TREML, V., BANAŠ, M. (2000): ALPINE TIMBERLINE IN THE HIGH SUDETIES. ACTA UNIVERSITATIS CAROLINAE, GEOGRAPHICA, PRAHA, 35: 83-99.

# Alpine timberline in the High Sudeties

Mgr. Václav Treml*, Mgr. Marek Banaš**
*Department of Physical Geography and Geoecology Přf UK Praha
**Department of Ecology Přf UP Olomouc

Key words: alpine timberline, alpine treeline, geoecology, mountains.

Abstract
The alpine timberline is an essential boundary in mountain relief. In the High Sudeties there are three mountain ranges rising over alpine timberline - the Krkonoše Mts. with largest and well diferentiated alpine area, Králický Sněžník, which is small, summit phenomenon efected enclave and Hrubý Jeseník Mts. with seven alpine areas of different extend. Using orthophotomaps and air photos we assesed such a characteristics of alpine timberline as its length, avorage height and extend of alpine belt. Also we discussed a natural origin of an alpine belt in the High Sudeties. We have founded out many differenties in synmorphology of alpine timberline between the Krkonoše Mts. and Hrubý Jeseník Mts.

## Introduction

There are four different areas above the alpine timberline (ATL) in the mountains of the Czech massif. Three of them – Krkonoše, Králický Sněžník and Hrubý Jeseník Mts. are situated in the High Sudeties, last one is the highest peak of the Šumava Mts. – Velký Javor (Grosser Arber, 1456 m). We are going to engage to High Sudeties area, because of small and heavily man – degraded Velký Javor area. Krkonoše Mts. belong to group of mountains with well differenced alpine belt, Hrubý Jeseník and Králický Sněžník Mts, aproximate to this group, Šumava Mts. belong to the group of mountains with slight features of alpine ecosystems (Jeník 1973).

The ATL is a fundamental boundary in the mountain relief from the geodynamic, microclimatic and phytocenologic point of view. It is fairly conservative system, which responds on the macro and mezoclimatic changes with longer delay than single specimens of trees (alpine tree species line respectively). In the case of pasage ATL into dwarf shrubs, the essential boundary from floristic and sozologic point of view is its upper limit (Ellenberg 1996). ATL isn't sharp line boundary, in reality it is a transition zone, which has its own two boundaries and they are in turn, also transition zones with their own boundaries, and so on endless (Körner 2000). For practical reasons it is necessary to define convention criterions for its delimination. Differencation of ATL and tree species line is caused by the ecotop conditions in the microscale (Körner 1999). High frequency of catastrophic events is next reason for it. The abruptly ending ATL, without so called „kampf" zone, we have recorded only by the plantations or by geomorphologicaly influenced ATL (rocks and block of fields). As regards to the main factors induced establishing of ATL, the most probably reason is the insufficient incorporating of asimilates rising by photosynthesis into a cell structures, causing by low temperatures in vegetation period (globaly average temperatures 5,5 – 7°C at ATL). Often mentioned average july temperature 10°C isn't predictive value on the global scale, there are big differences between avorage july temperatures at ATL across the Europe. Tree growth isn't limited by low intensity of photosynthesis (Körner 1999). Tranquilini and also Körner suggested significant meaning of mycorhiza. Besides above mentioned factors, there are, especialy in the midle mountains with intensive summit phenomenon, another stress factors – snow and ice injury, winter dessicitation and low germinating rates in the vegetation across ATL (*Deschamsia cespitosa, Avenella flexuosa, Nardus stricta, Calamagrostis villosa*).

Habitus of Norway spruce at ATL in the Krkonoše and Hrubý Jeseník Mts. is much more stressed by effected force of wind and ice injury compared with spruces in the Tatra Mts. or the Alps, where a rate of such injured spruces is lower. It is caused by more intensive summit phenomenon, ATL runs near summits. Such a summit phenomenon hasn't changed throughout the holocene, nor by oscillations of regional (and global) temperature conditions, that's why there is no reason for significant natural oscillations of ATL.

Today's ATL is ecologicaly stabilized system, which cours is result of climatic proceses of several last centuries (Körner 1999). There are generaly accepted mild movements of ATL throughout holocene, Wick et Tinner (1999) mentioned for the central Alps rate of oscillation 150 m. There hasn't been recorded considerable natural changes of ATL course in the middle mountains of the central Europe, where the cold oscillations haven't been forced by oscillations of snowline and glaciers (Hüttemann et Bortenschlager 1987). It coheres with strong effect of summit phenomenon.

The ATL in some studied regions across the Europe desplays remarkably increasing tendention, either as continuing of this tendention from last periods  (Wick et Tinner 1999, central Alps) or as deviation from generally decreasing tendention (Kullman et Kjällgren 2000, the Scands).

Presence of closed canopy forest in the summit areas (today situated above ATL) isn't probably until melting of permafrost (cca 8000 BP, Czudek 1997). The only cold oscillation recorded by decrease of ATL in the Krkonoše Mts. is paralleled by Hüttemann et Bortenschlager (1987) with cold event Oberhalbstein (8000 - 7500BP uncal.). After this oscillation ATL increase slightly above its present level (avorage cca 26m, Jeník et Lokvenc 1962) and hadn't showed significant oscillations until the man induced changes started happen, it means in the Krkonoše Mts. in the time span 1100 AD (Speranza et. al. 1999) - cca 1500 AD (Hüttemann et Bortenschlager 1987).

There is asumed same evolution of ATL course in the Hrubý Jeseník Mts, however there is lasting presence of an alpine belt throughout the holocene casting doubt on no dwarf pine occurence. Jeník (1973), Jeník et Hampel (1991) suggested similar rate of human induced decrease of ATL as in the Krkonoše Mts., but they mentioned some localities where occured temporary artificial increas of ATL.

The vegetation indicated a natural origin of an Alpine belt in the High Sudeties

As indicator of original natural alpine area we consider plant communities which presence is caused by climatic extrems on deflation summits of highest peaks, where „periglacial“ phenomenons occures (pipcrake, cryosegregation, soli(geli)fluction, deflation). On those ecotops there are wind blown alpine grasslands (Chytrý et al. 2001) of alliance Juncion triffidi (as. *Carici-rigidae-Juncetum trifidi* Šmarda 1950 and *Cetrario festucetum supinae* Jeník 1961) with arcto-alpine species (*Carex bigelowii, Juncus trifidus, Diphassiatrum alpinum, Hieracium alpinum*, and abundant lichens and mosses – *Cetraria* sp., *Cladonia* sp.) and alpine heatlands of the same association. Its occurence coheres with cryo-eolian zone sensu Soukupová et al. (1995).

The another type of plant communities which occurence is limited on an unforested ecotops are communities strictly limited by extreme snow deep or periodical avalanche activity, solifluction and snow drift. There are present in the cirques and nivation hollows. The members of this group are associations of snow beds vegetation - *Salicion herbaceae*, species rich communities of alliance *Calamagrostion arundinaceae* Luquet 1926, Jeník 1961, subalpine shrubs of alliance *Adenostylion*, as. *Salicetum lapponum* Zlatník, 1928 and alliance *Salicion silesiacae* Rejmánek et al. 1971.

**Methods**

We used definition and criterions for determinating ATL publicated by Jeník et Lokvenc (1962): „The alpine timberline is such a vegetation line which joins all of empiricaly ascertainable highest limits of forest". It is generally accepted definition, however there are differences in the standarts, how to comprehend forest. It is determinated by majority of authors as growth of trees with minimal height, minimal density of canopy and minimal area.

Table 1: Standarts for determination of ATL by various authors

| Author | Minimal canopy | Minimal height | Minimal area | Other criterions |
|---|---|---|---|---|
| Vincent (1933)* | >0.5 | 8m | 1ha | Stem density>0,5 |
| Sokolowski (1928)* | | 8m | | |
| Somora (1958)* | | 8m | | |
| Jeník et Lokvenc (1962) | >0,5 | 5m | 1ar | Distance of isolated forest eclave included in continuous ATL<100m |
| Plesník (1971) | >0,5 | 5m | 10a | |
| Zientarski (1989) | >0,4 | 8m | 10a | |
| Ellenberg (1963) | > 0,3-0,4 | > 2m | | |
| Körner (1999, 2000) | | >3m | | |

*cited in Jeník et Lokvenc (1962)

From geoecological point of view there is sufficient criterion of Ellenberg (1996) and Körner (1999), whose defined tree as an upright woody plant with single above-ground stem, that reaches a height of at least 3m. This height assures that such a tree would have closely coupled to prevailing atmospheric conditions and protrudes above deep snow where snow occurs. However in the middle Europe there is ussualy occured at the ATL Norway spruce, which is by the minimal canopy 0,5 always higher than 5m. That's why we consider choice criterion for minimal height of tree for conditions of the middle european mountains as according. More over there is ensured possibility to compare height of timberlines in different regions, because of the main criterion is density of canopy and height of trees isn't such a important.

Many autors don't state minimum area as a characteristic of forest. The basic standarts are proposes of Jeník et Lokvenc (1962) - 1a and Plesník (1971) - 10a. According to using airphotos and orthophotomaps, we chose criterion proposed by Jeník and Lokvenc, which enable more detailed maping of ATL course. The minimum horizontal length of alpine vegetation lobes of is next criterion, we maped all of lobes apprehensible in scale 1:4000, it means cca 10m broad, same value we used for maximum distance of an outpost growths included into continous ATL. Those criterions were getting bigger by subsequent generalisation. For calculation of average height of ATL we used formula, publicated by Jeník et Lokvenc (1962):

$$H = \frac{\sum^1 i_1 l_1 + i_2 l_2 + i_3 l_3 + \ldots.. + i_a l_n}{\sum^1 l_1 + l_2 + l_3 + \ldots\ldots.. + l_n}$$

$i_1$ , $i_2$ ….$i_n$ - middle height of an interval (m)

$l_1$ , $l_2$ ….$l_n$ – length of ATL in an interval (km)

The ecotone of forest passage into alpine belt, so called „kampf" zone, we were determinated as area which upper limit is a line joining all of Norway spruce groups with minimum area of 1a and lower limit is the ATL. We maped it at orthophotomaps and air photos and we eliminated error caused by different inclination. Based on digital model of relief, inclination map respectively, we divided inclination into seven classes: 0 – 5, 5 – 10, 10 – 15, 15 – 20, 20 – 25, 25 – 30, 30 and more degrees, and identified width of „kampf" zone in certain class we multipled with relevant coeficient using ArcView script.

All of determinated phenomenons we maped by GPS and assesed in GIS ArcView and Topol.

## Results

### The Krkonoše Mts.

Characteristics

The Krkonoše Mts., consider to extend of an alpine belt, are largest amount High Sudeties. Extend of an alpine area is 5465 ha altogether, 3178 ha in the east part of the Krkonoše Mts. and 2286 ha in the west part of the Krkonoše Mts. Average height of ATL is 1230 m, in the east part of the Krkonoše Mts. 1245 m., in the west part of the Krkonoše Mts.1207 m. From total length 124 km, there is 74 km in the east part and 50 km in the west part. 92,5 km of ATL occures in the czech part of the Krkonoše Mts. and 31,6 in the Poland. 21,5 km of ATL runs around avalanche tracks and 5,1 km around scree habitats. Minimal height of ATL is 960m on the bottom of Labský důl, maximum elavation is reached on the west slope of Růžová hora – 1340 m.

Origin of an alpine belt

Jeník (1961) and Jeník et Lokvenc (1962) convincely proved natural origin of alpine belt in the Krkonoše Mts. based on the theory of anemo-orographical systems. It was confirmed also by subsequent palynological analyses (Bortenschlager et Hüttemann 1987).

We consider as crucial proofs of natural origin of alpine belt occurence such a periglacial phenomenons (active, conserved and phosil) as recently developing nivation hollows, nivation benches, pasive morains, solifluction blocks, patterned grounds, avalanche acumulations and above descripted plant communities. Those phenomenons occures on the summit platforms of etchplain and in the cirques and nivation hollows, where presence of unforested area throughout holocene is assumed. Vegetated patterned rounds occurs on the planation surfaces even 50 m above the ATL. In the Krkonoše Mts. there are quite plentiful proceses, well known from periglacial areas. Except areal abundant solifluction blocks, which occurs strictly above ATL, other phenomenons are structuraly, orientation and exposition predisponed and limited, so their distance from ATL is'nt remarkable feature.

For other parts of area we have only historical data. There are needed further palynological researches and dated macrofossils for reconstruction of former course and oscillations of ATL.

Recent tendences and historical evolution

A historical evolution of man induced changes of ATL was in detail elaborated by Jeník et Lokvenc (1962) and Lokvenc (1978, 1992). Avorage anthropogenic decrease of ATL is estimated at 20m at czech part and 13m at polish part of the Krkonoše Mts. Highest rate of decrease is observed in surroundings of mountain chalets, former farms. An afforestation which pased through the and of 19. century and start of 20. century didn't generally reached a level of ATL (except dwarf pine aforestation). Plantations ussualy had their upper limit below recent ATL (cca 20 – 50m).

In the last century there is remarkable increasing tendention in localities further exploated by pasture and gras mewing (Stoh 1315 m, Svorová hora 1410 m), on further avalanche tracks (north oriented slopes of Zadní Planina 1422 m) and on the small block of fields, where a forest has increased by joining small groups of trees shadowing over dwarf pine today (south slope of Kozí hřbety, sotheast slopes of Svorová hora). In consequence of timber exploatation after imision injury, there is evident decrease of ATL on south slope of Železný vrch and north slope of Stoh. Where the exploatation didn't occure, ATL in consequence of imisions didn't decrease, however there is recorded a decrease of upper tree line in some localities (north slopes of Malý Šišák 1439 m).

Local characteristic, synmorphology

The ATL is situated in two different sections, shorter west part and east part. In the the east part of the Krkonoše Mts. there is besides main alpin area also one alpine enclave on a summit of Železný vrch. (1320 m).

Table 2: Characteristics of ATL ecoton („kampf“ zone) in the Krkonoše Mts.

| Width of „kampf“ zone (m) | Length of ATL* (km)/% | | |
|---|---|---|---|
| | Total | W Krkonoše | E Krkonoše |
| 0 - 50 | 29,8/**37,3** | 11,4/36,0 | 18,4/36,9 |
| 50 - 100 | 14,0/**17,5** | 5,4/17,4 | 7,6/15,1 |
| 100 and more | 37,8/**47,2** | 14,1/46,6 | 23,7/48,0 |
| Total | 80,6 | 30,9 | 49,7 |

Table 3: Length of ATL on the scree habitats and avalanche tracks in the Krkonoše Mts.

| | Length of ATL section* (km)/% | | |
|---|---|---|---|
| Stressed factor | Total | W Krkonoše | E Krkonoše |
| Avalanche tracks | 21,5/**22,6** | 5,6/18,1 | 15,9/32,4 |
| Block of fields | 5,1/**5,4** | 0,8/2,6 | 4,3/8,8 |

*It is valid for the czech part of the Krkonoše Mts. only, there are not included lengths of human influenced ATL (Krkonoše Mts total: 12 km, west part: 2,7 km, east part: 9,3 km.

Generally in the Krkonoše Mts. at localities, where there aren't took place any factors as avalanche tracks, block of fields, pasture and gras mewing (surroundings of chalets), in such places, the ATL with ecoton broader than 100 m prevails. This is very significant especially in the east part of the Krkonoše Mts., where this ecoton, except avalanche tracks and block of fields, clearly dominates. The thinnest ecoton (until 50 m) is supplied in the east part of the Krkonoše Mts. only on the avalanche tracks and block of fields, in the west part of the Krkonoše Mts. it takes place also besides those habitats. Middle ecoton (50 – 100 m) exists only as a passage between thinnest and widest one, that's why this type of ATL is in the Krkonoše Mts. shortest.

**Hrubý Jeseník and Králický Sněžník Mts.**

Characteristic

Avorage height of ATL is in the Hrubý Jeseník Mts. 1310 m and in the Králický Sněžník 1305 m. Maximum elevation of ATL is reached on the northwest slope of Praděd – 1405 m, minimum takes place on the bottom of Velká kotlina – 1100 m. Total length of ATL is in the Hrubý Jeseník 44 km, in the Králický Sněžník 4,1 km. An Extend of alpine area is 1048 ha in the Hrubý Jeseník Mts. and 65 ha in the Králický Sněžník Mts.

Origin of an alpine belt

The originality of alpine belt in the highest positions of the Hrubý Jeseník Mts. and Králický Sněžník Mts. was regulary casting doubt, that's why we suppose to be necessary comprehensively discussing this problem. Many opinions about it have its origin in palynological analyses of Salaschek (in Jeník et Hampel 1991) and Firbas (1949). Mentioned authors didn't wrongly consider influx of pollen from lower positions as important, how refered to Jeník et Lokvenc (1962).

Based on pollen analyses (Müller et Salaschek in Jeník et Hampel 1991) from peat bogs on Vysoká Hole and Velká Máj, mentioned authors comed to conclusion that ridges of the Hrubý Jeseník Mts. hadn't been forested before a start of the man induced changes. There are conserved patterned grounds and thufurs at summits of the Hrubý Jeseník and Králický Sněžník Mts., those phenomenons clearly shows that at places where it occures haven't existed throughout holocene closed forest, the block of fields have been also unforested (Břidličná and other smaller localities). Species rich plant communities of cirques and nivation hollows of alliance *Calamagrostion arundinaceae* (Velká, Malá Kotlina, Králický Sněžník), which evolution is joined with periodical avalanche activity, are the next evidence of natural origin of an alpine belt, because regular avalanche activity couldn't be possible in the case of forested summits. Similar features shows some alliances of *Calamagrostion villosae,* for example association *Avenastro planiculmis - Poetum chaixii,* (eastern slopes of Petrovy kameny, Velká, Malá kotlina, Králický Sněžník) and snow patches communities of alliance *Salicion herbaceae* (Velká Kotlina). Communities of deflation summits are also suitable indicators of natural alpine belt, there are alliances *Juncion trifidi* (as.*Cetrario - Festucetum supinae, as. Empetro hermaphroditi - Juncetum trifidi* aj.) and alliance *Nardo-Caricion rigidae*: Praděd, Petrovy kameny – Břidličná, Keprník, Šerák, Červená hora, Králický Sněžník, Mravenečník. Subalpine tall-forb vegetation of alliance *Adenostylion* (wind lee ward positions of localities Petrovy kameny-Jelení hřbet, Praděd, Králický Sněžník), subalpine springs vegetation of alliance *Swertio-Anisothecion squarrosi* (northeast slopes of Petrovy kameny, Praděd, Velká and Malá Kotlina) and arcto-alpine bogs (Velký Máj) surly proves natural origin of alpine belt.

Besides plant communities there are another idicators of natural origin of alpine belt, especially indication group of the arcto-alpine species of butterflies, becouse of their low vagility. Its presence indicates a primary unforestation of their habitat. Species composition on investigated habitats is poor but with remarkable domination of typical alpine species (Beneš et al. in Banaš, Lekeš et Treml 2001 ). All of autochton butterflies species of alpine belt are glacial relicts limited on arcto-alpine tundra (cenobiont species) (Kuras in Banaš, Lekeš et Treml 2001).

Possible proof of former presence of forest on summits of the Hrubý Jeseník Mts. could be absention of dwarf pine (*Pinus mugo*). Králický Sněžník Mts. and Hrubý Jeseník Mts. are islands without dwarf pine among the Krkonoše Mts., the Alps and the Babia hora mountain. Absention of dwarf pine as a proof of forest presence is casted doubt, because of occurence another heliophil indicator – *Juniperus nana*. However there is possibility of its plantation by „german beutifiing clubs" because of an increase of *juniperus* sp. pollen in a recent (Rybníček, verbal information). There were no discoveries of dwarf pine macrofossils, finded pollen of pine belonged to Scotch pine (*Pinus sylvestris).*

Absention of natural dwarf pine growths displays in synmorphology of ATL and also in composition of plant communities above it. Jeník (1973) puted recent species richnes in direct conection with florogenetic absence of dwarf pine. For example in the Krkonoše Mts. there are many similar localities as Petrovy kameny and Tabulové kameny rocks but none of them have so many plant communities and plant species. Absention of dwarf pine (and natural absence of similar edificators such as *Duschekia viridis, rododendron* sp., nanophanerophyts, which in the other alpine regions ensure passage of a forest into a tundra) is also displayed in specific conditions for altitudional vegetation graduality and richnes of alpine hemicryptophyts and chamaephyts, include many endemits and relicts (Jeník 1972). Because of absention dwarf pine, ATL is here situated relatively high, considering temperature conditions (Plesník 1972).

Recent tendences and historical evolution

Based on historical research (Hošek in Jeník et Hampel 1991, Banaš, Lekeš et Treml 2001) we can say, that general tendention of ATL in last centuries in the Hrubý Jeseník Mts. was at first decreasing in consequence of a pasture and a grass mewing, localy also a timber exploatation. After, on the end of 19. and beginning of 20. century it was increased by artificial afforestation, localy above its natural (climatical) level (Keprník). Majority of a growths across ATL are a plantations. We didn't record any localities with natural increasing tendention of ATL.

Local characteristic, synmorphology

In the Hrubý Jeseník Mts. there is ATL located in six different localities. The larger one is the section Vysoká hole (1464 m n.m.) – Pecný (1334 m n.m.), followed by the Praděd (1492 m n.m.) area, Malý Děd (1355), Mravenečník (1343 m n.m.), Červená hora (1337 m n.m.), Keprník (1423 m n.m.) and Šerák (1351 m n.m.). Forest transition into tundra usually displays as abrupt passage into soliters, which cold be very distant from a position of ATL.

Table 4: Characteristic of the ecoton of ATL („kampf" zone) in the Hrubý Jeseník Mts.

| Width of „kampf" zone (m) | Length of ATL section* (km)/% |
|---|---|
| 0 - 50 | 17,6/**40,4** |
| 50 - 100 | 13,1/**30,3** |
| 100 and more | 12,6/**29,3** |
| Total | 43,3 |

Table 5: Length of the ATL on the avalanche tracks and block of fields in the Hrubý Jeseník Mts.

| Stressed factor | Length of ATL section* (km)/% |
|---|---|
| avalanche tracks | 2,6/**6,0** |
| block of fields | 1,1/**2,6** |

*It isn't included 0.7 km of ATL at Mravenečník area, destroyed by building of water dam

ATL with thinnest ecoton mostly occures in the Hrubý Jeseník Mts. (even after including of ATL length on the avalanche tracks and block of fields). Both wider ecotons occurs, consider its length, equable. The widest ecoton (over 100 m) is often enlarged by occurence of small groups of Norway spruce distant from ATL.

**Králický Sněžník (1423 m n.m.)**

In the southeast part of summit region of the Králický Sněžník, there are Norway spruce plantations at ATL, on south and southeast slopes, there is ATL limited by block of fields. On the northwest and west side the ATL pasages into low spruces with dense canopy. Dwarf pine plantations aren't very extensiv.

Summit plant communities are composed in contradistinction to the Hrubý Jeseník Mts. from dominant *Festuca supina. Avenella flexuosa* and *Nardus stricta* are less abundant. Those plant communities belongs to the wind swept alpine grasslands, as. *Cetrario-Festucetum supinae* Jeník 1961 from association *Juncion trifidi* Krajina 1933. There is quite abundant indicator of arcto-alpine plant communities *Carex bigelowii* and also patterned grounds occures on the summit plateau (on the cryoplanation terraces, especialy NW direction). There is significant decrease of ATL in the Morava valley, where taking place avalanche track. It isn't so species rich as that of the Hrubý Jeseník Mts. (prevailing *Calamagrostis villosa* and at the bottom *Athyrium* sp.). As a proof of regular activity of intensive slope proceses (and permanence of unforested area, where those proceses acts) we take flat bottom of Morava valley at the altitude 1150 – 1200 m with avalanche and debris avalanche acumulations.

Photo 3: ATL in the Králický Sněžník Mts.


**Discussion**

In the High Sudeties there are three mountain ranges rising over ATL – the Krkonoše Mts. with largest and well diferentiated alpine area, Králický Sněžník, which is small, summit phenomenon efected enclave and Hrubý Jeseník Mts. with seven alpine areas, of different extend. Maximal elavation of ATL is in the Hrubý Jeseník 60 m higher than in the Krkonoše Mts, it confirms well known fact of increasing continentality gradient.

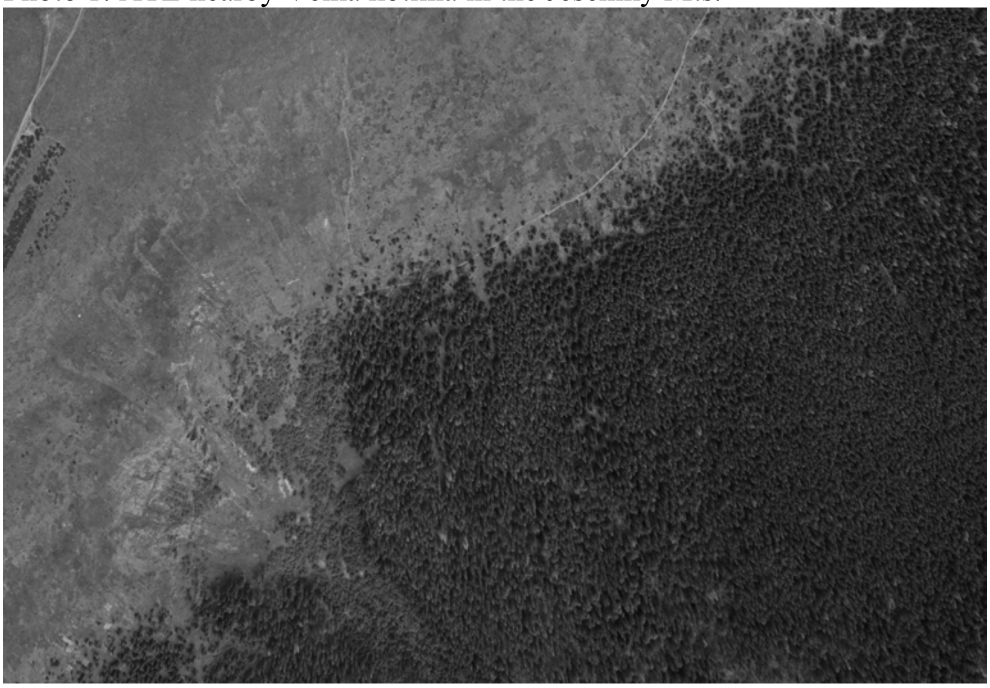
Table 6: The basic characteristic of ATL in the High Sudeties

| | Krkonoše Mts. | Králický Sněžník Mts. | Hrubý Jeseník Mts. |
|---|---|---|---|
| avorage height ahl (m) | 1230 | 1305 | 1310 |
| Maximum elevation (m) | 1340 | 1340 | 1405 |
| total area (ha) | 5465 | 65 | 1048 |
| Total length | 124 | 4,1 | 44,0 |
| Width of „kampf“ zone:<br>a) 0 – 50m<br>b) 50 – 100m<br>c) 100 and more | *km/%<br>29,8/37,3<br>14,0/17,5<br>37,8/47,2 | | km/%<br>17,6/40,4<br>13,1/30,3<br>12,6/29,3 |

*it is valid for Czech part of Krkonoše Mts. only, for 94,5 km length of ATL

In the Krkonoše Mts. the course of ATL is more curved compared with Hrubý Jeseník and Králický Sněžník Mts. It’s caused by higher altitude, relief energy and higher rate of slope proceses (avalanches, debris avalanches). In all of the mentioned mountain ranges there are many morphological proofs of natural origin of the alpine belt. Above all there are fosil or conserved patterned grounds, recent nivation hollows with active solifluction proceses, solifluction blocks, avalanche and debris avalanche acumulations.

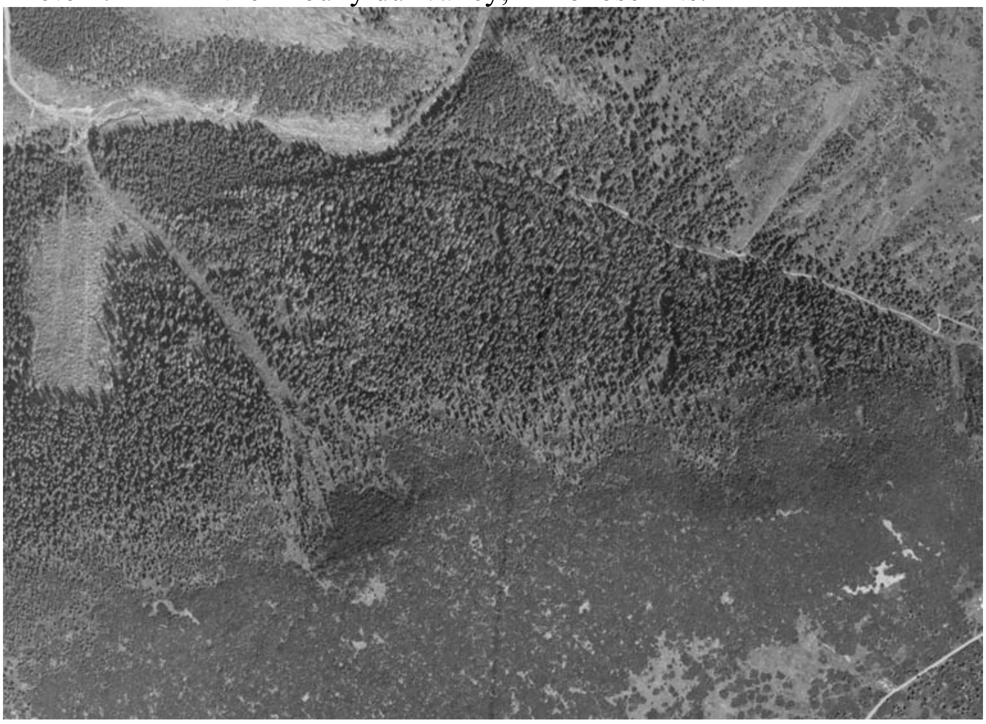
Photo 1: ATL nearby Velká kotlina in the Jeseníky Mts.



The main tendention of last century is un increase of ATL on the places formerly effected by pasture and gras mewing and on the little block of fields. There are some oscillations of ATL on avalanche tracks. Even on some avalanche tracks the ATL decreased, because of imisions, localy as a result of imisions injuries the alpine treeline decreased too. In the Hrubý Jeseník and the Králický Sněžník Mts. in last century the ATL artificially increased by afforestation and also because of terminating pasture.

The Krkonoše Mts. differ a lot from Hrubý Jeseník and Králický Sněžník Mts. by width of kampf zone. In the Krkonoše Mts. prevails the ecoton over 100m width, the thinnest ecoton occurs on the avalanche tracks and block of fields only, middle width ecoton acts as a pasage between both above mentioned. On the contrary in the Hrubý Jeseník and Králický Sněžník Mts. there is typical the thinnest ecoton and quite long is also middle one. In our opinion it results from more intensive human impacts and natural absence of dwarf pine, which is crucial difference of ATL in the Hrubý Jeseník and Králický Sněžník Mts. from the Krkonoše Mts.

Photo 2: ATL in the Dlouhý důl valley, Krkonoše Mts.



**Aknowledgements**

We would like to thank to Ing. Vladimír Lekeš, Taxonia, for the helpful comments, also our gratitude goes to KRNAP and CHKO Jeseníky for permission to work in both protected areas and for providing data.

**Resumé**

Alpinská hranice lesa se ve Vysokých Sudetách nachází ve třech pohořích, a to v Krkonoších s největší plochou bezlesí a dobře vyvinutou alpinskou oblastí, dále na Králickém Sněžníku, kde jde o malou vrcholovým fenomenem ovlivněnou enklávu a konečně v Hrubém Jeseníku se zhruba pětinovou plochou alpinského bezlesí ve srovnání s Krkonošemi. Maximální elevace alpinské hranice lesa

je v Hrubém Jeseníku o cca 60 m výše než v Krkonoších, což potvrzuje známý fakt vzrůstajícího gradientu kontinentality.

Oproti Jeseníkám a Králickému Sněžníku je hranice lesa v Krkonoších členitější, což je způsobeno jejich větší nadmořskou výškou a reliéfovou energií a s ní spojenými procesy (laviny, mury). Ve všech uvedených pohořích se nachází morfologické doklady o dlouhodobé přítomnosti bezlesí. Zejména jde o fosilní a více či méně recentně konzervované strukturní půdy. Zarostlé strukturní půdy se nachází na zarovnaných površích již 50 m nad alpinskou hranicí lesa. V Krkonoších probíhají i dnes ve větší míře procesy známé z periglaciálních oblastí. Kromě plošně se vyskytujících putujících balvanů, jejichž výskyt je striktně omezen od linie hranice lesa vzhůru, jsou ostatní jevy strukturně, orientačně a expozičně podmíněny, takže jejich odstup od hranice lesa je pouze orientačním ukazatelem.

Trendem posledního století je v Krkonoších vzestup alpinské hranice lesa na místech dříve ovlivňovaných budním hospodářstvím a na menších kamenných mořích. Na lavinových drahách dochází k oscilacím. V důsledku imisního odumírání stromů pak místy na lavinových drahách hranice lesa klesla, následkem imisních spadů je místní pokles hranice stromu. V Jeseníkách a na Králickém Sněžníku docházelo po odeznění hospodaření v nejvyšších polohách a vysokohorským zalesňováním v posledním století ke zvýšení hranice lesa.

Typickou šířkou ekotonu alpinské hranice lesa se Krkonoše výrazně liší od Králického Sněžníku a Hrubého Jeseníku. Převládá v nich ekoton širší než 100m, ekoton užší než 50m se vyskytuje zejména na lavinových drahách a kamenných mořích, střední ekoton je zpravidla přechodem mezi dvěma výše uvedenými. Naproti tomu v Jeseníkách a na Králickém Sněžníku převládá nejužší ekoton, relativně dlouhý je i úsek hranice lesa se střední šířkou ekotonu. Vysvětlujeme si to větším antropogenním ovlivněním hranice lesa v těchto pohořích a přirozenou absencí kleče, čímž se zde hranice lesa zásadně liší od alpinské hranice lesa v Krkonoších.

**References cited**


Banaš, M., Lekeš, V., Treml, V. (2001): Stanovení alpinské hranice lesa v Hrubém Jeseníku a Králickém Sněžníku. Taxonia, 76 pp.

Czudek, T. (1997): Reliéf Moravy a Slezska v kvartéru. Sursum, Tišnov, 213 pp.

Ellenberg, H. (1963): Vegetation Mitteleuropas mit den Alpen in kausaler, dynamischer und historischer Sicht. Eugen Ulmer, Stuttgart, 943 pp.

Firbas, F. (1949, 1952): Spät- und nacheiszeitliche Waldgesichte Mitteleuropas nördlich der Alpen, Vol. 1 und 2. Jena, 956 pp.

Chytrý, M., Kučera, T., et Kočí, M. (eds.) (2001): Katalog biotopů České republiky. Agentura ochrany přírody a krajiny ČR, Praha, 307 pp.

Hüttemann, H et. Bortenschlager, S., (1987): Beitrage zur Vegetationsgeschichte Tirols VI: Riesengebirge, Hohe Tatra – Zillertal, Kühtai. Ber. Nat. – med. Verein Innsbruck, Band 74 : 81 – 112.
Jeník, J. (1961): Alpinská vegetace Krkonoš, Králického Sněžníku a Hrubého Jeseníku. Praha, Academia, 407 pp.
Jeník, J. , Lokvenc, T. (1962): Die alpine Waldgrenze im Krkonoše Gebirge. - Rozpr. Čs.Akad. věd , Praha, ser. Math. - natur., 72/1 : 1-65.
Jeník, J. (1972): Výšková stupňovitost Hrubého Jeseníku: otázka alpínského stupně. Ostrava, Campanula, č.3, s.45-52.
Jeník, J. (1973): Alpínské ekosystémy a hranice lesa v Hrubém Jeseníku z hlediska Ochrany přírody. Ostrava, Campanula, č.4, s.35-42.
Jeník, J., Hampel, R. (1991): Die waldfreien Kammlagen des Altvatergebirges (Geschichte und Ökologie). Stuttgart, MSSGV, 104 pp.
Körner, Ch. (1999): The alpine plantlife. Gustaf Fischer Verlag, 350 pp.
Kullman, Kjällgren (2000): Arctic, Antarctic and Alpine Research, 32/4: 419-428.
Lokvenc, T. (1978): Toulky krkonošskou minulostí. Kruh, Hradec Králové, 267 pp.
Lokvenc, T. et al. (1992): Zalesňování Krkonoš. KRNAP and VÚLHM Opočno, 112 pp.
Paulsen, J., Weber, U.M. et Körner, Ch. (2000): Tree growth near treeline: Abrupt or gradual reduction with altitude? Arctic, Anctartic and Alpine Research, 32/1: 14-20.
Plesník, P. (1971): Horná hranica lesa vo Vysokych a v Belanskych Tatrách. Bratislava 475 pp.
Plesník, P. (1972): Horná hranica lesa v Hrubém Jeseníku. Brno, Studia geographica 29: 33- 85.
Soukupová, L. et al. (1995): Arctic alpine tundra in the Krkonoše, the Sudetes. Opera Corcontica, 32: 5-88.
Speranza, A., Hanke, J., Geel, B., Fanta, J.: Late – holocene human impact and peat development in the Černá hora bog (Krkonoše Mountains, Czech republic). Accepted to print - The Holocene.
Wick, L., Tinner, W. (1997): Vegetation changes and timberline fluctuations in the central Alps as indicators of holocene climatic oscillations. Arctic and Alpine Research, 29/4:569-595.
Zientarski, J. (1989): Studia na górna granica lasu w Polsce. Reczniki Akademii Rolniczej w Poznaniu 24: 63–66.