

## Principles of classification of geological processes

*Oleksandr Kobzar*

Kyiv National University of Construction and Architecture  
Povitroflotskyi Avenue, 31, Kyiv, Ukraine, 03037  
ale-vlad@mail.ru, orcid.org/0000-0001-5074-1315

**Summary.** In this paper, basic geological processes and factors affecting the formation and activation of geological processes are discussed. With consideration for the effects of these factors, the classification system for geological processes is proposed. In order to more objectively estimate geological processes according to this classification system, the classification schemes of exogenic and endogenic processes have been developed. These classification schemes may be used in the analysis of geological processes, in respect with the engineering measures for preparation and protection of urban areas with complex engineering and geological processes selection evaluation.

**Key words:** geological process, exogenic process, endogenic process, cryogenic process, eolian process.

Therefore, the activities in studying conditions for the development, extension, activation, and control of geological processes are also considered as high-priority and urgent issues.

Geological processes are of interest with respect to protection, development, planning, and management of urban territories, as such processes affect existing and design buildings and structures.

At the present time, the land plots that are actively used in urban development include land plots, both low-convenient and inconvenient for construction, where geological processes are present, were present, or could be present in favorable conditions.

### INTRODUCTION

The enhancement of the density of the urban areas, the development of the areas with difficult terrain are leading to the changes in geological and hydrogeological processes in such areas. In most cases, any changes in existing geological conditions cause deformation of ground surfaces.

The works for protection and development of land, which are necessary in order to ensure comfortable living conditions for urban population, are high-priority and first-order problem in the reconstruction and development of urban territories.

### ANALYSIS OF PAST STUDIES AND PUBLICATIONS

The results of the analysis of geological processes have been discussed in various publications and attracted attention. At the present time the local classification systems with respect to geological processes, and causes of geological processes are being analyzed, and basic principles and methods of protection against negative effects of geological processes have been determined.

Geological processes have been studied by such domestic and foreign researchers as Savarenskiy F.P., Kolomenskiy M.V., Nayfeld L.R. [4], Vladimirov V.V. [5], Naza-

renko I.I. [7], Nishchuk V.S. [8], Bakutis V.E. [6], Kaplan L.Z. [9], Gorshkov G.P. [17], Peredelskiy L.V. [14], Sergeyev E.M. [12] and Lomtadze V.D.

## STATEMENT OF THE PROBLEM

The purpose of this paper is implementing the classification system for geological processes having effect on the development of urban territories, determining new methods for solving problems; developing and using of classification schemes as means for ensuring quality and efficiency of activities in solving problems associated with the means for information support, research activities, science-based complex engineering solutions, and methods with respect to the development of urban territories subjected to the effects of geological processes.

Only complex studies of geological processes can provide the possibility to obtain improved knowledge about the characteristics and causes of geological processes, as well as methods for predicting geological processes.

## CLASSIFICATION OF GEOLOGICAL PROCESSES

The term "*geological process*" means a change of components of the geological environment in time and space under the influence of natural and technogenic factors [20].

Depending on the source of changes or forces causing dynamic forces these processes are divided for the internal endogenic processes, and external exogenic processes. Therefore, the first stage in studying geological processes is to divide the geological proc-

esses and develop their classification (see Figure 1).

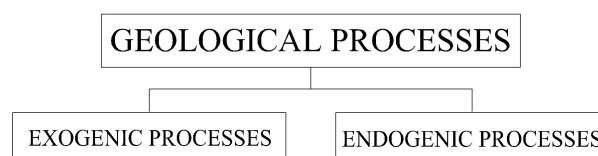
Lets consider in more detail each group of geological processes.

*Endogenic processes* are caused by changes within the internal geological structures of the Earth, that is, within the lithosphere, mantle, and core of the Earth. Endogenic processes result from internal forces inside the Earth and virtually do not depend or lowly depend on external factors. Endogenic processes promote tectonic stresses of the Earth crust and, for this reason, are associated with various processes which cause the nonuniformity, expansion, and bedding or rocks [16].

*Exogenic processes* are characterized by changes of rocks and mountain structures and general appearance of the earth surface under the influence of the energy of the sun, planets of the solar system, and space environment [16].

The basic sources of the energy of exogenic processes are the continuous movement of water and air masses, circulation of water in the atmosphere, on the earth surface, and in the entrails of the Earth, chemical and physical transformation of substances under the influence of the vital activity of living organisms, and human activity. Therefore, any exogenic process is characterized by the following three stages of development: destruction, transfer, and deposition of materials.

Exogenic processes are interconnected. The formation of any exogenic process causes the formation of another exogenic process. Therefore, only analysis of exogenic processes in combination allows all changes on the Earth surface to understand and the laws to which s changes are subjected to determine. This conclusion applies also to both the exogenic and endogenic processes. These



**Fig. 1.** Classification of geological processes

processes are interconnected and, accordingly, represent the complexity, diversity, and, at the same time, the unity of the dynamic forces acting on the Earth.

The most important feature of geological processes is the nonuniformity of their effects on the earth surface in different districts and regions due to different physical and geographic conditions, surface relief, rock anisotropy, and location of tectonic structures [16].

All geological processes occur and vary depending on the characteristic actions and mode of interaction of underground tectonic processes, stressed-deformed state of rock masses, changes of rock properties, temperature conditions at the upper part of the earth crust and at the earth surface, hydrogeological conditions, and surface water. Such effect of diverse factors affecting the formation of natural, technogenic, and combined geological processes is the characteristic feature of geological processes.

While studying geological processes, the causes of and the conditions for the formation of geological processes were deter-

mined. The factors that directly promote the formation of geological process in a favorable environment may be used in grouping geological processes and creating groups with common characteristics.

For the first time, the classification of geological processes and events was proposed by F.P. Savarenskyi in 1937. The classification system developed by F.P. Savarenskyi in 1941 was based on the diversity of causes of formation and development of geological processes and events. Later, this classification system was complemented by M.V. Kolomenskyi in 1956. The classification system effective at the present time is presented in Tab. 1.

In the proposed classification system, the causes of geological processes and events are indicated. Due to this, the classification system has practical value, as the actions required for protection against these processes and events shall be focused, first of all, on the removal of the causes and consequences of the processes and events. If such removal is not possible, for example, in case of earthquakes, the actions shall be focused on re-

**Table 1.** Classification of geological processes

Nr.	Cause of occurrence and development of a geological process or event	Geological process or event
1	Activity of factors inducing weathering	Weathering
2	Activity of surface water (sea water, lake water, river water, channel water)	Underwashing and slide of banks (marine and fluvial abrasion) Water erosion of slopes (formation of ravines and gullies), earth flow
3	Activity of surface and underground water	Swamp formation, subsidence, karst formation
4	Activity of surface and underground water on slopes	Rock displacement
5	Activity of underground water	Subsoil erosion, shifting sand
6	Freezing and thaw of soil	Freezing and thawing of soil Permanently frozen soil and its effects
7	Activity of internal forces of Earth	Seismic events
8	Industrial activity of human beings	Land subsidence, compaction, bulking. surface and underground deformations in mine openings

ducing the effects of processes and events on buildings and structures.

The results of the studied sources analysis were used for the classification of geological processes with consideration for the basic affecting factors.

#### I. Exogenic processes:

1. Processes associated with climatic factors.

2. Processes associated with activity of surface water.

3. Processes associated with activity of underground water.

4. Processes associated with activity of gravitational forces on slopes.

5. Processes in regions with permanently frozen soil (cryogenic processes).

#### II. Endogenic processes:

1. Processes associated with activity of internal forces of the Earth.

The classification of geological processes is performed with consideration for factors that cause the formation and development of processes. The final result of the study of geological processes consists in the devel-

opment of the classification scheme of processes (see Figs. 2 and 3).

In developing the classification schemes, the basic factors to be considered are factors of natural origin. Anthropogenic factors are not considered.

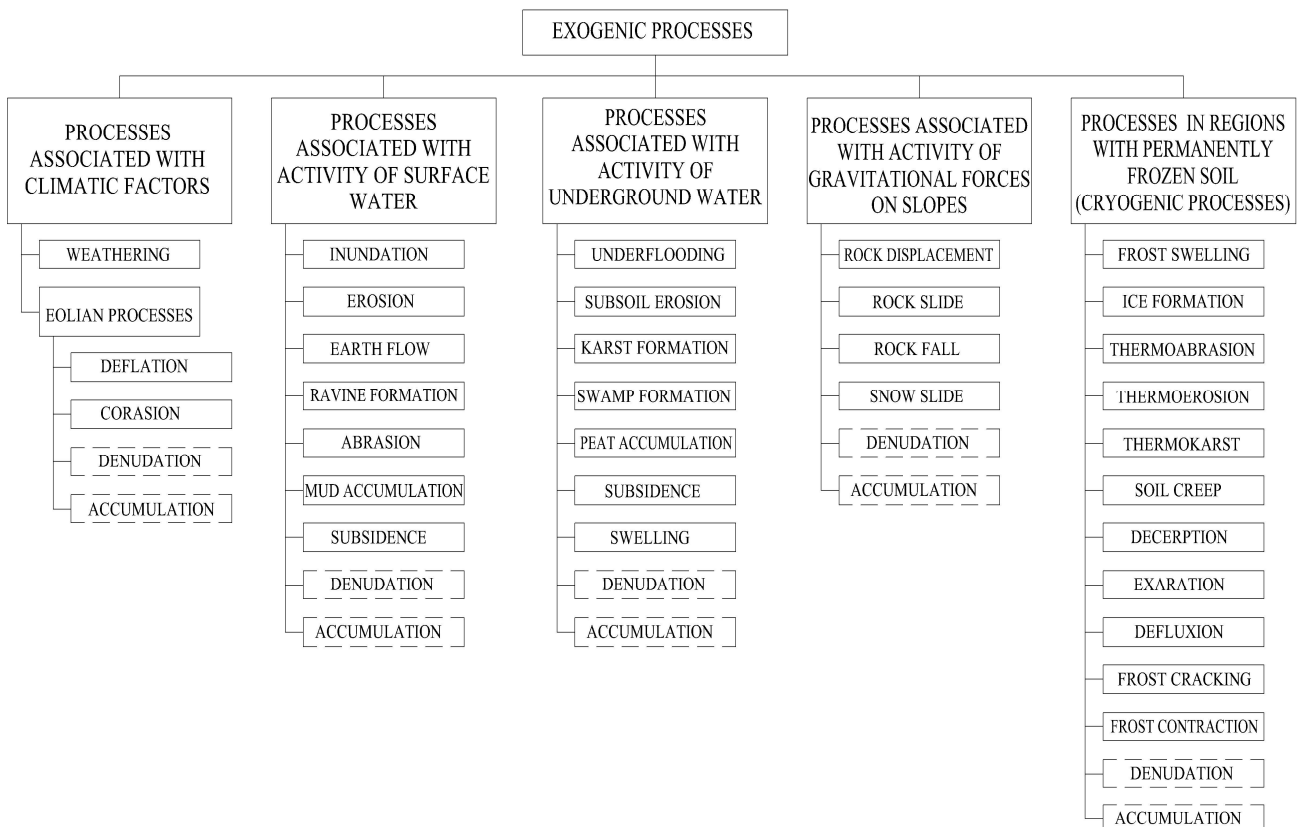
The processes associated with climatic factors are weathering and eolian processes (deflation, corasion, denudation, and accumulation).

These processes are characterized by changes in rocks and rock minerals in the thermodynamic conditions on the earth surface under influence of natural factors.

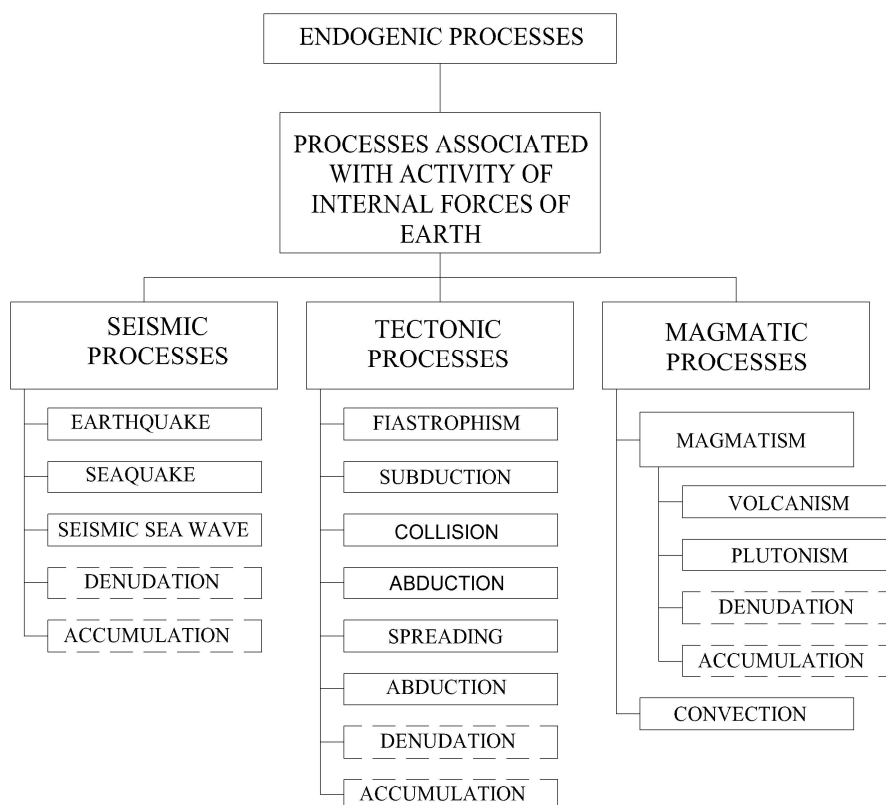
*Eolian* processes are processes of blow-out, transfer, and accumulation of sandy and silty rocks under action of wind.

The geological action of wind appears as *deflation, corasion, denudation, and accumulation*.

Eolian processes cause the formation of specific objects of surface relief, such as barchans, barchan patterns, sand ridges, dunes, and hilly sands [16].



**Fig. 2.** Classification scheme of exogenic geological processes



**Fig. 3.** Classification scheme of endogenic geological processes

The classification schemes include repeated processes, for example, denudation and accumulation processes. This repetition is possible due to that these processes are formed under some elements: the effect of climate, surface and underground water, gravitational forces, and internal forces of the Earth. The process results in the movement of material from the higher areas to the lower areas of the surface relief. Denudation processes cause changes in the surface relief that promote the relief leveling. Denudation processes include processes that are formed in the result of climatic factors (eolian processes such as deflation) and activity of surface water (inundation, erosion, earth flow, abrasion), activity of underground water (subsoil erosion, karst formation), and activity of gravitational forces on slopes (rock displacement, rockslide, snow slide), and proc-

esses in areas with permanently frozen soil (cryogenic processes, such as ice formation, soil creep, thermoabrasion, thermokarst, thermoerosion, and exaration).

In the process of transfer of products of rock degradation, the products accumulate according to the size, density, and chemical composition of the products. The accumulation of products of rock degradation and formation of rocks occur at settlements of the surface relief, therefore, the final stage of the corresponding processes is accumulation.

The processes associated with activity of surface water include inundation, erosion, earth flow, ravine formation, abrasion, mud accumulation, and subsidence.

These processes are characterized by a free water surface on land plots due to the increase of water levels at waterways and water storage reservoirs and due to the accumula-

tion of water at settlements of the surface relief. In this case, both the permanent and temporary formation of a free water surface is possible. As a result, rocks are being destructed due to water flow or land drainage.

The effects and activation of this group of processes result in formation of unfavorable surface relief.

The main medium that activates these processes is surface water.

The processes associated with activity of underground water include underflooding, subsoil erosion, karst formation, swamp formation, peat accumulation, subsidence, and swelling.

These processes are characterized by their effects in certain conditions of the natural environment, including urban environment, and are caused by various factors having natural and technogenic origin, specifically due to the increase of the soil humidity or ground water level to the limit values beyond which the environmental conditions become unfavorable.

The main medium that activates these processes is underground water.

The subsidence processes are caused by different factors promoting these processes. For this reason, these processes pertain to both the group of "processes associated with activity of surface water" and the group of "processes associated with activity of underground water". The main media for the subsidence processes are surface and underground waters.

The processes associated with activity of gravitational forces on slopes include rock displacement, rock slide, rock fall, and snow slide.

These processes are characterized by the relatively slow or, in specific cases, fast movement of earth masses, rock fractions, or snow masses down the hill slopes due to the change of physical properties of hills and action of surface and underground waters as well as atmospheric precipitation.

The causes of reduction of the resistance of a slope to these processes can be overload of the slope surface, underwashing of the slope base due to abrasion, or decrease of the

strength of rocks in some layers due to the increase of the ground water level or decrease of filtration pressure to the rocks.

The *cryogenic processes* are represented by thermophysical, mechanical-and-physical, and chemical processes in frozen and thawed grounds and ground rocks [20].

Frozen water present in soils and rocks and seasonal and daily changes of the aggregative state of the water cause various cryogenic processes.

Such cryogenic processes are: the frost swelling, ice formation, thermoabrasion, thermoerosion, thermokarst, soil creep, deceleration, exaration, defluxion, frost cracking, and frost contraction.

The extent and intensity of the cryogenic processes depend on atmospheric precipitation characteristics, heat and moisture exchange in the upper layers of rocks, and dynamical characteristics of freezing and thawing.

Cryogenic processes occur in combination and interact with other exogenic processes. These processes have different effects in denudation, accumulative, and relatively stable areas.

In mountain areas, where denudation grounds are dominant, weathering products, such as column-like rocks of irregular shape, and exaration – the stone streams as deposits of stony or crushed stone material are formed. On mountain slopes, stony terraces and strips are formed. If the slope contains soft rock deposits, solifluction surface relief can be formed in cases when the thawing surface soil layer creeps down. The characteristic feature of horizontal surfaces and flat beds is the formation of structural surface relief represented by such equitable polygonal objects as stony polygons, rows, rings, and other like objects with a diameter from 10 cm to several meters. Such structural relief appears due to seasonal changes, when the surface ground water freezes in autumn, with the formation of polygonal cracks and soil swelling, and in winter, frozen ground fractions are squeezed out to the surface. In spring, such fractions move downhill and accumu-

late in polygonal cavities. This cycle will be repeated in the subsequent year.

The effects and activation of this group of processes result in formation of unfavorable surface relief.

The processes associated with activity of internal forces of the Earth include seismic processes (earthquake, seaquake, seismic and sea wave), tectonic processes (fiastrophism, subduction, spreading, and rifting), and magmatic processes, such as magmatism (volcanism and plutonism) and convection.

These processes are characterized by changes occurring due to the abrupt release of the potential energy of the earth interior, including elastic vibrations and movement of lithosphere plates.

In such cases, the change of the parameters of any process can cause the activation and effects of other processes. This feature is characteristic for both the exogenic and endogenic processes.

## CONCLUSIONS

The proposed classification system is the basis for the further studies of geological processes. The ground is the systematization of geological processes by developing of the classification schemes that will enable an objective assessment of the areas conditions subject to the influence of certain geological processes, combining them into blocks according to certain criteria and, as a result, making optimal engineering decisions when selecting methods of engineering protection. In the development of the classification schemes are considered the factors promoting effects or activation of geological processes.

The developed classification schemes can be used effectively in carrying out the engineering and construction estimation of territory, engineering preparation and protection of territories, design documentation elaboration (of stages "P", "RP", "R", etc.):

- districts and regions;
- general localities plans (towns, villages and settlements);
- detailed plans of territories.

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#### ПРИНЦИПЫ ПОСТРОЕНИЯ КЛАССИФИКАЦИИ ГЕОЛОГИЧЕСКИХ ПРОЦЕССОВ

**Аннотация.** Рассмотрены основные геологические процессы, факторы влияния на их активизацию. Учитывая признаки действия основных факторов, влияющих на формирование процессов, разработана классификация геологических процессов. Для более объективной оценки этой классификации разработаны модели экзогенных и эндогенных процессов. Предложено использование разработанных моделей при анализе и изучении геологических процессов, принятии инженерно-планировочных решений.

**Ключевые слова:** геологический процесс, экзогенный процесс, эндогенный процесс, криогенные процессы, эоловые процессы.