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# TYPOLOGY OF THE UPPER DWARF-PINE (*Pinus mugo)* LIMIT IN THE BIELOVODSKÁ DOLINA VALLEY, THE TATRA MTS

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Abstract

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Typology of the close dwarf-pine thickets boundary, an equivalent for the krummholz line in the Alps, is presented in this paper. The typology resulted from fieldwork carried out in the Bielovodská dolina valley from 2002 to 2003. Approximately 32 km of the krummholz line were surveyed. Five krummholz line types have been distinguished on the basis of orography, type of bedrock, geomorphic processes, landform types, slope gradient and the theoretic mean annual temperature. These are orographic, morphological, edaphic, mechanically lowered and anthropogenic boundaries. The relationships between krummholz line pattern, altitude and slope aspects have been assessed in particular types.

*Key words*: mountain pine, krumholz-line, typology, Tatra Mts, Bielovodská dolina valley

## Introduction

The upper border of the dwarf-pine (*Pinus mugo*) belt in the Tatra Mts is an equivalent for the krummholz line in the Alps. In contrast to the timberline it creates a relatively abrupt transition between close dwarf-pine thickets and the patches of dwarf-pine individuals. Thus it is one of the most distinct landscape boundaries in the natural environment of the Tatra Mts. The average altitude of this boundary is about 1650-1700 m a.s.l.

The natural and anthropogenic types of timberline are frequently mentioned in the literature pertaining to the forest - alpine tundra ecotone (Sokołowski, 1928; Plesnik, 1956). The detailed typology of timberline in the Západné and the Belianske Tatra Mts was carried out by Plesnik (1971). On the basis of the critical environmental factor controlling the timberline pattern five boundary types were distinguished. These were climatic, edaphic, orographic, avalanche driven and anthropogenic boundaries.

This typology was the basis for Seko's (1983) studies on the typology of the upper boundary of dwarf-pine thickets in the Western Carpathians. The results of the investigations conducted on a regional scale encompassed description of natural and anthropogenic boundary types. The natural boundaries were divided into climatic, edaphic and mechanically-lowered ones. Since the subject of typology was not defined precisely it is unclear whether the typology is related to the boundary of close dwarf-pine thickets, the upper limit of krummholz patches or the entire ecotone.

The detailed typology of the krummholz line in the Bielovodská dolina valley in the Tatra Mts presented in this paper resulted from extensive fieldwork conducted by the author from 2002 to 2003.

## Characteristics of the study area and methods

The study area encompasses the Bielovodská dolina valley, the upper part of the Biela voda catchment (Fig. 1). It is located in the central part of the massif on the northern side of the main ridge. The rocks building the valley are mainly granitoids with some limestone and dolomites in the northernmost part of the study area. It has typical features of glacial relief, e.g., U-shaped valleys, hanging valleys, cirques with lakes and moraines (Lukniš, 1973; Klimaszewski, 1988). The relief of the catchment is approximately 1500 metres and the maximum elevation is 2606 m a.s.l. at Zadný Gerlach peak. Human impact on the natural environment of this part of the Tatra Mts was considerably smaller in comparison to other parts of the massif.

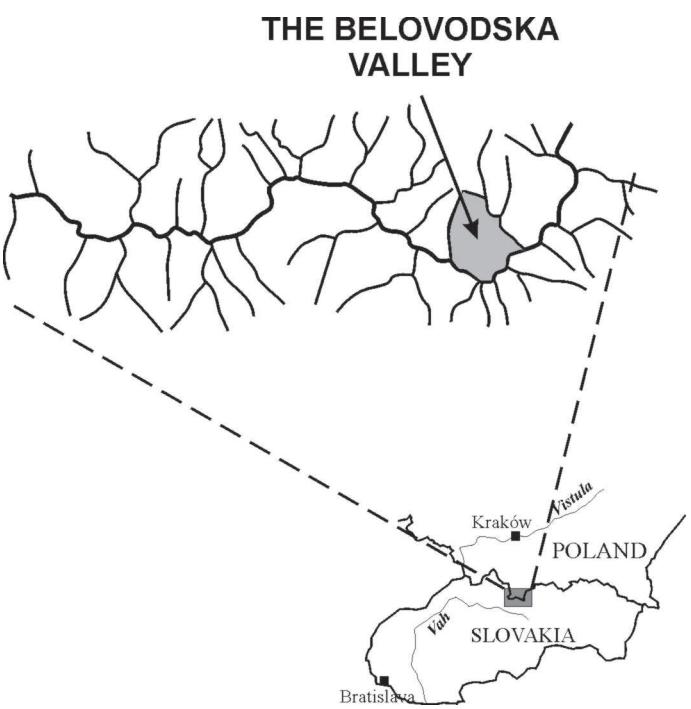



Fig. 1. Location of the study area.

Fieldwork involved mapping homogeneous reaches of krummholz line in the 1:10 000 scale. The pertinent data concerning the variability of natural environment and impact of geomorphic processes on the course of the boundary were noted on a reach-evaluation form. Morphometric data were obtained from digital maps, which were later verified in the field. The maps of slope gradient, aspect and annual mean tem-

perature were computed on the basis of digital elevation model (DEM) using GIS programs. DEM has been created through the digitalisation of topographic maps in the scale of 1:25 000.

Factors likely to lower the krummholz line were the criteria of typology. These were orography, type of bedrock, geomorphic processes, landform types, slope gradient and the theoretic mean annual temperature. Human impact has been taken into consideration as well.

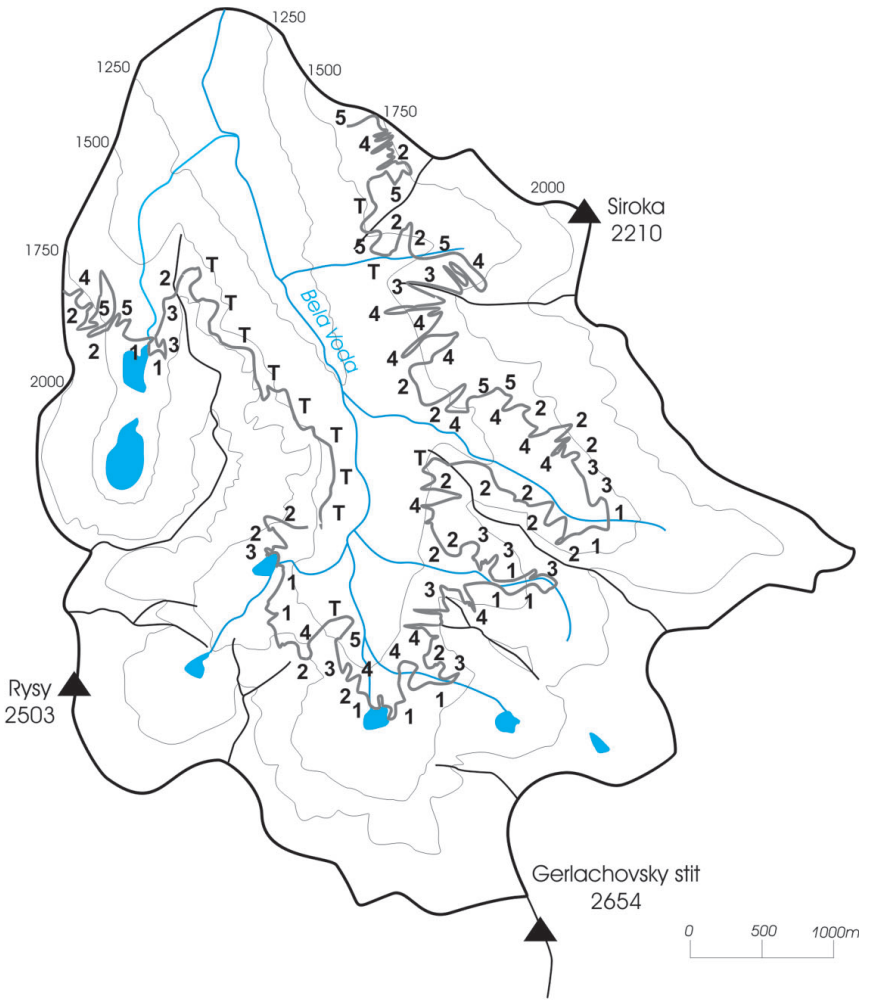
## Results

Approximately 32 km of the krummholz line were surveyed. The critical factors controlling the course of the krummholz line were determined in homogeneous reaches. Finally, five types of krummholz line were distinguished (Fig. 2). These are orographic, morphological, edaphic, mechanically lowered and anthropogenic boundaries. The data referring to the altitude and aspect of krummholz line in particular types are shown in Table 1.

In some parts of the Bielovodská dolina valley only patches of dwarf-pine thickets occur above the timberline. In that case, the reaches of timberline were surveyed. The altitude of timberline attains its highest value on the eastern slopes of Mlynár massif., 250 metres higher than the lowest position of krummholz line (Fig. 2).

T a b l e 1. Krummholz line types altitude on slopes with particular aspect

| Krummholz line type | | | Orograhic (valley bottom) | Morphological | Edaphic | Mechanically lowered | Anthropogenic | Timberline |
|---|---|---|---|---|---|---|---|---|
| Length | | | 3870 | 8360 | 4430 | 8090 | 2270 | 5020 |
| av. altitude | | | 1639 | 1612 | 1642 | 1594 | 1651 | 1479 |
| max altitude | | | 1560 | 1400 | 1520 | 1385 | 1470 | 1350 |
| min altitude | | | 1810 | 1870 | 1815 | 1790 | 1835 | 1650 |
| Aspect | E | length | 350 | 560 | – | 340 | 350 | 2030 |
| | | av. altitude | 1723.14 | 1749.75 | – | 1731.37 | 1690.03 | 1459.24 |
| | NE | length | 1230 | 310 | 290 | 130 | 100 | – |
| | | av. altitude | 1630.64 | 1581.13 | 1684.31 | 1532.92 | 1677.5 | – |
| | N | length | 600 | 1910 | 710 | 400 | 740 | 1810 |
| | | av. altitude | 1617.5 | 1627.47 | 1552.70 | 1598.65 | 1699.58 | 1495.02 |
| | NW | length | 360 | 360 | 710 | 1880 | – | – |
| | | av. altitude | 1638.97 | 1665.19 | 1610.37 | 1617.36 | – | – |
| | W | length | – | 640 | 200 | 110 | – | 90 |
| | | av. altitude | – | 1535.52 | 1674 | 1641.81 | – | 1437.11 |
| | SW | length | 60 | 250 | 160 | – | – | – |
| | | av. altitude | 1626.83 | 1723 | 1667.69 | – | – | – |
| | S | length | 150 | 2570 | 1670 | 3130 | 900 | 210 |
| | | av. altitude | 1608.27 | 1602.8 | 1656.16 | 1584.61 | 1625.42 | 1530 |
| | SE | length | 1120 | 1750 | 690 | 2100 | 180 | 860 |
| | | av. altitude | 1682.46 | 1561.19 | 1702.03 | 1565.37 | 1492.61 | 1482.73 |



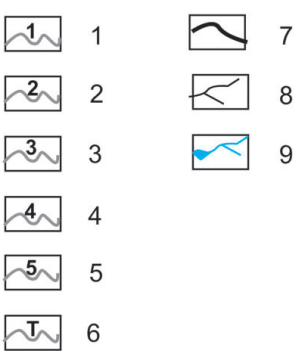




Fig. 2. Krummholz line types in the Bielovodská dolina valley. Krummholz line types: 1 – orographic, 2 – morphological, 3 – edaphic, 4 – mechanically lowered, 5 – anthropogenic, 6 – timberline, 7 – catchment border, 8 – ridge crests, 9 – streams and lakes.

No significant correlation has been found between mean annual temperature computed on the basis of linear regression equation (Hess et al., 1975) and the altitude of krummholz line. Thus it can be assumed that the upper boundary of close dwarf-pine thickets is not a climate-driven boundary. However, climate is the crucial factor in controlling the upper limit of dwarf-pine patches.

*Orographic boundaries*

Local orographic conditions constitute the main factor controlling orographic krummholz line. Reaches of such boundaries are located at the valley bottoms, where the slope gradient is lower than 6°. At some locations (e.g. České pleso lake and Kačacie pleso lake) krummholz line corresponds to the lake shore closer to the bottom of the main valley. Such pattern of krummholz line can be also observed in other valleys of the Tatra Mts. So-called valley-bottom treeline has been mentioned in the literature pertaining to causes of treeline in high mountains of Europe and North America (Sokołowski ,1928; Arno, 1984; Steven, Fox, 1991). Cold-air flows as well as the inversion of temperature are considered to control these boundaries. The influence of lakes may also be significant.

*Morphological boundaries*

Reaches of morphological boundaries were delineated on the border between landforms of different type. An abrupt change in slope gradient and occurrence of rock walls and steep rocky slopes could be a restraint for dwarf-pine growth. Great variability in landform types is the main cause of the common occurrence of reaches of morphological krummholz line in the entire the Bielovodská dolina valley. They are present on slope irrespective of aspect and attain their maximum altitude at 1870 m a.s.l., close to the climate-driven boundary of krummholz patches (Table 1).

*Edaphic boundaries*

The features of bedrock determine the occurrence of edaphic boundaries. Close dwarf-pine thickets cannot grow on scree slopes. Only the krummholz patches could encroach on the scree slopes Thus edaphically driven boundaries occur at the base of scree slopes or talus slopes.

*Mechanically lowered boundaries*

Geomorphic processes i.e. avalanches, debris flows and rock falls determine the pattern of krummholz line on steep slopes (gradient 25–45°) with gullies and chutes. Large avalanches and debris flows can dissect the subalpine belt down to the timberline (Hreško, Boltižiar, 2001). Thus, in comparison with other boundary types the average altitude of

mechanically lowered boundaries is the lowest. Avalanche and debris-flow paths are very narrow (not exceeding 50 metres) but their altitudinal range may attain several hundred metres. Such boundaries typify the western slopes of Široká massif.

*Anthropogenic borders*

Although human impact on the natural environment of the Bielovodská dolina valley was considerably smaller in comparison with other parts of the Tatry Mts anthropogenic boundaries are present on the slopes of Žabia kopa crest hill and in the vicinity of the Litvorová kotlina gully. The lack of dispersed dwarf-pine zone above krummholz line and the abrupt transition from krummholz formation to alpine pastures are the characteristic features of such boundaries.

## Discussion and conclusions

The krummholz-line types distinguished in this paper may occur in vast majority of high-mountain massif with mountain pine thickets in the Západné Karpaty Mts as well as in the Eastern Alps. They also correspond well with the types distinguished by Seko (1983) in the Nízke Tatra Mts. The observations conducted by the author in other Tatra valleys, the Babia Góra massif and the Dolomites confirm this hypothesis. However, the internal structure of forest - alpine tundra ecotone, average altitude of krummholz line as well as the share of particular types might vary. Due to intensive human activity the anthropogenic landscape boundaries are common in many parts of the Západné Karpaty Mts. The proportion of mechanically lowered and morphological krummholz lines would be considerably lower in the mountain ranges with less differentiated relief. The aim of the author's further research is to assess and compare variability in the pattern of krummholz line in the Tatra Mts, the Babia Góra massif and the Giant Mts.

*Translated by the author*

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