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EVIDENCES OF RECENT FAULT ACTIVITY IN LITHUANIA FROM PRECISE GEODETIC LEVELLING DATA

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Abstract. Located in the western section of the East European Craton, which is overlain by the Baltic sedimentary basin, Lithuania is regarded as a tectonically stable area. The basin saw many stages of tectonic activity during the Phanerozoic, resulting in selective (often exploiting Proterozoic structural characteristics) faulting of the Earth's crust. This faulting activity peaked between 425 Ma and 410 Ma ago.
The National Levelling Network's frequent readings provide light on recent alterations to the vertical position of the earth. Subsidence and uplift patterns of a few millimeters per year have been mapped out in Lithuania. Contrasted with the underlying vertical motions, a number of zones with pronounced gradients were identified. Geological and geophysical data analysis has shown that these areas are often associated with faults and fault zones. The vertical displacements reach a rate of 0.5-1 mm/a. Such information is crucial for assessing the seismic risk and making strategic territorial decisions.

Keywords: Recent activity, faults, and geodetic leveling.

Introduction

Long before the turn of the century, Lithuania set up a national geodetic vertical network. In the time since then, other measuring initiatives have been conducted. The system was upgraded and remeasured between 1998 and 2006 (Petrokeviius et al., 1996; Petrokeviius et al., 1998; Petrokeviius et al., 2005; Parelinas et al., 2000; Zakareviius, 2003; Skeivalas, 2007). Repeated baseline height measurements allow for the identification of ground level fluctuations that are vertical in nature and are indicative of recent tectonic activity in the area. Zakareviius (2003; Zakareviius et al., 2008) conducted a comprehensive analysis of the current upheaval in Lithuania. However, hardly any research has been done on the recent activity of tectonic faults. Understanding fault activity is crucial for calculating seismic risk and making predictions about other geological processes (karst activity, land-slides, ground water flow, etc.).

1. Method

Drilling and geophysical data have identified faults in the sedimentary cover, and we utilized data from two measurement campaigns (1986 and 2006) to examine recent ground vertical motions along these faults.
Drilling data was analyzed to determine the patterns of evolution of recognized faults. Further evaluation of their neotectonic activity included analyzing the fault's effect on Quaternary cover and relief.

Fault tectonics of Lithuania

The sedimentary layer of Lithuania, which varies in thickness from 200 meters in the south to over 2,000 meters in the west, is faulted densely throughout its entire surface. The Late Caledonian period (425-410 Ma) is when the majority of faults were first developed. This is between the end of the Silurian and the beginning of the Devonian. As the Baltica continent clashed with Laurentia along the Scandinavian coast and East Avalonia along the North German and Polish edge, it triggered a period of faulting. Most of these faults in the Late Caledonian period run West to East and North to South. Throughout the subsequent geological eras, the faults remained active, but at a considerably reduced level of activity. As an additional note, faulting occurred throughout the Hercynian and Alpine tectonic phases.
In terms of size, the greatest faults in Lithuania are the Telsiai and Gargzdai faults (Fig1). In this case, the amplitudes are more than 150–200 m. The remaining faults have significantly smaller amplitudes, often under 50 m.

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2. Recent fault activity in Lithuania

Thirteen faults in Lithuania's territory have been active recently, as measured by the country's National Geodetic Vertical Network on several occasions between 1986 and 2006. These are, for the most part, large-scale faults that have been well delineated in the sedimentary layer. Those that define Recent fault activity is seen in the table below:

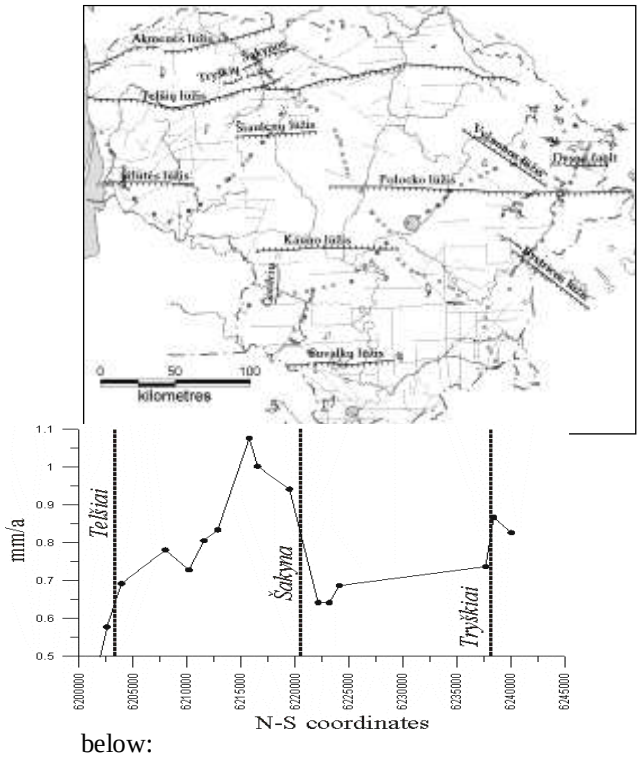

Table 1. Recent activity of faults

Fault name	Vertical movements mm/a	Relatively uplifting flank
Akmenė	0.13	northern
Telšiai	0.4	northern
Šakyna	0.3	northern
Tryškiai	0.1	southern
Šiaulėnai	0.2	northern
Šilutė	0.3	northern
Kaunas	0.15	southern
Giedriai	0.25	eastern
Suvalkai	0.7	northern
Vyžuona	0.1	southern
Dysna	0.9	southern
Polotsk	0.25	northern
Bystrica	0.15	northern

Recent vertical block movements along active faults have occurred at rates ranging from 0.1 mm/a to 0.9 mm/a (Table 1). Among these, the Suvalkai and Dysna faults (at 0.7 and 0.9 mm/a, respectively) are the most dynamic. Lower rates of 0.1-0.4 mm/a are seen for the other faults. These numbers are far less than those determined from places like the Ignalina NPP region, where measurements have been taken on an annual to multi-yearly basis. It's connected to the periodicity of small-scale vertical motions, such as elevation followed by depression. As a consequence, the resultant amplitude over a longer time period has a lower frequency..

Fig 1. Faults defined in the sedimentary cover (hatchet lines). Faults showing recent vertical movements are indicated by bold lines. Bergstrichs point to subsiding fault flanks. Stars show geodetic benchmarks. Rivers and lakes are shown

Eleven active faults have been identified, and eight of them run W-E. The Giedriai and Vyzuona faults strike north to south, while the Dysna fault runs northwest to southeast.

The greatest size Silute-Polatsk shear zone is located in the crystalline foundation and contains Silute and Polotsk faults. The Alpine structural complex (Permian-Cretaceous deposits) is where the Silute fault is most easily recognized, whereas the Polotsk fault is most easily located in the Devonian.

deposits (Hercynian structural complex) (Hercynian structural complex). Fault amplitudes may be up to 20 meters.

In the northern section of Lithuania, the Telsiai and

Akmene faults are the most well characterized examples of Late Caledonian faults. Northern flanks are being

lifted relative to the rest of the mountain range, as seen by these reversal faults (Fig2). The Sakyna and Tryskiai faults are tectonic phenomena associated with the larger scale Late Caledonian faults, however they are of a considerably lower order.

Fig 2. Rates of ground vertical motions across Telsiai,Sakyna and Tryskiai faults, north Lithuania

Suvalkai fault is the major fault defined in the southern part of Lithuania. Its amplitude exceeds 50 m. The fault was most active during Carboniferous – Early Permian times.

The defined faults showing recent activity are well reflected in the present relief that suggests their activity during the Quaternary time.

3. Geodynamic hazard related to active faults

The faults showing recent tectonic activity are considered as zones of increased geodynamic hazard. Theavailable seismological data seem to support this implication. Bystrica earthquake of 1908 was related

to the fault of the same name. The intensity of the earthquake is assessed as large as I_o=7 (MSK-64 scale). Kaunas fault is located in proximity to Skirsnemune earthquake of 1328. It is still debated as to reliability of this earthquake (Grünthal & Riedel, 2007). The historical descriptions, though, suggest high magnitude of the earthquake. Peter from Duisburg describes "…people were so scared of ground tremor that were about of throwing themselves down the castle walls). There is also a hint of seismic activity of Polotsk fault. Small earthquake was reported from Troskunai area in 1909.02.03. This event is considered of little confidence, but its location within the Polotsk zone is an interesting association that should not be neglected. Suvalkai fault extends along the Polish and Kaliningrad border. The Margrabova (Olecko) earthquake was registered in northernmost Poland in 1909.01.08 that is located within the influence zone of Suvalkai fault.

4. Conclusions

Recent activity on thirteen previously known faults in the Baltic basin sedimentary layer in Lithuania is shown by geodetic data. Speeds up to 0.9 mm/a are seen in the vertical direction. The most recent active fault population consists mostly of W-E faults. Some active faults have been linked to earthquakes, suggesting that these geological features provide a greater risk than others and should be included into any future land use decisions.

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