Exodynamic Processes of the Coast in the South-Eastern Part of Crimea

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Abstract. The main exogenous geological processes developing in the coastal zone of the Karadag nature reserve are considered in this article. Karadag coastal zone – as a site with minimal anthropogenic impact, fully shows the nature of the development of natural processes in the coastal zone in the South-Eastern part of the Crimea. The article provides an overview of the exogenous geological processes considered by the authors in the field survey of the territory in the summer of 2018.

1. Introduction
The sea’s coastal zone is a geodynamical zone, the position of which on the border of land and sea provides a high speed of the coastline dynamic. This dynamic is directly related to changes in natural systems, the nature of human anthropogenic activity, as well as the conditions of his residence. In this regard, the coastal zone should be considered and studied as a multicomponent ecosystem, which has a special structure and which is involved in the formation of the ecological state of coastal areas’ parameters. Thus, to identify the patterns of functioning, transformation and potential for the development of the sea’s coastal zones is an urgent task today [11].

A number of foreign works are devoted to the problems of studying coastal exogenous geological processes. The dynamic of the coastline has been considered by different researchers in many parts of the world: Andre Giskard Aquino da Silva with co-authors (Coastan zone of Parnaiba river delta, Brazil, 2019), Hau Tien Le Nguyen (Can Gio Biosphere reserve, Vietnam, 2018), K. Sowmya with co-authors (Coast of Karnataka, India, 2019) and Annibale Guariglia with co-authors (Ionian coastal area, Italy, 2019). [3, 4, 7, 10].

There are in the coastal area of the Black sea on the Crimean Peninsula located many villages, resorts. It is an important recreational area. In particular, there are many protected areas, including unique in its natural characteristics, the territory of the Karadag nature reserve. [1].

Any activity that takes place in the coastal zone requires a full study of the coast’s current state, its dynamics and trends in its changes. Such data allow carrying out complex actions for protection and the prevention of negative influences on the sea coast’s territory. In this regard, it is clearly seen the need for an overall geoenvironmental assessment of the coastal zone, to establish the natural features of the functioning of this territory and to establish the relationship of all processes occurring in it.
The aim of this article is to consider the main manifestation of exogenous geological processes in the undisturbed territory of the southeastern coast of Crimea. Namely the coastal zone of the Karadag nature reserve. The work is more focused on the consideration of modern dynamic and development of the sea coast of the study area.

2. Objects and methods of research
As an example of the coastal zone’s study it was taken anthropogenically undisturbed area of the Karadag reserve’s coastline. It is about 8 km in its length. The nature of the coastline depends on the anti-denudation resistance of rocks and its geological and structural conditions [8]. To a large extent, the coastline is abrasion.

The place of study is located on the coast of the Sudak-Karadag lowlands [5], mostly within the ridge Beregovoy. Its seaside scarp slope is dismembered by notches. Changes in the coastline occur simultaneously under the influence of erosion, slope and abrasion processes. Different intensity of abrasion leads to the formation of bays, with the result, there is coastline dismemberment [12].

To solve the problems associated with the study of exogenous geological processes within the of the Karadag reserve’s coastline, on-site study was conducted with the recording of the main exogenous processes presence in the coastal zone. Surveys were carried out both from the water area, when going on a boat, and recording the state of the coastline by camera records, and directly on foot with marking of the main exogenous geological processes (mainly gravitational processes) along the coastline.

3. Results and discussion
In the Karadag coastal area, gravitational-slope processes (eboulements, screes), slope processes of hydratogenous sliding and flow (creeping wastes), coastal accumulation, abrasion waves activity and wind-generated currents are observed [2].

Exogenous geological processes in the coastline are activated by the active interaction of the three environmental components, actively in contact with each other: air, sea, geological environment. During a storm, air and water under high pressure penetrate into the rocks’ cracks, expanding them and thus reduce rocks’ resistibility. Rock weathering superpose on this processes. Permanently wettable rocks erode rapidly.

The impacts of the stone fragments that fall from the cliff to the foot of the cliff, driven by the wave processes of the sea, most strongly destroy the coast. In this case, the rock debris is split itself into small parts. They round by waves, and gradually turn into pebbles. In addition, a significant part of the rock reduce to the sand and the smallest particles [9].

One of the most common exogenous processes in the coastal zone is abrasion, which carries out active processing of the coastal sediments. The coast configuration depends on the rock resistance and geological and structural conditions (Fig. 1). Average-resistant rocks of the coast presents dacites, liparie-dacites, and resistant rocks - andesites, basalts, volcanic breccias, spilites and etc., and soft rocks are shales, marls and flysch sediments.

A convex arc of the Karadag coast complicate slightly incised bays and headlands separating them [6].

![Figure 1. Part of the Karadag coastal zone (view from the sea side).](image-url)
On the Karadag coastal area (from Karadag bay, located near the village Kurortnoe to Koktebel bay near the village Koktebel) in the coastal zone annually 245 m$^3$ [5] deposits receives as a result of abrasion of the cliff and bench.

Along the coastal zone of the Karadag massif, slope exogenous processes (slope denudation) are also actively developing, which progress due to the special dismemberment of the relief within the coastal zone and the different steepness of the slopes facing the sea. Very steep and scarp slopes are typical for the ridge Beregovoy. It should be noted the main manifestations of slope processes: scree, eboulements, as well as the accumulation of colluvial-deluvial formations.

Deluvial tails are located at the foot of the slopes. They are characterized by a concave surface, the steepness of which increases from bottom ($3^\circ$) to top ($20^\circ$). Fig. 2 shows deluvial tail at the foot of the ridge Kok-Kaya.

![Figure 2](image1.png)

**Figure 2.** Colluvial-deluvial tail, partially overgrown with bushes, near the village Koktebel (view from the sea side).

As the waves cut the cliff's footprint, then eboulements are activated, the volumes of which can reach large sizes. Eboulements are observed locally throughout the coastline, forming a kind of headlands, separating some bays (for example, to the East of the bay, located near the abrasive outlier “Zolotye vorota”). Eboulements have the cone and tails shape up to a length of 100-150 m and a width of 300 m. They consist of rubble-blocky deposits with a thickness of up to 10-20 m, sometimes they accommodate blocks with a diameter of 10-30 m (Fig. 3).

![Figure 3](image2.png)

**Figure 3.** The eboulements western of the Severnaya Serdolikovaya bay.
Among the many screes are dominated by small formations of triangular, trapezoidal and glacier shapes, and scree-spots on the slopes. The length of the screes varies from 1 to 100 m, and the steepness of the surface – from 32 to 40° (Fig. 4).

Figure 4. Scree slope of the Beregovoy ridge.

Proluvial-scree debris cones are formed in the mouths of some short slit-like gullies, developed in robust and medium-robust rocks of the ridge Beregovoy. Screes’ and ebourlements’ fragmented material partly moved as a result of surface runoff, and partly rolls and accumulates on the alluvial debris cones the length and width of 10-100 m, a slope of 20-40°. Such cones, for example, go down to the beaches near the rock Kuz’michev Kamen’ and Yuzhnaya Serdolikovaya bay [6].

Summarizing all the observations made on the undisturbed by anthropogenic impact coastal area, it is noted that the main exogenous processes of the coastal zone are screes, ebourlements and colluvial-deluvial tail.

In general, the study of exogenous processes and any of their manifestations in coastal areas is necessary for the further formulation of quantitative and comparable indicators, which carry a variety of actual and forecast information about natural hazards in such areas.

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