

## **Subfossil pines from loamy slope sediments reflect Lateglacial climatic variations**

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### **Introduction**

During the last glacial maximum (c. 20 kyrs BP), Alpine glaciers formed numerous lateral drainage channels on the Swiss plateau. Adjacent to then existing nunataks (e.g., Uetliberg, plateaus of Brütten and Kyburg), drainage channels were formed such as the Daetttau valley, Rumstal near Winterthur, and the valleys of Sihl and Reppisch in the vicinity of Zurich. Mass movements, precipitation and meltwater filled the channels with predominantly loamy sediments. These developed to huge archives containing subfossil pines and other macro and micro remains. Greenland ice cores show that the Lateglacial (i.e., the beginning of the Bølling-Allerød interstadial around 14.500 cal BP) is characterized by an abrupt warming to ca. 1°C below the average Holocene level (Dansgaard et al. 1993, GRIP Members 1993). Until the end of the Allerød, at least 3 cycles of climatic cooling can be distinguished (Bond et al. 1999). These are the Older Dryas (OD), the Inner Allerød Cold Phase (IACP), and the Gerzensee deviation (GS). A significant warming followed each of these cooling events (Taylor et al. 1993). The Bølling-Allerød interstadial was terminated abruptly by the final event of the Younger Dryas (YD), the temperature dropping ca. 7°C relative to the early Bølling (Dansgaard et al. 1993, GRIP Members 1993).

At present, there is an abundance of known sites containing subfossil pine trunks that date back to the early Holocene (Preboreal) and the Lateglacial (Bølling, Allerød and Younger Dryas). Consequently, numerous Lateglacial floating chronologies have been constructed. The chronologies from the late Younger Dryas and early Preboreal have been dated absolutely against the Hohenheim pine/oak master chronology (Kaiser 1993, Friedrich *et al.* 1999, Friedrich *et al.* 2001, Spurk *et al.* 1998). The Hohenheim pine chronology from gravel beds of the Danube River dates back to 11919 cal BP [9969 BC]. The Swiss Preboreal pine chronology built parallel to the Hohenheim chronology extends the absolutely dated sequence backwards with 35 years, to 11954 cal BP [10004 BC] (B. Müller 2000). Subfossil pine trunks from the French Alps have been used to build several floating chronologies for the same period (Miramont 2000a/b).

### **Aims**

The research objectives at the Gaenziloh site were:

1. The compilation of one or more independent chronologies;

2. The identification of phases of increased germination of the trees;
3. Crossdating the new chronologies against existing chronologies from Daetttau;
4. Assessing whether the new chronologies reflect Lateglacial climatic signals such as OD, IACP, GS and YD.

In this paper we present preliminary answers to question 1, 3, and 4, based on the Daetttau material (Kaiser 1993) and a subset of samples from Gaenziloh. More precise results will be presented when all pine trees from the Gaenziloh site have been included in the analysis.

### Material and methods

In the summer of 2000, near Zurich the construction started of a tunnel through Uetliberg. In the glacial meltwater channels on both slopes of Uetliberg (i.e. Reppischtal and Sihltal), 120 fossil pine stumps were recovered from the construction sites of Gaenziloh and Landikon. During their lifetime, the pine trees were buried continuously beneath loamy alluvia washed down from the slopes. Hence the wood is well preserved. Our study focusses on the trees found at Gaenziloh in combination with those from Daetttau (Kaiser 1993) (Fig.1). The majority of the studied samples were dated by means of the radiocarbon method (Figs. 2 and 4).

Several disks were taken from each stump: a first one at the level where the roots spread, in order to obtain the germination date of the tree, and one or two more at a 30 to 40 cm higher level, in order to avoid growth disturbances caused by roots.

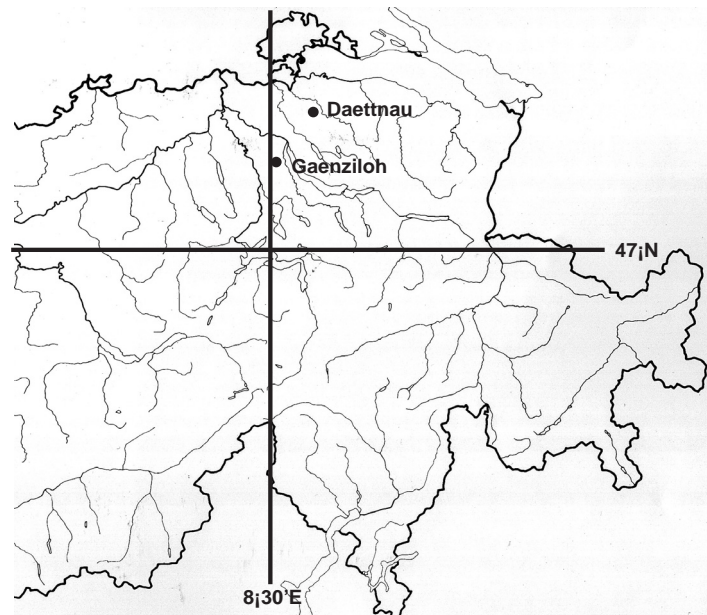


Figure 1: Location of the studied sites

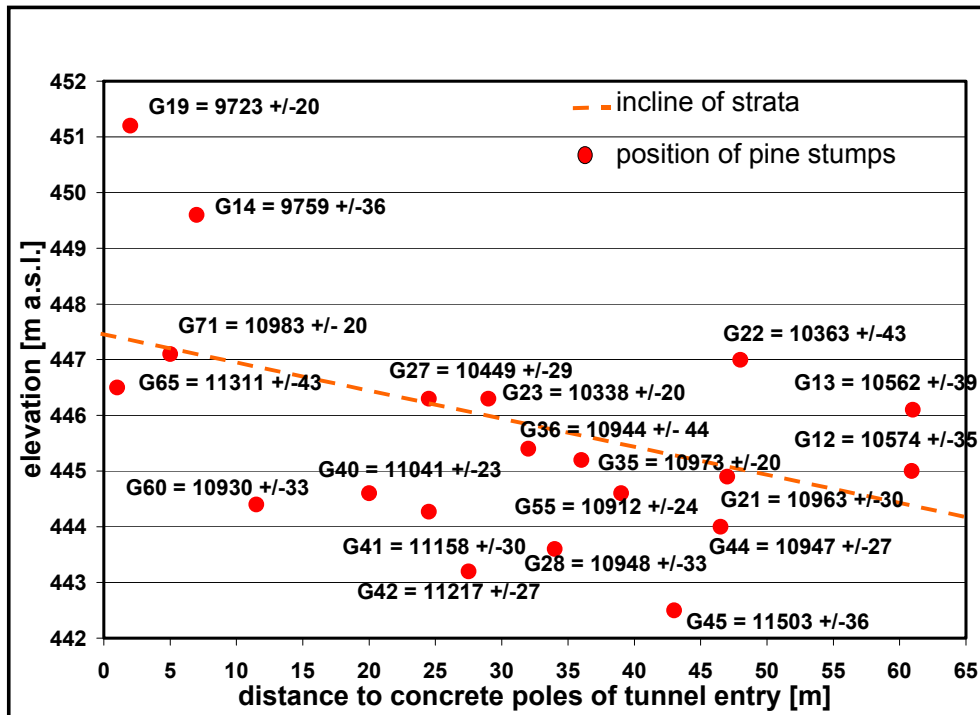


Figure 2: General position of the  $^{14}\text{C}$ -dated pine stumps at Gaenziloh.

## Results

Radiocarbon dating places the pines from Gaenziloh in the Allerød, with some scattered samples dating to the Younger Dryas (Fig. 2).

We first constructed a floating chronology, CHR65, from the ring-width series of five pines (Fig. 3). Since the replication of CHR65 is low, we relied in part on stratigraphy and radiocarbon dates when we placed the constituting time series on a relative time scale. Figure 4 shows that the available  $^{14}\text{C}$  dates agree well with the dendrochronological results. CHR65 covers 830 years and may extend just into the Younger Dryas cold phase. Using CHR65, the gap between two floating chronologies from Daetttau (DAEALCH1 and DAEALCH2; Kaiser 1993) could be bridged (Fig. 3). Our results show that the latter chronologies do in fact overlap in time, but with an insufficient number of tree rings to allow for statistical certainty.

We then used the crossdated series from Gaenziloh and Daetttau to construct a combined chronology, which we termed CHR213 (Fig. 3). It covers an 1109-year interval, and agrees well with chronology Aller14 by Friedrich *et al.* (2001), the older part of which consists of chronology DAEBOCH from Daetttau (Kaiser 1993).

Minimum values in CHR213 seem to reflect climatic deteriorations of the Allerød such as IACP and GS (Siegenthaler *et al.* 1984). The distinct growth disturbance after relative growth year 1050 (see Fig. 3, x-axis) probably synchronizes with the Laachersee eruption (LSE) (Schminke *et al.* 1999, (Friedrich *et al.* 1999). However, these results are tentative, given the fact that they are based on a subset of the Gaenziloh material. Their validity will have to be assessed as soon as all samples have been evaluated.

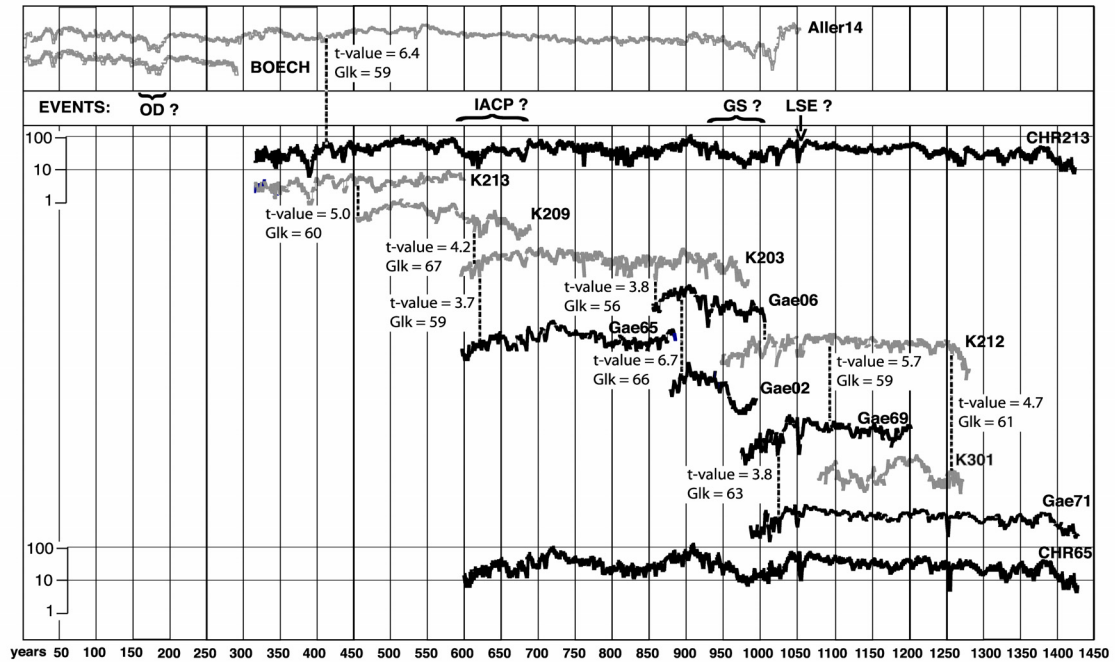


Figure 3: Lower part: The first chronology of Gaenziloh, entitled CHR65, was compiled from samples Gae65, Gae06, Gae02, Gae69, and Gae71. It covers 830 years and matches with important samples within the Daettnau chronologies DAEALCH1 (samples K213, K209, K203) and DAEALCH2 (samples K212, K301). The combined chronology, entitled CHR213, covers an interval of 1109 years. Intervals of below-average annual growth possibly reflect the Inner Allerød Cold Phase (IACP), the Gerzensee deviation (GS) and the Laachersee eruption (LSE). Upper part: Chronology Aller14 (Friedrich et al. 2001) represents the average of Dättnau chronologies DAEBOECH and ALCH1 (Kaiser 1993). It matches well with CHR213 ( $t = 6.4$ ;  $Glk = 59\%$ ).

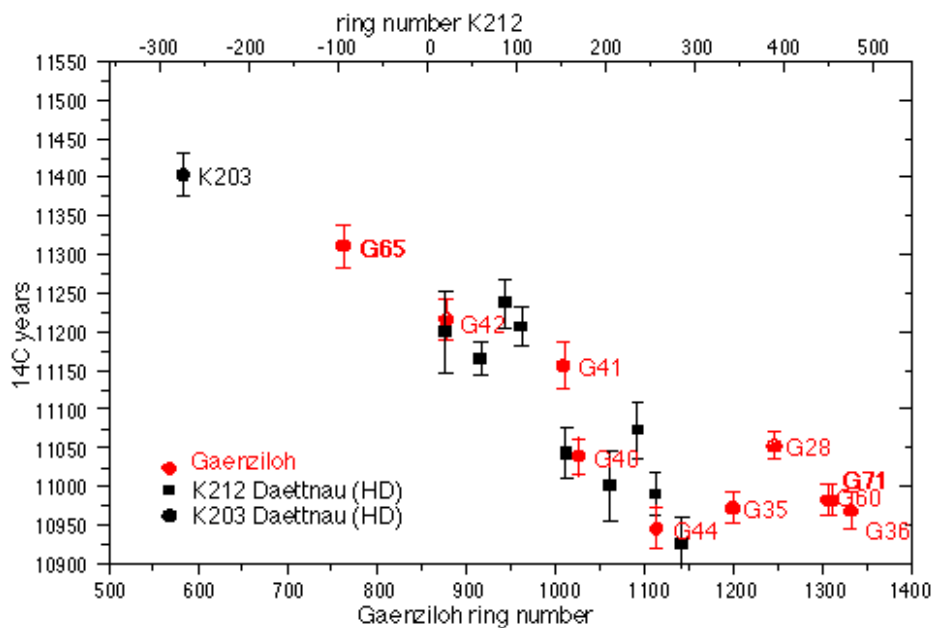


Fig. 4: The relationship between radiocarbon dates and relative tree-ring dates. Sample numbers appearing in bold typecast are also shown in Fig. 3.

## **Discussion**

In our study, crossdating in some cases was impeded by (a) the occurrence of extreme growth disturbances in the series, and (b) insufficient overlap between the series. However, research in the area is still continuing, and the more samples we recover, the higher the chances are, that we will obtain samples that span chronological gaps. Due to the large number of trunks in the area, in addition we are able to restrict our sampling to those trees that are most useful for the development of long chronologies, i.e., trees whose growth patterns do not show extreme growth disturbances.

Growth disturbances mainly occur during the first 50 to 100 years of tree growth, when the tree is relatively young. By truncating the tree-ring series (i.e., by removing the first 50 to 100 annual values), the degree of crossdating should improve. This is the reason why we did not yet standardize the tree-ring sequences used in our study.

The fact that the studied tree-ring patterns show growth anomalies implies that rings may be missing. Undetected missing rings strongly affect the statistical results of crossdating efforts. We will have to solve this problem by analyzing more samples. In addition, we consider truncation of tree-ring curves prior to crossdating as a tool to determine missing rings.

## **Conclusions**

Tree-ring chronologies have always been an extremely reliable high-resolution archive. Other annually resolved archives, such as Greenland ice (GRIP/GISP), marine varves and varves from freshwater lakes, rely on a few records only and therefore may have age-scale problems. Individual records from the same archive may differ considerably. Therefore, questions about the exact duration of (the cold phases within) the Bølling-Allerød interstadial, and of the Younger Dryas, can be answered best by analyzing tree-ring chronologies.

Events on a global or hemispheric scale, such as IACP, GS and LSE, cause distinct signals in all high-resolution archives, and therefore constitute important isochrones (Dansgaard et al. 1993, GRIP Members 1993, Taylor et al. 1993, Broecker 1994). These isochrones are an important tool for the calibration of varve, ice core and floating tree-ring records.

## **Summary**

At the construction sites of the A4-highway tunnel through Uetliberg near Zurich, more than 100 buried subfossil pine stumps have been excavated. The trees were buried during their lifetime by loamy alluvia washed down from the upper part of the slopes. The stumps have remained well preserved for more than 13.000 years. The wood samples (cross sections of the trunks) were analyzed dendrochronologically. The radiocarbon method was used to determine their age. Five trees were used to build a new chronology, termed CHR65. CHR65 crossdates with two floating chronologies from Daetttau produced by Kaiser (1993), termed DAEALCH1 and DAEALCH2, and bridges the presumed gap between these chronologies.

CHR65, DAEALCH1 and DAEALCH2 were combined into chronology CHR213, which covers the main parts of the Allerød and ends at the transition to the Younger Dryas. Student's t-

values, percentages of parallel variation ('Gleichläufigkeit') and radiocarbon wiggle matching ( $^{14}\text{C}$  dates on a decadal scale) support the validity of the resulting chronology. CHR213 contains climatic signals triggered by a series of cooling cycles such as the Inner Allerød Cold Phase (IACP), the Gerzensee deviation (GS), and perhaps the Laachersee eruption (LSE).

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