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Radiocarbon ages of soil charcoals from the southern Alps, Ticino, Switzerland

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Abstract

Radiocarbon dating of macroscopic charcoal is a useful tool for paleoclimatic and paleoecologic reconstructions. Here we present results of ^{14}C dating of charcoals found in charcoal-rich soils of Ticino and the Misox Valley (southern Switzerland) which indicate that the Late Glacial and early Holocene fires coincided with warm phases in the North Atlantic region and low lake levels in the Central Europe. Late Holocene charcoals found in these soils document an earlier than believed presence of sweet chestnut (*Castanea sativa* Mill.) in southern Switzerland. Sweet chestnut trees play a key role in Mediterranean woodlands, and for longer than two millennia have been used as a food source. Based on palynological evidence it is commonly believed that in southern Switzerland *C. sativa* was first introduced 2000 years ago by the Romans, who cultivated it for wood and fruit production. Our results indicate that this tree species was present on the southern slopes of the Alps ~1500 years earlier than previously assumed, and therefore was likely introduced independently from cultivation by the Romans.

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Keywords: AMS ^{14}C dating; Charcoal; *Castanea sativa*; Paleo fires; Misox Switzerland

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1. Introduction

The genus *Castanea* has been present in the northern hemisphere for the last 80 Ma with the maximum of its extension during the tertiary when the mild, moist climate favoured its growth and expansion. Cooling that occurred sometime between 5 and 1.8 Ma and the following Quaternary glaciations led to the extinction of chestnut at high latitudes and finally to its retreat to the glacial refuges in southern and central Italy, and the Balkans [1]. Spatial distribution of the locations, into which chestnut retreated during the last glacial maximum (LGM), has been exclusively based on pollen reconstructions and correlation with ^{14}C dated records. Krebs et al. [2] summarized the data on distribution of *Castanea sativa* in Europe and North Africa showing more frequent glacial refuge areas and possibly earlier post-glacial presence of chestnut in some of the regions. Despite being an extremely powerful tool for paleo-reconstructions, pollen analyses have limitations, which in the case of *C. sativa* appear to add to the controversy. Drawing maps of the past vegetation distribution is inconclusive if the pollen of a specific taxon are not frequent or not present at all. In addition, pollen of *C. sativa* is difficult to identify precisely because it is morphologically

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very similar to other pollen of *Lotus, Hypericum, Sedum* [3,4]. Macrofossils can be helpful in resolving problems with pollen strata, especially where fragments of charcoal are present. Wood-anatomical analyses of macroscopic charcoal fragments (>2 mm) provide additional information about the presence of trees in the region. Moreover, well characterised charcoal macro remains can be used as a material for radiocarbon dating. In many cases dating of single pieces of macroscopic charcoals, which weigh as little as a few milligrams, is possible using the AMS technique. Such analyses had been successfully applied in archaeology and, more recently, have been used in studies of paleo fires as well as environmental reconstructions (for a review see [5]).

Recently, Willis and van Andel [6] published a compilation of radiocarbon ages (^{14}C ages between 16 and 40 ka BP) of full-glacial age charcoal macrofossils found in 40 archaeological locations of central and eastern Europe. This collection of 151 radiocarbon ages, which was obtained on identified charcoals of various tree species, calls into question the previous picture of steppe-tundra vegetation covering land between the Alps and the Scandinavian Ice Sheet.

Based on the pollen data of the Alpine regions it is believed that *C. sativa* was reintroduced into this region by humans but the arrival path and timing remain controversial. Most previous pollen studies concluded that the Romans introduced *C. sativa* [1,7–9]. However, we believe that an earlier post-glacial expansion of the chestnut tree may have been obscured in pollen spectra. The direct ^{14}C dating of charcoal found in soil and sediments has a great potential for resolving the paleoecology of *C. sativa* in the southern Alps region.

1.1. Study site

Charcoal macrofossils were collected from three soil profiles sampled at two locations near Pura (Ticino) and Roveredo, in the Misox valley (Grisons), in southern Switzerland. The climate is temperate with a mean annual temperature of 12 °C (January, 1 °C; July, 22 °C) and a mean annual precipitation of 1800 mm, which is characteristic of the southern Alpine region. Forest fires are common during dry winters with mean monthly precipitation of 60 mm or less. Heavy rains occur during the rest of the year with a maximum monthly precipitation of 200 mm during the summer. The deciduous forest at the lower elevations (below 1000 m above sea level) is dominated by chestnut (*C. sativa* Mill.) accompanied by oak (*Quercus petraea*, *Q. pubescens*), birch (*Betula pendula*), beech (*Fagus sylvatica*) and to lesser extend elm (*Alnus glutinosa*), ash (*Fraxinus excelsior*), and linden (*Tilia cordata*). Between 1000 and 1400 m the beech (*F. sylvatica*) tree dominates and coniferous forest, whereas Norway spruce (*Picea abies*) and silver fir (*Abies alba*) prevails at elevations higher than 1400 m.

1.2. Soil profiles

Two soil profiles at Roveredo were sampled: Pian d'Arf at 515 m (46°22′51″N, 9°13′25″E) and Prebonella at 1000 m (46°22′50″N, 9°13′57″E). The profile sampled at Pura, is located west from Locarno at 650 m (Pura, 45°98′50″N, 8°86′24″E). These three profiles were studied by Blaser et al. [10] who classified them as cryptopodzolic soils. They contain a thick blackish-brown mineral horizon of exceptionally stable soil organic matter. Soils at the sites dominated by chestnut forest in southern Switzerland usually have extremely high soil organic matter (SOM) stocks (the highest found in Switzerland) of approximately 177 tC ha^{-1} [4]. This feature is explained as the result of a unique combination of mild/wet climate, Fe–/Al– rich acidic bedrock (gneiss) and the presence of high amounts of phenols and tannins in the litter layer, which is characteristic for the chestnut forest [10]. A high content of black carbon (BC), which is formed by incomplete combustion, was also found in our profiles [11] but not in control profiles with low C content, which implies that this form of carbon might have contributed significantly to the high SOM.

1.3. Charcoals

Six charcoal-rich soil profiles were sampled to reconstruct fire frequencies and the impact of burning on the vegetation in Ticino and Misox Valley, Switzerland [11]. Charcoal was extracted from each soil horizon by floating/washing technique then dried and weighted to estimate charcoal content. More than 500 pieces of charcoal (pieces larger than 2 mm) were analysed under the microscope using wood identification techniques in order to determine the botanical species or genus of charred wood [12].

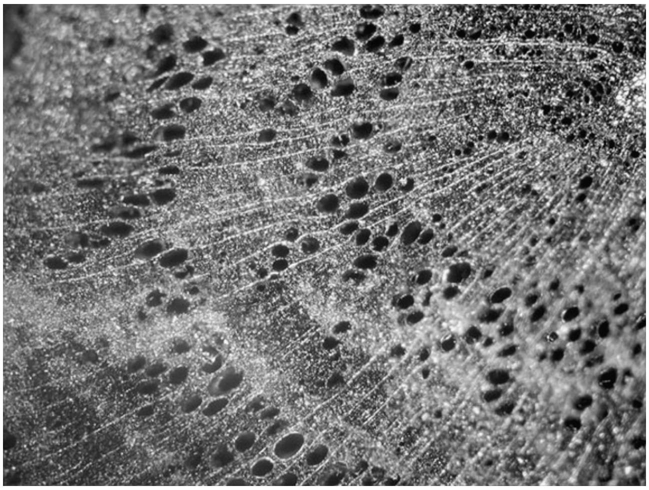

Fig. 1. Microphotograph (50×) of the oldest chestnut charcoal piece found in Swiss soils (ETH-28464, 1640–1420 BC). The wood-anatomical structure is ring-porous, with pores in radial dendritic groups, and homogeneous uniseriate rays, which is characteristic for charcoal derived from the burning of a chestnut tree (*Castanea sativa* Mill.).

Differentiation between deciduous and coniferous trees is straightforward because of the uniform distribution of cells within the annual layer of coniferous trees. However, identification of botanical species requires well-preserved charcoals. Particularly relevant for our study was the identification of charcoal that derived from *C. sativa*. Structure of this wood shows similarities to that of oak (*Quercus* sp.) so that sufficiently large pieces are required for identification. The wood of chestnut is ring-porous, with pores in radial dendritic groups, and homogeneous uniseriate rays (Fig. 1). These are rather narrow (1–2 cells wide) in contrast to the typical 30 cell-wide rays of oak wood.

Fourteen identified charcoal samples were selected from three soil profiles as material for AMS ^{14}C dating. These included silver fir (*Abies alba*) ($n = 4$), pine (*Pinus* sp.) ($n = 2$), diffuse-porous broadleaf species ($n = 2$), chestnut (*C. sativa*) ($n = 5$) and one piece not identified at the species level, described as either oak (*Quercus* sp.) or chestnut (*C. sativa*). The problems with the identification of this one piece of charcoal were caused by small size of the sample (approximately 2 mm in diameter) which does not allow for observation of structure of dendritic rays (thin or thick), because the fragment may derive from a piece of wood between two rays.

1.4. Radiocarbon dating

Charcoal samples were cleaned using the modified acid–alkali–acid (AAA) procedure [13] in order to remove possible contamination with carbonates and humic acids. This involved longer treatment (12–24 h) with the first acid (0.5 M HCl, 60 °C) that removes carbonates. The dry sample i.e. ca. 2–4 mg of clean charcoal was weighed, placed in the pre-cooked Vycor tube together with pre-cooked CuO (oxidizing agent) and silver, which removes gases (SO_2) that might hamper conversion of CO_2 to graphite. The evacuated tube was then sealed and left for 2 h in 950 °C to combust. The purified CO_2 was mixed with H_2 and heated to 625 °C to reduce to graphite over the cobalt catalyst [13]. The ^{14}C/^{12}C ratio was then measured for each graphite sample. Measurements were corrected for blank values and isotopic fractionation [14]. Conventional radiocarbon ages (Table 1) were calculated following the convention of Stuiver and Polach [15] and calibrated using OxCal program [16].

2. Results and discussion

In both profiles from Roveredo (Profile C1 and C2) inversions in the ^{14}C chronology indicate reworking and replacement of the material (Table 1 and Fig. 2). Erosion processes, freeze and thaw cycles, bioturbation, and uprooting can lead to transport of charcoal in soil profile [17]. These two 'disturbed' profiles represent late Holocene deposits whereas the third profile from Pura C3, which is the oldest of all, is free of such disruption (Fig. 2). The Late

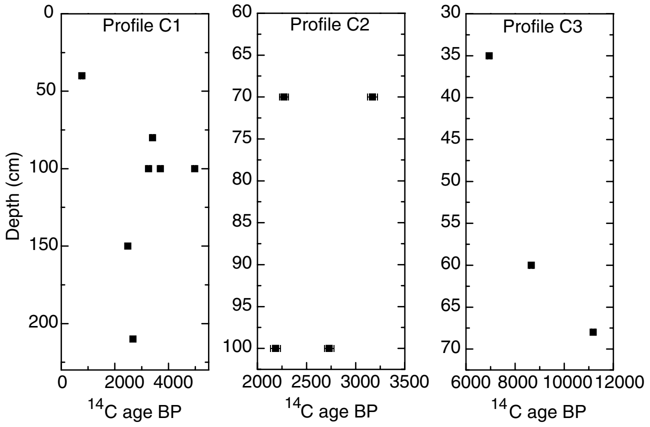

Fig. 2. Radiocarbon ages of identified charcoal samples found in soil profiles plotted versus depth scale.

Table 1
AMS ^{14}C ages of charcoal samples from three soil profiles: C1 (Pian d'Arf), C2 (Prebonella) and C3 (Pura), Ticino, Switzerland

Lab number ETH	Profile	Depth (cm)	Tree species BP	^{14}C age ± 1σ	Calibrated ages
28466	C1	40	*Castanea sativa*	770 ± 45	1170–1300 AD
28457	C1	80	*Abies alba*	3405 ± 50	1880–1530 BC
28464	C1	100	*Castanea sativa*	3255 ± 50	1640–1420 BC
28465	C1	100	Diff. porous broad leaf	4980 ± 55	3950–3650 BC
28456	C1	100	*Abies alba*	3695 ± 50	2280–1940 BC
28463	C1	150	*Castanea sativa*	2480 ± 50	780–410 BC
28462	C1	210	Diff. porous broad leaf	2675 ± 50	930–780 BC
28459	C2	70	*Abies alba*	3170 ±50	1540–1310 BC
28468	C2	70	*Castanea sativa*	2270 ± 45	410–200 BC
28467	C2	100	*Castanea sativa*	2730 ± 50	1000–800 BC
28458	C2	100	*Abies alba*	2185 ± 50	390–100 BC
28469	C3	35	*Quercus*[a] *(Castanea sativa)*	6945 ± 70	5990–5710 BC
28460	C3	60	*Pinus* sp.	8660 ± 65	7940–7570 BC
28461	C3	68	*Pinus* sp.	11180 ± 75	11270–10980 BC

Calibrated ages (2σ ranges, 95% confidence level) were obtained using OxCal v3.10 calibration program [16] (INTCAL04 data set [26]) are expressed in BC/AD.

[a] Because of the small sample size, exact identification of this sample was impossible.

Glacial/Early Holocene radiocarbon ages of charcoal provide direct dating of forest fires. It had been shown previously that annual fire frequencies before 4.5 ka BP remained on low level and corresponded to the natural level of fire frequencies in this region [18]. Moreover, pollen and charcoal analysis of sediments from Lago di Origlio and Lago di Muzzano (Ticino), which are located close to our studied soil profiles, have shown that charcoal minima coincide with cold and wet climate periods [18]. The remarkable old ages of charcoal from profile of Pura C3 coincide with the warm periods of late Alleröd (ETH-28461; 11 180 ± 75 BP) and the early Holocene (ETH-28460; 8660 ± 65 BP). The later age falls in the Preboreal low lake level period (11 050–10 300 cal BP), which has been recognized in Holocene sediments of central European lakes [19]. This is also in agreement with the oldest ^{14}C ages (B–6228, 8663 ± 45 BP and B–6229, 8782 ± 35 BP) of *Larix* tree trunks transported by Riedgletscher (Central Alps, west of Ticino) which were found at the elevation of 2060 m [20] thus indicating that the early Holocene fires in Ticino coincided with the glacial recession in the central Alps. The ^{14}C ages of charcoals of oak/chestnut (6945 ± 70 BP) and deciduous tree (4980 ± 50 BP), coincide with low lake level phases documented in the Swiss and French Jura [19], and other Swiss and Austrian lakes [21]. Such climatic conditions resulted in high density of the Early Neolithic lake dwelling villages (Cortaillod-Pfyn culture) [19]. Interestingly, there are no matching data from the Alpine tree-line reconstructions published to date which show glacial recession between 6000 and 5500 cal BP [20]. Following the wet and cold period between 5600 and 5300 cal BP [22] the lake levels were very low in the Jura and Alpine region and lakeside dwelling villages of the Middle Neolithic had grown dense. For this reason the observed increase of charcoals in lake sediments of Lago di Origlio and Lago di Muzzano, which were interpreted as an anthropogenic impact on the forest [18], should rather be viewed as a mixed signal of anthropogenic and natural induced fires. Similarly, the ages of soil charcoals obtained in our study are most frequent between ca. 4250 and 3250 cal BP and 2950 and 2050 cal BP (Fig. 3) and the origin of the fires in this time period can be due to natural and/or anthropogenic factors.

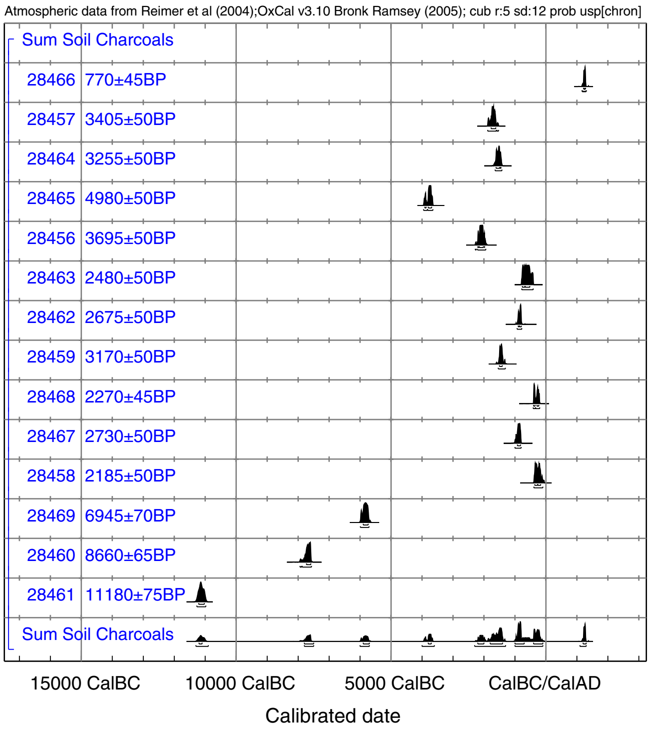

Fig. 3. Combined probability distribution of charcoal ages from all three Ticino soil profiles.

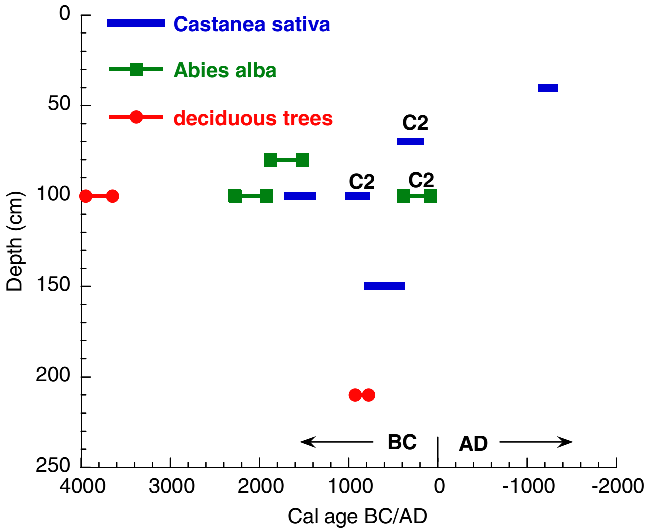

Fig. 4. Calibrated radiocarbon ages (BC/AD) (2σ ranges, 95% confidence level) of charcoal found in two soil profiles of Misox: Pian d'Arf and Prebonella (labelled C1 and C2, respectively see Table 1) shown on the common depth scale. With one exception, the ^{14}C ages of chestnut indicate its presence in southern Switzerland prior to Roman times.

Pollen and charcoal studies suggest that in contrast to the early and mid Holocene, there is a clear evidence in vegetation development that sometime after 2000 BP fires were of anthropogenic origin [18]. Our late Holocene record does not provide evidence that the fires were more frequent after 2000 cal BP. Perhaps the location of our soil profile in chestnut dominated forests can explain the results. As shown by a 'jump' in concentration of chestnut pollen at $\sim$2000 BP this fire resistant tree [23] became the dominating species in the southern Alps forest. Paradoxically, these significant pollen changes at 2000 BP created a common believe that have obscured the real history of the postglacial re-colonisation of the southern slops of the Alps. For this reason our radiocarbon dating of chestnut charcoal provides interesting new evidence. According to the pollen based model of chestnut arrival the *C. sativa* charcoals found in the Alps should be 2000 years old or younger Surprisingly, our data contain only one age of chestnut charcoal that falls into the expected calibrated age interval and all the other calibrated ages are older than 200 BC (Fig. 4 and Table 1). These findings are challenging the common believe based on pollen analysis of lake sediments that the Romans have introduced the chestnut into the studied region and more generally in the Alps (northern Italy) [7,9]. Previous studies showed pollen and macrofossils of chestnut in bronze age settlements (1200–750 BC) in Switzerland [24], pointing to an earlier introduction of chestnut, which was attributed to contacts with Mediterranean populations (e.g. trade with the Etruscans). Moreover, recent research on chestnut glacial refugia and Holocene cultivation [2,25] questions a direct link between Romans and the expansion of the chestnut tree. The radiocarbon ages of chestnut charcoals presented here date back to 1690–1410 BC and provide the first unambiguous evidence for an earlier presence of sweet chestnut in southern Switzerland. It is still an open question whether *C. sativa* arrived through natural dispersal or was introduced through pre-Roman cultures such as the ancient Celtic populations identified by the ancient Greek and Roman authors as Lepontians, who occupied territories of the present Canton Ticino during the whole first millennium BC.

3. Conclusions

Results of radiocarbon analyses performed on macroscopic charcoal found in three charcoal-rich soil profiles from Ticino and Misox Valley (Switzerland) show the great potential for paleo studies. The main advantage of using ^{14}C dating as a tool is the ability to directly date the climate proxy, in this case macroscopic charcoals. Four ^{14}C ages were obtained on charcoals, which presumably originated from natural fires that occurred in the southern Alps during dry and warm periods of the Late Glacial and early-mid Holocene. The two groups of late Holocene ages (Bronze Age and Iron Age) might reflect a combination of anthropogenic and natural impact on the forest fire frequencies. The presented radiocarbon ages of *C. sativa* charcoal are older than 2000 years and provide the first clear evidence of a pre-Roman presence of the chestnut in the Southern Alps.

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References

[1] B. Huntley, H.J.B. Birks, An atlas of past and present pollen maps for Europe: 0–13000 years ago, Cambridge University Press, 1983.
[2] P. Krebs, M. Conedera, M. Pradella, D. Torriani, M. Felber, W. Tinner, Veg. Hist. Archaeobot. 13 (2004) 145.
[3] W.O. van der Knaap, J.F.N. van Leeuwen, Rev. Palaeobot. Palynol. 89 (1995) 153.
[4] D. Perruchoud, L. Walthert, S. Zimmermann, P. Luscher, Biogeochemistry 50 (2000) 111.
[5] I. Figueiral, V. Mosbrugger, Palaeogeogr. Palaeocl. 164 (2000) 397.
[6] K.J. Willis, T.H. van Andel, Quaternary Sci. Rev. 23 (2004) 2369.
[7] C.A. Burga, New Phytol 110 (1988) 581.
[8] A. Paganelli, A. Miola, Il Quaternario 4 (1991) 99.
[9] H. Zoller, Denkschr. Schweiz. Naturforsch. Ges. 83 (1960) 45.
[10] P. Blaser, P. Kernebeek, L. Tebbens, N. VanBreemen, J. Luster, Eur. J. Soil Sci. 48 (1997) 411.
[11] N. Schlumpf, Diplomaarbeit, University of Zurich, 2005, p. 114.
[12] F.H. Schweingruber, Mikroskopische Holzanatomie, Internationale Buchhandlung fuer Botanik und Naturwissenschaften, Teufen, Switzerland, 1990, p.
[13] I. Hajdas, G. Bonani, J. Thut, G. Leone, R. Pfenninger, C. Maden, Nucl. Instr. and Meth. B 223–224 (2004) 267.
[14] G. Bonani, J. Beer, H. Hofmann, H.A. Synal, M. Suter, W. Wölfli, C. Pfleiderer, C. Junghans, K.O. Münnich, Nucl. Instr. and Meth. B 29 (1987) 87.
[15] M. Stuiver, H.A. Polach, Radiocarbon 19 (1977) 355.
[16] C. Bronk Ramsey, Radiocarbon 43 (2001) 355.
[17] C. Carcaillet, H. Almquist, H. Asnong, R.H.W. Bradshaw, J.S. Carrion, M.-J. Gaillard, K. Gajewski, J.N. Haas, S.G. Haberle, P. Hadorn, Chemosphere 49 (2002) 845.
[18] W. Tinner, P. Hubschmid, M. Wehrli, B. Ammann, M. Conedera, J. Ecol. 87 (1999) 273.
[19] M. Magny, Quatern. Int. 113 (2004) 65.
[20] A. Hormes, B.U. Muller, C. Schluchter, Holocene 11 (2001) 255.
[21] J.N. Haas, I. Richoz, W. Tinner, L. Wick, Holocene 8 (May) (1998) 301.
[22] M. Magny, J.N. Haas, J. Quaternary Sci. 19 (2004) 423.
[23] W. Tinner, M. Conedera, E. Gobet, P. Hubschmid, M. Wehrli, B. Ammann, Holocene 10 (2000) 565.
[24] H. Kuster, in: W. Van Zeist, K. Wasilikowa, K.-E. Behre (Eds.), Progress in Old World Palaeoethnobothany, Balkema, Rotterdam, 1991, p. 179.
[25] M. Conedera, P. Krebs, W. Tinner, M. Pradella, D. Torriani, Veg. Hist. Archaeobot. 13 (2004) 161.
[26] P.J. Reimer, M.G.L. Baillie, E. Bard, A. Bayliss, J.W. Beck, C.J.H. Bertrand, P.G. Blackwell, C.E. Buck, Radiocarbon 46 (2004) 1029.