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Morphotectonic implication of the Paleoproterozoic Mid-Lithuanian Suture Zone

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The Paleoproterozoic Mid-Lithuanian Suture Zone represents one of the major structures of the crystalline basement of Lithuania, separating the West Lithuanian and the East Lithuanian domains. This zone has shown persistently low tectonic activity during the Phanerozoic. The Mid-Lithuanian Suture Zone is marked by a distinct Middle Lithuanian topographic low underlain by a trough in the sub-Quaternary surface that suggests the morphotectonic nature of this depression. This is supported by high-precision geodetic levelling data that has unravelled the subsidence trend of the Middle Lithuanian trough. The zone is also distinct in its pattern of topographic lineaments. The persistence of the tectonic activity of the Mid-Lithuanian Suture Zone suggests that it represents a large-scale mechanical boundary of the Earth's crust, resulting in increased accumulation of tectonic strain.

Key words: morphotectonic, Mid-Lithuanian suture zone, Paleoproterozoic basement, Quaternary, tectonic inheritance.

INTRODUCTION

The identification of control of the tectonic structures on surface morphology is a complex problem in platform areas covered by glacial deposits, due to low tectonic activity and a specific sedimentary environment that requires more comprehensive approaches than those commonly used in palaeotectonic analysis. Lithuania can be considered as a classic region of Quaternary cover formed during continental glaciations. The thickness of the Quaternary succession varies from 5 m in northern Lithuania, an area where glacial erosion dominates, up to 300 m in marginal uplands and buried palaeoincisions. However, little evidence has been reported that the formation of the Quaternary cover and of recent relief was influenced by tectonic structures expressed in pre-Quaternary rocks (e.g., Baltrūnas et al., 2006; Čyžienė and Satkūnas, 2008).

Lithuania is located in the intracratonic Baltic sedimentary basin, which was initiated in the Cambrian Period. A sedimentary succession overlies Paleoproterozoic continental crust that represents a part of the Fennoscandian lithospheric segment (Bogdanova, et al., 2006).

Abundant boreholes together with geophysical surveys (mainly gravimetric and magnetometric) allow mapping of tectonic structures in the basement. The impact of this tectonic grain on the Quaternary succession can be interpreted through considering different mechanisms, e.g. (1) the influence of the preexisting pre-Quaternary topography on the dynamics of the ice sheets and meltwater streams, (2) the activity of the tectonic structures during the Quaternary. The present study is focused on the Middle Lithuanian topographic lowland that represents one of the main topographic features of Lithuania. It geographically coincides with one of the main structures in the crystalline basement referred to as the Mid-Lithuanian Suture Zone that also had a long-term influence on the development of the overlying sedimentary cover (Šliaupa et al., 2012).

MID-LITHUANIAN SUTURE ZONE

The thickness of deposits covering the crystalline crust of Lithuania varies from 200 m in the southeast to 2300 m in the west (Paškevičius, 1997). The tectonic structure of the crust was unravelled by extensive deep drilling, and potential field and deep seismic sounding data. The basement is composed of two major domains – the West Lithuanian Domain (WLD) and the East Lithuanian Domain (ELD) differing in crustal thickness, lithological composition and tectonic fabric (Fig. 1). These domains represent two tectonic plates that collided at around 1.84 Ga (Motuza, 2005; Linneman et al., 2008). At the time of collision the WLD existed as a newly formed continental block (Motuza and Motuza, 2011), while the East Lithuanian Plate, subducting to the north-west, was of oceanic type, in places possibly thickened within intraoceanic volcanic arcs. This ancient collision zone is identified as a specific structural unit referred to as the Mid-Lithuanian Suture Zone (MLSZ). This zone

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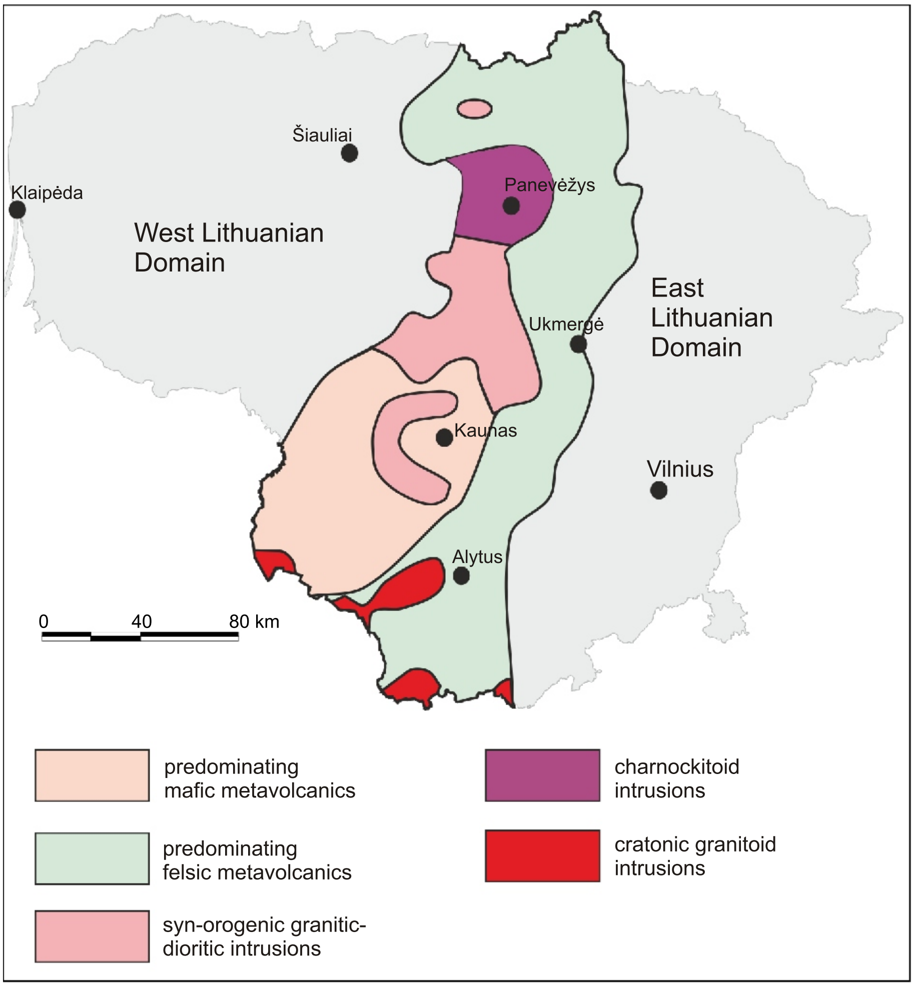

Fig. 1. Geological scheme of the Mid-Lithuanian Suture Zone (modified after Motuza, 2005)

is distinguished as a transitional structure of the crust as it gradually thickens to the east from 40 km in the WLD up to 50–55 km in the ELD. The transition zone is up to 35–40 km across.

A specific association of rocks showing beltiform distribution is defined in the MLSZ (Fig. 1). A belt of amphibolites, originally basalts and diabases with subordinate felsic supracrustal gneisses, occurs in the eastern part of the MLSZ. A belt of felsic gneisses, originally lavas of andesitic and dacitic porphyry composition, represents the western part of the MLSZ. The supracrustal rocks of the western belt are intruded by granitic and charnockitic plutons in the north. The width of the MLSZ is ~80–100 km (EUROBRIDGE'95 Seismic Working Group and Yliniemi, 2001).

The internal tectonic grain of the crust of MLSZ is not well constrained. It is presumed that the eastern part of MLSZ represents part of an eroded accretionary prism composed of a series of wedges extending NNE–SSW. The bounding faults are mapped by sharp gradients in the gravity and magnetic fields. Furthermore, EUROBRIDGE deep seismic sounding data revealed sharp discontinuities interpreted as shear zones. Some of these dissect the whole crust down to the Moho boundary (Giese, 1998; EUROBRIDGE'95 Seismic Working Group and Yliniemi, 2001; Bogdanova et al., 2006; Linneman et al., 2008). The existence of such shear zones is supported by mylonite bands documented in deep boeholes in central and southern Lithuania and farther south-southeast in Belarus.

The MLSZ is traced into northeastern Poland as indicated by a thickening of the crust defined in the DSS profiles POLONAISSE P4 and P5 (Czuba et al., 2002; Grad et al., 2003). The beltiform lithological fabric is less distinct in this part of the MLSZ because on the zone there are superimposed large cratonic intrusions such as those of Suwałki, Gołdap and Kętrzyn, forming a chain in an E–W direction possibly controlled by the large-scale fault structure (Wiszniewska et al., 2007). Farther south-west is the the Mazowian granitic-migmatitic dome, which has also obliterated the structural features of the supracrustal sequences of the suture zone (Wiszniewska et al., 2005).

In the north, the MLSZ is truncated along the Lithuanian-Latvian border. Its continuation into Latvian territory is supported neither by structural, nor by lithological data. The thickness of the crust in southern Latvia sharply increases up to 65 km, as defined by the Kochtla–Jarve–Sovietsk DSS profile (Ankundinov et al., 1994). Lithologically, the MLSZ is limited by an E–W trending belt of different granulite facies rocks, predominantly migmatites (Bogatikov and Birkis, 1973; Vetrennikov, 1991).

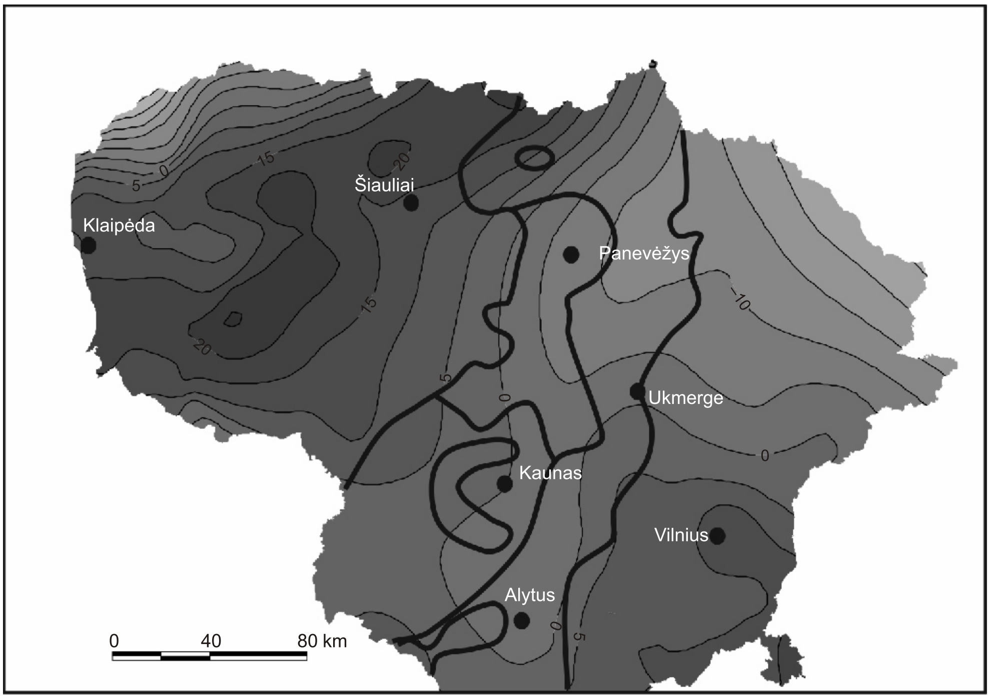

Fig. 2. Map of 1st order residuals of thicknesses of Cambrian deposits (without the oldest Baltic Group)

Contours of the Mid-Lithuanian Suture Zone are shown for comparison (after Šliaupa et al., 2012)

TECTONIC ACTIVITY OF THE MLSZ DURING PRE-QUATERNARY TIME

The MLSZ is confined to the first-order tectonic boundary of the Baltic sedimentary basin that separates the Mazury–Belarus anteclise in the east from the Baltic syneclise in the west (Stirpeika, 1999).

The structural studies revealed persistent tectonic activity of the MLSZ during deposition of the overlying sedimentary cover (Šliaupa et al., 2012). Activity along the zone has been traced from as long ago as the Late Ediacaran to Cenozoic, despite the dramatically changing geodynamic regime in the Baltic sedimentary basin throughout the Ediacaran–Phanerozoic. The zone was characterized by prevailing relative subsidence from Cambrian (Fig. 2) to Devonian times, as suggested by increases in the thicknesses of the sedimentary layers. The Middle Lithuanian depression underwent inversion, showing relative uplift, during post-Devonian time (Šliaupa et al., 2012). Persistent tectonic mobility implies specific mechanical properties of the crust that cause accumulation of tectonic strain in this zone. The post-Devonian tectonic activity of the MLSZ remains ambiguous. Yet, the control of the MLSZ on the distribution of Jurassic and Paleogene deposits and some deformation of Triassic strata hint at persistent tectonic activity of the zone.

RELIEF AND QUATERNARY GEOLOGY

The sub-Quaternary surface was formed by glacial and meltwater erosional processes and by tectonic vertical movements that took place during the Quaternary period (Šliaupa et al., 1995a, b; Dzierżek, 1997; Kurzawa, 2002, 2003; Šliaupa and Šliaupa, 2011; Krotova-Putintseva and Verbitskiy, 2012). The subglacial relief had significant influence on the ice sheet dynamics, resulting in lateral variations in the composition of the Quaternary succession (Šliaupa and Bitinas, 1986; Niewiarowski and Pasierbski, 1999). Conversely, the cyclic glacial loading-unloading may have reactivated pre-Quaternary tectonic structures, such as local- and regional-scale faults and fracture zones, as inferred from the alignment of the marginal moraine chains, thickness gradients of Quaternary deposits, and lineaments defined in the drainage network (Liszkowski, 1993; Thorson, 2000; Morawski, 2009). There are no direct observations of faults cutting Quaternary strata in Lithuania and other parts of the Baltic sedimentary basin, that can be accounted for by the low tectonic activity of the region and a lack of precise geophysical documentation. Yet, conclusive evidence of such fault activity has been reported from adjacent (more tectonically active) regions. A number of postglacial faults of predominant compressional type have been documented in the Fennoscandian shield bordering the Baltic sedimentary basin to the north-west; the fault activity was related to NNW–SSE horizontal compression (Roberts et al., 1997). Most of territory of Denmark is situated within the northwestern corner of the East European Craton. Some faults penetrating the Quaternary succession there have been defined by high-resolution seismic survey (Gregersen et al., 1996). Some of these are related to recent seismic activity. Fracture valleys dissecting the relief have been studied in detail in central Jylland (Jakobsen and Pedersen, 2009).

A close correlation between the Precambrian crystalline basement and the tectonic evolution of the pre-Quaternary sedimentary cover has been identified in Polish territory (Ber and Ryka, 1998) that also influenced the Quaternary succession (Ber, 2000; Karnkowski, 2008; Dzierżek, 2009).

The sub-Quaternary surface of Lithuania is characterized by complex relief (Šliaupa et al., 1995b; Šliaupa, 1997). It is dissected by abundant palaeoincisions, variously termed overdeepened or tunnel valleys (Šliaupa, 1997; Bitinas, 1999).

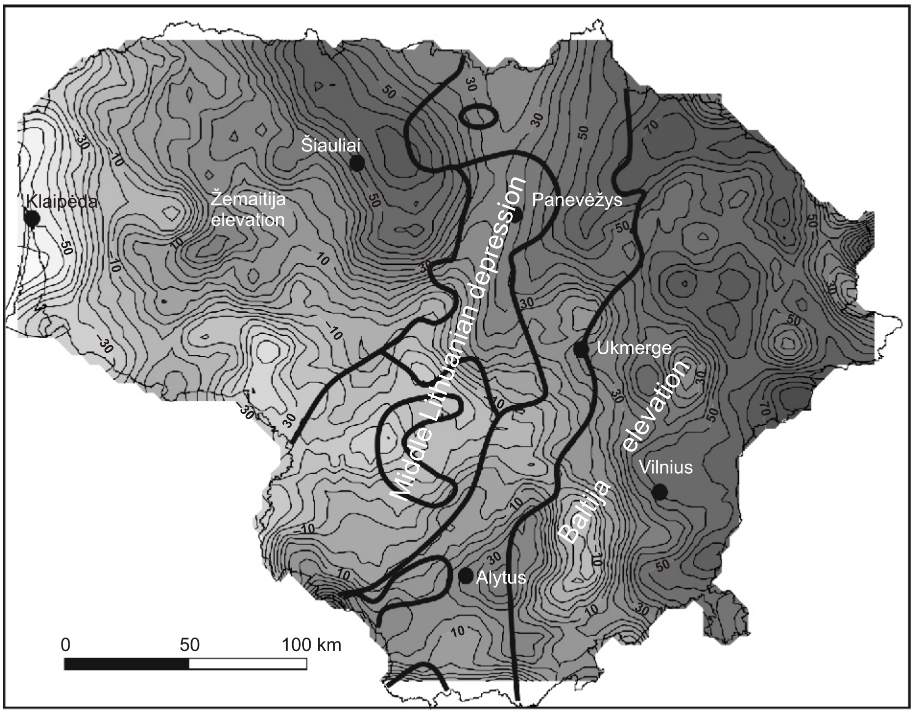

Fig. 3. Top depths (m) of the sub-Quaternary surface

Yet, some sub-regional trends can be defined using variations of altitudes of the sub-Quaternary surface that can be best unravelled by applying the summit altitudes method, which is based on interpolation of the depths of the positive forms of the sub-Quaternary relief (Fig. 3). Two distinct elevated areas are defined in the west and the east that are referred to as, respectively, the Žemaičiai elevation and the Aukštaičiai elevation. The altitude of the Žemaičiai elevation reaches +90 m close to Šiauliai. Similar +90 maximum altitudes are reported from the Aukštaičiai elevation.

The Middle Lithuanian trough, coincident with the MLSZ, separates these two major elevations (Fig. 3). It trends NNE–SSW. The summit altitudes range from +25 in the north to –30 in the south in the axial part of the trough. The axis of the Middle Lithuanian trough is confined to the western part of MLSZ. The difference between average depths of the trough and the flanking elevations reach 70 m. The width is ~50 km in the north and widens to 80 km in the south.

The inclination of the trough axis changes from southward to northward in the north; the hinge zone is situated close to Panevežys Town (Fig. 3). The western slope of the trough is steeper than that in the east. This is similar to the bedrock trough asymmetry reported from Estonia and Latvia. Karukäpp (1996, 2004) related this asymmetry to the Coriolis force effect. This is a rather ambiguous suggestion as the troughs were formed by ice sheet erosion rather than meltwater activity and the Coriolis force is too small to exert any discernable effect on ice sheet dynamics. Most likely such regularity in trough asymmetry is evidence of the regional-scale westward tilting of the ice sheet substrate that resulted in more intense sculpturing of the western trough slopes.

The sub-Quaternary relief considerably affected the glacial sedimentation processes. The map of thickness of the Quaternary deposits reflects the sub-Quaternary Žemaičiai and Aukštaičiai elevations and middle Lithuanian depression (Fig. 4). In general, the elevated areas are marked by more intense sedimentary accumulation compared to the depressions. This can be related to the more intense erosion processes affecting the sub-Quaternary substrate and previously deposited Quaternary sediments within the sub-regional scale depressions that is accounted for by faster ice sheet flow, while elevated areas favoured preservation of the sediments due to a slower dynamics of the overriding ice sheets.

The modern topography also closely correlates with the sub-Quaternary surface relief (Fig. 5). Moreover, the present topography shows more distinct variations in altitude that is related to the influence of the sub-Quaternary surface on the thickness of the Quaternary succession noted above. The Žemaičiai and Aukštaičiai sub-Quaternary elevations are confined to the Žemaitija and Baltija uplands. The surface altitude of the Žemaitija Upland reaches +230 m, while exceeding +290 m on the Baltija Upland.

The surface altitudes of the axial part of the Middle Lithuanian trough are about +45–60 m. The Middle Lithuanian trough comprises the Nevėžis River basin in the north and the Šešupė River basin in the south-west. The northern segment of the Middle Lithuanian trough, covered mainly by basal moraine, is punctuated by long (up to 40 km) subglacial bedforms (mega-scale glacial lineations; Fig. 6). They likely record fast-flowing ice (Stokes and Clark, 2002). Mega-scale glacial lineations are long in the axial part of the trough, suggesting maximum flow rates in this part of the depression. Those forms are not recorded in the southwestern segment of the trough as they are covered by glaciolacustrine deposits. Moreover, they are not discernable in the exposed moraine areas either. This suggests slower flow of the glacier due to widening of the trough to the south.

The relief of the Middle Lithuanian trough was clearly active during the last Nemunas (Weichselian) Glaciation and deglaciation. The southern margin of the trough is marked by the Baltija Marginal uplands (Fig. 7). The most distinct influence of the depression on the ice sheet dynamics is defined in the northern part of the trough that accommodated the Middle Lithuanian glacial lobe which marks the MLSZ. The lobe propagated for

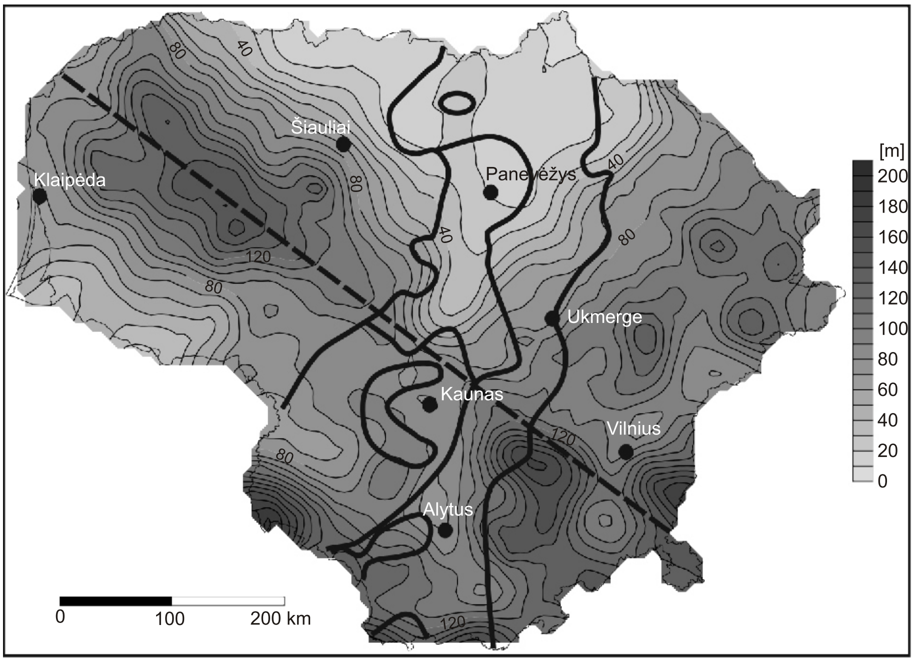

Fig. 4. Approximate thickness of the Quaternary deposits

Line of cross-section is indicated (see Fig. 12)

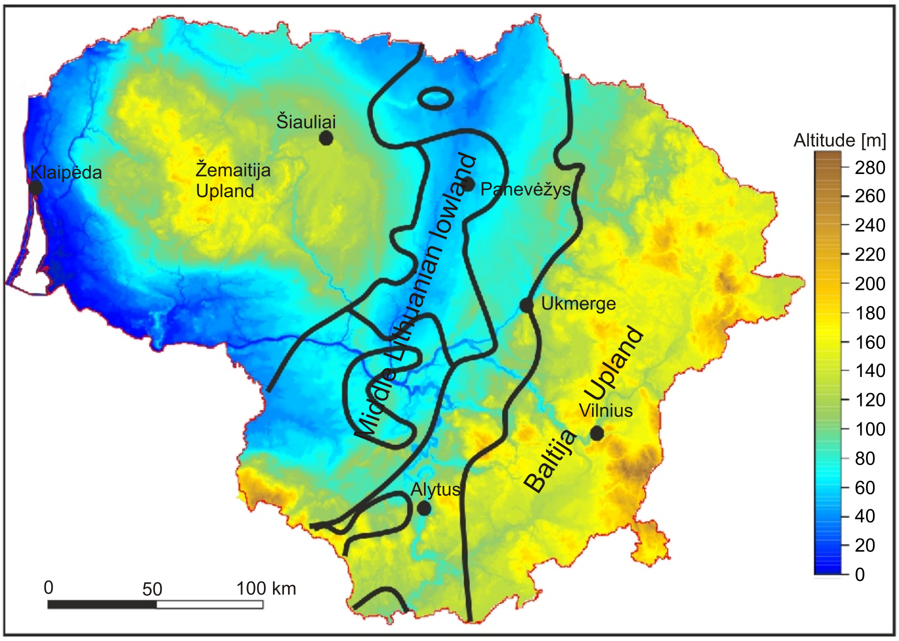

Fig. 5. Topography of Lithuania

Major features of the MLSZ are shown for comparison

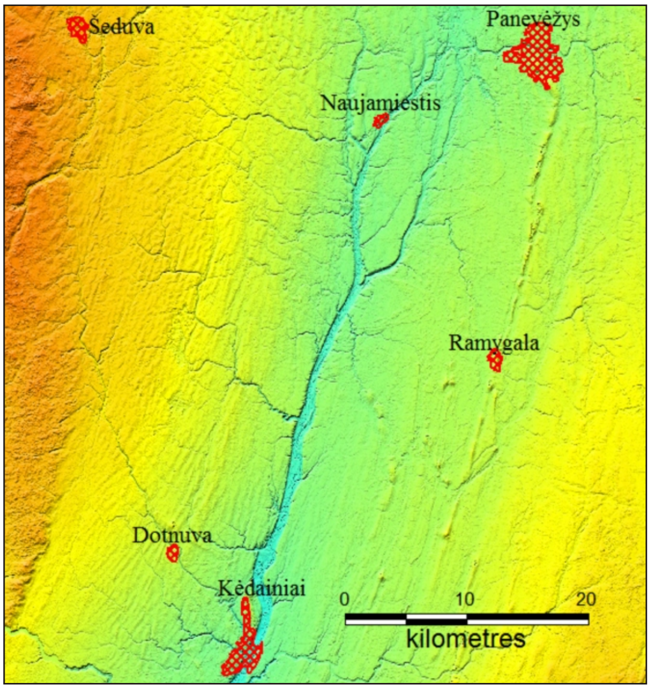

Fig. 6. LIDAR image of a fragment of the Middle Lithuanian topographic low

Please note the difference of mega-scale glacial lineations in the west and the east

~220 km southwards, which strongly suggests that the pre-existing topographic depression favoured fast ice sheet flow. A marginal ridge is prominent on the surface, clearly outlining an ice-lobe advance in the trough. It is referred to as the Middle Lithuanian Ridge (Fig. 7). Remarkable fluted moraine fields and several radial eskers are related to the till plain outlined by the ridge. The ridge is commonly intersected by subglacial channel valleys and proglacial spillways. The Middle Lithuanian (VL) phase limit is drawn along the distal slope of the ridge.

A detailed study of fragments of glaciolacustrine kame terraces on the distal slope of the Middle Lithuanian Ridge revealed them to have originated between the active ice lobe and blocks of dead ice. It is likely that there was no distinct boundary of the frontal Middle Lithuanian ice sheet. Moreover, areal rather than frontal deglaciation dominated the area (Bitinas et al., 2004), and this could explain the wide spread of boulder exposure ages between 11.0 and 15.4 ^{10}Be ka (Rinterknecht et al., 2008) obtained from seven dated boulders in the two genuine boulder fields in northwestern Lithuania. An age of 13.5 ± 0.6 ^{10}Be ka, obtained from ten dated boulders, is suggested to represent the final deglaciation from the Middle Lithuanian ice margin (Rinterknecht et al., 2008).

TOPO-LINEAMENT PATTERN

Topographic lineaments are a characteristic feature of glacial relief. They are defined using different methods, such as remote sensing, analysis of the drainage network, or morphometric techniques. Lineaments are defined as linear, curved or circular features of local and regional extent. Some lineaments might reflect the pattern of fractured zones in the bedrock (Oakey, 1994; Šliaupa et al., 1995b; Šliaupa and Popov, 1998; Kuivamäki, 2000, 2007; Jakobsen and Pedersen, 2009; Rychel et al., 2015). Yet, most of the lineaments identified are most likely related to dynamics of the ice sheet that leads to its fracturing punctuated by sedimentation features. Some might be confined to pre-existing tectonic structures, while other lineaments are seemingly not controlled by any substrate structures.

An intricate pattern of major lineaments is defined in Lithuania (Fig. 8; Šliaupa, 2001). Western Lithuania is dominated by NE–SW trending lineaments superimposed by orthogonal and rare NW–SE striking lineaments. In the east, lineaments oriented NW–SE predominate with abundant W–E striking features and scarce N–S and NE–SW trending lineaments. The MLSZ represents the core of this fishbone-shaped lineament pattern. The western part of the MLSZ is dominated by NNE–SSW striking lineaments, while NNW–SSW lineaments predominate in the eastern part of the zone. Also, N–S striking lineaments are abundant. Those differences are explained in terms of (1) the different structural grain of western and eastern Lithuania and the MLSZ; and (2) different ice sheet dynamics reflected by a specific glacial fracturing pattern.

RECENT TECTONIC ACTIVITY OF THE MLSZ

There is a moderately dense network of precise levelling benchmark lines of Class 1 in Lithuania (Paršeliūnas et al., 2000). The repeated levelling campaigns provide the basic information on recent vertical ground motions. The detailed correlation of the geodetic and geological data unravelled a close relationship between ancient tectonic structures and recent vertical movements, implying inheritance of tectonic activity in Lithuania (Zakarevičius et al., 2008).

The Vilnius–Jonava–Šiauliai geodetic levelling line, 290 km long, crosses the MLSZ from the north-west to the south-east (Figs. 9 and 10). Data from measurement campaigns of 1970 and 1998 were used in the present study to analyse trends of vertical ground motions across the MLSZ. The zone is distinct, with relative ground subsidence attaining 0.8 mm/y in its axial part (Fig. 10).

This pattern of vertical ground motions closely correlates with the topography and the sub-Quaternary relief (Fig. 11). Moreover, some short-wavelength sub-Quaternary surface undulations are reflected in vertical motions, such as the local uplift in the axial part of the Middle Lithuanian trough (geodetic benchmark N317). The correlation of vertical motions is as high as +0.55 with the sub-Quaternary relief and +0.64 with the modern relief.

DISCUSSION

The Middle Lithuanian topographic lowland is confined to the Paleoproterozoic Mid-Lithuanian Suture Zone (MLSZ) that also shows persistent tectonic activity throughout the Phanerozoic, mainly characterized by relative subsidence. The persistent tectonic activity can be explained in terms of the tectonic strain accumulation along the crustal-scale tectonic boundary, characterized by considerable change in the crustal mechanical properties.

The MLSZ is reflected on the sub-Quaternary and present surface, representing a distinct trough. The trough can be of either tectonic (subsidence) or erosional nature.

The previous studies of the pre-Quaternary layers unravelled the persistent tectonic activity of the MLSZ, dominated by a relative subsidence trend. This inherited tendency was also registered in the high-precision geodetic levelling network showing recent mm-scale relative subsidence within the zone. Tectonic activity of the MLSZ can therefore be reasonably suggested during the Quaternary Period.

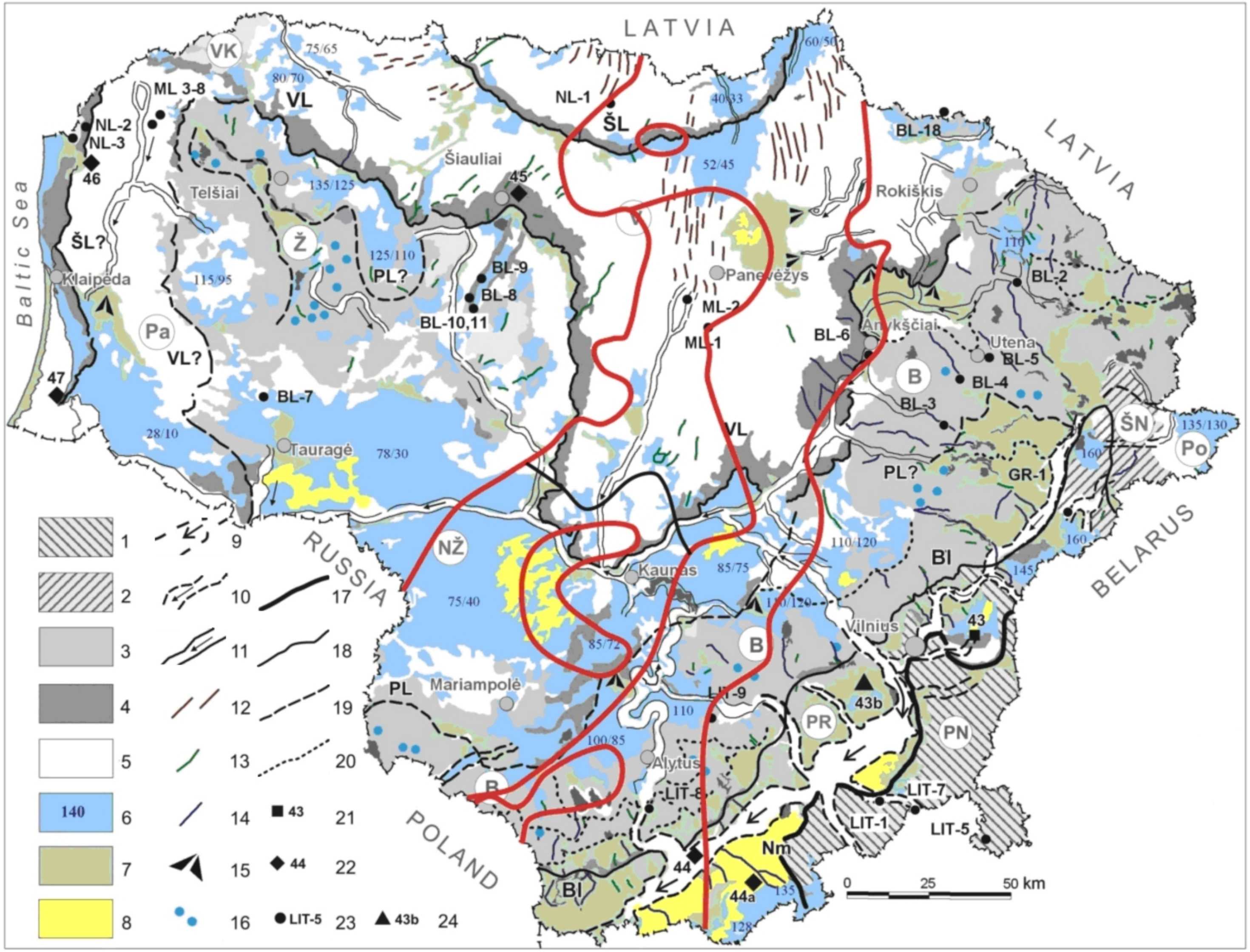

Fig. 7. Late Nemunas (Weichselian) glacial limits (after Guobytė and Satkūnas, 2011)

Glacial uplands of Saalian age: 1 – Southern Nališa (Ašmena), 2 – Northern Nalšia (Švenčionys); 3 – Glacial uplands of Weichselian age: B – Baltija Marginal Uplands, Ž – Žemaitija (Samogitia) insular Upland; 4 – distinct ice-marginal ridges; 5 – glacial lowlands: Pa – Meritime, NŽ – Lower Nemunas, PR – SE Lithuanian, Po – Polockas; 6 – glaciolacustrine plains with maximum/minimum altitude; 7 – outwash plains; 8 - aeolian landscape; 9 - The Voke–Merkys–Nemunas ice-marginal river valley (urstromtal); 10 - The Žeimena–Neris ice-marginal river valley; 11 – proglacial valleys; 12 – drumlinoid ridges; 13 – eskers; 14 – subglacial “tunnel” valleys; 15 – deltas; 16 – plateau-like hills; 17 – LGM limit, limits of ice-marginal zones; 18 – definite limit; 19 – supposed limit; 20 – positions of retreating ice margin; 21 – TL dating site; 22 – ^{14}C dating sites; 23 – ^{10}Be dating sites; 24 – OSL dating sites; red lines – MLSZ; Late Nemunas (Weichselian): **Nm** – Last Glacial maximum; ice marginal zone: **BI** – Baltija (Pomeranian), **PL** – South Lithuanian, **VL** – Middle Lithuanian, **ŠL** – North Lithuanian

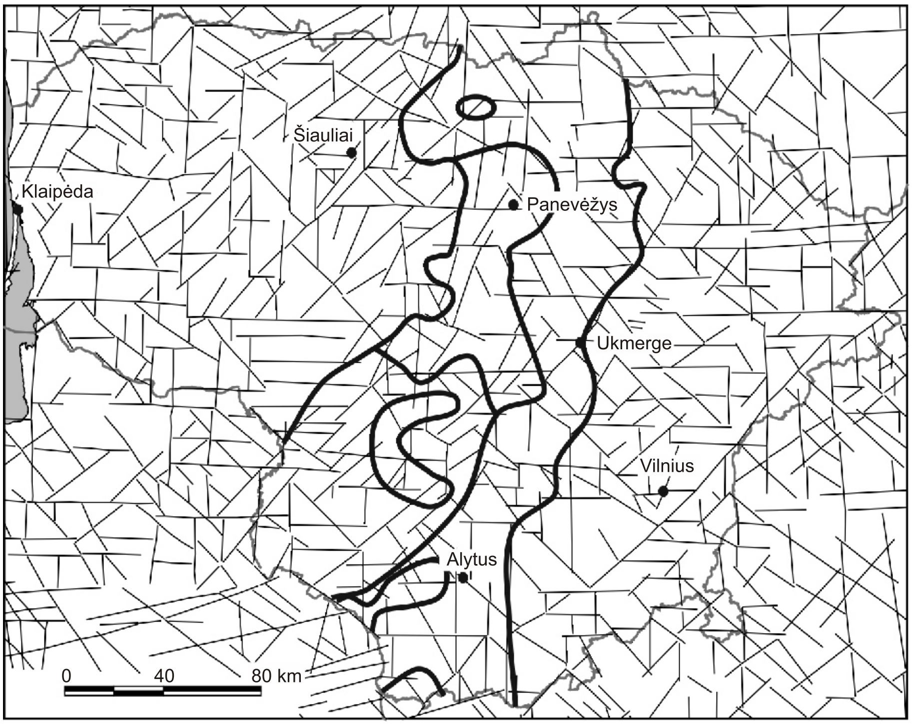

Fig. 8. Topographic lineaments defined by morphometric methods (after Šliaupa, 2001)

Major features of MLSZ are shown for comparison
(please note the fishbone-shaped pattern of lineaments along the MLSZ)

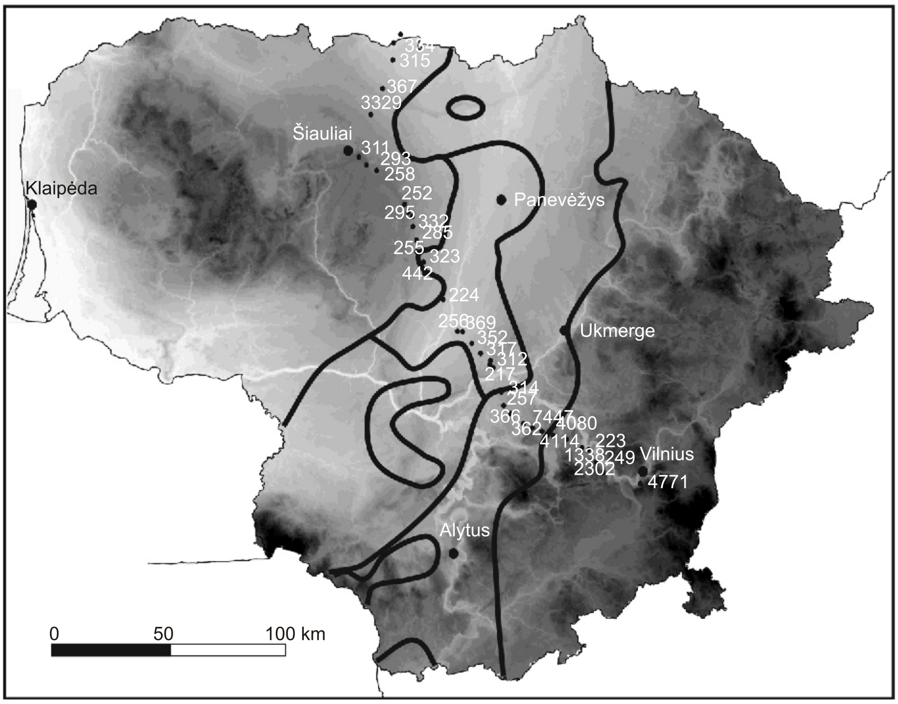

Fig. 9. Topography (grey scale) and line of precise geodetic levelling Vilnius-Šliauliai (benchmark identification numbers)

Major features of MLSZ are shown for comparison

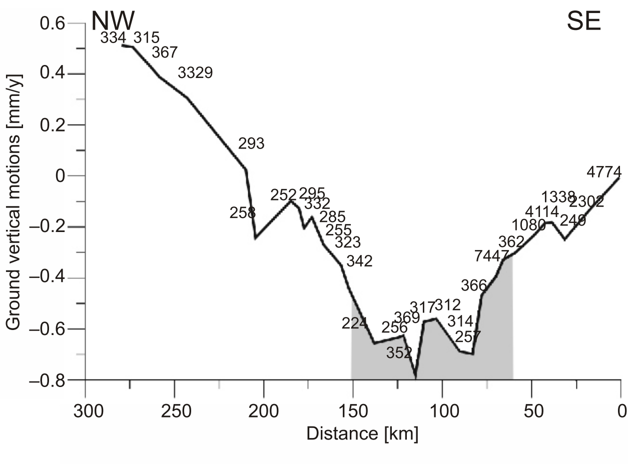

Fig. 10. Recent ground vertical motions along the Vilnius–Šiauliai geodetic levelling line

Benchmark identification numbers are indicated; shaded area shows location of the MLSZ

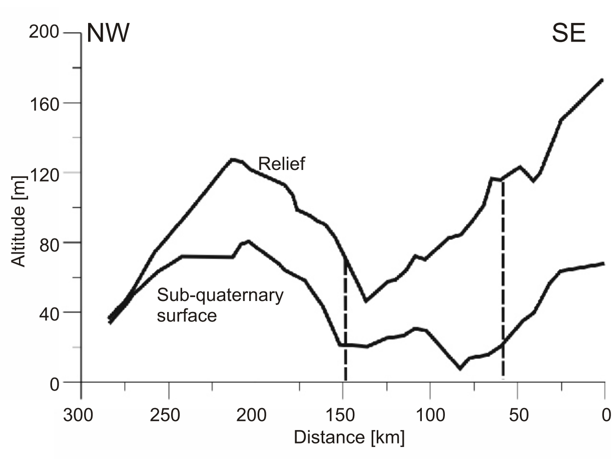

Fig. 11. Topography and sub-Quaternary relief, Vilnius–Šiauliai geodetic levelling line

Hatched lines show limits of MLSZ

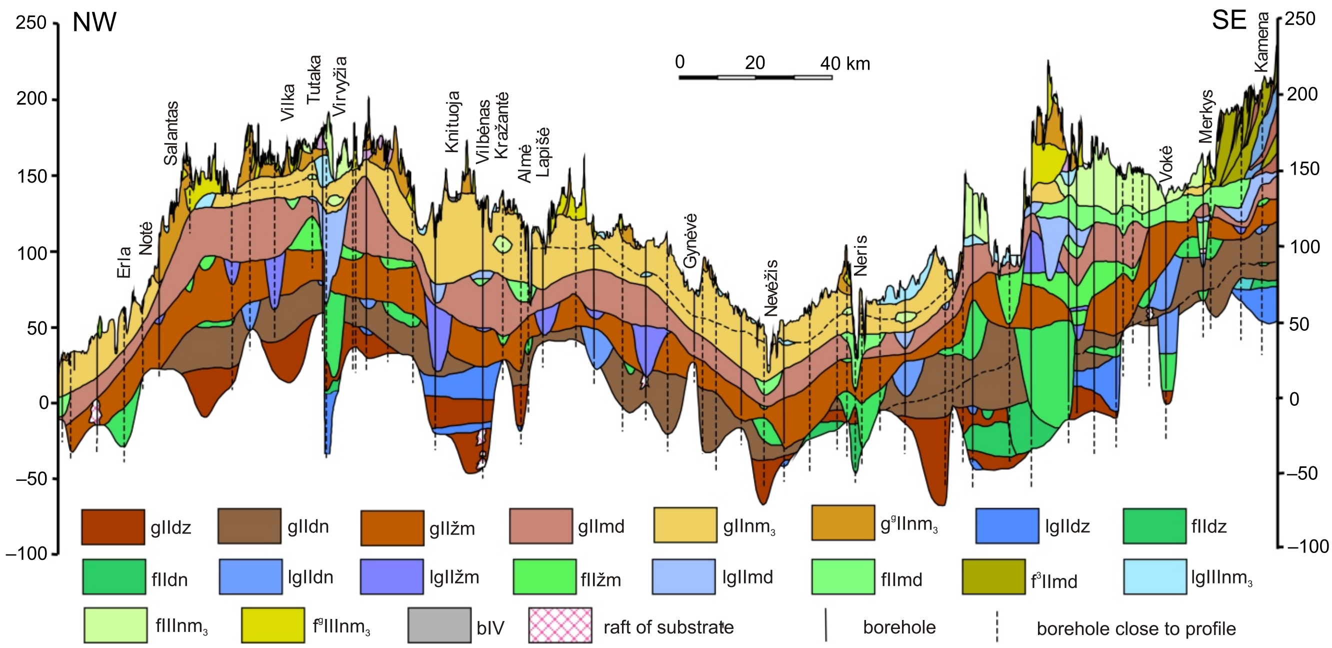

Fig.12. Geological cross-section NW–SE across Lithuania

gIIdz – glacial deposits of Dzūkija Stage; gIIdn – glacial deposits of Dainava Stage; gIIžm – glacial deposits of Žemaitija Stage; gIImd – glacial deposits of Medininkai Stage; gIInm$_3$ – glacial deposits of Upper Medininkai Formation; g^{9}IInm$_3$ – glacial deposits of Upper Nemunas Formation Stage; lgIIdz – limnoglacial deposits of Dzūkija Stage; fIIdz – fluvioglacial deposits of Dzūkija Stage; fIIdn – fluvioglacial deposits of Dainava Stage; lgIIdn – limnoglacial deposits of Dainava Stage; lgIIžm – limnoglacial deposits of Žemaitija Stage; fIIžm – fluvioglacial deposits of Žemaitija Stage; lgIImd – limnoglacial deposits of Medininiai Stage; fIImd – fluvioglacial deposits of Medininaki Stage; f^{3}IImd; lgIIInm3 – limnoglacial deposits of Upper Nemunas Stage; fIIInm$_3$ – fluvioglacial deposits of Upper Nemunas Formation; bIV – Holocene biogenic deposits

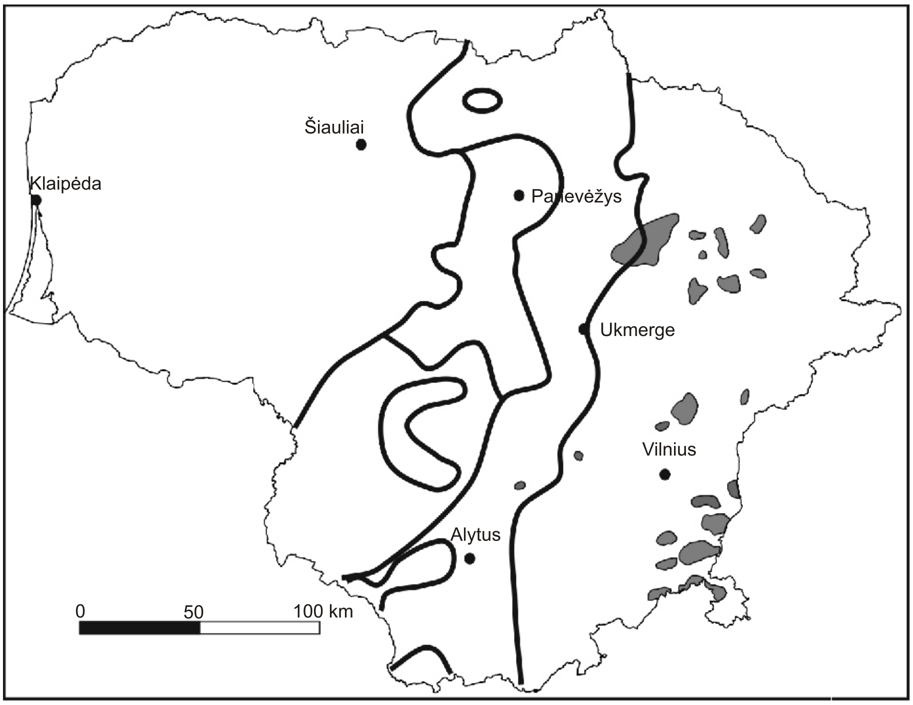

Fig. 13. Distribution of continental Neogene deposits (black polygons)

Hatched line indicates generalised limit of distribution of Neogene deposits

The pre-existing substrate topography strongly controls the ice sheet flow dynamics (Durand et al., 2011; De Rydt et al., 2012). This is well-illustrated by the Middle Lithuanian ice lobe that propagated to the south for >100 km to the south along the trough during the last glaciation. Such fast ice flow can result in more intense erosion of the substrate lithologies. Furthermore, the persistent activity of the MLSZ inevitably led to formation of the wide zone of increased fracturing in the overlying sedimentary cover. The evidence provided from different regions implies increased rates of erosion of fractured lithologies (Dühnforth et al., 2010) that is also consistent with modelling results (Iverson, 2012). The spacing of fractures also control the prevailing mechanism (e.g. abrasion vs. plucking) of erosion (Krabbendam and Glasser, 2011). This can potentially explain the more intense excavation of the MLSZ surface by the advancing ice sheet, and the formation of the Middle Lithuanian trough.

However, these erosional factors can hardly account for the 70 m difference in sub-Quaternary surface depths (altitudes) between the Middle Lithuanian trough and the flanking Žemaičiai and Aukštaičiai elevations, as the oldest Quaternary deposits (Dzūkija Stage) are mapped both on elevations and in the trough. This suggests only minor (if any) difference in the erosion rate of the sub-Quaternary substrate (Fig. 12). It is therefore concluded that a tectonic mechanism should account for the formation of the Middle Lithuanian through.

It is notable that the undulations of the sub-Quaternary surface are well-reflected in the variations in the thickness of the Quaternary succession. This can likely be related to differential erosion and sediment preservation rates within these forms. The pre-existing topographic low favours faster ice sheet flow that leads to a higher erosion rate of the substrate (including underlying Quaternary sediments) that results in reduced thickness of the Quaternary layers, essentially of the meltwater sediments most affected by an advancing ice sheet.

Alternatively, the varying thickness of the Quaternary deposits reflects active tectonic structures. The Neogene lacustrine and fluvial sediments are distributed in the eastern part of Lithuania covering the Aukštaičiai elevation, while absent from the Middle Lithuanian trough (Fig. 13). Furthermore, the Daumantai stage sediments comprising the oldest Quaternary deposits known in the Eastern Baltic region (Kondratiene et al., 1993) are also confined to this area. This Quaternary/Neogene boundary was established by pollen and lithological criteria. The stage is represented by lacustrine deposits, distributed as the patches up to a few dozens of kilometres wide. This hints at a relative subsidence of the eastern part of Lithuania during the Neogene–Prepleistocene, with relative uplift of MLSZ at his time. According to this scenario, inversion of the tectonic movements should have taken place leading to formation of the Middle Lithuanian trough during the Late Quaternary. These processes can scarcely be related to a glacial isostasy as they are much larger-scale phenomenon. This rather suggests regional-scale changes in the geodynamic situation in the region.

CONCLUSIONS

The Mid-Lithuanian Suture Zone (MLSZ) of the Paleoproterozoic age is marked by the Middle Lithuanian topographic lowland that is one of the major morphological features crossing the whole Lithuanian territory from north to south.

The present topography directly correlates with the topography of the underlying pre-Quternary deposits. The Middle Lithuanian topographic low is confined to the sub-Quaternary surface depression. It separates the Žemaičiai and Aukštaičiai elevations located, respectively, to the west and the east. The depth (altitude) difference between the average depths of the trough and flanking elevations reaches 70 m. Erosion cannot account for such a large difference, as the oldest glacial deposits are present within both the trough and flanking elevations. This implies that a tectonic mechanism is the main factor that formed the Middle Lithuanian depression. The MLSZ showed persistent tectonic activity throughout the Phanerozoic, mainly of relative subsidence. This suggests inheritance of the tectonic movements during the Quaternary, and the morphotectonic nature of the Middle Lithuanian lowland.

Increased tectonic activity of MLSZ is also reflected in the pattern of the topographic lineaments showing a fishbone pattern associated with the zone.

The Middle Lithuanian Lowland is characterized by a reduced thickness of the Quaternary succession. This can be a result of increased ice sheet and meltwater flow within the depression leading to a higher rate erosion of the sub-Quaternary substrate and of Quaternary sediments deposited during preceding glacial cycles. Alternatively, it might be explained in terms of tectonic inversion of the MLSZ during the latter part of the Quaternary, as suggested by the occurrence of Neogene deposits within the Aukštaičiai Upland, while absent in the trough.

The Middle Lithuanian lowland is also well reflected in the recent vertical ground motion pattern as defined by precise geodetic levelling, pointing to recent tectonic activity of the MLSZ. This corroborates the active tectonic nature of the Middle Lithuanian depression.

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