

## The main causes of landslide hazards in Kyiv region, Ukraine

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### SUMMARY

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The consideration is given to the main factors of the formation of gravitational processes within the Kyiv city. The decisive role of the tectonic regime of the region, the specific state of the geological environment, in particular lithological and stratigraphic conditions, geomorphological features, hydrogeological regime, meteorological conditions, as well as man-made loads on the slopes are demonstrated. The combination and priority of these factors determine the mechanism and conditions for the mass movements within Kyiv. A database of landslides has been developed. The observations include the long-term field research of more than 120 landslides and landslide-prone areas. It was proved the multi-factor character of the landslides formation, which is the basis for a detailed study of landslides at the large scale.



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## Introduction

One of the regions of the active formation of landslide processes within the Middle Dnieper area is the Kyiv city, where more than 120 landslides have been recorded (Fig. 1). The total number of slides from year to year changes due to occurrence of new landslides under the influence of the geologic and hydrometeorological factors. The most dangerous districts in terms of landslide hazard are currently Podilskyi, Pecherskyi and Holsiivskyi. Lithological, stratigraphic, geomorphological and hydrogeological conditions in conjunction with the hydrometeorological factor determine the intensive formation of landslide processes (Ivanik *et al.*, 2012, 2019a). A specific category of factors includes dynamic processes that change the state of slopes, including erosion processes, weathering, tectonic regime of the territory, seismicity and man-made loads on slopes (Ivanik *et al.*, 2020a, 2019b). The combination and priority of these factors determine the mechanism and conditions of gravitational processes formation.



**Figure 1** Distribution of landslides within Kyiv city

## Main causes of the landslide hazard

Landslides in the studied areas are associated with *specific features* of Kyiv terrain (significant horizontal and vertical differentiation, elevation differences, fluctuations of the erosion base level and slope angles) and the state of the *geological environment* of the right bank of Kyiv (Shevchuk *et al.*, 2019). In most of the studied landslides, the hydrometeorological factor was one of the priority factors of landslides initiating, which led to the intensification of numerous landslide processes in 2013 due to a significant amount of precipitation, causing the excessive water saturation of soils. Currently, the studied landslides are considered to be temporarily stabilized due to the implementation of anti-landslide measures from 2014 to 2018 years. The need to study the selected model areas have arisen because despite the conditional stabilization of slopes, landslides pose a real threat to the functioning of infrastructure objects, in particular:

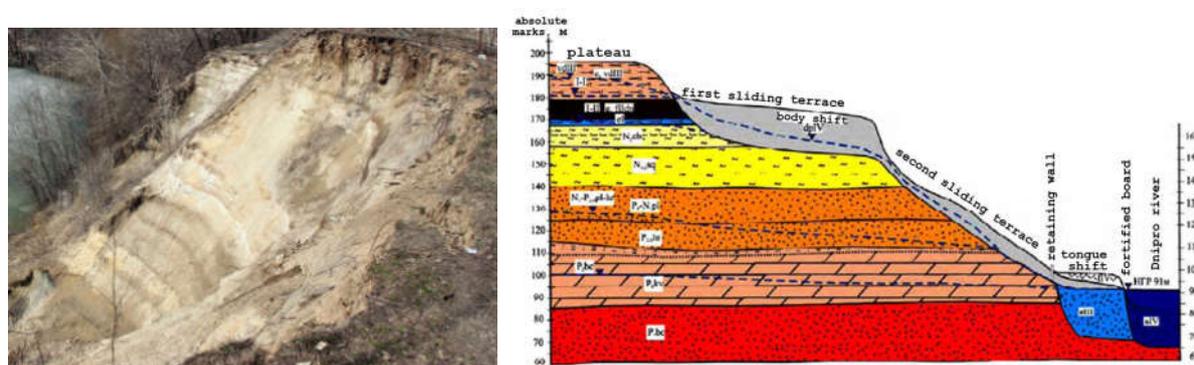


- Landslide within *lake Glynka* continues to threaten the functioning of the trunk pipeline and residential building at Filatova st.;
- Landslides within *Lysa mountain* possess a real damage of the railway along the Stolychne highway;
- Residential buildings close to landslides within *Baty* and *Zamkova mountains* are at risk.

**Tectonic regime.** Tectonically, the Kyiv area is located within the Bila Tserkva (Fastovsky) block on the northern slope of the Ukrainian shield. The crystalline basement has a series of faults of the submeridional, sub-latitudinal, northeast, and north-west direction. The most active are regional structures with a difference in the indicators of total amplitudes of movements up to 60 m. The largest zone is part of the Kyiv fault, which corresponds to significant indicators of average velocity gradient of neotectonic movements (more than 0.01 (cm/km)/ths. years) (Ivanik, 2020a). The analysis of residual relief maps confirmed the intensification of tectonic uplifts during the Neogene-Quaternary stage and revealed local areas with the most active erosion-denudation activity. (Shevchuk et al, 2019).

**Lithological & stratigraphic conditions.** One of the leading factors in the development of dangerous geological processes are the *lithological and stratigraphic factors*. Areas of development of hazardous geological processes are confined to certain formation complexes that have a complex spatio-temporal structure with the corresponding physical and mechanical properties of rock complexes (Ivanik et al., 2020b).

In the stratigraphy there are deposits of the Paleogene, Neogene and Quaternary systems (Fig. 2). The Paleogene rocks, which are represented by Eocene-Oligocene sediments of the Kharkivska series ( $P_{2-3}$  hr). The Neogene system is represented by sediments of Poltavska series ( $P_3 - N_1$  pl), Quaternary rocks are represented by sandy loamy rocks. The Kharkivska series are exposed, represented by blue-green clay silts (Obukhivska Suite,  $P_2$  ob), in which a weak-water horizon is formed, and green striped sands with interlayers of clays (Mezhygirskia Suite,  $P_3$  mž). Upper we can observe the sand silts of the Berek ( $P_3$  br) Suite of Oligocene. These formations are covered by Miocene deposits represented by quartz sands, siltstones and white loose fine sands of the Novopetrivska Suite ( $N_{1np}$ ) (Geological map, 2001). The area belongs to the glacial area of the northeastern periglacial subregion.



**Figure 2** Geological section, Kyiv region (Kuzmenko et al., 2017)

**Geomorphological conditions.** The main characteristics of the terrain that influence on the formation of gravitational and water-gravitational phenomena are the *steepness and height of the slopes*. A of the three-dimensional model of the relief, a map of the slopes and a map of the slopes exposition were constructed. Absolute elevations of sliding bodies position were defined. The most landslide-prone slopes are the southern exposure with the steepness of 15–20°, this parameter is one of the determinants for their formation (Ivanik et al., 2020b).



**Hydrogeological and hydrometeorological conditions.** The *hydrogeological conditions* of the slopes are associated with aquifers in the upper, middle Neopleistocene alluvial sediments, in the Middle-Lower Neopleistocene and Eopleistocene alluvial and lake sediments, in the Middle Neopleistocene aquatic-glacial, lacustrine-glacial loams, Lower Neopleistocene Eolian-Deluvial loams, in Mezhygirsky-Bereksky and Novopetrivsky sediments, Eocene sediments (Ivanik *et al.*, 2020b). *Hydrometeorological conditions* affecting the activation of landslides include significant rainfall and temperature regime. The influence of precipitation affects the stability of slopes, changing the regime of surface waters and groundwaters. The minimum stability of the slopes is observed during the excessive precipitation periods, which causes an increase in groundwater levels and saturation of soil masses. Saturated rocks that contribute to the activation of landslides are Quaternary and Oligocene deposits. The nearest to the surface aquifer is located at 10-12 m depth in the lower part of the loess layer, for which the brown clays of Neogene-Quaternary age are the level of sliding surface. They affect the formation of structural bevel displacements belonging to the first displacement zone (Bespalova, 2004). The temperature regime primarily determines the rate of soil moisture evaporation and the depth of soil freezing.

## Conclusions

The factors of formation and intensification of landslide processes have been identified within the city of Kyiv. Based on in-depth geological analysis, structural and morphometric studies, GIS analysis, systematization of factual material with the involvement of natural data, the role of lithological, stratigraphic, tectonic and geomorphological factors in the formation of gravitational processes have been studied. The zones of these processes formation are related to a certain formation complexes that have a complex spatial-temporal structure with the corresponding physical and mechanical properties of rocks. According to the analysis of cartographic and field data, the biggest landslide hazards belong to areas where there is a combination of several or more factors. It is proved that the existence of landslides phenomenon of any type and category requires a comprehensive integrated assessment of their factors with the identification of important complex relationships between components of the geological environment and defining the interdependencies between them.

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