Radiocarbon, Vol 66, Nr 1, 2024, p 46–58 DOI:10.1017/RDC.2024.30

NEW PERSPECTIVES ON OLD MATTERS: A REVIEW OF ARCHAEOLOGICAL AND CHRONOMETRIC DATA FROM ABRIGO DO SOL (MATO GROSSO, BRAZIL)

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ABSTRACT. Based on the study of the primary documentation related to the excavations carried out by Eurico Miller in the 1970s at Abrigo do Sol, Mato Grosso (Brazil), we propose a new reading of the stratigraphic and chronological information obtained from this rock shelter. Despite the apparent incongruity in the chrono-stratigraphic distribution of published dates, a detailed examination of the stratigraphy and field notes allowed us to identify a chronometric sequence with regular distribution between the Middle Holocene and the Late Pleistocene periods for the Abrigo do Sol site. We present here the original documents related to radiocarbon dating and their analysis. We finally show the implications of this study for understanding this site and the discussions related to the ancient settlements of the Amazon forest.

KEYWORDS: Abrigo do Sol, Amazon forest peopling, Brazilian radiocarbon dating.

INTRODUCTION

The rock shelter Abrigo do Sol in the Mato Grosso state, Brazil, has produced some of the oldest radiocarbon dates for the human occupation of the Amazon Forest region, with dates at around 14,700 BP (Miller 1987; Roosevelt et al. 2002; Meggers and Miller 2003; Morcote-Rios et al. 2021). The radiocarbon dating sequence indicates occupations from Late Pleistocene to Late Holocene. Unfortunately, data published by Miller (1987) presents several discrepancies that have driven scholars to question the reliability of the stratigraphic distribution of dated samples (Puttkamer 1979; Prous and Fogaça 1999; Bueno et al. 2013). Encouraged by the BRC14Database project (Bueno and Gilson 2021), we looked more closely at the Abrigo do Sol dating sequence. We present new perspectives on this matter here by researching field notes and documentation kept at the Marsul museum.

The main objective of this paper is to present and highlight all the dates and stratigraphic information obtained by Miller and build a new interpretative chronological model for the Abrigo do Sol site. To achieve this goal, a critical review of each date has been accomplished, including (i) the stratigraphical provenience of the sample, (ii) the sample itself, (iii) the sample's processing history, (iv) the laboratories responsible for the dating, and (v) examination of the different groups of dates.

GEOGRAPHICAL AND ARCHAEOLOGICAL CONTEXT

The Abrigo do Sol site is a sandstone cave located in the state of Mato Grosso on the Serra dos Parecis escarpments. The site's area is part of the Guaporé River Basin, one of the formations of the Madeira River in the Amazon River Basin (Figure 1). The shelter is located in an area of ecotone with interpositions between montane tropical semideciduous seasonal forest and Brazilian savannah (Miller 1987:39). At the regional level, the area is in a context of environmental contacts and transitions: to the north/northwest, the Amazon Forest; to the

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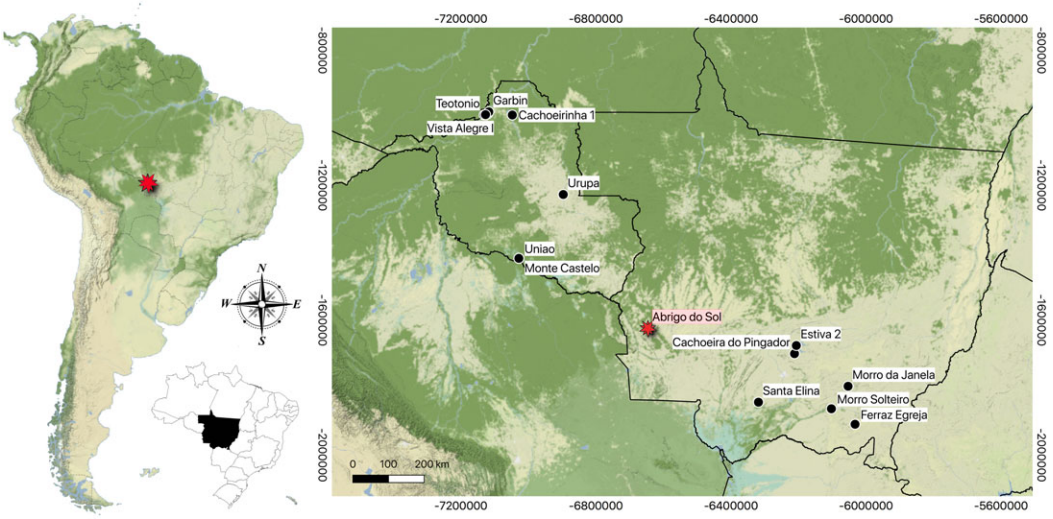

Figure 1 Geographical map of the Abrigo do Sol Rock shelter and other archaeological sites with Early/Middle Holocene dating.

southwest, the flooded lowlands of the Bolivian Chaco and Brazilian wetlands; to the east the highland savannah of the Brazilian Central Plateau.

From an archaeological point of view, there are, presently, a series of known sites around Abrigo do Sol that date back to the Middle Holocene Period (Figure 1). These sites occupy both tropical forest and Brazilian savannah areas. Regarding diversity, there are open-air sites, shelters, and riverine shellmounds. In chronological terms, the sites in Figure 1 indicate a consistent and continuous occupation since the Early Holocene (Miller 1987; Meggers and Miller 2003; Vialou 2005, 2006; Pugliese et al. 2017; Mongeló 2020). Beyond this period, the Santa Elina site, located about 300 km to the southeast, presents, in addition to a consistent Holocene occupation, dates that indicate the site's occupation by 24,000 cal BP (Vialou 2003; Vialou et al. 2017).

The Abrigo do Sol was excavated by E. Miller between 1974 and 1977. The shelter was topographed and mapped using 2 × 2 m squares. The excavated areas reached a depth ranging from 3.40 to 8.0 m. There were 32 excavation units defined, of which 12 were systematically excavated in more than one field season, reaching the base of the shelter (Miller 1987, Field Diaries). The excavation proceeded through artificial levels of 20 cm. As a result, two distinct stratigraphic units were identified: the first with a depth of 4.30 m from the surface and the second with about 3.70 m of thickness, reaching up to 8.0 m in depth.

The excavations carried out at the shelter showed a very diverse set of artifacts, with the presence of ceramics, lithics, artifacts in plant material, seeds, and many charred remains.

According to Table 2 published in Miller 1987 (1987:42), the most recent date obtained for the shelter is 115 ± 55 BP (SI-3105), while the oldest is 14,700 ± 195 BP (N-2359). This same table presents a set of dates obtained for the shelter, indicating information about the unit and depth of samples grouped into 3 groups: units M11/12, N11/12, and O11/12. In this table, it is also

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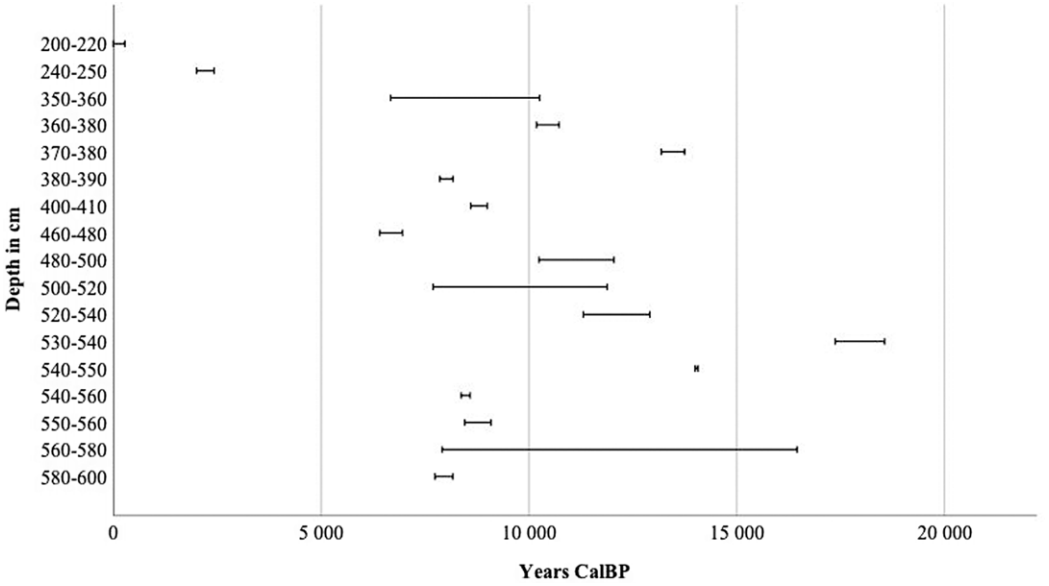

Figure 2 Distribution chart of newly calibrated dates with OxCal 4.4, Mixed curve SHCal20 and IntCal20 (Marsh et al. 2018), and 95% confidence interval following only the depth distribution of the data available in Miller (1987).

informed that some samples were divided and sent for dating in two different laboratories. The primary distribution of the data available after calibration, using OxCal 4.4 in this table is shown in Figure 2, arranging dates by depth without considering the units.

The sequence shows an uneven distribution, with possible inversions and chronological inconsistencies along the stratigraphy. For example, the 350–360 cm level (N-3237—9410 ± 120; N-3222—6460 ± 100; SI-3473—5750 ± 60) with a chronologic interval goes from 11079 to 6395 years cal BP (OxCal 4.4, Mixed curve SHCal20 and IntCal20, 95% confidence interval) compared to the 380–390 cm level (SI-3474—7190 ±70) with an interval from 8171 to 7856 years cal BP (OxCal 4.4, Mixed curve SHCal20 and IntCal20, 95% confidence interval). This last level also contradicts the 460–480 cm level (N-3056—5900 ±105) possessing an interval of 6957–6411 years cal BP (OxCal 4.4, Mixed curve SHCal20 and IntCal20, 95% confidence interval).

By calibrating the dates, analyzing the dating reports and primary documentation related to the excavation, and the stratigraphic context of the samples' provenance, we intend, in this article, to discuss precisely the discrepancies presented in Figure 2.

METHODS

As this paper's objective is to better understand the chronological information already available for the Abrigo do Sol rock shelter, we divided our analysis into two main steps.

First, we did a critical analysis of the original documentation produced during the excavation and the laboratory analysis. We had access to documents related to stratigraphy and dating. Our corpus documental was then composed of several unpublished documents: a stratigraphy profile, a topographic sketch with the implementation of the excavation grid, some of the

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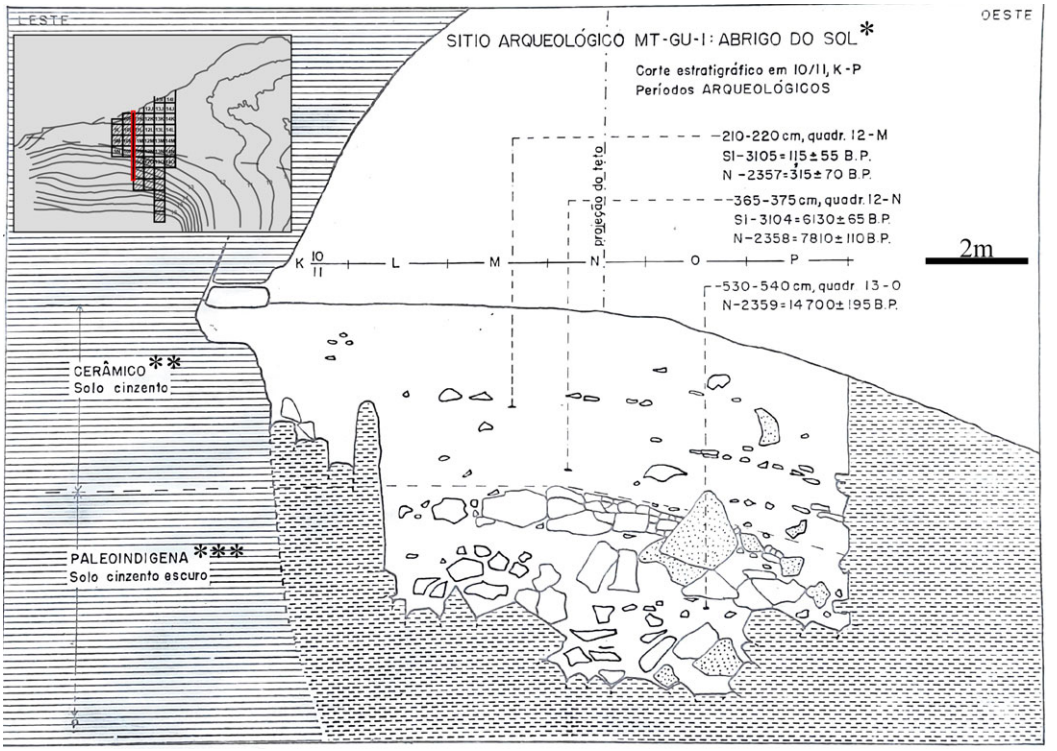

Figure 3 Profile from the 10/11 K to P. *Site MT-GU-I: Abrigo do Sol. Stratigraphic profile and Archaeological layers. **moist sandy soil. ***sandy with sandstone and basalt blocks. (the topographic map with the excavation grid, the scales and the * are included by the authors)

original dating reports by the Smithsonian Institution Radiocarbon Laboratory, the research diary, and the catalog referring to the stratigraphy and dated sample provenance. We also consulted Miller (1987) and Puttkamer (1979) publications along with these primary sources.

Once we obtained a better image of the stratigraphic dynamic of the site, the spatial relationships between each dated sample, and their nature, we proceeded to the second step, a graphical projection of all calibrated dates highlighting the outliers. The graph is used to infer information on the chronological occupation of Abrigo do Sol Rockshelter and conclude on the consequences of this series of datings for the Amazon Forest peopling.

ANALYSIS OF THE DATA

Examining the Sample's Provenance

Much essential stratigraphic information was obtained in (i) the published east-west stratigraphic profile from the 10/11 K to P excavation squares (Figure 3), (ii) the description of the stratigraphic, sediment dynamic, and excavation method published by Miller (1987) and Puttkamer (1979), (iii) the unpublished sketch map of the site (Figure 4), (iv) the unpublished stratigraphic profile from the 13/14 I to T excavation squares (Figure 5), and (v) the unpublished research diary containing data on the stratigraphy, the sediment dynamic, and the excavation method.

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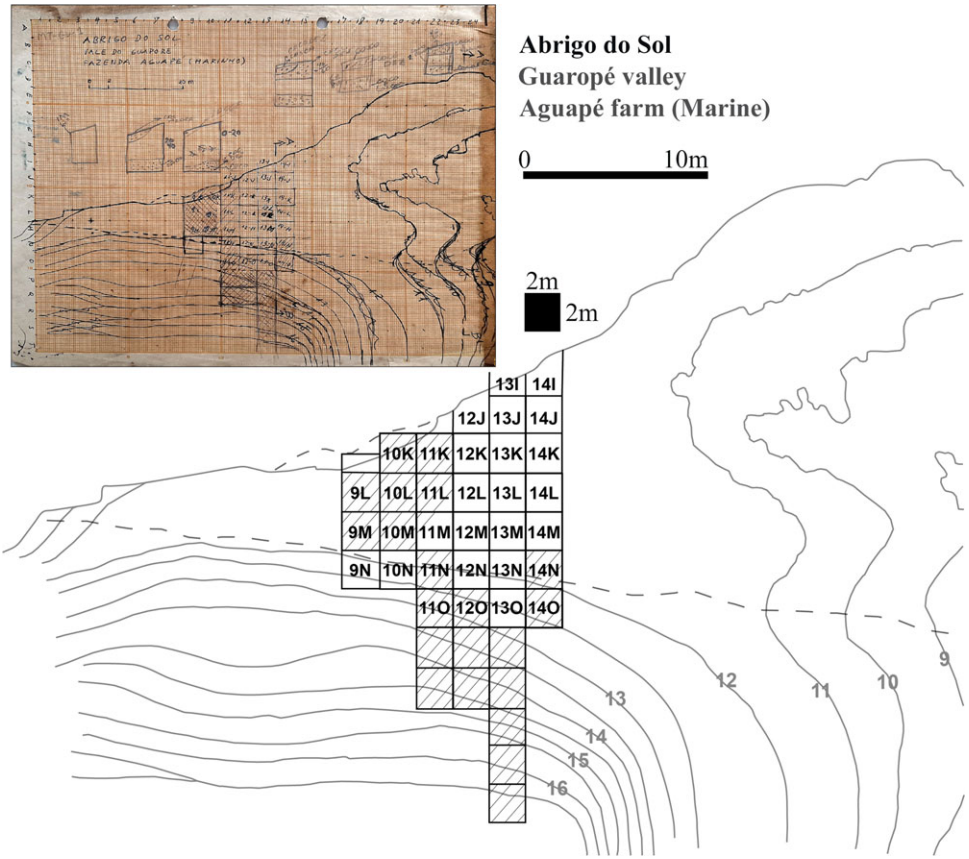

Figure 4 Unpublished topographic sketch map of the site (original and vectorized)

These primary sources offer the possibility to question the previous association between dates based only on depth as an objective measure for the whole site (Miller 1987:table 2). This association seems poorly reliable as (i) the site was excavated with a 2 × 2 m square grid and by an association of natural layers with artificial layers of 20 cm, which in rock shelter complex stratigraphy provides a low level of confidence in material association when based solely on depth, (ii) the presence of inclination visible in the published profile and unpublished sketch map (Figures 3 and 4) which seems particularly strong starting in the middle of N squares. The topography shows a 50 cm drop in one meter inside these squares, and (iii) the scattering of the charcoal samples in the excavation unit. Indeed, contrary to the table published by Miller (1987:table 2) presenting repartition of the dates in 3 sequences (M11/12, N11/12, and O11/12), the original documentation shows the distribution of the samples in 9 squares (11-M, 11-N, 11-O, 12-M, 12-N or 13-N, 12-O, 13-N, 13-O, 14-M). The main question here is that having different archaeological layers with the same depth, we must analyze stratigraphic sequences with a better spatial resolution.

Another element to consider is the high risk of sediment mixing for the sample collected under 4.40 m. These levels were excavated during the second campaign after the site had undergone heavy rain during the Amazon rainy season (Puttkamer 1979). In the research

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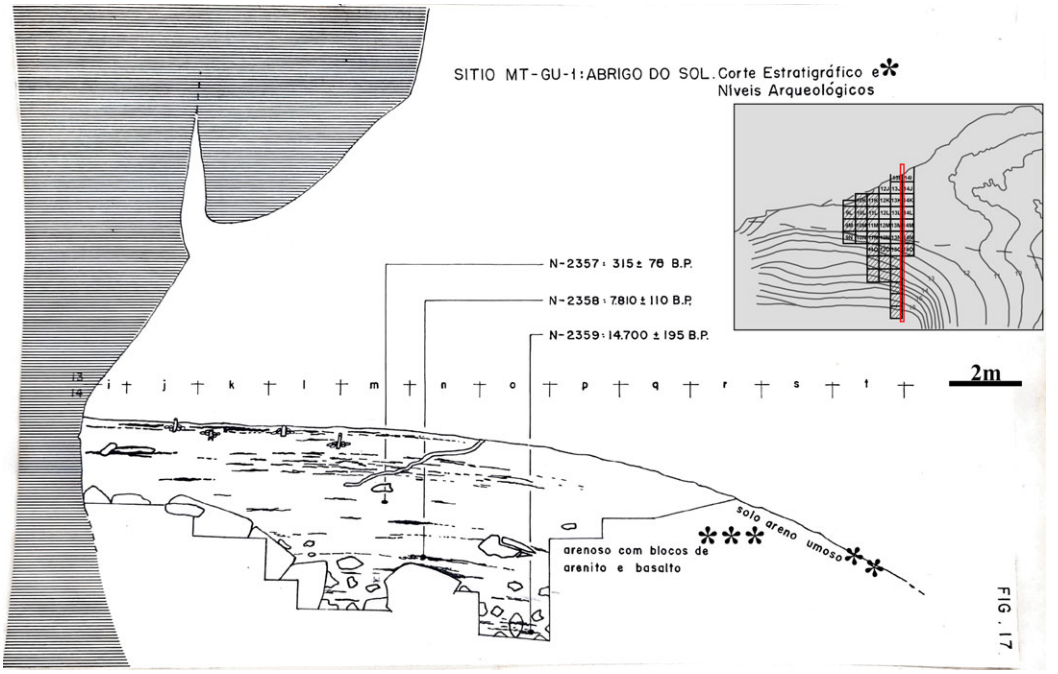

Figure 5 Unpublished stratigraphic profile from the 13/14 I to T. *Archaeological Site MT-GU-I: Abrigo do Sol. Stratigraphic profile at 10/11, K-P; Archaeological periods. ** CERAMIC, Gray soil. *** Paleoindians, Dark gray soil (the scale, the * and the topographic map with the excavation grid defining the position of the profile on the grid are included by the authors)

diary, Miller wrote that the sediment fell easily and that levels deeper than 4 m were reached only in two squares, where the work became very complicated due to a great deal of falling sediment.

Following this provenance analysis, we divided the dates into 9 groups (Table 1), one for each square. This mandatory separation consequently incurs the treatment of these 9 groups as separated groups before attempting a chronological interpretation of the whole site.

It should be noted that the exact provenance of the dates SI-3104 and N-2358 could not be determined. In the unpublished dating sheets and unpublished dating table (see supplementary material), these dates are associated with sample 5477 and square 12-N. However, in the sample catalog (see supplementary material), sample 5477 is registered in square 13-N. In the impossibility to determinate the correct provenance and due also to the problem inherent to the so-called duplicate dates (see Examining the sample's processing history further in the text), the dates SI-3104 and N-2358 are reproduced in Table 1 for informational purposes only but will not be considered in the analysis.

Examining the Sample's Nature

As mentioned in the research diary, the radiocarbon measurements were performed on charcoal. These charcoals were characterized as scattered in the sediment and not coming from any organized structure. Regarding the previous stratigraphic comments, this

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Table 1 List of conventional radiocarbon ages and calibrated ages of Abrigo do Sol by excavation square, laboratory, and depth.

Square	Laboratory	Depth (cm)	Lab code	Conventional dates (±1σBP)	Dates cal BP (OxCal 4.4, 95.4%)
11-M	Nishina Memorial	460–480	N-3056	5900 ± 105	6957–6411
		500–520	N-3057	6730 ± 85	7695–7427
		540–560	N-3058*	7630 ± 95	8592–8199
		560–580	N-3060**	7220 ± 85	8187–7845
		580–600	N-3061	7130 ± 85	8166–7740
		600–620	*N-3062*	*6470 ± 110*	*7570–7162*
	Smithsonian Inst.	540–560	SI-3740*	7695 ± 65	8590–8379
		560–580	SI-3741**	6900 ± 65	7914–7588
11-N	Nishina Memorial	350–360	N-3222	6460 ± 100	7563–7165
		480–501	N-3223***	10600 ± 130	12756–12045
		500–520	N-3224◆	7530 ± 105	8538–8040
		520–540	N-3225◆◆	11300 ± 140	13458–12909
		540–550	N-3226◆◆◆	11800 ± 110	14001–13436
	Smithsonian Inst.	350–360	SI-3473	5750 ± 60	6671–6395
		380–390	SI-3474	7190 ± 70	8171–7856
		400–410	SI-3475	7970 ± 75	8999–8600
		480–500	SI-3736***	8930 ± 100	10243–9680
		500–520	SI-3476◆	10405 ± 100	12617–11881
		520–540	SI-3737◆◆	9775 ± 70	11309–10799
		540–550	SI-3477◆◆◆	12300 ± 45	14798–14067
		550–560	*SI-3478*	*5730 ± 60*	*6662–6350*
		580–600	*SI-4379*	*9370 ± 70*	*10748–10298*
		600–620	*SI-3480*	*19400 ± 1100*	*26255–20968*
		630–640	*SI-3481*	*7885 ± 85*	*8990–8465*
		650–660	*SI-3482*	*9115 ± 600*	*12455–8786*
		670–680	*SI-3483*	*1940 ± 160*	*2315–1519*
11-O	Nishina Memorial	550–560	N-3059	7950 ± 115	9087–8454
	Smithsonian Inst.	560–580	SI-3738	14470 ± 450	18711–16452

Table 1 (*Continued*)

Square	Laboratory	Depth (cm)	Lab code	Conventional dates (±1σBP)	Dates cal BP (OxCal 4.4, 95.4%)
12-M	Nishina Memorial	200–220	N-2357****	315 ± 70	498– –4
	Smithsonian Inst.	200–220	SI-3105****	115 ± 55	276– –5
12-N or 13-N	Nishina Memorial	*365–375*	*N-2358◆◆◆◆*	*7810 ± 110*	*8983–8391*
	Smithsonian Inst.	*365–375*	*SI-3104◆◆◆◆*	*6130 ± 65*	*7164–6796*
12-O	Nishina Memorial	350–360	N-3227	9410 ± 120	11079–10256
13-N	Smithsonian Inst.	360–380	SI-3739	9245 ± 120	10725–10185
13-O	Nishina Memorial	370–380	N-3055	11600 ± 115	13745–13186
	Nishina Memorial	530–540	N-2359	14700 ± 185	18559–17370
14-M	Nishina Memorial	240–250	N-3228	2260 ± 80	2426–2004

Symbols * and ◆ indicate the theoretically duplicate radiocarbon measurements. All dates in italic were reproduced in the table for informational purposes only. All dates were calibrated with OxCal 4.4 (Bronk Ramsey 2021) and the Mixed IntCal20 and SHCal20 curve (Marsh et al. 2018) with the exception of the dates N-2357 and SI-3105 for which the Bomb13SH3 curve was used (Hua et al. 2013). All the samples are unidentified charcoal.

information provides an indication of the reliability of the selected samples, as scattered charcoals are more sensitive to vertical displacement than charcoal collected in organized structures.

The original documentation also states that all samples recovered in 11-M and 11-N squares under 5.80 m were very small and heavily diluted. As such, they are not reliable and must be disregarded. The respective dates are: SI-3479, SI-3480, SI-3481, SI-3482, SI-3483, and N-3062. These conventional dates have been reproduced in Table 1 for informational purposes only.

Another critical point is that all the samples are from charcoal without taxonomic identification. This gap opens the risk of the old wood effect. This assertion is reinforced by the anthracology analysis done by Goulart and coauthors (2017) in the Amazonian region. They identified the presence of 13 different families, including long-lived species.

Examining the Sample's Processing History

The dating samples were sent to two different laboratories: 17 samples to the Nishina Memorial (Japan) and 18 to the Smithsonian Institution (United States of America). Of these 35 dates, seven were obtained from duplicated samples, in which two pieces from the same specimen were sent to each laboratory. In the 1987 paper and inside the original sample files, Miller emphasized that the specimens were divided into two samples. Unfortunately, obtaining more information about the dividing method has not been possible. In theory, such samples could be combined by the R-Combine function in OxCal to produce a single date. However, except for two dates (N-3058 and SI-3740), none of the other samples passed the χ^2 test. This failure could result from no true duplicate samples (conglomerate charcoals) or differences in charcoal pretreatment of the two laboratories (Hamilton and Krus 2018). Considering that no single laboratory had consistently produced older or younger results, the issues seem to come from the samples. To solve this problem, the dates were separated by laboratories and squares to check the continuity of the sequences.

Examining the Laboratories

Laboratory sample processing can be the subject of systematic and experimental errors (Castro Martinez et al. 1996), creating unreliable results. Unfortunately, no information concerning such problems related to the Nishina Memorial or the Smithsonian Institution was found in the literature. Moreover, as already mentioned, neither has consistently produced older or younger results. Consequently, from a radiocarbon vetting point of view, neither laboratory results could be considered more reliable. Nevertheless, the standard deviations of the dates processed at the Smithsonian Institution are more precise than the ones of the Nishina Memorial, with 76% against 28% inferior or equal at 100 years. Therefore, the dates of the Smithsonian Institution are more precise.

Examining the Groups

Only the dates from squares 11-M and 11-N present a dating group with more than two samples. In these two proper sequences, except for the dates N-3058 and SI-3740, the so-called duplicate dates will be treated as separate samples once they fail the χ^2 test.

In the case of square 11-N, the division of the dates by laboratories (Table 1) shows a logical continuity between all dates except for N-3224 and SI-3476. It is interesting to note that these

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dates, coming from what Miller defined as a divided sample, in both laboratories, produced a date that seems devoiding logical continuity. Consequently, the problem probably comes from the sample recorded position (mixing sediment) or the sample itself (old wood effect) and not the laboratories measurement procedures. Besides this illogical succession, the dating 5730 ± 60 years BP (SI-3478) at a depth of 550–560 cm also presents a strong incoherence in the chronological sequence. Following the depth information, the dated sample came from a deeper level than the sequence of dates ranging from 5750 ± 60 (depth: 350–360 cm) to 12,300 ± 45 years BP (depth: 540–550). The understanding of this incoherent superposition can be found in 4 elements: (i) As already mentioned, the layers of 11-N square must have presented a strong inclination, so even if coming from a greater depth, the sample may be younger; (ii) as also mentioned, the deeper level presents a high risk of sediment mixing, as all charcoal samples came from scattered charcoal; (iii) the possible existence of unmentioned bioturbation; (iv) as demonstrated by Goulart and coauthors (2017), considerable variation in dates can be identified in the same charcoal set and could be reflecting different fire episodes. For all of these reasons and without the possibility of identifying with certainty the correct position of the dating in the sequence, the date was solely reported in Table 1 for reader's information.

Regarding square 11-M, the stratigraphic profile suggests a low inclination of the layers. The depth information could thus be more reliable. The only dates not consistent with the sequence are N-3058 (7630 ± 95) and SI-3740 (7695 ± 65), even once combined. Therefore, the problem probably comes from the sample and not the laboratories. This illogical succession could probably be explained by sediment mixing or the old wood effect.

Concerning the squares 11-O, 12-O, 13-O, 13-N, and 14-M, with only one or two datings per square, the groups did not present any illogical succession. For this reason, they were separately calibrated using the Mixed curve between SHCal20 and IntCal20 curves (Marsh et al. 2018) at 2 sigma (95.4% confidence interval) with the OxCal 4.4 software (Bronk Ramsey 2021). The two recent dates of 12-M were calibrated with the same software and the Bomb13SH3 curve (Hua et al. 2013) at 2 sigma (95.4% confidence interval; Table 1).

RESULTS

The analysis of the dates obtained at the Abrigo do Sol Rock Shelter offers interesting results.

The calibrated dates obtained in the squares 11-O, 12-O, 13-O, 13-N, and 14-M are in harmony with their square stratigraphy but have no clear stratigraphic relation. Regarding squares 11-M and 11-N, the separation of the dates by squares and laboratories show logical sequences except for the combined date in 11-M and two theoretically combined dates in 11-N (N-3224 and SI-3476). In both cases, the problem seems to be related to the samples themselves, sediment mixing, or the old wood effect.

The dates N-3058 and SI-3740 from the square 11-M are the only duplicated dates that passed the X^2 test and could be combined with the function R_Combine, resulting in the date of 7674 ± 54 (8585–8370 cal BP, 95%, OxCal 4.4).

Furthermore, considering the spatial and stratigraphical divisions, as well as the radiocarbon vetting (Table 1), the dates obtained at Abrigo do Sol Rockshelter can be projected in a new chart (Figure 6). Contrary to Figure 2, this chart shows a continuous sequence of dates from 18711–16452 years cal BP to 276– –5 years cal BP. However, as mentioned, two samples (three dates) are still problematic. These dates are indicated in red on the chart (Figure 6), as without

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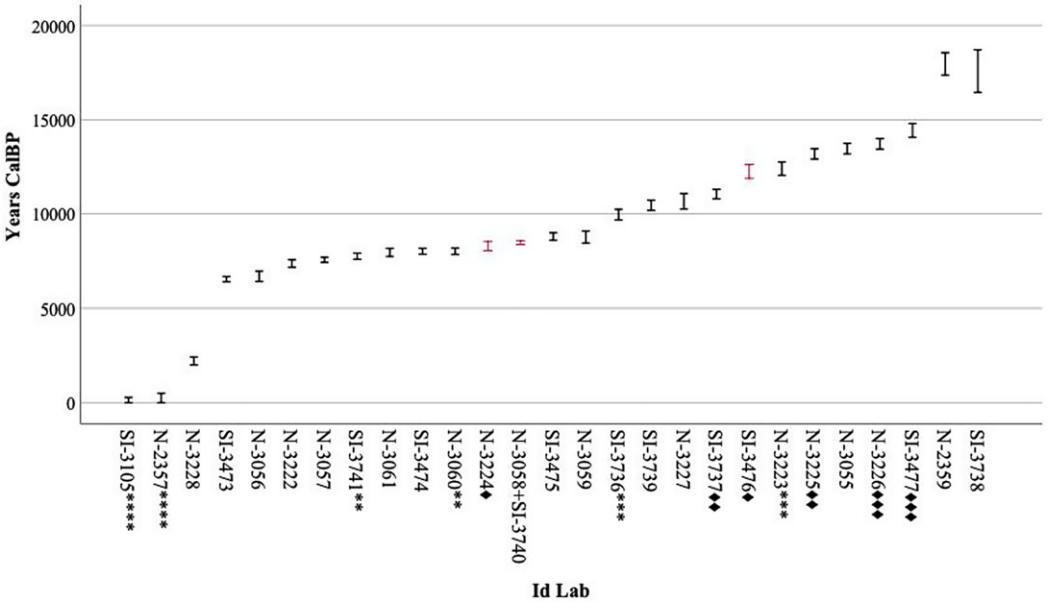

Figure 6 Graph of all the calibrated dates from Abrigo do Sol (OxCal 4.4, Mixed curve SHCal20 and IntCal20 (Marsh et al. 2018), 95% confidence interval).

modeling and outliers treatment (Bronk Ramsey 2009), they are still defying the logical succession of their sequence squares.

Finally, the analysis of the dating series (Figure 6) shows a gap around the oldest and youngest dates, probably reflecting the sampling choices rather than the interruption of human activity in the rock shelter. The primary sampling criterion was depth without considering stratigraphic layers and orientations. Consequently, due to the problematic results of the dates obtained in deepest levels in squares 11-M and 11-N and the absence of datings above 2 meters in other squares, we face a discrepancy of dates for the beginning and the end of the Rock Shelter use.

CONCLUSION

The use of the field documentation of the Abrigo do Sol rock shelter and the consideration of the spatial and stratigraphic origin as well as the nature of the dated samples demonstrates the importance of considering these elements before applying any chronological interpretation. Only the association of this information can resolve the confusion brought about by past publications and shine light onto the strong chronological sequence of Abrigo do Sol.

Besides offering a new perspective on the chronological information of the Abrigo do Sol Rock shelter, this critical analysis also highlights the importance of the archeological material recovered by Miller for the debate on the peopling and occupation of the Amazon Rainforest and South America. Abrigo do Sol as Santa Elina seems to indicate human activities in this region since the end of the Pleistocene, adding important information to improve the debate about early peopling of South America (Borrero 2015; Vialou et al. 2017; Ardelean et al. 2020).

The Abrigo do Sol rock shelter, as shown by this study, is an important piece of the archaeology of the Amazon Rainforest. We hope that the smoothing out of its radiocarbon

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dating sequence will encourage further investigation of the collected material or even the return to the site for new field seasons. In addition, future analyses should be encouraged to bring interesting information about the anthropic occupations and activities developed during the potential period of 18,000 years in this rock shelter.

ACKNOWLEDGMENTS

The authors wish to thank the team of the Marsul Museum for facilitating our access to the primary documentation. Our gratitude to the CNPq for the financial support (Processo: 311866/2018-2). We also want to thank the anonymous reviewers for their help and advice.

SUPPLEMENTARY MATERIAL

To view supplementary material for this article, please visit https://doi.org/10.1017/RDC.2024.30

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https://doi.org/10.1017/RDC.2024.30 Published online by Cambridge University Press