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Documentation of rock art motifs from the Kaua Cave in Yucatán, Mexico, using LiDAR

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Introduction

From a regional perspective, the study of rock art in caves in Yucatán, Mexico, is of particular importance, as it represents a line of research that remains underdeveloped in comparison with other areas of the Maya archaeological record. Despite the abundance of caves containing graphic and material evidence, systematic studies have been limited, largely due to the technical, logistical, and financial constraints involved in conducting research in subterranean contexts, as well as the difficulties associated with access and documentation in these environments.

This lack of detailed research has contributed to the undervaluation of many caves with rock art, which have remained marginally integrated into regional discussions concerning ritual practices, landscape use, and the symbolic construction of space. In this regard, the analysis of the rock art from the Kaua cave expands the corpus of documented sites in the region and provides fundamental elements for understanding the function of the cave within past social dynamics.

From an archaeological perspective, this cave stands out due to the presence of an extensive assemblage of rock art manifestations, as well as material evidence indicating recurrent human activities over time.

This report presents the results obtained with the support of grant **UK/1153/2025,** carried out during the summer of 2025, primarily in june and july. The project aimed to document the Kaua cave through the use of LiDAR technology. The most representative contexts were recorded using photography and photogrammetry; these materials are presented in a catalog entitled: Preliminary catalog of rock art in the Kaua Cave with the most representative paintings organized by area. In addition, several videos were produced to visualize the cave in three dimensions.

It should be noted that this research represents only an initial stage of the project; therefore, the application of additional methodologies will be required for a more detailed analysis of the rock art.

Location of Kaua Cave in Yucatán, Mexico

The town of Kaua

The town of Kaua is located in the eastern part of the state of Yucatán, between 20°24' N and 88°28' W, and covers an approximate area of 214.60 km². According to the 2010 Population and Housing Census conducted by INEGI, the locality had 2,761 inhabitants, the majority of whom are Maya speakers. The region is characterized by the absence of surface watercourses, a condition that has historically influenced patterns of human occupation, subsistence strategies, and cultural practices among both prehispanic and contemporary populations. In this context, the exploitation of subterranean water resources concentrated in cenotes and caves has been fundamental to life in the region.

Colonial church in the village of Kaua

Kaua is also recognized for its historical and documentary significance, as it is the place of origin of one of the most important Maya colonial manuscripts in the region: the Chilam Balam of Kaua, dated to 1824. This document contains an almanac, calendrical correlations, and medical-botanical texts. The calendrical years recorded span from 1797 to 1826, although entries conclude in 1824, and include three distinct numbering systems (Barrera and Rendón, 1969; George-Hirons 2015).

At present, the population of Kaua maintains a close relationship with its natural environment and preserves social, productive, and ritual practices of a communal nature that are transmitted across generations. Within this framework, caves continue to be recognized as meaningful spaces associated with collective memory and past events, reinforcing their cultural importance within the local landscape.

Early Explorations

The cave has long been known to local inhabitants due to its location within the urban area of the town. Its distinctive characteristics attracted the attention of several explorers in the past. The earliest references to the cave and its paintings—although lacking detailed descriptions—date to Franz Blom (1929) and Arthur Pearse (1938). In the 1970s, speleologists David McKenzie and James Reddell (1977) mapped much of the cave, determining the existence of nearly ten kilometers of labyrinthine passages, although no specific studies of the rock art were conducted.

In 1994, a group of U.S. explorers led by Peter Sprouse and Suzie Lasko continued the mapping efforts. Between 2002 and 2003, following multiple expeditions and refinements, additional details of the labyrinthine passages were completed with the collaboration of several teams. Until that time, all explorations had been carried out by foreign researchers.
The first publication addressing the Kaua paintings dates to 1998, by Terry Sayther, Deborah Stuart, and Allan Cob, motivated by the labyrinthine complexity of the karstic system. George Veni (2003) later detailed the history of the cave's mapping and its challenging complexity, noting that the cave comprises 565 surveyed passages connected in loops (Veni 2003:68). Currently, the cave has a total length of 10,360 meters, placing it among the longest caves in Mexico (Mixon 2003:23; Minton 2024).

Regarding its archaeological importance, in 1990, during the construction of the Mérida–Cancún highway, a branch of the cave was discovered. Archaeologists from the National Institute of Anthropology and History (INAH) became aware of the site but initially downplayed the paintings due to their characteristics, generating an academic controversy regarding their authenticity. Some specialists considered them to be contemporary expressions, based on the apparent freshness of the pigments and the absence of a systematic record that could contextualize them chronologically and culturally.

From the year 2000 onward, Mexican teams from the Ajau Speleological Group and French researchers conducted expeditions to assess the cave and its archaeological relevance (Tec 2009; Thomas, 2011). Although no exhaustive studies were formalized, the debate surrounding the authenticity of the paintings stimulated renewed interest in the cave as the subject of a thesis project. Thus, the present research not only documents the graphic manifestations but also understands the Kaua cave as a socially constructed space embedded in dynamics of use, memory, and temporal significance.

Cave Morphology

The complexity of the cave lies in its labyrinthine network of passages. It is located on the southern edge of the town center of Kaua. The main access consists of a descent along a three-meter conical slope that leads to an opening less than one meter in diameter, providing entry into a sharp-vaulted chamber. From this point, an eight-meter vertical drop—via a temporary ladder or rappel—leads to a rubble mound, followed by an additional ten-meter drop to the horizontal development.

Entrance to the cave

In general, the cave is composed of small galleries interconnected by low-ceilinged passages, with occasional water sheets. The system is predominantly horizontal and is divided into major sections: north, south, west, and the entrance; however, the most significant sections are the north and south. Along its development, the passages gradually slope toward the water table, where flooding occurs. It is important to note that water levels rise during the rainy season, and on occasion, the cave has become completely flooded.

The initial passages are wide but gradually narrow, becoming confusing and difficult to navigate, making it easy to become disoriented. The northern sector contains the most complex and entangled system, much of which lies beneath the present-day town. The interior lacks notable speleothems; walls are predominantly smooth and white, contrasting with ochre-colored floors formed by clay deposits, some of which have been extracted. In certain narrow galleries, oxygen restriction causes fatigue during transit, although other sections are better ventilated. Some areas of the cave remain unexplored. Clay deposits are particularly notable on the floors, a material commonly found in caves throughout the region. Another material present in limited sections is white earth, which is locally used as a construction material due to its properties.

Although only 650 meters of the cave were scanned using LiDAR, this recent documentation provides detailed information on heights, drops, fractures, and the spatial distribution of the paintings.

Archaeological Evidence

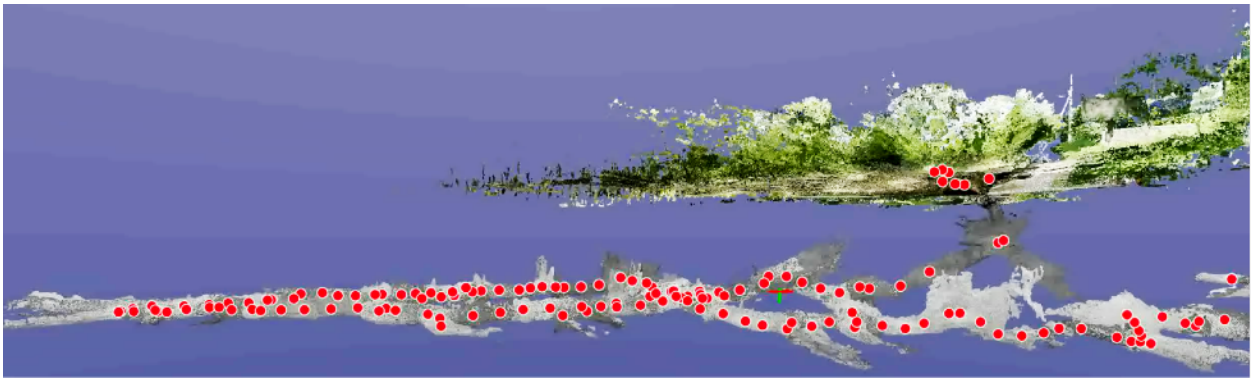
Many caves in the region were used in multiple ways by the ancient Maya, accumulating layers of meaning that persist in contemporary communities. From an archaeological perspective, the Kaua cave functioned as a physical space of repeated use over time. The passages exhibit clear evidence of clay or mud extraction, indicating its function as a prehispanic clay mine.

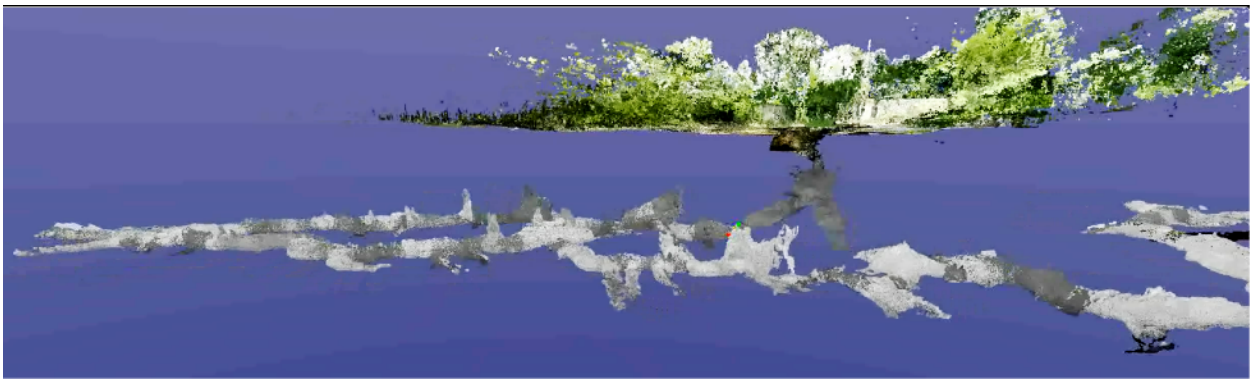
Natural deposits were excavated down to bedrock, leaving visible stratigraphic traces, such as ochre stains on the walls. Some areas show intensive exploitation, while others remain intact. The main access route is clearly marked as the principal transit path, intentionally cleared of rocks to facilitate movement.

Throughout the cave, scattered ceramic fragments were recorded, whose characteristics—color, decoration, and form—suggest a prehispanic date. Charcoal fragments were also identified both on passage surfaces and embedded within floor stratigraphy, providing useful data for chronological dating.The presence of an extensive assemblage of rock art manifestations confirms recurrent human activity. Their distribution is not random but rather associated with specific sectors of the cave, suggesting intentional spatial organization.

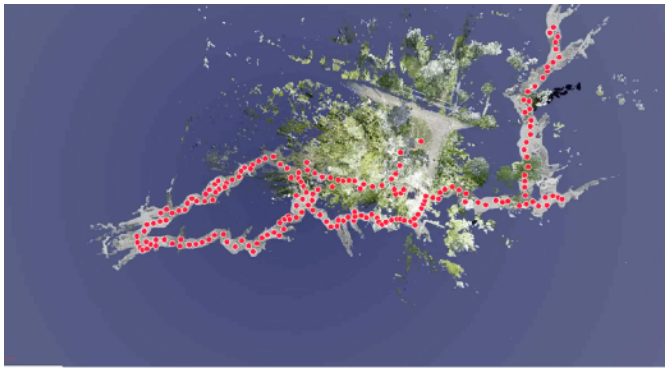
Documentation process with the Leica RTC360 scanner

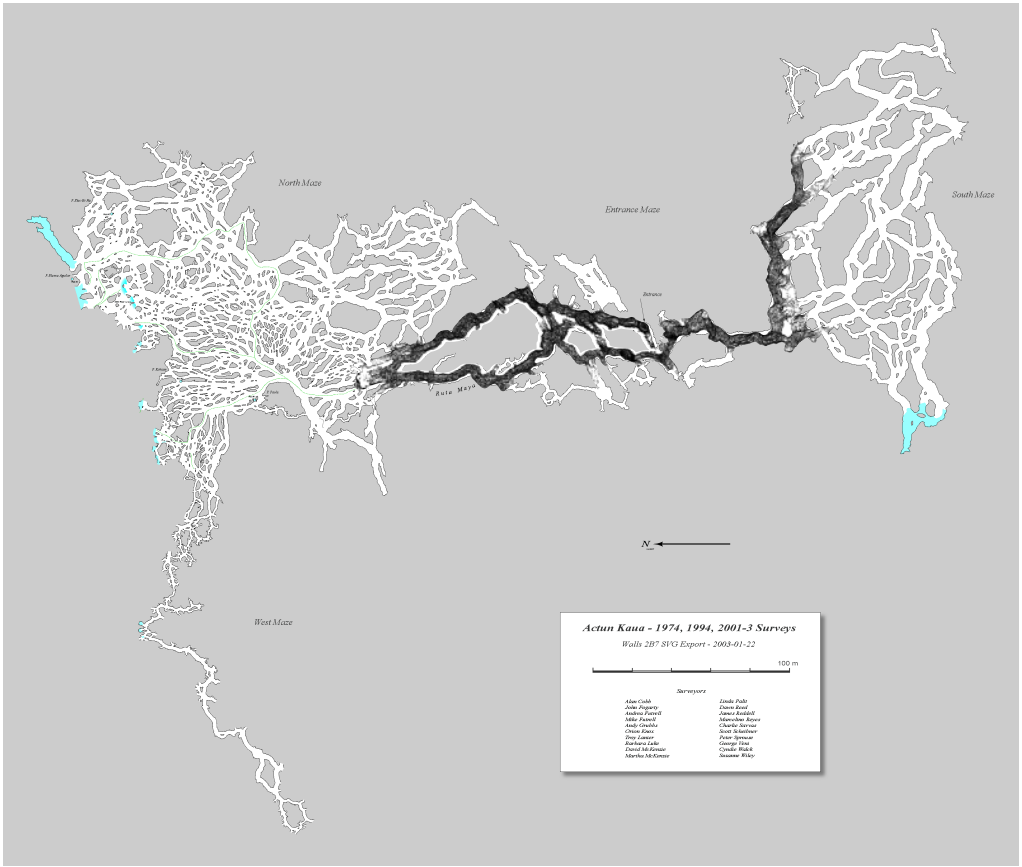
Narrow passageways during documentation.





Images showing the result of the profile scan with the unevenness from the surface to the interior of the cave. The red dots correspond to the scanner stations





The images illustrate the aerial view scan, showing the scanner stations. In order to show the dimensions of the cavern, the digital model was superimposed on the manually created map

Recent Research

With the support of grant UK/1153/2025, four visits to the Kaua cave were conducted during the summer of 2025 in order to document the cave using LiDAR scanning and to identify the most significant rock art paintings based on size, thematic content, or distinctive features. Although the total surveyed length of the cave is approximately 10,360 meters, only a 650-meter section was recorded during this initial phase using terrestrial laser scanning. This delimitation was based on methodological, archaeological, and logistical criteria:

1. the selected section includes the main access and the circulation axis leading to the central bifurcation, where a significant concentration of rock art and material evidence is located, making it the most representative area for analyzing the relationship between cave morphology and rock art distribution;
2. the use of the Leica RTC360 scanner under subterranean conditions—confined spaces, high humidity, mud, darkness, and low oxygen levels—required 197 stable scanning stations, limiting the extent of coverage during intensive fieldwork sessions.

The data were processed using Leica Register 360 Plus software to generate a point cloud and a three-dimensional model (TruView). This black-and-white survey represents an initial phase of a long-term project. The 650-meter model provides a solid basis for spatial analysis of the rock art and for comparison with previous manually produced maps. Its expansion is planned in future stages. Despite being partial, the documentation offers high-resolution information on elevations, heights, morphology, and the location of graphic manifestations, which is essential for understanding the internal organization of the cave and the spatial selection strategies employed by past populations.

Methodological Approach to Rock Art

During this stage, the most relevant groups of paintings within the scanned section were identified, along with the requirements for future documentation. Fieldwork consisted of four incursions, including local authorization procedures and logistical planning. The internal complexity of the Kaua cave—characterized by multiple galleries, elevation changes, and restricted-access sectors—has significantly shaped the challenges associated with documenting the rock art. In order to systematically organize the available information and establish a solid analytical foundation, this research includes an initial phase dedicated to the systematization of the most representative rock art sets and motifs recorded within the 650 meters documented through LiDAR scanning.

This phase is exploratory and descriptive in nature, intended to lay the groundwork for more in-depth analyses. The resulting catalog focuses on the main characteristics of the selected paintings, considering general criteria such as their location within the cave, spatial relationships with passages and surfaces, general theme—when discernible—and possible associations with other archaeological elements.

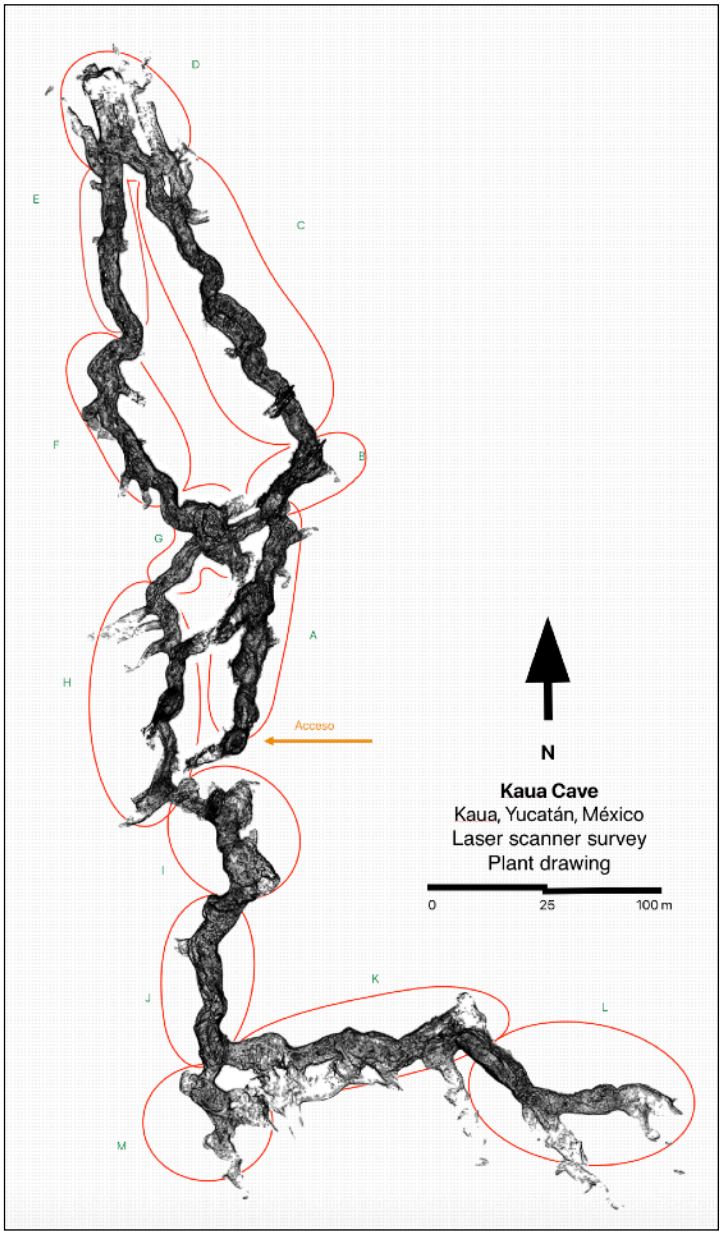
The selection of sets was based on representativeness, visibility, and spatial relevance, prioritizing sectors with higher concentrations of rock art. Although the analysis remains preliminary, it is fundamental for identifying initial patterns of distribution, thematic recurrence, and use of subterranean space.

One of the main methodological challenges lies in the organization and systematization of the rock art due to its heterogeneous distribution throughout the cave. Accordingly, the catalog is conceived not as a final product

but as a working framework to be refined and expanded in subsequent project stages. To address this spatial diversity, two complementary analytical levels were defined:

a) Macrospatial level.
This level refers to the general distribution of graphic evidence in relation to the cave's structure, including main galleries, chambers, recesses, tunnels, and cracks. It allows for the examination of preferential location patterns, such as concentrations in transitional zones (narrowings or bifurcations) or along accessible circulation routes, suggesting intentional spatial selection.

b) Microspatial or parietal level.
This level focuses on the arrangement of images on specific surfaces, such as panels, groups, or superimpositions, and includes the recording of isolated or dispersed images.



Map of the study area showing the division of the cave into areas

Pigments and Application Techniques

The pigments used in most motifs appear to have been produced from ochre-toned clay soils present on the cave floors. In some sections, sedimentary layers with noticeable chromatic variation are visible. This type of soil, locally known in the Maya language as *kankab*, is characterized by its fine, clay-rich texture. In many cases, the pigments exhibit a relatively fresh appearance, suggesting comparatively recent execution. Motifs created with charcoal are rare.

A particular type of motif was identified that was executed using a red pigment with characteristics distinct from those derived from local soils, suggesting a possible external source. Additionally, modern manifestations created with aerosol paints of various colors were documented and are clearly distinguishable from the ancient rock art corpus.

Regarding application techniques, freehand lines predominate, with notable variation in line thickness. These were produced using simple tools such as improvised brushes, fingers, entire hands, or fragments of clay used directly as natural crayons. Motifs executed with charcoal points, used in a pencil-like manner, were also identified, as well as positive handprints—created by direct stamping of a pigmented hand—and negative

handprints produced through stenciling or blowing pigment around the silhouette of a hand placed against the wall. These practices, characterized by their economy of resources, demonstrate direct engagement with the subterranean environment, in which figures adapt to wall topography to generate effects of volume, continuity, or restricted visibility.

Use of Natural Relief

A notable feature of the cave's rock art is the intentional use of natural relief and wall and ceiling irregularities. Several motifs follow curves, folds, or cracks in the rock; for example, a horizontal ladder-shaped figure adapts to the bends of a passage, suggesting continuity and movement. Similarly, some zoomorphic representations display elongated bodies that follow the wall's morphology. In addition, several images were executed within small cavities or recesses, where natural concavities provide depth and dimensionality. These figures are fully visible only from specific vantage points, suggesting deliberate control over the visual experience and viewing position.

Spatial Classification

To analyze the spatial distribution of the paintings within the cave, a hierarchical classification system is proposed, allowing movement from general spatial units to specific analytical entities. The spatial organization is structured as follows:

1. **General division:** The cave is divided into two major sectors, North and South, which contain the principal spatial developments: Kaua North (KN) and Kaua South (KS).
2. **Morphological areas:** Each sector is subdivided into main areas identified by letters (A–M), corresponding to natural cave divisions such as galleries, passages, bifurcations, curves, and recesses.
3. **Walls:** Each area is subdivided into walls, numbered using Arabic numerals (1, 2, 3, 4, etc.).
4. **Segments:** When a wall is particularly extensive, it is divided into segments grouping specific sets of paintings, designated using fractional Indo-Arabic numbers (e.g., KN-A1-1.1). This system allows hierarchical and scalable identification of graphic units.
5. **Individual motifs:** Motifs are identified using Roman numerals (i, ii, iii, iv) and include isolated images or panels.

Definition of Analytical Units

For the purposes of this study, the concepts used to organize the paintings are defined as follows:

Area:
A space within the cave corresponding to a gallery, passage, or route, delimited by natural morphology and interrupted only when a significant change in direction, form, or configuration occurs. Areas are identified using letters from A to M, totaling fourteen.

Group:
A spatially related aggregation of images forming a pictorial group without a clearly intentional internal arrangement. These display variations in tonality, line quality, and proportion, suggesting execution at different times or by different authors. A group consists of a minimum of two interrelated images. Multiple groups or a single group may occur on the same surface, reinforcing the idea of cumulative processes over time.
Isolated:

The minimal analytical unit, corresponding to an isolated image or recognizable element such as a hand, sign, or independent line. These motifs are recorded in various areas of the cave and, in some cases, are located at significant distances from other groups.

Panel:
A pictorial group characterized by thematic, stylistic, and technical coherence. The motifs composing a panel share color, line quality, and application technique, suggesting execution by a single author or a unified graphic event. Panels exhibit intentional internal organization, clear spatial delimitation, and allow for the development of scene-like representations involving events, characters, and possible narratives.

Themes and Preliminary Description

The represented themes admit multiple cultural and symbolic interpretations, some of which may be situated within the prehispanic Maya context. At this initial stage of analysis, basic descriptive categories are employed, including anthropomorphic (stylized human), zoomorphic, and geometric figures. The paintings are described based on observable attributes, prioritizing objective characterization to distinguish individual motifs and groups. This preliminary systematization contributes to addressing the long-standing debate regarding the authenticity of the pictographs by situating them within a probable chronological and functional framework integrated with cave morphology and evidence of recurrent subterranean use.

Preliminary Chronological Proposal
The preliminary analysis of the pictorial ensemble in Kaua Cave reveals prolonged and repeated use of the space over time. The diversity in pigment types, application techniques, and stroke styles suggests the involvement of multiple individuals and, likely, different human groups at distinct historical moments. Likewise, the presence of formal variations within the same motif—such as anthropomorphic figures and possible canid representations—allows observation of processes of transformation and iconographic evolution that serve as relevant indicators for proposing a relative chronological sequence.

Dating rock art represents one of the greatest methodological challenges, as absolute determination requires specialized archaeometric studies that, to date, have not been conducted in Kaua Cave. Nevertheless, comparative stylistic analysis provides a first chronological approximation. In this regard, some paintings exhibit formal and compositional features that can be related to graphic manifestations in the Maya area corresponding to the Late Classic period, approximately between 700 and 900/1000 CE, allowing their attribution to a well-defined prehispanic phase.

On the other hand, the presence of schematic figures, characterized by simplified strokes and distinct graphic conventions, raises the possibility of earlier execution phases. However, in the absence of sufficient contextual and analytical data, it is premature to establish a precise chronological attribution for these manifestations. Even so, their detailed analysis opens the possibility of exploring hypotheses that place them in earlier periods, potentially within the Preclassic, an issue that will need to be addressed in future research.

Regarding later graphic manifestations, the presence of Christian crosses superimposed on various prehispanic paintings stands out. These interventions clearly identify a moment of use during the colonial period, after the Spanish conquest in 1542, evidencing a resignification of the cavernous space and its images over time.

Overall, the available information suggests that Kaua Cave was used continuously and significantly across different historical periods. While it is likely that older paintings exist beyond those currently identified, at present there are not sufficient elements to confirm this. In this sense, the stylistic and formal analysis of the evolution of the images constitutes a fundamental tool for proposing relative chronological frameworks, which will need to be enriched and verified through archaeometric and contextual studies in subsequent stages of research



Example of representations of crosses that we consider to be from the colonial period, starting in 1542.



The first image corresponds to two glyphic cartouches, similar to those found in Mayan codices. The second image The second image corresponds to the profile with the following characteristics: they wear earmuffs, a flat headdress, and have a pronounced nose. Comparable to representations of Mayan culture. The third image displays a more contemporary style, not belonging to the pre-hispanic era.



Example of schematic anthropomorphic figures in different positions. The period to which these paintings belong is unclear. We propose that these are the oldest representations—pre-classical Maya or earlier?—however, there is still insufficient data to support this idea.

Final Considerations

The results obtained during this stage of research exceeded the initially proposed objectives, thanks to the support provided by the grant, which enabled not only the implementation of advanced documentation methodologies but also the generation of substantial information for the comprehensive study of the Kaua cave. Although this represents an initial phase, the work carried out produced relevant preliminary results that significantly contribute to knowledge of the site.

One of the main advances is the development of a preliminary classification of the rock art manifestations based on formal, technical, and spatial criteria, allowing for the identification of groups, recurrences, and variations within the graphic corpus (see Table 1). However, many paintings exhibit low visibility due to their state of preservation, making it likely that the number of recorded motifs will increase following more detailed analyses. In addition, defining the precise boundaries of pictorial groups proved challenging in many cases, highlighting the need to refine classification criteria and establish more precise parameters for numbering.

At present, a minimum of 24 individual motifs has been identified. 46 groups were recorded, each comprising between two and ten associated images, and 6 pictorial panels were recognized. In total, **76** analytical units have been documented, a number expected to increase with further detailed study of the rock art assemblage.

Differences in pigment use and application techniques suggest diverse graphic practices that may not be contemporaneous. These observations open the possibility of identifying different moments of execution and provide initial indicators for relative chronological assessment. In this regard, the presence of crosses executed with pigments distinct from the predominant corpus, as well as their superposition over earlier images, suggests a colonial-period attribution, likely after 1542. Conversely, motifs comparable to Maya symbolic forms point toward a prehispanic affiliation. It should be emphasized that although ceramic materials recovered from within the cave have been dated to between 600 and 900 CE, this does not necessarily imply that the paintings correspond to the same period.

The catalog produced represents only an initial step toward evaluating an appropriate classification of the spatial distribution of paintings in the Kaua cave. Given the limited number of comparable studies in caves

with similar characteristics, this research positions itself as one of the first systematic approaches to such contexts in the Yucatán Peninsula, Mexico. A first publication presenting the results of this stage of the project is currently in preparation.

Complementarily, spatial analysis derived from LiDAR surveying enabled a more detailed understanding of the relationship between cave morphology and rock art distribution. The identification of specific sectors, circulation routes, and zones of graphic concentration constitutes a fundamental contribution to interpreting cave function and spatial selection strategies employed by past populations. The visual material generated—including models and short videos—also represents a significant contribution to the community of Kaua, as it facilitates comprehension of the scale and complexity of the cave system underlying the present-day settlement.

Taken together, these preliminary results strengthen the theoretical proposals advanced in this research and lay the groundwork for subsequent stages of more detailed analysis integrating iconographic, technological, chronological, and contextual approaches. They further demonstrate the high potential of the Kaua cave as a key case study for understanding the role of cave rock art within the regional cultural landscape, as well as the relevance of continuing and expanding this research in future phases within the Cultures and Religions of the World program at Comenius University.

Table 1. List of rock art representations by area

Area	Unit		Set		Panel	
A			2	KA1-I KA1-II		
B	4	KN-B1-I KN-B1-II KN-B1-III KN-B3-IV KN-B3-V	5	KN-B2-1.1 KN-B2-1.2 KN-B2-1.3 KN-B4-1.4 KN-B4-1.5		
C	11	KN-C1-I KN-C1-II KN-C1-III KN-C1-IV KN-C2-V KN-C2-VI KN-C3-VII KN-C3-VIII KN-C3-IX KN-C5-XII KN-C5-XIII	11	KN-C1-1.1 KN-C1-1.2 KN-C1-1.3 KN-C1-1.4 KN-C2-1.5 KN-C2-1.6 KN-C3-1.7 KN-C3-1.8 KN-C3-1.9 KN-C4-1.10 KN-C5-1-11	2	KNC3-X KNC3-XI
D	4	KND1-I KND3-II KND4-III	1	KND2-1.1		
E			4	KNE1-1.1 KNE1-1.2 KNE2-1.3 KNE2-1.4	3	KNE2-I KNE2-II KNE2-III
F	1	KNF2-I	2	KNF2-1.1 KNF2-1.2	1	KNF2-II
G	1	KSG1-I				
H	1	KSH1-I	1	KSH-1.1		
I	1	KSI2-I	4	KSI1-1.1 KSI1-1.2 KSI2-1.3 KSI2-1.4		
J	1	KSJ1-I	7	KSJ1-1.1 KSJ1-1.2 KSJ2-1.3 KSJ2-1.4 KSJ2-1.5 KSJ2-1.6 KSJ2-1.7		
K			4	KSK1-1.1 KSK2-1.2 KSK2-1.3 KSK2-1.4		
L			2	KSL1-1.1 KSL1-1.2		
M			3	KSM1-1.1 KSM1-1.2 KSM1-1.3		
Total	24		46		6	

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