Albeluvisols (AB) in its western part (Venta and coastal lowlands) make 16%. Their saturation with basic compounds is different. This area contains also 9% of loamy and sandy Gleysols (GL), Albeluvisols (AB) and Luvisols (LV) which show distinct gleyic features.

The higher-lying areas in the central part of the profile (Venta and Žiemgala lowlands) show Cambisols (CM) and calcareous Gleysols (GS) with gleyic features prevailing; there are also 9% of loamy Leptosols (LP) and calcareous Cambisols (CM).

Profile II–II dissects soils of many different groups (7) which were later joined into larger soil units.

The major part (~36%) of the profile is composed of loamy and sandy loamy Gleysols (GL), Luvisols (LV) and Albeluvisols (AB) showing signs of gleying, stagnation and albeluvic tonguing of different levels. They are most abundant in the central part of the profile (East Žemaičiai Plateau) and extending southwards (towards Šešupė Lowland).

[1] Relative value according to the profile length (km).

Another group of soils (~24%) embraces loamy and clayey Cambisols (CM) and calcareous Gleysols (GL) with different signs of gleying (NE Žemaičiai Plateau and Šešupė Lowland). Higher relief areas among the above-mentioned soil groups contain also such soils (~12%) as loamy Leptosols (LP) and calcareous Cambisols (CM) with no signs of gleying. About 16% of the profile soils are made of loamy and sandy loamy Luvosols (LV) which occur in the central (Žemaičiai Plateau) and southern (Šešupė Lowland) parts of the profile. South of the Šiauliai City, Histosols (HS) occur (~7%).

Moreover, the southern part (Rudamina Hill Range) of the profile was found to contain about 4% of sandy Arenosols (AR) and about 2.5% of gleyic Arenosols (AR).

Profile III–III, being the longest of all those studied, comprises six prevailing soil groups (Fig. 4), which are joined into larger soil group units.

The major western (West Žemaičiai and East Žemaičiai plateaus) and smaller southeast (Sudervė Hill Range) parts of the profile contain well-developed loamy and sandy loamy Gleysols (GL) (~33%) of very different degree of gleying.

Albeluvisols (AB) of different erosion level alternate with Gleysols (GL) in the first half of the profile – its western part (West and East Žemaičiai plateaus and Central Lowland hills). Together with those met in the Medininkai Upland, GL make up 26%. On the both banks of the Nevėžis River (lower course area) there are loamy clayey calcareous Cambisols (CM) and calcareous Gleysols (GL) (~13%). The higher areas of the Nevėžis Lowland are observed to contain calcareous loamy Cambisols (CM) (~2.4%) without gleying signs, i. e. in the Vilnia and Vokė-Merkys lowlands. Moreover, the profile at the Dubysa River (southern outskirts of the East Žemaičiai Plateau) was found to contain 11% of loamy and sandy loamy Luvisols (LV).

3. DISTRIBUTION OF ELEMENTS IN GEOMORPHOLOGICAL PROFILES OF DIFFERENT SOIL GROUPS

The distribution of macro-elements in deposits of the profiles studied is presented in Figs. 5, 6 and 7, Tables 1, 2 and 3. The microelement contents in the sections are listed in Figs. 8, 9 and 10, and the above-mentioned tables.

The earlier works indicated rather significant changes in minimum and maximum contents of elements in different geomorphological regions of Lithuania (Kadūnas, 1998; Kadūnas et al., t., 1999) and in some profiles crossing them (Pustelnikovas, 2005). These changes are also apparent in the profiles analysed in the present work (Figs. 5–10) and are certainly related to the physical and chemical properties of soils, significant changes in relief micro-forms and their height, and to peculiarities of the hydrographic network in a geomorphological region,

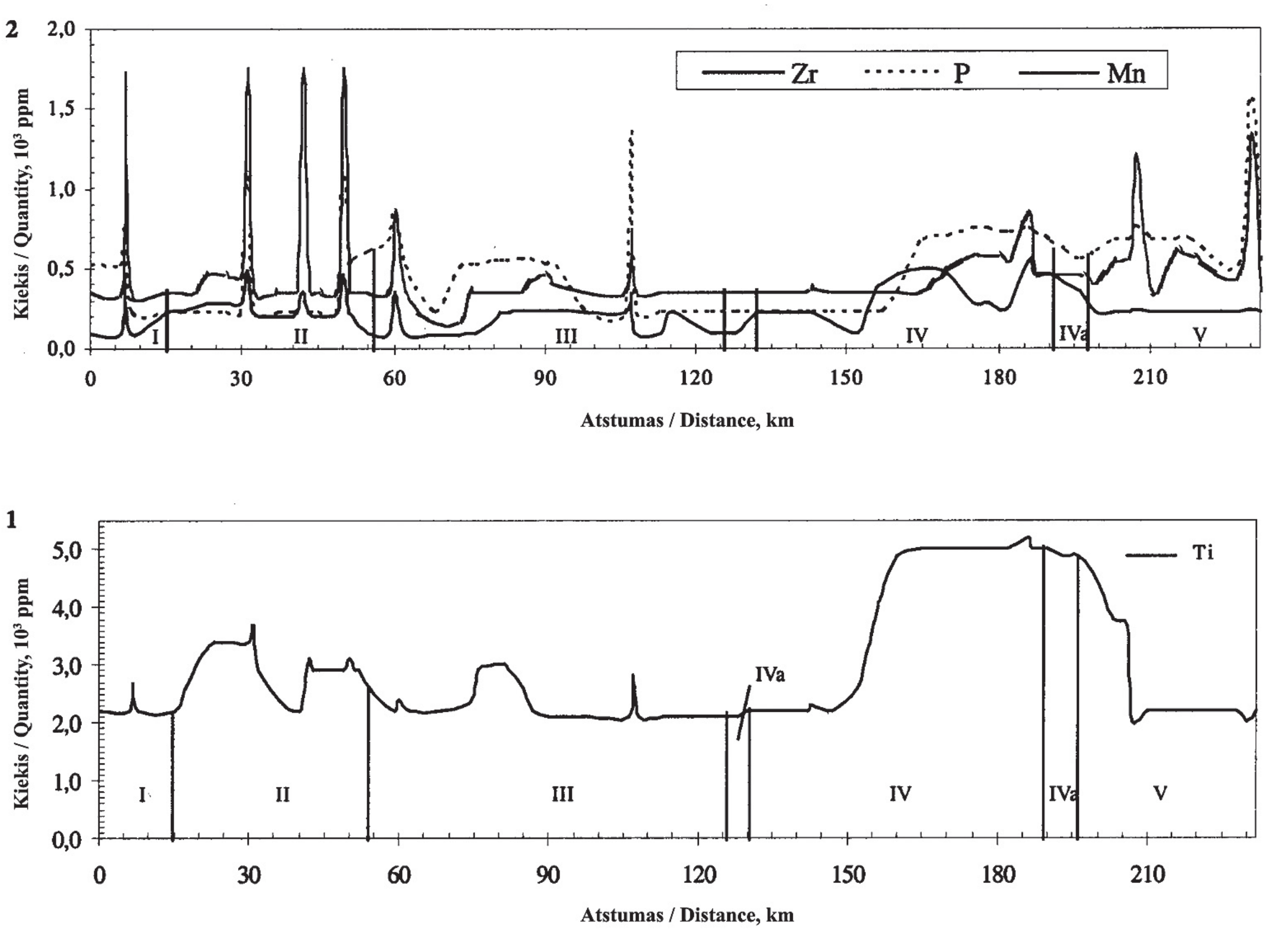

Fig. 5. Distribution of chemical elements in profile I–I. Elements, 10^3 ppm: *1* – Ti, *2* – Zr, P, Mn

5 pav. Cheminių elementų pasiskirstymas I–I profilyje. Elementai (10^3 ppm): *1* – Ti, *2* – Zr, P, Mn

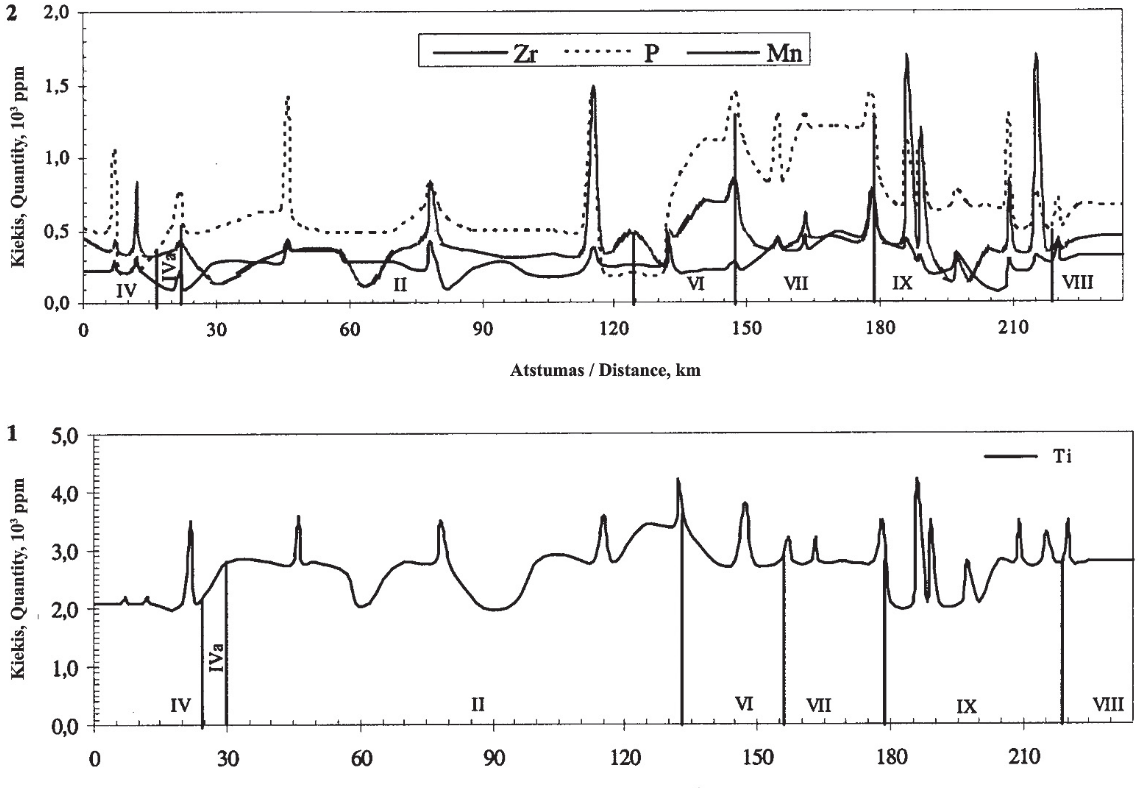

Fig. 6. Distribution of chemical elements in profile II–II. Elements, 10^3 ppm: *1* – Ti, *2* – Zr, P, Mn

6 pav. Cheminių elementų pasiskirstymas II–II profilyje. Elementai (10^3 ppm): *1* – Ti, *2* – Zr, P, Mn

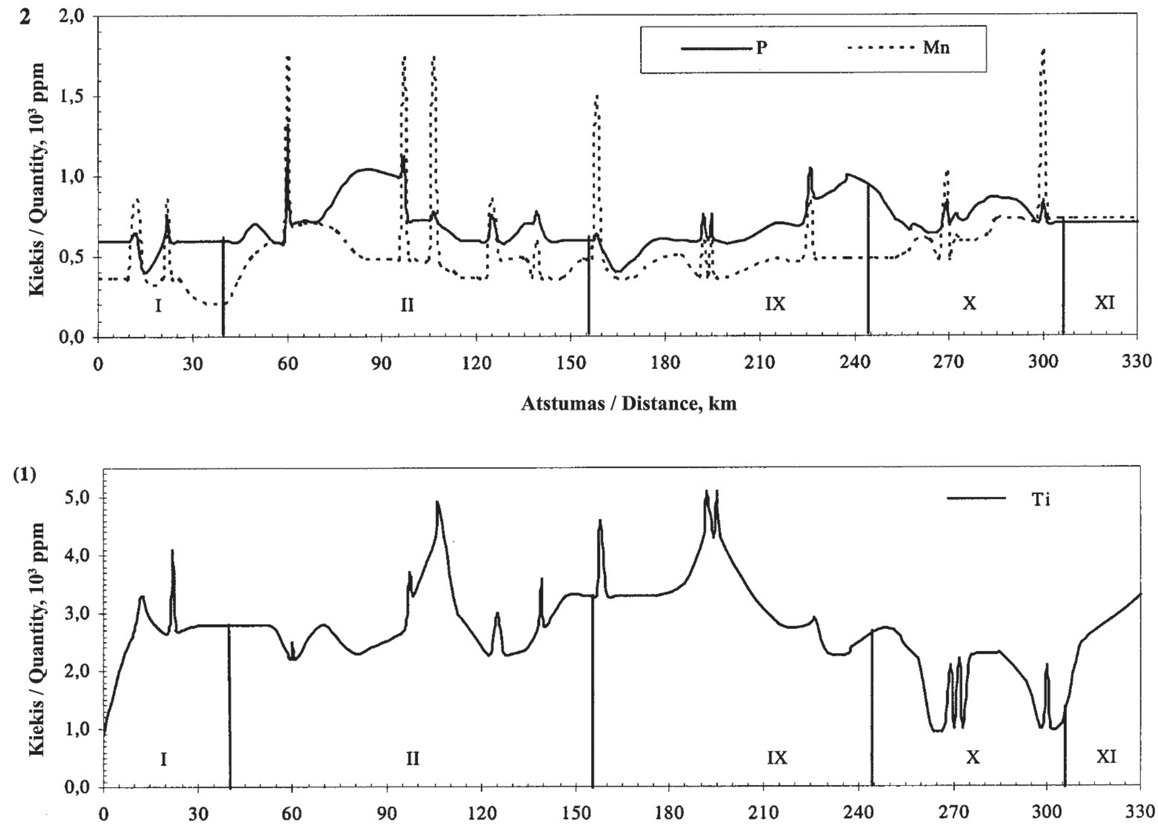

Fig. 7. Distribution of chemical elements in profile III–III. Elements, 10^3 ppm: *1* – Ti, *2* – Zr, P, Mn

7 pav. Cheminių elementų pasiskirstymas III–III profilyje. Elementai (10^3 ppm): *1* – Ti, *2* – Zr, P, Mn

Table 1. **Average content of elements in soil and river sediment profile I–I of North Lithuanian geomorphological (relief) areas**
1 lentelė. **Elementų vidurkiniai kiekiai Šiaurės Lietuvos geomorfologinių (reljefo) rajonų dirvožemiuose ir upių dugno nuosėdose (I–I profilis)**

Element	Unit	Geomorphological (relief) areas										
		Coastal Lowland		Žemaičiai Upland		Venta Middle-Course plain		Žiemgala Lowland		Linkuva Hill-Range	Mūša–Nemunėlis Lowland	
		Soils	River sediments	Soils	River sediments	Soils	River sediments	Soils	River sediments	Soils	Soils	River sediments
		I		II		III		IV		IVa	V	
Ti	10^3 ppm	2.2	2.7	2.7	2.9	2.3	2.6	4.2	3.1	4.9	2.5	2.0
Zr	10^3 ppm	0.13	0.46	0.23	0.43	0.16	0.35	0.32	0.38	0.38	0.22	0.24
P	10^3 ppm	0.37	0.76	0.31	0.82	0.40	1.11	0.52	0.47	0.58	0.63	1.16
Mn	10^3 ppm	0.36	1.74	0.38	1.75	0.35	0.80	0.44	0.60	0.46	0.49	1.26
Cr	ppm	38	58	39	51	32	52	48	52	61	31	42
V	ppm	41	56	43	55	40	40	56	61	52	26	36
Zn	ppm	28	84	27	58	29	44	43	55	44	30	58
Cu	ppm	10	14	9	13	7.5	14	10	13	7	3	9.5
Ni	ppm	18	26	15	19	14	22	22	18	16.5	9	13.5
Pb	ppm	20	20	16	20	13.5	20	18	17	22	18	24
Co	ppm	5	7	5	7	5	6	8	8.5	6.5	4	6.5
U	ppm	3.4	5	3.4	5	3.3	3.5	4.5	4.5	3.5	2.5	5

Table 2. **Average content of elements in soil and river sediment profile II–II of Central Lithuanian geomorphological (relief) areas**
2 lentelė. **Elementų vidurkiniai kiekiai Vidurio Lietuvos geomorfologinių (reljefo) rajonų dirvožemiuose ir upių dugno nuosėdose (II–II profilis)**

Element	Unit	Geomorphological (relief) areas											
		Žiemgala Lowland		Linkuva Hill-Range	Žemaičiai Upland			Karšuva Lowland		Šešupė and Central Lithuanian Lowland		Sūduva Upland	
		Soils	River sediments	Soils	Soils	Sediments		Soils	River sediments	Soils	River sediments	Soils	River sediments
						Lake	Rivers						
		IV		IVa	II			VI		VII, IX		VIII	
Ti	10^3 ppm	2.1	2.2	2.1	2.7	2.1	3.6	3.1	4.0	2.7	3.4	2.8	3.4
Zr	10^3 ppm	0.22	0.31	0.10	0.26	0.28	0.41	0.24	0.38	0.31	0.43	0.28	0.37
P	10^3 ppm	0.34	0.67	0.52	0.50	0.48	1.23	0.80	0.98	0.86	1.18	0.57	0.62
Mn	10^3 ppm	0.38	0.64	0.36	0.35	0.30	0.93	0.53	0.66	0.37	0.83	0.40	1.06
Cr	ppm	39	46	30	37	32	53	54	73	34	45	44	64
V	ppm	43	51	51	38	33	49	52	88	35	46	43	50
Zn	ppm	30	39	26	18	12	65	45	52	20	59	26	39
Cu	ppm	8	15	8	11	8	15	15	25	15	18	10	12
Ni	ppm	16	18	18	15	12	23	19	27	14	19	20	22
Pb	ppm	13	20	20	15	13	21	18	25	16	21	11	15
Co	ppm	5	6	6	5	4	7	6	7	<5	7	<5	6
U	ppm	3	3.5	3	2	2	3.5	3.5	4.5	2	3	3	6

as well as to different migration features of chemical elements (Pustelnikovas, 1998, 2005; Tyla, 1996). Their average quantities reflect general geochemical regularities in each region or in profile parts with certain soils at the relief surface and river (lake) bottom sediments.

The range of changes in the elements analysed is not extreme or exceeding maximum permissible concentrations (MPC). We found no anomalous distribution zones, although there were some cases of MPC levels reached in many upland areas, even remote from the potential point sources of human impact. There were, however, no anomalous (exceeding MPC) contents of elements in such areas within the range of our investigations. Indirectly, the fact of anthropogenous admixtures could be indicated by maximum contents of elements in fine-dispersed bottom sediments of the rivers crossing the profiles analysed, since they are 1.2–3.5 times higher than those in different soil types in all geomorphological regions, even those resembling the sediments by their grain size composition.

These ratios, differing in the relief zones, are the highest in the Aukštaičiai Upland with the Vilnius City located in it. However, we cannot state the fact of obvious human impact. River sediments are composed of fine-dispersed fractions (aleuritic and pelitic silt) where, for natural reasons, element contents are significantly higher than aleurite or sand deposits of larger grain size (Pustelnikovas, 1998). This undoubtedly depends on soil type and composition, the content of organic matter and relief genesis.

Table 3. **Average content of elements in soil and river sediment profile III–III (NW–SE) of Lithuanian geomorphological (relief) areas**
3 lentelė. **Elementų vidurkiniai kiekiai Lietuvos geomorfologinių (reljefo) rajonų dirvožemiuose ir upių dugno nuosėdose (ŠV–PR krypties III–III profilis)**

Element	Unit	Geomorphological (relief) areas								
		Coastal Lowland		Žemaičiai Upland		Central Lithuanian Lowland		Aukštaičiai Upland		Ašmena Upland
		Soils	River sediments	Soils	River sediments	Soils	River sediments	Soils	River sediments	Soils
		I		II		IX		X		XI
Ti	10^3 ppm	2.5	3.5	2.8	3.5	3.2	4.4	1.9	2.1	2.9
Zr	10^3 ppm	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.
P	10^3 ppm	0.58	0.70	0.71	0.95	0.69	0.80	0.78	0.80	0.70
Mn	10^3 ppm	0.34	0.86	0.53	1.34	0.44	0.89	0.60	1.13	0.72
Cr	ppm	33	49	41	54	48	55	32	59	37
V	ppm	39	45	47	62	50	59	32	39	38
Zn	ppm	31	78	37	59	38	61	27	77	39
Cu	ppm	7	11	10	15	12	16	7	24	9
Ni	ppm	11	19	16	24	18	23	12	23	12
Pb	ppm	18	19	17	21	14	19	16	20.5	16
Co	ppm	4	5	6	8	7	9	<4	5	<5
U	ppm	2	3	3	>4	3	3	>2	<3	>2

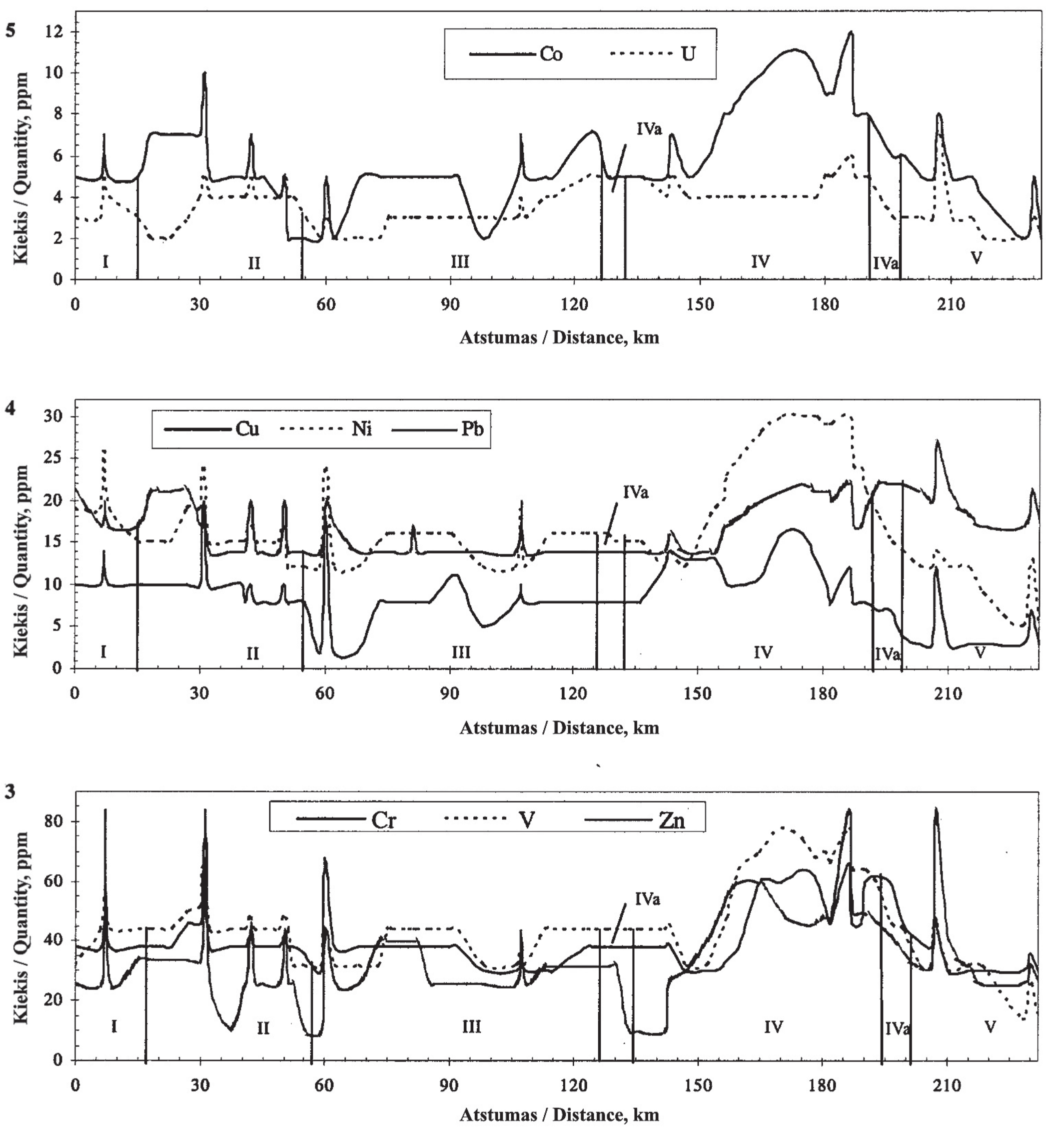

Fig. 8. Distribution of chemical elements in profile I–I. Elements, ppm: *3* – Cr, V, Zn, *4* – Cu, Ni, Pb, *5* – Co, U

8 pav. Cheminių elementų pasiskirstymas I–I profilyje. Elementai (ppm): *3* – Cr, V, Zn, *4* – Cu, Ni, Pb, *5* – Co, U

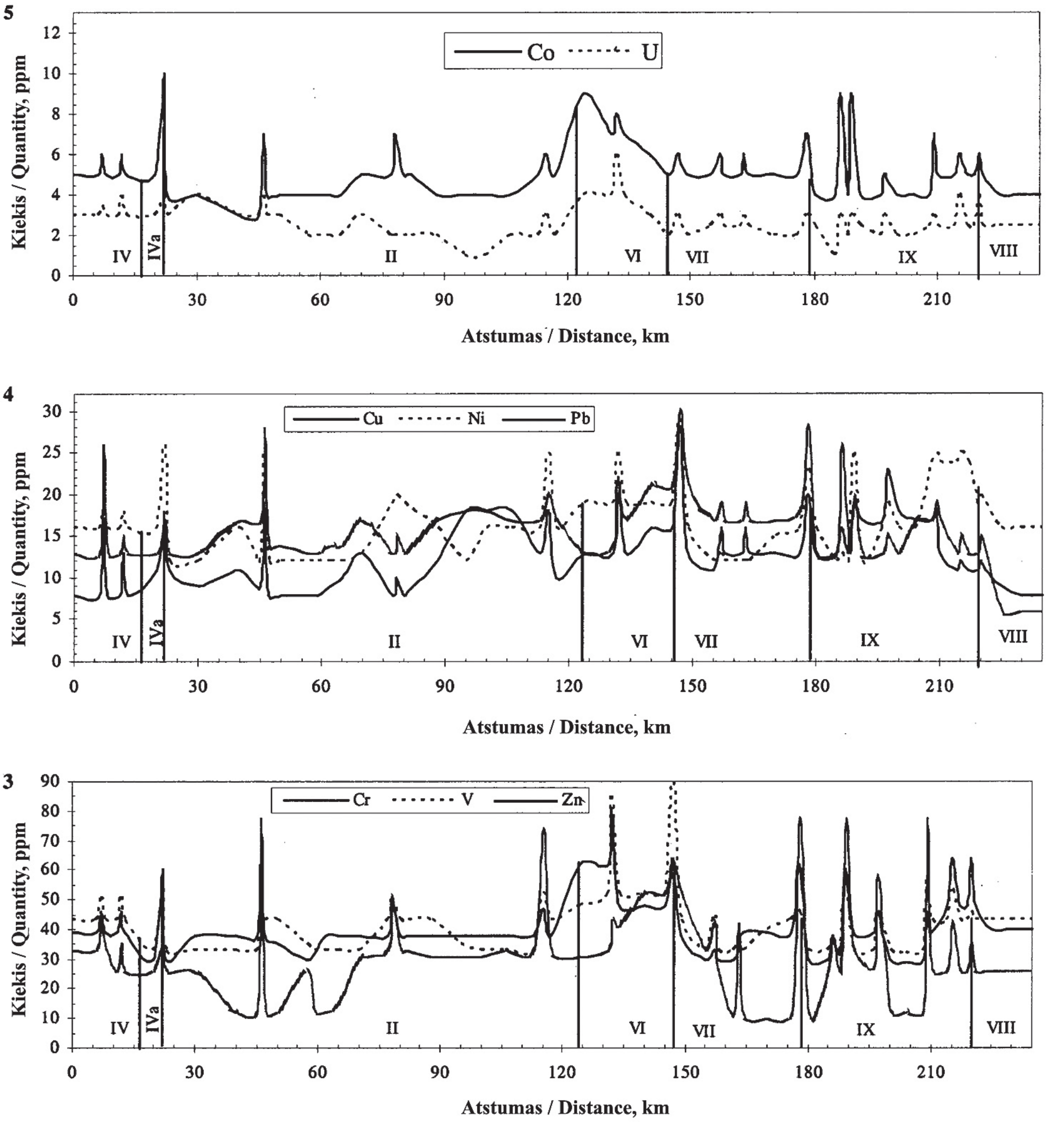

Fig. 9. Distribution of chemical elements in profile II–II. Elements, ppm: *3* – Cr, V, Zn, *4* – Cu, Ni, Pb, *5* – Co, U

9 pav. Cheminių elementų pasiskirstymas II–II profilyje. Elementai (ppm): *3* – Cr, V, Zn, *4* – Cu, Ni, Pb, *5* – Co, U

The relief-forming glacial deposits differ in composition and are differently weathered. These factors cause migration of the finest particles towards the base of hills, river valleys and their accumulation in the lowest relief places.

Analysis of element distribution in the soils for different profiles (Figs. 5–10) showed maximum or higher contents in the upland relief regions: Profiles I–I and II–II on the Linkuva Hill Range (Ti, Zr, P, Mn, Cr, V, Zn, Ni, Pb) as well as uplands of Žemaičiai Upland (Ti, Zr, Cr, V) and Sūduva (Zr, Mn, Cr, Ni). Profile III–III shows a similar pattern in the uplands of Žemaičiai and Aukštaičiai and, partly, Ašmena (Ti, P, Mn, Cr, V, Zn, Cu, Ni, Pb). In most cases, the contents of these elements in lowland geomorphological areas are lower (or even minimum) if compared to those of the upland regions, except the lowland areas of Karšuva (Ti, P, Mn, V, Zn, Cu, partly Ni and Cu) and Šešupė–Central Lithuania (Ti, Zr, P, Cr, V, Cu, Ni) as well as Žiemgala and Coastal Lowland to which, to a higher or lower extent, various element forms migrate from the upland regions. Such distribution is in most cases caused by soil grain-size composition, changes of soil types in local depressions of the glacial relief and a higher gradient of upland slopes towards the lowlands. The dependence of such distribution on the impact of nutrient factors cannot be rejected, either.

The regularities in element distribution in the bottom sediments of the rivers draining these regions are opposite to those in the soils. Maximum concentrations are observed in the rivers of their lower course geomorphological regions, where elements migrate with rain and meltwater or with wind in a dissolved or colloidal form, or within greatly fine-dispersed particles. In this case, contents of certain elements are apparently higher than in the Žiemgala, Coastal and Mūša–Nemunėlis lowlands, and partly higher in Central Lithuania (Profile I–I) as well as in the lowlands of Karšuva, Šešupė and Central Lithuania (Profiles II–II and III–III). The different geomorphological division of Žemaičiai Upland in its different parts (see Chapter 2) causes maximum or higher contents of some elements in the river bottom sediments as well as in all the three profiles analysed.

An opposite picture was observed in Lake Rėkyva (East Žemaičiai Plateau) bottom sediments where the contents of all elements were the lowest. The reason is related to local factors, such as a small gradient of morainic plain relief and limited migration of elements into the lake basin from Albeluvisols (AB)

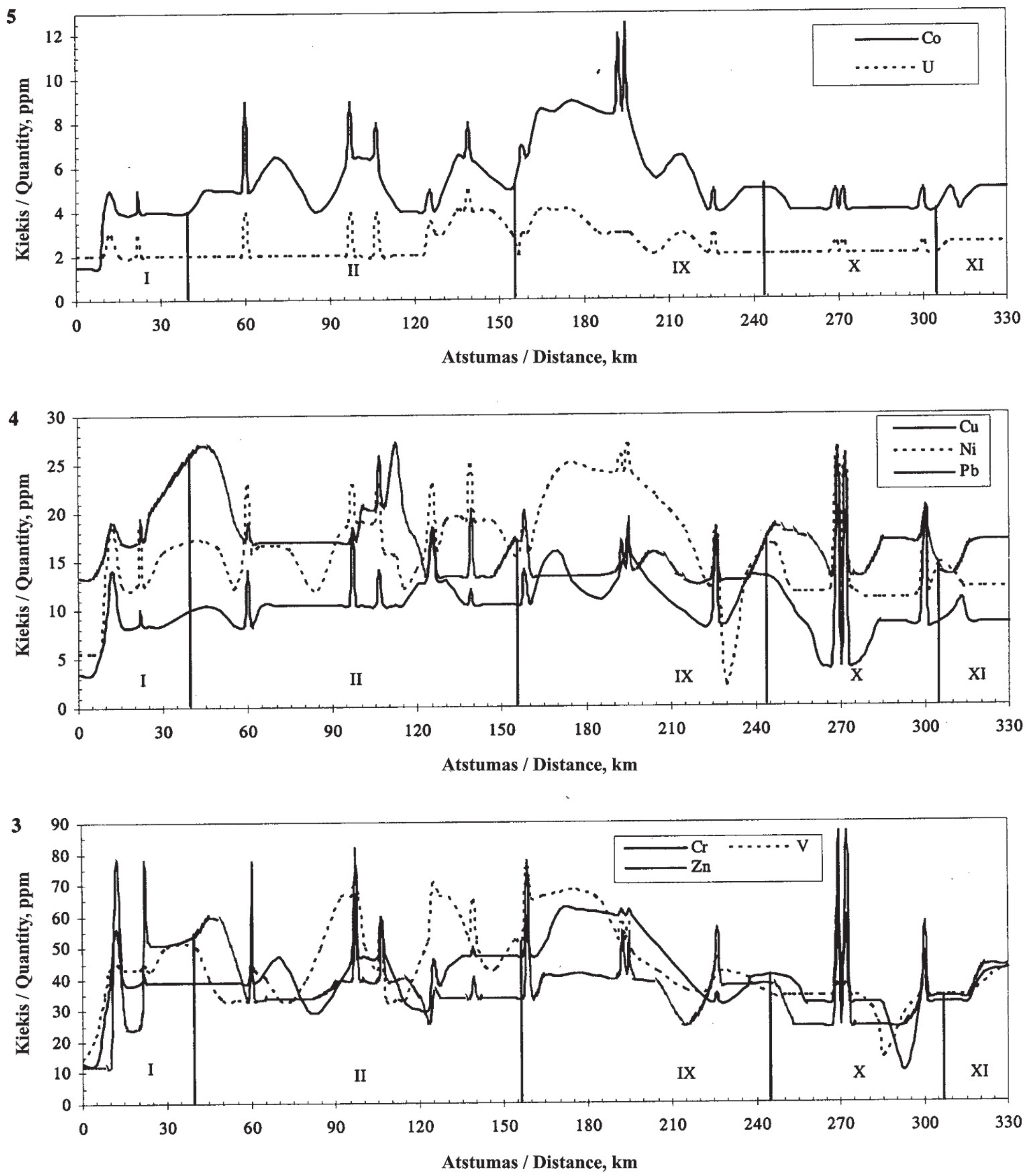

Fig. 10. Distribution of chemical elements in profile III–III. Elements, ppm: *3* – Cr, V, Zn, *4* – Cu, Ni, Pb, *5* – Co, U

10 pav. Cheminių elementų pasiskirstymas profilyje III–III. Elementai (ppm): *3* – Cr, V, Zn, *4* – Cu, Ni, Pb, *5* – Co, U

with gleying and stagnation signs. These factors do not enhance a higher inflow of elements and, hence, their higher content in bottom sediments. There again, some elements that reached the lake area in colloidal and dissolved state take part in the biological metabolism during the peat formation process.

High element contents (Mn, Cu, Ni, Pb) are observed in the rivers of the Aukštaičiai Upland (Profile III–III).

4. ASSESSMENT OF ELEMENT DISTRIBUTION IN LITHUANIA'S GEOMORPHOLOGICAL REGIONS ACCORDING TO THEIR RELATIVE AGE OF FORMATION AND PREVAILING HEIGHT OF THE RELIEF

The distribution of chemical elements in the soils and bottom sediments of different geomorphological regions of Lithuania shows the relationship of their maximum contents to the certain upland reliefs. Higher element contents in river sediments, however, are observed in the lowland or plateau areas even at their lowest concentrations in soils. The data obtained adjust and supplement previous knowledge on this subject (Pauliukevičius, 1986; Kadūnas, 1998; Pustelnikovas, 2005; Балтакис и др., 1976). An uneven quantitative and qualitative distribution of elements is observed even in the same geomorphological zone but at different heights, as well as in the upland and lowland regions of different height and formation age. Changes in the chemistry of Quaternary deposits were widely discussed in the literature (Лукашев, 1970; Балтакис и др., 1976) when the geochemical analysis methods were applied even to dating the relative age of glacial deposits (Битинас, 1991). The soils studied by us are regarded as a product that resulted from the weathering of moraines of different age, and the least steady matter in it, due to exogenous factors, is transported (migrating) as different elements and compounds in dissolved, colloidal and suspended forms to water bodies.

The composition of this matter is closely related to the character and grain-size composition of a soil group (see Chapter 2).

On the above described basis, analysis of element distribution regularities in certain geomorphological regions according

Table 4. Average content of elements in soils of Lithuanian geomorphological areas by their formation age and relief height
4 lentelė. Elementų vidurkiniai kiekiai Lietuvos geomorfologinių rajonų dirvožemiuose pagal šių rajonų santykinį formavimosi amžių ir reljefo aukštį

Geomorphological area	Relative age, thous. y.	Changes of prevailing heights, m above see level	Soil		Elements											
			Groups[2]	Grain-size[3]	Ti	Zr	P	Mn	Cr	V	Zn	Cu	Ni	Pb	Co	U
					Unit											
					10^3 ppm				ppm (10^{-4}%)							
Žiemgala Lowland	12–13	30–70	CM, GL	l, c	3.2	0.27	0.43	0.41	44	50	36	9	19	16	6.5	3.8
Coastal Lowland	13	2–35	AB	l, sl, s	2.8	0.13	0.53	0.61	44	43	53	11	19	20	5	3.2
Mūša–Nemunėlis Lowland	13–14	40–90	CM, GL	l, c	2.5	0.22	0.63	0.49	31	26	30	3	9	18	4	2.5
Venta Middle-Coarse Plain	13–14	70–100	AB, GL, CM, LV	l, sl	2.3	0.16	0.40	0.35	32	40	29	7.5	14	13.5	5	3.3
Linkuva Hill Range	13–14	50–90	CM	l,	3.5	0.24	0.55	0.41	46	52	35	8	17	21	6.3	3.3
Šešupė and Central Lithuanian Lowland	14–14.5	35–65	GL	l, sl, s	3.0	0.31	0.77	0.41	41	42	29	14	16	15	5.8	2.5
Karšuva Lowland	14–14.5	20–70	GL, CM	l, sl, c, s	3.5	0.24	0.55	0.41	46	52	35	8	17	21	6.3	3.3
Sūduva Upland	16–17	110–150 to 180–260	LV (GL, AR)	l, sl, s	2.8	0.28	0.57	0.40	44	43	26	10	20	11	4.8	3
Žemaičiai Upland (Kuršas, East and West plains)	14–14.5 to 24–25	95–220 30–70 Wp 100–135 Rp	LV, GL, AB	l, sl, s, p	2.7	0.25	0.51	0.42	42	43	27	10	15	16	5	2.8
Aukštaičiai Upland	15–17 to 24–25	130–200 (70–125) Neris plain	AB, AR, LV	l, sl, s	1.9	n.i.	0.78	0.60	32	32	27	7	12	16	3.8	1.8
Ašmena Upland (Medininkai Hill Area)	130–160	260–290 (190–210M.H.a)	AB	l, sl	2.9	n.i.	0.70	0.72	37	38	39	9	12	16	4.8	2.2

to their relative formation age and taking into account the absolute heights of targets (or their parts) influencing the element migration scale is presented in Tables 4 and 5. The data first of all show an obvious abundance of nearly all elements (even in the lowest contents of Co and U within the range 1.8–8.0 ppm) in very finely dispersed river sediments. An exception is sediments of Lake Rėkyva where element content is significantly lower than in the soils of the same region (East Žemaičiai Plateau). The high content of Ti in the lowlands of Mūša–Nemunėlis and Žiemgala is also an exceptional case.

Secondly, a varied-scaled increase of Ti, P, Mn, Cr, V and partly of Zn content is observed in the soils of upland regions of Ašmena in the following sequence: Ašmena → Aukštaičiai → Žemaičiai → Sūduva → Linkuva Hill Ridge, presented from the oldest and highest uplands to the youngest and lowest ones. However, the contents of Cu, Ni, Pb, Co and U are decreasing in this direction. Having in mind the very long period (over 120,000 years) of their formation and the intensity of the exogenous factors proceeding under the climatic conditions of subpolar or possibly early middle latitudes (late Pleistocene and Holocene), as well as migration of chemical elements within the very fine-dispersed and dissolved matter, we can state that the contents of the elements studied in the Ašmena Upland (Medininkai Hill Range) was considerably higher in the initial glacigenic matter. It was exclusively of natural origin that remains to be prevailing even now, since there are no technogenous sources in this area. The decrease in the content of the above-mentioned elements could be related to the weathering of minerals containing them and the intensity of their subsequent migration as well as to a lower content of these elements in the Last Glaciation moraines. Their distribution in river sediments of these uplands is in general analogous, i. e. the contents of major elements grow in a direction towards the younger uplands, except for Zn, Cu, Ni, and Pb, their concentrations being slightly higher in river sediments of the older and higher geomorphological regions.

In lowland regions formed at the end of the Late Pleistocene, the distribution of chemical elements is not regular, and the content of various elements in the lowlands of various age is sporadically increasing or decreasing to extreme values. As for the corresponding contents in the sediments of the rivers draining these lowlands, they

[2] Abbreviations see in the text (Chapter 2).

[3] Soil grain-size types: c – clay, l – loam, p – peat, s – sand, sl – silty loam.

Table 5. Average content of elements in river (lake) sediments of the Lithuanian geomorphological areas according to their relative formation age and relief height
5 lentelė. Elementų vidurkiniai kiekiai Lietuvos geomorfologinių rajonų upių (ežero) dugno nuosėdose pagal šių rajonų santykinį formavimosi amžių ir reljefo aukštį

Geomorphological area		Relative age, thous. y.	Changes of prevailing heights, m above see level	Soil groups[4]	Grain size of sediments[5]	Elements											
						Ti	Zr	P	Mn	Cr	V	Zn	Cu	Ni	Pb	Co	U
						Unit											
						10^3 ppm				ppm (10^{-4}%)							
Žiemgala Lowland		12–13	30–70	CM, GL	msc	2.7	0.35	0.57	0.62	49	56	47	14	18	19	7	4
Coastal Lowland		13	2–35	AB	msc	3.1	0.46	0.73	1.30	54	51	81	13	23	20	6	4
Mūša–Nemunėlis Lowland		13–14	40–90	CM, GL	msc	2.0	0.24	1.16	1.26	42	36	58	10	14	24	7	5
Venta Middle-Course Plain		13–14	70–100	AB, GL, CM, LV	msc	2.6	0.35	1.11	0.80	52	40	44	14	22	20	6	4
Šešupė and Central Lithuanian Lowland		14–14.5	35–65	GL	msc	3.9	0.43	0.99	0.86	50	53	60	17	21	20	8	3
Karšuva Lowland		14–14.5	20–70	GL, CM	msc	4.0	0.38	0.98	0.66	73	88	52	25	27	25	7	5
Sūduva Upland		16–17	110–150 to 180–260	LV (GL, AR)	msc	3.4	0.37	0.62	1.06	64	50	39	12	22	15	6	6
Žemaičiai Upland	rivers	14–25	95–220 (30–70-Wp, 100–135-Ep)	LV, GL, AB	msc	3.3	0.42	1.00	1.34	53	55	61	14	22	21	7	4
	lake				mc	2.1	0.28	0.48	0.30	32	33	12	8	12	13	4	2
Aukštaičiai Upland		15–17 to 24–25	130–200 (70–125– Neris plain)	AB, AR, LV	msc	2.1	n.i.[6]	0.80	1.13	59	39	77	24	23	21	5	3

are apparently increasing in a direction towards earlier-formed regions (Karšuva and Šešupė – Central Lithuania lowlands) (Ti, P, Mn, Cr, V, Zn, Cu, Ni, and Pb). Such distribution is related to element migration from upland geomorphological regions rich in these elements to the rivers and to their accumulation in bottom sediments.

These data are rather well comparable to those given in the monograph by Kadūnas et al. (1999), which deals with some other scientific and practical problems.

A comparison of chemical element distribution in the study areas and in the rocks and deposits of different genesis and age, as well as bottom sediments in the basin (the Curonian Lagoon and the Baltic Sea) collecting the Nemunas runoff shows that their content (Table 6) is at the same level or even lower than in the other comparable units, especially in buried soils, rotten wood or accumulated mass of sand and plankton. These contents in the most of bottom sediments of rivers draining the Lithuanian geomorphological regions are higher or the same as in the sediments of the Curonian Lagoon, but lower than in the pelitic mud of the Baltic Sea.

However, the contents of elements fixed by us do not exceed MPC and indicate the natural origin of the chemical elements occurring in reliefs of different age and height of the Lithuanian geomorphological regions. Is there any local influence of human pressure? The answer can be found only after a comprehensive research on element migration (state) forms; this has already been performed for some eastern parts of the Baltic Sea (Pustelnikovas, 1998; Pustelnikovas et al., 2005).

CONCLUSIONS

1. The distribution of chemical elements in terrestrial and aquatic landscapes of Lithuania has been analysed for the first time from the angle of their formation period and distribution of absolute heights, as well as element migration.

2. The highest contents of chemical elements were fixed in the very finely dispersed river bottom sediments.

3. Element distribution in the upland regions reflects the intensity of exogenous processes over the period of more than 120 thousand years of the relief evolution, as well as the variety in forms of chemical element state and the extent of their migration within the dissolved, colloidal or suspended matter.

4. Changes in element contents depend on soil groups and grain-size composition. Their decrease reflects deceleration in the weathering of minerals and the subsequent migration intensity.

5. The uneven distribution of elements in the soils of lowland regions and an increase of their content in river sediments of the regions formed 1.5–2 thousand years earlier is indicative of element migration from the upland regions rich in these elements.

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4 Abbreviations see in the text (Chapter 2).

5 Msc – mud silty clayey, mc – mud clayey.

6 n. i. – not investigated.

Table 6. **Comparison of elements in Neogene, Quaternary deposits and recent sediments of the Curonian Lagoon (by Pustelnikovas, 1998)**
6 lentelė. **Cheminių elementų kiekio neogeno, kvartero ir dabartinėse Kuršių marių dugno nuosėdose palyginimas (pagal Pustelnikovas, 1998)**

Deposits	Elements (average contents)									
	10^3 ppm			ppm						
	Ti	Zr	Mn	Cr	V	Zn	Cu	Ni	Pb	Co
Neogene sand of Sambia			0.08	48		14	6	17	n.i.	8
Holocene peat			0.30	34		36	17	17	n.i.	5
Sand lagoonal, piled up			0.20	46		13	13	20	n.i.	4
Sand of beach (seaside of the Curonian Spit)			0.21	44		14	8	14	<9	8
Sand of beach (lagoon side)			0.20	41		9	7	14	n.i.	6
Sand of beach (Vistula Spit, lagoon side)			0.15	54		35	19	25	<9	14
Loam morainic of Klaipėda Strait			0.30	57		52	16	n.i.	16	21
Buried soil of Vistula Spit			1.48	140		172	40	70	n.i.	32
Decayed tree (age >120 y.)			0.80	264		780	760	286	n.i.	28
Sandy-plankton mixture (Curonian Lagoon side)			7.60	142		88	24	28	80	40
Recent sediments (layer 0–5 cm) of the Curonian Lagoon	1.04	0.17	0.43	49	26	52	17	29	n.i.	2
Recent clayey mud of the Baltic Sea			2.00			109	33	31		6–20
Sedimentary rock (clay)			0.85			95	45	68	20	19
Sedimentary carbonaceous			1.10			20	4	20	9	n.i.
Magmatic rocks (granites)			0.60			60	20	8	20	5

6. The content of elements in soils of terrestrial landscapes of Lithuania are at the same level as those in the deposits of various genesis as well as in sediments of the Curonian Lagoon and the Baltic Sea.

7. The content of the elements in aquatic (river) landscapes are higher than in the Curonian Lagoon, but lower than in the very fine-dispersed (pelitic) mud of the Baltic Sea.

8. To assess the technogenous impact in the prevalence of elements of natural origin, a comprehensive research of their migration (state) forms should be carried out.

References

1. Baltakis V. 1993. Foniniai mikroelementų pasiskirstymai ir jų tarpusavio ryšiai Lietuvos dirvožemiuose. *Geologija*. ***15***. 32–42.
2. Baltrūnas V. 1995. Pleistoceno stratigrafija ir koreliacija. Vilnius. 178 p.
3. Bednarek R., Prusinkiewicz Z. 1990. Geografia gleb. Warszawa: PWN. 14–17.
4. Belickas J., Dėnas Ž. 1999. Skaitmeninės kartografijos duomenų posistemės kūrimas. *Lietuvos Geologijos Tarnybos 1998 m. veiklos rezultatai*. 71–72.
5. Baltrėnas P., Vaišis V. 2006. Research into soil contamination by heavy metals in the northern part of the Klaipėda city, Lithuania. *Geologija*. ***55***. 1–8.
6. Eidukevičienė M. 2001. Lietuvos vieta Europos glacigeninėje srityje. *Lietuvos dirvožemiai*. Vilnius: Lietuvos mokslas. 15–18.
7. Eitminavičius L., Mažvila J., Račinskas A. 2002. Dirvožemių, susiformavusių ant paskutiniojo ir priešpaskutiniojo kontinentinio apledėjimo ledynų nuogulų, agrocheminės savybės. *Geologija*. ***37***. 20–30.
8. Gaigalas A. 1995. Glacial history of Lithuania. *Glacial deposits in North-East Europe*. Rotterdam. 127–137.
9. Gaigalas A. 2001. Viršutinio (vėlyvojo) pleistoceno stratigrafija ir geochronologija. *Akmens amžius Pietų Lietuvoje*. Vilnius. 7–24.
10. Guobytė R. 1998. The relief of Eastern Lithuania as interpreted from aerial photographs. *Environmental History and Quaternary Stratigraphy of Lithuania*. PACT ***54***. Belgium, Rixensart. 239–249.
11. Guobytė R. 2002. Lietuvos paviršiaus geologijos ir geomorfologijos ypatumai bei deglaciacijos eiga. Vilnius. 143 p.
12. Kadūnas V. 1998. Gamtinės geocheminės anomalijos Lietuvos dirvožemiuose. *Geologija*. ***26***. 27–37.
13. Kadūnas V., Budavičius R., Gregorauskienė V., Katinas V., Kliaugienė E., Radzevičius A., Taraškevičius R. 1999. Lietuvos geocheminis atlasas. Vilnius.
14. Kadūnas V., Budavičius R., Katinas V., Kliaugienė E., Radzevičius A., Zinkutė R. 2001. Mažeikių rajono geocheminis atlasas. Vilnius–Mažeikiai.
15. Kudaba Č. 1983. Lietuvos aukštumos. Vilnius. 186 p.
16. Lietuvos TSR atlasas. 1981. Maskva.
17. Lietuvos dirvožemių agrocheminės savybės ir jų kaita. 1998. Kaunas.
18. Mažvila J., Vaičys M., Buivydaitė V. 2006. Lietuvos dirvožemių makromorfologinė diagnostika. Dotnuva-Akademija.
19. Pauliukevičius G. 1986. Cheminių elementų kiekiai landšafte. Vilnius.
20. Pustelnikovas O. 1998. Geochemistry of sediments of the Curonian Lagoon (Baltic Sea). Vilnius.
21. Pustelnikovas O., Dembska G., Radke B., Bolalek J. 2005. Sedymentacja i rozmieszczenie pierwiastków chemicznych w portach poludniowego Baltyku (w Klajpedzie i w Gdańsku). *Geologia i geomorfologia Pobrzeźa i Poludniowego Bałtyku*. ***6***. Slupsk. 67–88.
22. Pustelnikovas O. 2005. Zmienność występowania wybranych pierwiastków śladowych w glebach i osadach fluwialnych na Litwie. *Geologia i geomorfologia pobrzeźa i poludniowego Baltyku*. ***6***. Slupsk. 337–347.

23. Radzevičius A., Budavičius R., Kadūnas V., Katinas V., Tverkutė Z., Zinkutė R. 1997. Panevėžio miesto geocheminis atlasas. Vilnius–Panevėžys.
24. Radzevičius A., Gregorauskienė V., Kadūnas V., Putys P. 2004. Panevėžio apskrities geocheminis atlasas. Vilnius–Panevėžys.
25. Regiono ekologinis tvarumas istoriniame kontekste. 1998. Vilnius.
26. Satkūnas J., Kondratienė O. 1995. Quaternary Stratigraphy Scheme of Lithuania for National Geological Mapping. XIV International Congress / *INQUA. Berlin, August 3–10, 1995. Abstracts*. 239.
27. Satkūnas J. 1997. Outline of Quaternary stratigraphy of Lithuania. The late Pleistocene in Eastern Europe: stratigraphy, paleoenvironment and climate. *Abstract volume and Excursion Guide of the INQUA–SEQS symposium*. Vilnius. 65–68.
28. Šleinys R., Rimšelis J. 1993. Sunkiųjų metalų kiekis ir aktyvumas Rytų Lietuvos dirvožemiuose. *Žemėtvarka ir melioracija*. ***1–2***. 64–70.
29. Tyla A. 1996. Cheminių medžiagų migracija įvairiuose Lietuvos dirvožemiuose. *Žemdirbystė*. ***50***. 65–75.
30. Švedas K. 1995. Vištyčio aukštumos šiaurinės dalies geomorfologiniai bruožai. *Geomorfologija*. Straipsnių rinkinys. Vilnius. 68–84.
31. Балтакис В., Балтрунас В., Гайгалас А. 1976. Геохимическая характеристика морен. *Тр. ЛитНИГИ. Вып. 31*. Вильнюс. 50–56.
32. Басаликас А., Швядас К. 1976. Комплексы рельефа древнеперигляциальной области (Мядининкская возвышенность и Эйшишкское плато). *Geographia Lithuanica*. Вильнюс. 15–20.
33. Битинас А. 1991. Применение геохимических методов исследований для определения относительного возраста плейстоценовых морен. *Геохронологические и изотопно-геохимические исследования в четвертичной геологии и археологии*. Вильнюс. 93–102.
34. Лукашев В. К. 1970. Геохимия четвертичного литогенеза. Минск: Наука и техника.
35. Микалаускас А., Бяцонис М., Микутене Л. 1969. Морфология, строение и генезис рельефа Средне-Литовской низменности. *Труды АН Лит. ССР. Сер. Б*, т. *2*. 231–241.
36. Саткунас И. 1993. Стратиграфия и литологический состав средненямунской (средневалдайской) подсвиты по данным картирования Вильнясско-Нерисской гляциодепрессии. *Четвертичные отлоения и новейшая тектоника ледниновых областей Восточной Еврлпы. Апатиты*. 39–48.

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DIRVOŽEMIO IR DUGNO NUOSĖDŲ GEOCHEMINIO PROFILIO ĮVERTINIMAS SAUSUMOS IR AKVALINIUOSE LIETUVOS KRAŠTOVAIZDŽIUOSE

S a n t r a u k a

Cheminių elementų pasiskirstymas įvairių Lietuvos kraštovaizdžių dirvožemiuose bei upių dugno nuosėdose nagrinėjamas atsižvelgiant į jų formavimosi periodą, absoliučius aukščius ir laikantis vyraujančios elementų gamtinės genezės prielaidos.

Šiuo pagrindu išanalizuotas keturių makro- (Ti, Zr, P ir Mn) bei aštuonių mikro- (Cr, V, Zn, Cu, Ni, Pb, Co, U) elementų pasiskirstymas. Jų kiekiai tiriamose terpėse įvertinti 5 aukštumų bei 6 žemumų geomorfologiniuose rajonuose, kurių susiformavimo amžius kinta nuo 160–130 tūkst. (Ašmenos aukštuma – priešpaskutinio Medininkų apledėjimo reljefo forma) iki 25–13 tūkst. metų (visi kiti rajonai – paskutinio apledėjimo formos). Vyraujantys aukštumų rajonų aukščiai yra nuo 95–100 (Linkuvos kalvagūbryje – 50–90) iki 260–290 m, žemumų – nuo 2–35 iki 70–100 m virš jūros lygio.

Minėtuose geomorfologiniuose rajonuose paplitusios aštuonios I lygio dirvožemių grupės: šlynžemiai (GL), balkšvažemiai (JS), palvažemiai (PL), rudžemiai (RD), kalkžemiai (KD), išplautžemiai (I D), smėlžemiai (SD) ir durpžemiai (PD). Šių dirvožemių granuliometrinę sudėtį nusako šie nuogulų tipai: priemolis, smėlis, žvyras, smėlis su priesmėliu, priesmėlis su priemoliu, durpingas priemolis ir molis.

Pateikiami duomenys rodo maksimalius tiriamų elementų kiekius itin smulkiadispersinėse upių dugno nuosėdose (išimtis – Rėkyvos ežeras, kurio dugne jie minimalūs).

Ti, P, Mn, Cr, V (iš dalies Zn) kiekiai aukštumų rajonų dirvožemyje didėja nuo seniausių ir aukščiausių link jauniausių ir žemiausių aukštumų rajonų. Cu, Ni, Pb, Co ir U kiekiai šia kryptimi mažėja. Tai rodo egzogeninių procesų intensyvumą, cheminių elementų migracijos (būsenos) formų įvairovę ir jų migracijos mastą ištirpusioje, koloidinėje ar itin smulkiadispersinėje medžiagoje per trumpesnę nei 120 tūkst. metų reljefo raidą. Elementų kiekio kaita neatsiejama nuo dirvožemio grupių bei granuliometrinės jų sudėties. Bendro tirtų elementų kiekio pasiskirstymas rodo akivaizdžiai vyraujančią gamtinę jų prigimtį. Jo mažėjimas sietinas su elementus turinčių mineralų ir vėlesnės jų migracijos intensyvumu bei galimai mažesniu šių elementų kiekiu pirminėse paskutinio apledėjimo morenose palyginus su priešpaskutiniuoju.

Elementų pasiskirstymas vėlyvojo pleistoceno pabaigoje susiformavusių žemumų rajonų dirvožemiuose yra netolygus. Jų kiekio didėjimas šias žemumas drenuojančių upių nuosėdose yra ypač akivaizdus prieš 1,5–2 tūkst. metų susiformavusių žemumų rajonų upėse. Tokį pasiskirstymą lemia elementų migracija iš aukštumų rajonų dirvožemių į žemumų upes ir jų kaupimasis dugno nuosėdose.

Elementų kiekiai įvairių Lietuvos sausumos kraštovaizdžių dirvožemyje yra beveik tokie patys (ar kur kas mažesni) kaip ir įvairiagenetinėse uolienose, Kuršių marių ir Baltijos jūros dugno nuosėdose. Šiuos kraštovaizdžius drenuojančių upių nuosėdose elementų koncentracijos yra truputį didesnės nei Kuršių marių, bet mažesnės nei Baltijos jūros itin smulkiadispersiniame (pelitiniame) dumble.

Kai tiriamose terpėse vyrauja gamtinės prigimties elementai galimam technogeniniam poveikiui įvertinti būtini išsamūs jų migracijos (būsenos) formų tyrimai.

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ОЦЕНКА ГЕОХИМИЧЕСКОГО РАЗРЕЗА ПОЧВ И ДОННЫХ ОСАДКОВ НАЗЕМНЫХ И ВОДНЫХ ЛАНДШАФТОВ ЛИТВЫ

Р е з ю м е

Распределение химических элементов в почвах и донных осадках рек рассматривается с позиции оценки периода формирования и абсолютных высот различных ландшафтов Литвы, предполагая преобладание элементов природного генезиса.

На этом основании было изучено распределение 4 макро- (Ti, Zr, P и Mn) и 8 микроэлементов (Cr, Zn, Cu, Ni, Pb, Co, U). Их содержания в исследуемых средах были оценены в 4 (5) геоморфологических районах возвышенностей и в 5 (6) районах низин,

период образования которых изменяется в пределах от 160–130 тыс. лет (Ашмянская возвышенность – форма рельефа предпоследнего Мядининкайского оледенения) до 25–13 тыс. лет (все остальные районы – формы последнего оледенения). Преобладающие высоты районов возвышенностей находятся в пределах 95–100 (Линкувский кряж – 50–90 м) – 260–290 м, районов низин – 2–35 – 70–100 м над уровнем моря.

В пределах вышеупомянутых геоморфологических районов распространены 8 групп почв I уровня (терминология на английском языке): Gleysols (GL), Albeluvisols (AB), Planosols (PL), Cambisols (CM), Leptosols (LP), Luvisols (LV), Arenosols (AR) и Histosols (HS). Гранулометрический состав этих почв характеризуют 8 типов отложений: суглинок, песок, гравий, песок с супесью, супесь с суглинком, суглинок торфяной, торф и глина.

Представленные данные указывают на максимальные содержания исследуемых элементов в тонкодисперсных донных осадках рек (исключение – оз. Рекивос, в осадках которого содержания элементов минимальные).

В районах возвышенностей содержание Ti, P, Mn, Cr, V (частично Zn) в почвах увеличивается от наиболее старых и высоких в направлении наиболее молодых и низких районов возвышенностей. В этом же направлении содержания Cu, Ni, Pb, Co и U уменьшаются. Это указывает на интенсивность экзогенных процессов на протяжении более 120 тыс. лет истории развития рельефа, на разнообразие форм нахождения химических элементов и на масштабы их миграции в составе материала в растворенной, коллоидальной либо тонкодисперсной формах. Изменения содержаний элементов неразрывно связаны с группами почв и гранулометрическим их составом. Распределение общего содержания элементов свидетельствует об очевидном преобладании природного их генезиса. Уменьшение содержания обуславливается выветриванием содержащих элементы минералов и интенсивностью последующей их миграции, а также возможно более низким содержанием этих элементов в первичных моренах последнего оледенения по сравнению с предпоследним.

Распределения элементов в почвах районов низин, образовавшихся в конце позднего плейстоцена, неравномерны. Увеличение их содержания в донных осадках рек, дренирующих эти низины, особенно очевидное в реках районов, образовавшихся на 1,5–2 тыс. лет ранее остальных. Такое распределение определяется миграцией элементов из обогощенных ими почв районов возвышенностей в реки низинных районов и накоплением их в донных осадках.

Содержание элементов в почвах различных земных ландшафтов Литвы находится на уровне (либо значительно ниже) их содержания в разногенетических породах, а также в донных осадках Куршского залива и Балтийского моря. Концентрации же элементов в донных осадках рек, дренирующих эти ландшафты, незначительно более высокие, чем в осадках залива, но более низкие, чем в тонкодисперсных (пелитовых) илах моря.

Для оценки возможного техногенного влияния на исследуемые среды при преобладании в них элементов природного генезиса необходимы исчерпывающие исследования форм миграции (нахождения) химических элементов.