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# INVESTIGATION OF THE RECENT EARTH'S CRUST DEFORMATIONS IN THE TERRITORY OF LITHUANIA

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**Abstract.** The paper discusses the horizontal movements of the Earth's crust in the territory of Lithuania. The curves of horizontal deformations are found by comparing the changes in coordinates of geodetic network points obtained after repeated measurements carried out after a certain period of time. The goal of the investigation was to analyse the regularities of indications of horizontal movements of the Earth's crust established according to the data of three different geodetic measurements. The parameters of horizontal movements were calculated using the method of finite elements and applying tensor analysis. To implement the investigation in the territory of Lithuania, the authors used the points of the triangulation network, formed in the year 1942; and the points of GPS networks of zero class and first class, formed in the year 1993, and measured once again in the year 2007 (the total of 45 joint points). After the investigation, new curves of horizontal deformations (such as relative linear deformations, relative shear deformations, relative dilatation, the maximum and the minimum elongation of the key horizontal deformations, and the directions of the maximum elongation) were found. In case of the analysis of obtained results, it was found that the positive values of deformations predominate in the direction of the maximum related elongation and the negative values of deformations predominate in the direction of the minimum related elongation. The maximum elongation of the key horizontal deformations varies between $-1.608 \cdot 10^{-6}$ and $20.832 \cdot 10^{-6}$. The minimum elongation of the key horizontal deformations varies between $-29.424 \cdot 10^{-6}$ and $1.397 \cdot 10^{-6}$. Dilatation varies between $-27.580 \cdot 10^{-6}$ and $-8.612 \cdot 10^{-6}$. It was found that more intensive changes of indications of deformations were observed at the boundaries of deep blocks of the lithosphere.

**Keywords:** finite element method, strains, GPS, triangulation.

## 1. Introduction

Investigation of the Earth's crust movement is a topical problem that is not only related with formation and use of geodetic networks but also with identification of seismically active territories, forecasting of seismic activity of tectonic faults, construction of environmentally hazardous objects and prospecting of minerals (Stanionis 2005).

Up to the beginning of the last decade of the 20th century, the attention of the world was focused on movement of the Earth's crust in seismically active territories (Anikienė 2008). Seismic events in territories are predetermined by the seismotectonic potential, i.e. the strongest expectable quake as well as the interdependence between the strength and the frequency of the quake. Seismotectonic potential and deformation of the Earth's crust are interdependent phenomena. They often are caused by the same processes in the entrails of the Earth.

The territory of the Baltic States and adjacent regions distinguishes itself for low seismic activity predetermined by the Earth's crust formed in the Early Precambrian Period and a long distance from seismically active zones. The Earth's crust in the Baltic region is affected by horizontal tectonic tensions and the deformations are concentrated along tectonic faults. When their concentration exceeds the fault resistance threshold, it moves thus causing a quake.

The territory of Lithuania is considered aseismic territory, or territory of low seismic activity. Although its seismic activity is low, as compared to neighbouring countries, nevertheless the historical and current data show that perceptible earthquakes took place in the territory of Lithuania as well (The new nuclear power plant... 2008). In Lithuania, the earliest earthquake was documented back in 1328, in Skirsnemunė. The second earthquake, which caused a 1 km long rupture, took place close to Vilnius in January 1909.

In the eastern part of the Baltic region, as in Lithuania, no detailed geodynamic investigation was carried out. Up to the last decade of the 20th century, a negative standpoint on platform areas in respect of their seismic activity existed in the world. It was supposed that no noticeable quakes can occur in platform regions of low seismic activity (up to the magnitude 3 according to the 12-point scale). However, in course of accumulation of the data from instrumental observation of seismic phenomena, the opinion on seismic activity of platform areas and the applicative character of such investigation changed.

In Lithuania, more serious interest in seismic risk zoning was taken after the earthquake in Osmussaare (Estonia) with the magnitude 6–7 (according to the 12-point scale) in the year 1976 (Ilginytė 1998) and the Carpathian earthquake in Romania in the year 1977. In the latter region, quakes were perceptible in the years 1986 and 1990 as well. In Lithuania, registered quakes remained within the magnitude 3–4. On 21 September 2004, the quake of the magnitude 4.4 was registered in Ladushkin (Kaliningrad Region); its focus was situated in the depth of 10 m. The second quake in the same Region (in Primorsk town) reached the magnitude 5. Vibrations caused by the above-mentioned quakes were perceptible in a considerable part of the territory of Lithuania. The intensity of vibrations of the ground in Klaipėda reached the magnitude 5, in Kaunas and Vilnius – approx. 3 (Pačėsa *et al.* 2005).

For investigation of horizontal movement of the Earth's crust, geodetic networks (triangular, trilateral, poligonometry, GPS) are widely used in the entire world (Hollenstein *et al.* 2008; Hsu, Li 2004; Kaiser *et al.* 2005; Mahmoud 2003; Tesauro *et al.* 2006; Tyshkov *et al.* 2008; Vigny *et al.* 2009; Weber *et al.* 2011; Stanionis 2005; Zakarevičius 2003). If the data on changes of the coordinates of points of geodetic networks are available, the properties of horizontal deformations of the Earth's crust can be assessed and the changes of the geodynamic tensions can be identified.

The investigation aimed to analyse the regularities of the indications of the horizontal movements of the Earth's crust established according to the data of three different geodetic measurements.

## 2. Methodology of indications of horizontal movements of the Earth's crust

In the territory of Lithuania, points of the triangular geodetic network were formed in the year 1942; while points of the GPS network of the class 0 and the class 1 were formed in the year 1993 and repeatedly measured in the year 2007. The total of 45 joint points is used for investigation of movement of the Earth's crust.

The accuracy of the triangular network in the territory of Lithuania is defined by the mean square errors equal to 0.3"–1.2" for measurement of angles and the relative errors equal to 1:295000–1:206000 for measurement of sides (Zakarevičius 2003; Stanionis 2005). The relative errors of the vectors of the chords for connection of points equal to $1 \cdot 10^{-7}$ and the ones of ellipsoid heights – to $2 \cdot 10^{-7}$. The errors of the geodetic latitude and the geodetic longitude of points of GPS of the class do not exceed 9 mm, and the error of ellipsoid height does not exceed 30 mm (Zakarevičius 2003; Stanionis 2005). The maximum relative error of chords of the *GPS* network of the class 1 equals to $1.7 \cdot 10^{-7}$ (Petroškevičius, Ramanauskas 1995; Skeivalas 2008). Errors of coordinates of points in the directions of the meridian and the parallel do not exceed 6 mm in respect of points of the class 0.

In the territory of Lithuania, horizontal movement of the Earth's crust was explored in works by A. Zakarevičius in 2003 and A. Stanionis in 2005. So, for verification of the reliability of the available data and assessment of the regularities of the indicators of horizontal deformations of the Earth's crust obtained from the data on measurements in three epochs according to joint points of the triangular and GPS networks, a scheme of a network for repeated measurements consisting of 69 finite elements (triangles) other than provided in works by Zakarevičius 2003 and Stanionis 2005 is required (Fig. 1).

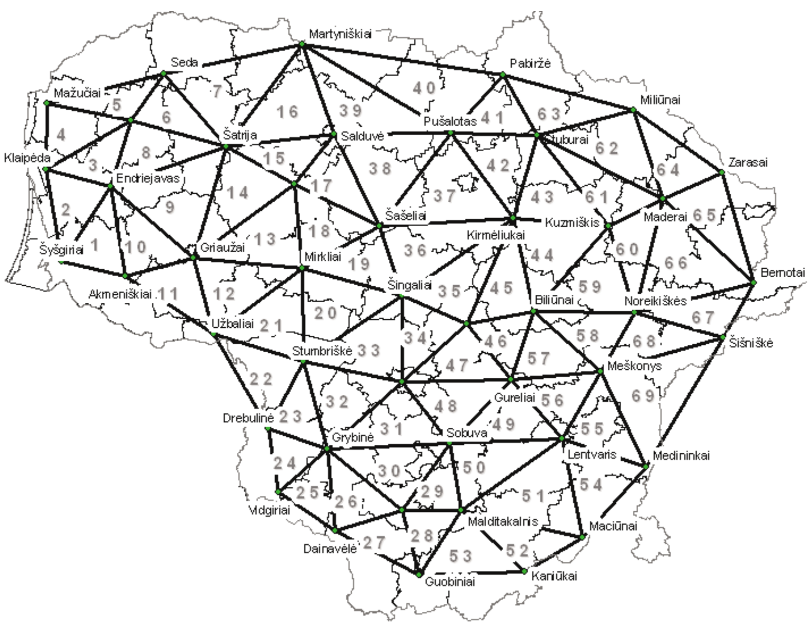


**Fig. 1.** Scheme of continues measurements of Network:
Seda – station and the name of station, 1 – the number of a triangle

If changes in coordinates of points of the triangular and GPS networks are known, deformations of the Earth's crust are computed for the area of the finite element (Atkočiūnas, Nagevičius 2004). The model on shifts of points (Gamal, Kato 1998; Zakarevičius, Stanionis 2007):

$$\Delta X = A \cdot E, \tag{1}$$

where: $\Delta X$ – the vector of shifts of planar coordinates of the points; $A$ – the matrix of deviations of planar coordinates of the points from their average values; $E$ – the vector of the parameters of horizontal deformations of the Earth's crust, where

$$\Delta X = \begin{pmatrix} \Delta x_1 \\ \Delta x_2 \\ \Delta x_3 \\ \Delta y_1 \\ \Delta y_2 \\ \Delta y_3 \end{pmatrix}, \tag{2}$$

$$A = \begin{pmatrix} 1 & x_{s_1} & y_{s_1} & 0 & 0 & 0 \\ 1 & x_{s_2} & y_{s_2} & 0 & 0 & 0 \\ 1 & x_{s_3} & y_{s_3} & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & x_{s_1} & y_{s_1} \\ 0 & 0 & 0 & 1 & x_{s_2} & y_{s_2} \\ 0 & 0 & 0 & 1 & x_{s_3} & y_{s_3} \end{pmatrix}, \tag{3}$$

$$E = \begin{pmatrix} \alpha_x \\ \varepsilon_{xx} \\ \frac{1}{2} \cdot \varepsilon_{xx} - \omega \\ \alpha_y \\ \frac{1}{2} \cdot \varepsilon_{xx} + \omega \\ \varepsilon_{yy} \end{pmatrix}. \tag{4}$$

The values included in the formula (2–4):

$\Delta x_i = x_i' - x_i$, $\Delta y_i = y_i' - y_i$, $x_i$, $y_i$, – the planar coordinates of the points in the first measurement; $x_i'$, $y_i'$ – the planar coordinates of the points in the second measurement; $i$ = 1, 2, … $n$ – numbers of points; $x_{S_i}$, $y_{S_i}$ – deviations of the planar coordinates of points of the geodetic network from their average values; $\alpha_x$, $\alpha_y$ – shifts of the final element in the directions of abscissas and ordinates; $\varepsilon_{xx}$, $\varepsilon_{yy}$ – relative linear deformations; $\varepsilon_{yy}$ – relative shear deformations; $\omega$ – turn of the finite element.

The vector of the parameters of horizontal deformations of the Earth's crust is assessed by the least-squares method (Zakarevičius, Stanionis 2007):

$$E = (A^T \cdot A)^{-1} \cdot A^T \cdot \Delta X. \tag{5}$$

The relative dilatation of the finite element (Zakarevičius, Stanionis 2007):

$$\Delta = \varepsilon_{xx} \cdot \varepsilon_{yy}. \tag{6}$$

The maximum and the minimum relative elongations of the most important horizontal deformation (Zakarevičius, Stanionis 2007):

$$\varepsilon_1 = \frac{1}{2} \cdot (\Delta + \gamma), \tag{7}$$

$$\varepsilon_2 = \frac{1}{2} \cdot (\Delta - \gamma), \tag{8}$$

were

$$\gamma = \left\{ \left( \varepsilon_{xx} - \varepsilon_{yy} \right)^2 + \varepsilon_{xy}^2 \right\}^{\frac{1}{2}}. \tag{9}$$

The direction of the maximum relative elongation (Zakarevičius, Stanionis 2007):

$$\varphi = \frac{1}{2} \operatorname{arctg} \left( \frac{\varepsilon_{xy}}{\varepsilon_{yy} - \varepsilon_{xx}} \right). \tag{10}$$

## 3. Results on indications of horizontal deformations of Earth's crust

Using the formulas (1)–(10), the indicators of horizontal deformations in the territory of Lithuania were assessed according to the data on measurements in three epochs (version I – the changes of coordinates between the points of the triangular network of the year 1942 and the points of the GPS network of the year 1993; version II – the changes of coordinates between the points of the triangular network of the year 1942 and the points of the GPS network of the year 2007; version III – the changes of coordinates between the points of the GPS network of the year 1993 and the points of the GPS network of the year 2007). The identified properties of the horizontal deformations include relative linear deformations, relative shear deformations, relative dilatation, the maximum and the minimum elongation of the most important horizontal deformations and the directions of the maximum elongation. In Table 1, the maximum and the minimum elongation of the most important horizontal deformations, and dilatation are provided. In Table 2, the limits of changes of relative linear deformations and relative shear deformations between the data on measurements in three epochs are provided.

First of all, let's compare the indicators of horizontal deformations of the Earth's crust provided in the version I and the version II.

In the direction of the maximum elongation of the most important of horizontal deformations, positive values prevail. In the version I, deformations of 59 triangles of 69 are positive; and in the version II, deformations of 52 triangles are positive. The principal area of negative deformations is concentrated in the triangles 39–41, i.e. in the northern part of the territory of Lithuania (the territory of Linkuva Ridge).

**Table 1.** Characteristics of the Earth's crust horizontal deformations

| Triangle No. | Triangulation – $GPS_{1993}$ (version I) | | | Triangulation – $GPS_{2007}$ (version II) | | | $GPS_{1993}$ – $GPS_{2007}$ (version III) | | |
|---|---|---|---|---|---|---|---|---|---|
| | $\varepsilon_1 \cdot 10^{-6}$ | $\varepsilon_2 \cdot 10^{-6}$ | $\Delta \cdot 10^{-6}$ | $\varepsilon_1 \cdot 10^{-6}$ | $\varepsilon_2 \cdot 10^{-6}$ | $\Delta \cdot 10^{-6}$ | $\varepsilon_1 \cdot 10^{-6}$ | $\varepsilon_2 \cdot 10^{-6}$ | $\Delta \cdot 10^{-6}$ |
| 1 | 1.342 | −2.704 | −1.362 | 1.357 | −2.644 | −1.287 | 0.349 | −0.274 | 0.075 |
| 2 | −0.473 | −6.701 | −7.174 | −1.128 | −6.326 | −7.454 | 0.477 | −0.757 | −0.280 |
| 3 | 1.921 | −6.125 | −4.204 | 1.663 | −6.089 | −4.426 | 0.394 | −0.616 | −0.223 |
| 4 | −1.608 | −9.375 | −10.983 | −1.173 | −8.877 | −10.050 | 0.791 | 0.142 | 0.933 |
| 5 | 0.874 | −6.442 | −5.569 | 1.262 | −6.570 | −5.308 | 0.605 | −0.344 | 0.261 |
| 6 | 0.274 | −4.525 | −4.251 | 0.439 | −4.729 | −4.290 | 0.256 | −0.295 | −0.039 |
| 7 | −0.458 | −6.982 | −7.440 | −0.127 | −7.386 | −7.513 | 0.336 | −0.407 | −0.071 |
| 8 | 3.927 | −6.039 | −2.113 | 3.792 | −6.174 | −2.382 | 0.059 | −0.328 | −0.269 |
| 9 | 2.010 | −0.709 | 1.302 | 2.002 | −0.904 | 1.098 | 0.103 | −0.307 | −0.204 |
| 10 | 2.697 | −0.618 | 2.079 | 2.908 | −0.816 | 2.092 | 0.287 | −0.274 | 0.013 |
| 11 | 2.820 | 0.868 | 3.688 | 2.994 | 0.986 | 3.980 | 0.303 | −0.012 | 0.291 |
| 12 | 2.655 | −0.144 | 2.511 | 2.399 | −0.259 | 2.140 | 0.030 | −0.401 | −0.371 |
| 13 | 0.400 | −0.896 | −0.496 | 0.154 | −0.923 | −0.769 | 0.044 | −0.317 | −0.274 |
| 14 | 0.671 | −3.375 | −2.704 | 0.437 | −3.298 | −2.861 | 0.158 | −0.315 | −0.157 |
| 15 | 1.245 | −3.643 | −2.398 | 0.420 | −3.557 | −3.137 | 0.099 | −0.838 | −0.739 |
| 16 | −0.571 | −9.642 | −10.213 | −0.881 | −9.983 | −10.864 | −0.253 | −0.397 | −0.651 |
| 17 | 3.727 | 0.745 | 4.473 | 3.665 | 0.139 | 3.804 | 0.204 | −0.874 | −0.669 |
| 18 | 3.639 | −2.188 | 1.451 | 3.698 | −2.104 | 1.594 | 0.210 | −0.066 | 0.144 |
| 19 | 7.412 | −6.393 | 1.019 | 7.623 | −6.570 | 1.053 | 0.296 | −0.261 | 0.034 |
| 20 | 7.789 | 0.823 | 8.612 | 7.985 | 0.492 | 8.477 | 0.228 | −0.362 | −0.134 |
| 21 | 2.312 | 0.474 | 2.786 | 1.938 | 0.210 | 2.148 | −0.248 | −0.388 | −0.636 |
| 22 | 2.440 | 1.397 | 3.837 | 2.463 | 1.026 | 3.489 | 0.079 | −0.428 | −0.348 |
| 23 | 19.922 | −15.308 | 4.614 | 20.832 | −14.727 | 6.105 | 1.160 | 0.328 | 1.488 |
| 24 | −0.849 | −3.604 | −4.453 | −0.953 | −3.727 | −4.680 | 0.084 | −0.311 | −0.227 |
| 25 | 0.981 | −3.536 | −2.555 | 0.800 | −3.285 | −2.485 | 0.270 | −0.199 | 0.071 |
| 26 | 0.701 | −0.959 | −0.258 | 0.611 | −1.067 | −0.457 | 0.044 | −0.243 | −0.199 |
| 27 | 4.010 | −4.860 | −0.850 | 4.032 | −4.859 | −0.827 | 0.059 | −0.036 | 0.023 |
| 28 | 4.526 | −5.112 | −0.586 | 4.344 | −5.396 | −1.052 | 0.061 | −0.528 | −0.467 |
| 29 | 1.956 | −4.848 | −2.892 | 1.484 | −4.844 | −3.360 | 0.047 | −0.514 | −0.467 |
| 30 | 0.439 | −2.855 | −2.415 | 0.057 | −3.042 | −2.985 | −0.111 | −0.458 | −0.569 |
| 31 | 2.877 | −0.619 | 2.258 | 3.213 | −0.833 | 2.380 | 0.573 | −0.451 | 0.122 |
| 32 | 1.498 | −0.813 | 0.685 | 1.617 | −0.661 | 0.956 | 0.344 | −0.073 | 0.271 |
| 33 | 5.992 | 0.023 | 6.015 | 5.714 | −0.289 | 5.425 | 0.060 | −0.650 | −0.590 |
| 34 | 3.773 | −1.166 | 2.607 | 3.149 | −1.341 | 1.808 | −0.154 | −0.645 | −0.799 |
| 35 | 7.164 | −7.573 | −0.409 | 6.744 | −7.710 | −0.966 | −0.125 | −0.431 | −0.556 |
| 36 | 3.279 | −8.822 | −5.543 | 3.101 | −9.026 | −5.924 | −0.142 | −0.238 | −0.381 |
| 37 | 2.579 | −2.123 | 0.457 | 2.835 | −2.363 | 0.472 | 0.257 | −0.241 | 0.016 |
| 38 | 2.085 | −2.174 | −0.089 | 2.246 | −2.305 | −0.060 | 0.197 | −0.167 | 0.030 |
| 39 | −0.537 | −11.220 | −11.757 | −0.549 | −11.431 | −11.980 | 0.060 | −0.286 | −0.226 |
| 40 | −0.521 | −7.044 | −7.565 | −0.595 | −7.150 | −7.745 | −0.037 | −0.142 | −0.180 |
| 41 | −1.231 | −4.892 | −6.123 | −0.826 | −4.934 | −5.760 | 0.439 | −0.076 | 0.364 |
| 42 | 2.599 | −5.023 | −2.424 | 2.834 | −5.152 | −2.318 | 0.273 | −0.167 | 0.106 |

*End of Table 1*

| Triangle No. | Triangulation – $GPS_{1993}$ (version I) | | | Triangulation – $GPS_{2007}$ (version II) | | | $GPS_{1993}$ – $GPS_{2007}$ (version III) | | |
|---|---|---|---|---|---|---|---|---|---|
| | $\varepsilon_1 \cdot 10^{-6}$ | $\varepsilon_2 \cdot 10^{-6}$ | $\Delta \cdot 10^{-6}$ | $\varepsilon_1 \cdot 10^{-6}$ | $\varepsilon_2 \cdot 10^{-6}$ | $\Delta \cdot 10^{-6}$ | $\varepsilon_1 \cdot 10^{-6}$ | $\varepsilon_2 \cdot 10^{-6}$ | $\Delta \cdot 10^{-6}$ |
| 43 | 1.401 | −2.929 | −1.528 | 1.303 | −3.216 | −1.913 | −0.017 | −0.368 | −0.385 |
| 44 | 1.942 | −1.676 | 0.266 | 1.618 | −1.987 | −0.370 | −0.291 | −0.345 | −0.636 |
| 45 | 1.890 | −3.794 | −1.904 | 1.584 | −4.102 | −2.518 | −0.296 | −0.318 | −0.614 |
| 46 | −0.360 | −3.834 | −4.194 | −0.487 | −4.130 | −4.617 | −0.119 | −0.304 | −0.423 |
| 47 | 1.216 | −2.904 | −1.688 | 0.904 | −3.135 | −2.231 | −0.169 | −0.373 | −0.542 |
| 48 | 2.900 | 0.664 | 3.564 | 3.133 | 0.379 | 3.512 | 0.257 | −0.309 | −0.053 |
| 49 | 3.189 | 0.809 | 3.998 | 3.142 | 0.694 | 3.836 | 0.050 | −0.212 | −0.162 |
| 50 | 2.457 | −5.138 | −2.681 | 2.307 | −5.185 | −2.878 | 0.097 | −0.292 | −0.195 |
| 51 | 0.053 | −27.633 | −27.580 | −0.320 | −27.230 | −27.550 | 0.461 | −0.430 | 0.031 |
| 52 | 15.184 | −29.424 | −14.240 | 14.974 | −28.744 | −13.770 | 0.698 | −0.236 | 0.461 |
| 53 | 3.947 | −5.248 | −1.301 | 3.823 | −5.615 | −1.792 | −0.004 | −0.487 | −0.490 |
| 54 | 14.407 | −20.618 | −6.211 | 13.893 | −20.558 | −6.665 | 0.121 | −0.574 | −0.453 |
| 55 | 0.297 | −1.184 | −0.887 | 0.264 | −1.121 | −0.857 | 0.164 | −0.134 | 0.030 |
| 56 | 3.064 | −1.174 | 1.890 | 3.048 | −1.076 | 1.971 | 0.189 | −0.108 | 0.081 |
| 57 | 2.745 | −1.131 | 1.613 | 2.552 | −1.226 | 1.326 | −0.070 | −0.218 | −0.288 |
| 58 | 4.059 | −2.737 | 1.322 | 3.833 | −2.800 | 1.033 | −0.053 | −0.237 | −0.290 |
| 59 | 1.600 | −2.849 | −1.249 | 1.260 | −2.950 | −1.690 | −0.056 | −0.386 | −0.441 |
| 60 | 2.140 | −1.595 | 0.545 | 1.975 | −1.748 | 0.227 | 0.041 | −0.360 | −0.319 |
| 61 | 1.606 | −0.523 | 1.083 | 1.721 | −0.587 | 1.134 | 0.293 | −0.243 | 0.051 |
| 62 | 0.697 | −1.294 | −0.598 | 0.504 | −1.386 | −0.882 | −0.033 | −0.251 | −0.285 |
| 63 | 0.515 | −1.710 | −1.195 | 0.453 | −1.301 | −0.849 | 0.447 | −0.101 | 0.346 |
| 64 | 0.007 | −4.448 | −4.442 | 0.121 | −4.141 | −4.020 | 0.665 | −0.243 | 0.421 |
| 65 | 6.657 | −4.113 | 2.544 | 6.869 | −3.589 | 3.280 | 0.695 | 0.041 | 0.736 |
| 66 | 3.460 | −1.204 | 2.256 | 3.438 | −1.252 | 2.187 | 0.069 | −0.139 | −0.070 |
| 67 | 1.513 | −1.193 | 0.320 | 1.400 | −1.282 | 0.118 | 0.125 | −0.327 | −0.202 |
| 68 | 5.088 | −3.506 | 1.582 | 4.854 | −3.673 | 1.181 | −0.149 | −0.251 | −0.400 |
| 69 | −0.589 | −3.501 | −4.090 | −0.686 | −3.668 | −4.354 | −0.081 | −0.183 | −0.264 |

In the direction of the minimum elongation of the most important of horizontal deformations, negative values prevail: in the version I, deformations of 61 triangles are negative; and in the version II, deformations of 62 triangles are negative. The maximum negative value of the minimum relative elongation is found in the triangle 52 and the maximum positive elongation – in the triangle 22.

In both versions, the maximum negative value of the maximum relative elongation is found in the triangle 4 and the maximum positive value of it – in the triangle 23 (Table 2).

Dilatation of 38 out of 69 triangles (the version I) and 42 triangles out of 69 (the version II) is negative. In both versions, the maximum negative value of the maximum dilatation is found in the triangle 51 and the maximum positive value of it – in the triangle 20.

**Table 2.** Characteristics of the Earth's crust horizontal deformations

| Triangulation – $GPS_{1993}$ (version I) | | | |
|---|---|---|---|
| $\varepsilon_{xx} \cdot 10^{-6}$ | −16.160–11.960 | $\varepsilon_1 \cdot 10^{-6}$ | −1.608–19.922 |
| $\varepsilon_{yy} \cdot 10^{-6}$ | −26.200–12.890 | $\varepsilon_2 \cdot 10^{-6}$ | −29.424–1.397 |
| $\varepsilon_{xy} \cdot 10^{-6}$ | −28.163–27.674 | $\Delta \cdot 10^{-6}$ | −27.580–8.612 |
| **Triangulation – $GPS_{2007}$ (version II)** | | | |
| $\varepsilon_{xx} \cdot 10^{-6}$ | −16.300–11.880 | $\varepsilon_1 \cdot 10^{-6}$ | −1.173–20.832 |
| $\varepsilon_{yy} \cdot 10^{-6}$ | −25.650–14,040 | $\varepsilon_2 \cdot 10^{-6}$ | −28.744–1.026 |
| $\varepsilon_{xy} \cdot 10^{-6}$ | −27.957–26.882 | $\Delta \cdot 10^{-6}$ | −25.550–8.477 |
| **$GPS_{1993}$ – $GPS_{2007}$ (version III)** | | | |
| $\varepsilon_{xx} \cdot 10^{-6}$ | −0.645–0.787 | $\varepsilon_1 \cdot 10^{-6}$ | −0.296–1.160 |
| $\varepsilon_{yy} \cdot 10^{-6}$ | −0.467–1.147 | $\varepsilon_2 \cdot 10^{-6}$ | −0.874–0.328 |
| $\varepsilon_{xy} \cdot 10^{-6}$ | −1.066–0.788 | $\Delta \cdot 10^{-6}$ | −0.799–1.488 |

If data on geodetic measurements (triangular and GPS) of different accuracy are used in investigation of movement of the Earth's crust, only general regularities of its indicators can be identified. For assessment of reliability of the values of individual numerical indicators of horizontal deformations of the Earth's crust, the data of the repeated measurement of Lithuanian GPS networks of the class 0 and the class 1 were used (the version III).

In the version III, in the direction of maximum relative elongation, positive horizontal deformations prevail (the total of 50 triangles) and in the direction of the minimum relative elongation, negative deformations prevail (the total of 66 triangles). The principal area of negative deformations is concentrated in the middle part of Lithuania (the triangles 33–36 and 43–46). Positive deformations are found in the triangles 1, 4 and 23. Values of dilatation are negative in 45 triangles. More considerable changes of dilatation are found in the north – in the zones of faults near Telšiai and Mažeikiai.

At Figs 2 and 3 isograms of the maximum and the minimum elongation of the most important horizontal deformations are provided.

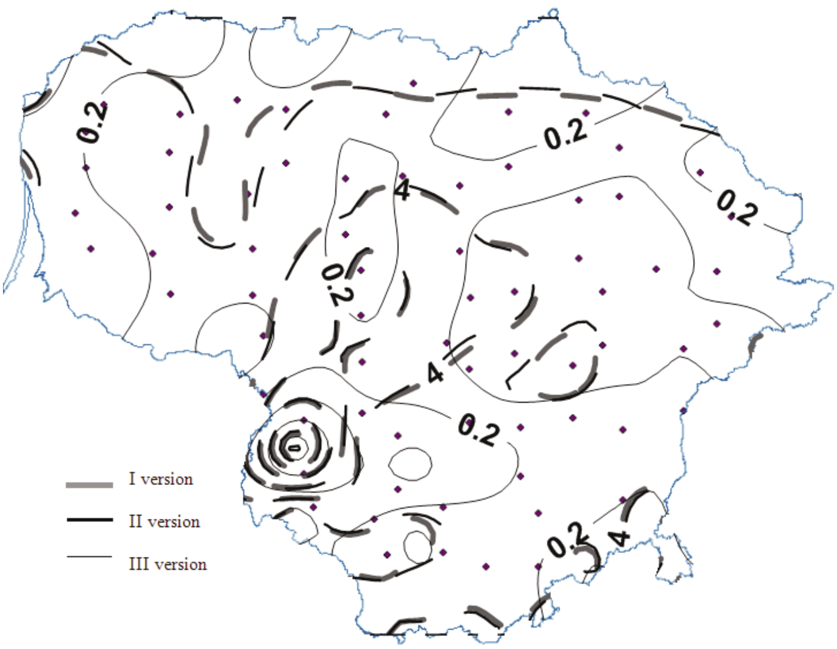


**Fig. 2.** The isogram of the maximum related elongation

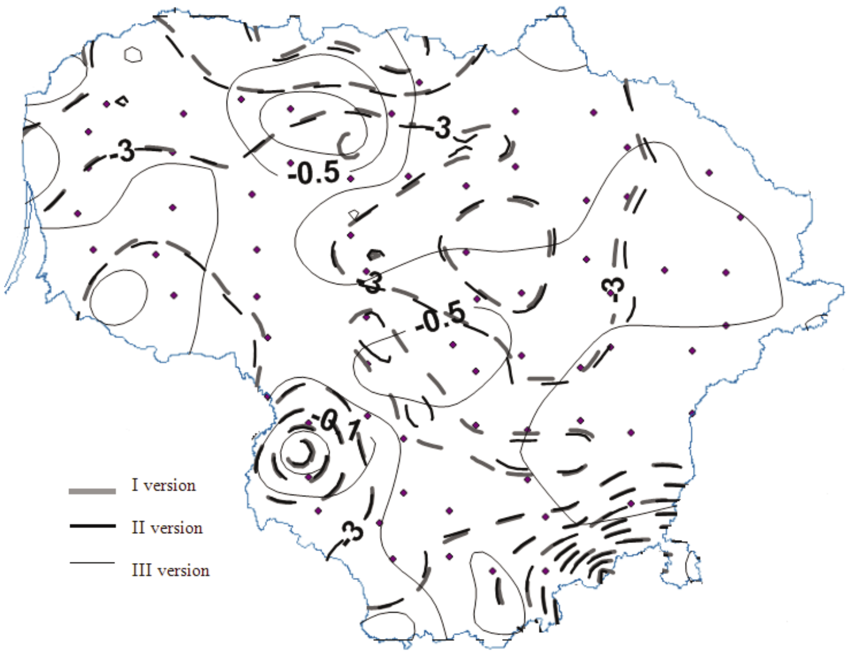


**Fig. 3.** The isogram of the minimum related elongation

As it can be seen from the isograms, the dislocation of isolines of the indicators of the maximum and the minimum elongations related to the most important horizontal deformations coincides in the version I and the version II. In the version III, the dislocation of isolines of the indicators differs from two first versions; however, the general trends remain unchanged.

Changes of the gradients of horizontal movements are more significant at potentially seismogenic zones. They are particularly significant in the zone of faults near Raseiniai. Less significant changes are found in the zones of faults near Tauragė as well as in the eastern and south-eastern parts of Lithuania.

More significant changes of the minimum relative elongation take place in zones of faults of Klaipėda and Telšiai regions (between the faults of Šilalė and Tauragė regions) and in zones of faults in the south-eastern Lithuania. In addition, territories of the Middle Lithuania, Jurbarkas and Raseiniai regions should be singled out as well.

The obtained results show that the undertaken investigation, presented in this paper, ant the obtained indicators of horizontal deformations of the Earth's crust correlate with the results of the works carried out by A. Zakarevičius (2003) and A. Stanionis (2005). Although the territory of Lithuania is considered an aseismic region, summarization of the results of the investigation on horizontal movement of the Earth's crust suggests that the territory of Lithuania is geodynamically active. In all versions, the values of the gradients of the maximum and the minimum elongation of the most important horizontal movement are fixed at borders of deep blocks of the lithosphere.

## 4. Conclusions

The properties of the Earth's crust movement and their regularities assessed according to the data of geodetic measurements of different accuracy reflect general trends of the movement only. More detailed values of numerical indicators of horizontal deformations of the Earth's crust were obtained while carrying out investigation according to the repeated GPS measurement.

The limits of changes of relative linear and relative shear deformations are: $\varepsilon_{xx}$ varies between $-16.300\cdot10^{-6}$ and $11.960\cdot10^{-6}$, $\varepsilon_{yy}$ varies between $-26.200\cdot10^{-6}$ and $14.040\cdot10^{-6}$, $\varepsilon_{xy}$ varies between $-28.163\cdot10^{-6}$ and $27.674\cdot10^{-6}$ (versions I and II); $\varepsilon_{xx}$ varies between $-0.645\cdot10^{-6}$ and $0.787\cdot10^{-6}$, $\varepsilon_{yy}$ varies between $-0.467\cdot10^{-6}$ and $1.147\cdot10^{-6}$, $\varepsilon_{xy}$ varies between $-1.066\cdot10^{-6}$ and $0.788\cdot10^{-6}$ (version III).

The limits of the dilatation varies between $-27.580\cdot10^{-6}$ and $8.612\cdot10^{-6}$ (versions I and II); between $-0.799\cdot10^{-6}$ and $1.488\cdot10^{-6}$ (version III).

The limits of changes of the maximum relative elongation are: $\varepsilon_1$ varies between $-1.608\cdot10^{-6}$ and $20.832\cdot10^{-6}$, $\varepsilon_2$ varies between $-29.424\cdot10^{-6}$ and $1.397\cdot10^{-6}$ (versions I and II), $\varepsilon_1$ varies between $-0.296\cdot10^{-6}$ and $1.160\cdot10^{-6}$, $\varepsilon_2$ varies between $-0.874\cdot10^{-6}$ and $0.328\cdot10^{-6}$ (version III).

After summarizing the results of the investigation on horizontal Earth's crust movement, it may be supposed that the territory of Lithuania is geodynamically active.

A distribution of the values of gradients of the maximum and the minimum relative elongations of the most important horizontal movements in all versions is found at borders of deep blocks of the lithosphere.

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