Source: Gärtner H, Esper J, Schleser G (eds.) (2005) TRACE - Tree Rings in Archaeology, Climatology and Ecology, Vol. 3: Proceedings of the DENDROSYMPOSIUM 2004, April 22nd – 24th 2004, Birmensdorf, Switzerland. Schriften des Forschungszentrums Jülich, Reihe Umwelt Vol. 53, p. 96 – 101.

Lateglacial tree-ring chronologies - A high resolution archive of the past

M. Schaub[1,2], K.F. Kaiser[1,2] & B. Kromer[3]

[1] *Swiss Federal Research Institute WSL, Zürcherstrasse 111, 8903 Birmensdorf, Switzerland*

E-mail: matthias.schaub@wsl.ch

[2] *GIUZ, Institute of Geography, University of Zurich, 8057 Zurich, Switzerland*

[3] *Institute for Environmental Physics, Heidelberg Academy of Sciences, INF 229, 69120 Heidelberg, Germany*

Introduction

Lateral melt-water channels were formed along the margins of the Alpine glacier lobes on the Swiss plateau after the last glacial maximum (approx. 16 ka BP). As soon as these outlets became inactive, landslide, solifluction, and surface water processes started to fill the channels with loamy alluvia. Pioneer forests (birch, pine) established themselves in response to the abrupt warming at the beginning of the Lateglacial. While the pioneer vegetation was developing, continuous sedimentation processes led to the tree stumps being buried in sediments some 10 m thick. This process ended when the Boreal vegetation began to migrate to higher elevations, suppressing the Lateglacial and Preboreal pioneer forests and stopped weathering and alluvial downwash from the slopes.

Figure 1: Fossil pine stump (Pinus sylvestris)

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 approx. 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 Period (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), accompanied by a temperature dropping approx. 7°C relative to the early Bølling (Dansgaard et al. 1993, GRIP Members 1993).

Material and methods

Construction work for the highway tunnel through the Uetliberg near Zurich started in summer 2000. 144 fossil pine stumps have been recovered on the construction sites Gaenziloo and Landikon in the glacial melt-water channels on both slopes of Uetliberg. The valleys of Reppisch on the western slope and of Sihl on the eastern one (Schaub, 2003a).

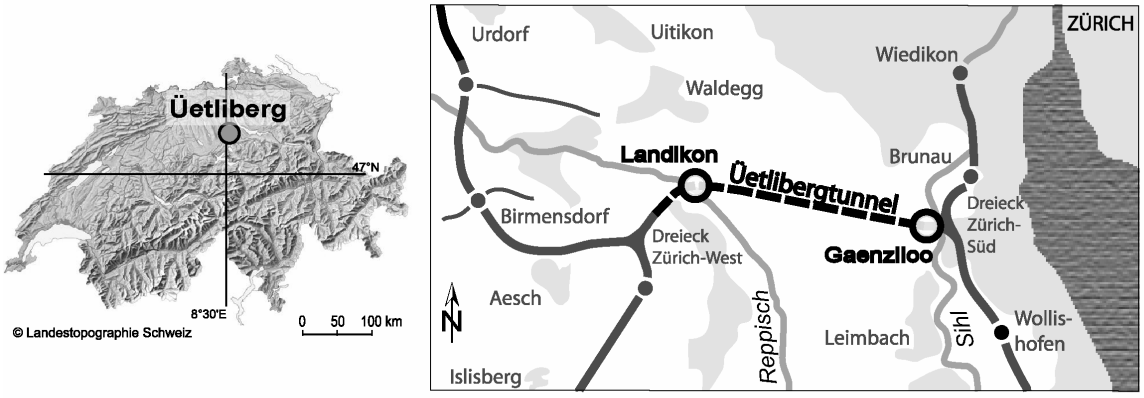

Figure 2: Site location

Mass movements, precipitation and melt-water filled the channels with material weathered from Upper Freshwater Molasse and glacial till deposits upon the slopes. These mainly loamy sediments developed with sedimentation rates of 2 to 6 mm/year to huge archives containing fossil pines, other plant remains, snail shells, other macro- and micro- remains. The pine trees have been buried continuously during their lifetime by loamy alluvia, which were washed down from the slopes; hence the wood is well preserved. Object of this study are the finds from Gaenziloo in combination with those from Daettnau (Friedrich et al. 2001; Friedrich et al. 1999; Kaiser 1993). The stumps recovered were cut into disks: A first one was taken at the level where the roots are spreading for the purpose of finding the germination age of each tree. Another or more disks were taken 30 to 100cm above to avoid the disturbances caused by the roots. The samples were dried and sandpapered. The disks were smoothed with razor-blades and contrasted with white chalk or water on hardly visible areas. To measure the tree-ring widths the program TSAP has been applied (Rinn, 1996). Thus the annual growth rings can be measured on 1/100 mm exactly. The radii are synchronized on the light-table, checked by statistical values by the TSAP program (t-values and Gleichläufigkeit), get averaged, and form a curve for each tree. Several tree curves may be combined to a chronology. The program Cofecha is used to do a data quality control as well as a check of the crossdating among the trees within chronologies. (Grissino-Mayer, 2001).

Results

Three independent chronologies at Gaenziloo have been developed (Schaub, 2003a):

1. ALLCH_A spanning 428 years, mid Allerød (ending approx. 11,400BP)
2. ALLCH_D spanning 544 years, end of Allerød (ending approx. 10,900BP)
3. YD_A spanning 205 years, Younger Dryas (ending approx. 10,500BP)

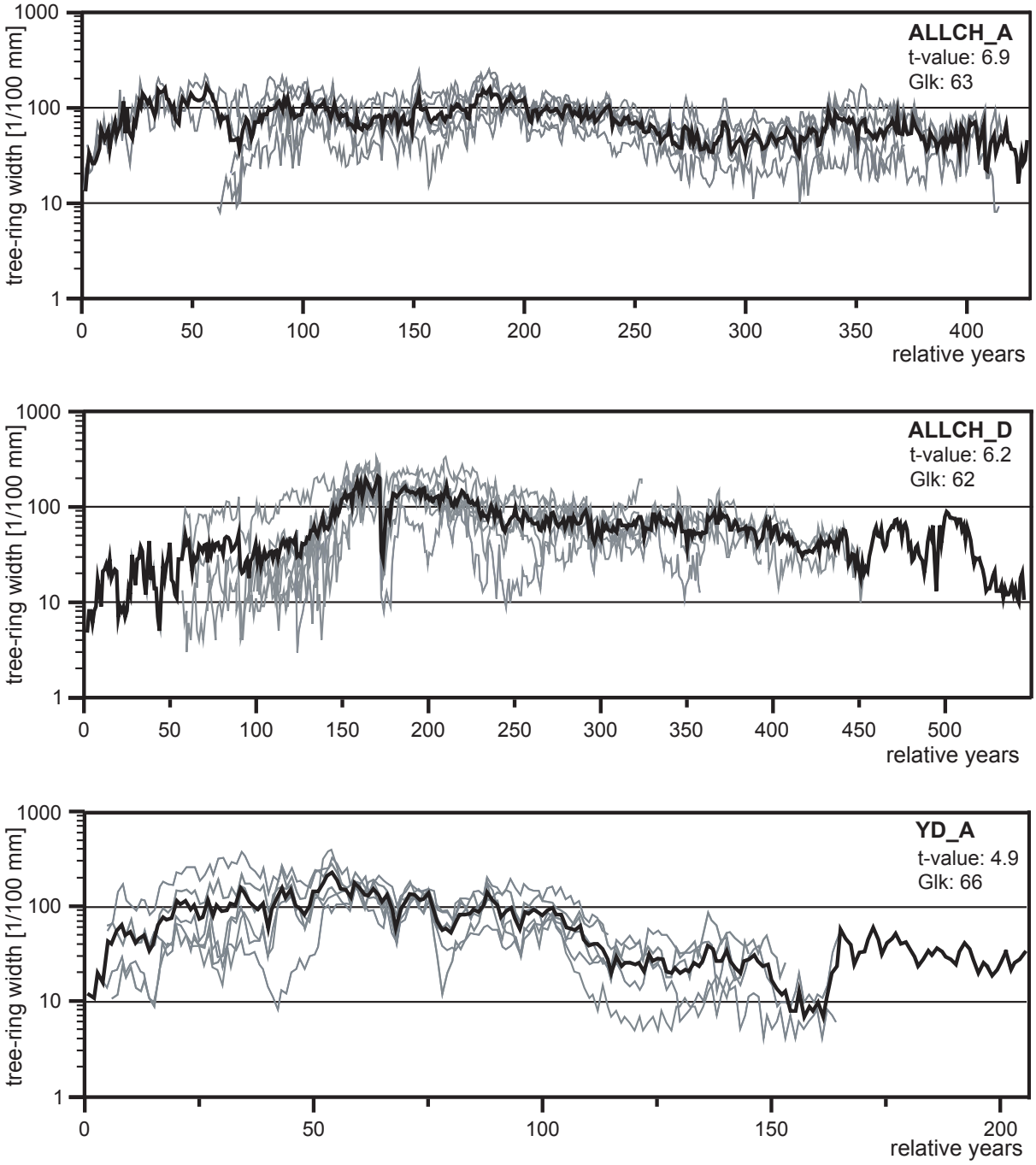

Figure 3: The different Gaenziloo chronologies (ALLCH_A, ALLCH_D and YD_A) in black and the tree-mean curves (grey) are displayed in relation to each other.

The position of floating chronologies on the absolute timescale is determined by ^{14}C datings. In Figure 4 the different chronologies are displayed in the correct position to each other. Moreover the dendromatches between different chronologies are shown by a vertical lines. ALLCH_A is crossdated with chronology Daealch_1 from Daettnau of early Allerød (totally 669 rings). ALLCH_D and Daealch_2 form also a chronology (544 rings) of late Allerød (Kaiser, 1993). Chronology KW_1 forms the oldest part of the absolute Hohenheim pine chronology (PPC) (Kaiser, 2003; Schaub 2003b; Friedrich, 2001).

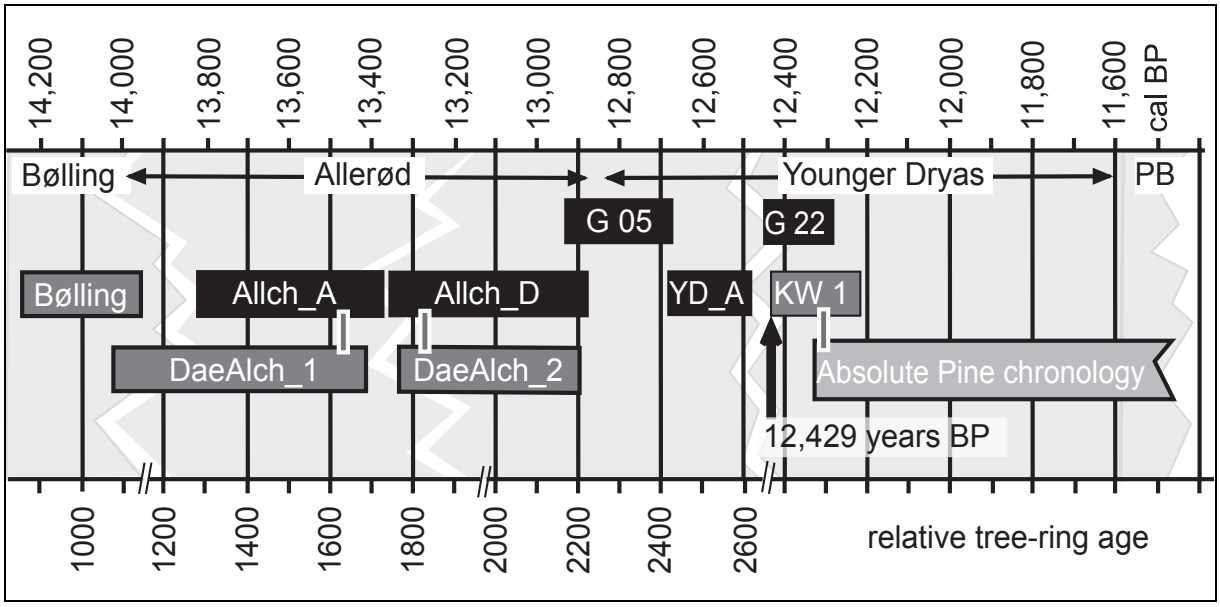

Figure 4: Dendromatches and positions of the different Gaenziloo chronologies in relation to existing ones

Discussion

In our study, crossdating in some cases was impeded by (a) the occurrence of extreme growth disturbances within the series, and (b) insufficient overlap between them. However, research in the area is still continuing, and the more samples we recover, the higher the chances are, to 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. By truncating the tree-ring series (i.e., by removing the first 50 to 100 annual values), the degree of crossdating improve. That's why the tree-ring sequences used in our study have not been standardized. 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 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.

Summary

At the construction sites of the A4-highway tunnel through Uetliberg near Zurich, more than 140 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 BP. The wood samples (cross sections of the trunks) were analyzed dendrochronologically. The radiocarbon method was used to determine their age. Three new floating chronologies were built and they were linked with chronologies from Daettnau produced by Kaiser (1993), termed DAEALCH_1 and DAEALCH_2. The newly built chronologies cover the main parts of the Allerød (ALLCH_A and ALLCH_D) and also a part of the Younger Dryas (YD_A). Student's t-values, percentages of parallel variation ('Gleichlaeufigkeit') and radiocarbon wiggle matching (^{14}C age determinations on a decadal scale) support the validity of the resulting chronology.

Acknowledgements

The results presented in this article are the product of the cooperation with the dendrolab of the Institute of Botany, Stuttgart-Hohenheim University (M. Friedrich and co-workers), as well as with Dr. Bernd Kromer (^{14}C Lab, Institute for Environmental Physics, Heidelberg Academy of Science). For financial support we are highly obliged to the following institutions or companies: The "kantonales Tiefbauamtes des Kantons Zürich" and the "Dr. Heinrich Jäckli AG Zürich (Geologie – Geotechnik - Grundwasser)".

References

Bond, G.C., Showers, W., Elliot, M., Evans, M., Lotti, R., Hajdas, I., Bonani, G., Johnson, S. (1999): The North Atlantic's 1-2 kyr Climate Rhythm, Relation to Heinrich Events, Dansgaard/Oeschger Cycles and the Little Ice Age. In: Clark, Webb, Keigwin (Eds) Mechanisms of Global Climate Change at Millennium Time Scales. Geophysical Monograph, 112, AGU, Washington DC: 35-58.

Dansgaard, W., Johnsen, S.J., Clausen, H.B., Dahl-Jensen, D., Gundestrup, N.S., Hammer, C,U., Hvidberg, C.S., Steffensen, J.P., Sveinbjörnsdottir, A.E., Jouzel, J., Bond, G. (1993): Evidence for general instability of past climate from a 250-kyr ice-core record. Nature, 364: 218-220.

GRIP (Greenland Ice-core Project) Members (1993): Climate instability during the last Interglacial period recorded in the GRIP ice core. Nature, 364: 203-207.

Grissino-Mayer, H. (2001): Evaluating crossdating accuracy: A manual and tutorial for the computer program cofecha. Tree-ring research, 57 (2): 205-221.

Friedrich, M., Kromer, B., Kaiser, K.F., Spurk, M., Hughen, K.A., Johnsen, S.J. (2001): High resolution climate signals in the Bølling-Allerød Interstadial (Greenland Interstadial 1) as reflected in European tree-ring chronologies compared to marine varves and ice core records. Quaternary Science Reviews, 20: 1223-1232.

Friedrich, M., Kromer, B., Spurk, M., Hofmann, J., Kaiser, K.F. (1999): Paleo-environment and radiocarbon calibration as derived from Lateglacial/Early Holocene tree-ring chronologies. Quaternary International, 61: 27-39.

Kaiser, K.F., Kromer, B., Friedrich, M., Schaub, M. (2003): Late glacial tree-ring chronologies – status and perspective. In: The Desert Research Institute (Ed): XVI INQUA Congress - Programs with Abstracts. The Desert Research Institute, Reno, USA. 223 p.

Kaiser, K.F. (1993): Beiträge zur Klimageschichte vom Hochglazial bis ins frühe Holozän, rekonstruiert mit Jahrringen und Molluskenschalen aus verschiedenen Vereisungsgebieten. Ziegler Druck- und Verlags-AG, Winterthur. 206 p.

Rinn, F. (1996): TSAP 3.0 Reference Manual. Heidelberg. 262 p.

Schaub, M. (2003a): Fossile Föhren der Uto – Autobahnbaustelle als Zeugen spätglazialer Klimaschwankungen. Diplomarbeit, Geographisches Institut der Universität Zürich, WSL Birmensdorf, Universität Zürich, Zürich. 80 p.

Schaub, M., Kaiser, K.F., Kromer, B. (2003b): Records of Late-glacial pioneer forests on the Swiss plateau provide a high resolution archive. In: The Desert Research Institute (Ed): XVI INQUA Congress - Programs with Abstracts. The Desert Research Institute, Reno, USA. 232 p.

Taylor, K.C., Lamorey, G.W., Doyle, G.A., Alley, R.B., Grootes, P.M., Mayevski, P.A., White, J.W.C., Barlow, L.K. (1993): The "flickering switch" of late Pleistocene climate change. Nature, 361: 432-436.