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In memoriam Assoc. Prof. Dr. Marius Sălăjan (1952-2004)

RADIOCARBON DATING OF THE HISTORIC DERBY BOAB TREE FROM DERBY, KIMBERLEY, AUSTRALIA

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ABSTRACT. The paper presents the AMS (accelerator mass spectrometry) radiocarbon dating investigation of the historic Derby Boab Tree from Derby, Kimberley, Australia. This well-known boab (*Adansonia gregorii*) is often considered a prison tree, where Aboriginal prisoners were temporarily incarcerated in its cavity. According to recent research, the Derby Boab Tree was never used as a prison tree. The boab has a closed ring-shaped structure, with 3 perfectly fused stems enclosing a false cavity. A number of six punctiform wood samples, the size of a grain of sand were collected from the cavity door wall. The radiocarbon date of the oldest dated punctiform sample was 1285 ± 21 BP, a value which corresponds to a calibrated age of 1185 ± 20 calendar years. This result indicates that the age of the Derby Boab Tree is 1250 ± 50 years. This is the first accurate dating result of a boab and demonstrates that the species is a millennial angiosperm.

Keywords: *AMS radiocarbon dating, Adansonia gregorii, dendrochronology, Australia, age determination, false cavity.*

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INTRODUCTION

The *Adansonia* genus is classified into the Bombacoideae subfamily of the Malvaceae family, and comprises eight officially recognised species. One species is native to mainland Africa, six to Madagascar, and one can be found solely in northern Australia [1-7].

In 2005, we launched an extensive research program aimed at clarifying several controversialor poorly understood aspects related to the architecture, growth and age of the African baobab (*Adansonia digitata* L.).

Using our original methodology that enables the study and dating of living individuals rather than relying only on demised specimens, we conducted investigations based on AMS (accelerator mass spectrometry) radiocarbon dating of small wood samples. These samples were collected from inner cavities and/or from different areas of the trunk/stems of baobabs [8-21]. Our research revealed that all large African baobabs are multi-stemmed, featuring open and closed ring-shaped structures that allow them to attain old ages and exceptional sizes. We also identified false cavities, which are large natural empty spaces formed between perfectly fused stems that are disposed in a (semi)circular manner, in a so-called closed ring-shaped structure. The age of the oldest African baobabs exceeds 2,000 years old, establishing the African baobab as the longest living angiosperm [10,11].

In 2013, we expanded our research on the *Adansonia* genus to Madagascar, where we investigated by radiocarbon large individuals of the most representative three *Adansonia* species, namely the fony baobab (*Adansonia rubrostipa* Jum. & H. Perrier), the za baoab (*Adansonia za* Baill.) and the Grandidier baobab (*Adansonia grandidieri* Baill.). These Malagasy species are found in the western and southern parts of the island [23-30].

Eventually, in 2015, we started to investigate superlative specimens of the Australian baobab, commonly known as boab (*Adansonia gregorii* F. Muell.) [4].

Adansonia gregorii is native to the Kimberley region of the Western Australia state and it extends to the closely adjacent parts of the Northern Territory (**Figure 1**). Its most common name is boab, but it had also other names, such as Australian baobab, boabab and baob [4, 31-33].

The Kimberley is the northernmost of the nine regions of the Western Australia state. It has a surface of 424,517 km^2 and a population of only 34,800 inhabitants. The population is concentrated in the major towns with Aboriginal settlements and scattered homesteads. Around 40% of the population is of Aboriginal descent. According to scientific studies and archaeologial discoveries, the Aboriginal occupation of the region began 60,000 years ago [32, 34]. The boab is a prominent symbol in Aboriginal culture, spirituality and history. The stems of many specimens have inscriptions and drawings made by them. Such tree markings are also known as “dendroglyphs” [35].

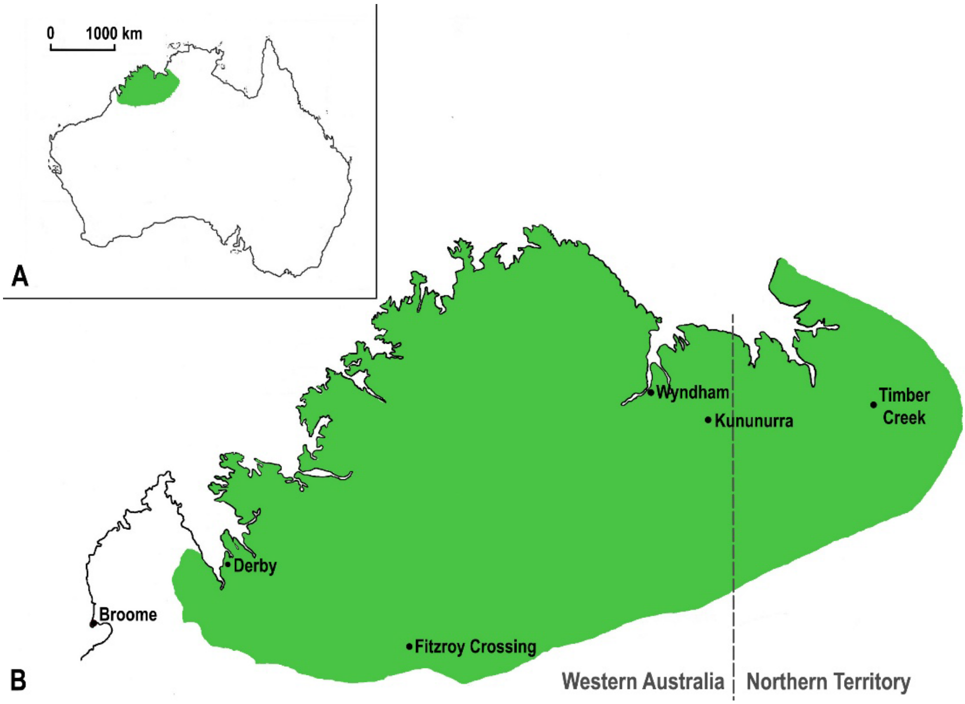

Figure 1. Geographic distribution of the Australian boab (green).

The boabs are concentrated along seasonal waterways and floodplains, suggesting that the presence of groundwater could be important for the species' distribution [32, 33]. Boabs are typically shorter than other *Adansonia* species, with heights between 5-12 m. The bottle-shaped trunks have girth values of 5-10 m for mature individuals. Exceptional specimens can reach heights close to 20 m and circumferences of up to 20 m [32, 33]. The boabs exhibit a very high morphologic variety, which shows that *A. gregorii* is a younger species with a high phenotypic plasticity [32, 36].

There are two gaps in the boab distribution, out of which the plateau gap is the most important, with a length of over 400 km along the Great Northern Highway. The existence of the plateau gap must be associated with two facts: i) the vast majority of boabs are young and very young (probably up to 100-150 yr); ii) the number of old boabs (with ages over 500-600 yr) is very low (probably up to a dozen individuals) for a species with a lifespan of over 1,000 yr [33, 37].

There was probably a critical period for boabs during the Little Ice Age (ca. 1500-1850), which reached a maximum around 1700. In the Northern Hemisphere, the Little Ice Age (LIA) was cold and wet. Acccording to climate research on baobabs of southern Africa, the LIA was cold and dry, in some areas and wetter in others [21]. The climate of western Australia during the LIA likely saw periods of increased rainfall, particularly in the southern part of the region. Evidence from flood deposits and other climate proxies indicates that while northern Australia experienced drier conditions, the south became wetter during this period. These wetter conditions are recorded in various hydrological studies, including extreme floods during the 1400-1850 period [38].

It is possible that the majority of old boabs have died during the LIA and many mature specimens stopped growing. It was a severe decline of the species across its entire distribution range and the boabs disappeared from the areas with the most severe climate conditions, such as the Kimberley plateau, by producing the gap.

According to the IUCN Red List of Threatened Species, *Adansonia gregorii* is listed as Least Concern, with a stable population [39].

In the case of African and Malagasy baobabs, we collected wood samples with long increment borers (from 0.60 to1.50 m), out of which we extracted tiny segments, each 5 x10^{-3} m long with a weight of 5 x 10^{-4} kg, for AMS radiocarbon dating. For boabs, we extracted for dating punctiform wood samples of the size of a grain of sand. This new methodology is described in the Experimental section.

Here we present the AMS radiocarbon dating results and the investigation of the historic Derby Boab Tree.

RESULTS AND DISCUSSION

The Derby Boab Tree and its area. Derby is a town in the Kimberley region of Western Australia. It was founded in 1883, when the new pastoral industry required a port from which to ship the wool. Derby has the highest tides in Australia, with a difference of 11.8 m between high and low tide. The population is 3,300, out of which over 40% are of Aboriginal descent. Derby is characterized by a hot semi-arid climate (*BSh* in Köppen classification), with a short wet season lasting from late December to March. The area in which the baobab grows has a mean annual temperature of 27°C and its mean yearly rainfall is 622 mm [34].

The Derby Boab Tree, which resembles a barrel in shape, grows on the outskirts of Derby, 6 km south of the town, at the end of a 0.5 km deviation towards east. The trunk is completely furrowed with deep signs and inscriptions carved by locals and tourists.

The indigenous people considered the Derby Boab Tree as a significant landmark before European settlement, calling it Kunumudj.

The first photograph of the Derby Boab Tree dates back to 1916 and was captioned on glass plate by Herbert Basedow (**Figure 2**).

Figure 2. The first photograph of the Derby Boab Tree taken by Basedow in 1916.

The GPS coordinates of the Derby Boab Tree are 17º21.043’ S, 123º43.191’ E and the altitude of its location is 29 m. The height of the boab is 8.20 m (above the cavity level). The measured circumference revealed a value of 13.79 m at breast height (cbh, i.e. at 1.30 m above mean ground level), while at 2.03 m above ground it reached 14.40 m (**Figure 3**).

Figure 3. General view of the Derby Boab Tree as taken from the east.

The boab has a closed ring-shaped structure, with a ring of 3 perfectly fused stems around a false cavity which was never filled with wood.

The false inner cavity reaches a height of 3.90 m, with its base at 0.77 m under the ground level (Figure 4). The interior of the cavity has the following dimensions: 1.51 (WE) x 2.29 m (NS) (at the base: ground level – 0.77 m); 2.50 (WE) x 2.69 m (NS) (at the cavity door level: ground level + 0.10 m); 2.98 (WE) x 3.76 m (NS) (ground level + 2.20 m). The cavity door has a height of 1.60 m and a maximum width of 0.47 m. The side walls of the cavity door measure 0.45 m (to the left of the entrance) and 0.40 m (to the right of the entrance). The thickness of the trunk bark is between 0.05-0.15 m.

Figure 4. The image shows the base of the false cavity of Derby Boab Tree.

The canopy has several large branches, and its horizontal dimensions are 14.4 (NS) x 14.8 (WE) m. The overall volume of the tree is 60 m^3 (trunk and branches, including the false cavity).

The trunk and also the primary branches, which show tears and gaps, appear to be very old. However, according to the photos, the boab has not changed its appearance over the last hundred years.

The Derby Boab Tree is also frequently named Derby Prison Tree, Boab Prison Tree or Derby Boab Prison Tree. These names are associated with the Prison tree myth and with the conceptual framework of Dark Tourism. The Derby Boab Tree is a major attraction for tourists, who visit it each year by the thousands. It is presented as a major historic site, where Aboriginal prisoners, chained by the neck, were temporarily incarcerated in its hollow trunk by colonial police en route to the townships [34].

Officially signposted as a prison tree, the site of the Derby Boab Tree has undergone several upgrades over the years, becoming a major Kimberley tourism attraction. The concept of Dark Tourism is applied to tourism sites associated with death, crime and destruction, including ‘dark dungeons’, such as former courthouses or prisons.

New research by the academics Elisabeth Grant and Kristyn Harman, which were published in 2017 challenges the claim that the Derby Boab Tree once served as a temporary prison for Aboriginal captives. The authors contend that there is insufficient evidence to support the notion that the tree was ever used as a prison. They suggest that the belief in its use as an overnight holding cell for Aboriginal prisoners during the colonial 1890s stems from misinformation and that the rise of dark tourism has fueled this growing myth [34]

However, the site was listed as protected in 1999 under the Aboriginal Heritage Act of 1972. A fence and sign were erected around the tree to protect it from excessive human traffic, carvings and compacting of surrounding soil by vehicles. However, many tourists are still posing within the perimeter sign and inside the cavity [34].

Wood samples. Six punctiform wood samples of the size of a grain of sand, weighing each around 10^{-6} kg (0.001 g), were collected from the right side wall of the cavity door at a height of 1.35 m. At this height, the width of the right side wall of the cavity door (inside bark) is 0.40 m. The samples are labelled from 1 to 6.

AMS results and calibrated ages. Radiocarbon dates of the six punctiform samples are listed in Table 1. The radiocarbon dates are expressed in ^{14}C yr BP (radiocarbon years before present, i.e., before the reference year 1950). Radiocarbon dates and errors were rounded to the nearest year.

Calibrated (cal) ages, expressed in calendar years CE (CE, i.e., common era), are also displayed in Table 1. The 1σ probability distribution (68.3%) was selected to derive calibrated age ranges. For one sample (DBT-2), the 1σ distribution corresponds to one range of calendar years. Instead, for two samples (DBT-4, DBT-5) the 1σ distribution corresponds to two ranges, for three samples (DBT-1, DBT-6) it is consistent with three ranges, while for one sample (DBT-3) it corresponds to four ranges. In these cases, the confidence interval of one range is considerably greater than that of the others; therefore, it was selected as the cal CE range of the sample for the purpose of this discussion.

For obtaining single calendar age values of samples, we derived a mean calendar age of each sample, called assigned year, from the selected range (marked in bold). Sample ages represent the difference between the year 2024 CE and the assigned year, with the corresponding error. Sample ages and errors were rounded to the nearest 5 yr.

This approach for selecting calibrated age ranges and single values for sample ages was used in all our previous articles on AMS radiocarbon dating of large and old angiosperm trees.

Dating results of punctiform samples. As mentioned, the tri-stemmed Derby Boab Tree exhibits a closed ring-shaped structure, that consists of a ring of three perfectly fused stems disposed around a false cavity. This false cavity represents an empty space that was never filled with wood and is covered by bark. Over time, stem growth determines the false cavities to become progressively smaller. Even more, false cavities may close completely or incompletely, by maintaining a small opening/door. In such cases, the age sequence of samples extracted from the cavity walls shows a continuous increase up to a certain depth into the wood, after which it decreases toward the exterior. Research revealed that the oldest part of the fused stems is found between the false cavity walls and the outer part (exterior) of each stem, being always closer to the cavity than the exterior [10].

Table 1. AMS Radiocarbon dating results and calibrated ages of punctiform samples collected from the Derby Boab Tree

Sample code	Distance from cavity wall / from exterior [height] (m)	Radiocarbon date [error] (^{14}C yr BP)	Cal CE range 1σ [confidence interval]	Assigned year [error] (cal CE)	Sample age [error] (cal CE)
DBT-1	0.01 / 0.39 [1.35]	210 [± 18]	1672-1685 [13.5%] **1732-1782 [46.9%]** 1797-1805 [7.9%]	1777 [± 25]	245 [± 25]
DBT-2	0.08 / 0.32 [1.35]	445 [± 20]	**1450-1486 [68.3%]**	1468 [± 18]	555 [± 20]
DBT-3	0.17 / 0.23 [1.35]	1285 [± 21]	690-704 [10.2%] 718-737 [12.7%] 787-797 [5.9%] **819-855 [39.6%]**	837 [± 18]	1185 [± 20]
DBT-4	0.24 / 0.16 [1.35]	930 [± 18]	**1153-1188 [56.8%]** 1197-1209 [11.5%]	1170 [± 17]	855 [± 15]
DBT-5	0.32 / 0.08 [1.35]	352 [± 17]	**1510-1584 [63.8%]** 1625-1628 [4.5%]	1757 [± 37]	265 [± 35]
DBT-6	0.39 / 0.01 [1.35]	151 [± 19]	1698-1723 [16.6%] **1834-1891 [35.3%]** 1924-... [16.4%]	1862 [± 28]	160 [± 30]

The oldest investigated punctiform sample DBT-3 originated from a depth of 0.17 m from the cavity walls and 0.23 m from the exterior. Its radiocarbon date of 1285 ± 21 BP corresponds to a calibrated age of 1185 ± 20 calendar yr.

The two youngest samples, DBT-1 and DBT-6, were extracted from wood layers adjacent to the false cavity (DBT-1) and to the external bark (DBT-6). Their radiocarbon dates of 210 ± 18 BP and 151 ± 19 BP correspond to calibrated ages of 245 ± 25 and 160 ± 30 calendar yr. These values demonstrate that the stem which corresponds to the right side of the cavity door stopped growing around 245 yr ago from the false cavity and 160 yr ago toward the exterior, due to old age.

The other three punctiform samples, DBT-2, DBT-4 and DBT-5, have intermediary radiocarbon dates and calibrated ages between the oldest sample DBT-3 and the youngest samples DBT-1 and DBT-6.

Age of the Derby Boab Tree. The age of the stem corresponding to the right side of the cavity door was determined by extrapolating the age of the oldest punctiform sample DBT-3 to the point of maximum age at sampling height. The oldest dated sample DBT-3 had a calibrated age of 1185 ± 20 calendar yr, and it was extracted from a depth of 0.17 m into the cavity walls, at 0.23 m from the corresponding exterior of the tree. This point, must also be very close to the point of maximum age. We consider that the stem is between 1200 -1300 old, i.e. its age is of 1250 ± 50 years.

According to our research, for baobabs with a closed ring-shaped structure and a quasi-spherical or cylindrical trunk, the stems that build the ring have close or identical ages. Thus, the age of the investigated stem can also be considered as the age of the Derby Boab Tree.

CONCLUSIONS

The study reports the AMS radiocarbon investigation results of the historic Derby Boab Tree from Derby, Kimberley, Australia. The tree is usually presented as a prison tree, were chained Aboriginal prisoners were temporarily incarcerated in its hollow trunk by colonial police. However, according to recent research, there is no evidence to support the myth that the Derby boab was ever used as a prison tree. The boab has a closed ring-shaped structure that comprises three perfectly fused stems around an empty space called false cavity, a common feature among very large individuals of the *Adansonia* genus. Six punctiform samples were collected from the cavity door, by using a novel methodology. The oldest dated punctiform sample had a radiocarbon date of 1285 ± 21 BP, which corresponds to a calibrated age of 1185 ± 20 calendar years. This result shows that the Derby Boab Tree is 1250 ± 50 years old. It can be stated that the Derby Boab Tree started growing around 775 CE.

EXPERIMENTAL SECTION

Sample collection. The punctiform wood samples were extracted in a non-invasive manner from predetermined positions with a stainless steel pair of tweezers. The extracted punctiform sample was introduced in a small conical aluminium tube for preventing contamination. Next, the punctiform sample was pretreated and investigated by AMS. The AMS, which counts directly C-14 atoms, needs less than 10^{-6} kg (0.001 g) wood for an accurate dating.

Sample preparation. The modified α-cellulose extraction method was used for removing soluble and mobile organic components [40]. The pretreated samples were combusted to CO_2 by using the closed tube combustion method [41]. Next, CO_2 was reduced to graphite on iron catalyst [42]. Eventually, the resulting graphite samples were investigated by AMS.

AMS measurements. AMS radiocarbon measurements were performed at the NOSAMS Facility of the Woods Hole Oceanographic Institution (Woods Hole, MA, U.S.A.), by using the Pelletron ® Tandem 500 kV AMS system. The obtained fraction modern values, corrected for isotope fractionation with the normalized $\delta^{13}C$ value of $-25^0/_{00}$, were converted to a radiocarbon date.

Calibration. Radiocarbon dates were calibrated and converted into calendar ages with the OxCal v4.4 for Windows [43], by using the SHCal20 atmospheric data set [44].

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