

Landslide25_20**Monitoring of activation and neotectonic dependence of landslide processes within the Right Bank of Kyiv**

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SUMMARY

The article examines the relationship between landslide distribution and activation, and the neotectonic and modern tectonic structures of the Right Bank of Kyiv. Using high spatial resolution satellite data, active and relatively stabilized landslide areas were identified for the period from 2006 to 2024. Based on data from the Geological Service and our interpretation of the satellite data, a neotectonic map was compiled, featuring active tectonic blocks and discontinuities of various ranks. As a result of monitoring the development of landslide-prone areas, certain patterns of landslide localization were identified, depending on the tectonic structure of the territory. It has been established that intensification of gravity processes occurs in geodynamically unstable areas that tend to fluid-permeable zones that develop along the boundaries of neotectonic blocks. When conducting economic activities, especially large-scale construction, it is necessary to consider the neotectonic component of the territory and the attraction of slope landslide areas to zones of increased fluid permeability and rock decompaction.

Introduction

Landslide processes in the city of Kyiv are widespread on the right bank slopes of the Dnieper and the steep slopes of the valleys of the right bank tributaries of the Dnieper – Lybid, Klov, Syrets, and Nyvky – which cut into the plateau. Landslide areas are characterized by a multi-level geological structure with interlayering of water-permeable, water-saturated, and water-impermeable deposits. There are two areas of landslide development: the city area and the Dnipro area. Drainage tunnels, embankments, and tree plantations (phytomelioration) were laid on the slopes. Artificial changes in the hydrological regime of the Dnieper, intensive development of the slopes, and construction of the necessary communications network caused the activation of gravitational processes in the second half of the 19th century. Due to climate change in recent years, there has been an increase in torrential rainfall, leading to the activation of erosion, which may subsequently contribute to secondary flooding and landslide formation, all other conditions being equal. Factors influencing the development of landslides in the Dnieper region have been discussed in previous works (Filipovych et al, 2023; Lischenko et al., 2017).

In addition to the main geological, hydrogeological, geomorphological factors, and hydrometeorological prerequisites, in recent years, the development and activation of landslides has been provoked by anthropogenic factors (Zhydkova, and Chepurna, (2023) – slope undercutting, water supply network breaks, increased slope loading, disruption of its integrity due to large-scale construction, etc. Interference with the geological environment disrupts the hydrological regime, creates dam conditions, changes the angle of the surface, disrupts the geological integrity of rocks, and destroys tree stands and turf cover (Lyalko et al., 2016). During construction, the most landslide-prone areas are those that gravitate toward neotectonic active blocks and lineament zones, which are well traced (identified) by satellite data in the optical range and because of DTM (digital terrain model) analysis based on radar data. So, the main objective of the study is to identify the most vulnerable areas of the Right bank of Kyiv to the activation of landslide processes depending on the neotectonic structure of the Kyiv region.

Materials and methods of investigation

The main materials used in the work were satellite data of medium spatial resolution from the Landsat series (15, 30 m), Sentinel 2 (10 m), high (2 m), and ultra-high (0.5 m) spatial resolution from Pleiades, WorldView - 2,3, and QuickBird from different periods of satellite imaging. The former were used for neotectonic analysis of the territory and creation of a map of fault-block tectonics, while the high-precision data were used for georeferencing and outlining of landslide bodies.

In addition, geological data from the State Enterprise “Ukrainian Geological Company” (SE “UGC”) and the Municipal Enterprise Specialized Management of Landslide Prevention Underground Works (ME SMLPUW) were used. The fault-block structure of the territory is based on materials from the State Geological Map of Ukraine at a scale of 1:200,000 (sheet M-36-XIII) (Kovalev et al., 2001). To develop a map of the neotectonic, data from scientific research by the Institute of Environmental Geochemistry of the NAS of Ukraine (Yaroshchuk et al., 2020) and scientists from the S. Subbotin Institute of Geophysics of the NAS of Ukraine (Orlyuk et al, 2021) were used. The processing and interpretation of satellite data were carried out using standard methods in open-source software packages.

Results

As a result of the analysis of geological, neotectonic, geochemical and remote sensing data, cartographic models of fault-block tectonics of the Kyiv region with localization of landslide processes for the period 2006-2024 were developed (Fig. 1-3). According to these models, landslides are concentrated in the intersection zone of large faults that have roots in the consolidated basement and have become active at the neotectonic stage. At the same time, these faults are block separations of the II and III order, along which geochemical and geophysical anomalies are observed (Yaroshchuk et al., 2020; Orlyuk et al., 2021). Often,

such zones are considered zones of geodynamic stress discharge.

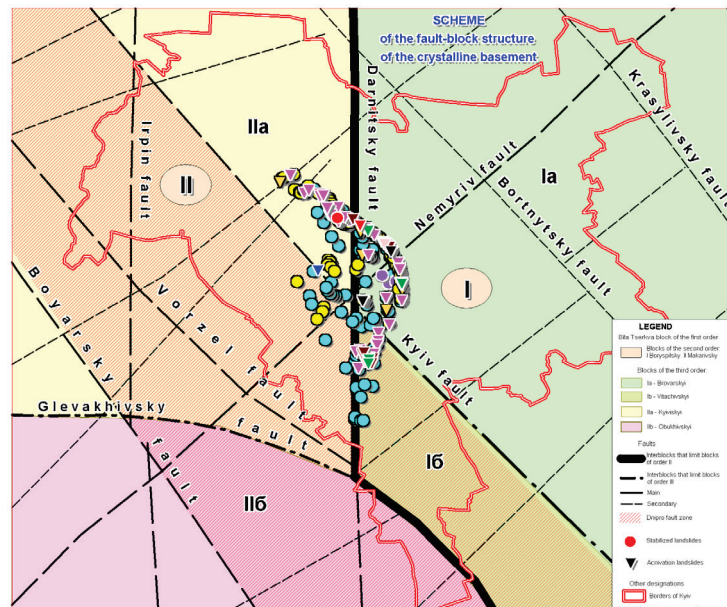


Figure 1. Scheme of the fault-block structure of the crystalline basement with temporarily stabilized and active landslides localized at different times. (Using the data: Kovalev et al., 2001; Orlyuk et al., 2021)

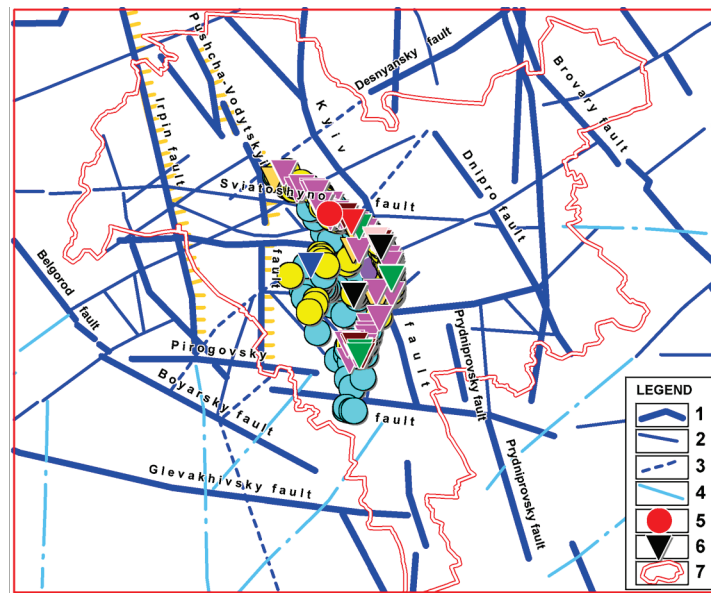


Figure 2. Scheme of neotectonic activity of fault tectonics. (Based on data from Starostenko et al., 2001; Yaroshchuk et al., 2020 and Orliuk. et al. 2021)

Legend: 1 - Faults detected in the crystalline basement, the neotectonic activity of which is confirmed by geological and geomorphological data. 2 - Faults detected in the crystalline basement, the neotectonic activity of which is not currently confirmed by geological and geomorphological features; 3 - The faults are predictable, the neotectonic activity of which is confirmed by geological and geomorphological data. 4 - Lineaments identified by landscape and geomorphological features; 5 - Temporarily stabilized

landslides (different years, shown in color). 6 - Activated landslides (different years, shown in color). 7 – Borders of Kyiv

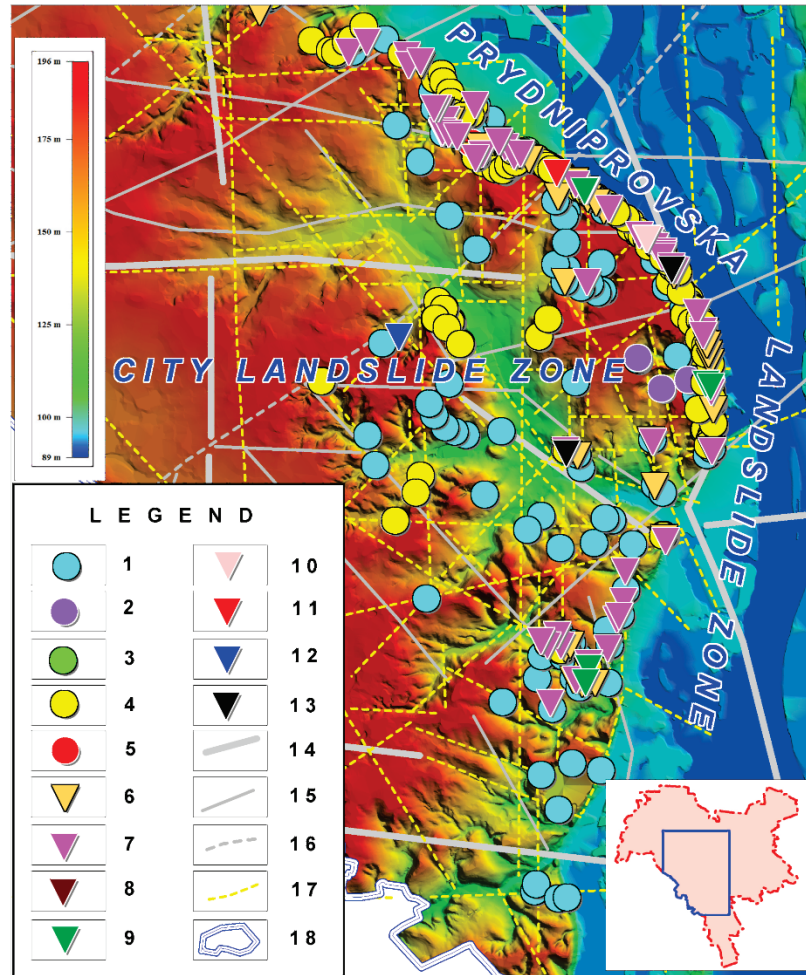


Figure 3. Map of fault-lineament grid comparison with localization and activation of landslides

Legend Development of the landslides at the territory of Kyiv: Temporarily stable landslides during 2006-2024: 1 - 206-2013; 2 – 2017; 3- 2018; 4- 2019; 5- 2024. Active landslides: 6- 2013; 7- 2016; 8- 2016; 9- 2018; 10- 2019; 11- 2021; 12- 2023; 13-2024. Faults: 14- Faults detected in the crystalline basement, the neotectonic activity of which is confirmed by geological and geomorphological data; 15- Faults detected in the crystalline basement, the neotectonic activity of which is not currently confirmed by geological and geomorphological features; 16- The faults are predictable, the neotectonic activity of which is confirmed by geological and geomorphological data; 17- Lineaments according to aerospace research; 18- Borders of Kyiv

Most of the natural landslide activations tend to occur along the Kyiv neotectonically active fault. For example, throughout the Khudozhnykiv Alley observation deck, there was a landslide of the topsoil due to its natural water saturation in 2018 and further activation in 2019 and 2021. Also in May 2024, there was an activation throughout the landslide circus on Dniprovskyi Descent along the sidewalk of the highway. The landslide occurred within the Late Miocene mottled clay layer, caused by the steepness of the slope and groundwater outflow. Landslide processes are periodically activated throughout Lake Hlynka, which is within the former quarry, where its northeastern slopes tend to the neotectonically active Chorna Hora

area and the corresponding lineaments that limit it. Despite the drainage adit, the landslide with an area of 1900 m² and a length of up to 20 m has been active since 2013 due to groundwater outflow and subsidence because of suffosion processes. A man-made landslide occurred in 2023 in Solomianskyi Landscape Park on the right bank slope of the Lybid River due to the undercutting of the slope by a pit during the construction of an office business center at 1-3 Generala Shapovalova Street. The 20-meter-high steep slope was out of balance, and the Kyiv marls of the Eocene were squeezed out, and the landslide body slid northward with a significant wall tear. This area belongs to a neotectonically active, landslide-prone, and fluid-permeable zone along the northeastern strike. Any geological disturbance should account for active tectonic blocks and faults.

Conclusion

Based on a comprehensive analysis of remote data, digital elevation models, in-house ground surveys, and existing factual material, new specialized thematic layers of the developed GIS were created to determine the localization of active landslides to neotectonically active blocks and faults. For this purpose, maps of the block structure of the basement and the construction of neotectonically active faults and blocks based on satellite data interpretation were used. As a result of the full range of studies, the forecast zones and areas with the maximum degree of landslide hazard were identified, which are fully compared with the areas of modern landslide activation, both natural and man-made, that occurred during 2006-2024. During the construction, it is necessary to consider the neotectonic zoning of the territory and the tendency of slope landslide areas to areas of increased fluid permeability and rock loosening.

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