forests

Article

Radiocarbon Investigation of the Historic African Baobabs of Omusati, Namibia

Adrian Patrut [1,2,*], Roxana T. Patrut [1], Laszlo Rakosy [3], Demetra Rakosy [4,5], Willie Oliver [6], Ileana Andreea Ratiu [1,2], Daniel A. Lowy [7,8], Gebhardt Shiimbi [9], Stephan Woodborne [10] and Karl F. von Reden [11]

1 Faculty of Chemistry and Chemical Engineering, Babeş-Bolyai University, 11 Arany Janos, RO-400028 Cluj-Napoca, Romania
2 Raluca Ripan Institute for Research in Chemistry, Babeş-Bolyai University, 30 Fantanele Cluj-Napoca, RO-400294 Cluj-Napoca, Romania
3 Faculty of Biology and Geology, Babeş-Bolyai University, 44 Republicii, RO-400015 Cluj-Napoca, Romania
4 Department for Community Ecology, Helmholtz Centre for Environmental Research—UFZ, 15 Permoserstr, D-04318 Leipzig, Germany
5 AG Spatial Interaction Centre, Centre for Integrative Biodiversity Research, 5e Deutscher Platz, D-04103 Leipzig, Germany
6 Independent Researcher, Windhoek 10005, Namibia
7 Genesis Sustainable Future Ltd., 33 Rakoczi St., H-3950 Sarospatak, Hungary
8 Department of Mathematics, Science, and Engineering, Northern Virginia Community College, 5000 Dawes Av., Alexandria, VA 22311, USA
9 Ombalantu Baobab Tree Heritage Site, Outapi P.O. Box 15, Namibia
10 iThemba LABS, Private Bag 11, WITS, Johannesburg 2050, South Africa
11 Woods Hole Oceanographic Institution, NOSAMS Facility, Woods Hole, MA 02543, USA
* Correspondence: apatrut@gmail.com

Abstract: The Omusati region belongs to historic Ovamboland, an area of northern Namibia populated by tribes of the Ovambo group. Four very large African baobabs of Omusati played an important role in historic events of the area, such as the tribal wars and the Namibian War of Independence. The four historic baobabs are the Ombalantu baobab (8 stems; circumference 24.50 m), Okahao baobab (4+ stems; around 25 m), Amadhila baobab (12 stems; 25.35 m) and Sir Howard baobab (9 stems; 31.60 m). Two historic baobabs collapsed totally or partially. The stems of the Amadhila baobab toppled and died in 2021, while 3 stems of the Okahao baobab collapsed a long time ago, but are still alive. Our research aimed to determine the architecture and age of these baobabs. Three baobabs (Ombalantu, Amadhila, Sir Howard) exhibit a closed ring-shaped structure, with a false cavity inside. One baobab (Okahao) had an open ring-shaped structure, before its collapse. Several wood cores were extracted from the baobabs and investigated by radiocarbon dating. The dating results indicate ages of 770 ± 50 years for the Ombalantu baobab, 650 ± 50 years for the Okahao baobab, 1100 ± 50 years for the Amadhila baobab and 750 ± 50 years for the Sir Howard baobab.

Keywords: age determination; radiocarbon dating; *Adansonia digitata*; ring-shaped structure; false cavity; multiple stems

check for updates

Citation: Patrut, A.; Patrut, R.T.; Rakosy, L.; Rakosy, D.; Oliver, W.; Ratiu, I.A.; Lowy, D.A.; Shiimbi, G.; Woodborne, S.; von Reden, K.F. Radiocarbon Investigation of the Historic African Baobabs of Omusati, Namibia. *Forests* **2022**, *13*, 1899. https://doi.org/10.3390/f13111899

Received: 13 October 2022
Accepted: 8 November 2022
Published: 11 November 2022

1. Introduction

The African baobab (*Adansonia digitata* L.) is the most widespread of the eight recognised species of the *Adansonia* genus, which belongs to the Bombacoideae subfamily of the Malvaceae family. This iconic tree is endemic to the arid savanna of continental Africa, between the latitudes 16° N and 26° S. It can also be found on several African islands and outside Africa, in different regions throughout the tropics, where it has been introduced [1–7].

The African baobab typically occurs as a solitary tree or in small scattered groups in the savanna and also along roads. It is often associated with settlements, where it may develop small baobab groves. The baobab distribution and density mainly depend on abiotic factors (temperature, rainfall, altitude, soil) and on anthropogenic factors (settlements, human activity, such as land clearing for agriculture, real estate constructions, or, more recently, to provide raw material for cement factories).

There are very large and dense baobab populations in Senegal, especially in the Thiès, Dakar, Fatick and Tambacounda regions. There are dense baobab stands on the shell deposits of estuaries and lagoons, which confirms its penchant for calcium. Baobabs thrive on limestone, marl and basalt. In the above-mentioned Senegalese regions, there are several baobab forests, composed exclusively or almost exclusively of baobabs. According to our observations, these impressive baobab forests occupy areas up to several tens of km^2 and have a crown cover between 20 and 50%. Some smaller baobab forests exist in western Mali and southern Sudan [1–3,6,7].

The African baobab has a high ecological tolerance. It grows in zones with annual rainfall between 100 and 2000 mm, on a variety of well-drained soils, as long as sufficient anchoring for the shallow root system is guaranteed [2,7,8]. The fruit of the African baobab is a superfood due to the high bioavailability of micro- and macronutrients rendering it ideal for supplementing and diversifying the diet, thus contributing to combating malnutrition and malabsorption, especially in disadvantaged areas of Africa [9,10]. There are over 300 documented uses for *A. digitata*, which demonstrate its valuable potential for cultivation and sustainable development [8,10]. Furthermore, the environmental envelope, the long lifespan and the superlative size of this multipurpose tree indicate it is well suited for mitigating and adapting to climate change as it grows well in drylands and may accumulate and store carbon for thousands of years.

We started an extended research study in 2005 on the development, age and architecture of the African baobab. Our research relies on AMS (accelerator mass spectrometry) radiocarbon dating of small wood samples extracted from the exterior of large baobabs, inner cavities, fractured stems and/or deep incisions in the trunk [11–20]. The investigation revealed that all large and old baobabs are multi-stemmed and have preferentially closed or open ring-shaped structures. African baobabs are longevous trees, the age of the oldest individuals was found to be up to 2500 years [14,16,17].

Namibia is among the African countries with the largest number of baobabs. Here, the local abundance and distribution of baobab trees are very different in the 14 regions, restricted by climatic conditions, soil type and altitude [21,22]. The greatest density and number of baobabs can be found in the north-central part of Namibia, namely in the Omusati region, which has a surface area of 26,551 km^2. Recently, a survey established the density of baobabs in Omusati to have a mean value of 6.7 trees/ha, which would lead to a total number of 17.80 million individuals in this region [21]. We consider that such excessively high estimates for large areas should be verified by satellite imagery.

The Omusati region has a semi-arid climate, with rainfall occurring during the summer (from November to April). The vegetation belongs to the Angolan Mopane woodland ecoregion with the African baobab a conspicuous natural feature [22].

Our survey in Omusati identified 11 monumental baobab trees, with a circumference exceeding 20 m, out of which 6 individuals can be found in and around Outapi, 3 are located in Onesi, one in Okahao and one in Tsandi. The high baobab density, especially around Okahao, Outapi and Onesi and the great number of superlative specimens are also due to vast areas rich in sandy soils, sodium and calcium. Outapi lies close to the border with Angola and is the capital of Omusati. It hosts 6 superlative baobabs spread over a surface area of less than 10 km^2 [23].

The Omusati region belongs to historic Ovamboland (or Owamboland). The Ovambo ethnic group includes nine communities, which had been involved in several violent tribal wars.

In 1870, the Finnish Lutheran Church sent in missionaries to Christianise this part of Africa. The Ovambo people were predominantly converted, hence they identified themselves as Lutheran Christians [24].

After the First World War, the Namibian territory was annexed to the South African administration by the British, becoming the South West Africa province. The South African Border War, also called the Namibian War of Independence, had a crucial importance for present-day Namibia, Ovamboland and for the Ovambo community. The Border War spanned from August 1966 to March 1990, and was fought by the South West African People's Organisation (SWAPO) against the South African Defence Force (SADF). The Border War ended with the victory of SWAPO, and in March 1990, Namibia gained independence from South Africa [25].

Some very large and old-looking African baobabs witnessed important events, were discovered and visited by early explorers, or had special destinations in the past. Such trees, some of which have been declared natural monuments, can be considered historic baobabs. Over the past years, we investigated and dated by radiocarbon several famous historic baobabs, such as the Chapman baobab (Botswana) [18], Ngouye Ndiouly (Senegal) [16], the Big tree at Victoria Falls (Zimbabwe) [26], Dorslandboom (Namibia), Leydsdorp baobab (South Africa) and the Livingstone tree at Chiramba (Mozambique) [27].

Four of the superlative baobabs of Omusati played an important role in the violent historic events of this region; therefore, they can be considered historic baobabs. These are the Ombalantu baobab, Okahao baobab, Amadhila baobab and Sir Howard baobab (Figure 1).

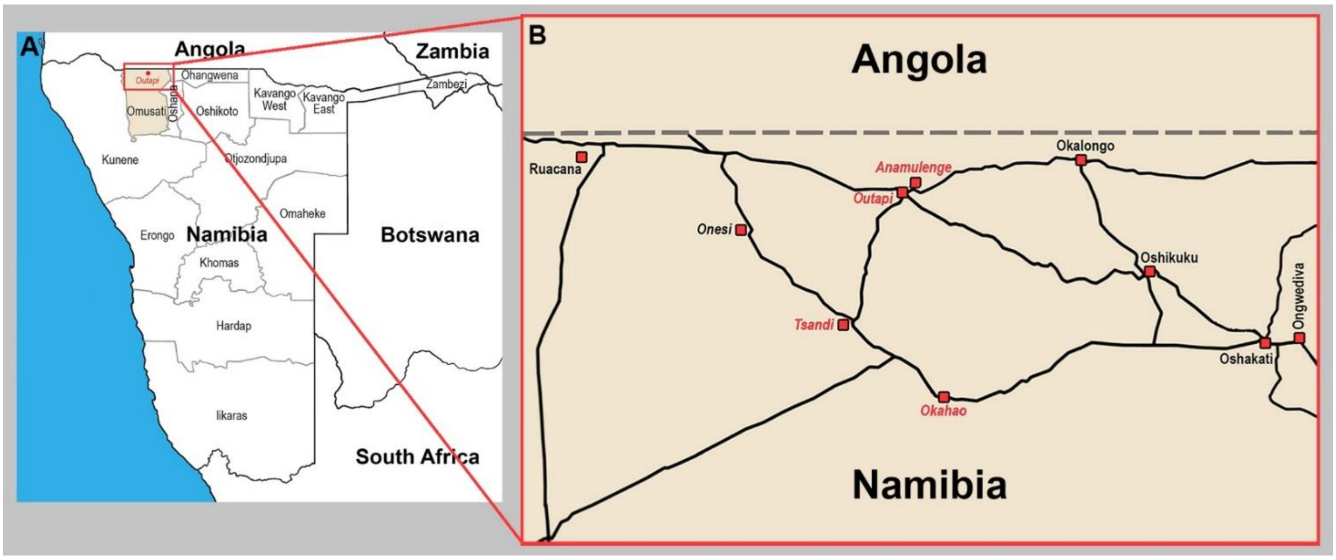

Figure 1. Map showing Namibia and its 14 regions. The Omusati Region and its capital Outapi are displayed in color (**A**). Close-up of the Omusati Region showing the main localities and roads. The localities that host large baobabs are written in italics and the localities that host the investigated historic baobabs are in red (**B**).

In this paper we report the investigation and AMS radiocarbon dating results of the four historic baobabs of Omusati.

2. Material and Methods

2.1. The Four Historic Baobabs and Their Areas

The legendary **Ombalantu baobab**, locally known as Omukwa waaMbalantu ("tree of life" in Oshiwambo) (Figure 2), is the focal point of the Ombalantu Baobab Tree Heritage Centre in Outapi, located just behind the open market, along the Outapi-Tsandi road. Its GPS coordinates are 17°30.710′ S, 014°59.274′ E and the altitude is 1116 m asl. The mean annual rainfall in Outapi is 367 mm.

Figure 2. The Ombalantu baobab inside the Ombalantu Baobab Tree Heritage Site (opened in 2013). The door to the cavity has a height of 1.76 m.

The history of the tree is very impressive being connected to the history of the Aambalantu people (inhabitants of the Ombalantu Kingdom). In 1835, the King of Ombalantu died and the Aambalantus, therefore, remained without a ruler. Other tribes from the area started attacking the Aambalantu people, stealing their cattle, capturing their people as slaves and killing many of them. Over these difficult times, the hollow trunk of the Ombalantu baobab served as a sanctuary and refuge to the Aambalantu people. A scenic entrance to the cavity, in the shape of a door, was carved into the trunk close to ground level, just between two buttressed stems. Previously, access into the cavity was possible through a much smaller entrance, close to the top. Women and children could be protected inside the cavity during the invasion of other tribes [24].

In 1940, the Ombalantu baobab became the first official Post Office in Outapi. People writing letters to relatives or friends left their messages here, which were then collected from the cavity.

The Ombalantu baobab, which played an important role in the history of the Ovambo community that was converted to Christianity, was also used as a chapel. The stone pulpit and three benches in the large cavity of the tree are reminders of its use as a chapel (Figure 3).

In 1975, during the Border War, a South African military base was built around the Ombalantu baobab and became a place where local people were harassed by the South West African Police (Figure 4).

In 2003 the Ombalantu site was recognised as a historical monument and a tourist attraction. In September 2011, the Ombalantu baobab was declared a National Heritage Centre by the National Heritage Council of Namibia [28].

Figure 3. The false cavity of the Ombalantu baobab with the stone pulpit that served as an altar and benches.

The Ombalantu baobab has a maximum height h = 20.1 m, a circumference at breast height (i.e., at 1.30 m above ground level) cbh = 24.50 m and an overall wood volume V = 230 m^3. The multi-stemmed trunk is composed of 7 fused stems, out of which 6 are common (ordinary) stems and one is a false stem (for details see Section 2.2). It also has several buttressed stems. The baobab displays a closed ring-shaped structure enclosing a false cavity, i.e., a cavity which was never filled with wood. An opening with the shape of a door, 1.76 m high and 0.90 m wide provides access to the large false cavity, which has a base of 3.08 × 2.30 m and a height of 8.32 m. The cavity can accommodate over 25 people. The horizontal dimensions of the canopy are 33.8 (NS) × 28.0 m (WE).

The **Okahao baobab** is the central point of the Okahao Baobab National Heritage Site in Okahao, a town located 55 km south of Outapi. Its GPS coordinates are 17°53.555′ S, 015°03.932′ E and the altitude is 1097 m. The mean annual rainfall in Okahao is 850 mm. Okahao is found in the Ongandjera tribal area inhabited by the Aangandjera people.

In September 2011, the Okahao baobab was declared a National Heritage Site in memory of the dramatic events that happened there during the South African Border War. Scripts and drawings by the South African colonial army are still visible all over the tree. The Okahao baobab is considered a true symbol of the Namibian struggle for independence [29].

The Okahao baobab is a "lying tree", i.e., "le boom" in Afrikaans (Figure 5), such as two other very large Namibian baobabs, namely Dorslandboom and Makuri Lê boom. The baobab possesses an open ring-shaped structure composed of 4 units (stems), out of which only the largest unit (stem), with a diameter of 5 m, is still standing upright. The tree suffered a major collapse over one century ago, when 3 stems, with diameters of 2.5 to 3 m, toppled. The collapsed stems are still alive and new stems and branches emerged at their tops.

Figure 4. The Ombalantu baobab witnessed many violent events during the South African Border War. The photograph was taken in 1980.

Figure 5. General view of the partially collapsed Okahao baobab inside the Okahao Baobab National Heritage Site (opened in 2013).

The largest unit now consists of the original large old stem and 4 young and short false stems. It has a height h = 15.7 m and a circumference cbh = 14.80 m. The old stem also has a relatively large normal cavity formed by wood decay. The cavity is up to 1.30 m tall and has a large entrance at ground level (Figure 6). Two stems are completely fallen and each has 3 regrowth stems. Finally, a fourth stem, positioned between the two fallen stems, is inclined at 45° and leans on a wooden formation like an anchor. The (restored) circumference cbh of the Okahao baobab before the collapse was around 25 m. The horizontal dimensions of the canopy are 34.2 (NS) × 30.5 m (WE).

Figure 6. Detail of the largest unit of Okahao baobab which is still standing upright. The normal cavity can be seen at the base of the main stem.

The **Amadhila baobab** is/was located at the edge of Omundjalala village of the Anamulenge commune, a suburb of Outapi, only 12 km from the border with Angola. Its GPS coordinates are 17°30.106′ S, 015°00.933′ E and the altitude is 1125 m. The mean annual rainfall in the area is 367 mm.

Amadhila was a very large baobab in the traditional area of the Aambalantu community that was used as a fortification when, during the first decades of the 19th century, the Aambalantu people were attacked by other communities.

The baobab was named after Amadhila, a skilled Bushman (San) craftsman captured by Aambalantu warriors. Amadhila made spears and arrows and taught Aambalantu warriors how to prepare poison for their arrows [30].

The Amadhila baobab (Figure 7) had a maximum height h = 19.2 m, a circumference cbh = 25.35 m and an overall wood volume V = 200 m^3. The tetragonal trunk consisted of 12 fused stems, out of which 8 were common (ordinary) stems and 4 were false stems. Two of the false stems were very long (3.40 and 2.85 m) and disposed of in a V-shape. The tree exhibited a closed ring-shaped structure with a false cavity inside. The false cavity, defined by 5 stems, had an opening toward the exterior at the height of 3.50 m. The dimensions of the false cavity at ground level were 4.56 × 1.84 m and its height was 4.57 m. The horizontal dimensions of the large canopy were 34.5 (WE) × 32.8 m (NS).

Unfortunately, on 10 April 2021, several stems broke off and collapsed after sparks from a nearby fire accidentally set the baobab alight (Figure 8). Because the fire spread through the cavity, it seemed inevitable that the other stems would also collapse in the near future. As expected, on 8 November 2021 the other remaining stems fell. Only one stem, which is now dry, was still standing in July 2022 (Figure 9).

Figure 7. General view of the Amadhila baobab taken from the north-west, when the tree was still standing.

Figure 8. The image shows the Amadhila baobab after the first collapse of April 2021, when several stems toppled toward the west.

Figure 9. In July 2022, only one stem of the Amadhila baobab was still standing.

Sir Howard baobab is found in the self-governed village Tsandi, located 31 km south of Outapi. Its GPS coordinates are 17°44.871′ S, 014°53.697′ E and the altitude is 1113 m. The mean annual rainfall in Tsandi is 379 mm.

This very large baobab was named after Sir Edmond Howard Lacam Gorges (1872–1924), the first Administrator of South West Africa, who visited Ovamboland in June 1916 [30].

The Sir Howard baobab (Figure 10) has a maximum height h = 23.8 m, a circumference cbh = 31.60 m and an overall wood volume V = 300 m^3. In terms of circumference, Sir Howard baobab ranks fifth in the world, after Holboom, Sagole big tree, Makuri Lê boom and Dorslandboom [13]. Its trunk consists of 9 stems, out of which 5 are common (ordinary) stems and 4 are false stems. Two false stems, disposed of in a V-shape, are extremely long (4.76 m and 2.87 m, with a distance of 4.42 m between them), so they enable better stability in the sandy soil (Figure 11). Sir Howard baobab exhibits a closed ring-shaped structure, with a large false cavity defined by 3 stems. The false cavity, with the dimensions of 3 × 4 × 4 m is practically closed; however, it can be accessed in a very unusual way through an opening in a false stem, at the height of 2.60 m. The horizontal dimensions of the canopy are 33.5 (WE) × 32.1 m (NS).

Figure 10. General view of Sir Howard baobab taken from the south.

Figure 11. Another view of Sir Howard baobab taken from the west, showing to the right the two long false stems disposed in a V-shape.

2.2. Architecture of the Four Historic Baobabs

Our long-term research has revealed that all big baobabs are multi-stemmed. This feature of baobabs is the result of their ability to produce new stems periodically, such as other tree species generate branches [13,19,31]. It is obvious that the four historic baobabs, all with circumferences over 24 m, consist or consisted of several fused stems, i.e., 7 stems for Ombalantu, 4+ stems for Okahao, 12 stems for Amadhila and 9 stems for Sir Howard. The latest photographs of the Amadhila baobab, showing its stems that toppled successively (Figures 8 and 9), are suggestive in this regard.

Many researchers still consider an important parameter for large baobabs to be their diameter calculated from the circumference value. In fact, one can discuss about a diameter of large baobabs exclusively in the case of smaller single-stemmed individuals.

Baobab stems typically emerge from the roots or from broken or fallen stems. Radiocarbon dating results indicate that, in addition to common or ordinary stems, false stems also exist. False stems are triangular or tetragonal in a horizontal section and emerge from a large adjacent stem. The oldest age can be found towards the upper contact with the adjacent stem. Sometimes, baobabs have two false stems disposed of in a V-shape, displaying a 30–60° opening. False stems can reach lengths up to 3–5 m and provide a much better anchorage and stability in sandy soils. The Ombalantu, Amadhila and Sir Howard baobabs possess such false stems [19,27].

We also determined a novel architecture, which enables baobabs to attain large sizes and old ages. In this new structure, named by us ring-shaped structure (RSS), the stems define at ground level a circle or an ellipse creating an empty space between them. The RSS includes two subtypes, i.e., the open RSS and the closed RSS [11,13].

The most spectacular is the closed RSS, in which the perfectly fused stems are disposed of in a ring enclosing an empty space, which was never filled with wood. This empty space between the fused stems was referred to as a false cavity [15,17,23,31]. For closed RSS with a false cavity inside, we found an anomalous age sequence. Thus, for samples collected from the false cavity walls toward the exterior, as well as for samples collected from the exterior toward the false cavity, ages increase from the sampling point up to a point of maximum age, after which ages decrease in the opposite direction.

The four historic baobabs exhibit or exhibited RSSs. Before its main collapse, the Okahao baobab had an open RSS, with 4 stems disposed in a ring. The other three baobabs present or presented a closed RSS with a false cavity inside, defined by 6 fused stems (Ombalantu), 5 stems (Amadhila) and 3 stems (Sir Howard). All three baobabs have or had false cavities with high openings, at the height of several meters, which are more frequent in northern Namibia. Unfortunately, for Sir Howard baobab and especially for Amadhila baobab the base of their false cavities has become a dump of garbage and waste (Figure 12).

The misleading statements that the cavities of Amadhila and especially of Ombalantu baobab (with a height over 8 m) would have been formed via hollowing out the trees by locals during the tribal wars are often accepted [28]. In fact, these false cavities are part of the internal structure of the baobabs, representing natural empty spaces. Thus, samples collected from the cavity Ombalantu baobab exhibit the anomalous age sequence characteristic for false cavities.

Figure 12. The base of the false cavity of the Amadhila baobab was covered by scraps, trash and waste, thrown through the high opening at the height of 3.50 m.

2.3. Investigation of the Four Historic Baobabs

Sample collection. Three wood cores were collected from the stems of each baobab, using a Haglöf increment borer (0.80 m long, 0.0108 m inner diameter) (Figure 11). After each coring, the increment borer was cleaned and disinfected with methyl alcohol. The small coring holes were sealed with Steriseal (Efekto), a special polymer sealing product, which prevents any infection of the trees.

Several tiny pieces/segments, of the length of 10^{-3} m (1 mm), were extracted from each sample. Here we present and discuss the dating results of the oldest dated segment extracted from each sample, with the exception of sample OMB-1, for which two dated segments were chosen.

Sample preparation. The α-cellulose pretreatment method was used for removing soluble and mobile organic components [32]. The resulting cellulose samples were combusted to CO_2, which was next reduced to graphite on an iron catalyst [33,34]. The graphite samples were analysed by AMS.

AMS measurements. The AMS radiocarbon measurements of the samples collected from the Ombalantu baobab (OMB-1a, OMB-1b, OMB-2 and OMB-3) and Sir Howard baobab (HOW-1, HOW-2 and HOW-3) were performed at the NOSAMS Facility of the Woods Hole Oceanographic Institution by using the Pelletron®®Tandem 500 kV AMS system [35,36].

Radiocarbon measurements of the samples extracted from the Okahao baobab (OKA-1, OKA-2 and OKA-3) and Amadhila baobab (AMA-1, AMA-2 and AMA-3). were conducted at the AMS Facility of the iThemba LABS, Johannesburg, Gauteng, South Africa, using the 6 MV Tandem AMS system [37].

The obtained fraction of modern values were finally converted to a radiocarbon date. The radiocarbon dates and errors were rounded to the nearest year.

Calibration. Radiocarbon dates were calibrated and converted into calendar ages with the OxCal v4.4 for Windows [38], by using the SHCal20 [39] atmospheric data set [40].

3. Results and Discussion

3.1. Radiocarbon Dates and Calibrated Ages

Radiocarbon dating results of the 13 sample segments that originate from the four historic African baobabs are presented in Table 1. Radiocarbon dates are expressed in ^{14}C yr BP (radiocarbon years before the present, i.e., before the reference year 1950) and were rounded to the nearest year together with their corresponding errors.

Table 1. Radiocarbon dating results and calibrated ages of sample segments collected from the Ombalantu (OMB), Okahao (OKA), Amadhila (AMA) and Sir Howard (HOW) baobabs.

Sample/ Segment Code	Depth [1] [Height [2]] (m)	Radiocarbon Date [Error] (^{14}C yr BP)	Cal CE Range 1σ [Confidence Interval]	Assigned Year [Error] (cal CE)	Sample/ Segment Age [Error] (cal CE)	Accession #
OMB-1a	0.59 [1.32]	679 [±19]	**1300–1324 (30.6%)** 1346–1364 (22.9%) 1378–1390 (14.7%)	1312 [±12]	710 [±10]	OS-85751
OMB-1b	0.40 [1.32]	335 [±23]	**1510–1550 (36.5%)** 1560–1578 (14.1%) 1622–1640 (17.7%)	1530 [±20]	490 [±20]	OS-91318
OMB-2	0.54 [1.30]	646 [±26]	**1320–1354 (52.7%)** 1386–1397 (16.4%)	1337 [±17]	685 [±15]	OS-85762
OMB-3	0.30 [2.12]	411 [±27]	**1459–1502 (47.9%)** 1595–1615 (20.4%)	1480 [±21]	540 [±20]	OS-85142
OKA-1	0.60 [0.75]	604 [±22]	1328–1338 (17.0%) **1392–1413 (51.3%)**	1402 [±10]	620 [±10]	IT-C-2698
OKA-2	0.54 [0.78]	507 [±28]	**1429–1451 (68.3%)**	1440 [±11]	580 [±10]	IT-C-1714
OKA-3	0.66 [4.80]	471 [±38]	**1431–1488 (68.3%)**	1459 [±28]	565 [±30]	IT-C-2226
AMA-1	0.68 [1.45]	1067 [±35]	**988–1044 (68.3%)**	1016 [±28]	1005 [±30]	IT-C-2223
AMA-2	0.62 [1.48]	923 [±25]	**1155–1210 (68.3%)**	1182 [±27]	840 [±25]	IT-C-1685
AMA-3	0.33 [2.05]	625 [±20]	**1324–1345 (45.7%)** 1391–1401 (16.1%)	1334 [±10]	690 [±10]	IT-C-2225
HOW-1	0.66 [1.51]	648 [±17]	**1322–1352 (57.3%)** 1388–1394 (10.9%)	1337 [±15]	685 [±15]	OS-136722
HOW-2	0.53 [1.54]	443 [±23]	**1450–1496 (68.3%)**	1478 [±28]	545 [±30]	OS-121267
HOW-3	0.32 [2.40]	342 [±20]	**1510–1550 (39.3%)** 1560–1579 (17.1%) 1622–1635 (11.8%)	1530 [±20]	490 [±20]	OS-136086

[1] Depth into the wood from the sampling point. [2] Height above ground level.

Calibrated (cal) ages, which are expressed in calendar years CE (CE, i.e., Common Era), are also disclosed in Table 1. For deriving calibrated age ranges, we selected the 1σ probability distribution (68.3%). For five segments (OKA-2, OKA-3, AMA-1, AMA-2, HOW-2), the 1σ distribution is consistent with one range of calendar years. For other five segments (OMB-2, OMB-3, OKA-1, AMA-3, HOW-1), the 1σ probability distribution corresponds to two ranges of calendar years and for three segments (OMB-1a, OMB-1b, HOW-3) it corresponds to three ranges. In the last eight cases, the confidence interval of one range is significantly greater than that of the other (s); hence, it was selected as the cal CE range of the segment for the purpose of this discussion. For all investigated samples/segments, the selected age range is marked in bold in Table 1.

We derived an assigned year for each sample segment that corresponds to the mean value of the selected age range, with the error rounded to the nearest 5 yr. Sample segment ages, expressed in calendar years, represent the difference between the year 2022 CE (or 2021 CE for AMA-1, AMA-2 and AMA-3, when the corresponding stems died) and the assigned year. Sample ages and errors were rounded to the nearest 5 yr. This approach for selecting calibrated age ranges and single values for sample/segment ages was applied to our previous papers on radiocarbon dating of large angiosperms, in particular baobabs [11–20,23,31].

3.2. Stem Ages and Tree Ages

For the **Ombalantu baobab**, the first sample OMB-1 was taken from the cavity, above the altar, at the height of 1.32 m, where the thickness of the cavity walls is 1.60 m (without the external bark) (Figure 13). The sample OMB-1 had a length of 0.59 m. The segment OMB-1a, which represents the sample end, has a radiocarbon date of 679 ± 19 BP, which translates to a calibrated age of 710 ± 10 calendar yr. The segment OMB-1b originates from a distance of 0.40 m from the cavity walls. Its radiocarbon date of 335 ± 23 BP corresponds to a calibrated age of 490 ± 20 calendar yr. The ages of the two segments are in agreement with the anomalous age sequence characteristic to false cavities.

Figure 13. The oldest dated sample OMB-1 from the Ombalantu baobab originates from the walls of the false cavity, above the altar.

The second sample OMB-2 was also extracted from the cavity walls, but in the opposite direction, above the third bench. It had a length of 0.54 m and a radiocarbon date of

646 ± 26 BP, corresponding to a calibrated age of 685 ± 15 calendar yr. At the sampling point height, the cavity walls have a thickness of 1.58 m.

Eventually, the sample OMB-3 was collected from the false stem, under its upper contact with the adjacent stem from which it originates. Its radiocarbon date of 411 ± 27 BP translates to a calibrated age of 540 ± 20 calendar yr. This value is very close to the age of the false stem.

The age of the oldest part of Ombalantu baobab can be calculated by extrapolating the position and age of the oldest dated sample segment, OMB-1a, to the point of maximum age from the cavity walls at the height of the sampling point (by taking also into account an estimated growth rate). For false cavities, the point of maximum age is always closer to the cavity than to the exterior. In the sampling point OMB-1, we estimate that the point of maximum age is situated at 0.70 m from the cavity walls and 0.90 m from the exterior. In this case, the distance from the end of sample OMB-1 (which corresponds to segment OMB-1a), which is 710 yr old and the point of maximum age is 0.11 m. These values indicate an age of 770 ± 50 yr for the Ombalantu baobab.

For the **Okahao baobab**, the two oldest dated samples, OKA-1 and OKA-2, were collected close to the deepest end of the normal cavity in the large standing stem. The sampling points are located at distances of 1.66 and 1.61 m from the cavity entrance and at heights of 0.75 and 0.78 m. The lengths of the two samples are 0.60 and 0.54 m. The radiocarbon date of sample OKA-1 is 604 ± 22 BP and corresponds to a calibrated age of 620 ± 10 calendar yr, while sample OKA-2 has a radiocarbon date of 507 ± 28 BP and a calibrated age of 580 ± 10 calendar yr. The diameter of the large stem at sampling height is 4.80 m.

According to calculations, the end of sample OKA-1, which is 620 yr old, has a depth in the wood of 2.26 m and is situated at 0.14 m from the theoretical/calculated pith of the large stem. All these values indicate an age of 650 ± 50 yr for the largest stem of the Okahao baobab, which also represents the age of the oldest part of the tree.

The third sample OKA-3 was extracted from a fallen stem at 4.80 m from the base, where its diameter is 1.40 m. The sample length was 0.66 m. Its radiocarbon date of 471 ± 38 BP corresponds to a calibrated age of 565 ± 20 calendar yr. The sample end is positioned at 0.04 m from the theoretical/calculated pith. These values indicate an age of 580 ± 50 yr for the fallen stem.

For the fallen **Amadhila baobab**, the oldest dated sample AMA-1 was collected, at the height of 1.45 m, from the exterior of a stem from the southwestern part of the tree, which belonged to the ring of 5 stems that defined the false cavity. Sample AMA-1 had a length of 0.68 m and a radiocarbon date of 1067 ± 35 BP, corresponding to a calibrated age of 1005 ± 30 calendar yr. The thickness of cavity walls in the sampling point was 1.40 m.

The second sample AMA-2 was extracted from a neighboring stem which also belonged to the ring of 5. It had a length of 0.62 m, a radiocarbon date of 923 ± 35 BP and a calibrated age of 840 ± 25 calendar yr. In the sampling point area, the cavity walls were 1.38 m thick.

Finally, the third sample AMA-3 was extracted from the longest false stem (3.40 m), under its upper contact with the adjacent stem from which it emerged. Its radiocarbon date of 625 ± 20 BP translates to a calibrated age of 690 ± 10 calendar yr. This value is close to the age of the longest false stem, which was around 700 yr old.

The age of the Amadhila baobab can be calculated by extrapolating the position and age of the oldest dated sample segment AMA-1 to the point of maximum age from the cavity walls, at the sampling point height. We consider that, in the area of the sampling point, the point of the maximum age was situated at 0.60 m from the cavity and 0.80 m from the exterior. Thus, the distance from the end of sample AMA-1, which was 1005 yr old, and the point of maximum age was 0.12 m. These values indicate an age of 1100 ± 50 yr for the Amadhila baobab when it toppled. We can state that Amadhila was the oldest of the four historic baobabs of Omusati and started growing around the year 920 CE.

For **Sir Howard baobab**, the oldest dated sample HOW-1 was extracted at the height of 1.51 m from the exterior of a stem that belongs to the ring of 3 that delimits the false cavity.

Sample HOW-1 had a length of 0.66 m. Its radiocarbon date of 648 ± 17 BP corresponds to a calibrated age of 685 ± 15 calendar yr. In the sampling point, the thickness of the cavity walls is 1.30 m.

The second oldest sample HOW-2 originates from another stem which also belongs to the ring of 3. It was collected at the height of 1.54 m and had a length of 0.53 m. Sample HOW-2 has a radiocarbon date of 443 ± 23 BP, which corresponds to a calibrated age of 545 ± 30 calendar yr.

Sample HOW-3 originates from the longest false stem (4.76 m) right under its upper contact with the stem from which it emerged. Its radiocarbon date of 625 ± 20 BP corresponds to a calibrated age of 690 ± 10 calendar yr. This value is close to the age of the false stem, which was around 700 yr old.

The age of Sir Howard baobab can be calculated by extrapolating the position and age of the oldest dated sample segment HOW-1 to the point of maximum age from the cavity walls, at the height of 1.51 m. We estimate that, in the sampling point area, the point of the maximum age was situated at 0.55 m from the cavity and 0.75 m from the exterior. The distance from the end of sample HOW-1, which is 685 yr old, and the point of maximum age is 0.09 m. These values indicate an age of 750 ± 50 yr for the oldest part of Sir Howard's baobab.

4. Conclusions

Namibia hosts a large number of African baobabs. The greatest density can be found in the Omusati region, where at least 11 trees are superlative baobabs, with a circumference of over 20 m. The Omusati region belongs to historic Ovamboland, an area of northern Namibia. Four of the superlative African baobabs played an important role in the historic events of the area, such as violent tribal wars and the armed resistance of the Ovambo people against the colonial forces, especially during the Namibian War of Independence (1966–1990). The four historic baobabs of Omusati are the Ombalantu baobab (of Outapi; circumference 24.50 m), the Okahao baobab (of Okahao; around 25 m), the Amadhila baobab (of Anamulenge; 25.35 m) and Sir Howard baobab (of Tsandi; 31.60 m).

Our research reports the investigation of the architecture and age of the four historic baobabs. All four baobabs are multi-stemmed. They consist of 8 stems (Ombalantu), 4+ stems (Okahao), 12 stems (Amadhila) and 9 stems (Sir Howard). It should be mentioned that two historic baobabs collapsed totally or partially. A total of 11 of the 12 stems of the Amadhila baobab toppled and died in 2021, while 3 of the 4 stems of the Okahao baobab collapsed more than a century ago, but are still alive. Three baobabs (Ombalantu, Amadhila, Sir Howard) exhibit or exhibited a closed ring-shaped structure, with a false cavity inside. The Okahao baobab exhibited an open ring-shaped structure, before the major collapse.

Several wood cores were collected from the four historic baobabs, prepared and analysed by AMS radiocarbon dating. The oldest dated sample originates from Amadhila baobab. Its radiocarbon date is 1067 ± 35 BP, which translates to a calibrated age of 1005 ± 30 calendar years. The extrapolation of the oldest dated sample to the corresponding point of maximum age (for Ombalantu, Amadhila and Sir Howard) or to the pith of the corresponding stem (for Okahao) indicates the maximum ages of the four baobabs. These age values are 770 ± 50 years for Ombalantu, 650 ± 50 years for Okahao, 1100 ± 50 years for Amadhila and 750 ± 50 years for Sir Howard.

Owing to their rich history, the Ombalantu and the Okahao baobabs are protected. Had the Amadhila baobab been granted similar protection, the accidental fire that led to its demise could have been prevented. We recommend protection measures to be established as soon as possible for the Sir Howard baobab.

Based on our results, future baobab investigations in the Omusati Region could focus on pollution history and on past climate reconstruction. Studies on the carbon sequestration potential and changes in longevous African baobabs should be considered a priority for future research.

Author Contributions: Conceptualization A.P.; data curation I.A.R.; formal analysis R.T.P.; funding acquisition A.P.; investigation A.P., R.T.P., L.R., D.R. and G.S.; methodology A.P. and R.T.P.; project administration R.T.P.; resources A.P., R.T.P., L.R., W.O., I.A.R. and G.S.; software S.W. and K.F.v.R.; supervision A.P.; validation S.W. and K.F.v.R.; visualisation A.P. and W.O.; writing—original draft A.P. and R.T.P.; writing—review and editing L.R. and D.A.L. All authors have read and agreed to the published version of the manuscript.

Funding: The research was funded by the Romanian Ministry of Education and Research CNCS-UEFISCDI under grant PN-III-P4-ID-PCE-2020-2567, No. 145/2021.

Data Availability Statement: All data is contained within the article.

Acknowledgments and Ethics Statement: The investigation an d sampling of the baobabs was authorised by the Ministry of Environment and Tourism of Namibia through the Research/Collecting Permit 1934–2014.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Wickens, G.E. The Baobab–Africa's Upside-Down Tree. *Kew Bull.* **1982**, *37*, 172–209.
2. Wickens, G.E.; Lowe, P. *The Baobabs: Pachycauls of Africa, Madagascar and Australia*; Springer: Dordrecht, The Netherlands, 2008; 498p, ISBN 978-1-4020-6431-9.
3. Baum, D.A. A systematic revision of *Adansonia* (Bombacaceae). *Ann. Missouri Bot. Gard.* **1995**, *82*, 440–471. [CrossRef]
4. Baum, D.A.; Small, R.L.; Wendel, J.F. Biogeography and floral evolution of baobabs (*Adansonia*, Bombacaceae) as inferred from multiple data sets. *Syst. Biol.* **1998**, *47*, 181–207. [CrossRef]
5. Cron, G.V.; Karimi, N.; Glennon, K.L.; Udeh, C.A.; Witkowski, E.T.F.; Venter, S.M.; Assogbadjo, A.E.; Mayne, D.H.; Baum, D.A. One African baobab species or two? Synonymy of *Adansonia kilima* and *A. digitata*. *Taxon* **2016**, *65*, 1037–1049. [CrossRef]
6. Petignat, A.; Jasper, L. *Baobabs of the World: The Upside-down Trees of Madagascar, Africa and Australia*; Struik Publishers: Cape Town, South Africa, 2016; 112p, ISBN 9781775843702.
7. Gebauer, J.; Adam, Y.O.; Cuni Sanchez, A.; Darr, D.; Eltahir, M.E.S.; Fadl, K.E.M.; Fernsebner, G.; Frei, M.; Habte, T.-Y.; Hammer, K.; et al. Africa's wooden elephant: The baobab tree (*Adansonia digitata* L.) in Sudan and Kenya: A review. *Gen. Res. Crop. Evol.* **2015**, *63*, 377–399. [CrossRef]
8. Buchmann, C.; Prehsler, S.; Hartl, A.; Vogl, C.R. The Importance of Baobab (*Adansonia digitata* L.) in Rural West African Subsistence-Suggestion of a Cautionary Approach to International Market Export of Baobab Fruits. *Ecol. Food Nutr.* **2010**, *49*, 145–172. [CrossRef]
9. Muthai, K.U.; Karori, M.S.; Muchugi, A.; Indieka, A.S.; Dembele, C.; Mng'omba, S.; Jamnadass, R. Nutritional variation in baobab (*Adansonia digitata* L.), fruit pulp and seeds based on Africa geographical regions. *Food Sci. Nutr.* **2017**, *5*, 1116–1129. [CrossRef]
10. Asogwa, I.S.; Ibrahim, A.N.; Agbaka, J.I. African Baobab: Its Role In Enhancing Nutrition, Health, And The Environment. *Trees For. People* **2021**, *3*, 100043. [CrossRef]
11. Patrut, A.; von Reden, K.F.; Lowy, D.A.; Alberts, A.H.; Pohlman, J.W.; Wittmann, R.; Gerlach, D.; Xu, L.; Mitchell, C.S. Radiocarbon dating of a very large African baobab. *Tree Physiol.* **2007**, *27*, 1569–1574. [CrossRef]
12. Patrut, A.; Mayne, D.H.; von Reden, K.F.; Lowy, D.A.; Venter, S.; McNichol, A.P.; Roberts, M.L.; Margineanu, D. Age and Growth Rate Dynamics of an Old African Baobab determined by Radiocarbon Dating. *Radiocarbon* **2010**, *52*, 727–734. [CrossRef]
13. Patrut, A.; von Reden, K.F.; Van Pelt, R.; Mayne, D.H.; Lowy, D.A.; Margineanu, D. Age determination of large live trees with inner cavities: Radiocarbon dating of Platland tree, a large African baobab. *Ann. For. Sci.* **2011**, *68*, 993–1003. [CrossRef]
14. Patrut, A.; von Reden, K.F.; Mayne, D.H.; Lowy, D.A.; Patrut, R.T. AMS radiocarbon investigation of the African baobab: Searching for the oldest tree. *Nucl. Instr. Meth. B* **2013**, *294*, 622–626. [CrossRef]
15. Patrut, A.; Woodborne, S.; von Reden, K.F.; Hall, G.; Hofmeyr, M.; Lowy, D.A.; Patrut, R.T. African Baobabs with False Inner Cavities: The Radiocarbon Investigation of the Lebombo Eco Trail Baobab. *PLoS ONE* **2015**, *10*, e0117193. [CrossRef] [PubMed]
16. Patrut, A.; Woodborne, S.; von Reden, K.F.; Hall, G.; Patrut, R.T.; Rakosy, L.; Danthu, P.; Leong Pock-Tsy, J.-M.; Lowy, D.A.; Margineanu, D. The growth stop phenomenon of baobabs (*Adansonia* spp.) indentified by radiocarbon dating. *Radiocarbon* **2017**, *59*, 435–448. [CrossRef]
17. Patrut, A.; Woodborne, S.; Patrut, R.T.; Rakosy, L.; Lowy, D.A.; Hall, G.; von Reden, K.F. The demise of the largest and oldest African baobabs. *Nat. Plants* **2018**, *4*, 423–426. [CrossRef]
18. Patrut, A.; Woodborne, S.; Patrut, R.T.; Hall, G.; Rakosy, L.; Winterbach, C.; von Reden, K.F. Age, growth and death of a National icon: The historic Chapman baobab of Botswana. *Forests* **2019**, *10*, 983. [CrossRef]
19. Patrut, A.; Garg, A.; Woodborne, S.; Patrut, R.T.; Rakosy, L.; Ratiu, I.A.; Lowy, D.A. Radiocarbon dating of two old African baobabs from India. *PLoS ONE* **2020**, *15*, e0227352. [CrossRef]
20. Patrut, A.; Patrut, R.T.; Rakosy, L.; Ratiu, I.A.; Bodis, J.; Nassor, M.N.; von Reden, K.F. Radiocarbon investigation of two large African baobabs from Kizimkazi, Zanzibar, Tanzania. *Studia UBB Chemia* **2022**, *LXVII*, 143–153. [CrossRef]

21. Lisao, K.; Geldenhuys, C.J.; Chirwa, P.W. Assessment of the African baobab (*Adansonia digitata* L.) populations in Namibia: Implications for conservation. *Glob. Ecol. Conserv.* **2018**, *14*, e00386. [CrossRef]
22. Munyebvu, F.; Mapaure, I.; Kwembeya, E.G. Abundance, structure and uses of Baobab (*Adansonia digitata* L.) populations in Omusati Region, Namibia. *S. Afr. J. Bot.* **2018**, *119*, 112–118. [CrossRef]
23. Patrut, A.; Patrut, R.T.; Rakosy, L.; Rakosy, D.; Ratiu, I.A.; von Reden, K.F. Radiocarbon investigation of the Big baobab of Outapi, Namibia. *Studia UBB Chemia* **2021**, *LXVI*, 153–163. [CrossRef]
24. Nampala, L.; Shigweda, V. *Aawambo Kingdoms, History and Cultural Change, Perspective from Northern Namibia*; P. Schlettwein Publishing: Basel, Switzerland, 2006; pp. 21–64, 73–104. ISBN 978-3908193166.
25. Dale, R. *The Namibian War of Independence, 1966–1989: Diplomatic, Economic and Military Campaigns*; McFarland & Company, Incorporated Publishers: Jefferson, NC, USA, 2014; pp. 74–77, 93–95. ISBN 978-0786496594.
26. Patrut, A.; Patrut, R.T.; Rakosy, L.; Ratiu, I.A.; Lowy, D.A.; von Reden, K.F. Age, growth and architecture of the historic Big Tree at Victoria Falls assessed by radiocarbon dating. *Dendrochronologia* **2021**, *70*, 125898. [CrossRef]
27. Patrut, A.; Patrut, R.T.; Rakosy, L.; Lowy, D.A.; von Reden, K.F. Radiocarbon Dating of the Historic Livingstone Tree at Chiramba, Mozambique. *Studia UBB Chem.* **2020**, *LXV*, 149–156. [CrossRef]
28. Bause, T. History of the Ombalantu baobab tree. *The Namibian*, 31 August 2010; p. 1.
29. Okahao Baobab National Heritage Site. *Ombupupu.Okahao Town Counc. Newsl.* **2013**, *3*, 1–8.
30. Oliver, W. The Monumental Baobabs of Owambo. *FlyWestair* **2020**, 43.
31. Patrut, A.; Garnaud, S.; Ka, O.; Patrut, R.T.; Diagne, T.; Lowy, D.A.; Forizs, E.; Bodis, J.; von Reden, K.F. African baobabs with a very large number of stems and false stems: Radiocarbon investigation of the baobab of Warang. *Studia UBB Chem.* **2017**, *LXII*, 111–120. [CrossRef]
32. Loader, N.J.; Robertson, I.; Barker, A.C.; Switsur, V.R.; Waterhouse, J.S. An improved technique for the batch processing of small wholewood samples to α-cellulose. *Chem. Geol.* **1997**, *136*, 313–317. [CrossRef]
33. Sofer, Z. Preparation of carbon dioxide for stable carbon isotope analysis of petroleum fractions. *Anal. Chem.* **1980**, *52*, 1389–1391. [CrossRef]
34. Vogel, J.S.; Southon, J.R.; Nelson, D.E.; Brown, T.A. Performance of catalytically condensed carbon for use in accelerator mass-spectrometry. *Nucl. Instr. Meth. B* **1984**, *5*, 289–293. [CrossRef]
35. Povinec, P.P.; Litherland, A.E.; von Reden, K.F. Developments in Radiocarbon Technologies: From the Libby Counter to Compound-Specific AMS Analyses. *Radiocarbon* **2009**, *51*, 45–78. [CrossRef]
36. Roberts, M.L.; Burton, J.R.; Elder, K.L.; Longworth, B.E.; McIntyre, C.P.; von Reden, K.F.; Han, B.X.; Rosenheim, B.E.; Jenkins, W.J.; Galutschek, E.; et al. A high-performance ^{14}C Accelerator Mass Spectrometry system. *Radiocarbon* **2010**, *52*, 228–235. [CrossRef]
37. Mbele, V.L.; Mullins, S.M.; Winkler, S.R.; Woodborne, S. Acceptance Tests for AMS Radiocarbon Measurements at iThemba LABS, Gauteng, South Africa. *Phys. Proc.* **2017**, *90*, 10–16. [CrossRef]
38. Bronk Ramsey, C. Bayesian analysis of radiocarbon dates. *Radiocarbon* **2009**, *51*, 337–360. [CrossRef]
39. Hogg, A.G.; Heaton, T.J.; Hua, Q.; Palmer, J.G.; Turney, C.S.M.; Southon, J.; Bayliss, A.; Blackwell, P.G.; Boswijk, G.; Ramsey, C.B.; et al. SHCal20 Southern Hemisphere Calibration, 0–55,000 Years cal BP. *Radiocarbon* **2020**, *62*, 759–778. [CrossRef]
40. Hajdas, I.; Ascough, P.; Garnett, M.H.; Fallon, S.J.; Pearson, C.L.; Quarta, G.; Spalding, K.L.; Yamaguchi, H.; Yoneda, M. Radiocarbon dating. *Nat. Rev. Methods Primers* **2021**, *1*, 62. [CrossRef]