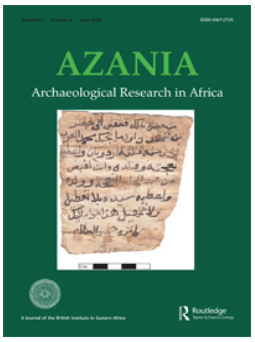

Azania: Archaeological Research in Africa

ISSN: 0067-270X (Print) 1945-5534 (Online) Journal homepage: www.tandfonline.com/journals/raza20

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To cite this article: Nuno Bicho, Ana Gomes, Elena Skosey-LaLonde & Mussa Raja (18 Aug 2026): The geochronological landscape of Mozambique: absolute dates from archaeological and palaeoenvironmental contexts, Azania: Archaeological Research in Africa, DOI: 10.1080/0067270X.2026.2717852

To link to this article: https://doi.org/10.1080/0067270X.2026.2717852

Published online: 18 Aug 2026.

AZANIA: ARCHAEOLOGICAL RESEARCH IN AFRICA
https://doi.org/10.1080/0067270X.2026.2717852

The geochronological landscape of Mozambique: absolute dates from archaeological and palaeoenvironmental contexts

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ABSTRACT

This paper presents a systematic review of absolute dating data from Mozambique, drawing on a compiled database of 442 dates from 69 sites. The dataset spans archaeological and palaeoenvironmental contexts and encompasses dates ranging from the present day to close to a half a million years ago, covering the whole of the Holocene and part of the Middle and Upper Pleistocene. The most widely used dating method is radiocarbon (AMS and original), followed by luminescence techniques (OSL variants and pIRIR), electron spin resonance (ESR), uranium-series and cosmogenic nuclide dating. More than 250 dates belong to archaeological contexts distributed across four cultural phases — the Ceramic Phase, the Later Stone Age, the Middle Stone Age and the Early Stone Age — while the remaining entries come from palaeoenvironmental contexts. Regionally, the southern provinces of Inhambane, Gaza and Maputo are the most densely sampled, followed by the central region (Zambezia, Tete, Sofala and Manica) and lastly the northern region (Cabo Delgado, Niassa and Nampula). These distributions are discussed in the light of research history and the chronological resolution offered by each method. Significant gaps are identified in the geochronological coverage of Mozambique that call for targeted future investigation.

RÉSUMÉ

Cet article présente une revue systématique des données de datation absolue provenant du Mozambique à partir d'une base de données rassemblant 442 dates issues de 69 sites. L'ensemble des données comprend des contextes archéologiques et paléoenvironnementaux, avec des datations allant de l'époque actuelle jusqu'à près d'un demi-million d'années, couvrant ainsi l'ensemble de l'Holocène, ainsi qu'une partie du Pléistocène moyen et supérieur. La méthode de datation la plus courante est le radiocarbone (AMS et originel), suivie par des techniques par luminescence (variantes OSL et pIRIR), de la résonance paramagnétique électronique (ESR), de la datation par séries

ARTICLE HISTORY
Received 20 April 2026
Accepted 6 August 2026

KEYWORDS
Mozambique; absolute dating; archaeological chronology; palaeoenvironment

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uranium et de la datation par nucléides cosmogéniques. Plus de 250 datations proviennent de contextes archéologiques et sont réparties entre quatre phases culturelles: la Phase Céramique, le Later Stone Age, le Middle Stone Age et l'Early Stone Age. Les autres données sont issues de contextes paléoenvironnementaux. A l'échelle régionale, les provinces situées au sud d'Inhambane, de Gaza et de Maputo sont les plus densément échantillonnées, suivies par la région centrale (Zambezia, Tete, Sofala et Manica), puis par la région septentrionale (Cabo Delgado, Niassa et Nampula). Ces distributions sont discutées à la lumière de l'histoire de la recherche et de la résolution chronologique offerte par chaque méthode. Des lacunes significatives sont identifiées dans la couverture géochronologique du Mozambique, appelant à effectuer de futures recherches ciblées.

Introduction

Mozambique has considerable potential for understanding the long-term human occupation of Sub-Saharan Africa (Bicho *et al.* 2018a, 2026). Stretching approximately 2700 km along the continent's eastern seaboard, the country encompasses a diverse range of ecological zones, including the Zambezi Delta and the Gorongosa wetlands in central Mozambique, the coastal dunes and lake systems of the south and the miombo woodlands and highland forests of the north. These landscapes have supported human populations from at least Acheulean times (Early Stone Age) through to the arrival of farming communities and the historic period (García-Heras *et al.* 2021). Their environmental variability is now becoming well documented through an increasing number of publications on lacustrine (Norström *et al.* 2018), deltaic (Massuanganhe *et al.* 2018) and coastal dune (Armitage *et al.* 2006) palaeoclimatic archives.

Despite growing archaeological and palaeoenvironmental interest in the region, systematic overviews of the geochronological framework underpinning Mozambican research remain scarce. Available absolute dates are still few when compared to neighbouring countries such as South Africa or Tanzania and they are widely distributed across site reports, journal articles, theses and the grey literature. This dispersion makes it difficult to assess the overall state of chronological knowledge, the representativeness of different dating methods or the spatial and temporal biases that may affect interpretations of past human behaviour and environmental change.

This paper addresses that gap by presenting an open access database (https://doi.org/10.17605/OSF.IO/APJF2) with a comprehensive analysis of 442 absolute date entries from 69 sites in Mozambique (Figure 1). Furthermore, it seeks to: 1) characterise the distribution of dating methods across the dataset; 2) examine the breakdown of dates by context (archaeological and palaeoenvironmental); 3) analyse the temporal and spatial coverage of archaeological cultural periods; and 4) identify regional patterns and gaps in the geochronological record. We do not attempt to interpret or critically evaluate the dating results here as detailed interpretation of the archaeological sequences and palaeoenvironmental datasets falls beyond the scope of this study. Rather, we direct readers to the original publications for site-specific analyses. By synthesising the current chronological evidence for Mozambique, this study nevertheless provides both a reference resource and a framework for integrating future chronological data.

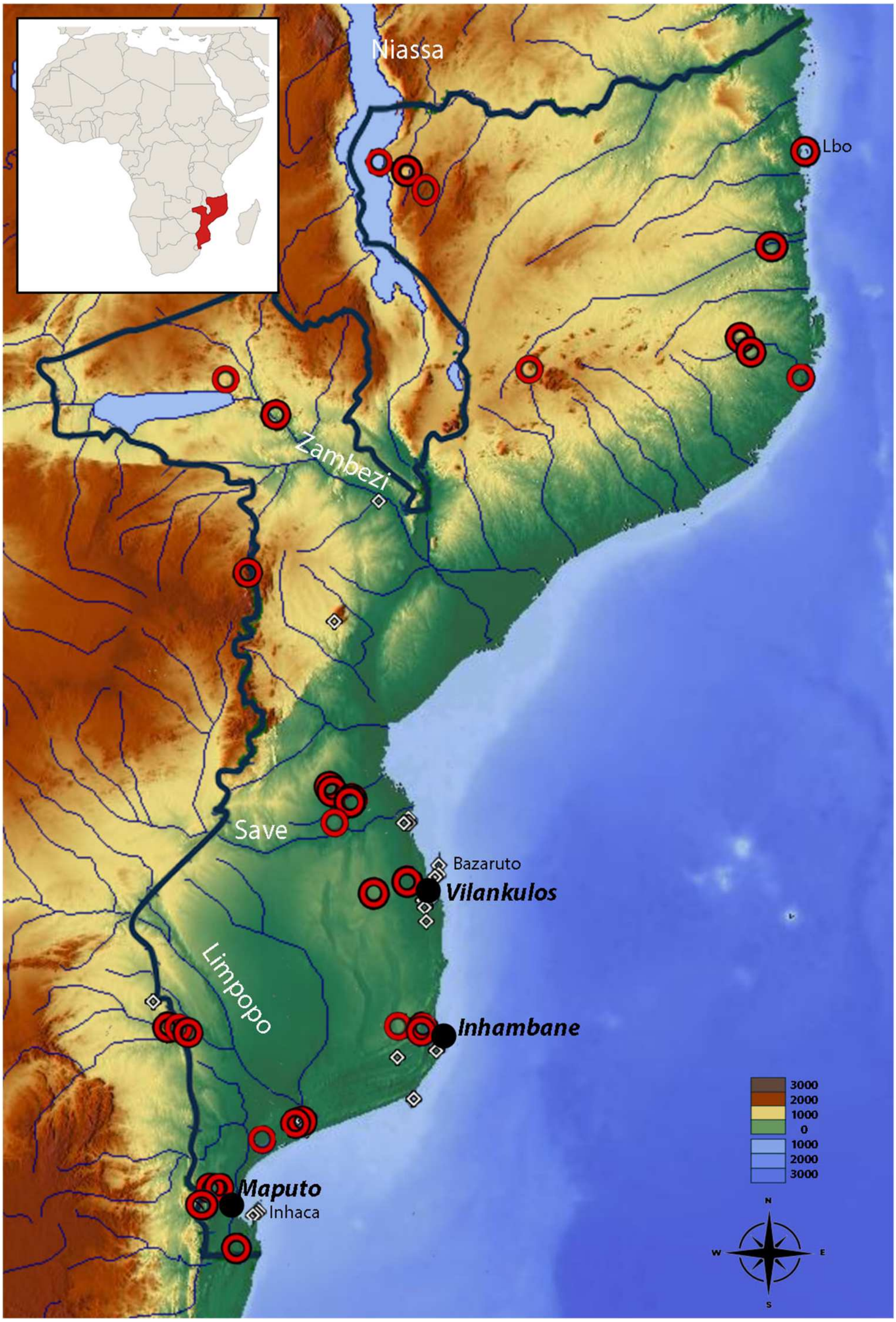

Figure 1. Map of Mozambique showing the distribution of dated sites in the database. Symbols distinguish archaeological sites (circles) from palaeoenvironmental sites (diamonds).

Geochronological methods in archaeology and palaeoenvironmental research

Radiocarbon dating

Radiocarbon dating is the most widely applied method for building late Quaternary chronologies up to ~50,000 years ago (Hajdas *et al.* 2021; Talamo *et al.* 2023). In Mozambique, as in much of Sub-Saharan Africa, two analytical approaches are represented: decay-counting (hereafter ^{14}C) and accelerator mass spectrometry (AMS). AMS permits the analysis of considerable smaller sample sizes (typically a few milligrams of carbon, compared with the several grams generally required for ^{14}C) and is commonly applied to discrete materials such as charcoal fragments, bone collagen and short-lived plant remains. Radiocarbon determinations are generally reported in years Before Present (BP; relative to AD 1950) and are typically calibrated using the SHCal20 curve for the Southern Hemisphere (Hogg *et al.* 2020) or IntCal20 for the Northern Hemisphere (Reimer *et al.* 2020). The Marine20 calibration curve (Heaton *et al.* 2020) is applied to samples derived from marine organisms.

Marine shell, bone apatite and bulk organic sediments all carry specific complications — reservoir effects, diagenetic contamination and the averaging of inputs spanning decades to centuries, respectively — that must be considered in interpreting radiocarbon results from these materials.

Luminescence dating

Luminescence techniques, including Optically Stimulated Luminescence (OSL) and Post-Infrared Infrared Stimulated Luminescence (pIRIR), date the last exposure of mineral grains (quartz and feldspar) to sufficient light or heat to reset their accumulated radiation dose (Rhodes 2011; Mahan *et al.* 2022). In sedimentary contexts, this corresponds to the timing of burial following transport and exposure. The single-aliquot regenerative dose (SAR) protocol is commonly applied in quartz OSL analyses with green or blue stimulation, while pIRIR measurements at elevated temperatures are used for feldspar to address anomalous fading. When both OSL and pIRIR measurements are obtained from the same sample, they represent nearly independent determinations of the same burial event and are often used to assess the reliability of bleaching, dose estimates and dose rates.

Luminescence methods extend beyond the effective range of radiocarbon dating and several sites in this dataset yield age estimates within the Middle and Early Pleistocene. These techniques are also valuable for dating contexts that fall within radiocarbon calibration plateaux, in particular those at 800–400 cal. BC and cal. AD 1550–1950, where radiocarbon offers little chronological resolution. A practical limitation of OSL and pIRIR, however, lies in determining the environmental dose rate: estimates derived from *in situ* dosimetry and those obtained from laboratory measurement of uranium, thorium and potassium in associated sediments do not always agree and such mismatches can introduce uncertainty into the resulting ages (Buylaert *et al.* 2011). No Thermoluminescense (TL) dates on ceramics have so far been reported for Mozambique.

Electron spin resonance (ESR) and uranium-series (U-series)

Electron Spin Resonance (ESR) dating (Duval 2018; Richard 2023) measures the accumulation of free radicals in crystalline materials, primarily tooth enamel. It is frequently applied in Middle and Early Stone Age contexts where faunal remains are preserved (Mercader *et al.* 2009).

U-series dating of speleothems and secondary carbonate deposits provides chronological constraints on archaeological or palaeoenvironmental events bounded by calcite formation, such as speleothems (Mercader *et al.* 2009).

Cosmogenic nuclide dating

Cosmogenic nuclide burial dating (Bierman *et al.* 2021, Schaefer *et al.* 2022), which is based on the differential decay of ^{10}Be and ^{26}Al following burial-induced shielding from cosmic rays, is used to estimate the timing of sediment burial and is particularly useful for deeply buried or exhumed surfaces. A single cosmogenic nuclide date is recorded in this dataset (Mercader *et al.* 2012).

The database: structure and coverage

The database compiled for this study comprises 442 entries from 69 sites in Mozambique (Figure 1). It consolidates two types of dating contexts — archaeological and palaeoenvironmental — and excludes data from marine cores (e.g. Van der Lubbe *et al.* 2016; Hall *et al.* 2017; Koutsodendris *et al.* 2021). Each entry records the site name, geographic co-ordinates, context category (archaeological or palaeoenvironmental), cultural phase (where applicable), geological period, depositional environment (where applicable), dating method, material used, sampling depth, laboratory code, age in BP with associated uncertainty, calibrated age range where relevant using OxCal v4.4 (Ramsey 1995, 2009) and SH20 (Hogg *et al.* 2020) and Marine20 curves (Heaton *et al.* 2020) and bibliographic reference. The calibration curves applied to the dataset are explicitly recorded in the database since they may be superseded by future releases; recalibration with the most current curve is recommended for any synthesis depending on precise calendar ages. With the exception of radiocarbon, ages for all other methods are reported in kilo-years (kya). Data were drawn from two main elements: published journal articles, book chapters and edited volumes, as well as the XCronos database (https://xronos.ch/data). Additionally, an important number of dates were amassed from theses and dissertations (Morais 1988; Ekblom 2004; Macamo 2006; Kohtamäki 2014; Sitoe 2017; Muianga 2025; Skosey-LaLonde 2025; Samawi *et al.* 2026) or related work. Finally, a large set of new dates produced by our team are presented here for the first time.

All available technical information for each dated sample was compiled from the original publications. Archaeological and palaeoenvironmental sites were georeferenced where co-ordinates were available in the source literature; 23 entries (representing 13 sites) lack geographic co-ordinates and are therefore not used in the regional analysis. To enable the construction of a queryable dataset organised by cultural phase, dates were assigned, where appropriate, to one of four broad phases: ESA (Early Stone Age), MSA (Middle Stone Age), LSA (Later Stone Age) and Ceramic. The latter category encompasses contexts described in the original literature as Early or Late Farming Communities, Iron Age, Chifumbaze, Medieval and Historical, or that are otherwise associated with ceramics. It is not intended to imply that all ceramic-bearing contexts represent iron-producing or farming communities; the more specific cultural attribution reported in the original source is retained wherever available and reported in the database entry notes.

Dates on the few marine samples are not corrected for the marine reservoir effect for three main reasons: the reservoir oscillates between -8 and -2 years depending on which dates are used for the correction; most of these reference dates come from locations 400 to >1000 km away from the samples to be corrected; and, finally, there is considerable variability in the reservoir values among those reference samples (from -64 ± 26 to 112 ± 26 years).

A noticeable methodological caveat underpins the analysis presented here. Luminescence dating in this dataset employs two protocols, OSL and pIRIR, which are routinely applied to the same sediment sample. Because both protocols are applied to a single physical sample and yield an independent age estimate, the database, as compiled, records 91 luminescence results coming from only 60 samples. This distinction is consequential for any assessment of the true number of dated contexts and must be considered throughout any analysis.

The dataset spans a significant temporal range, with the youngest entry, a radiocarbon date of 17 ± 25 BP (OS-87454) from a palaeoenvironmental (baobab (*Adansonia digitata*)) context, while the oldest, a U-series date on speleothem of approximately 470 kya from N'Galue Cave in the Lake Niassa (Malawi) region (Mercader *et al.* 2009). Holocene contexts (the last ~11,700 years) account for 361 of the 442 entries (81.7%), reflecting both the greater survival of organic materials suitable for radiocarbon dating and, likely, the greater density of Holocene human occupation evidenced in the archaeological record. Pleistocene contexts account for 81 entries (18.3%), primarily from OSL, pIRIR, ESR and U-series measurements.

Radiocarbon methods dominate the database: AMS accounts for more than 170 entries and ^{14}C for 160, together representing 334 dates (75.6% of the total 442 entries; Table 1). This prevalence reflects both the long history of radiocarbon as the main chronometric tool in African archaeology and palaeoenvironmental areas, and the dominance of organic-rich contexts — charcoal, bone, shell and bulk organic sediment — at Mozambican sites.

Luminescence techniques (OSL in its various forms plus pIRIR) account for 93 database entries, but, as discussed above, corresponding to only 60 samples once the pairing

Table 1. Distribution of absolute dating entries by method.

Method	Total entries	% of total
AMS	174	39.4
^{14}C	160	36.2
OSL	60	13.6
pIRIR	33	7.5
ESR	8	1.8
U-series	6	1.4
Cosmogenic nuclide	1	0.2
Total	442	100.0

of OSL and pIRIR measurements on the same physical sample is taken into account (Table 1). Of these 60 unique samples, the majority derive from new work presented in this study, with additional luminescence data from Armitage *et al.* (2006) applying OSL (SAR) to aeolian depositional environments from the Inhaca and Bazaruto barrier islands.

ESR provides eight entries (Table 1), all from one archaeological site in the northern region of Mozambique, while U-series contributes six entries from speleothems associated with the same MSA deposits of N'Galue, although the beginning of the sequence places the chronology of that site into the Middle Pleistocene (Mercader *et al.* 2009). A single cosmogenic nuclide date is also recorded from the open-air MSA site of Myumu in the Niassa Rift (Mercader *et al.* 2012).

Archaeological contexts and phases

Of the 442 entries in the database, 257 (58.1%) are associated with archaeological contexts. These span four primary chronological phases recognised in the Mozambican archaeological sequence: the Ceramic, the Later Stone Age, the Middle Stone Age and the Early Stone Age (Table 2). A small number of entries are classified simply as 'Stone Age' in the original literature (Gonçalves *et al.* 2016), reflecting ambiguity in the original reports.

Only two OSL/pIRIR entries in the database are assigned to the Early Stone Age, both from the site of Mapa, Massingir region, in the Limpopo Basin (Table 2) and they do not reliably date its Acheulean human occupation. Rather, this likely reflects the aeolian sediments overlaying the archaeological horizon. The scarcity of ESA dates is expected, given the considerable antiquity of relevant deposits and the limited deployment of the appropriate chronometric methods (cosmogenic nuclide burial dating, OSL/pIRIR and U-series) that would be required to push the record further back in time.

The Middle Stone Age is the least abundantly dated of the following phases, with only 29 entries (11.3% of all archaeological dates). This sparsity reflects genuine challenges: MSA contexts in Mozambique are numerous and located in many regions of the country (Bicho 2026), mostly because diagnostic materials are easy to identify. Most sites, however, are surface sites and very few cases have been excavated and dated. The exceptions are N'Galue Cave (Mercader *et al.* 2009), and two open-air sites, Mvumu (Mercader *et al.* 2012) and Zimuara (found and tested by our team in 2019 and 2023), respectively located in the Niassa and Save Valleys. Due to the scarcity or absence of organic material suitable for radiocarbon at these sites, as well as their age, they require the deployment of other techniques (such as ESR, U-series and luminescence (Mercader *et al.* 2009).

Table 2. Archaeological dates by cultural phase and method.

Cultural phase	N	AMS	^{14}C	OSL	pIRIR	ESR	U-series	Cosmogenic nuclide
Ceramic	134	24	110	-	-	-	-	-
Later Stone Age	90	34	6	25	25	-	-	-
Middle Stone Age	29	2	-	6	6	8	6	1
Early Stone Age	4	-	-	2	2	-	-	-
Total	257	60	116	33	33	8	6	1

The results from the MSA span the period from the present (AMS) to approximately 470 kya (U-series), the oldest result in the database being that of a speleothem at the base of the sequence at N'Galue (Mercader *et al.* 2009) This broad range encompasses what is now understood to be a behaviourally complex and geographically variable phase of African prehistory. The very recent AMS results are inconsistent with the expected chronological frameworks and may reflect contamination or contextual uncertainties, demonstrating the limited geochronological resolution currently available for Mozambican MSA sites and significantly constraining out ability to integrate the region into broader debates about the emergence and dispersal of complex behaviours in *Homo sapiens*.

The LSA is represented by 90 dates (35.0% of all archaeological dates), making it the second most abundantly dated phase. The method profile is now more diverse with AMS (34 entries) and ^{14}C (6 entries) joined by quartz OSL and pIRIR (25 dates each). The dominance of luminescence in the LSA record partly reflects the geological character of many LSA sites in Mozambique, which are frequently embedded in coastal dune sequences or sand bodies where organic preservation is poor, but sediment is well-suited to luminescence analyses.

The LSA database includes a substantial contribution from new dates reported here for the first time, particularly from five sites in the coastal region in the Save Basin, Chessungalane, Bunga 4, Bunga 6, WP131 and Zimuara, as well as one site, Txina Txina (Bicho *et al.* 2023), located in the Gaza province of southern Mozambique. The Zimuara site alone contributes 39 dates, covering both the MSA and the LSA, suggesting continuous or recurrent occupation across a long stretch of the late Pleistocene and Holocene.

The Ceramic phase is the most abundantly dated period, with 134 entries (52.1% of all archaeological dates). The overwhelming majority of these were obtained using ^{14}C (110 entries), supplemented by AMS (24 entries). This pattern reflects both the chronological range of the most recent phase, predominantly within the last two millennia, and the relative abundance of charcoal, carbon residues on ceramics and other organic materials in these recent archaeological and palaeoenvironmental contexts.

Geographically, the Ceramic phase sites cluster in the region north of the Zambezi River (28 entries) and in the southern coastal zone (74 entries), with a markedly smaller contribution from the area between the Save and the Zambezi Valleys. This spatial bias may partly reflect the historical concentration of research effort in the hinterland of Maputo Bay and Mozambique Island in the Cabo Delgado corridor, as well as the density of published site reports from researchers such as Sinclair (1987), Morais (1988) and Macamo (2006), who together contribute 97 ^{14}C dates to the total Ceramic phase dataset.

Palaeoenvironmental contexts

A total of 185 entries (41.9% of the database) is classified as palaeoenvironmental, documenting a range of sedimentary and other natural archives that record Quaternary environmental change in Mozambique. The dating methods used to obtain palaeoenvironmental dates are less diverse than those used in the archaeological contexts: AMS dominates (114 entries, 61.6%), with ^{14}C contributing a further 44 entries (23.8%) and OSL accounting for 27 dates (14.6%) (Table 3). No ESR, U-series, pIRIR or cosmogenic nuclide dates are reported from palaeoenvironmental contexts in this dataset.

The palaeoenvironmental database is dominated by lacustrine sediments (112 entries, 60.5%), reflecting the substantial investment in lake sediment coring across the southern coastal plain of Mozambique. This body of work (Sitoe *et al.* 2015, 2017), largely undertaken by a Swedish palaeoclimatological research group (Ekblom 2008; Holmgren *et al.* 2012; Ekblom *et al.* 2014a; Norström *et al.* 2018), has produced high-resolution records of Holocene hydroclimate variability in southern Mozambique and provides an important environmental backdrop for interpreting archaeological patterns.

Aeolian deposits (21 entries) are dated exclusively by OSL, documenting the formation history of coastal dune systems (Armitage *et al.* 2006). These dates, primarily from the southern coast, are particularly important for understanding the geomorphological context of archaeological sites embedded within dune sequences. Deltaic and fluvial samples together contribute six more results, documenting the dynamic depositional history of the Save Delta (Massuanganhe *et al.* 2018) with OSL and radiocarbon methods applied in a complementary fashion.

The vast majority of AMS dates from palaeoenvironmental contexts are on bulk organic material (55 samples) or plant macrofossils and roots (ten dates) (Ekblom 2008; Holmgren *et al.* 2012; Ekblom *et al.* 2014; Sitoe *et al.* 2015; McWethy *et al.* 2016; Norström *et al.* 2018; Skosey-LaLonde 2025), with additional contributions from gastropod shells, predominantly *Melanoides tuberculata* and *Achatina* spp. (Sitoe 2017; Bicho *et al.* 2018a), mussel valves (Matias 2020) and baobab wood (Patrut *et al.* 2015, 2020). Dating of bulk organic matter introduces potential age offsets because sediments typically contain a mixture of contemporaneous and reworked older carbon, as well as mobile humic compounds that can bias the results toward either older or younger ages, and several of the Mozambican lake records address this issue. Baobab wood dating (Patrut *et al.* 2015, 2020), which contributes 24 dates, targets directly dated growth-ring events and circumvents these issues.

Regional patterns in the geochronological record

The 57 sites with geographic co-ordinates, of which 19 have palaeoenvironmental data and 38 are archaeological sites, show a pronouncedly uneven spatial distribution of dated samples across Mozambique (Figure 1). Archaeological samples are concentrated primarily in southern Mozambique, particularly along the coastline south of Maputo (Kohtamäki 2014; Muianga 2025) and within the Limpopo and Save Basins (Bicho *et al.* 2023). Additional sites occur along the southern coastline in clusters around

Table 3. Palaeoenvironmental dates by depositional environment and method.

Depositional environment	N	AMS	^{14}C	OSL
Lacustrine	112	74	38	-
Dune	21	-	-	21
Deltaic	14	10	-	4
Estuarine	6	6	-	-
Fluvial	2	-	-	2
Baobab tree	30	24	6	-
Total	185	114	44	27

Inhambane and Vilankulos (e.g. Macamo 2006; Ekblom *et al.* 2014). In contrast, northern Mozambique is sparsely represented (around 13.5% of dated samples), with only a limited number of inland sites in the Zambezi and Lunho Valleys and a small number near the shores of Lake Niassa (Mercader *et al.* 2009, 2012; Bicho *et al.* 2018b).

The palaeoenvironmental locations are greatly concentrated on the southern coast, from the Save estuary to Maputo Bay, with the exceptions of the two baobab tree locations inland and the Mount Gorongosa sample, which also lies inland. Palaeoenvironmental dates (N = 154) outnumber archaeological dates (N = 91) in this region. This pattern reflects the extensive programme of lake sediment coring carried out on the Inhambane and Gaza coastal plains, which has yielded over a hundred radiocarbon dates from organic-rich lacustrine sediments.

Archaeological coverage in the south is dominated by the Iron Age and other ceramic component sites, the LSA and a small number of MSA sites. The coastal zone between Inhambane and Maputo has been the focus of sustained research since the 1980s, yielding key sequences at sites such as Chibuene (the southernmost Iron Age entrepôt in the Indian Ocean trade network) (Sinclair 1982; Sinclair *et al.* 2012; Ekblom *et al.* 2014), Manyikeni (a Zimbabwe Culture stone enclosure; Barker 1978; Berger 2004) and the Txina-Txina Stone Age open-air site with a complete LSA sequence (Bicho *et al.* 2023) among many others.

The Save Basin has brought new OSL dates from Chessungalane, Zimuara and WP131 and the Bunga sites extend LSA chronologies south of the Zambezi Valley into the Pleistocene for the first time. The large site of Zimuara, in the Sofala coastal plain, alone contributes 39 entries, making it the most densely dated single site in the database. Zimuara's OSL and pIRIR dates, extending to the late Middle Pleistocene, document one of the longest stratigraphic records so far obtained from Mozambique.

The entire luminescence dataset with pIRIR measurements (33 entries, now published) falls within the aeolian contexts of the Save River basin while the southern palaeoenvironmental luminescence dates collected in dune contexts use OSL (SAR) rather than pIRIR. This does not reflect a sedimentological difference, since feldspar is not absent from the southern dune sequence; rather, the southern dataset was published in 2006, prior to the development of the pIRIR protocol (post-2008), and earlier feldspar dating approaches were not widely applied owing to the complexity, time demands and lower precision of fading correction (Thomsen *et al.* 2008).

The inland central region is also notable for the Mount Gorongosa wetland record (McWethy *et al.* 2016), which documents Middle Pleistocene and Holocene environmental change in the interior. The relative scarcity of dated sites in the Zambezi Valley and Manica Highlands reflects an important gap in the geochronological coverage of what is likely to have been a key corridor for human migration and environmental connectivity between eastern and southern Africa.

The area north of the Zambezi Valley is the most sparsely sampled, with only 59 dated samples from 13 sites (13.5% of the total). Almost all of these are archaeological (54 dates), with only five palaeoenvironmental dates. This imbalance reflects the near-total absence of paleoclimate continental coring programs in northern Mozambique, a significant gap considering the ecological and climatological significance of the region, which lies within the domain of the East African monsoon system and hosts major lake systems of which Lake Malawi/Niassa is the most prominent, although it straddles the Malawi border with important results (Thompson *et al.* 2012, 2014, 2018; Wright *et al.* 2014; Lyons *et al.* 2015; Streib *et al.* 2024).

Archaeological research in the north has focused disproportionately on Early/Late Farming Community sites (e.g. at Degue-Mufa, Ibo Island, Lumbo Ponte and Songo), thereby skewing the dates in favour of the Iron Age and away from the few MSA and LSA sites near Lake Niassa (Chicaza, N'Galue and Mvumu) largely researched by Mercader and his team (Mercader *et al.* 2008, 2009, 2012, 2013) and more recently by Bicho (Bicho *et al.* 2016, 2018b, 2026; Gonçalves *et al.* 2016). The northern MSA record is geochronologically crucial but currently built on a relatively small number of ESR and U-series dates with large uncertainties.

Temporal patterns and chronological biases

The prevalence of Holocene entries in the database (361 of 442 entries, 83.7%) is expected but warrants critical reflection. Holocene dominance is partially a taphonomic and methodological artefact: organic material preserves more reliably in younger deposits and radiocarbon (the cheapest and most widely available geochronometric tool) can only date material younger than approximately 50,000 years. However, this dominance of Holocene sites also reflects a genuine research bias toward the later prehistoric and historic periods, which offer richer material culture, clearer connections to ethnohistorically documented societies and a more straightforward articulation with landscape archaeology.

The 81 Pleistocene entries in the database are entirely dependent on luminescence, ESR, U-series and cosmogenic nuclide methods and their distribution is strongly skewed toward a small number of intensively studied sites (Chessungalane, N'Galue, Txina-Txina and Zimuara). There is currently a limited number of Pleistocene dates prior to Marine Isotope Stage 2 (McWethy *et al.* 2016) from the palaeoenvironmental archive in Mozambique, a fact that limits our ability to contextualise MSA and ESA occupations within environmental frameworks.

A substantial number of entries in the database, particularly for the Iron Age, derive from radiocarbon measurements made between the 1980s and the early 2000s using decay-counting at the Uppsala Tandem Laboratory (St-series) and the Pretoria laboratory (Pta-series). These dates, compiled chiefly from Morais (1984, 1988), Macamo (2006) and Sinclair (1982, 1987; Sinclair *et al.* 2012), often carry large standard deviations (1–2 σ, uncertainties of 50–270 years): pretreatment at these laboratories was generally adequate (standard-acid-base-acid protocols), but some decay-counting laboratories active in this periods struggled to measure blind samples of known radiocarbon content accurately, as shown by interlaboratory comparison exercises, whereas AMS laboratories have performed consistently well in such exercises, including the most recent in 2023. While they provide a broad chronological scaffold for the archaeological sequences, their precision is insufficient for the fine-grained questions now being asked about the timing and tempo of agricultural dispersal, Indian Ocean trade connectivity and political centralisation. Reinvestigation of key Iron Age assemblages with modern AMS methods, is desirable, ideally sampling charred annual plants and wild-fruit stones such as those of marula (*Sclerocarya birrea*) to avoid the old-wood effect associated with charcoal.

A recurring challenge in compiling the database has been the inconsistent reporting of calibrated age ranges across the literature with some authors reporting calibrated ages in cal BP, others in cal. AD/BC and some older publications reporting only uncalibrated BP ages. Calibration curves have changed substantially since many of the ^{14}C dates were first reported, while updated calibrations using SHCal20 or IntCal20 would shift some probability distributions meaningfully. We have retained the uncalibrated ranges as originally reported by the relevant primary authors but systematic calibration using current curves should be undertaken for any synthesis that depends on the precise ages of specific sites.

Gaps, biases and research priorities

Our analysis reveals several significant gaps in the geochronological record of Mozambique that deserve targeted attention.

Northern palaeoenvironmental records

The near-total absence of dated palaeoenvironmental sequences from northern Mozambique represents a critical gap. The region's lakes, wetlands and floodplains have not been systematically cored, except for the 1.3-million-year-long core in Lake Malawi (Lyons *et al.* 2015), meaning that the environmental backdrop for MSA and early Holocene occupations in Cabo Delgado, Niassa and Nampula provinces are essentially unknown. Linking the Stone Age record from sites like N'Galue and Chicaza to regional palaeoclimatic records requires precisely this type of archive.

MSA and ESA chronology

Twenty-nine MSA dates from across the country currently rest on a relatively small number of ESR, U-series and luminescence dates with large uncertainties and on radiocarbon measurements at the very limit of the methods reliability. Systematic OSL/pIRIR dating of MSA sediment sequences, combined with refinement of existing ESR chronologies, is urgently needed. No ESA dates are available outside Mapa, and these are to be rejected as argued above.

Central corridor coverage

The Zambezi Valley, Manica Highlands and the interior of Tete and Zambezia provinces are almost entirely undated. These zones are likely to have been key corridors for human dispersal and biotic exchange between eastern and southern Africa, but remain a chronological blank, although sites are known from them (Gonçalves *et al.* 2016).

Reinvestigation of legacy radiocarbon dates

Many Iron Age chronologies are founded on ^{14}C dates with large uncertainties measured by outdated techniques. A targeted programme of high-precision AMS redating at key sites would substantially improve the resolution of these archaeological sequences.

Palaeoenvironmental–archaeological integration

Despite the large number of palaeoenvironmental dates from the southern lakes, these records have rarely been directly integrated with adjacent archaeological chronologies to test hypotheses about human-environment interaction. Future research should aim to date both contexts in the same study area using complementary methods.

Conclusion

This paper presents the first systematic overview of absolute dating data from Mozambique, drawing on a database of 442 entries from 69 sites. The analysis reveals a chronometric record that is rich in some dimensions, namely in southern Holocene contexts, but sparse and methodologically narrow in others, especially in Pleistocene contexts, at northern sites and across palaeoenvironmental archives outside the southern coastal plain.

Radiocarbon dominates the dataset (75.6% of entries), reflecting both its versatility and its long history as the main geochronometric tool in late Quaternary African archaeology and palaeoenvironmental research. Luminescence techniques such as OSL and pIRIR applied to aeolian and coastal dune sediments are rapidly expanding the dataset's temporal reach into the Pleistocene. Luminescence dating remains the primary tools for dating the MSA in the absence of organic material, since sedimentary quartz and feldspar grains are rarely absent from a given site, with ERS and U-series providing valuable results where suitable materials such as tooth enamel and carbonated are preserved. Resolution in Mozambican contexts nonetheless requires improvement through expanded sampling.

The regional and contextual biases documented here, including the dominance of southern sites, the scarcity of northern palaeoenvironmental records, the limited chronological precision of many Iron Age and other ceramic sites and the near absence of dated Pleistocene palaeoenvironmental sequences, define a clear agenda for future geochronological investment. As Mozambique's archaeological and palaeoenvironmental research communities grow in capacity, and as international collaborations bring new methods and resources to bear, the chronological framework assembled here provides both a baseline and a roadmap for the work ahead.

Acknowledgements

We thank the Direcção Nacional do Património Cultural de Moçambique for archaeological permits and logistical support. Survey work was funded by various grants from the Fundação para a Ciência e Tecnologia (PTDC/EPH-ARQ/4168/2014 to JH; grant PTDC/EPH-ARQ/4998/2012 to NB; project PTDC/HAR-ARQ/28148/2017 and contract 2023.10993.TENURE.024/CP00040/CT00012 to AG), the Wenner-Gren Foundation for Anthropological Research and the National Geographic Society to NB (grants HJ-033R-17 and W-373-17). Since 2023, NB has been funded by an ERC Advanced grant: DISPERSALS (101052761). We also want to thank the reviewers for their extensive comments, which greatly helped to improve the manuscript.

Data availability statement

The data that support the findings of this study are openly available in OSF at https://doi.org/10.17605/OSF.IO/APJF2. The database will be maintained by the corresponding author and researchers are encouraged to submit new dates for inclusion via email.

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