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THE SINKHOLES OF THE SURFACE TIER OF MINING LANDSCAPES IN THE KRYVYI RIH LANDSCAPE-TECHNICAL SYSTEM

The Kryvyi Rih landscape-technical system (the KLTS) is a system that was formed 150 years ago and has completely transformed natural landscapes into anthropogenic ones in such a short period of time. Mining landscapes are of particular importance in the KLTS, which are complex dynamic systems that determine the emergence of derivative processes and phenomena [4]. They are the leading factors in the formation of the surface tier of mining landscapes and cause natural and technological emergencies. The surface tier of the KLTS mining landscapes is represented by surface facilities and structures: quarries, dumps, sludge dumps, mining and processing plants, etc [3]. During active mining of iron ore in the KLTS, derivative processes and phenomena appear on the surface layer, which lead to the emergence of technogenic hazards, especially in the KLTS landslide zones.

Earth surface displacement zones usually arise as a result of underground mining, and this, in turn, forms a dip and subsidence relief on the surface layer.

The dip relief is actively developing in the northern and central part of the KLTS. The sinkhole relief is the end result of the process of rock displacement, which is activated by the use of a subsurface rock collapse system during mining operations [2]. The essence of such system is that the roof of underground cavities of significant total volumes, which are formed after mines have mined the upper horizons of ore-bearing layers (up to 300 m in depth), is artificially collapsed, thus filling the space. According to G.I. Chernoho research, surface displacement begins approximately one to two months after the deposit has been mined over a significant length or after most of the target areas have been excavated at a certain horizon [5]. The collapse can also occur uncontrollably due to the Earth's gravity, as well as due to drilling and blasting operations in the mining allotment.

On the territory of the KLTS, the largest shifts are observed on the territories of Sukha Balka OJSC, Rosa Luxemburg Ore Mining Department, Ordzhonikidze Saksahan Mine, and Kirov Ore Mining Department. According to Palienko research, the area of landslides and sinkholes in the KLTS is estimated at more than 3.3 thousand hectares [1].

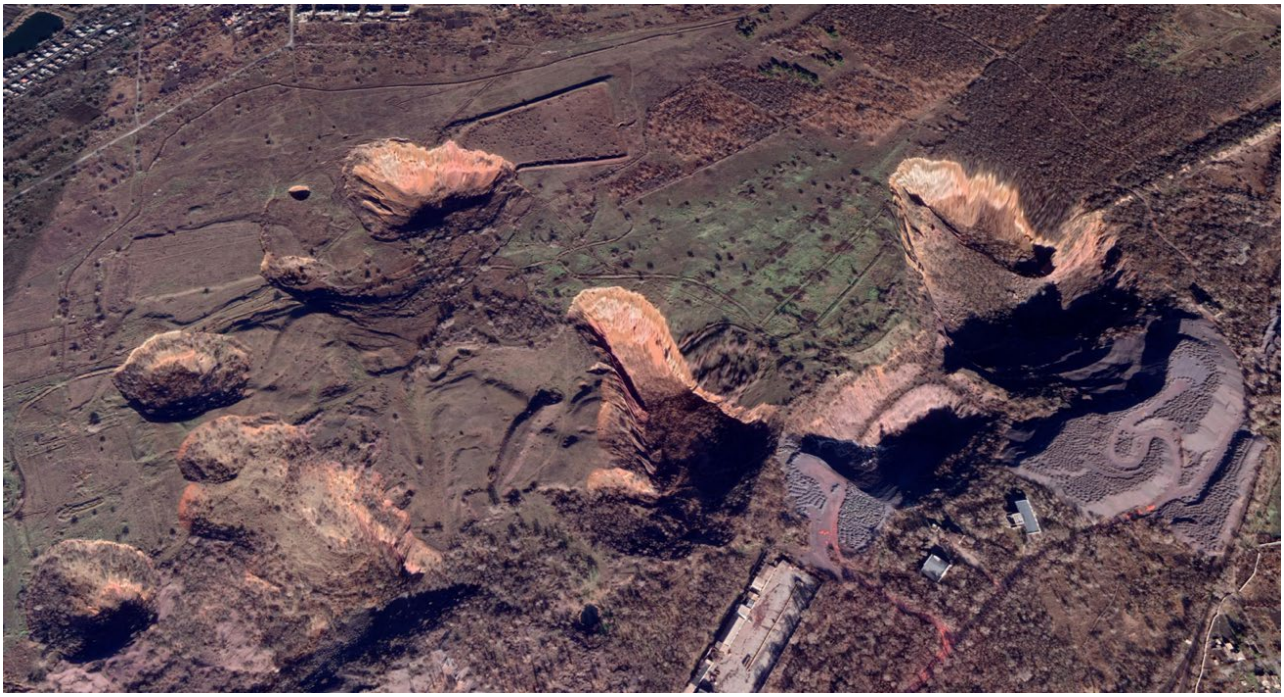

Fig. 1. Sinkholes formed on the territory of the Ordzhonikidze Mine Administration

Sinkholes are meso-relief forms in size; the size of modern sinkholes reaches 100-150 m in depth, and their diameter ranges from several tens of meters to 200-500 m. Each sinkhole has a number of morphological elements, such as a rim, slopes, and a cone-shaped bottom [1].

The first forms of sinkhole relief were recorded in the 1930s and continue to form in the twenty-first century. On June 13, 2010, as a result of the collapse of the ceiling of the working chambers of the -477 m horizon of the Ternivska mine, a sinkhole was formed in an area of 16 hectares, with a depth of 80-82 m in the lying block and 5-20 m in the hanging block, which is called the "Dragon's Nest" of the KLTS industrial mountaineering and tourism, and several profile sinkholes were recorded in this area (Fig. 1).

The formation of the next sinkhole was recorded on August 17, 2010 at a depth of 20 m in the central City District, according to Zadorozhnia G.M., the occurrence of this sinkhole is associated with the self-collapse of rocks in the worked-out pre-revolutionary mine horizons.

Also, as a result of the earthquake that occurred on January 14, 2011 with a magnitude of 3.9, a sinkhole was formed in the territory of the Kirov Mining District sinkhole zone. The sinkhole is located within the supposititous landslide zone, which is formed as a result of mining operations at a depth of -1045 m.

Recently, on March 29, 2024, a large-scale sinkhole was formed on the territory of the Kirov Mining Administration, near the Halkovskyi Kut, with a width of about -100 meters and a depth of 200 meters. This sinkhole is still expanding in morphometric characteristics (Fig. 2).

Fig. 2. A sinkhole on the territory of the Halkovskyi Kut the KLTS

In general, sinkhole processes lead to the formation of fundamentally new landscape complexes at the level of terrain types, the further development of which is determined by landscape formation processes.

Thus, sinkholes are a phenomenon that is formed on the surface tier of the KLTS mining landscapes and passes into the underground tier; a considerable number of sinkholes have been recorded on the KLTS territory, so optimization measures to prevent technogenic hazards should be introduced in this system now [2]. A large percentage of the KLTS territory requires mining and technical reclamation of the failed relief, primarily backfilling and leveling, but recently, sinkholes have been occurring that are large-scale and dangerous. It is also necessary to investigate the entire KLTS territory and draw up detailed maps of the sinkhole terrain and potential areas where sinkholes may form in order to stop mining and reduce and prevent the construction of the KLTS settlement landscape.

Sinkhole zones are complex paradynamic systems, in which the leading role is played by mineral migration (development of landslides, landslides, and landslides on the slopes of sinkholes), water migration (outflow of deep groundwater and formation of reservoirs at the bottom of sinkholes). The migration of biogenic matter (formation of vegetation cover, animal colonization) is somewhat slowed down due to unfavorable environmental conditions that form in sinkholes.

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