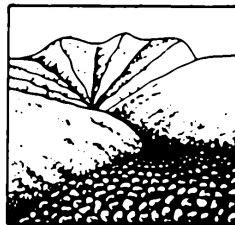


Труды Международной конференции

# **СЕЛЕВЫЕ ПОТОКИ: катастрофы, риск, прогноз, защита**

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Пятигорск, Россия, 22-29 сентября 2008 г.



Ответственный редактор  
С.С. Черноморец

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Институт «Севкавгипроводхоз»  
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# **DEBRIS FLOWS: Disasters, Risk, Forecast, Protection**

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Pyatigorsk, Russia, 22-29 September 2008



Edited by  
S.S. Chernomorets

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## Assessing the last moment of debris-flow activity on a fan using tree-ring data

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## Оценка даты последнего проявления селей на селевом конусе с использованием данных по кольцам деревьев

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Дендрохронологический анализ деревьев, нарушенных селевыми потоками, был систематически использован для датирования событий прошлого. Тем не менее, этот метод всегда был ограничен залесенными конусами выноса, на которых деревья фиксируют воздействия предыдущих потоков. Минимальный возраст деревьев, растущих на датированных селевых отложениях, может, напротив, содержать информацию о дате последнего случая предыдущего селя. В этой статье мы излагаем результаты, полученные путем комбинации обоих этих подходов на покрытом лесом конусе в Альпах Вале (Швейцария). По сбитостям на нарушенных деревьях *Larix decidua* Mill. и *Picea abies* (L.) Karst. удалось выполнить реконструкцию 49 событий между 1782 и 2005 гг. В селевых руслах, где деревья не сохранились, мы отобрали наиболее старые послеселевые деревья и оценили их возраст. Сочетание дендрогеймоморфологической реконструкции события с оценкой дат появления деревьев после селя позволило рассчитать минимальный возраст селевых отложений в селевых руслах на современной дневной поверхности конуса.

Dendrogeomorphological analyses of trees affected by debris flows have regularly been used to date past events. However, this method has always been limited to forested fans where trees registered the impact of previous events. The minimum age dating of trees growing in the debris deposits can, in contrast, provide information on the latest possible moment of past activity. In this abstract, we report on results obtained from a combination of these two approaches on a forested fan in the Valais Alps (Switzerland). Disturbed *Larix decidua* Mill. and *Picea abies* (L.) Karst. trees allowed reconstruction of 49 events between AD 1782 and 2005. In the debris-flow channels where survivor trees are missing, we selected the oldest post-event trees and assessed their age. The combination of the dendrogeomorphological event reconstruction with the assessment of germination dates of successor trees allowed realistic approximation of the minimum time elapsed since the last debris-flow activity in channels present on the current-day fan surface.

### 1 Introduction

Debris flows represent a widespread mass-movement process in the Swiss Alps, where their unpredictable and sudden occurrence may pose major threats to transportation corridors and settlements. However, there is still a considerable lack of knowledge on earlier events for many regions. Thus the reconstruction of past activity is essential for the understanding of current debris-flow dynamics in mountain torrents and possible future evolutions.

The most accurate method for dating events over several centuries in the past is the analysis of tree-ring series. Given that a tree is directly impacted by a geomorphic event, tree-

ring dating can pinpoint the year or even the season in which the growth disturbance (GD) occurred (Strunk, 1997; May and Gresswell, 2004; Bollschweiler and Stoffel, 2007; Bollschweiler et al., 2007; Stoffel and Beniston, 2006).

Particularly large or devastating debris flows may eliminate entire forest stands, rendering the reconstruction of previous events impossible with dendrogeomorphological methods. Since cleared surfaces are normally recolonized by seedlings in the years following the devastating event, germination ages of trees can help estimating the time of surface-clearing disturbances to existing landforms (Sigafos and Hendricks, 1969; McCarthy and Luckman, 1993; Winter et al., 2002). Similarly, this method can be used to date surfaces cleared by debris-flow activity.

The aim of this study was to combine dendrogeomorphological analyses with an assessment of germination dates of successor trees in order to understand the dynamics of past debris-flow events on a forested fan in the Valais Alps, Switzerland.

## 2 Study site

The study of past debris-flow dynamics was conducted on the fan of the Grosse Grabe torrent, located on the west-facing slope of the Matter Valley (Valais, Swiss Alps; 46°10' N, 7°47' E; Fig. 1).

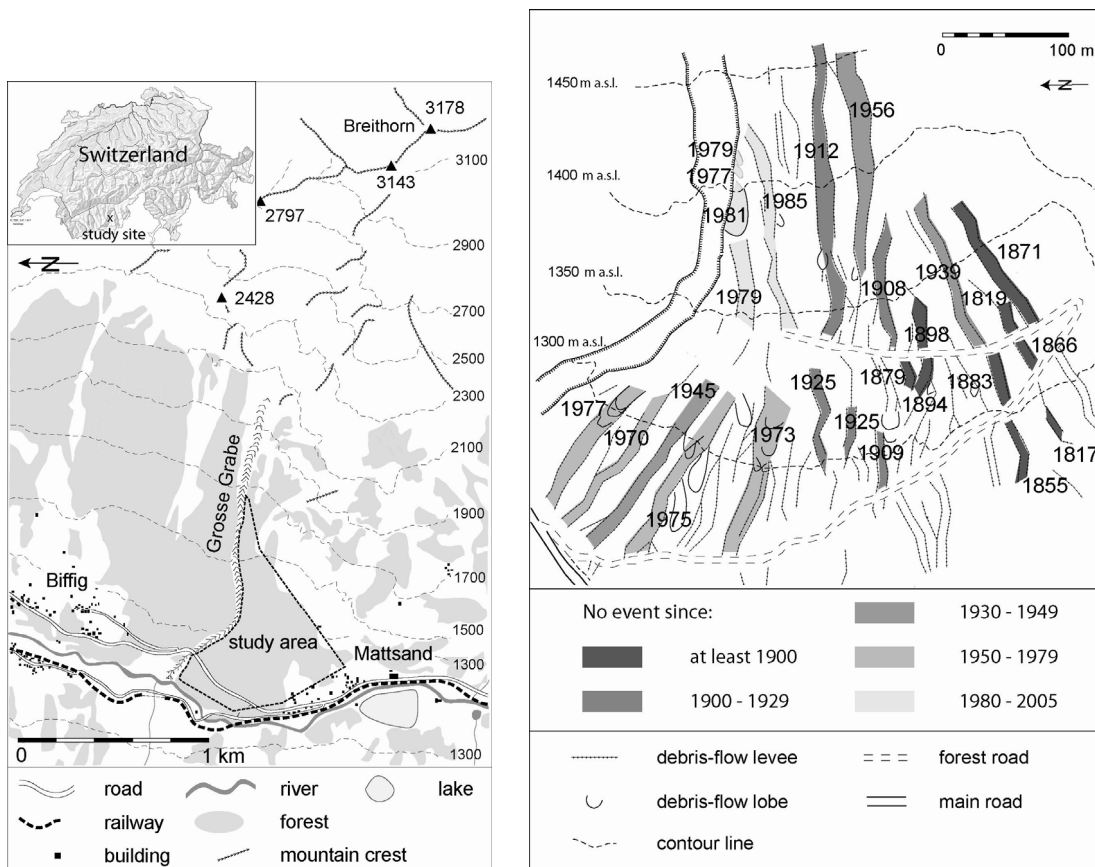


Fig. 1. Location and sketch map of the study site.

Fig. 2. The coupling of data on past events and minimum ages of undisturbed trees growing in channels provides information on the latest possible moment for debris-flow activity in particular channels.

The catchment area of the torrent totals 1.5 km<sup>2</sup> and extends from 3,178 m a.s.l. to the 1,200 m a.s.l. The upper part of the catchment is dominated by gneissic rocks belonging to the crystalline Mischabel unit, while in the lower part, debris originating from various gravitational processes (i.e. rockslides, rockfall) cover the bedrock. The debris-flow fan extends from 1,200 m a.s.l. to 1,600 m a.s.l. and is vegetated by a forest primarily composed of European

larch (*Larix decidua* Mill.) and Norway spruce (*Picea abies* (L.) Karst.). On the fan, slope gradients average 14° and deposits of past debris flows can exclusively be found south of the currently active channel. In its lowermost, the main road connecting Zermatt to Visp crosses the fan.

### 3 Methods

In a first analytical step, all forms and deposits related to previous debris-flow activity (i.e. lobes, levees or abandoned channels) were mapped in a scale of 1:1000 using compass, tape measure and inclinometer.

In a next step, *Larix decidua* and *Picea abies* trees that had obviously been disturbed by previous debris-flow events were cored using a Suunto increment borer (max. length 40 cm, Ø 6 mm). Within this study, we preferably selected trees that showed scars, candelabra growth, exposed root systems as well as buried or tilted stem bases resulting from the impact of past events. In total, 71 strongly affected *Larix decidua* and *Picea abies* trees were sampled with 150 cores for this study. In the channels located in the southern sectors of the fan, disturbed trees were very scarce and sometimes even totally absent. Therefore, we sampled 72 undisturbed trees for minimum age dating in these sectors.

The samples were analyzed using standard dendrochronological methods (see Stoffel and Bollschweiler, 2008). Afterwards, tree-ring series of the disturbed trees were analyzed visually so as to identify growth disturbances caused by past debris-flow events. For the trees sampled for the minimum age dating, an age correction factor was included in order to eliminate the influence of the sampling height and the absence of the center on the core.

For the determination of the last moment of debris-flow activity in the currently abandoned channels, we dated the last event by the growth disturbances in affected trees. In a second step, the germination date of the oldest tree was determined for channels where none of the trees of the present-day forest stand showed disturbances caused by past debris-flow activity. The coupling of data on debris-flow events with data on minimum ages of undisturbed trees growing in previously active channels allowed determination of the minimum time elapsed since the last event.

### 4 Results

#### 4.1 Debris-flow frequency

In total, the analysis of GD occurring simultaneously in different trees allowed the reconstruction of 49 event years between AD 1782 and 2005. The reconstruction yielded data for only a limited number of events in the 19<sup>th</sup> century. In contrast, the tree-ring records suggest several periods with increased activity during the 20<sup>th</sup> century. Such clustering of events can primarily be identified for the periods 1905–1907 or 1917–1928 as well as between 1970 and 1982.

#### 4.2 Approximation of last moment of past activity

Since past debris-flow events and their spatial extent could only be reconstructed on the northern part of the fan, we determined the age of the oldest post-event trees to approximate the minimum time elapsed since the last moment of debris-flow activity on the southern part of the fan. The results of the two approaches are coupled in Figure 2. Here, calendar years indicate the latest possible moment of debris-flow activity in the channels present on the current-day fan surface. From our data, we can see that the time elapsed since the last debris-flow activity clearly increases with the distance from the currently used channel, with the last activity identified in the early 1980s close to the current channel, whereas GD in trees are missing in the southern and central sectors of the fan since the late 19<sup>th</sup> century.

### 5 Discussion

In this study, we report on a reconstruction of debris-flow events on a forested fan in the Valais Alps (Switzerland) based on detailed geomorphic mapping and tree-ring analyses. Dendrogeomorphological investigations of 71 heavily affected *Larix decidua* Mill. and *Picea abies* (L.) Karst. trees allowed reconstruction of the past debris-flow frequency. In total, 49 events could be identified for the period AD 1782–2005. In addition, we determined the germination ages of the oldest trees in those channels where trees were missing obvious signs of

past debris-flow activity. These dates served as an approximation of the minimum time elapsed since the last possible event in channels.

The debris-flow frequency represents the minimum number of events that occurred in this torrent in the recent past since small debris-flow surges that did not leave the channel did not cause GD to trees on the fan. The study of past events was mainly limited by the age of the trees, which averaged only 140 years. At the same time, the apparent decrease in event frequency that starts to emerge from the tree-ring reconstruction in the 1980s was primarily due to considerable channel incision (about 6–8 m) and to bank stabilization measures, which prevented present-day debris-flow surges from leaving the channel.

The approach of the minimum age dating helped assessing the minimum time elapsed since the last event in channels where no disturbed trees could be identified. However, this approach remains an approximation as the number of missing rings needed to be estimated. Nevertheless, we are convinced that the results presented on the minimum age of the tree are reasonably accurate as the methods we used tend to underestimate rather than to overestimate the number of missing rings, which supports the idea of providing “minimum ages” of forms and deposits.

Even though the methods used have their limitations, this study allowed for the first time reconstruction of the spatial and temporal dynamics of debris-flow activity on a forested fan, where deposits are in some places older than the oldest trees.

## 6 Conclusion

The combination of different dendroecological methods allowed reconstruction of 49 event years between AD 1782 and 2005 as well as the determination of the minimum time elapsed since the last debris-flow event for previously active channels. For fans or sectors where trees are obviously influenced by debris flows, dendrogeomorphological methods analyzing distinct growth disturbances in the tree-ring series are suitable for the determination of event years. In contrast, for fans or sectors of fans where deposits of the current-day surface are older than trees growing in the deposits, this method is not applicable. However, tree ages of the oldest post-event trees growing in the previously active channels allow determination of the latest possible moment of debris-flow activity in these channels. The combination of both techniques – dating of growth disturbances and assessing tree age of post-event trees – allows determination of the spatio-temporal dynamics of past debris-flow activity over the past few centuries on forested fans.

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