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RADIOCARBON DATING OF THE HISTORIC OAK OF TEBEA, ROMANIA

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ABSTRACT. Two wood samples originating from the historic pedunculate oak (*Quercus robur*) of Ţebea, Romania, which died in 2005, were processed and radiocarbon dated by AMS for determining the age of the tree. The radiocarbon date of the oldest sample was 503 ± 25 BP, which corresponds to a calibrated calendar age of 580 ± 10 years. Taking into account the original position of this sample in the hollow trunk, one can estimate that the historic tree was around 800 years old.

***Keywords*:** *radiocarbon dating, accelerator mass spectrometry, pedunculate oak, age determination, calibration curve.*

INTRODUCTION

For trees from temperate zones, especially gymnosperms, ages in the pith/centre or in different points of tree trunks are determined by ring counting. This is performed on fallen logs or remaining stumps of dead trees, as well as on thin cores extracted from the exterior of the trunks of live trees. Therefore, when possible, ring counting is the most accurate and reproducible method for age and growth rate determination [1].

By contrast, for many old angisoperm trees, with large cavities in their trunk, the problem of age determination is a significantly more difficult task. For such old and hollow broadleaf trees, without a continuous ring sequence in the trunk, ring counting is of very limited value and is replaced by alternative direct (radiocarbon dating) or indirect dating methods (relation size/diametre-age, projections of short-term growth data, projections based on mortality rates etc.). Indirect dating methods can provide, however, only very approximate and questionable results. Therefore, radiocarbon dating of wood samples collected from the trunk represents the only alternative method for accurately aging these

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trees. This method determines the ^{14}C (radiocarbon) content relative to stable carbon [2, 3]. Due to its higher costs, so far radiocarbon dating of broadleaf trees was not used on the large scale. Several noteworthy investigations were performed, however, on different tree species, to determine the age of trees and/or growth rates or to provide climate information [4, 5].

The pedunculate oak (*Quercus robur*) and its close relative, the sessile oak (*Quercus petraea*), are the most representative and widespread European species of the genus *Quercus*, which belongs to the family Fagaceae. The two species, especially the pedunculate oak are usually considered to be the most longlived European deciduous trees. Their age limit is still controversial, even if modern tree researchers consider that the age of the oldest oaks is probably close to 1,000 years [6, 7].

Here we report the AMS (accelerator mass spectrometry) radiocarbon dating results of two wood samples that originate from the historic pedunculate oak of Țebea, Romania, which died in 2005.

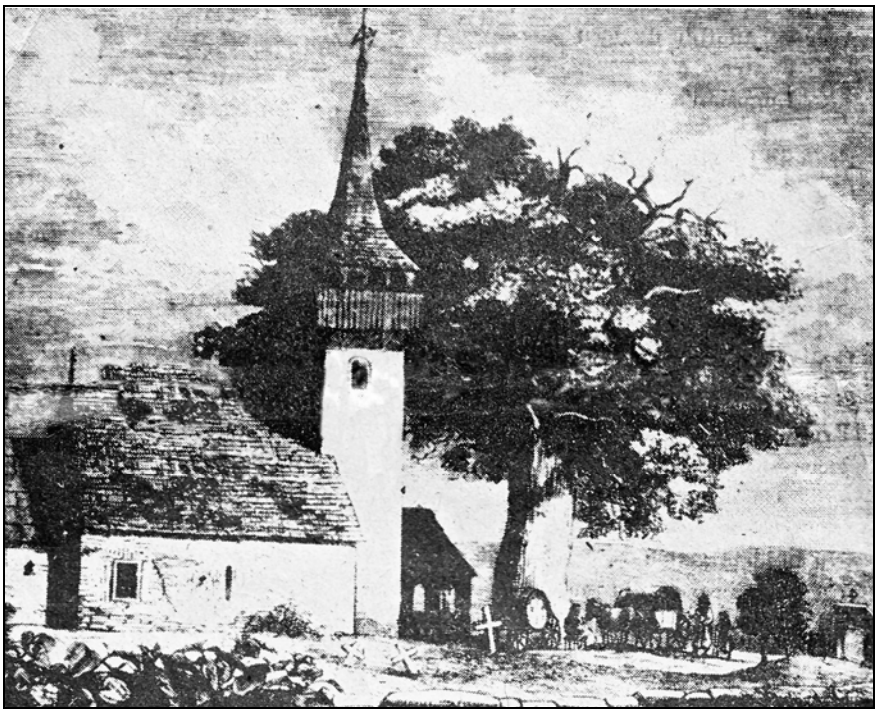

Figure 1. The drawing from the late 19th century showing the historic oak of Țebea and the tomb of Avram Iancu.

RESULTS AND DISCUSSION

The historic oak of Țebea and its location

The historic oak, known as "*gorunul lui Horea*", i.e., the sessile oak of Horea, even if it is in fact a pedunculate oak, was the most popular and famous

Romanian tree. Its faim arises from the fact that under its canopy, Horea, the main leader of the Revolt of 1784-1785, addressed his local force of serfs, known as “moți”. Horea called to battle against the feudal serfdom and for political equality between Romanians and other ethnicities in Transylvania. In 1872, Avram Iancu, another Romanian hero, who played an important role in the local chapter of the Austrian Empire Revolutions of 1848–1849, was buried by this tree.

The oak is located in the Heores’ Cemetery of the village Țebea, in the rural community Baia de Criş, Hunedoara county, in the north-western part of Romania. Its GPS coordinates are 46º10.213' N, 022º42.842' E, the altitude is 269 m and the mean annual rainfall in the area is 680 mm.

Figure 2. The photo taken in 1975 shows the remaining trunk of and the new branch which emerged from a high cut. The bark decline is obvious.

An ink drawing from the late 19th century (Figure 1) shows the large oak from Țebea, with a height of ca. 20 m, in a decline phase with several dry branches in its canopy. The decline of the tree worsened dramatically in the first decades of the 20th century; it was suffering probably from the complex disease called today “dieback of pedunculate oak”. In this disease, a number of biotic and abiotic agents interact to bring about a severe deterioration of the tree condition [8]. The foliage of the oak became very

thin, almost all branches died and large fissures appeared in the bark of its trunk. In order to save the historic tree from complete decay and drying out, the Romanian authorities decided to cut completely the trunk at a height of 9 m from the ground. The remaining trunk was secured with steel rings and its interior, which was partially hollowed, was cemented.

Over the next years, the oak recovered partially and from a high cut of the trunk developed a vigurous branch (Figure 2). However, the decline of the trunk could not be stopped, due also to the old age of the tree. The bark of the trunk continued fissuring and falling off. In 1977-78, for preventing the collapse of the tree, the trunk was encased in a concrete sarcophagus, which reconstituted its outline, retaining part of the original bark. In July 2005, during a violent storm, which affected many trees in the area, the single branch of the oak broke off. This is how the legendary oak died.

Figure 3. The image shows the remains of the dead oak, with the trunk encased in the concrete sarcophagus. The remaining original bark is visible on the left side of the photo.

The concrete sarcophagus damaged by the storm was rebuilt and it still incorporates ca. 10-15 % of the original bark in the exterior, while the interior is cemented and contains some original wood (Figure 3). Its circumference at breast height (cbh; 1.30 m above ground level) is of 9.90 m. This value can

be considered very close to the original cbh value of the trunk outside bark.

Two small wood samples originating from the upper part of the trunk, which was removed in 1924 were pretreated and investigated by AMS radiocarbon analysis.

AMS results and calibrated ages

Fraction modern values and radiocarbon dates of the two samples are listed in Table 1. Radiocarbon dates and errors were rounded to the nearest year. Calibrated (cal) ages, which were derived directly from fraction modern values, are also presented in Table 1. The 1-σ probability distribution was chosen to calculate calibrated age ranges. For sample 1, the 1-σ distribution corresponds only to one range. On the other hand, for sample 2, the 1-σ distribution corresponds to two ranges of calendar years. The confidence interval of one range (marked in bold) is much greater than of the other and it was selected as the most probable cal AD range.

For obtaining single calendar age values of samples, we derived a mean calendar age of each sample from the 1-σ range with the highest probability. Calendar ages of samples represent the difference between AD 2005 (when the tree died) and the mean value of the selected 1-σ range, with the corresponding error. Calendar ages of samples and errors were rounded to the nearest 5 years. The plotted OxCal calibration for the oldest sample is displayed in Figure 4. The radiocarbon dates of the investigated samples were found to be of 503 ± 25 BP (fm = 0.9393 ± 0.0031) and 291 ± 26 BP (fm = 0.9644 ± 0.0033). These values correspond to calibrated calendar ages of 580 ± 10 years and 455 ± 25 years, respectively.

Table 1. AMS dating results and calibrated calendar ages

Sample code	Fraction modern [error]	Radiocarbon date [error] (^{14}C yr BP)	Cal AD range(s) 1-σ [confidence interval]	Sample age (1) [error] (cal yr)
1	0.9393 [± 0.0031]	503 [± 25]	**1414-1435 [68.2%]**	580 [± 10]
2	0.9644 [± 0.0033]	291 [± 26]	**1522-1574 [46.5%]** 1628-1650 [21.7%]	455 [± 25]

(1) In 2005

Age of the tree

In order to determine the age of the oak of Ţebea, it is necessary to take into account the original position of the oldest sample, which was 580 ± 10 years old. As we mentioned above, the sample originates from a height of 9 m, from the removed upper part of the trunk. The main problem is to extrapolate the age of the oldest sample in the pith/center, by considering its position in a cross-section of the trunk at the height of 9 m. The only

information we have from 1924, when the hollow trunk of the oak was cut at 9 m above ground, is that it had only a thin layer of wood at the base, while at the cut height it was more than half empty. Therefore, in a conservative estimate, we can consider that the trunk was only half empty at the cut height and that the sample was collected from a cavity wall. In this case, the sample would originate from the midway between the center and the outside part/bark of the trunk.

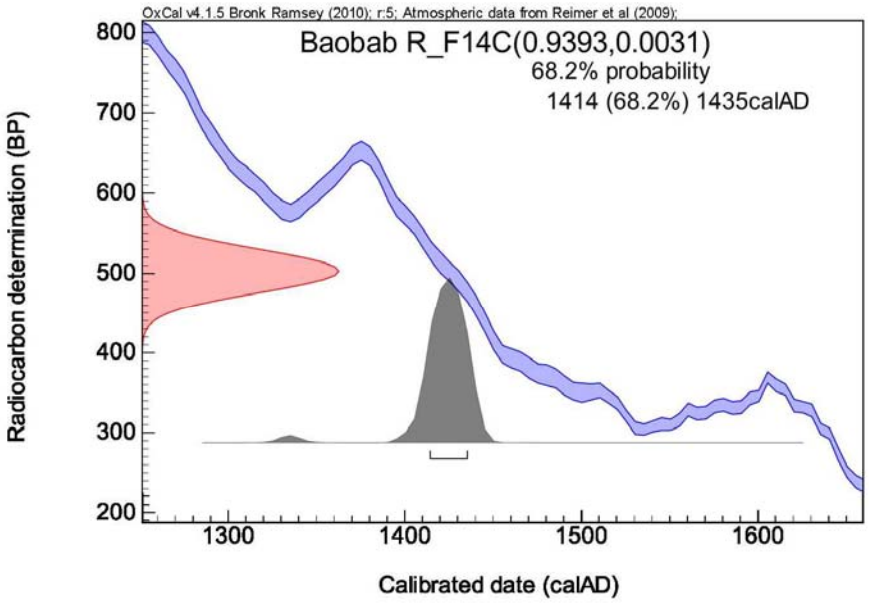

Figure 4. The plotted OxCal calibration for sample 1.

For establishing the true age of the tree, we must determine at what age did the old oak of Ţebea reach half the trunk radius it had in 1924. By considering the literature data on the growth rate dynamics of large deciduous broadleaf trees, especially oaks, during their life cycle and the decline of the mean annual increase in radius with age [3, 14], we estimate that the tree needed around 200-250 years of growth to reach half of its trunk radius in 1924. This value must be added to the determined sample age of 580 years, to find out the age in the pith/center of the trunk at a height of 9 m above ground. An additional value of at least 20-30 years, which is necessary to a pedunculate oak to reach a height of 9 m, must be also added for determining the true age of the tree.

According to these estimates, the investigated tree was around 800 years old in 2005, when it died. Thus, one can state that the historic pedunculate oak of Ţebea had started growing around AD 1200.

CONCLUSIONS

Two samples originating from the historic pedunculate oak of Ţebea were investigated by AMS radiocarbon analysis. According to the dating results and by considering the original position of the oldest sample, we estimate that the tree, which died in 2005, started growing around AD 1200.

This research is the first radiocarbon dating of a Romanian tree.

EXPERIMENTAL SECTION

Sample preparation. The acid-base-acid pretreatment method [9] was used to remove soluble and mobile organic components. The resulted cellulose samples were combusted to CO_2 by the closed tube combustion method [10]. Then, CO_2 was reduced to graphite on iron catalyst, under hydrogen atmosphere [11]. Eventually, the graphite samples were analyzed by AMS.

AMS measurements. Radiocarbon measurements were performed at the National Ocean Sciences AMS Facility of the Woods Hole Oceanographic Institution, with a 3 MV Tandetron (TM) AMS system. The surface of the graphite samples was sputtered with cesium ions and the secondary negative ions were extracted and accelerated in the AMS system. ^{12}C and ^{13}C ions were measured in Faraday cups, where a ratio of their currents was recorded. Simultaneously, ^{14}C ions were recorded in a solid state detector, so that instantaneous ratios of ^{14}C to ^{12}C were also recorded. The raw signals were compared to ratios obtained with a known standard material (Oxalic Acid I, NIST-SRM-4990) and converted to a fraction modern value. Fraction modern values, corrected for isotopic fractionation with the normalized $\delta^{13}C$ value of -25 $^{0}/_{00}$, were ultimately converted to radiocarbon dates, expressed in years BP (radiocarbon years before present, i.e., before AD 1950).

Calibration. Fraction modern values were calibrated and converted into calendar ages with the OxCal v4.1.5 for Windows [12], by using the IntCal09 atmospheric data set [13].

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REFERENCES

1. S.E. Nash, “Time, Trees and Prehistory: Tree-Ring Dating and the Development of North American Archaeology”, University of Utah, Salt Lake City, **2003**.
2. M. Worbes, *Dendrochronologia*, **2002**, *20*, 217.

3. A. Patrut, K.F. von Reden, D.A. Lowy, D.H. Mayne, K.E. Elder, M.L. Roberts, A.P. McNichol, *Nuclear Instr. and Meth. B*, **2010**, *268*, 910.
4. A. Patrut, K.F. von Reden, D.A. Lowy, A.H. Alberts, J.W. Pohlman, R. Wittmann, D. Gerlach, L. Xu, C.S. Mitchell, *Tree Physiol*., **2007**, *27*, 1569.
5. A. Patrut, K.F. von Reden, D.A. Lowy, P. Lindeque, A.H. Alberts, R. Wittmann, E. Forizs, D. Margineanu, J. Pohlman, L. Xu, D. Gerlach, C.S. Mitchell, *Studia Univ. Babes-Bolyai, Chem.*, **2006**, *51*, 71.
6. P.H. Raven, G.B. Johnson, J.B. Losos, S.R. Singer, "Biology: Seventh Edition", McGraw Hill, New York, **2005**.
7. A. le Hardÿ de Beaulieu, T. Lamant, "Le guide illustré des chênes", Vol. 1-2, Huitième, Paris, **2007**.
8. J.N. Gibbs, B.J.W. Greig, *Forestry*, **1997**, *70*, 399.
9. I.U. Olsson, in B. Berglund (ed.), "Handbook of Holocene palaeoecolgy and palaeohydrology", Wiley, Chichester, **1986**, p. 273.
10. Z. Sofer, *Anal. Chem.*, **1980**, *52*, 1389.
11. J.S. Vogel, J.R. Southon, D.E. Nelson, T.A. Brown, *Nuclear Instr. and Meth. B,* **1984**, *5*, 289.
12. C. Bronk Ramsey, *OxCal Program, v4.1.5*, **2010**, http://www.rlaha.ox.ac.uk/oxcal/oxcal.html.
13. P.J. Reimer, M.G.L. Baillie, E. Bard, A. Bayliss, J.W. Beck, P.G. Blackwell, C. Bronk Ramsey, C.E. Buck, G.S. Burr, R.L. Edwards, M. Friedrich, P.M. Grootes, T.P. Guilderson, I. Hajdas, T.J. Heaton, A.G. Hogg, K.A. Hughen, K.F. Kaiser, B. Kromer, F.G. McCormac, S.W. Manning, R.W. Reimer, D.A. Richards, J.R. Southon, S. Talamo, C.S.M. Turney, J. van der Plicht, C.E. Weyhenmeyer, *Radiocarbon*, **2009**, *51*,1111.
14. A J. Godet, "Collins guide to the trees of Britain and northern Europe", Collins, London, **1986**.