TECHNOGENOUS AND NATURAL-TECHNOGENOUS GROUND COLLAPSES IN MOSCOW

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ABSTRACT

Since 1969 till 2006, about 150 cases of ground collapses and surface subsidence were registered in the territory of Moscow megacity. Some of them resulted into ruining of buildings and disturbing subsurface service lines. Collapses and surface subsidence is the manifestation of karst-suffosion and suffosion processes; they may be also caused by the quicksand breakout to underground mine workings and construction pits. These processes arise as a result of the disturbance of engineering protection in deep construction pits; breaking of water-supply pipelines; underestimation of geological conditions upon engineering survey at the sites of ancient buried river valleys; as well as the alteration of geodynamic conditions in the urban territory.

The human-induced intensification of karst and suffosion processes took place in the north-west of Moscow in 1960-1970s. In 1969, a 5-storey dwelling house was ruined in the Khoroshevskoe Highway due to the surface collapse. The reason was the alteration of geodynamic conditions upon decreasing pressure in the Carboniferous aquifer and the simultaneous rise in the groundwater table, which led to the suffosional wash-out of Quaternary sand to karst cavities and fractures in the underlying Carboniferous limestone.

The accident that happened in May 1998 in the centre of Moscow (B. Dmitrovka Street) is the case of disastrous development of technonatural processes in the area occupied by the ancient buried river valley. Upon laying subsurface manifold system, the unknown earlier erosional valley filled with water-saturated sand was met. Breakout of water-saturated sand into tunnel face produced a surface sinkhole and ruined the building. Several sinkholes are registered in the vicinity of deep construction pits accompanied by the intense ingress of water into the pit.

The detailed engineering geological survey at the problematic sites will permit revealing the reasons of the process intensification as well as improving the protection measures, the monitoring system, and the requirements to engineering survey.

Key words: ancient buried river valleys, collapses, surface subsidence, sinkholes, karst, suffosion.

INTRODUCTION

About 150 cases of ground collapses and surface settlings were registered in the territory of Moscow megacity in the period 1969-2006. Some of them resulted in the disturbance of buildings and the rupture of subsurface pipelines. Ground collapses and surface settlings are the manifestation of karst and suffosion processes, as well as the inrush of quicksand into subsurface mine workings and construction pits. These exogenous processes develop as a result of disturbance of protective screens in deep construction pits, the rupture of water-bearing pipelines, inadequate estimation of geological structure upon geoengineering survey at the sites of ancient buried erosional cuttings; the variation of geodynamic conditions in the urban area, and the violation of geoenvironment development rules.

The ancient and modern erosional activity of rivers controls in many respects the geological peculiarities of Moscow territory [1]. Fractured and karstified carbonate deposits of Middle and Upper Cretaceous age occur at a depth of 5--100 m from the surface. These are limestone, dolomite, and marl. Clay layers of variable thickness are met within carbonate massifs. The fractured zones composed of limestone and dolomite fragments and ground limestone are also registered. The lateral and vertical variation in the karstification degree of Carboniferous carbonate rocks is controlled by the buried river valleys of different age. Mesozoic and Cenozoic sands and clays are underlain by the Carboniferous limestone, dolomite, marl, and clay. The Carboniferous rocks are exposed at the preQuaternary surface in thalwegs and on slopes of preglacial and current river valleys (Fig. 1).

Mesozoic deposits are represented by the Middle and Upper Jurassic continental sand and clay of Bathonian and Callovian stages, marine upper Jurassic clay of Callovian and Oxfordian stages, sand and clay of Volgian stage as well as the marine mainly sandy deposits of Cretaceous system. The Mesozoic deposits are the thickest in the south of Moscow within the Teplyi Stan elevation, where the preglacial watershed is located above the preJurassic valley.

The Quaternary deposits are composed of moraine loam of Oka, Dnieper, and Moscow glaciations, interglacial (mainly sandy) deposits, alluvial sands of three above floodplain terraces and the floodplain of the Moscow River and its tributaries, as well as technogenous deposits of variable composition and texture. The distribution of different genetic types of Quaternary deposits depends on the specific features of the modern and preglacial relief. The thickness of Quaternary deposits ranges from several to 40-50 m. It is maximal at the Teplyi Stan elevation, where the river network influence is insignificant. The large thickness of the Quaternary deposits is observed within deep preglacial valleys filled with fluvioglacial sands.

The natural geological conditions in Moscow provide for the possible surface manifestation of the processes related to the buried karst. Two types of karst deformations are distinguished, i.e., collapses and settlings. Their development in space is controlled by the geological structure specifics and by the technogenous load distribution. Saucer-shaped surface settling develop in places, where the weakly permeable clay layer is absent and water-saturated sand immediately overlie limestone. In places, where karstified limestone is separated from the water-saturated sands with a weakly permeable clay layer, sudden collapses may occur.

Karst and suffosion processes develop in thalwegs and on the slopes of preglacial valleys [2]. The Upper Jurassic clay stratum is either of low thickness there or is completely eroded. Under certain geodynamic conditions, this clay layer may by destroyed and the suffosional withdrawal of Quaternary sands into karst cavities and fractures in the underlying limestone massif begins to result in the collapse at the earth surface. Without a clay divide, the suffosional withdrawal of sandy fractions into a limestone horizon goes over a large area and is accompanied by the decompaction of sand massif to cause saucer-shaped surface settlings. Karst and suffosion processes develop most intensely in places, where preJurassic and preglacial cuttings are superposed. Limestone is karstified to the highest degree there, with the overlying Mesozoic deposits being either partially or completely eroded.

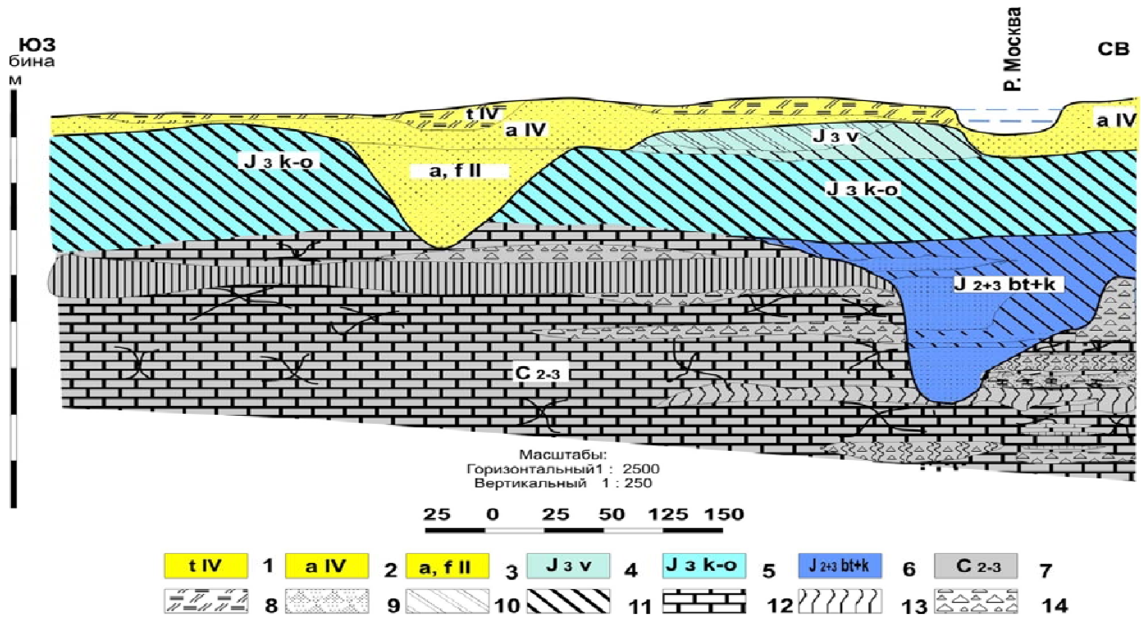

Figure 1.: Geological cross-section across the Moscow river valley from the Grebnoi channel to Serebryanyi Bor. Designations: Stratigraphy. 1- technogenous deposits, 2 - alluvium of the floodplain terrace of the Moscow river; 3 - undivided middle Quaternary alluvial and fluvioglacial deposits; 4 - upper Jurassic deposits of the Volgian stage; 5 -upper Jurassic deposits of the Callovian and Oxfordian stages; 6 - middle and upper Jurassic deposits of Bathonian and Callovian stages; 7 - Carboniferous deposits. Lithology: 8 - fill; 9 - sand; 10 - sandy loam; 11 - clay; 12- limestone; 13 - folded and crushed clay; 14 - limestone debris.

These areas enclose the northwestern part of Moscow, where the preglacial valley stretches over one of the tributaries of the Main Moscow preJurassic channel. Forty-two karst collapse funnels are known in the northwestern region of Moscow [3]. In 1960-1970s, the technogenous intensification of karst and suffosion processes took place there. In 1969, a 5-storey dwelling house was ruined at the Khoroshevskoe highway in Moscow due to the surface karst collapse. The accident was caused by the variation in the hydrodynamic regime upon a water-head decrease in the Carboniferous aquifer, which resulted in the suffosional withdrawal of Quaternary sand in karst cavities and fractures in the underlying Carboniferous limestones. Karst cavities were also registered in the northwest of Moscow in the end of 1980s; however, they were not of disastrous character, as karst-control engineering design had been already used in building foundations by that time. Nevertheless, these hazardous manifestations impelled urban authorities to reduce water intake from the Carboniferous aquifer.

The accident that happened in the center of Moscow in the Bol'shaya Dmitrovka street in May 1998 is an example of the disastrous development of natural technogenic processes within the area of ancient buried erosional cuttings [4]. Upon cutting a tunnel for the collecting sewer main, the erosional channel filled with water-saturated sands was exposed there. Breakout of water-saturated sands to the tunnel face produced a collapse funnel at the surface and ruined the building.

As proceeded from the detailed studies, the buried preglacial surface in the vicinity of Bolshaya Dmitrovka street is cut by ancient gullies filled with the Quaternary alluvial sands. The upper Jurassic clay massif overlying the Carboniferous limestone is unevenly eroded there, being characterized by the variable thickness. In some places, the Upper Carboniferous limestone occurs in the bottom of preglacial gullies under the Quaternary sands. According to the project, the tunnel for the collecting main was to be drawn below the upper Jurassic clay massif. The survey boreholes were drilled in every 50 m along the route in accordance with the engineering project. This investigation step did not permit engineers to reveal an abrupt decrease in the roof of upper Jurassic clay in the narrow buried preglacial gully. This buried erosional cutting filled with quicksand was exposed upon driving the tunnel. Quicksand rushed into the tunnel, filled it to a distance of 90 m and produced a large collapse at the surface. Luckily, no people suffered.

It appears necessary to conduct comprehensive engineering geological studies at the sites of disastrous manifestation of exogenous processes. These studies permit researchers to reveal the reasons of hazardous processes intensification and to improve the protective measures, the monitoring system and the requirements to engineering survey.

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