EXOGENOUS GEOLOGICAL PROCESSES AND RISKS IN THE CHECHEN REPUBLIC: THEORETICAL AND PRACTICAL ASPECTS

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Abstract

This article examines exogenous geological processes and their influence on relief formation and sediment accumulation in the Chechen Republic. The main types of exogenous processes are considered: weathering, slope processes, aeolian, fluvial, and karst processes. Attention is paid to the physical and chemical processes of weathering, as well as the formation characteristics of slope, aeolian, and fluvial landforms. Particular attention is paid to karst processes, the formation of specific landforms, and karst deposits. The geological and geomorphological characteristics of the Chechen Republic include a description of its physical, geographical, and climatic features, as well as a detailed analysis of the distribution and activity of landslides and mudflows in mountainous areas. The relief, hydrological, hydrogeological, lithological, petrographic, and climatic characteristics of the study area favor the development of exogenous geological processes. The diversity of geological, orohydrographic, and climatic conditions has led to the prevalence of various types of exogenous processes here.

Keywords: exogenous processes, weathering, slope processes, landslides, aeolian processes, fluvial processes, geomorphology, karst deposits.

I. Introduction

Exogenous geological processes play a key role in shaping the Earth's modern landscapes and relief. These processes include rock weathering, water, wind, and other factors that alter the shape and composition of the earth's surface. This study examines various types of exogenous processes, such as weathering, slope, aeolian, fluvial, and karst processes, and their influence on relief formation in the Chechen Republic. Particular attention is paid to landslides and mudflows, which have a significant impact on the region's landscape and infrastructure. It also examines the geological and geographical features of the Chechen Republic, including its physical location and climatic conditions, which determine the intensity and distribution of exogenous processes.

II. Methods

The studies utilized modern methods for determining the dynamics of landscape-landslide complexes, including both ancient stages of landslide formation and modern movements, as well as instability states (visual interpretation of optical images, multispectral image analysis, radar data, etc.). Vegetation and the stages of successional recovery after each landslide activation often serve as indicators of short-term states. Advances in the application of high-resolution Earth remote sensing data and the frequency of monitoring make it possible to approach the identification of landslide dynamics as an integral part of landscape dynamics. Thus, the concepts of spatiotemporal image resolution [19] and multi-temporal imaging allow for a systematic approach to the selection of images for the analysis of landslide landscapes and their dynamics. Images were needed that physiognomically reflect the characteristic states of landscapes [17, 18]. For low-mountain forest landscapes, spring images are the most physiognomic, reflecting the lateral structure of natural complexes containing landslide bodies: cracks, breakaway walls, delayed or early onset of vegetation in moist areas, small erosional incisions, etc., with reference to natural complexes of a certain rank and type. Laser scanning (LiDAR) from a quadcopter offers significant potential, allowing for the identification of relief without the "noise" introduced by vegetation. The use of digital elevation models allows for a detailed analysis of the contribution of morphometry to slope stability or instability. Currently, more than 100 geomorphometric characteristics are calculated for various tasks based on the projected grid of a Digital Elevation Model.

III. Results

The North Caucasus is one of the most dangerous regions in terms of natural and man-made emergencies. Landslides are the most common type of slope process in the Chechen Republic, posing a threat to life in this part of the North Caucasus. Over the past century, the active development of the republic's territory, primarily as a result of the development of the oil industry, has increased the pressure on natural landscapes, compromising their stability. At the same time, the population, the length of roads and infrastructure lines, new buildings have been constructed, and land use patterns have changed (from extensive to intensive). Economic development has been accompanied by a constant threat of landslides. Recurring landslides within villages, destroying vital communications and roads, have necessitated scientifically based approaches to landslide monitoring and the justification of measures to protect vital infrastructure.

Based on landforms and genetic types of sediments, the following types of exogenous processes are distinguished: weathering, slope, aeolian, fluvial, and karst.

Weathering processes. This group includes the processes of rock alteration and destruction under the influence of external agents—the atmosphere, hydrosphere, and biosphere—with the formation of the crust and weathering products. Two types of weathering products are distinguished: eluvium and coluvium. The former are weathering products of rocks lying in place where they formed, while the latter are displaced downslope by gravity. Depending on the factors affecting the rocks and the results of these actions, weathering processes are divided into two types: physical and chemical weathering. Physical weathering results in the sequential fragmentation of rocks into smaller fragments without changing their chemical and mineral composition. It occurs more actively at high latitudes, in high mountains, and in hot deserts. Chemical weathering leads to changes in the chemical and mineral composition of rocks or to their complete dissolution. The most important factors here are water, as well as the oxygen, carbonic acid, and organic acids it contains.

Slope processes. These include rockfall-slide, desiccation-solifluction, landslide, complex polygenic processes, and others. Their formation is determined by a combination of lithological, geomorphological, and climatic conditions predetermined by the recent endogenous development of the relief. One important condition for the development of these processes is a significant slope steepness (more than 350). Slope processes are associated with weathering. For example, the formation of scree is associated primarily with physical weathering.

Landslide processes are the most common. Landslides involve the displacement of a monolithic rock block. Landslide processes are largely determined by geological and hydrogeological features. The main geological conditions for their occurrence are the underlying permeable rocks beneath a horizon of impermeable rocks and the coincidence of the dip of the roof of the impermeable rocks with the direction of the surface slope. During landslides, rocks are partially crushed and transformed into a structureless mass. Accumulations of landslide masses at the foot of slopes are called delapsions [1, 2, 10]. Landslide processes form a specific complex of relief forms: landslide cirques, landslide blocks, landslide terraces, landslide embankments, etc.

Aeolian processes. These processes are associated with the geological action of wind. The end results are the accumulation of aeolian deposits of sand, silt, and, less commonly, clay composition, and the formation of certain landforms—dunes, barchans, aeolian ridges, cumulus sands, hummocky sands, etc. All aeolian forms are characterized by a gentle windward slope and a steep leeward slope.

Fluvial processes. These processes and the associated landforms are caused by the activity of sheet runoff (rainwater, melted snow, streams), permanent and temporary surface watercourses. During heavy rainfall and snowmelt, water flows in a continuous stream or a dense network of small streams downslope, picking up and transporting fine particles from higher ground. The geological material deposited at the bottom of the slope is called deluvial deposits.

Among the fluvial processes associated with permanent watercourses, erosion and corrosive processes are distinguished. Erosion refers to the process of channel deepening (deep erosion) or channel widening at the expense of banks (lateral erosion), while corrosive processes refer to the process of grinding and polishing rocks by moving masses of detrital material carried by water.

The predominant landforms associated with fluvial processes are erosive furrows and ruts, gullies, ravines, gullies, and river valleys, from which detrital material is transported to lower areas and accumulates there. Within these negative landforms, accumulative landforms are also present in smaller quantities as microrelief elements.

The debris deposited in river valleys by permanent streams (rivers) is called alluvium, consisting of sorted particles of varying sizes.

Temporary streams in the mountains form a mudflow after heavy rainfall and snowmelt. At the foot of the slope, the mudflow spreads, forming a debris flow fan. Such debris flows are called proluvium, which differ from alluvium in that they are less sorted and contain larger particles of debris.

Karst processes. Karst is a combination of processes involving the dissolution and leaching of rocks, followed by the erosion of accumulated material, resulting in unique landforms that arise in areas where rocks are relatively easily soluble in water. Karst is characterized primarily by negative landforms. Based on morphological characteristics, the following surface and underground forms are distinguished: carrs, wells, shafts, sinkholes, sinkholes, ponors, karst ravines, valleys, polyas, karst caves, underground karst channels, dry valleys, and karst bridges.

The main conditions for the development of karst are: a flat or gently sloping surface, a significant thickness of water-soluble rocks, the presence of aggressive groundwater and conditions that ensure their movement.

Karst deposits (formations) include stalactites, stalagmites, calcite curtains, draperies, and other dripstone formations in limestone caves.

Based on the lithological composition of soluble rocks, the following types of karst are distinguished: carbonate karst (limestone, dolomite, chalk, marble); Salt or halide karst (rock salt, sylvinite) and sulfate karst (gypsum, anhydrite).

Landslide processes. The greatest landslide activity in the republic was observed in 2016-2017. The peak number of activation events occurred in the spring and summer and was primarily due to heavy precipitation. The conditions, causes, activity, and danger of landslide events on the republic's roads are characterized. During the study period, approximately 70 such events (involving material damage) were recorded on roads running through the Vedensky, Itum-Kalinsky, and Shatoisky administrative districts of the republic. Information is provided on the activity and scale of landslide deformations and roadbed destruction in these districts during the study period. The highest activity of landslides and slides was observed on the roads of the Shatoi district (more than 40 manifestations). It was noted that the volumes of landslides and slides on the roads of the republic generally varied within the range from 100 m3 to 17.5 thousand m3. Landslides and slides were most developed in the areas of mid-low mountain relief and high mountain relief of the Greater Caucasus Meganticlinorium. Activation of individual manifestations is expected in April-May in the Shatoi and Itum-Kalinsky districts of the republic. In the Shatoi district, activation of landslides and slides is possible along the following roads: v. Yarysh-Mardy - v. Zony, v. Zony - v. Shatoi. In the Itum-Kalinsky district, activation of landslides and slides is likely along the following roads: v. Veduchi - v. Itum-Kale. The main factor causing the activation is hydrometeorological.

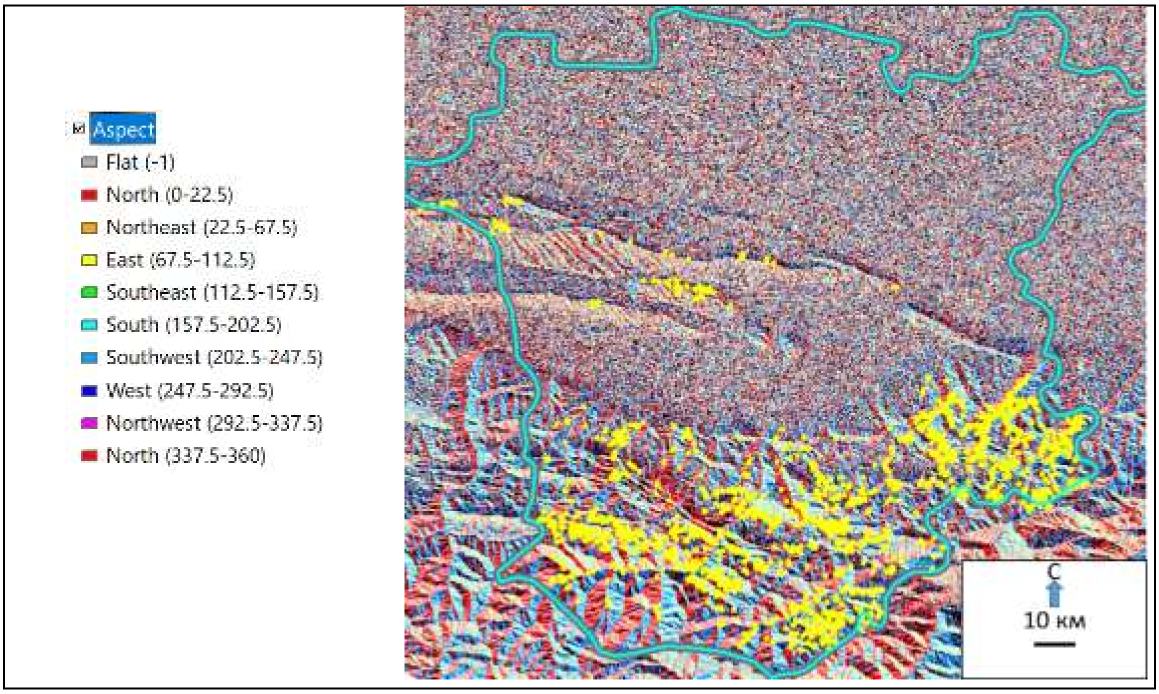
Landslides and mudflows. In general, low activity of dangerous EGP is predicted in the Chechen Republic. The landslide process is most widespread in the mid-low mountain relief of the Greater Caucasus Meganticlinorium, where the highest landslide activity is expected, namely in the Nozhai-Yurtovsky, Vedensky, Kurchaloevsky and Shatoysky districts of the republic. Activation of the landslide process is likely in April-May in the Shatoysky district within the highways of the village of KhalKiloy - the village of Nizhniy-Dai and the village of Yarysh-Mardy - the village of Zony. In May-June, with continuation of residual activity in July-August in the event of heavy rainfall, there is a high probability of activation of the landslide process: - in the Nozhai-Yurtovsky district within the highways: the village of Shovkhal-Berdy - the village of Alleroy; the village of Shuani - the village of Sayasan; Betti-Mokhk village – Sovragi village, Ayti-Mokhk village – Biltı village, Benoy village – Ayti-Mokhk village; - in the Vedensky district within the following highways: Tsa-Vedeno village – Pervomayskoye village, Pervomayskoye village – Agishbatoy village, Vedeno village – Dargo village, Marzoy-Mokhk village – Pervomayskoye village; - in the Kurchaloevsky district within the highways: Yalkhoy-Mokhk village – Enikali village; Koren-Benoy village – Biltı village; Dzhaglargi village – Regita village. The main factors of activation are hydrometeorological and man-made.

Mudflows and landslides are quite active in the mountainous part of the Chechen Republic. Here, as in some other regions, a synergistic effect of these processes is observed. Heavy rainfalls lead to rising river water levels and, consequently, to the erosion of banks composed of easily eroded rocks, which contributes to the sliding of coastal areas (mudflow material) and the formation of mudflows [3,4,12]. Landslides, most typical for low-mountain forest-steppe landscapes, occur near the village of Belgatoy. The landslide develops on Neogene deposits, represented by interbedded sandy argillites with multiple aquifers.

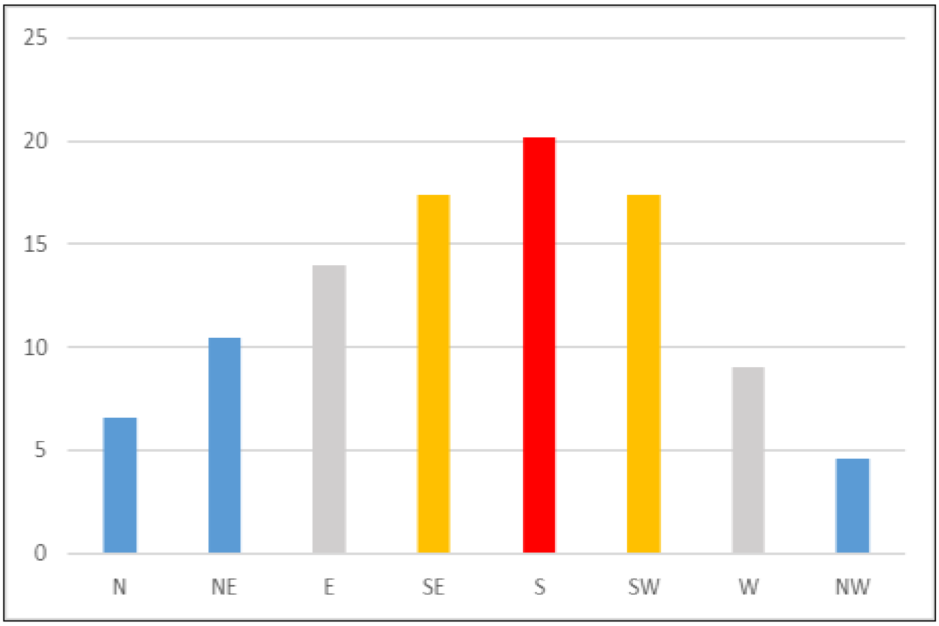
The Belgatoy landslide begins at an altitude of approximately 766 meters and ends on an alluvial fan superimposed on a river terrace, which steeply drops off to the Belgatoy River channel (water level is approximately 608 meters above sea level). The landslide extends for approximately 800 meters. Landslide processes are active in the upper part (above 700 m); in the transit zone, they are combined with erosion processes, while in the discharge zone, the accumulation of both landslide and erosion material predominates. In the southern, treeless areas of the lower part of the erosion-landslide cirque, talus is common [20].

The landslide develops on Neogene deposits consisting of interbedded sandy mudstones with multiple aquifers. These aquifers are exposed as the landslide deepens, forming a temporary watercourse in the thalweg portion of the erosion-landslide cirque, which, passing the alluvial fan at its base, incises to a depth of up to 5 meters.

Overall, the integration of the Belgatoy landscape-landslide complex into the landscape structure depends heavily on geomorphological features and moisture conditions. Long-term anthropogenic activity has significantly transformed both the topography and the moisture conditions of the soils and grounds. The construction of "heavy" housing and roads in the 1960s and the intensification of agriculture led to an increase in landslide phenomena, culminating in the catastrophic landslides of 1989 [5,6,11].



A.



B.

Figure 1. Distribution of the number of landslides in the Chechen Republic by exposure on the map (a) and on the graph below (b)(The y-axis shows the number of landslides as a percentage of the total. The x-axis shows slope exposure) (Compiled by the authors).

Landslide processes are most prevalent in the eastern and southeastern parts of the Black Mountains region, where landslides periodically intensify in the spring and fall due to increased precipitation and snowmelt. Given the rugged topography and significant amounts of precipitation, much of which filters into the mountain massif, clayey rocks become vulnerable to landslides, mudflows, and other processes. In the Black Mountains, landslides develop on the northern slopes of the mountains in a continuous band 15-25 km wide. Their activity increases significantly on the slopes of mountain river valleys, where mudflows can also occur.

Landslide activity is primarily determined by geological features. The region is characterized by widespread clayey rocks, predominantly of Sarmatian age, against a monoclinal structure complicated by a number of anticlines. In the area of the towns of Mekhdettankort, Amir-Kort, and the villages of Baitarki, Mazhgar, Tatay-otar, and elsewhere, Chokrak layers, consisting of sandstones with rare clay interlayers, surface. Lower and middle Sarmatian deposits, primarily clayey rocks, extend in a narrow band from the border of the Chechen Republic and the Republic of Dagestan in the east to the village of Sayasan and further west. These same deposits are also found near the villages of Benoy and Alkhan-otar. Their cross-sections can be observed along numerous small rivers and gullies – the B. Yaryksu, M. Yaryksu, Doku-ein, Yaman-Su, Erzumbere-ein, Sheren-ein, and others [7,9,13]. In places with significant channel slopes, the presence of loose material or clayey, easily eroded rocks, small alluvial mudflows are formed, caused by high-intensity rainfalls [8,14,15].

To the north of the described deposits, a thick layer of Upper Sarmatian rocks is exposed, composed in the lower part of dark gray clays with a thickness of over 300 m. The villages of Gilany, Zandak, Rogun-Kazha, Aiti-mokhk, and others are located in the zone of their outcrop. Thus, the dependence of the manifestation of landslide processes on the material composition (lithology) of geological horizons is clearly visible here. In the southern part, Chokrak sandstone beds and Upper Cretaceous carbonate rocks outcrop, while in the northern part, Quaternary Akchagyl-Apsheron layers, represented by sandy-siltstone rocks, are exposed. All of these rocks are classified as highly permeable. Landslide processes are either virtually absent or weakly manifested here.

Despite many years of experience in researching and predicting landslide processes, their periodic activation causes significant material damage and poses challenges to the future development of infrastructure in populated areas and the entire study area. Therefore, the development of scientifically sound methods for predicting these processes, as well as the improvement of existing and the development of new landslide control methods, remain highly pressing.

Eolian Processes. A wide variety of eolian landforms are common in the Chechen Republic. The most common sandy landform is ridged sands, which are relict landforms inherited from other physical and geographical conditions. In the northern and northeastern parts of the lowland, there are areas of open sand dunes, formed due to improper plowing and excessive grazing.

Aeolian processes affect the semi-desert and desert landscapes of the Trans-Terek Plain of the Chechen Republic. The total area of land subject to wind erosion is 1,603 km2 (36.9% of the total area of semi-desert and desert landscapes). Areas most susceptible to wind erosion occupy 301 km2 (6.9%), while moderately susceptible areas occupy 1,302 km2 (30.0%).

Karst processes. One of the main conditions for the development of karst processes, as noted above, is the presence of rocks readily soluble in groundwater. The nature of changes in the intensity of erosion processes plays a significant role in the formation of karst relief. It is well known that karst regions are characterized by weak erosional dissection. Here, erosion processes are reduced due to the rapid infiltration and influx of atmospheric precipitation into the subsurface of karst massifs. One interesting area with regard to karst is the interfluve of the Yaryk-Su and Benoy-Yassy rivers in the southeast of the Chechen Republic. This region is composed of Lower Cretaceous limestones and is heavily karstified. Most karst sinkholes are located near the summits of the slopes of watersheds. Sinkholes here are typically small in size: diameters range from 3 to 15 meters, and depths from 1 to 4 meters. In karst areas, the conditions for the formation of soil and vegetation cover change. In some areas, karst development leads to the formation of new soil types, primarily due to changes in soil moisture levels. The drying influence of karst in the interfluve of the upper reaches of the Benoy-Yassy and Yaryk-Su rivers has led to the predominance of meadow-steppe soils here, which act as a kind of blot in the mountainous zone of brown earth-forest soil development [7,16].

Karst formation processes lead to significant changes in the soil cover and transformations, which can lead to the creation of inter-type differences. Karst also has a significant impact on vegetation. Certain environmental factors in karst areas often present a sharp contrast to zonal ones, leading to the emergence of plant communities uncharacteristic of the zone and an overall increase in the diversity of vegetation. As atmospheric precipitation passes through the forest cover, it feeds karst waters and becomes enriched with organic acids, resins, and essential oils.

IV. Conclusion

Thus, the topographic, hydrological-hydrogeological, lithological-petrographic, and climatic features of the study area favor the development of exogenous geological processes. It is the diversity of geological, orohydrographic, and climatic conditions that has led to the spread of various types of exogenous processes here. The presence of clayey carbonate and gypsum-bearing rocks soluble in groundwater, increased rock fracturing, highly dissected topography, and a dense hydrographic network in the mountainous region facilitate the widespread development of erosion processes (karst, landslides, mudflows, and karst) with the accumulation of eluvial and deluvial-proluvial deposits. Karst processes predominate in the mid-mountain part of the area, where limestone (limestone belt) and gypsum-anhydrite rocks are widespread. Landslides and talus processes are observed in the highlands. Landslide processes are common in areas with thick clay strata (the southeastern and other parts).

Fluvial processes (primarily lateral erosion of permanent streams) are more characteristic of the low-mountain and flat zones of the central part. Aeolian processes are typical in the northern semi-desert zone, where strong winds prevail.

CONFLICT OF INTEREST.

Authors declare that they do not have any conflict of interest.

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