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Eccentric growth of trees as a tool for reconstruction of mass movement activity (example from the Carpathian Mountains - Central Europe)

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Introduction

Houses and other infrastructure in mountainous areas are quite frequently destroyed by mass movements, especially landslides. Therefore it is very important to study the conditions under which mass movements occur. Overall, various methods are used to study mass movement episodes such as radiocarbon dating, lichenometric dating, cosmogenic nuclide dating, uranium-series dating, Optically-Stimulated-Luminescence (OSL) dating, and dendrochronology (Lang et al., 1999). In forested areas, mass movements can be recorded by analyzing growth reactions in influenced trees: reaction wood, the occurrence of resin ducts, abrupt growth changes and the occurence of tree growth eccentricity (Baumann & Kaiser 1999, Gärtner, et al. 2003). Tree ring analysis allows dating e.g., the occurrence and course of eccentricity and thereby to indirectly date mass movement episodes. The years with episodes can be compared, for example, with the intensity of precipitation recorded at meteorological stations. Such studies can determine the threshold amount of precipitation above which mass movements occur on individual slopes.

Studying tree stem eccentricity was previously used to reconstruct mass movement activity (Braam et al. 1987), and in additional an eccentricity index was defined by Casteller et al. (2007) for reconstructing avalanches. Method developed by Casteller et al. (2007) was based on a morphometric comparison between, respectively, the measurements of both the maximum and minimum dimension of the trunk (external feature) and the annual ring width in a parallel and perpendicular direction with respect to the slope (internal feature).

In this paper authors propose an alternative approach and method for calculating the tree-ring eccentricity index. The application of the newly developed formula for the index was described. The index was also used to compare eccentricity in trees growing on slopes where mass movements occurred and in trees growing close to the streambank of a mountain stream where erosion had occurred.

The tree-ring eccentricity index as a tool for recognising mass movement

The aim of the study was to find the most useful and accurate method for the spatial and temporal reconstruction of mass movement activity. The growth pattern of spruce trees (*Picea abies*) was studied on a relatively stable slope with a smooth surface (reference site) and on a slope with distinct morphological symptoms of mass movements (study sites). The reference site was used to compare annual tree-ring records from trees growing under and without the impact of landsliding.

It was observed that spruce trees growing on the study sites are tilted and have deformed stems. Trees growing on the upper part of the studied slope are tilted upslope. Trees on the lower part, near the stream channel, tend to tilt downslope (Fig. 1).

We sampled 52 trees: increment cores were collected on the basis of surface gradient. Cores were taken from parts of trunks deformed by mass movements. Cores were taken from trees growing in different locations: on headscarps, flattenings and toes. One core was taken through each tree trunk. Samples were taken parallel to slope gradient. We compared the width of rings formed by individual trees on the upslope and downslope sides of trunks and calculated tree ring eccentricity upslope or downslope. To compare individual trees with one another, the eccentricity index was applied. The eccentricity index was calculated according to the following formulae:

$$E\ [\mathrm{mm}] = U - D; \qquad [1]$$

if $E\ [\mathrm{mm}] > 0$: upslope tree-ring eccentricity $Ei\ [\%] = (E / D) \times 100\% > 0;$ [2a]
if $E\ [\mathrm{mm}] = 0$: no tree-ring eccentricity; $Ei\ [\%] = E\ [\mathrm{mm}] = 0;$ [2b]
if $E\ [\mathrm{mm}] < 0$: downslope tree-ring eccentricity $Ei\ [\%] = (E / U) \times 100\% < 0;$ [2c]

where: U – upslope tree-ring width [mm];
D – downslope tree-ring width [mm];
E – eccentricity of tree ring [mm];
Ei – eccentricity index of tree ring [%].

In order to compare data from different trees, the raw data in mm was converted into percentages. An example of the eccentricity index calculation from raw data (transformation of graphs) is presented in figure 2. Figure 5 presents the differences between the eccentricity index calculated for samples taken from different geomorphological locations.

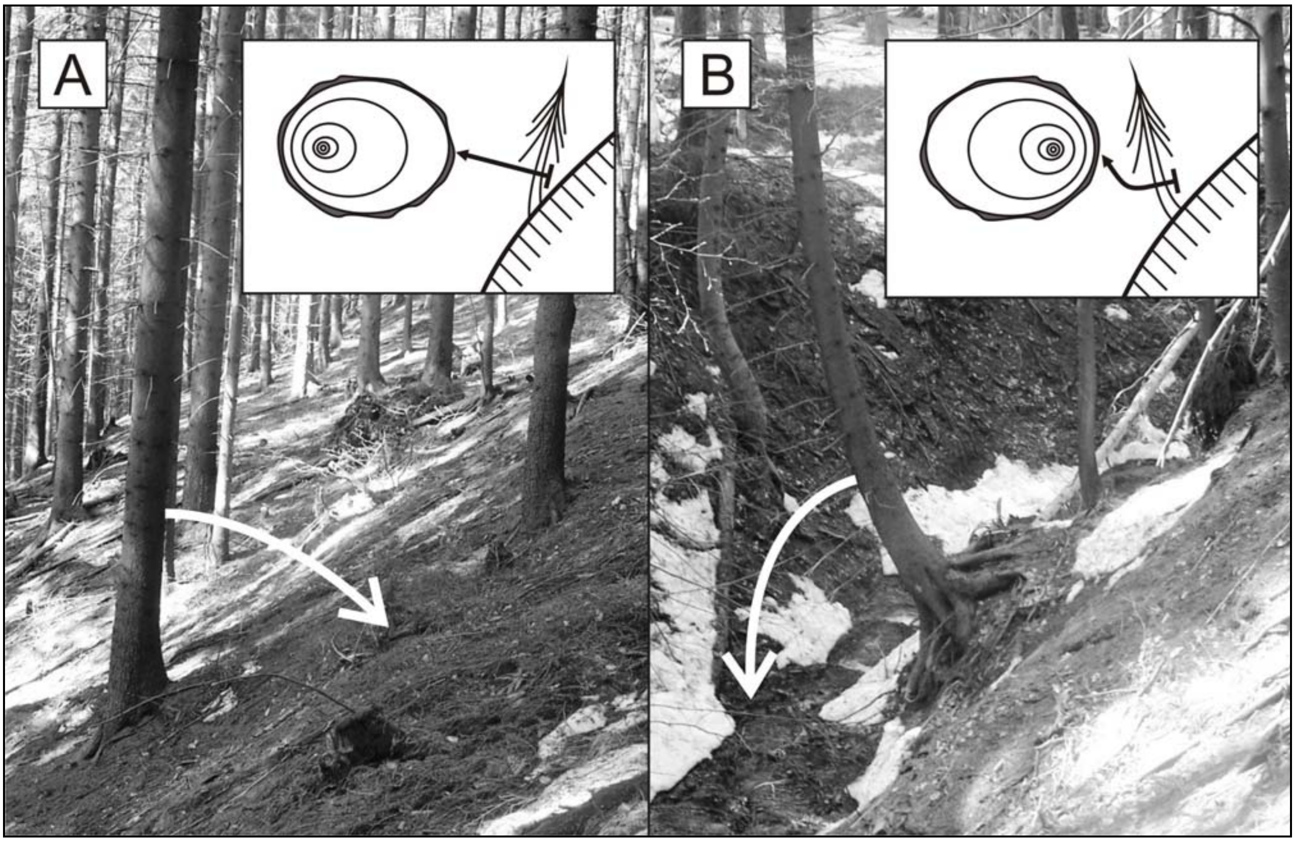

Figure 1: Trees tilted A – upslope, producing upslope tree-ring eccentricity, upper part of the study site Kp 2, B – downslope, producing downslope tree-ring eccentricity, lowest, near-channel zone of the study site Kp 2.

Results from the Skalka study area

The study was carried out in the Moravskoslezské Beskidy mountain range in the Western Outer Carpathians. The study site lay on a large landslide (650 m long, 250 m wide) filling up the valley head of the Skalka stream (Czech Republic, Fig. 3A-B). The bedrock of the study area is composed of sedimentary flysch, prone to mass movement including landsliding.

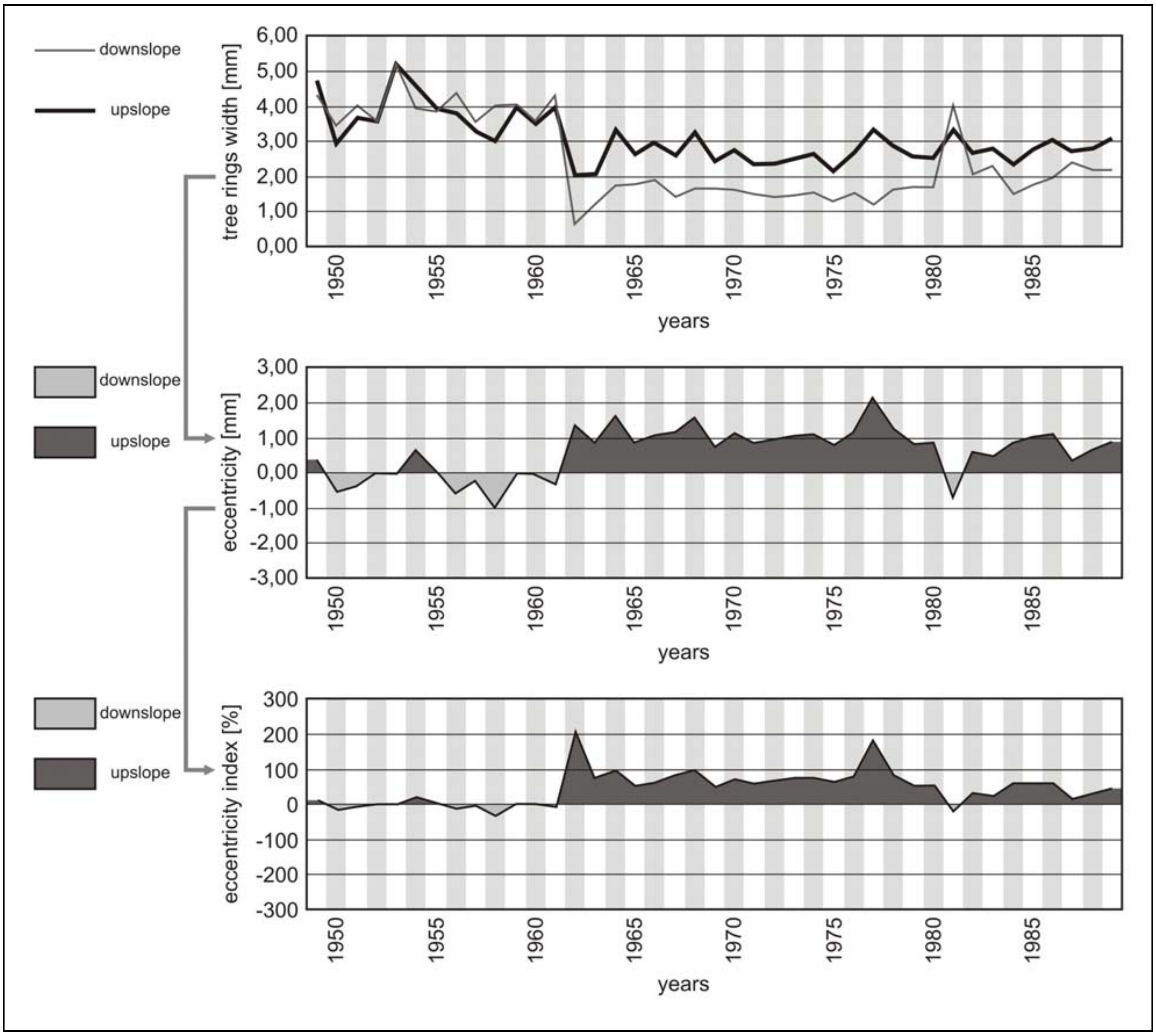

Figure 2: An example of raw data convertion and graph transformation: from tree-ring width [mm] into eccentricity index (for location of analysed sample Kp 2/1 – see figure 4).

The reference site Kp R

The reference site is located outside the boundaries of the large landslide (Fig. 3C). The slope is supported by a colluvial mound (part of the landslide tongue), which thus prevents it sliding. The surface of the slope is smooth. There is no geomorphological evidence of mass movement at this location.

The eccentricity indices of individual tree rings from the reference site rarely exceed 100%/-100% (upslope/downslope eccentricity). There is a balance and constant transformation between the upslope and downslope eccentricity (e.g. sample Kp R/1 on Figure 5). The eccentricity indices oscillate around a value of 0% (lack of eccentricity). The tree is continuously balancing to maintain its stability in response to wind, snow mass, soil creep, tilting and sliding under the tree's own constantly increasing weight.

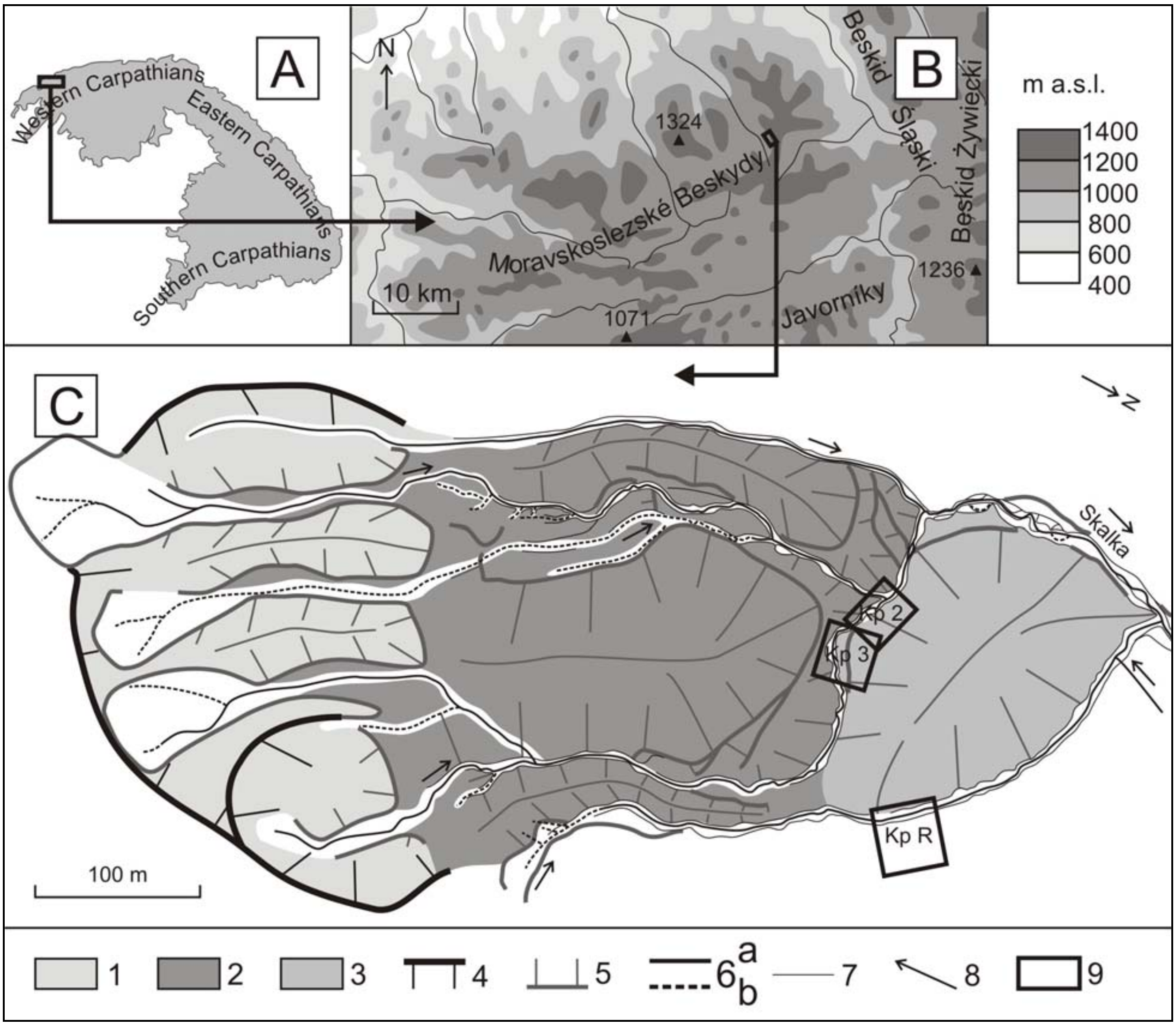

Figure 3: Location of the Skalka study area in A – the Carpathians , B – the Moravskoslezské Beskydy mountain range. C – The Skalka study area – large landslide – with the location of the reference site Kp R and study sites Kp 2 and Kp 3;
Legend: 1 – landslide niche, 2 – landslide tongue, 3 – landslide tongue: a colluvial heap, 4 – headscarps, 5 – escarpments, 6 – channels: a – active, b – inactive, 7 – channel undercuts, 8 – flow directions, 9 – study and reference sites.

Study sites Kp 1 and Kp 2

The study sites are located in the lowest part of the toe of a large landslide, on the colluvial mound (relative height: 60 m; Fig. 3C). Geomorphic mapping conducted on the slope investigated revealed the occurrence of cracks, crevices, headscarps and small toes descending from the slope to the stream channel. The relative height between the headscarps and toes is up to 1 m. The average gradient of the slopes is ~50%. Spruces growing on both study sites are tilted and some of them have deformed stems (Fig. 1).
Both slope and tree morphology suggest that active landsliding, and perhaps also lateral spreading, of the summit section of the mound are occurring. The morphology of the channel of the Skalka at the study sites is characterized by:

1. sinuosity imposed by the lateral delivery of colluvial material,
2. distinct traces of lateral erosion, particularly on the bank opposite the active slope.

Therefore it seems that the channel of the Skalka in the sections investigated is being pushed away by small (~30 m long) landslides.

The eccentricity indices of tree rings from the study sites Kp 2 and Kp 3 show a particular pattern. In the upper parts of the slope studied, the pattern at the start of tree growth is similar to that from the reference site in the case of trees tilted upslope. Afterwards abrupt jumps in the value of the eccentricity index occur: from about 0 to >100% (upslope eccentricity). These years can be described as the moment when mass movement of the slope was activated (Fig. 5: samples Kp 2/15, Kp 3/3). Trees growing in the lowest parts of slope, near the stream channel, are tilted downslope and represent a different eccentricity pattern (Fig. 5: Kp 2/6). Usually they have a clear downslope eccentricity from the very start of their growth. Jumps of the eccentricity index curves can reach -500%. This situation can be treated as a record of fluvial bank undercutting and the shallow sliding associated with this.

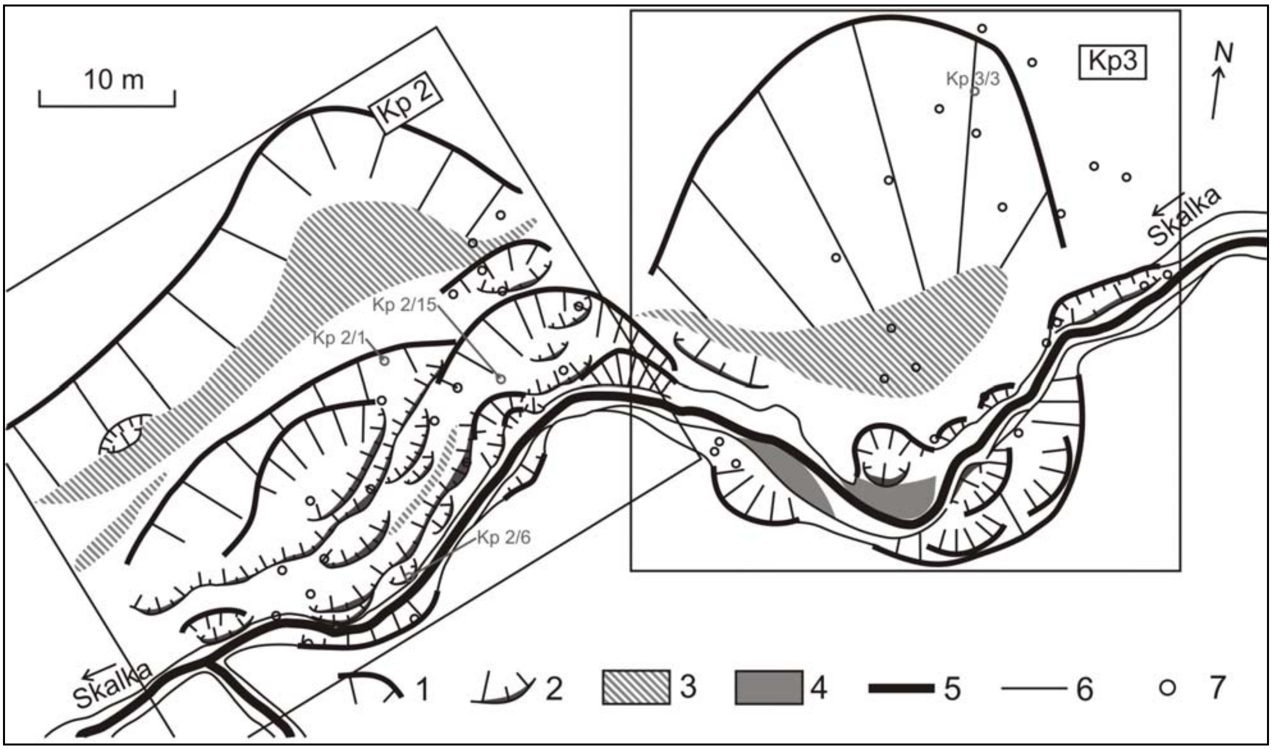

Figure 4: Morphology of the study sites Kp 2 and Kp 3. Location of trees sampled; legend: 1 – headscarps, 2 – landslide tongues, 3 – slope trenches, 4 – alluvial bars, 5 – channel, 6 – channel undercuts, 7 – sampled trees.

Conclusions

Tree-ring eccentricity is a good sensor for analysing mass movements. The eccentricity index enables one to compare trees growing in different conditions and assess the intensity of their eccentricity and by this, the intensity of mass movement. Spruces growing on unstable slopes are significantly more eccentric than trees from the reference site. The eccentricity method allows one to distinguish shallow slope movements (soil creep on the reference site) from relatively deep seated movement (landslides on the study sites).

On a stable slope (reference site) trees show minimal values of eccentricity index and a balance between the up- and downslope eccentricity. Spruces growing on the upper part of the active slope (study sites) are only tilted by mass movements and their rings are significantly wider upslope. Trees undercut by the stream produce rings which are much wider downslope.

Studies of eccentricity allow to:

a. distinguish geomorphic processes induced by mass movement and stream erosion,
b. distinguish zones where trees were tilted by lateral erosion of streams from areas dominated by the impact of mass-movement,
c. date the occurrence of mass movement on slopes and erosional events in the channel.

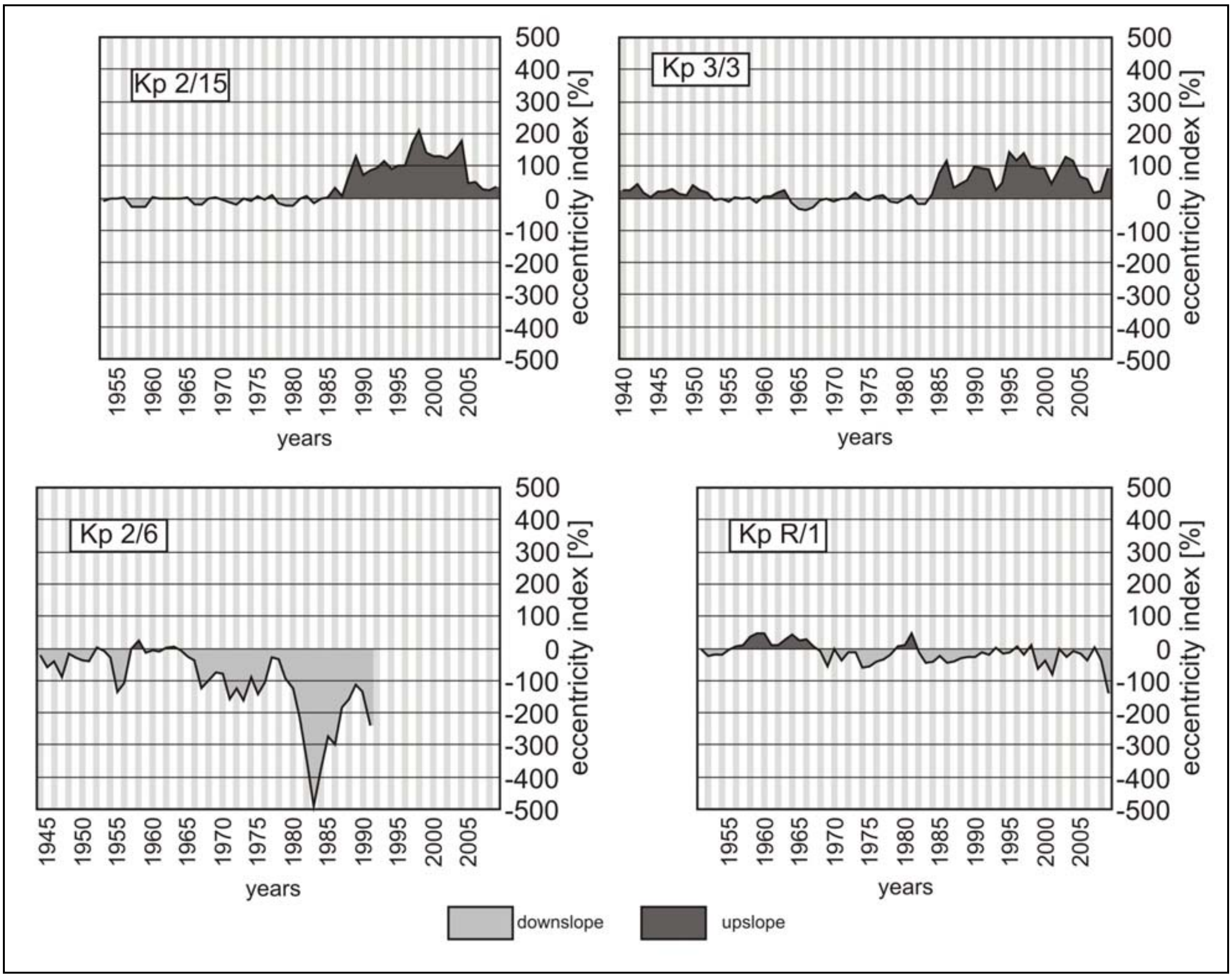

Figure 5: Examples of eccentricity index graphs from both study sites, from upper part of slopes (Kp 2/15,Kp 3/3), from the near-channel zone (Kp2/6) and from the reference site (Kp R/1) (for location of analysed samples – see figure 4).

References

Baumann, F., Kaiser K. F. (1999): The Multetta Debris Fan, Eastern Swiss Alps: A 500-year Debris Flow Chronology. Arctic, *Antarctic and Alpine Research* 31: 128-134.

Braam, R. R., Weiss, E. E. J., Burrough, P. A. (1987): Spatial and temporal analysis of mass movement using dendrochronology. *Catena* 9: 573–584.

Casteller, A., Stockli, V., Villalba, R., Mayer, A. C. (2007): An Evaluation of Dendroecological Indicators of Snow Avalanches in the Swiss Alps. *Arctic, Antarctic and Alpine Research*: 39: 218–228.

Gärtner, H., Stoffel, M., Lièvre, I., Conus, D., Grichting, M., Monbaron, M, (2003): Debris-flow frequency derived from tree-ring analyses and eomorphic mapping, Valais, Switzerland. *Debris Flow Hazards Mitigation: Mechanics, Prediction and Assessment* 1: 201-207.

Lang, A., Moya, J., Corominas, J., Schrott L., Dikau R. (1999): Classic and new dating methods for assessing the temporal occurrence of mass movements. *Geomorphology* 30: 33-52.