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Dedicated to professor Gh. Marcu at his 80th anniversary

ACCELERATOR MASS SPECTROMETRY RADIOCARBON DATING OF AN OLD TROPICAL TREE: PRELIMINARY REPORT. 1. RADIOCARBON DATES.

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ABSTRACT. Grootboom, the world's largest African baobab (*Adansonia digitata*), had collapsed in Bushmanland, Namibia, in late 2004. 11 samples collected from the remains of the huge tree were processed and analyzed by AMS radiocarbon dating. The radiocarbon dates of 3 samples, collected from different areas of the trunk, was greater than 1000 yr BP. The radiocarbon age of the oldest sample was found to be 1255 ± 35 yr BP.Several additional samples are under investigation.

KEY WORDS: radiocarbon dating, AMS, tropical trees, age determination, dendrochronology, dendroclimatology.

INTRODUCTION

In present, a number of 16 "millenarian" tree species with accurate dating, i.e. species with individuals that had lived over 1000 years (yr), are known [1, 2]. All these tree species are gymnosperms/conifers. The champion species is the bristlecone pine *(Pinus longaeva)*, with an age of 4844 yr for the cross-dated WPN-114 or Currey (Prometheus) tree [3].

Somewhat surprisingly, no angiosperm tree with a confirmed age of over 1000 yr has been identified, so far. The oldest angiosperm tree reported in the literature is an African baobab *(Adansonia digitata)*, felled in 1960 at Lake Cariba (in former Rhodesia, today Zimbabwe). This specimen, with a girth of 14.4 m (at a height of ca. 0.6 m above ground level), was far from being one of the largest trees of the species. It was dated by Swart via radiocarbon dating (using the beta decay counting method), who reported

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a radiocarbon age of 1010 ± 100 yr BP for a sample collected from the core of the stump [4]. After calibration, this value corresponds to a calendar age of 925 ± 105 yr (in 1960, when the tree died).

One should mention a singular study, which claimed incredible age values of over 1000 years, determined by radiocarbon dating, for two tropical trees of the Amazonian rainforest (i.e. 1370 yr for *Cariniana micrantha* and 1170 yr for *Dipteryx odorata*) [5]. These values contradict dramatically other results concerning the age limit of similar tree species from the Amazonian rainforest and have been questioned by several researchers [6-8]. It was mentioned that the respective results were outliers to all other findings in the dating of tropical trees. Criticism was raised due to the fact that results were based on single samples of each tree and on single radiocarbon measurements, without any corroborating data or replicated analyses [8].

According to a number of researchers, the species of the genus *Adansonia* are the main angiosperm candidates to become "millenarian". The genus *Adansonia*, which belongs to the Bombacacee family, comprises eight species of deciduous trees: six are endemic to Madagascar, one to Australia and one is widespread in continental Africa [9].

The African baobab (*Adansonia digitata* L.), which can be considered a tropical tree, is the largest and best-known of the eight *Adansonia* species. It is widespread south of the Sahara, especially in savanna regions. The familiar picture of the African baobab is of an almost grotesque tree, with a girth out of proportion to its height. Therefore, the African baobab is often named the upside-down tree. Although the baobab is a relatively short tree, with an usual height around 20 m, some individuals can reach an exceptionally large girth of over 25 m [10-12]. The African baobab is a very special tree. Baobabs are more similar to succulents than they are to woody trees. Thus, as they die, they might best be described as rotting, rather than slowly decaying. The trunk and the branches are constructed in concentric layers of succulent tissue, reminiscent of the layers of an onion. The wood is soft, spongy, fibrous and light; between each layer of xylem cells there is a layer of parenchyma cells that store water [10]. Thus, the African baobab can be considered a stem-succulent tree species. In the rainy season, baobabs store enormous quantities of water in their bulbous trunks, which they use to survive during the dry season.

The tremendous size of certain individuals has led many observers to state that the baobab lives to a long age. However, the age of the oldest baobab trees, i.e. the age limit of the African baobab, remains a controversial topic, which has generated two competing hypotheses:

(i)*The long lived baobab hypothesis* (baobabs as millenarian trees) is based on local traditions, the statements of pioneer explorers and the study of several large and old specimens. Early African explorers, such as Adanson and Livingstone, ventured to extrapolate the very slow growth rate of old baobabs over their entire life cycle, without any corrections, thus claiming incredible age values of several thousands years (up to 5150 yr) for the largest individuals [13, 14]. Modern measurements of several huge individuals from Botswana and Mozambique, performed by Guy, when compared to historic records of the same trees, evinced a very small increase or even a decrease in girth during a time span of ca. 110 yr, namely from ca. 1850–60 to1966 [15]. The studies of Guy and Swart evinced very small growth rates (i. e. annual increase in radius) for old baobabs of Southern

Africa (South Africa, Zimbabwe, Botswana, Mozambique) [15, 16, 4]. The singular result of Swart also suggests that much larger individuals than the radiocarbon dated tree could be well over 1000 yr old. [10, 12, 16].

(ii)*The short lived baobab hypothesis* (baobabs as centenary trees), promoted by many contemporary researchers, is based on several relatively recent studies that reveal very fast growth rates, especially for young baobab trees of Central Africa (Zambia, Sudan, Mali, Kenya, Tanzania) and of South Africa, as well [18-23]. These researchers, who discount or question the dating result of Swart, claim that the age limit of the African baobab is around 500–800 yr, perhaps reaching values close to 1000 yr, in the case of the largest trees [22-25]. Several additional remarks should be made. Even if an enormous girth would suggest a very old tree, the largest baobabs are not necessarily the oldest ones. As in the case of other tree species, the size of the baobab depends not only on its age, but also on the genetic variability and on its location, especially its access to moisture [26]. Consequently, there is a big problem to estimate the age of baobabs via girth measurements, due to the impact of the hydrostatic conditions within the tree and to the large variation in growth rates between individuals. In addition, most baobab researchers consider that the growth rate decreases severely with age.

Given that the trunk of the baobab is a water-storing organ, it swells and shrinks periodically, in direct relation to the water content. Seasonal, annual and long period girth variations have been reported; they may sometimes mask the radial increase du to cambial activity.

The baobab stops growing during the dry season and produces a sort of rings. These faint rings are believed by modern researchers to be annual rings, even if this has not been yet demonstrated conclusively [24]. The majority of researchers agree, however, that in areas with a distinct dry season, the baobab exhibits annual rings. Ring counting of young trees of known age have been shown to be within 2 % of the real age [10]. However, ring counting cannot be used to aging large baobabs, because of the presence of large hollows in the trunk.

Further, large baobabs have sometimes multiple stems, more or less fused in a single trunk. This could either be ascribed to multiple sprouting from the same rootstock or to the simultaneous germination of several seeds [24]. A baobab tree with two or more fused stems at an earlier stage of its life can be younger than its girth would suggest [12].

It should also be noticed that, when they die, baobabs collapse into a huge fibrous mass. The wood fibers dry out rapidly and the heat of the desert during the dry season may ignite them. It is also possible that the dehydrated, dry and friable wood fibers may be washed away by heavy rains over the rainy season or that they may crumble and be blown away by winds. Hence, a huge collapsed tree may disappear in a relatively short time, with no trace left behind. This fact may be at the origin of the popular myth which states that, after they die, baobabs catch fire spontaneously [24].

Hence, the sole technique for determining the age of old baobabs is radiocarbon dating of wood samples collected from a recently fallen tree, namely by measuring their ^{14}C content relative to the content of stable carbon.

In 1949, Libby pioneered the first radiocarbon measurements by monitoring the beta radioactive decay of individual ^{14}C atoms with modified Geiger counters. He

used samples of several grams of carbon-black powder. In the 1950's period, when atmospheric nuclear bomb tests were performed, this method was relatively insensitive and subject to statistical errors due to the absorption of nuclear contaminant [27].

More accurate methods in the decay counting technology had been developed by the conversion of sample solid carbon to CO_2 for measurement in gas-proportional counters and liquid-scintillation counters. Both methods rely on observing the decay of the radioactive ^{14}C atoms. When a ^{14}C atom decays, it emits a beta particle, which can be counted in a gas by the electrical pulse it generates. In a liquid-scintillation counter, the beta particle excites the emission of light from the molecules of an organic solvent, which acts as a "scintillant". Because only ca. 13.5 decays per minute occur in 1 g of modern carbon, it is necessary to use fairy large samples, up to several grams of carbon. Today, the majority of radiocarbon laboratories utilize these two dating methods [27].

It was recognized that direct counting of ^{14}C atoms in the sample would greatly enhance the sensitivity and accuracy of the dating. Some unsuccessful attempts were made by using conventional mass spectrometry. In 1977, a new development added a particle accelerator into a mass spectrometer to produce an accelerator mass spectrometer [28]. The technique uses a very high performance particle accelerator to accelerate sample atoms as ions to high energies. After a first attempt which utilized positive ion acceleration [29], the superior approach with negative ion acceleration was developed [30-31]. This so-called Accelerator Mass Spectrometry (AMS) method allows the determination with high accuracy of tiny amounts of isotopes with a small relative abundance. The dating with radiocarbon by AMS is of very high sensitivity, up to $1:10^{15}$ atoms for carbon, which is 10^3 to 10^5 higher than the older decay counting methods. Thus, it allows for the analysis of very small samples, well below 1 mg, in a much shorter time. The higher costs are justified by the value of results. Over the past years, new concepts and technologies have been brought into the field of AMS radiocarbon dating and new types of accelerators and ion sources have been developed [32].

Grootboom, an exceptionally large African baobab (Photo 1), collapsed unexpectedly in north-eastern Namibia, at the end of 2004. The huge dimensions of the tree, associated with the unusual fact that it did not have very large hollow parts, offered an unique opportunity to clarify certain aspects concerning the controversial age of large baobabs.

An international joint research project was initiated, with the following aims: 1) to determine accurately the true age of the tree; 2) to establish whether Grootboom's trunk was a single unit or was made up of several fused stems; 3) to learn about the dynamics of Grootboom's growth rate during its life cycle.

Several samples were collected from the remains of the collapsed tree and were processed and analyzed by AMS radiocarbon dating.

EXPERIMENTAL SECTION

Collection of samples. Grootboom collapsed stepwise and very chaotically into six stems. Several sets of wood samples have been collected from two fallen stems (samples Nos. 5–10), as well as from the remaining stumps of two other stems (Nos. 1–4), that broke at a variable height from the ground and collapsed. Two stems were not available for sampling, one being already severely decayed, while the other was covered and partially crushed by a larger stem. Another sample (No. 11) was collected from towards the upper part of the tallest unbroken fallen branch.

Several additional samples collected from the remaining stumps, from the fallen stems and from the thickest exposed root, as well, are being currently dated.

Photo 1. The image (facing north) shows the heavy trunk of Grootboom and its rich crown full of leaves, at the beginning of the rainy season 2001–2002.

The sampling of Grootboom was recorded on videotape, a number of photographs were taken and several measurements of the remains of the collapsed tree were undertaken. This allowed the subsequent establishment of the position of each sample in the trunk of the tree prior to its collapse.

Sample preparation. The preparation of the samples for AMS radiocarbon dating involved the standard steps: i) pretreatment of the wood samples to isolate cellulose from the bulk tissue; ii) combustion of the separated cellulose to CO_2; iii) reduction of CO_2 to graphite.

Pretreatment of samples. Wood samples (with a mass of 0.7–2.0 g) were subsampled by cutting with a clean razor blade. The wood shavings were weighed and placed into a pre-combusted glass centrifuge tube to undergo numerous wet chemistry pretreatment steps. The woody tissues of trees, involved in water transport, contain several hydrolizable and mobile organic substances. Pretreatment intends to remove non-structural mobile carbon and to isolate only structural non-mobile carbon components, mainly cellulose, which had been synthesized at the original formation of the respective woody tissue.

The pretreatment method used was, with the exception of one sample, the so-called Acid-Base-Acid (ABA), which is widely employed in the case of wood samples prepared for AMS analysis. This classic method consists of a sequential washes of weak acids and bases and yields a residue consisting primarily of cellulose [33].

First, wood samples were treated with HCl solution (10% v/v), and then placed in a water bath at 60º C, for 1 h, to remove any inorganic carbon. The acid solution was discarded by means of a pipette and the sample rinsed with organic-free water to neutral pH. NaOH solution (2% w/v) was added to the centrifuge tube, which was placed in the water bath for 1 h. The samples were treated with multiple

base rinses until the solution was clear and free of humic or fulvic acid discoloration. The base solution was removed with a pipette and the sample was rinsed to neutral pH with organic free water. HCl solution (10% v/v) was added to drive off any CO_2 gas that may have adsorbed onto the sample during processing. After being heated in the water bath for 1 h, the final acid solution was removed by pipette and the sample was rinsed again to neutral pH. Subsequently, the remaining residues of each sample were filtered on pre-combusted quartz fiber filters, which were dried overnight in a drying oven at 60ºC. All samples were stored in a dessicator, to await combustion.

One sample (No. 7) had the wood fibers quasi-totally destroyed, due to severe decay caused by microorganisms. Because in such cases the ABA method can produce large errors, the α-Cellulose (Jayme-Wise) method was used for pretreatment of this sample. The method involves an organic solvent extraction, followed by a bleach delignification process, which leaves only α-cellulose as residue.

α-Cellulose was extracted according to the method described by Jayme and Wise [34] and modified by Loader et al. [35]. Briefly, dried wood shaving was extracted with 9:1 (v/v) dichloromethane and methanol, using an accelerated solvent extractor (ASE 200, Dionex Corp., Sunnyvale, USA) at 100 ℃ a nd 1000 psi. The resulting sample was dried in an oven at 50 ℃. Then, the sample was introduced in a glass centrifuge tube and a bleaching solution of sodium chlorite (0.19 mol dm^{-3}) and HCl (0.07 mol dm^{-3}) was added. The centrifuge tube was placed in an ultrasonic bath at about 75℃ for 2 h, after which the acid solution was removed with a pipette. Three further additions of the bleaching solution were made, one after each hour. The resulting sample was thoroughly rinsed with pure water.

Next, a solution of NaOH (10% w/v) was added to the tube. The tube was placed in the ultrasonic bath for 45 min at 75 ℃. The sample was washed with pure water and treated with a solution of NaOH (17% w/v) in the ultrasonic bath at room temperature. The sample was washed with water and then with a diluted solution of H_3PO_4 (3% v/v). Finally, a large volume of cold pure water was used to wash the sample to neutral. The remaining α-cellulose residue was dried at 50 ℃.

Combustion to CO_2. The combustion method used for the resulted cellulose samples was the Closed Tube Combustion (CTC) method [36]. Samples were weighed and placed into pre-combusted quartz combustion tubes with 2 g copper oxide wires (to provide oxygen for the combustion) and 100 mg of silver powder (to scavenge sulfur and chlorine gases). The combustion tubes were then placed in a vacuum line where they were evacuated, leak-checked and flame-sealed. They were combusted in a muffle furnace at 850ºC, for 5 h. The generated CO_2 was cryogenically purified, quantified and transferred to a graphite reactor.

Reduction to graphite. In the graphite reactor, the generated CO_2 was converted to graphite by Fe catalysed reaction in a H_2 atmosphere. The graphite samples were submitted to AMS analysis.

AMS radiocarbon analysis. The radiocarbon (^{14}C) content of the graphite samples was determined at the National Ocean Sciences Accelerator Mass Spectrometry (NOSAMS) Facility of the Woods Hole Oceanographic Institution.

Graphite derived from each sample was compressed into a small cavity in an aluminum "target", which acted as a cathode in the ion source. The surface of the graphite was sputtered with heated cesium and the ions produced were extracted and accelerated in the 3 MV Tandetron (TM) AMS system. After acceleration and removal of electrons, the emerging positive ions were magnetically separated by mass and the ^{12}C and ^{13}C ions were measured in Faraday Cups, where a ratio of

their currents was recorded. Simultaneously, the ^{14}C ions were recorded in a gas ionization counter, so that instantaneous ratios of ^{14}C to ^{13}C and ^{12}C were recorded. These are the raw signals that were ultimately converted to a radiocarbon age [37].

The AMS analysis of the samples was performed relative to an array of primary and secondary standard samples. Two primary standards were used: NIST Certified Oxalic Acid I (NIST-SRM-4990) and the derived Oxalic Acid II (NIST-SRM-4990C). The ^{14}C activity ratio of Oxalic Acid II (Fm = 1.3605; $\delta^{13}C = -17.3\ ^{0}/_{00}$) to Oxalic Acid I (Fm = 1.0520; $\delta^{13}C = -19.0\ ^{0}/_{00}$) is taken to be 1.293. Three secondary standards were also used, namely FIRI B (Old Wood, Consensus Fm = 0.0033, NOSAMS Fm = 0.003), FIRI F (Dendro-dated Wood, Consensus Fm = 0.5705, NOSAMS Fm = 0.5668) and FIRI H (Dendro-dated Wood, Consensus Fm = 0.7574, NOSAMS Fm = 0.7450). System background measurements were performed with petroleum-derived Johnson-Matthey 99.9999% graphite powder (no chemical preparation, Fm < 0.002) and IAEA C-1 hydrolyzed Carrara marble (Fm < 0.002). The measurement of the secondary standards was used to assess the accuracy of the sample analysis. The overall system error is a function of the average deviation of the secondary standard results from their respective consensus values [38-40].

Radiocarbon date/age and auxiliary quantities/values. The quantities/values calculated from the experimental results of the AMS analysis are the following:

Fraction modern (carbon). Fraction modern (carbon) is a measurement of the deviation of the $^{14}C/^{12}C$ ratio of a sample from "modern." Modern is defined as 95% of the radiocarbon concentration (in AD 1950) of a NIST

Oxalic Acid I normalized to $\delta^{13}C_{VPDB} = -19\ ^{0}/_{00}$ [E7]. AMS results are calculated using the internationally accepted modern $^{14}C/^{12}C$ ratio of $1.176 \pm 0.010 \times 10^{-12}$ [38]; all results are normalized to $-25\ ^{0}/_{00}$ using the $\delta^{13}C_{VPDB}$ of the sample.The value used for this correction is specified in the report of final results. Fraction modern (Fm) is basically computed from the expression: Fm = (S – B) / (M – B) , where B, S and M represent the $^{14}C/^{12}C$ ratios of the blank, the sample and the modern reference, respectively. *$\delta^{13}C$ Correction*. In addition to loss through decay of radiocarbon, ^{14}C is affected by natural isotopic fractionation. Fractionation is the term used to describe the differential uptake of one isotope with respect to another. While the three carbon isotopes are chemically indistinguishable, lighter ^{12}C atoms are preferentially taken up before the ^{13}C atoms in biological pathways. Similarly, ^{13}C atoms are taken up before ^{14}C. The assumption is that the fractionation of ^{14}C relative to ^{12}C is twice that of ^{13}C, reflecting the difference in mass. Fractionation must be corrected for in order to make use of radiocarbon measurements as a chronometrical tool for all parts of the biosphere. In order to remove the effects of isotopic fractionation, the Fraction Modern is then corrected to the value it would have if its original $\delta^{13}C$ were $-25\ ^{0}/_{00}$ (the $\delta^{13}C$ value to which all radiocarbon measurements are normalized).

The Fraction modern corrected for $\delta^{13}C$, noticed by $Fm_{\delta^{13}C}$, is calculated by: $Fm_{\delta^{13}C} = Fm\ [(1 - 25 \cdot 10^{-3}) / (1 + 10^{-3}\ \delta^{13}C)]^2$.

Errors. Atoms of ^{14}C contained in a sample are directly counted using the AMS method of radiocarbon analysis. Accordingly, an internal statistical error is calculated using the total number of ^{14}C counts measured for each target, $\pm(n)^{1/2}$. An external error is calculated from the reproducibility of multiple exposures for a given target. The final error is the largest of the internal or external errors.

Aside from the normal statistical errors intrinsic to the counting of ^{14}C events, there are additional statistical errors associated with the corrections applied to the Fm value.

The error associated with $\delta^{13}C$ is described by :

$\delta^{13}C$ error = $4 \cdot 10^{-8} / (1 + 10^{-3} \delta^{13}C)^2$.

This component of the Fm error is added in quadrature as follows:

$Fm_{\delta}{}^{13}{}_C$ error = $Fm_{\delta}{}^{13}{}_C [(Fm\ error^2 / Fm^2) + \delta^{13}C\ error^2]^{1/2}$.

Radiocarbon date/age (^{14}C age). Conventional radiocarbon age, the main result of radiocarbon measurements, is calculated according to the formula:

$$^{14}C \text{ age} = -\tau \ln (Fm_{\delta}{}^{13}{}_C) ,$$

where $\tau = T / \ln 2 = 8033$ yr is the Libby mean life and $T = 5568$ yr is the Libby half-life.

Radiocarbon ages are calculated using the Libby half-life of ^{14}C.

The ^{14}C age is expressed in yr BP (radiocarbon years before present, i.e. before AD 1950).

The ^{14}C age error is given by:

^{14}C age error = τ ($Fm_{\delta}{}^{13}{}_C$ error).

According to the convention outlined by Stuiver and Pollach [41] and Stuiver [42], radiocarbon dates are reported as follows: ^{14}C age values < 1000 yr BP are rounded to the nearest 5 yr, ^{14}C age values > 1000 yr BP are rounded to the nearest 10 yr and the ^{14}C age errors < 100 yr are rounded to the nearest 5 yr etc. However, not all laboratories subscribe to this convention.

In our report, the radiocarbon age of the samples and the corresponding error values were rounded to the nearest 5 yr

RESULTS

General research on Grootboom. The area of Northeastern Namibia, located between the village of Tsumkwe and the border with Botswana, which belongs to the Tsumkwe Constituency, traditionally known as Bushmanland, has several large African baobab trees. Three of these baobabs, known under the names of *Dorslandboom, Grootboom* and *Holboom*, are of outstanding size.

Die Grootboom (*The Big Tree* in Afrikaans) site is situated at 15 km (as the crow flies) east of Tsumkwe, in close proximity of the Makuri and Djokhoe campsites. The position of *Grootboom* is defined by the following parameters: GPS coordinates 19.649317 S-lat, 020.657583 E-long (19º38'57.5" lat S, 20º39'23.7" long E); altitude 1149 m. Geographically, the region belongs to the Northern Kalahari Woodland basin and the corresponding vegetation type is known as woodland savanna. The semi-arid climate has a distinct dry season (April-October) and a rainy season (November-March) with ca. 60–100 rainy days. Average annual rainfall is 451 mm (measured from 1965 to 2005).

Grootboom was the largest tree of a so-called “Group of Seven“, composed initially of seven baobabs spread over an area of ca. 2 hectares, under the protection of the Nyae Nyae Conservancy.

The first records of *Grootboom* are found in the writings of the “Dorslandtrekkers“ (Thurstland trekkers), that moved from South Africa in 1875 through Namibia onwards to Angola. They were Afrikaan Boers oppressed by the English in South Africa in those years. In their writings, the Dorslandtrekkers state that they moved through the "Tebra veld" (Bushmanland), where they encountered large numbers of wildlife and big “kremetartbooms“ (baobab trees). Around 1890, they visited a huge baobab, known as *Homasi* by the San people (Bushmen), after the name of the respective place in the Juhoansi tongue (San dialect). The Dorslandtrekkers, which renamed the tree *Grootboom*, were impressed not only by its extraordinary dimensions, but also by its excellent condition.

The heavy trunk of *Grootboom* was accurately measured by the German researcher Rudolf Wittmann [43]. The measurements done in November 2001, at the beginning of the rainy season, when the tree was in leaf, indicated a cbh (circumference/ girth at breast height, i.e. at 1.30 m above ground) of 30.6 m. This value (that might have been even larger by the end of the rainy season) corresponds in a very illusory circular approximation to a dbh (diameter at breast height) of 9.74 m. The basal circumference of *Grootboom* was of ca. 36 m and the largest base diameter (west to east) was found to be 12.1 m.

The bark was very thin, measuring only 1-2 cm and its color was elephant gray with reddish spots. The trunk of Grootboom divided at a height of 2-6 m in seven branches, out of which the tallest four were pointed straight upwards. The height of these branches, estimated from the largest unbroken fallen branch, from other broken branches and from several photographs of the tree were (from west to east and than to northeast, facing north) the followings: 14.0, 26.5, 30.5, 32.0, 27.0, 20.5 and 17.0 m (estimated error: ± 0.5 m). The maximum height of 32.0 m is also exceptional for an African baobab. The estimated mean crown spread was of ca. 32 m.

Taking into account the 3 standard dimensions (height, circumference and crown spread), Grootboom can be considered the biggest known African baobab.

As for many other large baobabs, the shape of the trunk was very irregular. Several deep incisions and some obvious fissures determined certain researchers to consider that the huge trunk of *Grootboom* was possibly composed of 3-5 fused stems. Other researchers considered that the incisions and fissures were generated by the twisting movement of branches in time and that the trunk of *Grootboom* was in fact a single entity.

At the end of the 2003/2004 rainy season, Grootboom was full of leaves and looked very healthy. In late June 2004, however, it started dying suddenly. Several branches fell first, approximately two months before the trunk began to collapse. The huge trunk collapsed successively into no less than six stems. The last stem fell around New Year's eve of 2005. Grootboom was probably killed by the mysterious baobab disease, which has affected many baobabs in Southern Africa since 1960.

The fallen stems are labeled (from west to east and than to northeast, facing north) as: A, B, C, D, E, F, in the reverse order of collapse (Photos 2–4). The largest stem (D) fell with roots exposed, three stems (C, E and F) collapsed totally with no roots exposed, while two stems (A, B) broke at irregular heights from the ground (between 1–2 m), also leaving behind stumps.

The original positions of the collected samples in the trunk prior to its collapse are shown in Photo 5.

Growth rings. Growth rings could be identified on only one single sample out of the collected. This is quite surprising, as one considers that in addition to the dated samples, some other large samples (with sizes up to 30 x 30 x 10 cm) have been collected

Sample No. 3 exhibited two obvious growth rings and the external contour of a third ring, as well. The width values of the three consecutive rings, each composed of several wood layers, were the following: 4.8, 4.6 and 2.5 x 10^{-3} m (mm).

The alternation of two larger rings and one thinner ring is in agreement with the sequence of rainy seasons rich or scarce in precipitation, which have been recently recorded in the area. However, one cannot unmistakably state that the observed growth rings are true annual rings.

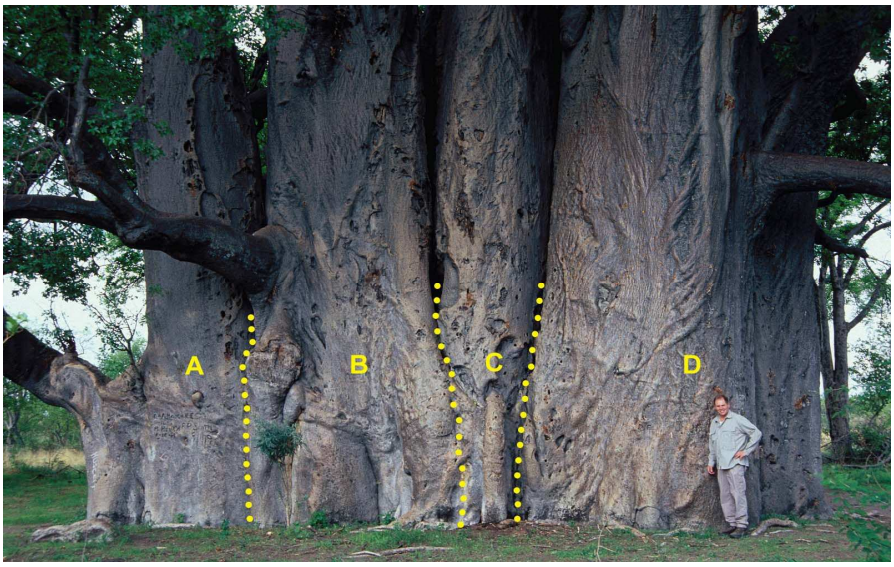

Photo 2. Location of stems on the southern flank.

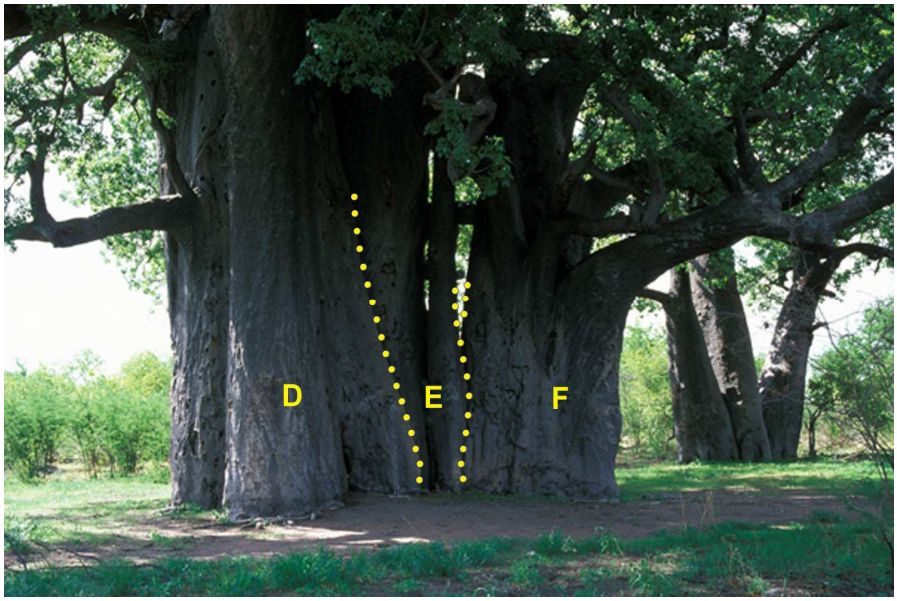

Photo 3. Location of stems on the eastern flank.

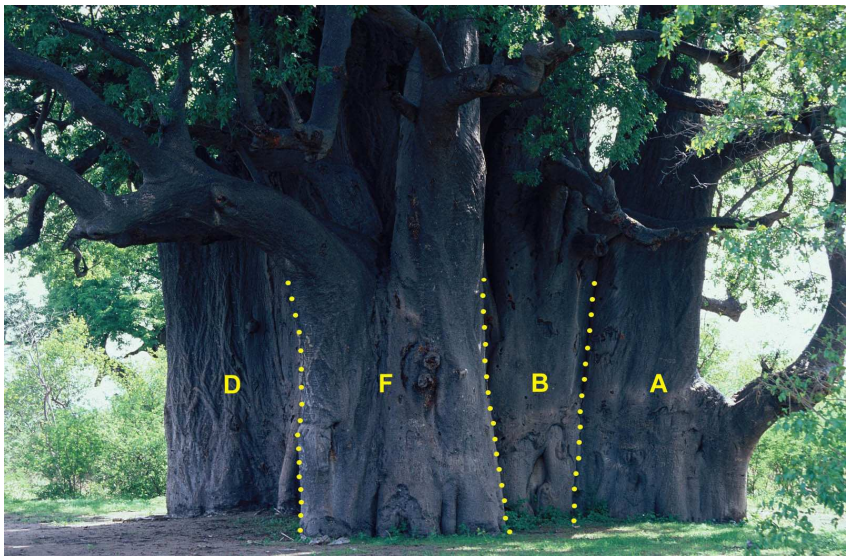

Photo 4. Location of stems on the northern and northeastern flanks.

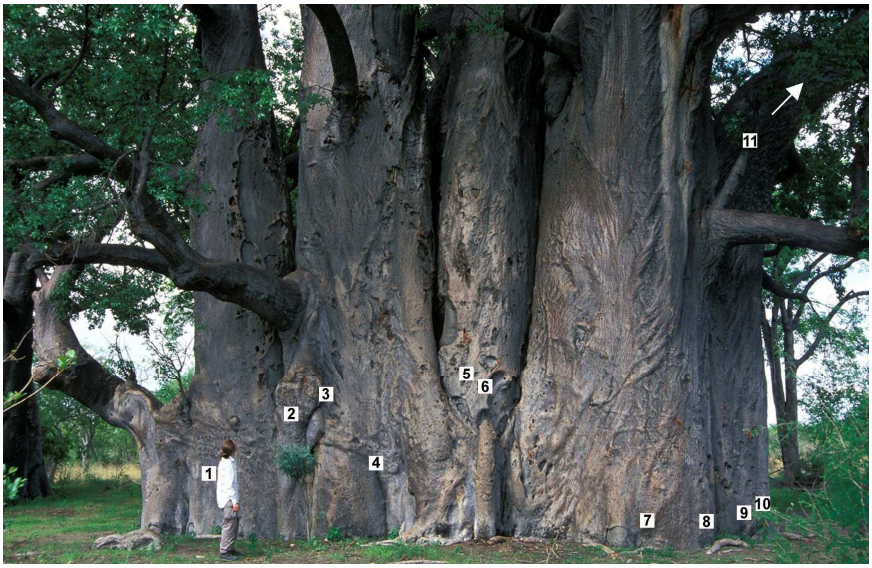

Photo 5. Original position of the samples prior to Grootboom's collapse.

Table 1.

NOSAMS dating results

No. sample	Stem	Code sample	NOSAMS Accession #	$Fm_{\delta}{}^{13}{}_{C}$	$Fm_{\delta}{}^{13}{}_{C}$ error (±)	$\delta^{13}C$ (‰)	$\Delta^{14}C$ (‰)	^{14}C age (^{14}C yr BP)	^{14}C age error (± ^{14}C yr)
1	A	LT-C	OS-50719	0.8555	0.0042	-23.60	-150.2	1255	35
2	B	WB-1	OS-54640	0.9559	0.0036	-24.89	-50.4	360	30
3	B	WB-3	OS-52830	0.9551	0.0024	-26.14	-51.2	370	20
4	B	WB-4	OS-58828	0.8778	0.0023	-25.56	-128.0	1045	20
5	C	LAS+1	OS-58821	0.9334	0.0032	-24.31	-72.8	555	25
6	C	LAS	OS-50711	0.9466	0.0030	-24.24	-59.6	440	25
7	D	TT-000	OS-52829	0.8981	0.0026	-25.66	-107.9	865	20
8	D	TT-100	OS-50716	0.8734	0.0071	-24.54	-132.4	1090	55
9	D	TT-220	OS-50712	0.9361	0.0053	-23.54	-70.2	530	45
10	D	TT-270	OS-52827	0.9419	0.0025	-24.69	-64.4	480	20
11	branch	HB-C	OS-50714	0.9965	0.0051	-24.32	-10.1	30	40

AMS dating results. The NOSAMS dating results are displayed in Table 1. The radiocarbon dates/ages of 3 samples (Nos. 1, 4 and 8), collected from three different stems, was found to be greater than 1000 yr BP, i. e. 1255 ± 35, 1045 ± 20 and 1090 ± 55 yr BP, evidence for Grootboom's old age.

The calibration of radiocarbon dates to calendar ages is presented in part two of the report.

Credits:
Photos 1–5 were taken by Rudolf Wittmann on November 14, 2001 and are copyrighted: © Rudolf Wittmann (www.baumsachverstaendiger.de).

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