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Bank erosion history of a mountain stream determined by means of anatomical changes in exposed tree roots over the last 100 years (Bílá Opava River — Czech Republic)

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Abstract

The date of exposure of spruce roots as a result of bank erosion was investigated on the Bílá Opava River in the northeastern Czech Republic. Following the exposure of roots, wood cells in the tree rings divide into early wood and late wood. Root cells within the tree rings also become smaller and more numerous. These processes permit dating of the erosion episodes in which roots were exposed. Sixty root samples were taken from seven sampling sites selected on two riverbed reaches. The results of root exposure dating were compared to historical data on hydrological flooding. Using the root exposure dating method, several erosion episodes were recorded for the last 100 years. The greatest bank erosion was recorded as consequence of an extraordinary flood in July 1997. In the upper, rocky part of the valley studied, bank erosion often took place during large floods that occurred in the early 20th century. In the lower, alluvial part of the valley, erosion in the exposed roots was recorded only in 1973 and has been intensive ever since. It is suggested that banks in the lower part are more frequently undercut, which leads to the falling of trees within whose roots older erosion episodes were recorded. Locally, bank erosion is often intensified by the position of 1- to 2-m boulders in the riverbed, which direct water into the parts of the banks where erosion occurs. Selective bank erosion could be intensified by debris dams and hillslope material supply to the riverbed.

Keywords: Bank erosion; Mountain stream; Dendrogeomorphology; Exposed roots

1. Introduction

The rate of bank erosion in mountain streams mainly depends on the bank material erodibility and the history of fluvial processes, particularly the character and frequency of high water episodes (Gregory and Walling, 1973; Krzemień, 1976; Thorne, 1982; Starkel, 2002). What is also of considerable importance for the erosion of banks composed of loose rocks is the activity of needle ice and ice floats, as well as the nature of the riparian vegetation (Klimek, 1989). Banks strengthened by root systems are more resistant to washing out and less undercut as compared to those without vegetation cover (Sttot, 1997; Rowntree and Dollar, 1999, Abernethy and Rutherfurd, 2000). Banks not strengthened by tree roots are by half more erodible than banks with root systems. Roots of riparian trees protect banks against erosion more effectively than species inhabiting non-riparian zones (Pollen and Simon, 2005).

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In order to define the history of bank erosion in riverbeds of mountain streams, a number of field methods are used (Thorne, 1981). Erosion pins and geodetic methods, e.g., repeated riverbed cross-section (Harvey, 1974; Lawler, 1978; Hooke, 1980; Lane et al., 1994) are used in short, several-year-long, study periods. Another way of estimating bank erosion intensity is the analysis of riverbed morphologies on maps and air photos of various ages (Trafas, 1975). However, the method is applied most frequently for medium-sized and large rivers with a riverbed at least several meters wide. Also, photo-electronic erosion pins (PEEP) can be applied, these based on photographs of the bank taken automatically during erosion episodes (Lawler, 1991, 2005). The analysis of anatomical changes within the wood of trees growing on the undercut levels allows flood frequency, and indirectly bank erosion rate, to be reconstructed (Sigafoos, 1964; Hupp and Osterkamp, 1996). A lot of information may be provided by the analysis of coarse woody debris (CWD) lying *in situ* under erosional undercuts (Malik, 2005, 2006). However, high discharges occur in mountain streams and CWD is most often redeposited, which prevents the drawing of conclusions about bank erosion intensity at particular sites (Wyżga and Zawiejska, 2005). It seems that the exposed roots of trees overgrowing rock-and-regolith banks, floodplains, and terraces, are a much more valuable material for the analysis of bank erosion rate in mountain streams.

Dendrogeomorphological studies focused on root exposure dating as a tool for calculating erosion rate are few. LaMarche (1966) found a correlation between the distance from the exposed root to actual soil level and by age of the root and used this information to calculate the slope erosion rate. Alestalo (1971) noted the morphological changes in the wood anatomy of roots occurring in reaction to changes from aerial to subaerial environments or *vice versa*. During successive tree root exposure, ring reduction (suppression) often occurs, sometimes masked by release resulting from the elimination of competition from nearby trees (Alestalo, 1971). Shroder (1980) and Strunk (1997) have also described the effect of sediment burial on the production of adventitious roots. The age of the adventitious roots enables the year in which the deposition occurred to be identified. Different event types occur within root cross-sections, such as width, density, reaction wood, and corrasion scars (Shroder, 1978, 1980; Shroder and Butler, 1987). Those types of events can provide information about erosion intensity.

Carrara and Carroll (1979) also calculated erosion rates by examining exposed roots. They used tree root anatomical features to identify the years in which erosion occurred. The study was based on the time of initial cambium dieback, interpretation of annual ring growth patterns, and the earliest occurrence of reaction wood. Cross-dating of root samples was used to estimate gully erosion rates by Vandekerckhove et al. (2001). The authors suggest that a large number of samples are required to understand gully evolution. In order to estimate precisely the gully erosion volume, samples should be collected from various places on the exposed root, depending on its position (Vandekerckhove et al., 2001). Cross-dating of tree ring series from trees and roots allows identification of the year when an erosion episode occurred. Scars on roots produced by transported material may also inform about the occurrence of geomorphic events.

Roots document erosion episodes that have led to their exposure. Exposed parts of the root undergo anatomical changes. Tree rings occurring in roots after exposure are wider, cells are clearly smaller and there are many more of them. In addition the division into early and late wood is often clearly marked (Gärtner et al., 2001). Clear visible anatomical changes are recorded after exposure of coniferous tree roots (Hitz et al., 2006). Erosion analysis is best performed on live exposed roots documenting the exact year where root exposure occurred. Dead roots only document the minimum time passed from exposure and a simultaneous erosion episode (Malik, 2006).

In this study, the authors assumed that it is possible to reconstruct bank erosion history by examining the anatomical changes in exposed tree roots. The purpose of this study is (i) to determine how many and which exposed roots – depending on their position related to the river bank and soil – are particularly useful in riverbank erosion dating; (ii) to explain anatomical changes in exposed roots in relation to bank erosion processes; (iii) to identify sources of error in the root exposure dating process; and (iv) to determine the bank erosion history in mountain streams using exposed roots dating based on the example of the Bílá Opava River.

2. Study area

The Bílá Opava River valley is located in the northeastern part of the Czech Republic, in the Hrubý Jeseník massif (Eastern Sudetes). The elevation of the massif is 1000–1500 m a.s.l. (Fig. 1a–c). Along the upper course of the Bílá Opava River drainage basin, the Hrubý Jeseník massif consists primarily of Devonian orthogneiss, local migmatites and – in the upper parts – fine- and medium-grained paragneiss. The northern