Taluses and Downfall Slopes as Geomorphological Refugia of Flora Relict Endemics of the Mountain Crimea and their Modern Phytoindication

A R Nikiforov¹, A A Nikiforova², E A Petlukova³

¹Federal State Budgetary Institution of Science "Order of the Red Banner of Labor Nikitsky Botanical Garden - National Scientific Center of the Russian Academy of Sciences"
²Taurida Academy, V.I. Vernadsky Crimean Federal University, Vernadsky Avenue 4, Simferopol, Republic of Crimea, 295007, Russia, a post graduate student, Department of Geography and Geomorphology
³Taurida Academy, V.I. Vernadsky Crimean Federal University, Vernadsky Avenue 4, Simferopol, Republic of Crimea 295007, Russia, a post graduate student, Department of Physical Geography, Oceanology and Landscape Study

E-mail: nikiforov.a.r.01@mail.ru, nikiforovaleksanda@mail.ru, petlukova@mail.ru

Abstract. In geomorphology, slopes are defined as any kind of irregularities of vertical and subhorizontal surface. A slope is an inclined part of the earth's surface, which steepness is sufficient to determine further development of relief as a single geomorphological complex over its entire surface. There were given the being heterogeneous geomorphologic structures, slopes and their azonal landscapes and the reasons for peculiarities of the ecological environment, the link of some rare species to specific relief microforms have. The study of this phenomenon is important for geomorphology, paleogeography, phytocenology, elaboration of measures for protecting rare species (relics, endemics, relic endemics).

1. Introduction

Slopes are of different origins and structure. The natural slope development influenced by a specific factor, which effect is due to surface direction, is considered as a slope process. Under different conditions, these processes lead to rock destruction, as well as to movement and accumulation of weathering products. As a result, both developed and accumulative forms of topography appear on the slopes.

The purpose of the research of this work is to analyze human impact on the landscapes of the south macroslope Main Crimea mountains.

Research concern: explore habitat places of relic endemics and make their geomorphologic identification as relief forms.

Research subject: morphostructural elements of relief in the habitat places of relic endemics.

Research subject: suppression of denudations, crust of weathering, aleurite as special understratum for the plant development.
Research tasks: discover structural elements of azonal relief of talus slope and talus slope downfalls of the Upper zone of the Main Crimea mountains ridge with their own vegetation. During the researching the method of the field study was used.

2. Results and discussion
The mountain Crimea is a small but unique mountainous country in terms of origin, structural history, geological structure, a combination of geomorphological processes and landforms – the Crimean meganticlinorium – that started to form in the Mesozoic and continues up to the present time [23, p. 46]. Distinctive features of Crimean Mountains are their low heights (the highest mountain point, Roman Kosh, is 1545 m above sea level), a sharp elevation changes in the southern macro slope. Each range structure includes a steep slope facing south and a hilly plateau at the range top (plateau), being the northern gentle slope. Landforms original in concentration and combinations are formed on steep slopes, such as the stripping walls and other denudation surfaces (steep brows, subsidence ditches, deep cracks of seismic origin) and accumulative deposits (landslide, talus and all sorts of karst cavities, beams, etc).

Azonal landscapes with special ecological environment and mosaic vegetation are formed on the slopes without soil cover. The structure of this vegetation type is distinguished by a large number of rare plants, such as endemics, relics, relict endemics and others. Being indicators of the local natural environment, these plants are able to reveal some landscape features and history. To protect these species also requires understanding environmental conditions in habitats.

The sparse vegetation of rocky habitats, which ecological environment peculiarities are caused by rock properties, is known as petrophyton. Petrophyton includes plants, within limits of the rocky habitats (obligate petrophytes) and vegetation elements of various ecological and coenotic origin, capable to grow in a wide range of environmental conditions, including gravelly and rocky substrates (optional petrophytes). All these heterogeneous species, represented by different life forms, are united by a set of features allowing plants to grow in rocky ecotopes and form mosaic groups here.

Obligate petrophytes are divided into ecological groups. This differentiation is based upon actual connection of plants with fine-grained deposits formed in weathering crust of different origin: on proluvia (debris displaced by water), diluvia (eroded soil), colluvia (sloughing products of weathering), delapsii (sliding from soil debris), landslide (eruption) sediments [21, p. 120] and in rock cracks.

An example of a talus slope in the Mountainous Crimea is the talus near Shagan-Kaya rock on the southeastern slope of Gurzuf (1430 m above sea level) (Fig. 3.3.). The talus slope surface is consists of denudation surface (rock) and an accumulative part of the slope covered with the colluvium layer (actually talus). The development of talus is determined by the Quaternary Period of surface forming and local peculiarities of the slope process depending on limestone characteristics of denudation surface exposed to frost weathering.

Figure 1. The Shagan-Kay talus on the southeastern slope of Gurzuf (1430 m above sea level).
The talus near Shagan-Kaya rock is wholly located in the eastern part of the rock. The length of the by-brow slope (considering its roughness) is 800 m. Denudation surface reaches 50 – 75 m in height from the cliff edge to the foot at the top of the talus cone. Its highest part is 110 – 120 m high. The relative height of the accumulative part of the slope reaches 50 m, but the length of the slope to the south vary enormously. This is caused by the surfaces covered with colluvium layer raise both from the foot of the rock and from its terrace, which can be traced from east to west (Fig. 1).

The denudation surface and colluvial cover are characterized by peculiar vegetation of mosaic sparse groups of plants adapted to cracks and colluvium on fine-grained deposits (optional and obligate petrophytes).

![Image of geomorphological map]

**Figure 2.** The geomorphological map of the talus near Shagan-Kaya rock. Provided by the author on the basis of an aerial photograph.

The half-shrub *Silene jailensis* N. I. Rubtzov (*Caryophyllaceae*) serves as an example of obligate chasmophytes is (Fig. 2). “*Silene jailensis* N. I. Rubtzov (*Caryophyllaceae*) is the rarest and least studied” among endemics of the Crimean flora. Plants of this species were first discovered in 1964 in three populations. Recently, the fourth population has been discovered. Its number reaches more than 300 plants in the Nikitskaya Yayla.

This species is characterized by environment associated with edaphic conditions and specific hydrothermal zones on the cliffs.

![Images of Silene jailensis]

**Figure 3.** An obligate chasmophyte *Silene jailensis* N.I. Rubtzov (*Caryophyllaceae*) (photo by author).

Seeds germinate in a temperature range between 7 to 15°C. Generative stages of ontogenesis are indicated by shape and density peculiarities of shrub plants. Population seed renewal is cyclical in nature: coevality and arrangement of most plants in loci prove their synchronous growth from seeds of a single parent plant.

A biological sign representing this link is disseminating *S. jailensis* when seeds mostly fall close to the parent plant. Another much less effective technique, which is transferring seeds inside fruitcases to tens and hundreds of meters, is affected by obligate nature of hazmophyte and the lack of suitable
conditions for growing plants outside the original habitat. As a result, generations of plants inherit the same habitats, practically without spreading beyond them. Populations are isolated from each other in space, and the number of species does not exceed 500 plants [17, p. 22].

A population of *S. jailensis* was found on the brow of the northeast buttress of Shagan-Kaya rock. On the accumulative slope, populations of obligate glareophytes, such as *Lamium glaberrimum* (*Lamiaceae*), (K. Koch) Taliev and *Scrophularia exilis* (*Scrophylariaceae*) Popl., were also found together with species of dual environmental nature, which are chasmophytes and glareophytes at the same time, such as *Lagoseris callicephala* (Asteraceae) Juz. and *Heracleum ligusticifolium* (Apiaceae) M. Bieb. The accumulation of rare species (obligate glareophytes and chasmophytes) allows to define a relative stability of edaphic parameters on downfall slopes as a feature of landscape and talus slopes.

Patterns of seasonal development of plants allow us to consider their relative mesophily and thermophily as integral ecological characteristics of these relict endemic species of the Mountain Crimea.

With regard to edaphic differences in ecological zones of rocks and talus deposits, certain features of ecological similarity, which explains the ecological linkage of all species with zones of these ecotopes, may be created by factors caused by some general edaphic conditions.

A high degree of steepness of talus covers provides the surfaces with additional heating. Consequently, the hydrothermal zone of steep rock brows located in the northeast and colluvial covers of the eastern slopes are characterized by an increased heat flow.

The generative development of plants in the yayla’s climate falls on the period of seasonal thermal maximum coinciding with minimum precipitation. In summer, fine-grained soil covered with the colluvial layer is known to be constantly moisturized with water condensed from the air. This means that plants both in cracks and on the colluvium are provided with regular moisture and are independent from precipitation. Lack of moisture needed for the development of these species compensates its condensation from the air, accumulation and weak evaporation.

The peculiar composition and specific structure of glareophytes of talus slopes and petrophytes of downfall slopes in the upper zone of the Mountain Crimea prove permanence of edaphic conditions from the surface formation. This condition allowed populations of relict endemics to survive here, despite all sorts of climatic changes, the development of zonal surfaces and vegetation zone types.

The term “geomorphotope” is introduced in this paper as a concept, the prototype of which is “klimatop” by I. P. Ved [39] or soil-climatic areas by V. G. Volobuev [40]. Both systems included several climatic parameters (radiation balance, precipitation, etc.), combined on one chart, where adjacent or overlapping climatic areas of zonal soils or plant communities were located.

Similar to these developments, this paper is an attempt to create geomorphotope as part of the ecotope, which is a combination of geomorphological factors contributing to maintaining and conserving protective (refugium) surface features for certain types and associations of the relict endemic species of flora. In contrast to the above-mentioned developments of I. P. Ved and V. G. Volobuev, the climatic component here has an indirect influence depending on surface. For example, the absolute height, steepness and exposure of slopes determine thermal conditions, the orographic effect, precipitation, wind conditions, evaporation intensity and other macro- and microclimatic features. This brings some anomaly to the total zonal-altitudinal climate distribution and generates azonal localities characterized by refugial nature.

Geomorphotope refers to key surface characteristics providing a favourable distribution of climatic parameters and edaphic conditions for the considered relict endemic species. This enables to create a visual distribution scheme for particular species in the high-altitude zone of the Main Ridge of the Crimean Mountains. To create diagrams illustrating geomorphology we will consider the following characteristics: 1. absolute height of population growth, 2. the slope’s exposure, 3. the slope’s steepness. All three parameters will be presented as a cone, where the conical surface angle corresponds to the average angle of the slope, the cone’s height is the range of local absolute heights. The base of the cone is divided into degrees and points relative to the cardinal directions. To visualize
geomorphotopes as conical shapes, averaged findings for each ecological group studied have been used. Among the endemic species of the Crimean flora, the chasmophyte Silene jailensis N. I. Rubtzov (Caryophyllaceae) is one of the rarest and least studied. According to current data, the population number does not exceed 500 plants [17, 25, 26]. In total, there are four narrowly localized, small habitats of the population: on the brow of the talus near Shagan-Kaya rock (locus classicus, Gurzuf Yayla, 1390-1430 m above sea level) and on downfall slopes – 1300-1350 m above sea level on the brow of Nikitskaya Yaila slope; 1410-1430 m above sea level on the brow in the upper Avunda river and 800-835 m above sea level on the brow of Paragilmen. Thus, the key parameters for designing the geomorphotope cone are the following:
1. The minimum and maximum height of habitats are 800 and 1430 m above sea level respectively.
2. The average steepness is 45 degrees.
3. Expositions are SE, NE, and E.

Figure 4. The geomorphotope of chasmophyte Silene jailensis N.I. Rubtzov. The author’s diagram.

The diagram shows the plant distribution depending on the above factors. The nucleus of the species growth is based on all habitats known. By analyzing the geomorphotope presented, similar conditions for distribution of the settlement, nuclei were defined: the height is 1200-1400 m above sea level and expositions are S., SE, and E. The average steepness depends on the ecological group. This suggests possible paleo-climatic growing conditions of relict endemics similar to this distribution. Edaphic factors ensure stable ecological environment of these surfaces.

3. Conclusion
1. It was established that the development of relic endemic flora of the Mountain Crimea is associated with azonal lithogenic surfaces formed on taluses and downfall slopes.
2. The stable ecological environment of these surfaces provide mainly edaphic factors, primarily geomorphological processes.
3. It was revealed that downfall slopes and taluses are the most heterogeneous structures among the elements of slope surface.
4. It is found that habitats of relict populations of endemic species are brows and by-brow slopes as well as colluvial plumes.
5. The regularities in the ontogenesis and seasonal development of relict endemic plants, which are associated with the habitats’ environmental conditions, were revealed.
6. The locality of habitat conditions and an inability of the studied species to migrate prove their permanent existence in specific ecotopes since their formation.
7. The term “geomorphotope” shows the most favourable altitude and exposition for the relic endemics growth of the Mountain Crimea flora.

4. References
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