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Regularities of mountain geoecosystems

ABSTRACT

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The main features of the mountains are considered and relation with the vertical zonality of temperature and precipitations are observed. Taking into account the mesoclimatic belts in mountain valleys, the diversity of vertical belts and the slope asymmetry in various climatic zones are discussed. Reconstruction of changes of vertical zones in european mountains during the Pleistocene and early Holocene is proposed.

Parole chiave: zonalità verticale, fasce mesoclimatiche, asimmetria del pendio, Tardo Pleistocene e Olocene antico.

Key words: vertical zonality, mesoclimatic belts, slope asymmetry, late Pleistocene and early Holocene.

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1. Main features of the mountains

Mountainous areas are elevated at least several hundreds of meters above their surroundings, and due to their heights above the sea level they may reach upper vertical zones in various latitudes. The mountains are also characterized by steep valley sides and high gradients of river channels. All this facilitates an accelerated runoff of water, of mineral matter (soil erosion including the gravitational processes) in the mountains, and the deposition or storage on their foreland.

Mountains originated due to tectonic movements, plate tectonics and subduction processes. Parallel with old mountain blocks elevated in the distant past we observe young ranges continuously lifting up. Among the last ones there are parts of the Apennines, Caucasus and the Tibetan Plateau with the Himalayas raised 2-3 km in the Quaternary.

Mountains form barriers for the circulation of air masses. The weather and rainfall regime of a defined mountain system depends on the zonal character of air masses. Parallely, the mountain barriers are characterised by higher rainfalls especially on the wind-side (WEISCHET, 1965) and a higher frequency of extreme events (STARKEL, 1976).

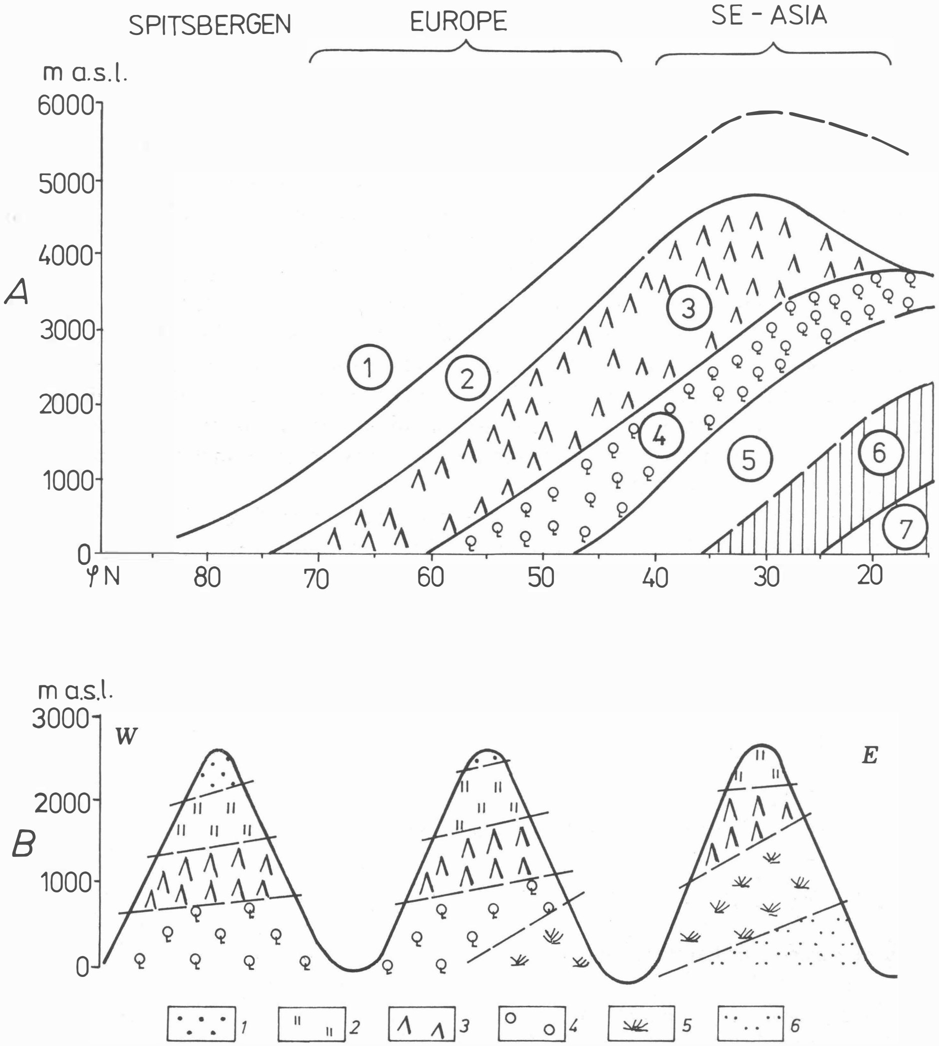

Fig. 1 - Vertical zonality of the Northern hemisphere in N-S transect (above) A, after TROLL (1964) and in the Eurasian W-E transect (simplified, below, B).
A. N-S transect numbers: 1. crionival belt, 2. tundra-alpine belt, 3. boreal forests, 4. mixed forests, 5. deciduous and evergreen forests, 6. substropical evergreen forests, 7. humid equatorial forests.
B. Signs; 1. crionival belt, 2. alpine belt, 3. boreal forests, 4. deciduous forests, 5. steppe, 6. desert.

2. Vertical zonality

With the rising elevation we observe the lowering of temperature increase of direct solar radiation, and of the atmospheric precipitations. The drop of the mean annual temperature reaches 0.4-0.5 °C per 100 meters. It is accompanied by the change in the water cycle (growing role of solid precipitations, shortening of the runoff season, rise of the storage in snow, firn and ice) change of the weatering processes (decreasing role of chemical and biological processes in relation to the physical ones), communities of vegetation (various possibilities of the particular species), type of soil, and animals.

Parallel with that thermal change we observe a rise of precipitation with the elevation, caused by the level of water vapour condensation and convection. Frequently, in the top part an inversion of precipitation is registered (Weischet, 1965; Hess, 1965).

Vertical change in amount of incoming energy and in processes cause that various geoecosystems may reach the threshold values, which lead to a substantial alteration in the exchange of energy and circulation of matter, which is manifested by distinct limits, between the vertical belts (fig. 1). Among them there are the snowline, the upper forest limit and the lower forest limit (cf. Troll, 1962; Rathjens, 1982). The snowline forms the limit between the subnival belt and the snow-ice mountain desert. The course of the upper forest line coincides with the izoline of the mean July temperature +10-12 °C and mean annual +2 °C (Hess, 1967). It is determined by the species capacity of photosynthesis, which may produce hard-wood during the short vegetation season (Tranquillini, 1966).

In the continental climate there exists in the mountains also a third limit of the lower tree line, determined by minimal soil humidity or by rainfall needed for tree growth. Both forest limits in the arid climate may come so close that finally the forest belt disseapeares (Starkel, 1980).

The detailed courses of both of the upper and of the lower forest lines are modified by various factors (fig. 2). The upper treeline is lowered in the axes of slope gullies (frequent frost), in routes of snow and debris avalanches (especially in the mountains with heavy snowfalls), in parts built of blockstreams and of permanent swamps (Plesnik, 1971). An opposite case is observed in the arid climate, where only patches of forest may exist or go higher in shadowed gullies with some water storage in the soil.

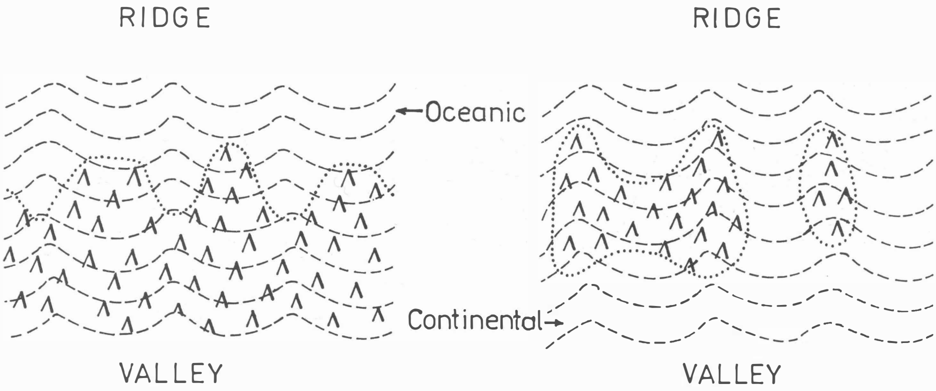

Fig. 2 - Position of the forest limits depending on slope morphology in oceanic and continental climate.

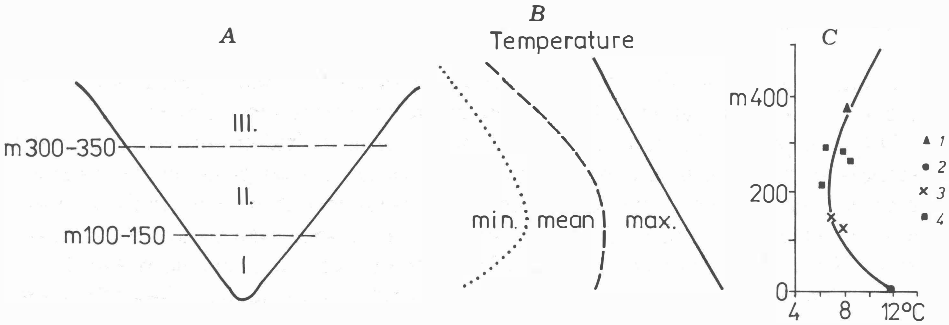

Fig. 3 - Mesoclimatic belts in the mountain valley: I. inversional bottoms, II. warm slopes, III. cool ridges; course of minimum mean and maximum temperate (simplified) and daily real amplitude of temperature in one Carpathian valley at 17- 23.VII.1963 (after Obrebska-Starkel, 1992).

3. Mesoclimatic belts in the mountain valleys

The advective air masses undergo transformation in the deep mountain valleys. Only the highest ridge zone is under the direct impact of advection. During the night cooling, especially during anticyclonic weather, the heavy cool air flows down to the deep floors of valleys and basins, which are characterised by higher amplitudes of temperate, inversions, and frost (fig. 3).

On the contrary, the warm air is collected in the middle «warm», portions of slopes, 100-300 m above the bottoms. In this belt in the Carpathians the frostless period is by 30-50 days longer if comparised with the valley floors (Obrebska-Starkel, 1972). In the particular cases this influences the inversion of the vertical vegetation zones (spruce forests in the valley bottoms of the Polish Eastern Carpathians), the climbing of human settlements and cultivated fields on the slopes and the simultaneous abandoning of the valley bottoms as regards cultivation.

4. Diversity of vertical belts in various climatic zones

While analysing the vertical zonation in N-S and W-E transects of Eurasia we conclude their distinct variations depending on the thermal and humidity characteristics of various climatic zones (fig. 1). For instance, the snowline rises from ca. 200 m a.s.l. on the Spitsbergen up to 6400 m a.s.l. in the distinct parts of the Tibetian Plateau and in the equatorial zone it goes down to ca 4500 m. The W-E directed mountains of Eurasia form distinct climatic barriers and therefore the vertical zonation is different on the opposite sides. A typical feature of the continental climatic approaches two forest limits, the upper and the lower one. In the Mongolian mountains (Kowalkowski & Starkel, 1984), at the southern extent of the boreal forest zone, the only patches of forest appear on the island of the permafrost, the active layer of which guarantees the supply of water during the vegetation season with a very flexible rainfall regime.

5. Slope asymmetry in various climatic zones

In this paragraph we discuss the geoecological diversity of the opposite slopes connected with topoclimate and not the structure controlled asymmetry of relief.

In the temperate climate with a distinct surplus of precipitation over evaporation the differences between north and south-exposed slopes are not so great; on the warmer, southern slopes the upper limits of the forest belts rise higher. In the case of the frequent foehn-type winds the northern slope may be in some seasons even warmer (Obrebska-Starkel, 1972). The west-exposed slopes of the extreme oceanic mountains of the British Isles after deforestation even passed the upper threshold of the water capacity of the forest soils and the blanket bogs spread over vast territories (Moore, 1983; Starkel, 1991).

In the cold semihumid climate of Eastern Siberia the forest communities developed better on the southern warmer slopes with a longer melting season; drier valley floors are occupied by mixed forest-steppe vegetation. The opposite asymmetry is established in the middle latitudes of some Central Asian mountains eg. Khangai, Khentey, where the south-exposed slopes are occupied by the xerothermic communities over castaneanan soils, and the only patches of Larix sibirica in the central parts of the cooler slopes coincide with permafrost.

Both types of the asymmetry present in the continental climate with sever winters should be carefully considered as the closest analogs of the vertical zonality, which probably existed in the European mountains during the last cold stage and the Pleistocene-Holocene transition.

6. Changes of the vertical zonality in Europe at the end of the Pleistocene and early Holocene

The reconstruction of the changes of the vertical zones in the European mountains between 18 and 8 ka BP is based on detailed studies of the glacial fluctuation and the accompanying glacifluvial sediments (Patzelt, 1977; Karlen, 1991), of the entering of plant species and forest communities into the mountains (Bortenschlager, 1972; Burga, 1988) and on the changes in the vertical zonality of the crionival forms and structures (Furrer *et al.*, 1975; Paizelt, 1977). These approaches are concentrated mainly on the vertical changes.

In all these discussions the substantial change from continental to oceanic climate is almost imperceptible. However, the signs of the cool continental climate are reflected in the loess deposits and cryogenic pseudomorphoses throughout Europe (cf. Velichko, 1984; Frenzel, Pecsi & Velichko, 1992; Starkel, 1984). Therefore we may expect a vertical zonality, similar to that presented now at the southern limits of permafrost in Asia.

This type of zonality during the pleniglacial was documented in Greece where the forests survived at the elevation belt of 500-1000 m a.s.l. (Bottema, 1974; Beug, 1982). At that belt in the mountains of Bulgaria and S-Romania solifluction deposits of a higher belt as well as loess of the lower belt are absent (Starkel, 1977).

Probably the picture was similar as in the Khangai Mts. at present (cf. fig. 4CD).

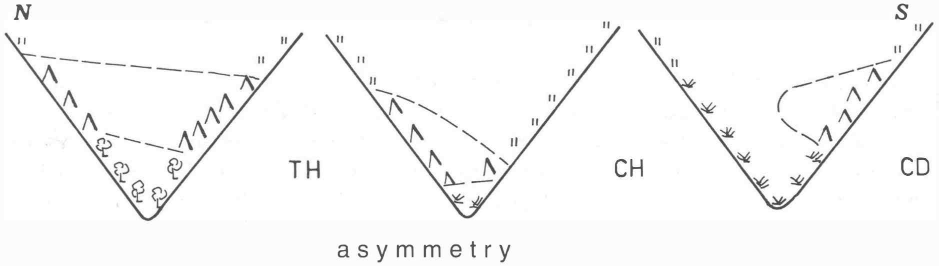

Fig. 4 - Asymmetry of vegetation on the opposite slopes in various climatic regions: TH - temperate humid, CH - cool humid, CD - cool dry.

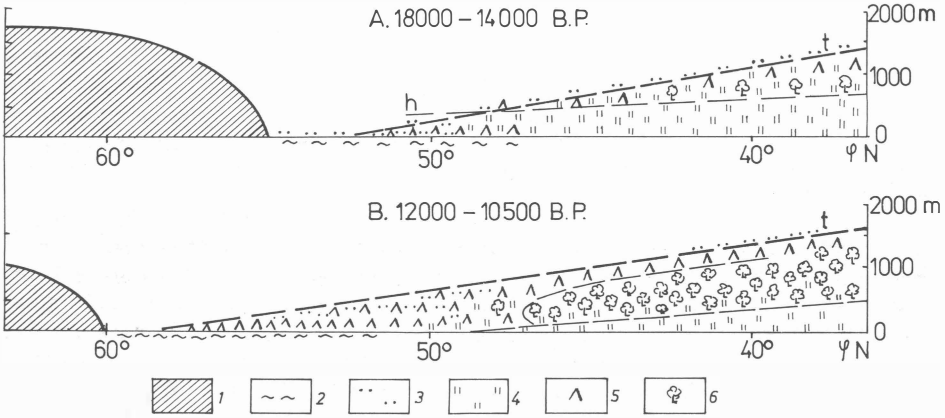

Fig. 5 - Evolution of vertical belts in the European transect between 18 and 11 ka BP (After Starkel, 1977).
Signs: 1. ice sheet, 2. permafrost, 3. tundra, 4. steppe, 5. boreal forest, 6. mixed forest. Mixed signatures indicate mixed vegetation. Upper tree line controlled by temperature (t) and lower tree line controlled by humidity (h).

During the late Vistulian the forest communities spread from two refugies located in the «warm» slope belt of S-Europe and on the vast plateaus of Europe, where warm summers of the Siberian type conditioned the survival of the open woodlands. At the beginning the leading role was played by the rise of temperature favouring the expansion of the boreal species, and in the foothills of the forest-steppe, but later on about 8.5-7.5 ka BP, a distinct turn to the oceanic climate caused a total expansion of deciduous trees and on the southern coast of the Mediterranean communities (Beug, 1982; Starkel, 1991).

In the existing climatic - vegetational vertical zones of the European mountains there are incorporated the elements inherited from the past due to the upslope shift of belts by ca 800-1000 meters. The present belt of alpine meadows and cronival processes is developed over the previously glaciated areas, the upper forest belt (with *Picea excelsa*) over the blockfields of the cryonival zone and glacial deposits, and finally the mixed forest frequently spreads over slopes covered by solifluction or loess deposits.

SUMMARY

Mountain areas due to their heights are characterized by vertical zonality of temperature, precipitation and connected with them water cycle, soils, geomorphic processes and vegetation. This is manifested by distinct limits like snow line, upper and lower forest limits. The transformation of air masses in the valleys caused formation of the mesoclimatic belts with inversional bottom and warm slope belts. The sequence of vertical zones varies with climatic zones. Of special importance in the biodiversity and variety of habitats is the slope asymmetry different in humid and dry, in cool and warm climates. During the late Pleistocene and Holocene in the mountain areas of the present-day temperate zone we observe not simply a vertical shift of belts but also a change from oceanic to continental climate with permafrost or vice versa.

RIASSUNTO

Le zone montane, data la loro altezza, sono caratterizzate dalla zonalità verticale della temperatura e delle precipitazioni nonché dal ciclo delle acque, dal suolo, dai processi geomorfici e dalla vegetazione ad esse connesse.

Ciò viene reso evidente da limiti ben precisi quali la linea delle nevi ed i limiti superiori ed inferiori delle foreste. La trasformazione delle masse d'aria nelle valli ha causato la formazione delle fasce mesoclimatiche con fondo inversionale e delle fasce di pendio caldo. La sequenza delle zone verticali varia con il variare delle zone climatiche. L'asimmetria del pendio, diversa per climi umidi o secchi, freddi o caldi, riveste una particolare importanza per la biodiversità e la varietà degli habitat. Nelle zone montane appartenenti all'attuale zona temperata osserviamo che durante il tardo Pleistocene e l'Olocene non vi fu solo uno scostamento verticale delle fasce, ma anche una modificazione del clima da oceanico a continentale con permafrost o viceversa.

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