# KARST DENUDATION INTENSITY AND CLIMATE CHANGE. THE CASE OF THE NORTH LITHUANIA

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Karst processes and phenomena are intensively developing in North Lithuania (and partly in South Latvia). It's related with dissolution of sulphatic (mainly gypsum) interlayers of Upper Devonian formations, that occur under the 1–10 metres thick Quaternary cover. Due to quick dissolution of gypsum the sulphatic karst is developing much more rapidly comparing to carbonatic karst (Fig. 1, 2) (after Narbutas et al., 2001).

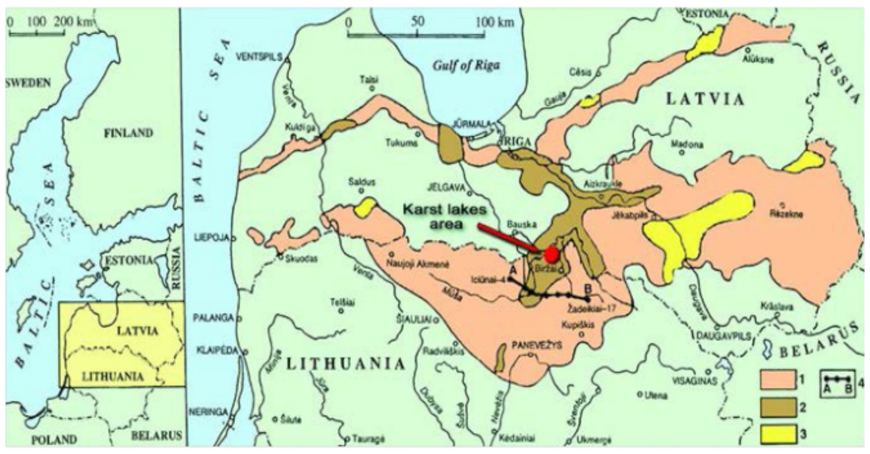


Fig. 1. Karstic area. 1 – carbonatic karst, 2 – sulphatic karst, 3 – intense carbonatic.

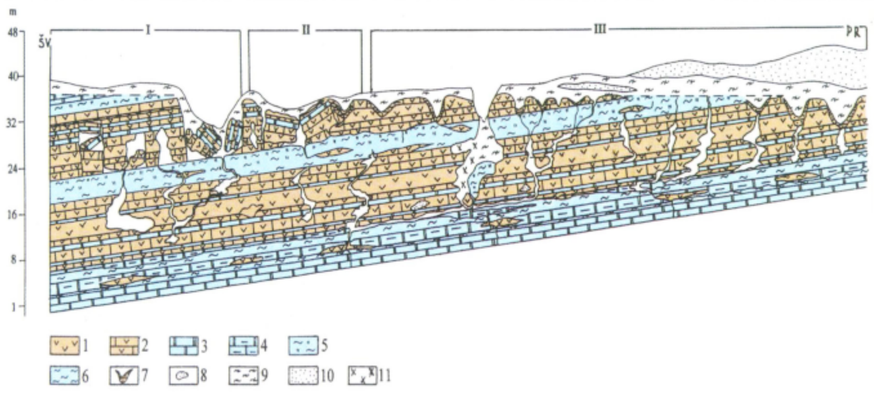


Fig. 2. Shematic geological cross-section of Upper Devonian Tatula formation.

North Lithuanian Karst Region occupies an area of 1046 km² (Fig. 3). In total there are counted over 11000 sinkholes of different age and size. Development of the karstic landscape is characterised by formation of new sinkholes, ground fissures, cavities, closed depressions and other phenomena. Besides geological conditions, intensity of the karst process is dependent on hydroclimatic factors: air temperature (Fig. 6), duration of seasonal frost period, amount of precipitation (Fig. 5) and its intensity of infiltration, saturation and fluctuations of groundwater that facilitates dissolution of sulphatic rocks (Satkūnas et al., 2007).

The monitoring of the karstic landscape is carried out by measuring of intensity of karstic gypsum chemical denudation and inventory (parametrisation) of karstic sinkholes. During the year 2018 it was found 38 new sinkholes of different size, in 2019 it was found 45 (15 new among them). All information on new karstic phenomena is stored and updated the Subsystem of Geological processes and phenomena of the Lithuanian Geological Survey (Mikulėnas et al., 2018).

During the last three decades of years more intense karst processes are indicated by new sinkholes that severely damage crops, constructions and communication systems. In farmland these phenomena are inconvenient at least, but in urban areas they constitute a geological hazard that can seriously affect development and human safety.

The climatic changes are proposed to be the main causes of karst process intensification – the higher amount of precipitation, especially during cold seasons, increase of temperature and warmer witers that in turn determines longer active circulation period between surface and groundwater. More intensive formation of sinkholes is expected in the case of climate warming and increasing precipitation. In order to prevent loses, engineering geological evaluation (mapping), hotspot areas investigation and relevant management means must be respectively more comprehensive. Definitely it's important to evaluate the loss of land surface due to karst phenomena as well as the velocity of the process.

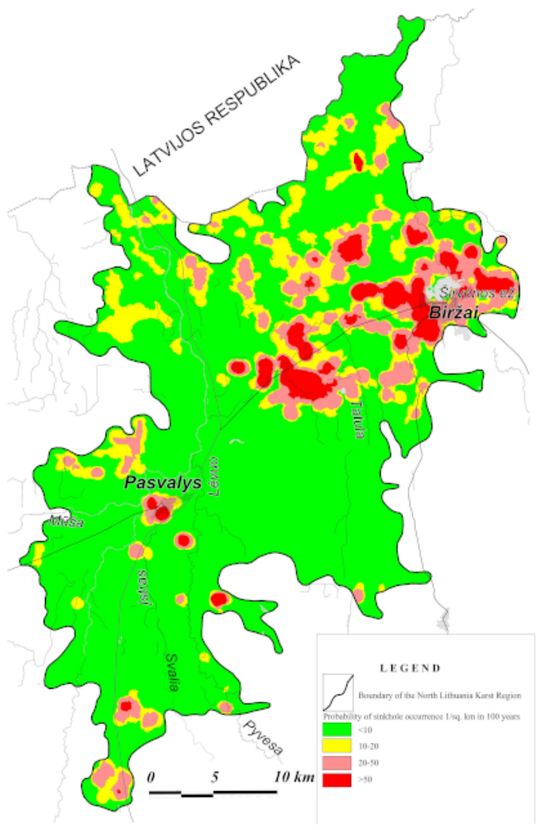


Fig. 3. Probability of sinkhole occurrence (Minkevičius, 2011).

The monitoring of the karstic chemical denudation is carried out in the North Lithuania since 1963 (with some gaps however) (Fig. 4). The monitoring of the karstic chemical denudation is based on measurements of chemical composition of surface and groundwater, thus enabling to determine amount of gypsum, dissolved and removed annually from the karstic region (the pattern river basin). The amount of dissolved gypsum is expressed via calculation as a space of cavities formed underground and measured as number of cubic metres of space formed during one year per one square kilometre of the karstic area.

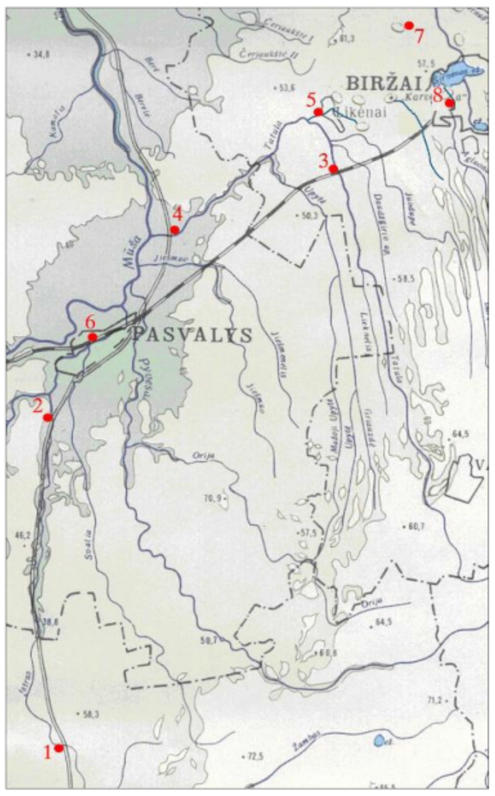


Fig. 4. Gypsum chemical denudation monitoring network.

Mean annual amount of dissolved gypsum in the pattern basin of the Tatula River (active sulphate karst zone) was 175 m³/km² during the period of measurements until 2019. Due to dry summer of 2019 the amount of denudation decreas-ed and was only 77 m³/km² (Fig. 7) (Taminskas, et al., 2019). It is noted that intensity denu-dation increased by 30% du-ring the period 1990–2019 and this period is characterised in general by climate change.

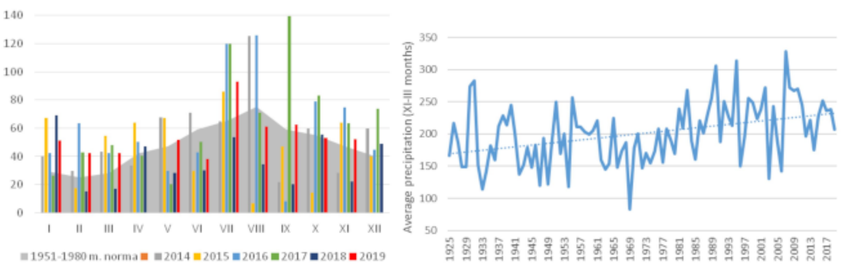


Fig. 5. Annual distribution of precipitation in Biržai WS, mm

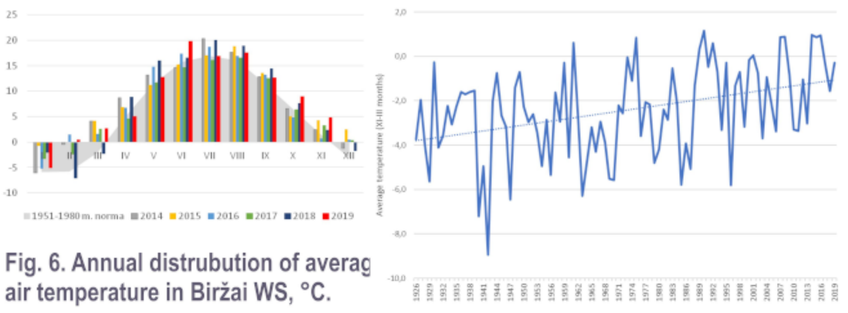


Fig. 6. Annual distrubution of averag air temperature in Biržai WS, °C.

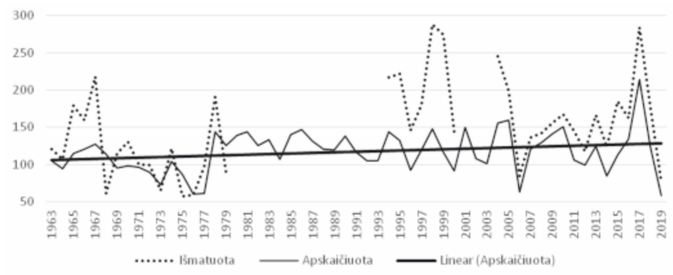


Fig. 7. Intensity of gypsum chemical denudation in Tatula River basin, m³/km² per year.

Increase of gypsum chemical denudation, generally is followed by more intensive occurrence of sinkholes, however direct correlation is still not established due to presence of number of other playing factors.

For instance, in 2017, which was exceptionally wet, it was recorded the highest rate of denudation during entire period of monitoring – even 284 m³/km²/ (54 % higher comparing with mean value of the period 1963–1979). However the increase of number of new sinkholes was not recorded in 2018.

We assume, the high groundwater level in the karstic cavities kept the cover of cavities stable and therefore conditions of forming new sinkholes were not favourable. Nevertheless, during the dry period, when the groundwater level dropped, active forming of sinkholes was not observed. It means that very complex factors are playing and determining collapse of sinkholes. It is proposed that rapid climate changes (wet or dry years, like 2017 and 2018) do not determine rapid increase the for-ming of new sinkholes. Gradual amelioration of climate, however, determines increase of gypsum chemical denudation.

In 2018 Lithuanian Geological Survey has started to use an unmanned aerial vehicle (UAV) for detection and mapping of karstic sinkholes and this methodology facilitated the inventory and registration of new phenomena (Mikulėnas at al., 2018). The Karajimiškis, Mantagailiškis, Drąseikiai, Naciūnai and Kirkilai areas (total 24 km²) were mapped the period 2018–2019.

Karstic lakelets in Kirkilai. K. Baronas, 2005

„Dry" karstic landscape in Padaičiai. K. Baronas, 2005

Karstic collapse sinkhole in Dauménai. V. Mikulėnas, 2005

9.5 m depth sinkhole appeared in the field of JSC Naradava apple garden. K. Baronas, 2013

The biggest deep sinkhole of 2017 appeared in the farmstead of Drąseikiai village. It was round shaped, 7.5 m in diameter and reached 2.1 m depth, 2/3 filled by water. B. Dagys, 2017

## References

Mikulėnas V., Minkevičius V., Danielius S., Taminskas J., Linkevičienė R., Dilys K., Dagys B. 2019. Monitoring of the karstic landscape and investigations of chemical denudation in 2018. Annual report of Lithuanian Geological Survey, 2018.

Satkūnas J., Marcinkevičius V., Mikulėnas V., Taminskas J. Rapid development of karst landscape in North Lithuania – monitoring of denudation rate, site investigations and implications for management // GFF. – 2007. –Vol.129, Pt. 4. – P. 345–350: iliustr. – Bibliogr.: p. 350.

Narbutas V., Linčius A., Marcinkevičius V. Devono uolienų karstas ir aplinkosaugos problemos Šiaurės Lietuvoje: monografija = Karst of the Devonian rocks and the problems of environment protection in North Lithuania : Monograph / Geologijos institutas, VšĮ „Tatulos programa". – Vilnius: Agora, 2001. – 191 p.: iliustr. – Santr. angl. – Bibliogr.: p. 170–180. – 551.435.8

Minkevičius V. Šiaurės Lietuvos karstinio rajono teritorijos pastovumo karsto atžvilgiu žemėlapis = Stability map of the territory of North Lithuanian karst region // Lietuvos geologijos tarnybos 2010 metų veiklos rezultatai : [metinė ataskaita] = Lithuanian Geological Survey: Annual Report 2010. – Vilnius: LGT, 2011. – P. 60–61: iliustr. – Santr. angl.

Šiaurės Lietuvos karstinio rajono gipso cheminės denudacijos monitoringas 2019 metais / Taminskas J., R. Linkevičienė, Dilys K., Skuodienė N.; Gamtos tyrimų centras. – Vilnius, 2019. – 45 p.