



First cross dating (U/Th-14C) of calcite covering rock paintings in Africa: The case of the Lovo Massif, Democratic Republic of the Congo

Geoffroy Heimlich, Edwige Pons-Branchu, Hélène Valladas, Arnaud Dapoigny, Jean-Pascal Dumoulin, Jocelyn Barbarand, Jean-Loïc Le Quellec, Clément Mambu Nsangathi

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Geoffroy Heimlich ^{a,*,1}, Edwige Pons-Branchu ^b, Hélène Valladas ^b, Arnaud Dapoigny ^b,
Jean-Pascal Dumoulin ^c, Jocelyn Barbarand ^d, Jean-Loïc Le Quellec ^e,
Clément Mambu Nsangathi ^{f,1}

^f Institut des Musées Nationaux du Congo (IMNC), Kinshasa, Democratic Republic of the Congo

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art of this region has never been the subject of extensive investigations and their age remains generally uncertain. The Pan-African Congress on Prehistory, which took place in Leopoldville (now Kinshasa) in 1959, revealed this artwork which was then largely unknown to the specialists of the time. Thanks to the indications of missionaries, Georges Mortelmans and Roger Monteyne inventoried numerous previously unknown rock art sites, which they attributed to the protohistoric period contemporary with the former Kongo kingdom, while they were preparing an expedition in the Lower Congo (now Kongo Central) (Mortelmans and Monteyne, 1962). This preliminary research revealed one coherent entity: the Lovo Massif, which was studied in 1952 by Joseph De Munck, Paul Raymaekers and Hendrik van Moorsel in 1962, and then by Pierre de Maret in 1972 and 1973 (De Munck, 1960; Raymaekers and van Moorsel, 1964; de Maret, 1982). Since Pierre de Maret, no more field research had been undertaken on the rock art of Kongo Central until 2007, when one of us (Geoffroy Heimlich) undertook the study in the framework of his doctoral research. Since 2016, it has been continued by a major cooperation project between the Democratic Republic of the Congo and France, co-directed by Geoffroy Heimlich and Clément Mambu Nsangathi (Heimlich 2020a, 2020b; Heimlich and Mambu Nsangathi, 2022).

To give an idea of the Lovo Massif, one has to imagine that on about 430 km² there are hundreds of limestone outcrops with spectacular relief, pierced by numerous caves and rock shelters (Fig. 2). With 117 inventoried sites (of which twenty are decorated caves), this massif

contains the largest concentration of rock art sites in the entire region. During our field studies, from 2007 to 2019, 73 sites were examined, 66 of which had not yet been inventoried, representing more than 5700 images (Heimlich, 2017). These figures are located in river beds, at the foot of cliffs, in shelters and in the depths of caves. They are mostly geometric figures (crosses, circles, squares), sometimes associated with zoomorphs (lizards, antelopes) or anthropomorphs armed with swords, bows and arrows or guns. Exceptionally, therianthropes, partly human and partly animal mythical beings, have been represented.

Inhabited by the present Ndibu, one of the Kongo sub-groups, the Lovo Massif is in the north of territories that were, from the 14th to the 18th centuries, under the direct or indirect control of the ancient kingdom of Kongo (Heimlich, 2017). It is a privileged field of observation, allowing us to analyze an African society over half a millennium. Although this kingdom has been, since 1500, one of the best documented in the whole of Africa both by historical sources and by ethnographic and anthropological sources for more recent periods, it remains partly unknown from an archaeological point of view (Clist et al., 2018; Thornton, 2018).

1.2. The red geometric paintings of the Lovo Massif

Until now, the red geometric paintings have not been the subject of pluridisciplinary studies even if several sites have been identified in the Lovo Massif. Their chronology and their association with different

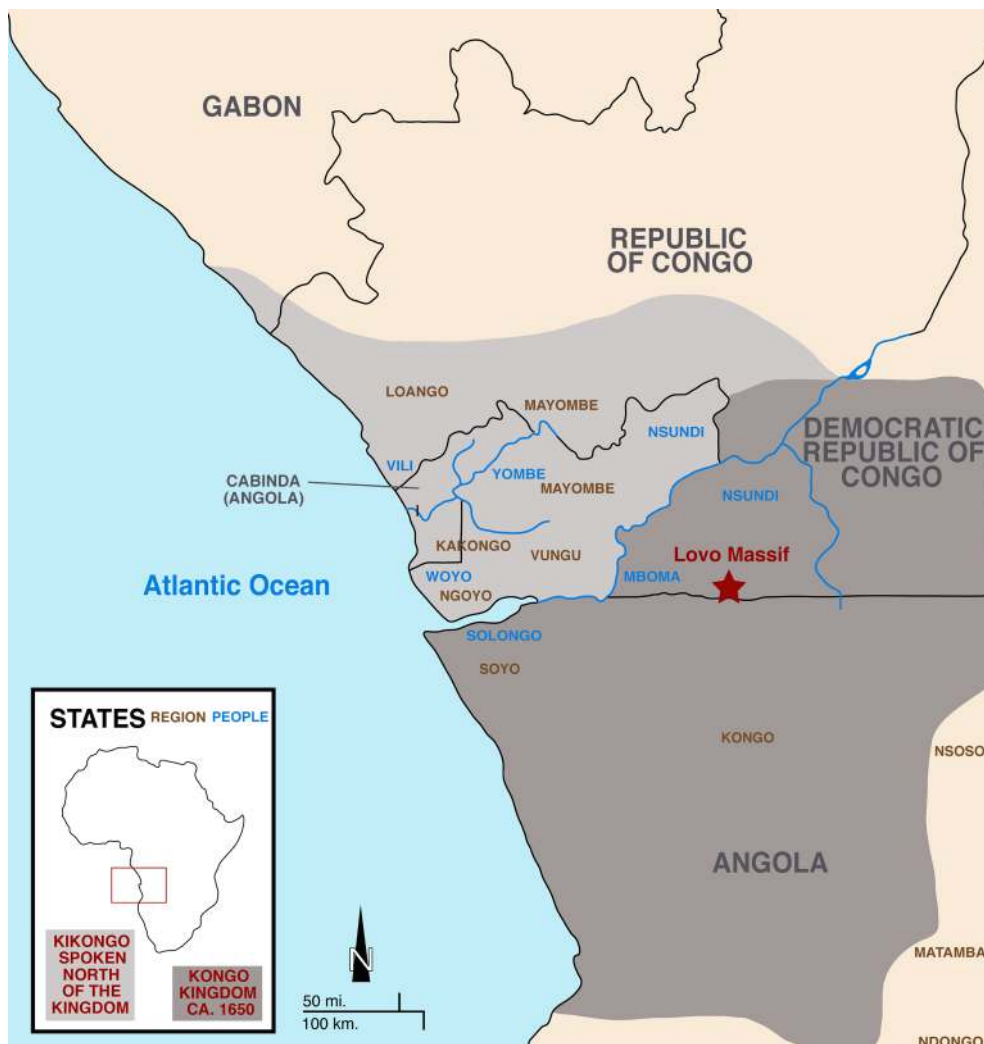


Fig. 1. Location of the Lovo Massif (map Cooksey et al. 2013, modif. Geoffroy Heimlich).



Fig. 2. General view of the Lovo Massif. Typical karstic landscape of the Lovo Massif (Florent de La Tullaye).

human groups are still very poorly established.

The objective of this paper was to date red geometric finger paintings in order to test the hypothesis of a rock art attributable to hunter-gatherer populations. This group of paintings is composed essentially of circular and linear motifs, scalariforms and groupings of finger daubings (Fig. 3).

Smith (1997, 2006) indicated that similar schematic paintings had been found in Zambia, Malawi, Mozambique, Angola, and Katanga province (Democratic Republic of the Congo). This distribution of red paintings, suggesting possible very ancient communication between large areas, less than three thousand years ago, is thought to be related to hunter-gatherer movements, particularly of Twa hunter populations who, according to traditions collected in Zambia and Malawi, lived there before the Bantu migrations (Clark, 1959, 1966; Namono, 2010; Phillipson, 1972, 1976; Smith, 1997; Zubieta, 2009). Assuming that Pygmies are descendants of former indigenous populations in Central Africa, this argument may thus have important implications for our understanding of how a large part of Africa was eventually populated (Smith 2006). The question is whether this Twa rock tradition extend as far as the Kongo Central, as assumed by Desmond Clark and later Benjamin Smith (Clark 1966).

According to Smith (1997), these red paintings were exclusively executed by women. He suggested that their significance is divinatory

and linked to fertility and rain rituals, the Twa being credited with great power over rain in Chewa traditions collected in eastern Zambia and Malawi. Vertical lines of dots appearing to “fall” from a scalariform pattern have been interpreted as rain falling from a cloud.

Elements of dating are still required. In the Chifubwa Stream rock-shelter (Zambia), for example, a series of hoops engraved and then painted in red and black was partially obliterated by a layer of sand that also covered charcoal dated to 6310 ± 250 BP (C-663), between 5712 and 4618 cal BC (Libby, 1952; Clark, 1958). The dating obtained is that of the sediment layer covering the motifs studied (*terminus ante quem*). At Nakapapula (Zambia), a date later than 1180 ± 100 BP, between 659 and 1026 cal AD (GX-535), can be proposed for red geometric paintings on the eastern bank of the Luangwa river. A block fell against the wall in the second half of the first millennium AD, and the paintings were made around but not below it (Phillipson, 1969). Unfortunately, these analyses were done several decades ago and the association between the dated materials and the decorated wall is not firmly established.

In a previous study (Heimlich, 2017), the rock art of the Lovo Massif was classified into four groups: A, B, C and D (Fig. 4). Group A includes anthropomorphs and therianthropes painted in red and armed with rifles or smoking pipes. The cross called SI-CR-A4 was the most frequently recorded motif. Group B essentially consists of engraved motifs. The only anthropomorphic type shows the trunk of a body represented by multiple lines. Lizard-like shapes and the cross (SI-CR-B) are the most frequently recorded motifs. In group C, the anthropomorphs, drawn in black, are armed with a sword or a bow. Lizard-like shapes and antelopes are the two most typical zoomorphic types. The cross (SI-CR-A1) is the most frequently found. Group D is characterized by red geometric paintings with fingered prints, which are the subject of the present study.

The results also show that there is a clear stylistic and thematic distinction separating the red geometric paintings of group D from those of groups A, B and C. We can, therefore, consider two possibilities. Either these stylistic traditions correspond to two groups, contemporary or not (confirming the hypothesis of a hunter-gatherer rock art tradition, Smith 1997), or they are associated with specific Kongo rituals.

Traditionally, researchers have tried to establish the chronological sequence of rock art styles in the region by observing the styles and overlays (De Munck, 1960; Mortelmans and Monteyne, 1962; Raymaekers and van Moorsel, 1964; de Maret, 1982). By collaborating with the Centre de Recherche et de Restauration des Musées de France, it has been possible to obtain direct dates for charcoal drawings from this region for the first time (Heimlich et al., 2013). Nine direct dates (the quantity was limited by the challenging nature of the work) were



Fig. 3. Example of red geometric paintings on one of the Mampakasa sites (Geoffroy Heimlich).

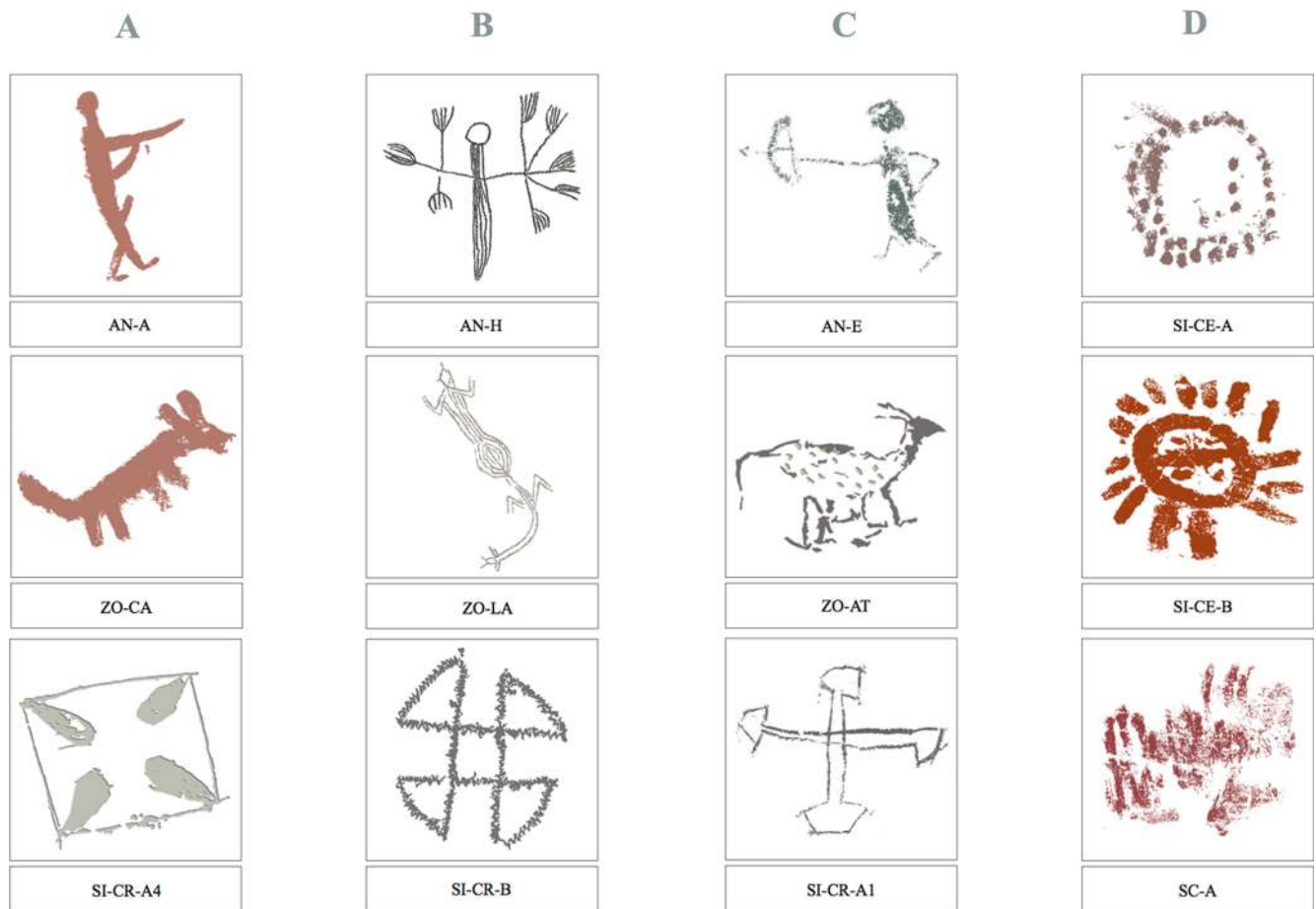


Fig. 4. The main image types associated with the four groups of rock art identified in the Lovo Massif area (Geoffroy Heimlich).

obtained from black paintings, including eight from Tovo Cave, which is unique in Africa. The ^{14}C dates obtained are mostly situated in the 15th–18th centuries, which allows us to associate these images with the Kongo kingdom.

In the Tovo decorated cave, analyses on red pigments of a geometric painting were carried out by scanning electron microscopy (SEM). They revealed the presence of a red ochre mineral pigment, composed essentially of hematite and kaolinite (Heimlich, 2017). These analyses did not reveal the presence of any organic matter (remains of binder) that could be dated by ^{14}C dating. The scope of this paper is to obtain information on the chronology of some parietal realizations. For this purpose, we used the uranium–thorium dating method applied to carbonate deposited on a decorated panel, with a control using ^{14}C on one sample. In fact, recent studies showed that in some particular cases, open system with radionuclides mobilization can produce biased ages (Pons-Branchu et al. 2020).

2. Material and methods

We present the dating by the uranium–thorium method of secondary calcite layers overlying red geometric paintings in order to get a minimum age (*terminus ante quem*) for the underlying paintings. When possible, we also dated the same samples by ^{14}C . In 2015, secondary carbonate layers covering certain figures, in particular red geometric paintings on the M'Bubulu rock art site, were sampled. To the best of our knowledge, this dating technique has never yet been applied on the African continent.

2.1. Sampling in m'bubulu (Lovo Massif)

This group of red geometric paintings has a homogeneous distribution throughout the Lovo Massif. A total of 187 motifs have been recorded on 24 sites. All these “red geometrics” are located in open-air walls, except for two of them that are in the Tovo cave. Among them, the M'Bubulu outcrop includes five rock art sites that are currently inventoried, representing a total of nearly 107 geometric motifs. The site of M'Bubulu 4, which is the subject of the present study, includes 12 red geometric paintings in total. It is located at the foot of a cliff (Fig. 5). The geometric motifs are painted in a recess of the wall.

At this site, four samples of calcium carbonate deposits covering paintings were taken using a scalpel (M1, M2, M3 and M5 weighing a few tens of milligrams) (Fig. 6). Samples M1, M2 and M3 were taken on calcium carbonate deposits covering an oval-shaped motif, and sample M5 from a second undetermined geometric figure with finger lines and dots (Figs. 7–8). For comparison, a sample of bare rock in vicinity to paintings was also taken (M4). They were stored in aluminum folds.

At the laboratory, the fragments of samples were cleaned using a scalpel in order to remove dirty or altered surface (dust and sediments). M1, the smallest, was prepared for ^{14}C analysis. M2 was split into two parts, one for ^{14}C analysis and the second for U/Th analysis while M3, M4 and M5 were treated for U/Th analysis. Thin sections of M3 and M5 samples were prepared in order to determine their structure and mineralogy using optical and cathodoluminescence microscopy and scanning electron microscopy.

2.2. Uranium-thorium analysis

Since a decade, the uranium–thorium (or $^{230}\text{Th}/^{234}\text{U}$ or U/Th)



Fig. 5. General view of the M'Bubulu 4 rock art site (Geoffroy Heimlich).

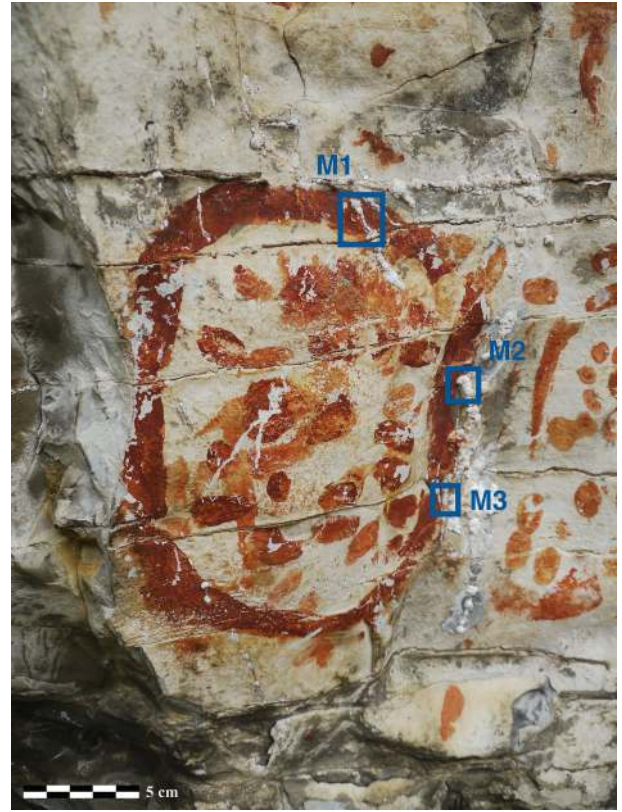


Fig. 7. Geometric painting, which was the subject of the samples M1, M2 and M3 (Geoffroy Heimlich).



Fig. 6. Location of samples at the M'Bubulu 4 rock art site (Geoffroy Heimlich).



Fig. 8. Undetermined geometric motif with finger lines and dots, where the M5 sample was taken (Geoffroy Heimlich).

method has been used for the dating of secondary calcitic crusts over- or under-lying rock art in order to give minimum (*terminus ante quem*) or maximum (*terminus post quem*) ages for the rock art (Bischoff et al., 2003; Pike et al., 2012; Aubert et al., 2014). A controversy arose on the validity of U/Th dating on these thin layers that could in certain cases suffer diagenetic alteration (open system behavior due to radionuclide mobilization) or bias due to the presence of detrital components (Bednarik, 2012; Pons-Branchu et al., 2014; Slimak et al., 2018; Pearce and Bonneau, 2018). Open system behavior could result in uranium

leaching, with apparent ages older than true ages due to uranium loss. In such a case, a correlation between uranium content and apparent age has been observed (Pons-Branchu et al., 2020). In order to test for the validity of the ages determined by this method, it has been proposed to compare U/Th and ^{14}C ages. In the event of disagreement, considering the mandatory corrections (i.e., dead carbon for ^{14}C and detrital thorium for U/Th), open system behavior is suspected for U-series nuclides and/

or radiocarbon, and the results of both methods need to be further evaluated.

This cross-dating has been successfully applied in different geological and archaeological contexts, including decorated caves from Spain, Brazil or Borneo, but also from open air sites such as those in Huashan mountains or Cangyuan County in China (Shao et al., 2017, 2021; Fontugne et al. 2013; Plagnes et al., 2003; Corchón Rodríguez et al., 2015; Valladas et al., 2017). This cross-dating has enabled the ages to be validated in most cases, and in some cases has led to biased ages being discarded.

Uranium-thorium analyses were performed at the *Laboratoire des Sciences du Climat et de l'Environnement* in Gif-sur-Yvette (France). Between 20 and 60 mg of sample were weighed in a beaker where a known amount of a mixed ^{236}U - ^{233}U - ^{229}Th spike had been previously added. The dissolution was performed using diluted HCl (sample covered with water and HCl added drops by drop), and for the residual fraction concentrated HNO_3 overnight on a hot plate. Once totally dissolved, U and Th fractions were co-precipitated with FeOH , and separated using UTEVA resin (Eichrom Technologies, USA), following a procedure described in Pons-Branchu et al. (2014). Uranium and thorium isotopes were determined simultaneously using a ThermoScientific Neptune^{plus} multicollector-ICP-MS fitted with a jet pump interface and an aridus II desolvating system, following the protocol developed at LSCE (Pons-Branchu et al. 2014).

2.3. Radiocarbon analysis

The two carbonate samples were cleaned as described by Dumoulin et al. (2017). The clean samples were oxidized in CO_2 and then converted to graphite sample prior to being measured at the Artemis AMS-facility (CEA Saclay, LMC14; Moreau et al., 2013; Moreau et al., 2020). The ^{14}C measurements were corrected to the isotopic fractionation according to the ^{13}C values measured on the Artemis facility, following international recommendations (Mook and van der Plicht, 1999).

3. Results

3.1. Dating

All the samples were analyzed for U/Th, except the smallest one (M1) (Table 1). They displayed very high U content and $\delta^{234}\text{U}_\text{M}$ (respectively between 5.16 ± 0.09 and 11.03 ± 0.11 ppm, and between 831.0 ± 1.0 and 1172.4 ± 1.4 ‰). Corrected ages from detrital content ranged from 1492 ± 76 to 1964 ± 7 (years AD), with large error bars for the samples displaying large amounts of detrital fraction (high ^{232}Th content and low $^{230}\text{Th}/^{232}\text{Th}$ ratios). The determination of radiocarbon ages is hampered by the possible presence of dead carbon (DCP), not from the atmosphere but from old carbon stored in soil or coming from host rock dissolution (Genty and Massault, 1997; Goslar et al., 2000; Genty et al., 2001). We first calibrated the ages assuming 0 % of DCP to obtain the maximum ^{14}C age (Table 2). For sample M1, the calibrated age is very young (300 years to modern), indicating that M1 could not be corrected for DCP higher than a few percent. On the contrary for sample M2, the ^{14}C age is much older (5313–5045 year cal BP) than the U/Th age which is recent (1964 ± 7 year AD); the “dead carbon portion”

Table 2

AMS ^{14}C ages determined on samples M1 and M2, with calibrated ages (using SHCal20 Hogg et al., 2020) assuming 0% of dead carbon (DCP). For the M2 sample, the dead carbon proportion was calculated using paired U/Th and ^{14}C ages, see text for details.

Lab code	Sample	$\delta^{13}\text{C}$	Age BP	Age Cal BP (0 % C mort)	Dead Carbon (%)
SacA43957	M2	3.7	4555 ± 30	5313–5045	42.03
SacA43958	M1	−1.1	200 ± 30	300–modern	

(DCP) calculated from paired U/Th and ^{14}C ages using the equation: $\text{DCP} = [1 - (a^{14}\text{C}_{\text{init}}/a^{14}\text{C}_{\text{atm.init}})] \times 100$ (Genty and Massault, 1997) is equal to 42 %.

Errors are given at 2 s errors. $\delta^{234}\text{U}$ initial was calculated based on ^{230}Th age (t), i.e., $\delta^{234}\text{U}_{\text{ini}} = \delta^{234}\text{U}_\text{M} \times e^{\lambda^{234}t}$, and t is corrected age. The U/Th ages were calculated from measured atomic ratios through iterative age estimation (Ludwig and Titterton, 1994), using the ^{230}Th , ^{234}U and ^{238}U decay constants of Cheng et al. (2013) and Jaffey et al. (1971). Ages are given as raw age (ka) and ages corrected from detrital fraction (using $^{230}\text{Th}/^{232}\text{Th}$ activity ratio of the detrital fraction of 1.5 ± 0.75) as calendar years.

3.2. Mineralogy

Microscopic examination shows that the samples have a heterogeneous structure with variations between the inner and outer parts of the samples. The internal part is homogeneous and consists of calcite. Towards the outside, very minor precipitations of silica appear then a consequent partial replacement of calcite by celestine (SrSO_4) (Fig. 9).

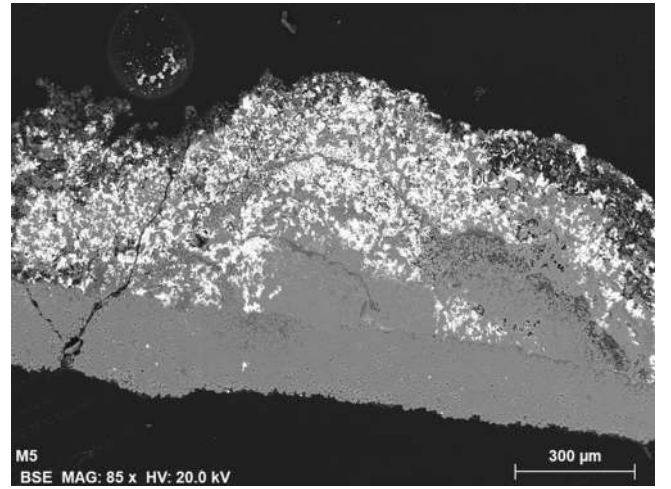


Fig. 9. BSE image of sample M5 showing the progressive replacement of the initial calcitic phase (dark phase) by celestine (white phase). The darker phase corresponds to high porosity calcite. SEM images have been acquired using a HIROX SH3000 microscope equipped with a KE BSE detector.

Table 1

Uranium and thorium concentrations, isotopic composition and ages of the samples. Uranium isotopic ratio is expressed as $\delta^{234}\text{U}_\text{M} = ([^{234}\text{U}/^{238}\text{U}]_{\text{measured}} \text{ activity ratio} - 1) \times 1000$.

Sample	$[^{238}\text{U}]$ ppm		$[^{232}\text{Th}]$		$\delta^{234}\text{U}_\text{M}$		$(^{230}\text{Th}/^{238}\text{U})$		$(^{230}\text{Th}/^{232}\text{Th})$		Raw Age (ka)		Corrected age (AD)		$\delta^{234}\text{U}_\text{ini}$	
			ppb		(‰)										(‰)	
M3	5.16	±0.09	160.35	±0.12	1051.7	±1.8	0.0142	±0.00014	1.39	±0.01	0.756	±0.009	1838	±179	1052.3	±1.8
M4	11.03	±0.11	54.05	±0.04	831.0	±1.0	0.0112	±0.00006	6.94	±0.03	0.668	±0.004	1492	±76	832.2	±1.0
M5	7.86	±0.02	13.99	±0.01	1025.7	±1.4	0.0080	±0.00006	13.79	±0.10	0.434	±0.004	1629	±27	1026.8	±1.4
M2	8.29	±0.01	2.94	±0.002	1172.4	±1.4	0.00122	±0.00004	10.31	±0.35	0.062	±0.002	1964	±7	1172.6	±1.4

For sample M3 only, a late phase of gypsum is recognized.

4. Discussion

4.1. Validity of the ages

For the M'Bubulu site, the different U/Th ages display no clear relation and the uranium content of the samples suggests that there is no uranium loss; for sample M2, ^{14}C is compatible with the U/Th age, if a high dead carbon content (42 %) is taken into account. On the contrary, for sample M1, the young ^{14}C age implies low DCP (a few % at most). High DCP variability (from low values to up to 42 and 57 % DCP) has already been observed for secondary carbonate deposits over/under rock art on open air sites (Shao et al., 2017). In this previous study, it was shown that DCP varies with mineralogy (calcite /aragonite /hydromagnesite) and with $\delta^{18}\text{O}$, indicating different deposition processes, but this variability does not affect the reliability of the ages. The partial replacement of calcite by celestine in the outer part of the sample may not affect the validity of the age because external part has been removed before analysis. Moreover, since celestine do not incorporate uranium (Balboni et al., 2015), the very high uranium content measured in the samples is a good indication that calcitic part has been analyzed, and not the part with celestine replacement.

Likewise the calculated U/Th ages of the Lovo Massif can be used for the discussion of the chronology of its rock art. The very recent ages (1964 ± 7 and 1838 ± 179 yr AD) obtained on the carbonate samples M2 and M3 suggest that they were taken at the surface of the carbonate deposit where the crystallization process is still in progress. The oldest age (1629 ± 27 yr AD) obtained on sample M5 taken on a red punctuation sign gives the most relevant information on the chronology of these decorations. Moreover the age obtained on the sample M4 taken on the same carbonate deposit but outside the painting gives similar chronological information. We can then conclude that the red paintings of the M'Bubulu site are older than the secondary carbonate layers M5

dated at 1629 ± 27 year AD.

4.2. The chronology of the Lovo rock art: Questioning the authorship of the red geometric paintings

The “*terminus ante quem*” (minimum date) obtained for M'Bubulu (1629 ± 27 years AD) are consistent with the direct radiocarbon dating carried out on charcoal drawings sampled in the decorated caves of Tovo and Nkamba of the Lovo Massif (Heimlich et al., 2013; Heimlich, 2017). Even though still imprecise, the ^{14}C dates obtained are mostly situated in the 15th-18th centuries, meaning that these motifs can be associated with the Kongo kingdom (Fig. 10). Comparison of the ethnological, historical, archaeological and mythological points of view also confirms that certain ritual and symbolic aspects of Kongo are pre-Christian and refer to cosmogony, anthropogony or narratives associated with the mythical origin of death. This is the case for the motifs, which are closely related to oral traditions (Heimlich et al., 2018).

Our chronological studies based on radiometric results suggest that the red geometric paintings of M'Bubulu and the black drawings of Tovo and Nkamba could be contemporary even if they are clearly distinguished by their style and theme. We can deduce that the first three stylistic groups identified in the Lovo Massif (A, B and C) are several variants of the same Kongo stylistic tradition (Heimlich, 2016, 2017). These three groups, to which the black drawings dated at Tovo and Nkamba sites are related, have common themes. Their distribution also intersects the boundaries of the ancient Kongo kingdom. We find anthropomorphs armed with a gun, a shield or a bow, or smoking a pipe, or simply with their right arm raised. Lizard-like shapes are also present, as are therianthropes, and typical cross motifs. The fourth and last group (D) is composed of red geometric paintings made with finger-drawn lines, as in the M'Bubulu outcrop. There is no visible stylistic evolution or common theme with the other groups.

In addition to a similar graphic repertoire, we can also note other points of convergence. Among the 24 sites where we have been able to

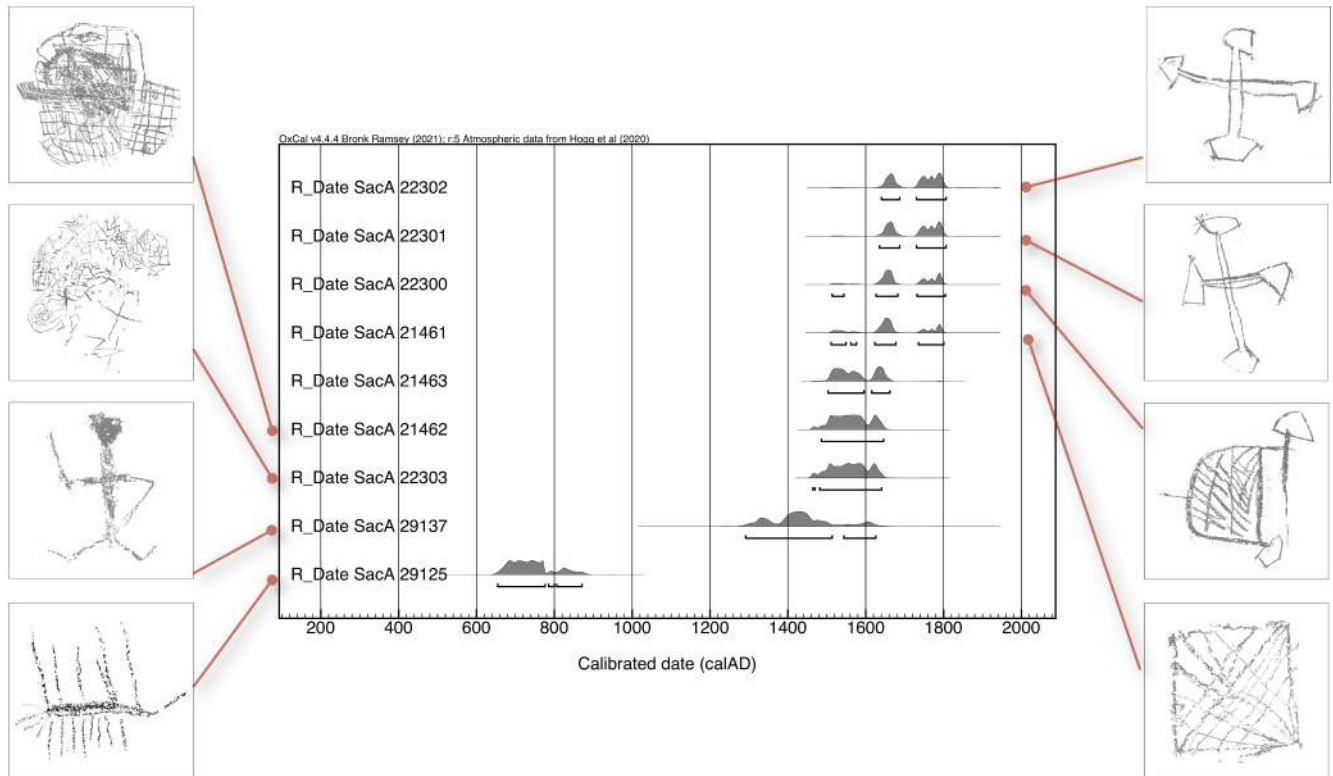


Fig. 10. Direct radiocarbon dates for the rock art: presentation of probability densities of age (in AD) after calibration in OxCal v4.4 using the ShCal20 calibration curve (Heimlich et al., 2013).



Fig. 11. Black drawings superimposed on red geometric paintings at the Mabwita rock art site (Geoffroy Heimlich).

inventory “red geometrics,” all are located outside, with the exception of two of them, which are in the Tovo cave. The study of superimpositions has also allowed us to show that in 20 cases, the red paintings are always older than the black drawings (Fig. 11). As the majority of the red paintings are associated with each other, their mutual avoidance in space with the black drawings would therefore suggest that they correspond to different traditions.

In the M'Bubulu Massif, some of these are also found high up, up to five meters above the ground, as is frequently observed for this Twa rock art tradition (Smith, 1995) (Fig. 12).



Fig. 12. Red geometric paintings on one of the M'Bubulu sites. These finger paintings are located more than five meters above the ground (Geoffroy Heimlich).

In the M'Bubulu and Mbanza Mbota outcrops, we also observed that on several occasions, the “red geometrics” are covered with marks that may be caused by ancient stoning (as attested by their patina). Rituals of this type, involving the stoning of red paintings as part of rain rituals, were observed by David Phillipson in Zambia (Phillipson, 1976). There is also evidence that geometric paintings have sometimes been a concern in recent times. For instance, a pit had been dug at the foot of the decorated wall of the M'Bubulu site, and limestone concretions, of a particularly brilliant aspect, had been taken there. A similar observation was made in the cave of Tovo. It was reported to us that this was the work of people in search of raw materials, and who thought that the paintings indicated the location of deposits of raw materials.

Another important point is the relationship between rock art and mythology (Heimlich et al. 2018). All known mythical narratives in Central Africa show a double anthropogony. According to these myths, the first creation produced small, deformed beings who carved the rocks before disappearing. When they dispersed, the various Kongo clans settled on the lands of these *mafulamengo*, *mbwidi mbodila* and *mbaka* (Cuvelier, 1930; Laman, 1953; van Wing, 1959; Wannyn, 1961). In the traditions collected in the Lovo Massif, however, there is no mention of the *mbaka*, who are sometimes identified with dwarfs, sometimes with Pygmies. Although some of the decorated rock shelters are currently considered sacred, the traditions of the *mbaka* are very disparate in the Lovo Massif and the Nkula SNEL region. All traditional chiefs use this term in reference to the Pygmies, clearly distinguishing it from *mbwidi mbodila* and *mafulamengo*. Some even doubt their existence in this region. Traditions collected in the Nkula SNEL region reveal the enmity of the Kongo towards them, which allegedly justified many battles. Nevertheless, none of the traditions collected relates the *mbaka* to the paintings.

In the present state of our ignorance, we can only make a few cursory observations, pending new archaeological excavations, new dating of the paintings, and further investigation of oral traditions. However, the dates obtained for the M'Bubulu site suggest that these red geometric paintings are coeval with the time of the ancient Kongo kingdom, or even older. This would suggest that they were related to specific Kongo rituals.

The function of these images over the long term can only be elucidated by taking into account both the changes and the continuities revealed by combining historical, archaeological, and mythological approaches. These initial results will therefore need to be systematized in order to obtain a more precise chronological framework, as it is possible that the origin of the rock art traditions lies at an earlier period, as suggested by one of the dates of Tovo dating back to the sixth century but which needs to be confirmed (Heimlich, 2017).

For the moment, as our data are not precise enough and require confirmation, we agree with the remark of one of us (Le Quellec, 2004) for whom “everywhere in the world, the ‘signs’ and geometric tracings, by their elementary character, either ‘resist’ interpretation, or call, according to fashion, for uncontrollable readings (astral, calendrical, shamanic, etc.) [...] The universality in question is in no way archetypal or genetic, but simply inevitable whenever the comparison concerns the simplest signs, unfolding only on the two dimensions of a decorated surface.”

5. Conclusion

In this study, we applied the uranium–thorium method for the first time to African rock art in order to constrain the chronology of secondary carbonate layers covering red geometric paintings. Unfortunately, radiocarbon analysis could only be carried out once in order to validate these U/Th ages. As in previous studies of open air rock art sites, a large variation of dead carbon proportion was found. Nevertheless we were able to validate the absolute chronology of these layers. We thus determined a minimum age of 1629 ± 27 (years AD) for the red geometric paintings found in the Lovo Massif. These geometric paintings

ontemporary with the ancient Kongo Kingdom or older, and could be attributed to a specific Kongo ritual.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

All data were published in the paper.

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