Engineering and geological features of technogenic deposits and cultural layers in the territory of Samara

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Abstract. The engineering and geological features of technogenic deposits in the territory of the city of Samara have been studied. Their features are revealed and a classification is carried out. The article presents the results of a petrographic study of samples taken at the archaeological site of Staraya Samara, Khlebnaya Square, carried out in 2019. The object represents cultural layers that were formed in the XVIII-XIX centuries at the site of the alleged location of the second Samara fortress. The studies were performed under a binocular microscope at an 8.75-fold magnification, in the passing light of a polarization microscope at a 72-fold magnification, and under a digital microscope at a 10-fold magnification. It has been determined that the pebble fraction is represented by quartzite and jasper flint, the sandy and silty fractions are angular quartz fragments with an admixture of undecomposed organic remains. Organic cultural layers, which reach 7-8 meters or more in the ancient part of the city, are especially powerful. Their presence is a limiting factor in modern urban construction.

1. Introduction
The study of man-made deposits and ancient cultural layers of settlements and cities provides a large amount of information about the first stages of settlement and use of the territory, about which few written sources have survived. Involvement of the methods of natural sciences, including soil science and geology, makes it possible to comprehensively consider the problems that people faced at the initial stages of the development of the territory, and understand the ways to solve them. The study of the history of changes in the geological environment under the influence of anthropogenic activity helps in making forecasts of its development and, possibly, in preventing geoecological problems.

2. Methods
Much attention is currently being paid to the study of technogenic deposits and cultural layers, but it is noted that their unified classification has not yet been created, which would take into account the different conditions and factors of their formation of technogenic deposits, the peculiarities of the inflow and transformation of technogenic material and the intensity of technogenic impact [1].

Technogenic deposits are a specific genetic group of modern continental formations, the origin of which is associated with practical human activity [2, 3]. The term "cultural layer" first appeared in the scientific works of archaeologists, who used it to refer to layers or formations of rocks and soils that have traces of ancient human activity and contain ancient artifacts [1]. The accumulation of cultural layers occurs constantly in the course of human life on a certain territory – during the production of earthworks, construction, landscaping, as well as during the accumulation of garbage.

In the Samara region, technogenic landscapes predominate, of which 75.93% account for agricultural
landscapes; 6.72% - urban landscapes, 1.32% - industrial, including mining industrial landscapes [4]. On the territory of the city of Samara, the following technogenic deposits can be identified (table 1).

| Complex                        | Type                | Kind                                      | Variety                                      |
|--------------------------------|---------------------|-------------------------------------------|----------------------------------------------|
| Bulk                           | Construction        | Soils of modern buildings                 | Loam and sandy loam with inclusions of building material |
|                                |                     | Road soils and road embankments           | Carbonate crushed stone, gravel, sand        |
| Industrial                     | Waste of modern production |                                        | Slag, ash                                   |
| Household                      | Soils of modern and former cemeteries | Cultivated soils of orchards and vegetable gardens | Loam with inclusions of brickwork, stones, bones |
|                                |                     | Mixture of household and household waste  | Loam, sandy loam, enriched with humus        |
|                                |                     | Filled-in ravines                         | Specially stacked or spontaneously accumulated |
| Polygenic                      |                     | Soils of floodplains of the Volga, Soka and Samara rivers | Loam, sand, organic deposits and variegated material |

Technogenic sediments are found throughout the Samara city, while the most ancient part of the city is covered with a sedimentary sheath. Several zones can be distinguished on the urban territory:

1) unchanged relief, which is not characterized by the formation of technogenic sediments;
2) minimal changes in the relief, where the power of technogenic sediments does not exceed 1 m;
3) the maximum change in the relief, with the power of technogenic sediments over 5-6 m.

For the oldest part of the city Samara is characterized by the maximum change in relief and the greatest thickness of technogenic sediments.

The aim of the article is the study of the structure and engineering-geological peculiarities of technogenic sediments and cultural layers in the most ancient part of the city Samara, the examples of archaeological excavation at Khlebnaya Square and materials of a technical survey of the pavilion-cafe on the territory of the River Station.

Methods of scientific literature analysis, tabular and graphical methods were used in the research process. With the help of generally accepted methods researches under a binocular microscope (at magnification 8.75 times), in passing light of a polarization microscope (at magnification 72 times) and under a digital microscope at magnification 10 times were carried out.

3. Results and discussions
The territory of the research object “Old Samara. Wooden structures, erected no later than the middle of the XIX century”, located on the Khlebnaya square in the Samara district of the city Samara (figure 1). Archaeological excavations of this object were carried out many times, starting in 2013, which made it possible to obtain a large amount of data on the early stages of the settlement of Samara. Archaeological research in 2019 was carried out by JSC Transenergoproekt (Saratov) on the basis of an open sheet of V.V. Tikhonov. In the 2019 excavation, part of the slope of the second above-floodplain terrace of the Samara river was uncovered.

In geomorphological terms, the investigated territory represents the above-floodplain terraces of the Samara and Volga rivers of different ages and complex structures, with a significant slope of the terrain and gradually turning into the watershed surface [5].
Figure 1. The layout of the objects of research in the historical center of Samara.

For this territory, before the development and leveling of the surface, the following exogenous geological processes were characteristic: ravines, planar erosion, landslides, flooding, etc. [6].

Gully formation is a very unfavorable exogenous geological process [7]. Most of the ravines belong to ancient erosional incisions, and only some of them are the result of modern erosion [8-10]. Perhaps it was to strengthen the construction site and prevent the activation of gully formation at the site of the fortress that wooden structures were erected, uncovered by archaeological excavations in 2013-2014 and 2017.

The 2019 excavation revealed the edge of the second terrace above the floodplain in Samara and a sharp drop in the relief to the first terrace. To smooth out the unevenness of the relief from about 1722 (the date was determined from the coins found in the cultural layers), the lowered areas of the terrain were backfilled with organic remains and construction debris. At present, the thickness of these layers reaches 7-8 meters and more (figure 2).

Figure 2. General view of the archaeological excavation site of Khlebnaya Square in 2019.
The cultural layers are located on the "mainland" - yellow ancient alluvial sand with a large number of ferruginous interlayers. At present, we can observe a sharp change in the continental layer up to 3 m high, which is completely planned by filling in organic cultural layers.

The pavilion-cafe object is located on the Volga river Embankment near the intersection of M.Gorky and Pionerskaya streets in the Samara district of Samara. The technical condition survey was carried out by employees of the Samara State Academy of Architecture and Civil Engineering (SamGASA) under the guidance of one of the co-authors of this article. In structural terms, the object was a one-story frame building made of metal elements, measuring 16 x 12 m in plan, operated only in the summer. The purpose of the survey is the possibility of reconstructing the building and replacing the light metal frame with capital brick walls for year-round operation of the cafe.

An analysis of the engineering-geological conditions of the pavilion-cafe site showed that, in geomorphological terms, the surveyed area is confined to the left-bank floodplain of the river Volga. Before the start of the Embankment construction, the absolute elevations of the natural relief were 30.1-34.0 m. As a result of planning works by the method of soil filling during the construction of the river station, the site currently has a flat surface with absolute elevations of 36.2-36.4 m with a weak slope in the northwest direction towards the river Volga.

Based on the results of engineering-geological surveys in the soil massif of the site of the building under study, 8 engineering-geological elements (IGE) were identified:

- IGE-1 (tQIV) - bulk soil, packed, compacted, complex composition-a mixture of black soil (60%), clay, sand, crushed stone, broken bricks and glass, with a capacity of 0.5 to 2.4 m;
- IGE-2 (tQIV) - bulk soil, similar to IGE-1, with a manure content of up to 30%, with a thickness of 1.8 to 3.2 m;
- IGE-3 (tQIV) - black manure, decomposed, with a content of black soil and sand up to 20%, up to 2.0 m thick;
- IGE-4 (tQIV) - brown-brown bulk sand, medium size, dense and medium density with inclusions of broken brick and glass, low moisture, up to 3.2 m thick;
- IGE-5 (aQIV) - sand is dark gray, fine, medium density, moist, from a depth of 7.10 m from the ground surface, water-saturated, slightly humus, with a thickness of 2.8 to 4.2 m;
- IGE-6 (aQIV) - gray sandy loam, plastic, slightly humus, up to 1.6 m thick;
- IGE-7 (eP2L) - gray, highly weathered, loose dolomite, reduced strength, up to 3.4 m thick;
- IGE-8 (eP2L) - grey dolomite, highly weathered, fractured, low-strength, with a thickness of 0.6 to 2.2 m.

The main indicators of soil properties are shown in Table 2.

**Table 2. Basic physical and mechanical properties soils the base.**

| Number IGE | Name IGE     | Soil density $\rho$ g/cm$^3$ | Organic content, in unit fractions | Deformation modulus $E$ MPa | Adhesive power $c$ kPa | Internal friction angle $\varphi$ deg. | Limit of compressive strength $R_c$ MPa | Calculated resistance of the base soil $R_0$ kPa |
|------------|--------------|-------------------------------|-----------------------------------|-----------------------------|-----------------------|----------------------------------------|--------------------------------------------|-----------------------------------------------|
| 1          | Bulk soil    | 1.80                          | 0.09                              | 15                          | -                     | -                                      | -                                          | 120                                           |
| 2          | Bulk soil with a manure to 30% | 1.75                         | 0.20                              | 7                           | -                     | -                                      | -                                          | 100                                           |
| 3          | Manure with a content of black soil and sand up to 20% | 1.50                          | 0.40                              | 3                           | -                     | -                                      | -                                          | 50                                            |
| 4          | Bulk sand    | 1.80                          | -                                 | 30                          | 0                     | 34                                     | -                                          | -                                             |
| 5          | Sand fine    | 1.78                          | -                                 | 22                          | 0                     | 30                                     | -                                          | -                                             |
| 6          | Plastic sandy loam | 1.87                      | -                                 | 10                          | 10                    | 20                                     | -                                          | -                                             |
| 7          | Dolomite strongly weathered of reduced strength | 1.90                          | -                                 | 6                           | -                     | -                                      | 4                                          | -                                             |
| 8          | Dolomite highly weathered low-strength | 2.20                          | -                                 | 35                          | -                     | -                                      | 12                                         | -                                             |
The technical inspection of the object showed that the massif is represented by soils of different thickness and character of bedding, significantly differing in their physical and mechanical characteristics. Therefore, the base is characterized by heterogeneity and anisotropy of properties. Directly below the sole of the existing foundations, the bearing layer is bulk soil. In addition, the base to a depth of 4-6 m is represented by various weak bulk soils (having low values of the design soil resistance in the range from 50 to 120 kPa), which are underlain by low-strength dolomites.

Most of the verification calculations showed that under the brick walls of the cafe building after its reconstruction, a strip foundation with a width of 1 m and depth laying down of the bottom plane of the foundation of 1.9 m, resting on bulk soils IGE-1, is sufficient. However, the presence of large amounts of manure and chernozem (i.e. organic matters) in the weak underlying layers of the IGE-2 and IGE-3 base made it possible to classify these soils as biogenic and consider their stress-strain state as unstabilized. The calculation for a weak underlying layer led to the fact that as the foundation for a small one-story cafe, a foundation plate was recommended for the entire building with dimensions in the plan of 18 × 14 m.

Therefore, the superstructure of existing and the construction of new multi-storey buildings in the historical center of Samara is associated with the need to take into account the complex geological conditions during construction. The presence of man-made and cultural layers, prone to heterogeneity and anisotropy of the properties and texture of the soil massif, in most cases leads to uneven settlements of the foundation under the load from the building. In addition, deformations of the base can be long in time and the dependence of settlement on time is not always predictable.

The study of engineering and geological features of construction on the territory of Samara depends on the physical and geographical conditions and geological structure, including stratigraphy, tectonics, karst occurrences and the level of groundwater.

Back in 1969, the research of doctor of geological and mineralogical sciences V.I. Rachitsky [12] made it possible to identify the engineering-geological area, confined to the high part of Samara from the street Polevay to the Khlebnaya Square. It covers the territory of distribution of quaternary alluvial deposits of the second above-floodplain ancient terrace at the confluence of the Volga and Samara rivers. The edges of the terrace are lowered by denudation processes and, especially on the Samara slope, are poorly expressed in the relief. This area, according to V.I. Rachitsky, composed of layered and cross-bedded ancient quaternary alluvial sands and sandy loams up to 30 meters thick. Sands and sandy loams were very well studied by V.I. Rachitsky from their physical and technical side (table 3).

Table 3. General characteristics of the properties of alluvial deposits.

| Physical and mechanical properties of soils | Loams | Sandy loams | Sands |
|-------------------------------------------|-------|-------------|-------|
| Soil moisture, w, %                       | 17.25 | 13.50       | 8.60  |
| Degree of soil moisture, Sr, in unit fractions | 0.75  | 0.30        | 0.30  |
| Density of mineral particles, ρs, g/cm³    | 2.67  | 2.66        | 2.62  |
| Soil density, ρ, g/cm³                     | 1.91  | 1.78        | 1.76  |
| Porosity, n, %.                            | 38.20 | 42.00       | 43.00 |
| Porosity coefficient, e, in unit fractions  | 0.62  | 0.73        | 0.76  |
| Humidity at the border of plasticity, wp, % | 16.75 | 16.60       | -     |
| Plasticity number, Jp, %                   | 10.85 | 3.86        | -     |
| Calculated ground resistance of the base at a depth of 2 m, Ro, kPa | 270.00 | 234.00 | 200.00 |

As follows from table 3 loam, sandy loam, and sand are partially suitable for construction. The sand sequence is underlain by limestones and, more rarely, dolomites, and is partially suitable for construction. But in general, a specific engineering-geological region is less favorable, since in this region there are fears of encountering karst rocks of the Kazan tier. The groundwater level confined to the Kazan aquifer is located at absolute elevations from 30 to 40 m.

The authors carried out a petrographic study of the material of samples taken from the continental layer.
and organic cultural layers. The research was carried out under binoculars at an 8.75-fold magnification, in the passing light of a polarizing microscope at a 72-fold magnification, and under a digital microscope at a 10-fold magnification. Generally accepted methods were used [13-18].

Samples from the underlying "mainland" layer are represented by a weakly compacted bulk mass in the amount of 2 kg. The color of the whole mass is brown. The sandy-siltstone fraction predominates, in which there are single dense well-rounded pebbles.

Pebble fraction. The shape of the fragments is slightly flattened elliptical, ranging in size from 5 to 20 mm. The surface is well smoothed with shallow indentations, dark brown to black in color. In the cleavage, brown fragments have a conchoidal fracture, a light gray color with a faint creamy tint, and a fine-grained structure. On the action of 10% hydrochloric acid solution, boiling is observed. The Mohs hardness is 3, which indicates limestone. Black fragments in the cleavage also have a conchoidal fracture, cherry-red color, structure from fine-grained to latent-crystalline. The Mohs hardness is slightly above 6, indicating jasper-like flint (figure 3).

Sand-siltstone fraction. The sand fraction has a size from 0.1 to 0.8 mm. The predominant grain is rounded with a strong glass luster, translucent in the passing light of a polarizing microscope, with a refractive index close to 1.54, which indicates quartz. In smaller quantities, there are dark brownish non-translucent angular fragments of the same size and large with a sliver-like elongated shape up to 3 mm in size, which probably indicates soil and plant formations (figure 4). The siltstone fraction has a size from 0.01 to 0.05 mm. Their shape is lamellar, angular. The composition is the same as in the sand fraction, but dark dusty grains predominate (figure 5).

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**Figure 3.** Photo of the pebble fraction (A-jasper flint, B-limestone).

**Figure 4.** Photo of the sand fraction.

**Figure 5.** Photo of the siltstone fraction.
Samples from man-made deposits (organic cultural layers) are represented by a dense mass of dark brown color with not clearly defined layering. When splitting, the mass easily splits into lumpy and flattened fragments, in the cleavage of which there are intermittent and very thin layers of white color. Cracks are observed in these layers (figure 6). The mass structure is porous granular-fibrous. The pore configuration varies from incorrectly isometric to elongated in one direction (figures 6 and 7). Fine-grained inclusions are present in the total mass, but elongated wood remains with preserved microstructure predominate (figures 7 and 10). The contact of dense and uniformly porous layers is observed in individual samples. Cracks are present in dense layers, and oval formations are present in porous layers (figure 8).

Figure 6. Chipped surface with cracks and white interlayers.

Figure 7. Treelike inclusions in a fine-grained mass.

Figure 8. Contact of dense and porous layers.
These formations are covered with a white crust, which have a mossy surface, possibly fungal formations on oval inclusions of organic debris (figure 9). In the loose fraction, tree-like remains and individual quartz grains are clearly distinguished (figure 10).

**Figure 9.** White formations on oval inclusions.

**Figure 10.** Plant residues and grains of transparent quartz in a loose fraction.

Thus, at the initial stage of settling the territory of Samara, the settlers faced significant difficulties due to the natural components of the landscape: high dissection and relief changes, loose sandy soils, active erosion processes. At the location of the modern Khlebnaya Square, these problems were solved with the help of the construction of wooden structures and the forming high-capacity of anthropogenic deposits of high power from organic materials and construction waste.

4. Conclusions
As a result of the study, the following conclusions can be drawn:

1. Technogenic deposits of Ancient Samara are characterized by a large thickness of organic cultural layers (7-8 meters or more), compacted, having a layer-by-layer occurrence, a porous structure, with remnants of wood and household waste.

2. Natural ancient alluvial deposits in the form of sand, sandy loam and gravel are located as the underlying rocks under the technogenic organic deposits.

3. Engineering and geological features of technogenic sediments can complicate the use of the territory for urban construction.
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