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Dendrogeomorphological analysis of the enlargement of cracks at the Wellenkalk-scarp in the southern Thuringia Basin

I. Sahling[1], K.-H. Schmidt[1] and H. Gärtner[2]

[1]Geographical Institute of the Martin-Luther-University Halle - Wittenberg, Domstr. 5, D-06108 Halle / Saale, Germany; e-mail: ingosahling@web.de, schmidt@geographie.uni-halle.de;

[2]Swiss Federal Research Institute WSL, Zürcherstrasse 111, CH-8903 Birmensdorf, Switzerland; e-mail: holger.gaertner@wsl.ch

Introduction

The Wellenkalk cuesta scarp in the Thuringia Basin (Fig. 1) is characterised by the occurrence of massive block displacements. Their initial phase is marked by the formation of tension cracks. Until now, dendrogeomorphological studies of corresponding movement rates are rare. However, the study of affected trees offers many possibilities for the reconstruction of past and recent mass movements, especially using anatomical analysis of the growth-ring structures of affected roots.

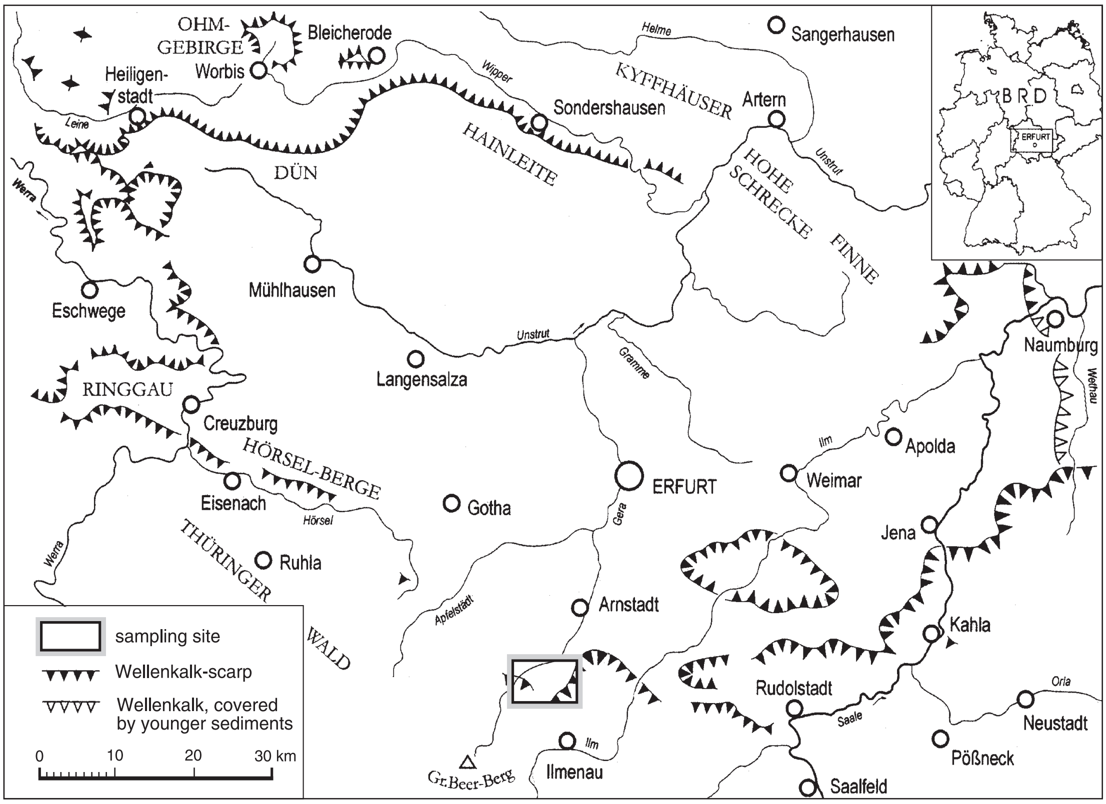


Figure 1: Wellenkalk scarp in the Thuringia Basin (Thüringer Becken). (Johnson & Schmidt 2000: 97; after Weber 1955).

In this study we focus on stems and roots of *Picea Abies* (L.) Karst growing at the tension cracks at the top of the Wellenkalk scarp. We analyse variations in growth, which are considered to explicitly reflect dynamic slope patterns. Of special interest in this context are structural variations in the xylem of the stem (growth reductions and formation of compression wood) and of the root (eccentricities and cell size reductions).
The purpose of our study is to measure the relatively slow geomorphological dynamics of block movements during the initial phase of the opening of the crack. In this context we focussed on the relationship between the dynamics of geomorphological processes and extreme precipitation events, a relationship that has been described frequently (e.g., Ackermann 1958; Johnson 1974, 1981, 1984; Johnson and Schmidt 2000).
The basis for the dendrogeomorphological evaluation presented here is a combination of methods, including detailed characterisation of the terrain in the form of detailed geomorphological mapping, dendrochronological data analysis, and the analysis of recognisable variations in the cell structure of the roots.

Site selection

The studied sites are situated about 16 km South of Arnstadt, between Angelroda to the North and Geraberg to the South, in the area of the "Kammerlöcher" (Fig. 1). The occurrence of mass movements is limited to the west-facing slope of the scarp, from the "Kirchwald" to the "weißen Stein". Cracks at the Wellenkalk-scarp of the Kammerlöcher were chosen to provide a setting for the study of recent block movements. According to Johnson (1981) the movement of Wellenkalk-blocks generally takes place very slowly, in the range of millimetres per year. When selecting the sites, attention was paid to their position along the crack, in order to ensure that enlargement of the crack would have influenced the growth of the trees. To ensure the comparability of the different sites, we selected trees of one species only: *Picea Abies* (L.) Karst.
We took samples at three sites, which we termed 01, 02 and 03 respectively. Sites 01 and 02 are located at a tension crack, and site 03 on a displaced block (Mauerscholle). The reference site was selected with the precondition that the tree stand would be undisturbed by mass movements.

Methods

Tree cores were taken with an increment corer. At the reference site we sampled 30 trees. Because the influence of reaction wood is minimised by slope-parallel extraction, the cores were extracted in the *a* and *b* directions shown in Figure 2, (at a height of 1.30 m). At sites 01, 02 and 03, four cores were taken from each disturbed tree in the directions *a*, *b*, *c* and *d* at the height of 1.30 m (Fig. 2). At site 02 it was also possible to sample two roots growing across the tension crack. The environment of the disturbed trees and roots was mapped geomorphologically at scale 1:50.

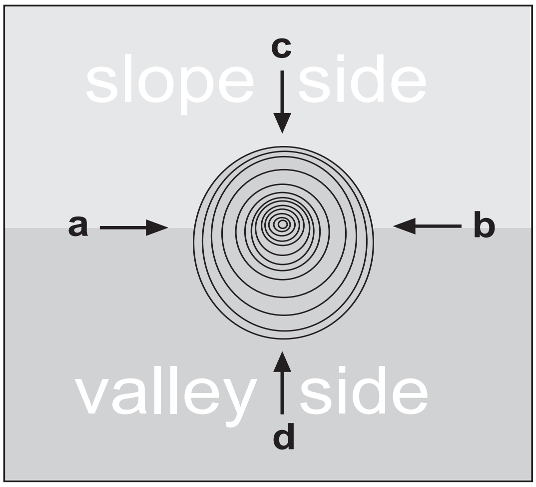


Figure 2: Coding of the core-directions

In the laboratory, the cores were fixed onto wooden core mounts. We took slices from the root samples at regular intervals and prepared them for further measuring. We also prepared microtome slices of selected samples. The data series were generated by visual analysis of the growth patterns and, next, by using a standard system for the measurement and ring-width analysis (TSAP).

Results

General

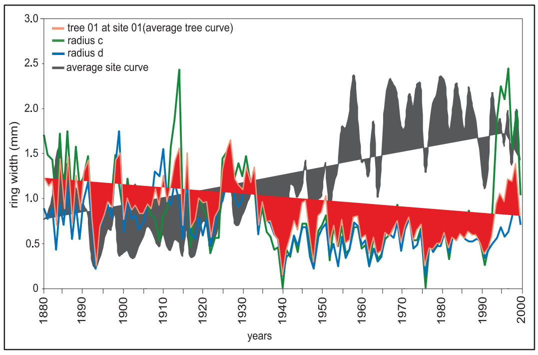
The results of our study show an obvious influence of mass movements on tree growth. Growth reductions (stem), formation of reaction wood (stem, roots) and variations in cell size (roots) provide information on the date of the opening of the crack. From the year 1953 onwards, at each surveyed site the opening of the crack increased to such a degree that that tree growth became remarkably disturbed.

Using the collected data, it was possible to determine periods of crack movements at sites 01 and 02. All sampled trees at these sites show patterns of prominent movement for the years 1884 - 1885, 1899 - 1901, and 1910 - 1915. Crack movement occurred in the years 1953 (site 01) and 1954 (site 02), with preliminary phases of opening joints in the 1930's and 1940's, respectively. After the opening of the crack, the growh patterns of the trees only differed in detail. Between 1981 and 1985, the trees at both sites again reacted synchronously, due to a less intense movement of the crack. Between 1994 and 2000 only tree 01 at site 01 (Fig. 3) records a repeated intense opening of the crack.

The results of the investigation at site 03 (displaced block; Mauerscholle) clearly support the hypothesis that the crack opening at sites 01 and 02 is younger than the formation of the displaced block. The crucial reduction in the growth pattern of the sampled trees at sites 01 and 02 cannot be found in the ring patterns of the trees at site 03.

Tree analysis (example)

Figure 3: View from the crack to the sample tree 01 at site 01



Fiure. 4: Comparison of the tree radii c-d (site 01) and of the average tree curve with the average site curve

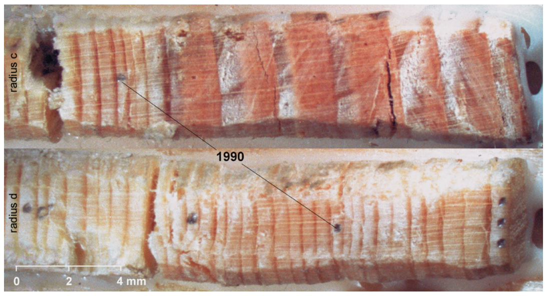


Figure 5: Photo of the compression wood formation (radius c, top) from the year 1994 on compared to radius d (bottom).

For site 01 we compared tree radii *c* and *d* to the average curve of tree 01 (*a*-*d*) and the average site chronology (Fig. 4). From the year 1953 onwards a persistent growth reduction occurred. Based on the position of the tree (fig 3), we assume that the opening of the crack caused serious damage of the roots. In core *c* we detect a notable reaction, by the formation of compression wood, from the year 1994 onwards (Fig. 5). This marks the most recent movement of the rift at site 01. The movement impulse that caused the tangential deviation of the tree was preceded by an extreme precipitation event. On April 12th of 1994, the climate station of Gräfenroda (4 km NW of site 01) recorded 85 mm of precipitation, which exceeds the monthly averages for the period 1973 - 2000 with 85% (Fig. 6).

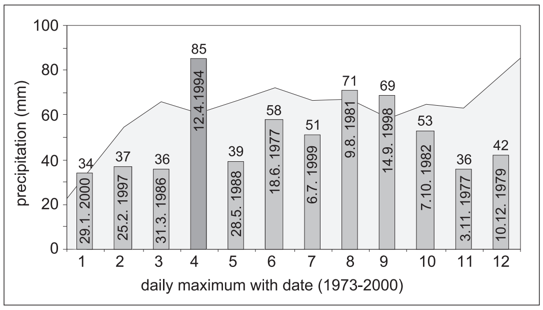


Figure 6: Comparison of the absolute daily maxima with the monthly averages (grey,background) climate station Gräfenroda (Meteorological Service)

Root analysis

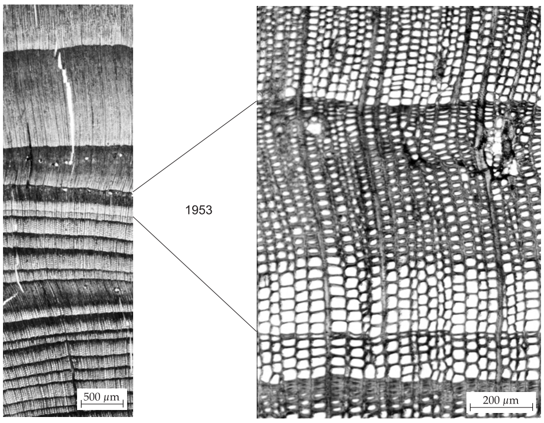


Fig. 7: Microtome of the root slice 4DK0201f

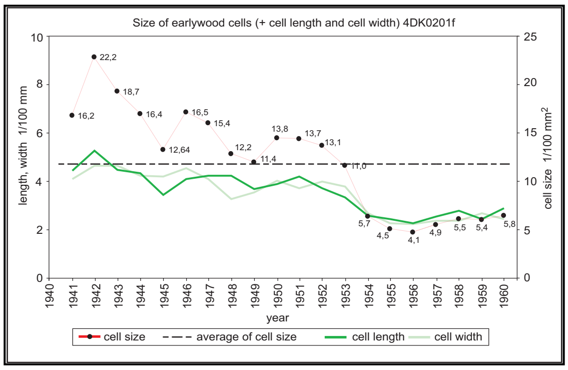


Fig. 8: Cell size measurements of the cross-section 4DK0201f

Root samples of site 02 were analysed using the method of Gärtner (2001). The findings confirm the results of the dendrogeomorphological analysis of the site 01 material and allow an even better approximation of the date of the crack opening. Remarkable compression wood formation occured during the year 1953 (Fig 7). From 1954 onwards, a noticeable reduction of the earlywood cell size took place (Fig 8). This reduction exceeded 50%, the threshold value for root exposure (Gärtner 2001). In other samples along the root the same structural changes were noted, implying that the roots were exposed over a partial length of 450 mm.

Summary

Relating the crack width to the dates of the opening of each crack, the following average movement rates were obtained:

Site 1:

Tree analysis: 21 mm / a (1953 - 2000) crack width near the tree 1m

Site 2:

Tree analysis: 35 mm / a (1954 - 2000), crack width near the tree 1.65m

Root analysis: 28 mm / a (1953 - 2000), crack width next to the root sample 1.35m

Microtome analysis: 450 mm long root piece was exposed as a result of an event

Site 03:

The sampled tree on the displaced block (Mauerscholle) does not show any remarkable growth reduction in the year 1953, in spite of the small distance (15 m) to site 02.

Phases of intense movements of the study sites between AD 1900 and 2000 could be correlated to extreme precipitation events.

We conclude that the combination of root- and stem-structure analysis provides a powerful dendrogeomorphological tool for the study of mass movement, in this case the determination of widening rates of cracks at the Wellenkalk-Escarpment in the Thuringia Basin.

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