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MORPHOGENETIC CLASSIFICATION OF THE SPATIAL PATTERNS IN THE HIGH-MOUNTAIN LANDSCAPE STRUCTURE (ON EXAMPLE TATRA MTS)

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Abstract

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This paper focuses on the analysis of the geomorphic forms and processes and their influences on the spatial patterns in order to prepare the specific classification according to numerous criteria. The algorithm of this study is based on the spatial identification of forms, processes and patterns considering large-scale aerial photographs, a field reconnaissance and the partial classification. As the result, the research shows the morphogenetic multifarious classification of patterns which represents an important informative and interpretative base for the knowledge of the structure and the mosaic of the Tatra high-mountain landscape.

Key words: high-mountain landscape structure, aerial photographs, geomorphic forms and processes, spatial patterns, Tatra Mts

Introduction

The landscape structure as one of three main characteristics of the landscape is, in the relationship to relief, the result of not only long-lasting geomorphic processes, but also of relatively short-term morphodynamic disturbances, mainly in the mountain or high-mountain areas. The landscape structure represents a spatial differentiation of the interactions between the comparatively stable landscape components and dynamically formed landscape elements (Ružička, 2000). In this research, we concentrated particularly on the identification and classification of spatial patterns in the relationship to certain geomorphic processes and the attributes of the constituent genetic forms of the middle-scale and micro-scale landscape. The geomorphic forms and the following processes determine not only the shape of patches or the character of boundaries, but also the character of fragmentation, the heterogeneity of patches, the gradient and the tendency of patches development within the limits of the basic matrix. Relief, especially its spatial morphodynamic attributes, represents relevant phenomena of the landscape which facilitate to understand the scale and hierarchy of the landscape structure of the high-mountain areas (Hreško, 1998; Hreško, Boltižiar, 2001, 2009; Hreško et al., 2009).

The aim of this paper is to submit a proposal of the classification system of the spatial patterns in the form of a 'catalogue' regarding the physiognomic spatial attributes of the landscape structure mosaic in the high-mountain areas. Thus, the suggested classification can be regarded as a basis for the quantitative statistic analyses of the landscape structure and the detailed research of spatial patterns.

Study area

The study area comprises the Tatra Mts of the exact part above the upper timber line that is termed as the high-mountain landscape (Fig. 1). It covers the whole subalpine, alpine and subnival level, approximately above the isohypsis 1500 meters above sea level and according to our analysis in the GIS equipment; it comprises (without the Polish part) the area of 27 482 ha, 0.6% of the Slovak Republic. High-mountain environment of Tatra Mts represents a specific archetype of landscape (Hreško et al., 2010).

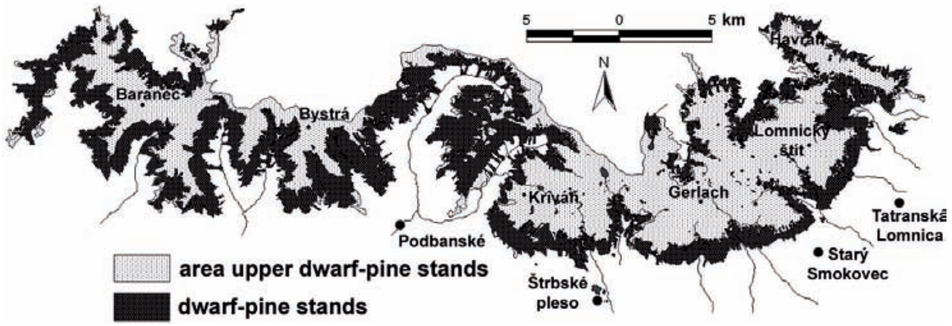


Fig. 1. Study area: high-mountain landscape of Tatra Mts (Slovakia).

Methodology

The introductory phase of the study of spatial patterns dealing with the Tatra high-mountain landscape involved the acquisition of infrared aerial images, thematic maps, and particularly, the terrain research directed at the observation of relief influences on the spatial differentiation of the landscape structure elements. The rich photo documentation was taken during the fieldwork. The methodology of this research is displayed by the Fig. 2.

The analysis of the influence of constituent geomorphic processes on the formation of diverse spatial patterns functioned as the first step. The individual processes were identified applying the geomorphic map (Lukniš, 1968), the map of debris flows (Mahr, 1973), the map of avalanche tracks (Kňazovický, 1978), the literary facts, however, mainly concentrating on the interpretation of aerial photographs and the direct observation in terrain.

The next step was fulfilled by the study of genetic geomorphic forms whose genesis, age, structure and affecting relevant relief processes seem to be crucial to the formation and further development of spatial patterns. We used the method of the analogue interpretation of vertical infrared aerial photographs taken by Eurosense, s. r.

o. Bratislava to identify the exact types of spatial patterns of the Tatra high-mountain landscape. Employing the antecedent concepts together with our photographs and information of field research, we could identify the definite types of patterns on the geomorphic forms, which we gradually transformed into schematic outlines. Afterwards,

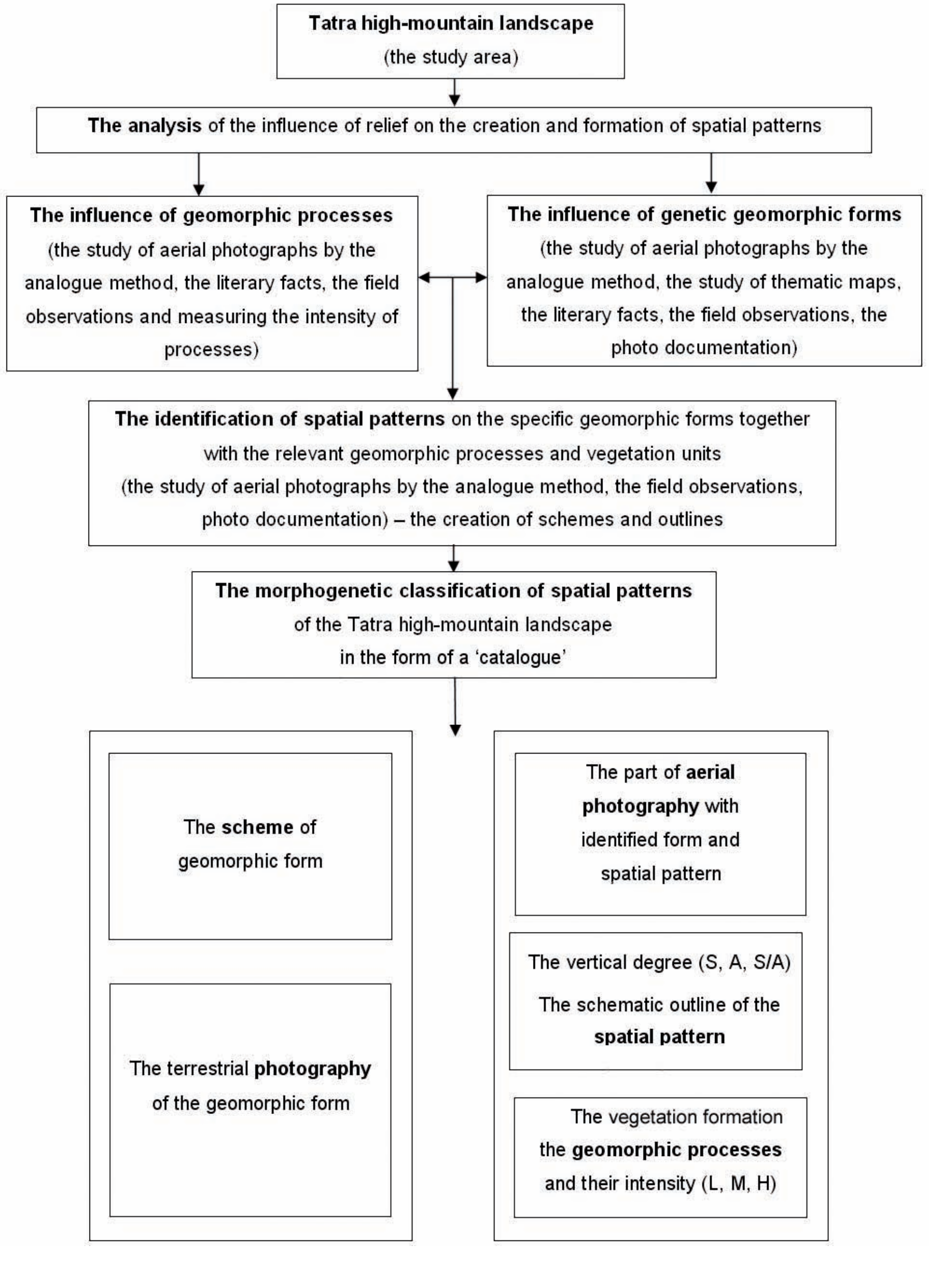


Fig. 2. Methodology of the patterns studying in the Tatra high-mountain landscape structure.

we created the morphogenetic classification in the form of a "catalogue" as the consequence of physiognomic spatial attributes of the Tatra high-mountain landscape and its mosaic.

During its creation we took into consideration these principles:

1. We defined the basic geomorphic mezoforms and microforms of relief according to the Lukniš's map (Lukniš, 1968), moreover, some other forms were filled in.
2. A "catalogue" contains the part of the aerial photograph with identified spatial patterns on the relevant geomorphic forms. The real terrestrial photograph of such a field form with the pattern is placed underneath the image. It is accompanied by the outline of the form or its part with the schematically drawn repatriation of these landscape structure elements – vegetation (dwarf pine and thallus-herbaceous stands), outcrops, debris slopes and destructed areas including the mentioned spatial pattern.
3. We decided on the basic matrix (colourfully distinguishable) for each individual case or pattern in the outline; for example: dwarf pine stands, thallus-herbaceous stands, rocks or debris slopes.
4. The exact spatial patterns were depicted by visually perceived geometric elements, the degree of fragmentation and external physiognomy. These are effectively represented by their schematic outline in which the colour of background substitutes the content of matrix and the colour of another elements stands for the content of patches or corridors (dark green – dwarf pine stands, light green – thallus-herbaceous stands, brown and brown-orange – rocks, grey, yellow, light brown – debris slopes, orange – destructed areas, blue – lakes, water streams). In the outlines were introduced the vertical degrees and the occurrence of the patterns – subalpine (S), alpine (A) or the transition between them (S/A).
5. The vegetation units according to syntaxonomy were mentioned under the schematic outline of all the patterns, frequently on the level of alliance typical for the chosen spatial pattern.
6. In the following lines were stated geomorphic processes and their intensity (L – low, M – middle, H – high) that influence the origin and the next development of patterns. The intensity was set on the basis of the expert assessment gained during the long-time observations and measurements in terrain or according to the degree of fragmentation of patches represented chiefly by vegetation.

Composing the morphogenetic classification of spatial patterns on the one hand, we considered the genetic geomorphic forms (of different scales), on the other hand, the attributes of morphodynamic processes (mostly their intensity). This classification can be applied as the ground for the subsequent quantitative statistical analyses of spatial vegetation patterns using the methods of fractal geometry (McGarigal, 2002; Krummel et al., 1987; Leduc et al., 1994; Li, 2000; Milne, 1991a, b, 1992; O'Neill et al., 1988; Sugihara, May, R.M., 1990; Turner, 1989; Turner M.G. et al., 2001; Turner S.J. et al., 1991; Bradbury et al., 1984; De Cola, 1989).

We verified many phenomena and the results of aerial photographs' interpretation by long-time intensive terrain research (2000–2009) connected with the photo documentation.

Results

To understand the present high-mountain landscape structure we must unequivocally deal with the information about the effects of contemporary geomorphic processes in this extreme environment (Boltižiar, 2007; Hreško, 1994; Hreško, Boltižiar, 2001; Barka, 2004, 2005). As relevant processes of the Tatra high-mountain landscape we regarded the landscape formation processes, simply the geomorphic processes, classified according to the main factor of destruction (Midriak, 1983) or on the basis of gravitational dominance and the processes conditioned by water: fluvial processes, gravitational processes, fluvio-gravitational processes, nivation-gravitational processes, cryogravitational processes (solifluction, gelisaltation), aeolian processes (aeolian corasion, deflation and transporting), nivation processes, cryogenic processes (regelation, gelivation-congelifraction), antrophogenic processes, organogenic (bio-) processes (phyto- and zoo-processes).

As relevant geomorphic forms of relief we regarded that of the Lukniš's geomorphic map of the High Tatras with a scale of 1:50 000 (Lukniš, 1968). We extended these by the other forms which we considered to be important for the spatial differentiation of landscape structure elements. We distinguished 12 mezorelief forms (outcrops, uniformly graded slopes, periglacial debris slopes, landslides, debris and debris-flows cones, glacifluvial cones, Holocene floodplain, glaciated knobs, late würm moraine, rock glaciers, protalus ramparts) and 6 microrelief forms (sorted soil circles, girland soils, aeolian and nivation patches).

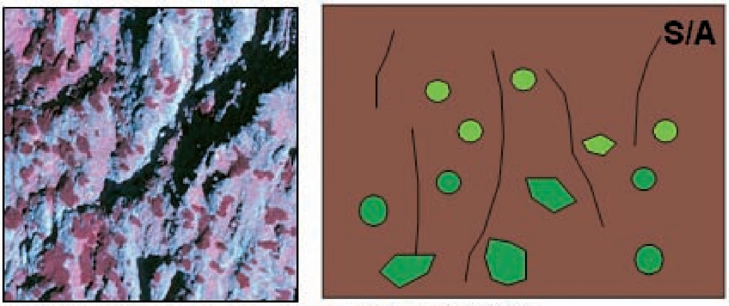
In this paper, we mention few examples of a "catalogue" containing the morphogenetic classification of spatial patterns (Figs 3–20) on the selected geomorphic forms together with an outline of the spatial pattern including relevant geomorphic processes, their intensity and also vegetation formations.

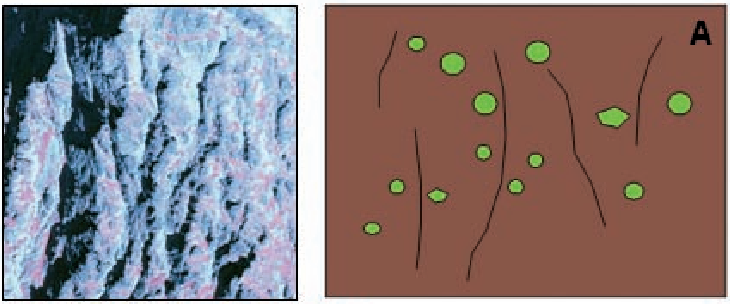
Conclusion

The paper is aimed at detailed knowledge of the Tatra landscape structure above the upper timberline; it proposes problems or questions connected with the spatial diversification and the mosaic formed by the different types of patches, corridors and matrices that made the sundry types of spatial geometric patterns. These arise from the interaction of various factors reflecting the extreme environment of the high-mountain landscape. The significant position is adopted by the relief, its geomorphic forms and the related geomorphic processes.

Understanding the influences of relief and the morphodynamic processes on the landscape structure as results in the outline of morphogenetic classification which considers the spatial patterns of the Tatra high-mountain landscape based on the interpretation of aerial photographs and the detailed fieldwork or research. The genesis of spatial structure patterns and their formation enables us to improve the deeper genesis of the high-mountain landscape structure – its function and contents in this environment. The morphogenetic classification of patterns represents an important informative and interpretative base for the knowledge of the structure and the mosaic of the Tatra high-mountain landscape. We see the application of this work and the possibilities of such a research to methods of the landscape ecological planning, e. g. the exact specification and scientific approach to sensitivity and carrying capacity of the high-mountain landscape (Hreško, Boltižiar, 2001; Boltižiar, 2007).

The paper presenting the results of our research focuses on the identification and the classification of spatial patterns in the relation to geomorphic forms and processes considering the middle-scale and micro-scale of the high-mountain landscape. These determine not only the shape of patches or the character of boundaries, but also the character of fragmentation, the heterogeneity of patches, the gradient and the tendency of patches development within the limits of the basic matrix. Relief, especially its spatial morphodynamic attributes, represents relevant phenomena of the landscape which facilitate to understand the scale and hierarchy of the landscape structure. The algorithm of this study is based on the spatial identification of forms, processes and patterns considering large-scale aerial photographs, a field reconnaissance and the partial classification. The main aim of this paper is to create





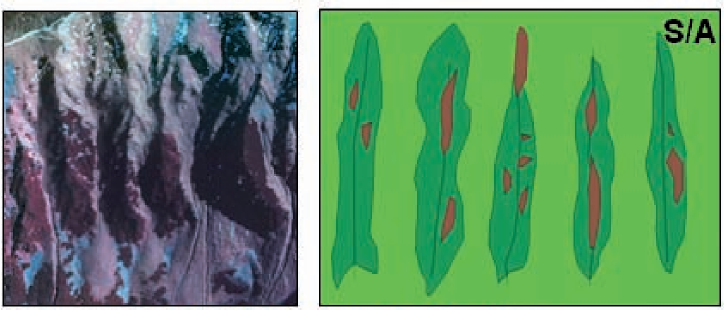


Fig. 3. Spatial patterns on the outrops.

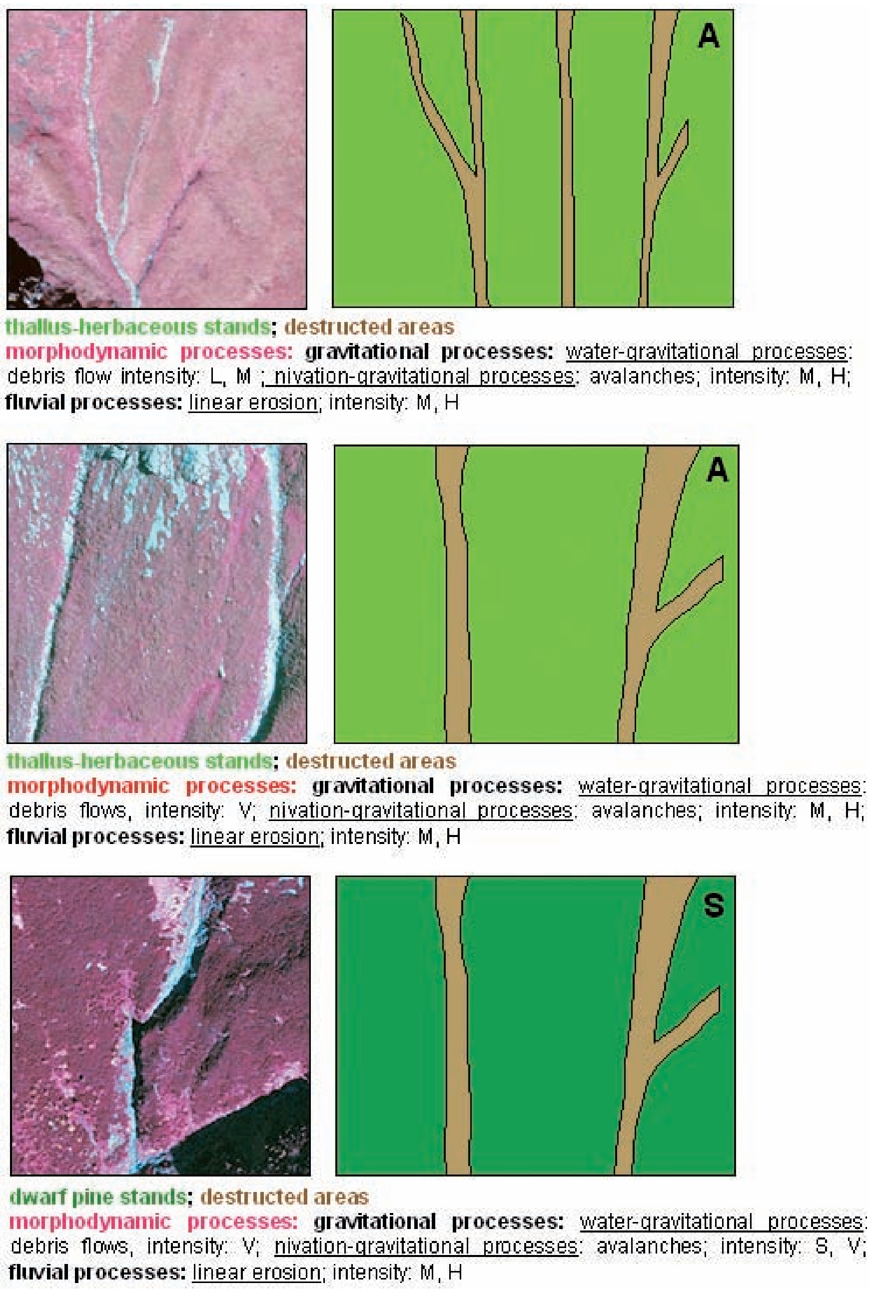


Fig. 4a. Spatial patterns on the uniformly graded slopes.

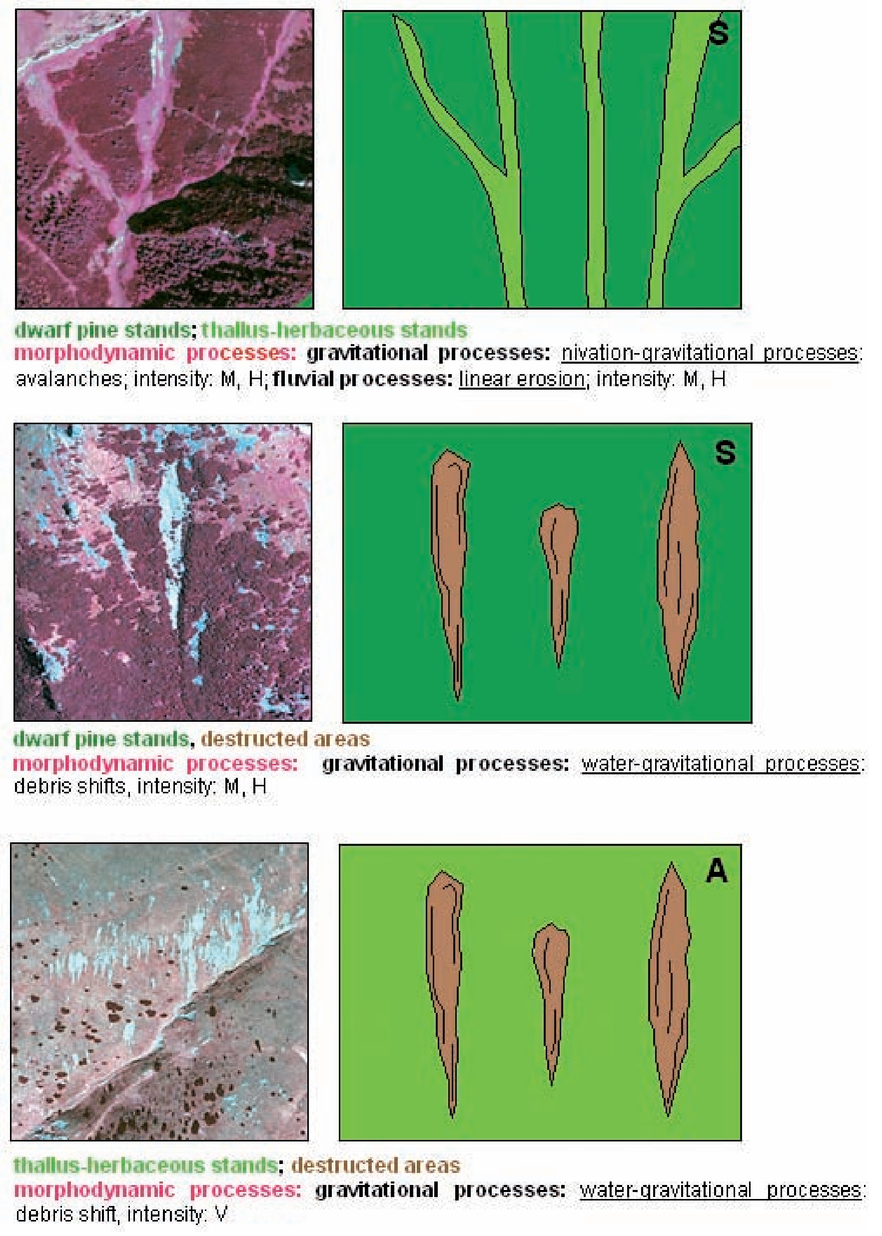


Fig. 4b. Spatial patterns on the uniformly graded slopes.

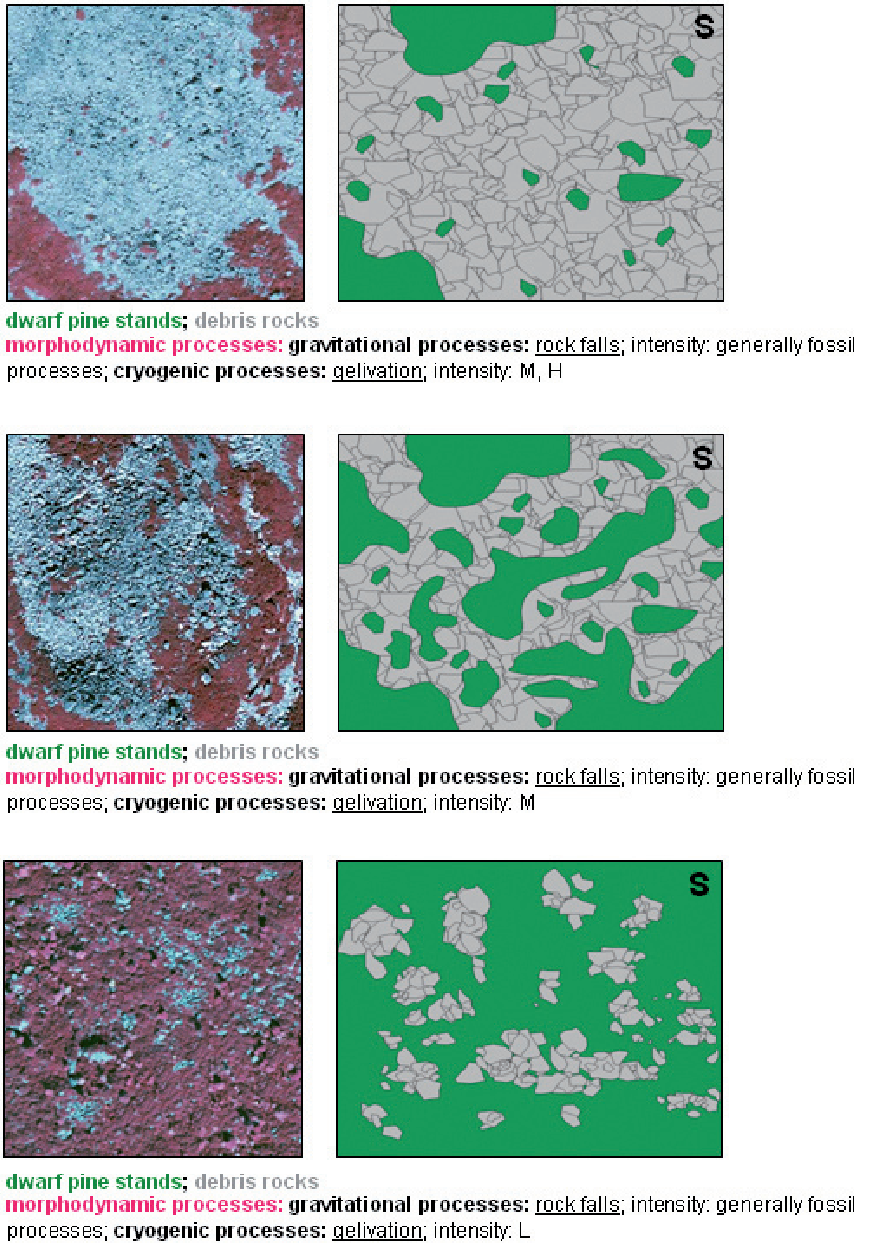


Fig. 5. Spatial patterns on the landslides.

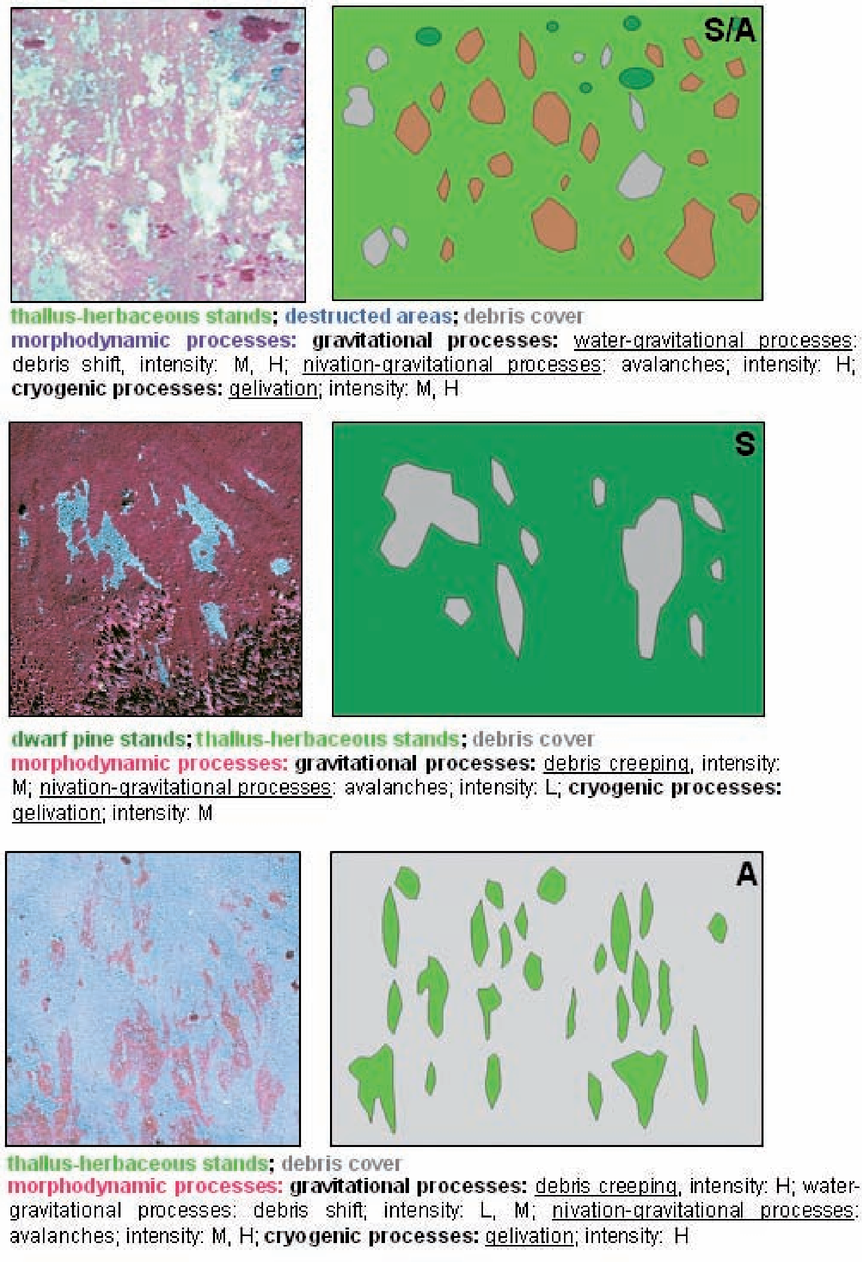
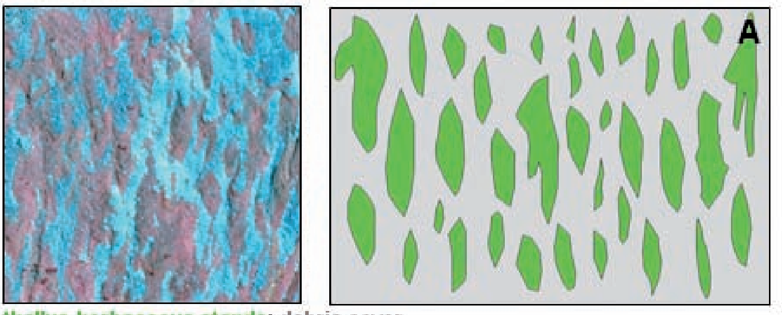
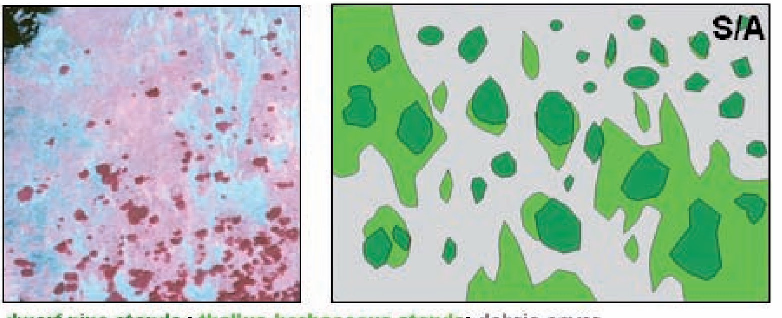


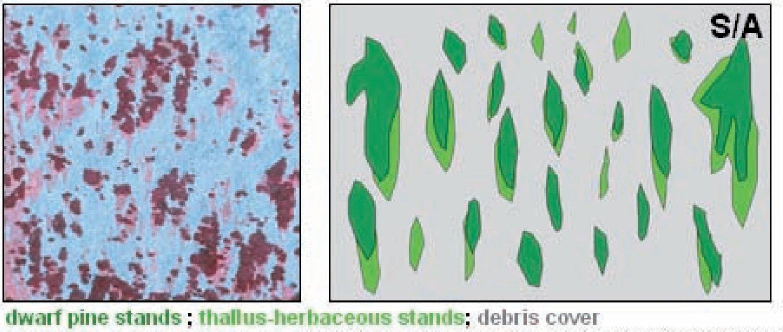
Fig. 6a. Spatial patterns on the periglacial debris cover.



thallus-herbaceous stands; debris cover
morphodynamic processes: **gravitational processes:** debris creeping, intensity: H; water-gravitational processes: debris shift; intensity: H; nivation-gravitational processes: avalanches; intensity: M, H; **cryogenic processes:** regelation, gelivation; intensity: H

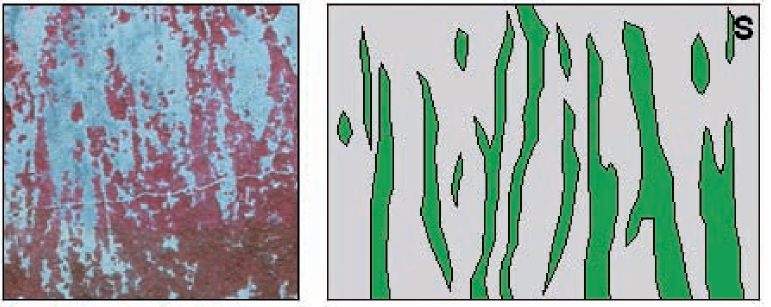


dwarf pine stands ; thallus-herbaceous stands; debris cover
morphodynamic processes: **gravitational processes:** debris creeping, intensity: M, H; water-gravitational processes: debris shift; intensity: M; nivation-gravitational processes: avalanches; intensity: L; **cryogenic processes:** regelation, gelivation; intensity: H



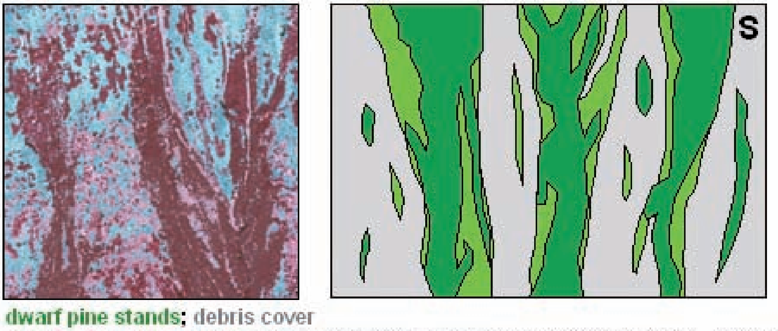
dwarf pine stands ; thallus-herbaceous stands; debris cover
morphodynamic processes: **gravitational processes:** debris creeping, intensity: M, H; water-gravitational processes: debris shift; intensity: L, M,; nivation-gravitational processes: avalanches; intensity: M, H; **cryogenic processes:** regelation, gelivation; intensity: H

Fig. 6b. Spatial patterns on the periglacial debris cover.



dwarf pine stands; debris cover
morphodynamic processes: **gravitational processes:** debris creeping, intensity: H, water-gravitational processes: debris shift, debris flows; intensity: M, H; nivation-gravitational processes: avalanches; intensity: H; **cryogenic processes:** regelation, gelivation; intensity: H

dwarf pine stands; thallus-herbaceous stands; debris cover
morphodynamic processes: **gravitačné procesy: gravitational processes:** debris creeping, intensity: L, M, water-gravitational processes: debris shift, debris flows; intensity: L, M, H; nivation-gravitational processes: avalanches; intensity: M; **cryogenic processes:** regelation, gelivation; intensity: L, M



dwarf pine stands; debris cover
morphodynamic processes: **gravitational processes:** debris creeping, intensity: N, S; water-gravitational processes: debris shifts, debris flows; intensity: N, S; nivation-gravitational processes: avalanches; intensity: S, V; **cryogenic processes:** regelation, gelivation; intensity: N, S

Fig. 6c. Spatial patterns on the periglacial debris cover.

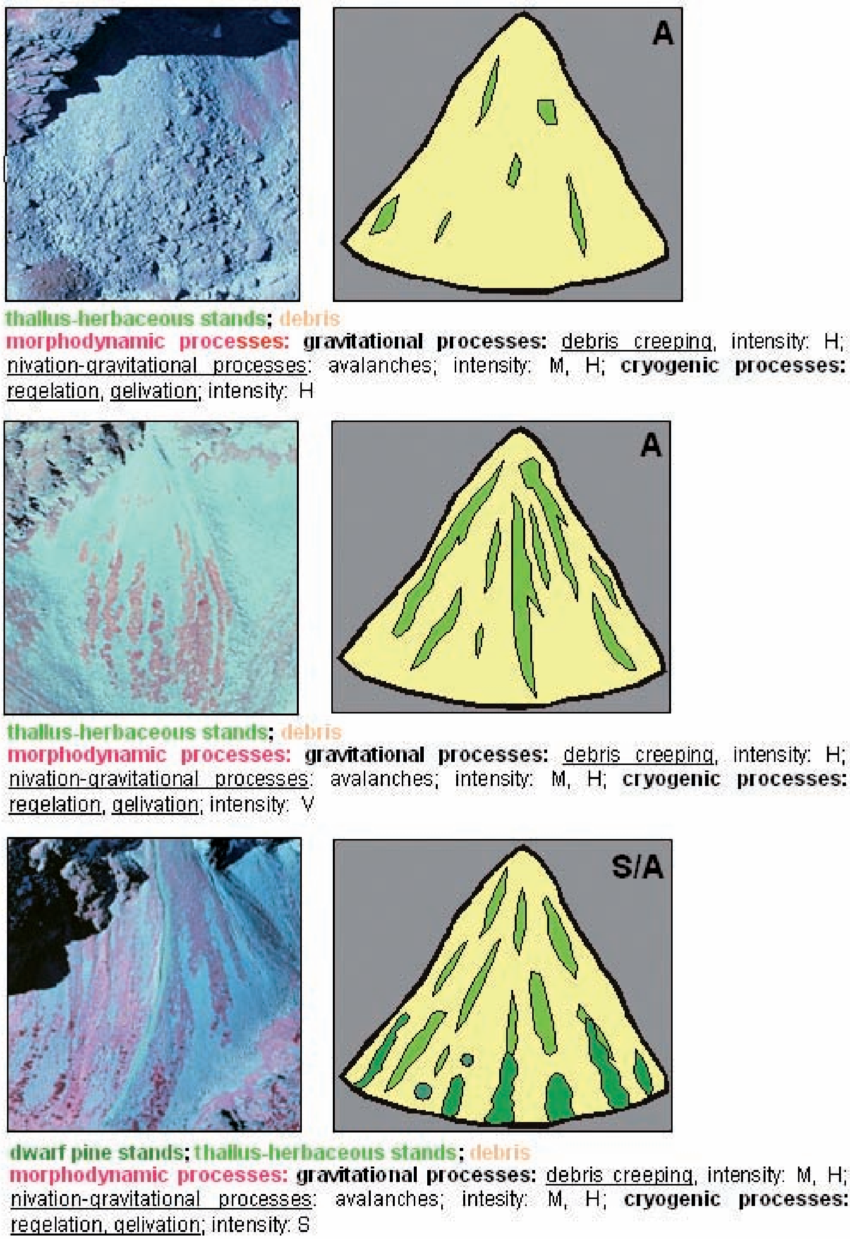


Fig. 7a. Spatial patterns on the debris cones.

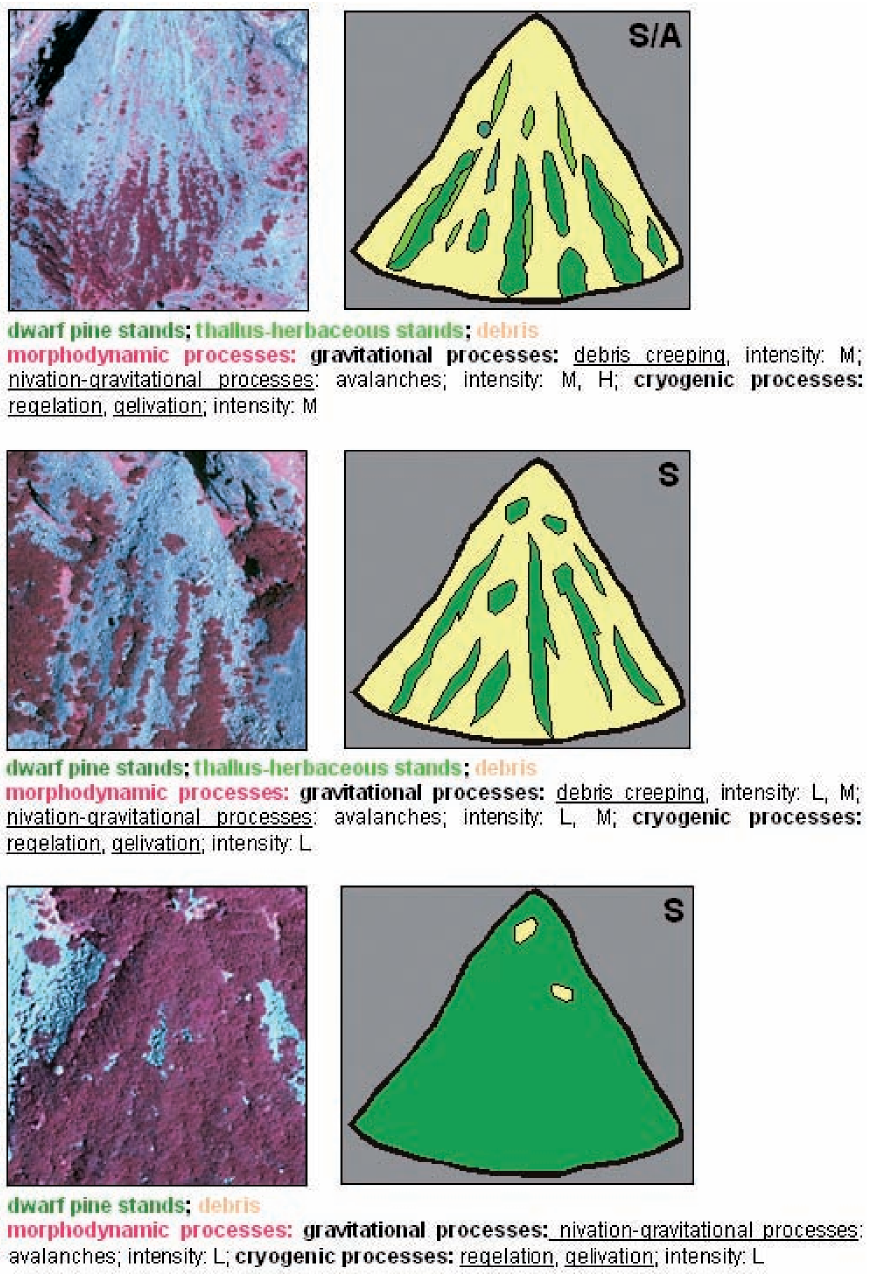


Fig. 7b. Spatial patterns on the debris cones.

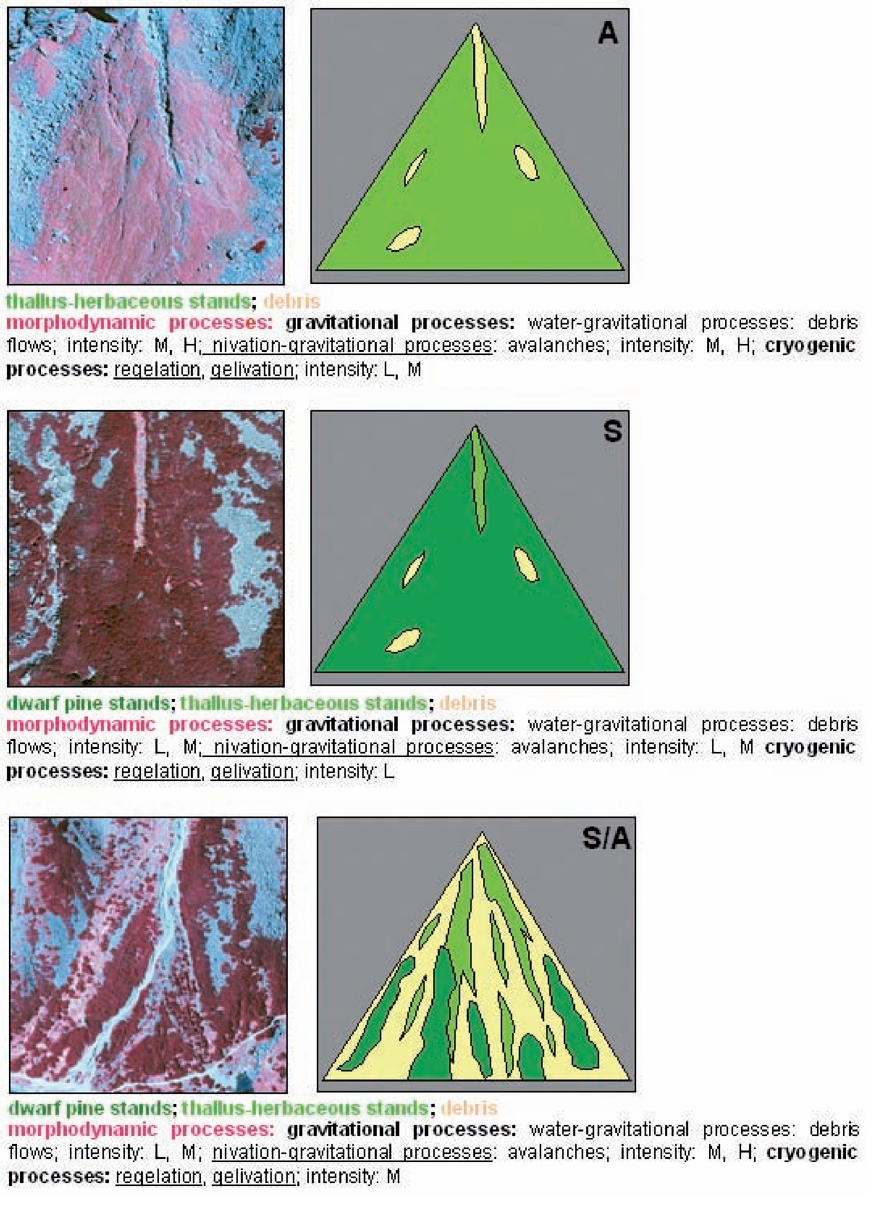


Fig. 8. Spatial patterns on the debris-flow cones.

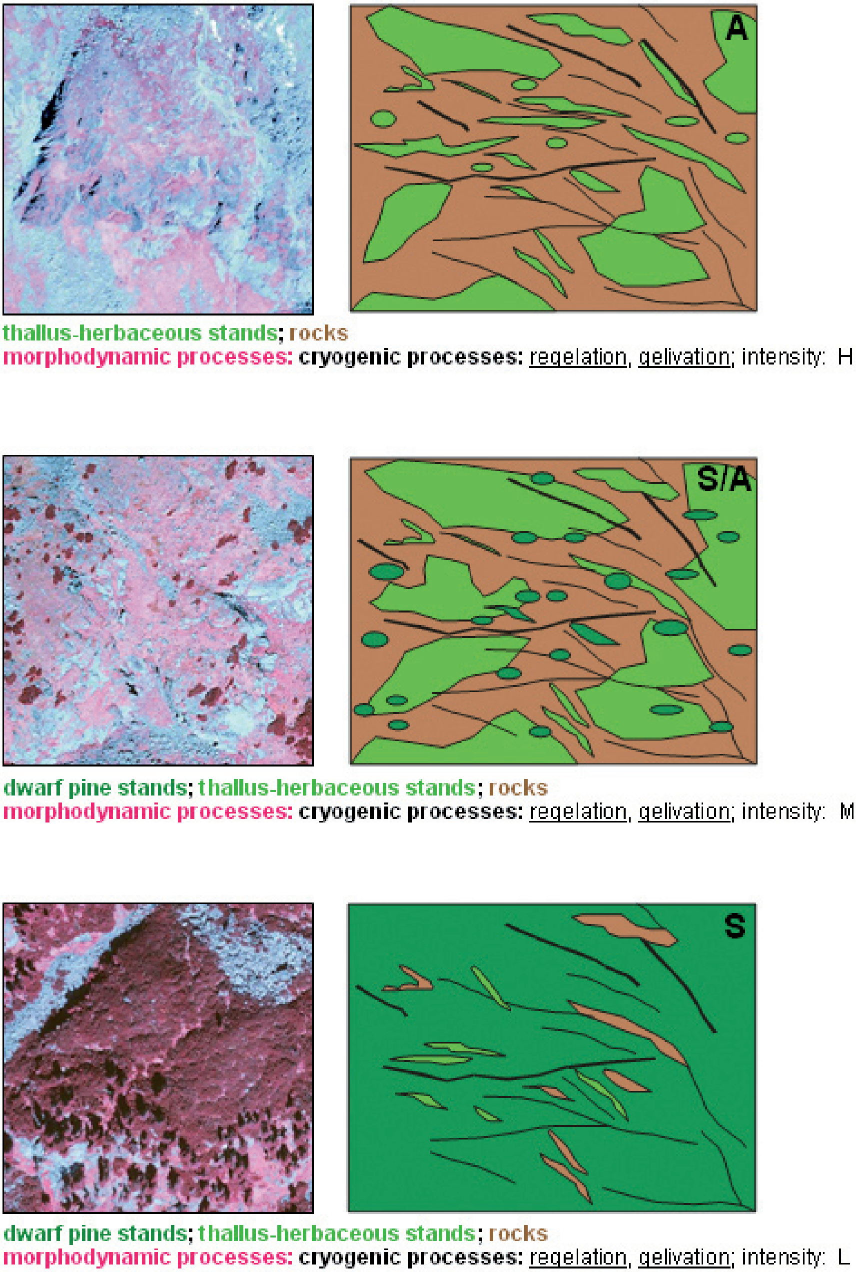


Fig. 9. Spatial patterns on the glaciated knobs.

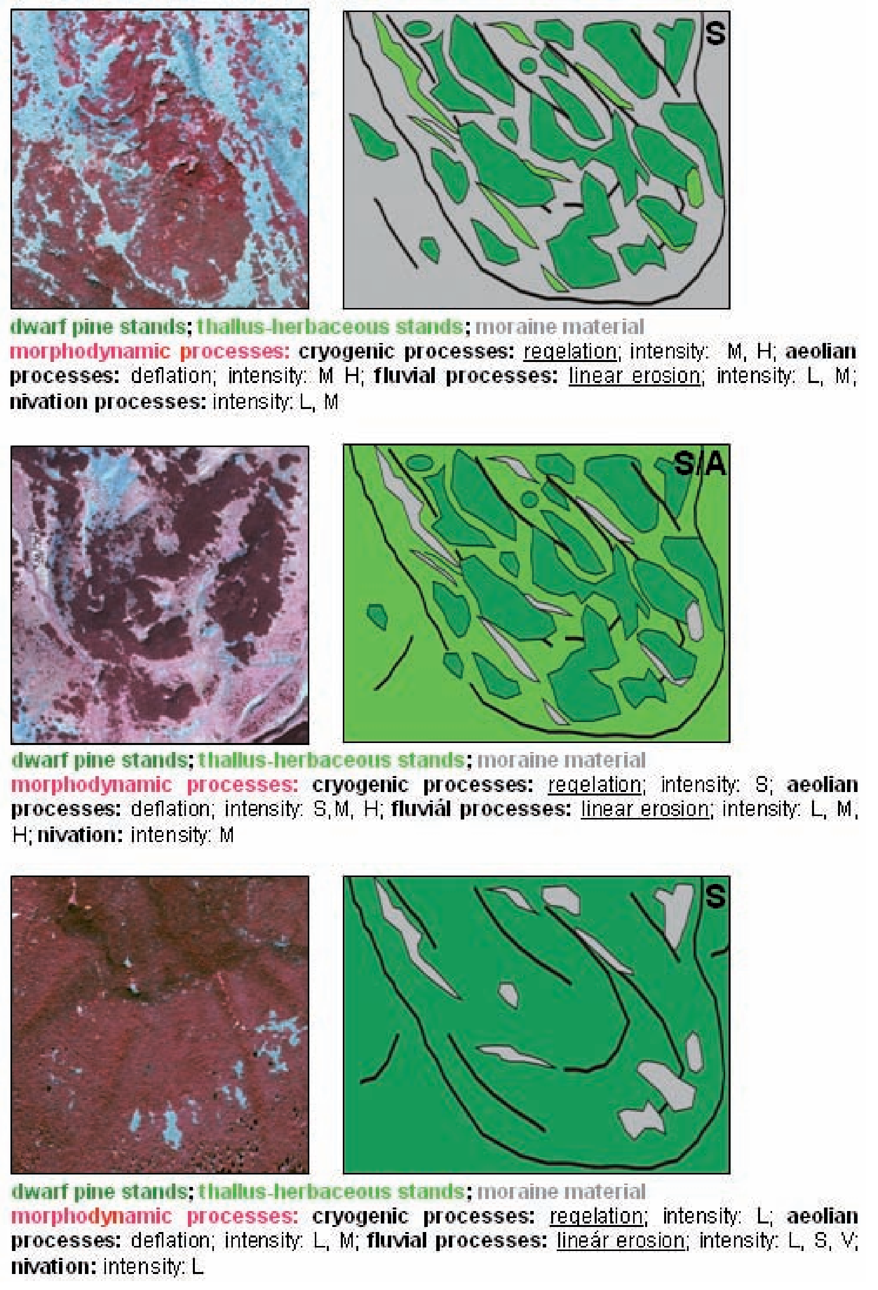


Fig. 10. Spatial patterns on the würm moraines.

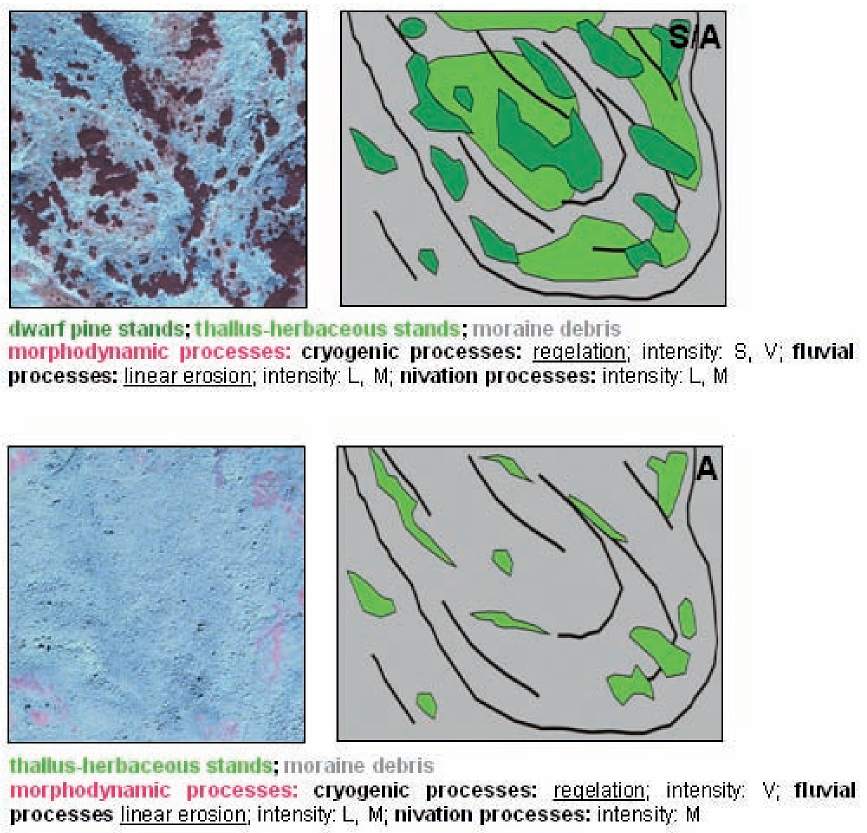


Fig. 11. Spatial patterns on the firn moraines.

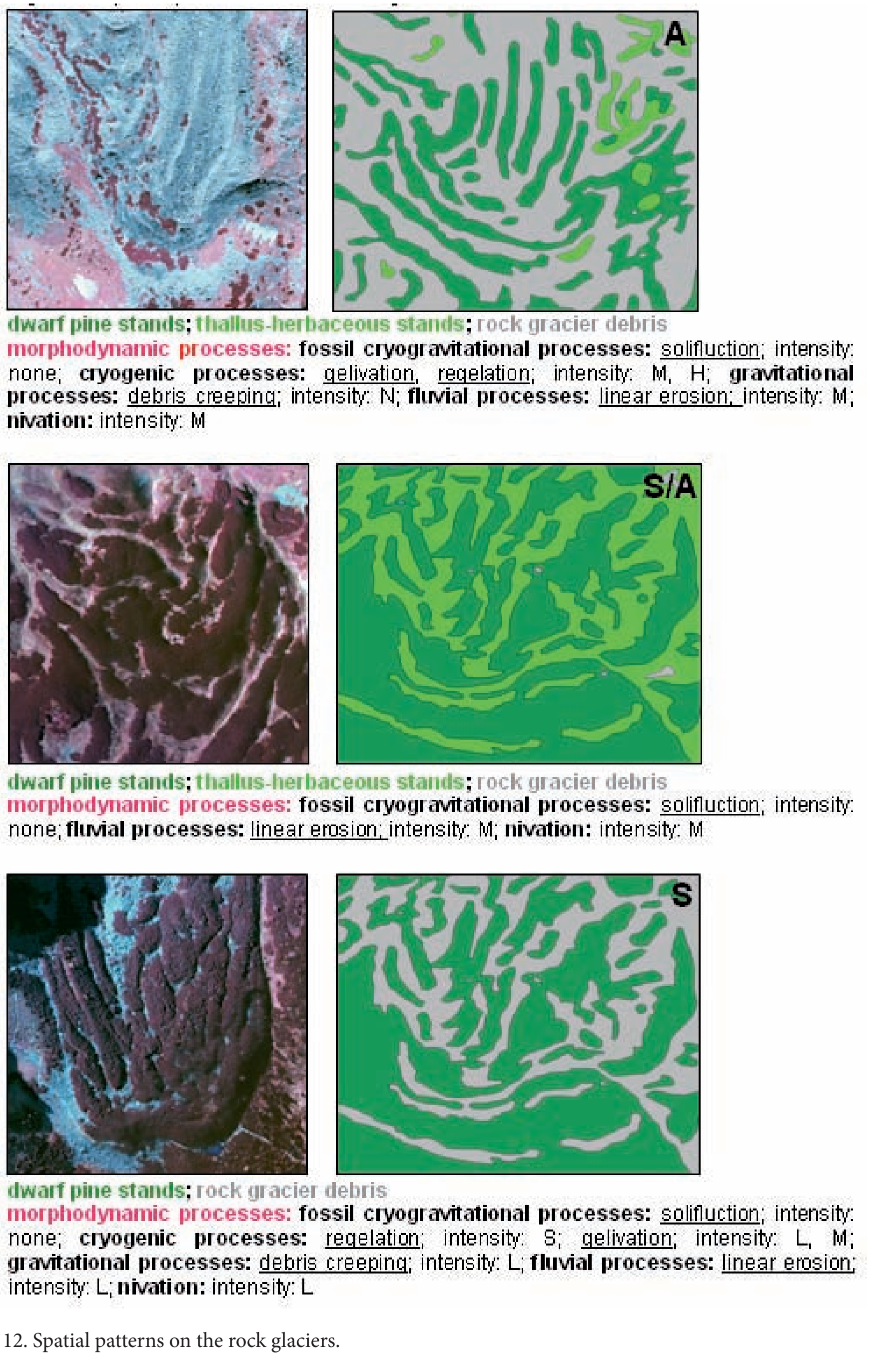
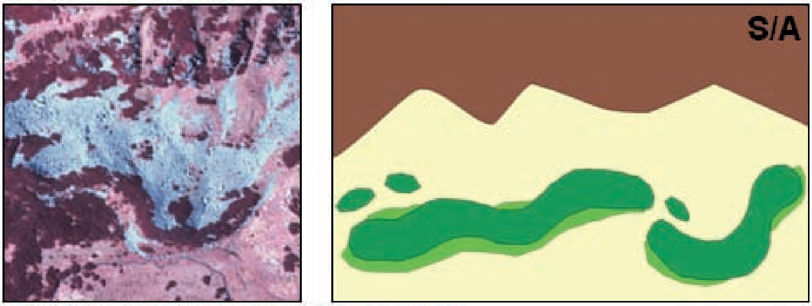
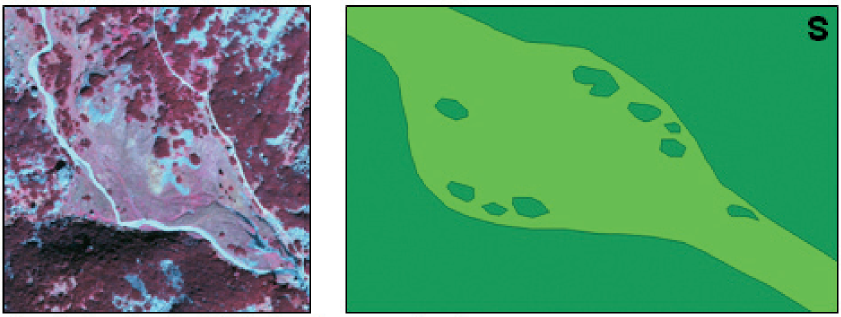


Fig. 12. Spatial patterns on the rock glaciers.

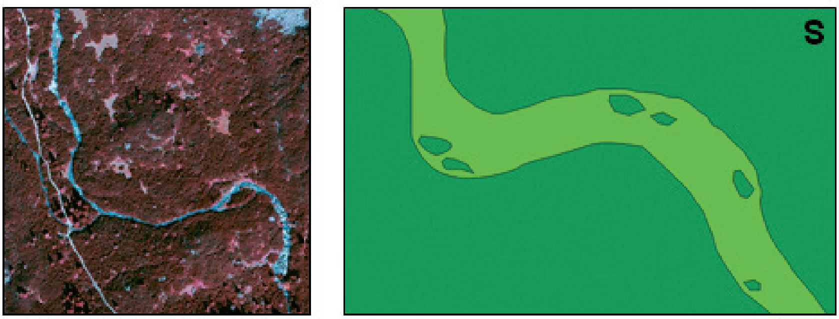


dwarf pine stands; thallus-herbaceous stands
morphodynamic processes: **gravitational processes:** nivation-gravitational processes: M; intensity: generally fossil processes; **nivation processes:** intensity: M, H; **cryogenic processes:** regelation; intensity: L, M

Fig. 13. Spatial patterns on the protalus ramparts.

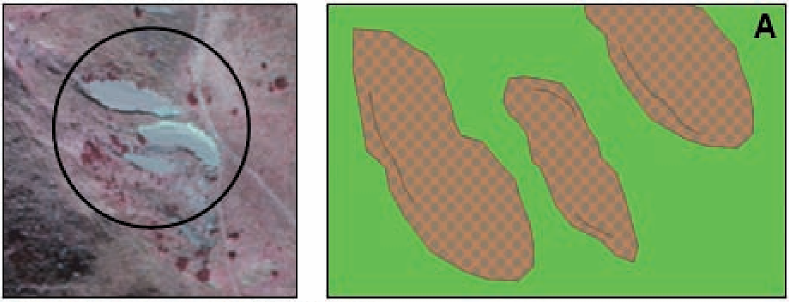


dwarf pine stands; thallus-herbaceous stands
morphodynamic processes: **fluvial processes:** linear erosion; intesity: M, H; sedimentation; intensity: M, H



dwarf pine stands; thallus-herbaceous stands
morphodynamic processes: **fluviál processes:** linear erosion; intensity: H; sedimentation; intensity: L, M

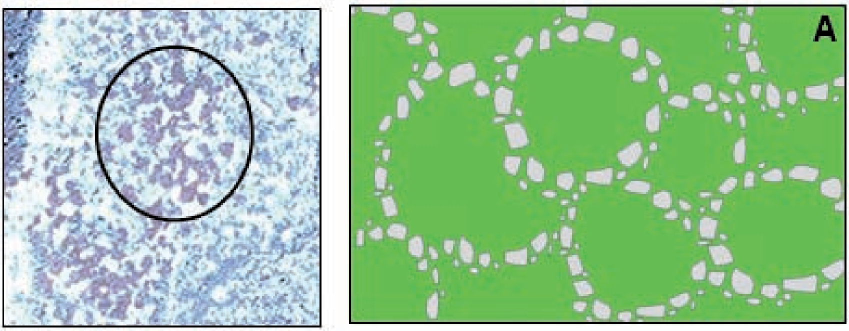
Fig. 14. Spatial patterns on the holocene floodplain.



thallus-herbaceous stands; soil cover

morphodynamic processes: **aeolian processes:** deflation; intensity: H; **cryogenic processes:** regelation; pipkrake; intensity: H; **cryogravitational processes:** gelisaltation; intensity: M, H

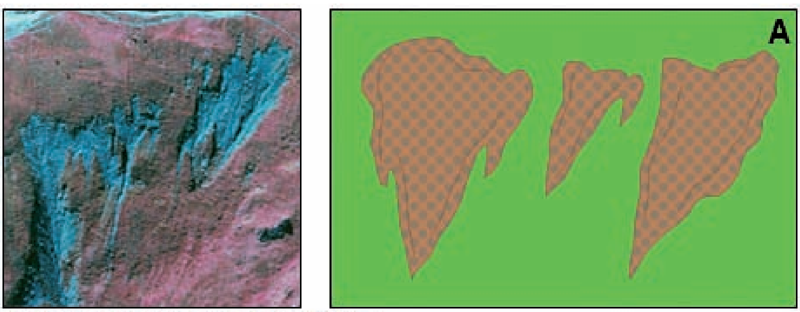
Fig. 15. Spatial patterns on the aeolian patches.



thallus-herbaceous stands; stones

morphodynamic processes: **cryogenic processes:** regelation; pipkrake; intensity: H

Fig. 16. Spatial patterns on the sorted soil circles.



thallus-herbaceous stands; soil cover

morphodynamic processes: **nivation processes:** intensity: H; **cryogenic processes:** regelation; intensity: H; **aeolian processes:** deflation; intensity: M, H; **cryogravitational processes:** gelisaltation; intensity: M, H

Fig. 17. Spatial patterns on the nivation patches.

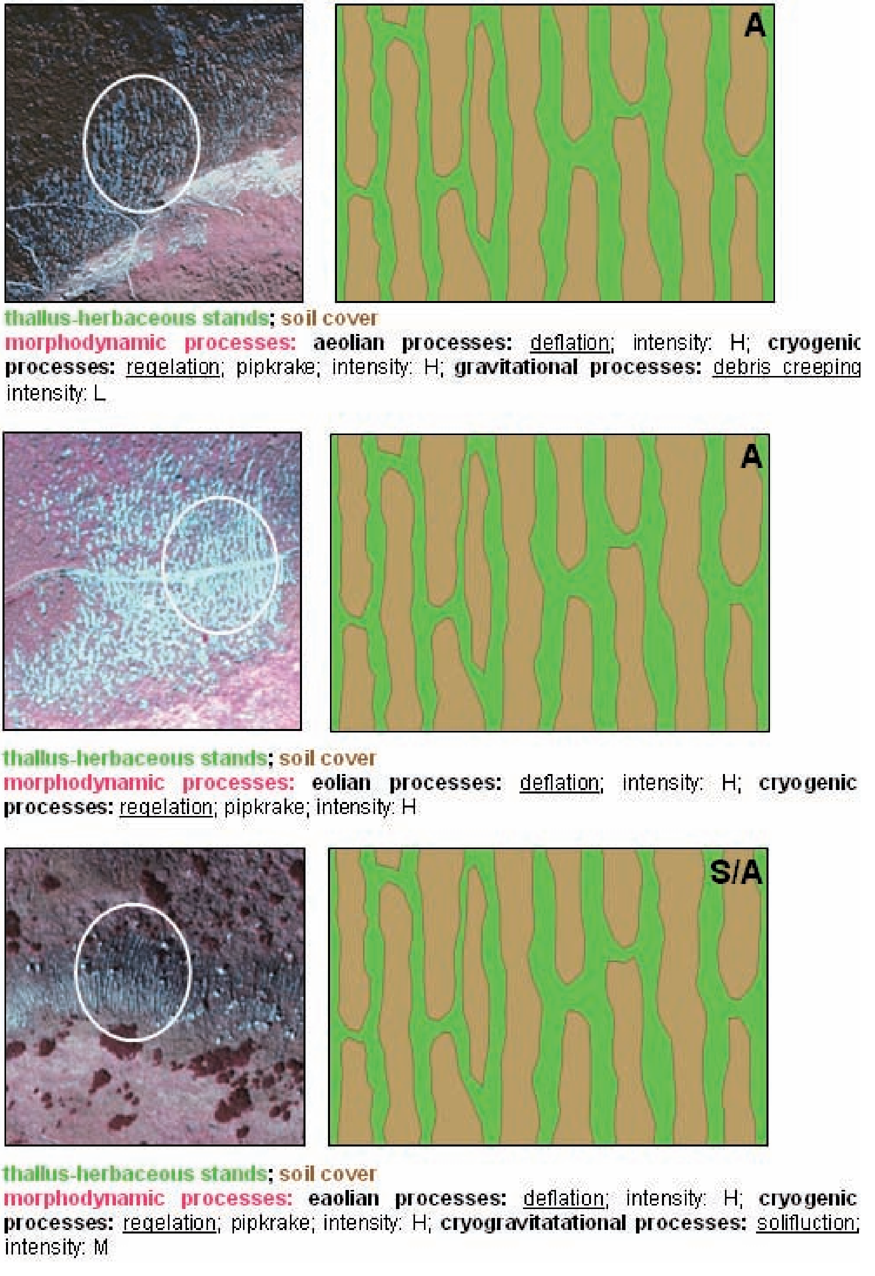


Fig. 18. Spatial patterns on the stripped soils.

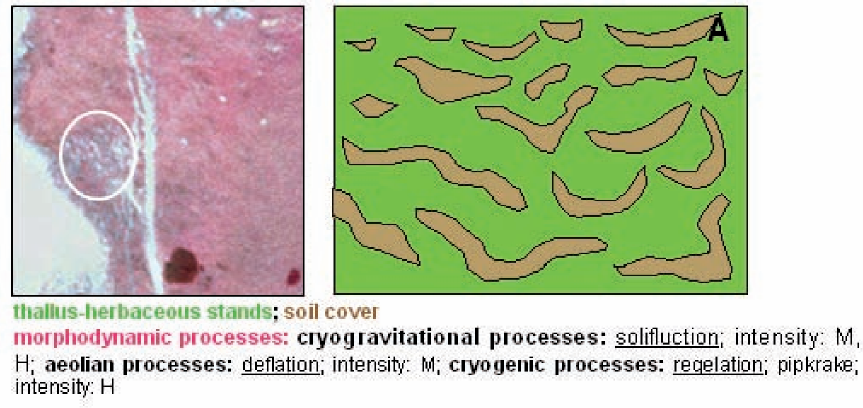


Fig. 19. Spatial patterns on the girland soils.

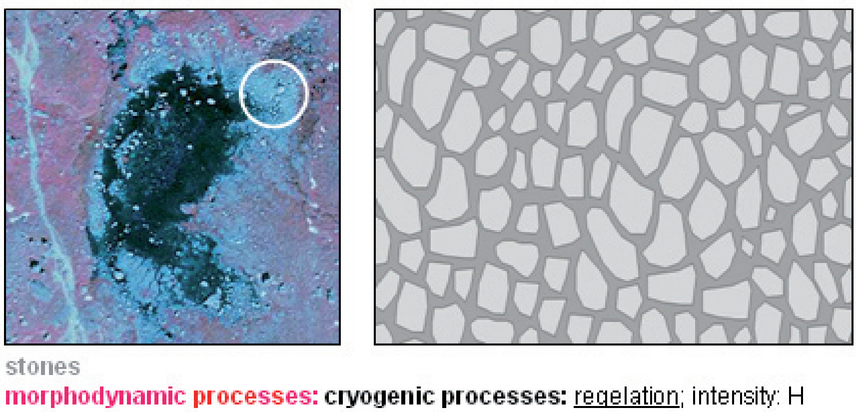


Fig. 20. Spatial patterns on the sorted soils.

the classification system of spatial patterns as the physiognomic spatial attributes of the landscape structure mosaic in the high-mountain areas. The genesis of spatial structure patterns and their formation enables us to improve the deeper genesis of the high-mountain landscape structure, its function and contents in this environment. Such a classification can be regarded as a basis for the quantitative statistic analyses of the landscape structure and for the detailed research of spatial patterns.

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English corrected by M. Ištoková

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