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Documentation of the 6J2-Sub2 Building in the Acropolis of La Blanca (Guatemala): methodologies, workflow and results.

Superposition of buildings from different periods is a distinctive feature of Maya architecture. The Maya often built new structures directly over the pre-existing ones, using volume to achieve larger buildings. This “building upon the built practice” permitted many ancient structures to be preserved inside the volume of the superimposed ones. The documentation of these former structures is an intricate challenging process. Digital survey technologies can give a significant contribution providing highly accurate records.
In order to enhance the importance of digitation of Maya architecture, we present the results of the digital documentation of the Building 6J2-Sub2, an earlier structure included in the Acropolis of La Blanca (Peten, Guatemala), and we detail the specific methodology and workflow developed for it.
We documented the building 6J2-Sub2 during the excavation from 2015 to 2019, with a laser scan daily recording system that was progressively improved, obtaining a digital database of the excavation that contains all the architectural remains discovered. This survey was complemented with photogrammetric data collections. As a result, we obtained an accurate survey of the building 6J2-Sub2, a 3D reality-based model of the Acropolis with the earlier building in context, and a complete documentation of all the elements necessarily dismantled to continue the excavation.
Documentation with digital survey techniques of the 6J2-Sub2 building was a pioneering experience in the research of Maya earlier buildings. Specific workflows and methodologies to record and study these structures were developed for the first time.

Keywords:
6J2-Sub2 Building; Maya architecture; “Building upon the built”; Architectural Digital Database; Digital Survey.

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1. INTRODUCTION

The Maya had a symbolic approach to construction as they often built new structures directly on pre-existing ones (Fig. 1), previously filled and closed, using their volume to achieve larger buildings (Muñoz Cosme, 2006, 50). Incorporating previous structures into superposed ones was closely related to religious beliefs, such as cosmogonic, time concepts, and to the ancestors worship (Rivera Dorado, 1982, 240-250). Moreover, it permitted to save effort and materials (Abrams, 1994, 54-55), allowing them to accelerate and improve the construction process' efficiency. As part of this practice, the Maya used a construction system similar to their own system to erect large and stepped platforms or basements. It was based on the fabrication and filling of caissons and allowed them to obtain highly resistant volumes. This technique consisted of compartmentalizing the volume to be filled into smaller spaces using masonry walls. The resulting cells were filled with compacted masonry mixed with lime mortar (Fig. 2). In this way, Maya builders also fulfilled and reinforced pre-existing buildings that were then enclosed inside new superimposed structures (Muñoz Cosme, 2006, 92).
This "Building upon the built" practice permitted many ancient structures [1] to be integrally preserved inside the volume of the superimposed ones (Hohmann-Vogrin, 2001, 195). The exploration of buildings such as the E-VII pyramid at Uaxactun, Guatemala (Ricketson & Ricketson, 1937), the Temple I at Tikal, Guatemala (Muñoz Cosme, 1997), the 10L-16 temple at Copan, Honduras (Agurcia Fasquelle & Fash, 2005), or the Palace of the Governor at Uxmal, Yucatán-México (Huchim Herrera & Toscano Hernández, 2021), permitted the Mayanists to achieve significant progress in the study of Maya architecture and culture. Nowadays, the study of these architectural complexes is a valuable opportunity for research into this ancient civilization, although many Maya buildings remain unexplored.
Due to the aggressiveness of the tropical climate and natural environment that in many cases requires reburying architectural vestiges to ensure their preservation (Muñoz Cosme, 2021, 19), and due to this "Building upon the built" practice, digitization is essential for the study and conservation of Maya architecture. However, the documentation and study of these former structures is often an intricate process and a challenge, firstly because of the difficult accessibility to their vestiges that usually remain buried under solid masonry fillings and, secondly, because the architectural features of these structures can differ substantially from those of the superimposed ones. In these cases, digital survey technologies can provide highly accurate records. However, it is necessary to develop specific workflows and methodologies, especially when the focus of the survey is a former building under long-term excavation, and since introducing vestiges from different construction phases into a common reference system is essential.
In the last decades, digital survey techniques led to a revolutionary approach to cultural heritage documentation (Guidi et al., 2010; Remondino, 2014). Development of technology and research improved workflows and methodologies to obtain 3D models of artefacts with high accuracy and precision in both geometrical and chromatic aspects. Because excavation is a destructive process by nature, digitization has become necessary also in archaeology: archaeologists are required to transmit as much evidence as possible to future generations, so digitization has become the most effective strategy for it (Roosevelt et al., 2015).
Although later than other cultural areas, surveying with digital technologies has become the norm also in the Maya area for documenting architecture (Campoverde et al., 2021), artefacts or sculptures (Vidal Lorenzo & Horcajada Campos, 2022) and even at geographical and urban scales (Inomata et al., 2017). However, there is still a lack of application of these technologies to the study of buildings with an extensive construction history and their former structures. Following-up the excavation of these buildings with an on-going digital survey methodology can be an effective strategy for in-depth research into this construction practice.

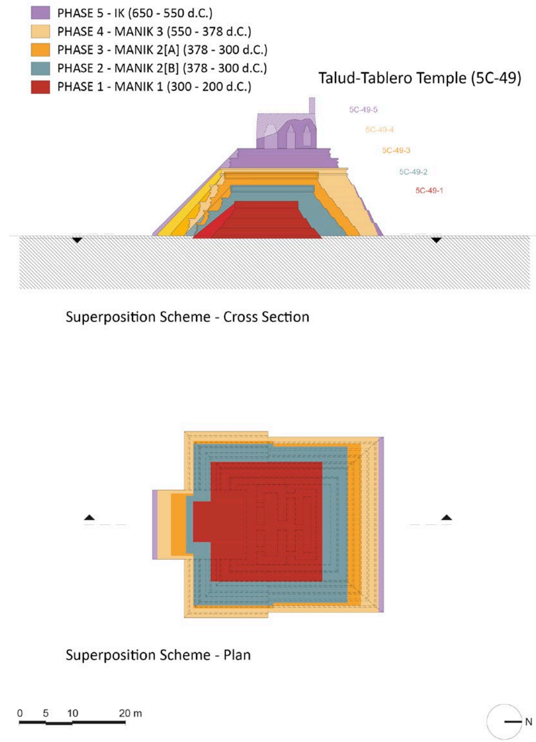
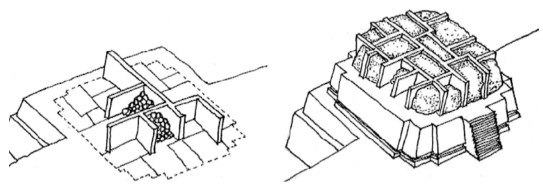


Fig. 1 - Diagram showing the architectural evolution of the Talud-Tablero Temple (building 5C-49) at Tikal, Guatemala (Montuori, 2022, 243). Drawing and chronology based on Laporte (1998) and Laporte & Fialko (1995).

Fig. 2 - Construction system used by the Maya to erect stepped platforms (Muñoz Cosme, 2006, 92).



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In other archaeological contexts, researchers have recently tested digital survey techniques for documenting on-going excavations. In addition, they have created databases to store data collected throughout the entire excavation in a unified system (Garstki et al., 2018; Notarian et al., 2020). This enables the diachronic documentation of excavations and the availability of digital copies of the vestiges (Boyd et al., 2021).
In this paper, we present the results of the digital documentation of the 6J2-Sub2 building, an earlier structure included in the Acropolis of La Blanca (Guatemala) that we surveyed ongoing from the start to the end of its excavation. We also detail the methodologies and workflows developed for it, emphasizing the importance of digitization for studying Maya former structures.

2. THE 6J2-SUB2 BUILDING IN THE ACROPOLIS OF LA BLANCA, GUATEMALA.

La Blanca is one of the ancient settlements founded close to the Salsipuedes river, part of the Mopan River system, in the Department of Peten in northern Guatemala. This area became strategic for trading in the Late Classical Period (AD 600-850) (Muñoz Cosme & Vidal Lorenzo, 2014). In this area of the Maya Lowlands emerged some of the most politically influential and culturally relevant cities of the Maya area such as Tikal, Yaxhá, Naranjo, Nakum or Caracol. La Blanca developed mainly administrative and commercial functions and peaked during the Terminal Classic (AD 850-1000) (Muñoz Cosme & Vidal Lorenzo, 2014). In this period was also completed the construction of the main palatial architectural complex of the site: the Acropolis (Fig. 3), the centre of political power and the residence of La Blanca's elite (Muñoz Cosme & Vidal Lorenzo, 2017).
The Acropolis is located in the central area of the settlement and consists of three buildings erected on a stepped platform 8 m high that was original-

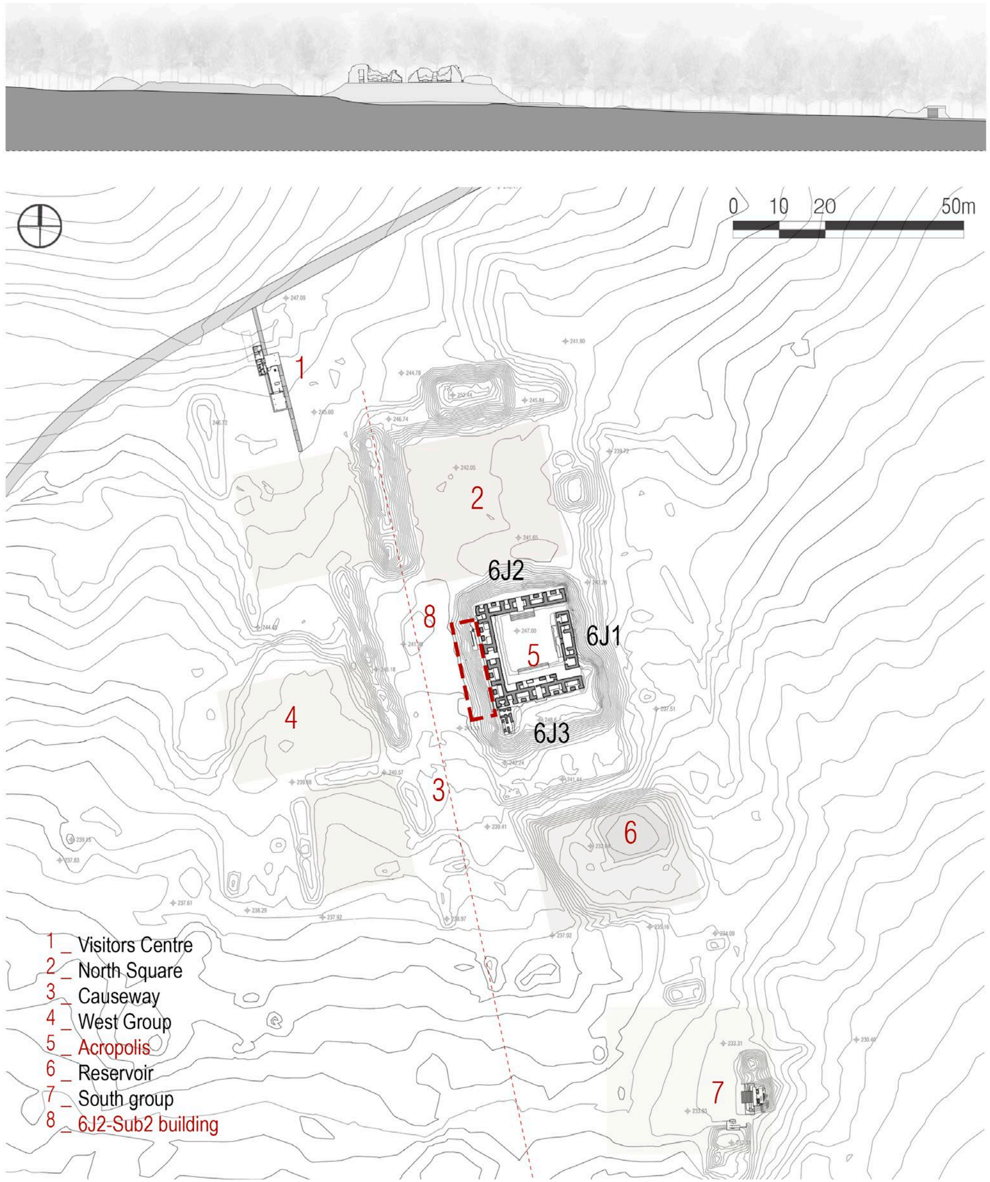

Fig. 3 - Plan of La Blanca with localization of the Acropolis and of the 6J2-Sub2 building.

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ly accessible from the North Square via a monumental stairway (Fig. 3). Two of the buildings form a quadrangle of about 50 meters on each side: the Palace 6J1 on the east, a freestanding building with a 28 m length, and the Palace 6J2, a U-shaped building with three wings that, together with the previous one, encloses a courtyard of approximately 36 m per side (Fig. 3). Finally, the 6J3 Palace, the smallest building of the complex around 12 m long, is located on the terrace in front of the 6J2 south wing. The rooms of these buildings were originally roofed with stone corbelled vaults, one of the most characteristic elements of this architecture (Gilabert Sansalvador, 2021).
As usual in Maya architecture, the Acropolis of La Blanca reached its final configuration in several construction phases. Evidence of a former structure was found while exploring a looting tunnel under the 6J2 west wing. This earlier building, named 6J2-Sub2 (Fig. 4), remained preserved inside the Acropolis until the La Blanca Project [2] discovered part of its north-eastern corner in 2010 (Vidal Lorenzo & Muñoz Cosme, 2010). After the discovery, due to the closeness to the west façade of the Acropolis and with the aim to preserve the stability of the superior buildings, it was explored from the exterior between 2012 and 2019.
Building 6J2-Sub2 (Fig. 4) includes three structures, each consisting of a single room. The first structure has a small interior room that runs along a north-south axis with a single door placed in the center of its west façade. It was originally roofed with a vault that the Maya probably dismantled before constructing the superimposed buildings. The second structure is located south of the first and approximately 1 meter below it. It is also organized along a north-south axis and has three access doors on its main façade. This structure still preserves the corbelled vault that roofs the interior space. The third structure is located further to the south running in an east-west direction, perpendicular to the previous one. This structure was cross-sectioned by the Maya and today it preserves only half of its interior ambience and of the corbelled stone vault that covered it.

Fig. 4. - Building 6J2-Sub2 at the end of the excavation in 2019.

3. METHODOLOGIES AND WORKFLOWS

Once the excavation of the three superior buildings was completed, the Acropolis was digitized with laser scanning survey in three campaigns, between 2012 and 2015 (Montuori et al., 2020, 482-483). After processing and aligning all the data collected, we obtained a point cloud model of the Acropolis from 118 scans, most of them acquired at 1/4 resolution, at 4x quality and aligned with a maximum deviation lower than 4 mm. The resultant Acropolis model was the basis of the Architectural Digital Database we built progressively during the excavation of its former structure.
The survey of the 6J2-Sub2 building started in 2013, when a sculptural relief of high artistic significance was discovered close to the 6J2-Sub2 façade. The relief was documented with both traditional and digital techniques. Then it was reburied to ensure its preservation so that it is no longer visible (Muñoz Cosme et al., 2015). The importance of this archaeological finding made the 6J2-Sub2 building the focus of archaeological excavations in La Blanca from the 2015 field season forward. Therefore, we paid special attention to the documentation of this structure under excavation.

3.1. FOLLOW-UP OF THE 6J2-SUB2 EXCAVATION BY LASER SCANNING

At the beginning of the 2015 survey campaign, we decided to experiment and develop an excavation follow-up procedure based on a daily record-

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ing system by laser scanning (Merlo et al., 2017). Our goal was to introduce all the data collected into a general database and reference them to the Acropolis point cloud (Montuori et al., 2022). This surveying methodology was then applied and improved up to the end of the 6J2-Sub2 building excavation. It was also integrated with photogrammetric surveys generally conducted at the end of each excavation campaign.

In the first follow-up campaign in 2015 we extracted the model of the 6J2 building west wing from the Acropolis point cloud and we set it in an *.imp* file to be used as the master database in which reference all the data collected through the entire season. Targets fixed to the stanchions of the roof system protecting the 6J2 building ensured the correct scan alignment. The daily routine consisted of 5 to 7 scan collections with 1/4, 1/5 or 1/8 resolution, depending on the distance between the device and the vestiges to be documented. To reduce scanning time and obtain small file sizes for faster processing, they were collected at 3x quality. The data collected were then processed and aligned in the laboratory to the general reference system into the master file of the campaign and were organized in layers per workday. This procedure allowed us to build progressively a database of the 2015 excavation (Fig. 5), aligning all the architectural findings of the season to each other and to the building above [3]. At the end of each workday, we provided the whole research team with an actualized set of scaled bitmap plans and elevations extracted from the database. These graphical materials were useful for determining the spatial relationships between the elements of the 6J2-Sub2 building and for assessing excavation progress. The team could interpret the architectural remains daily and adjust the next day's excavation plan if necessary [4]. This follow-up methodology was applied and improved in the following three campaigns, from 2016 to 2018. In 2019 we documented building 6J2-Sub2 after excavation was completed and before the building accesses were blocked.

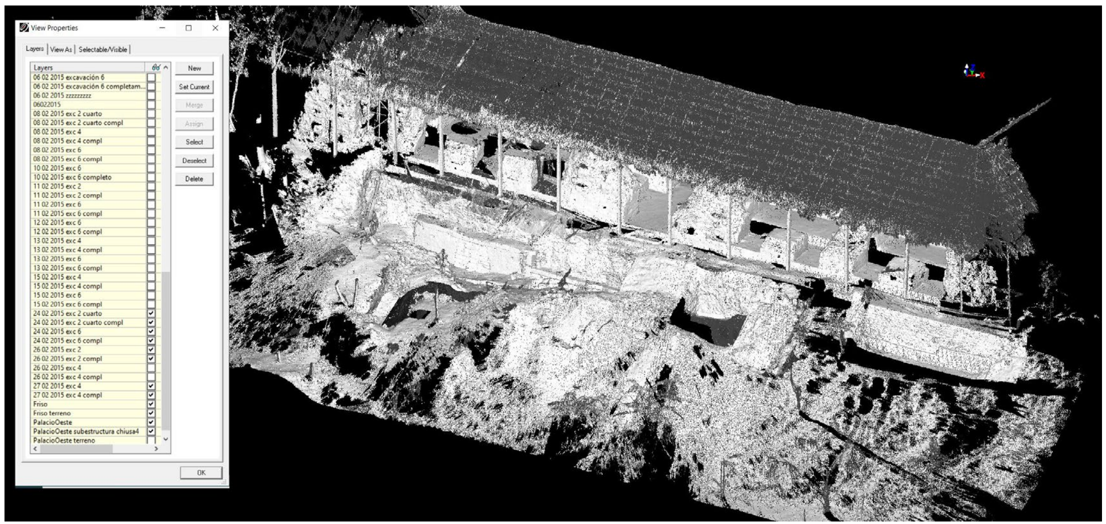
In 2016, we replaced the classic chequerboard targets with expanded polystyrene spheres. Some of them were fixed to the stanchions of the roof system protecting the 6J2 building, as in the previous campaign. We fixed the others to wooden bases so that we could easily and safely lean them on the terrain or directly on the exposed architectural remains. The use of spheres as reference points, whose geometrical centre is automatically recognized and tagged by the point cloud processing software, allowed us to improve the accuracy of the alignments and speed up daily data processing.

In 2017 and 2018, we remodelled our follow-up procedure adapting data collection frequency to the rhythm of the archaeological works. The daily scanning routine was replaced by the selection of relevant excavation days, with the aim of digitizing all architectural vestiges in their archaeological contexts once completely unveiled. In this way, we condesded the data collections on the key days of the excavation. This avoided redundant data collections and refocused documentation activities on obtaining data relevant to the study of architecture. As a result of these procedures, we collected 420 scans to document the architectural remains and the excavation process of the 6J2-Sub2 building (Table 1). In every field season, we incorporated the data collected into a specific database per survey campaign. All these repositories included (1) the point cloud model of the west wing of the 6J2 building, (2) the 6J2-Sub2 building in the final state at the end of the previous season and (3) the data acquired in the campaign ongoing, always aligned in the general reference system and organized in layers (Fig. 5).

In addition, we built an Architectural Digital Database of the entire excavation. To achieve this goal, after each season of fieldwork, we reviewed the specific database of the campaign, we selected the most relevant data for the analysis and study of the 6J2-Sub2 remains, and we introduced them progressively into the master *.imp* file containing the entire Acropolis that we show in section 4 of this paper.

3.2 PHOTOGRAMMETRIC SURVEY OF THE 6J2-SUB2 BUILDING

Fig. 5 - Database of the 2015 field season.



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FOLLOWING-UP THE EXCAVATION OF THE BUILDING 6J2-sub2

Data collection with a laser scanner FARO Focus^{3D} S120

FIELD SEASON 2013-2018

FIELD SEASON	DAY	FOCUS	NOTES	Nº SCANS COLLECTED	TOTAL SCANS/DAY	TOTAL SCANS/SEASON
2013						
		Building 6J2-Sub2 - Sculptural Relief		13	13	13
2015						
	01/02/2015	Building 6J2-Sub2	Follow-up excavation	8	8	95
	02/02/2015	Building 6J2-Sub2	Follow-up excavation	7	7	
	04/02/2015	Building 6J2-Sub2	Looting Tuinnel + Follow-up excavation	11	11	
	06/02/2015	Building 6J2-Sub2	Follow-up excavation	5	5	
	08/02/2015	Building 6J2-Sub2	Follow-up excavation	5	5	
	10/02/2015	Building 6J2-Sub2	Follow-up excavation	2	2	
	11/02/2015	Building 6J2-Sub2	Follow-up excavation	9	9	
	12/02/2015	Building 6J2-Sub2	Follow-up excavation	2	2	
	13/02/2015	Building 6J2-Sub2	Follow-up excavation	3	3	
	14/02/2015	Building 6J2-Sub2	Follow-up excavation	4	4	
	15/02/2015	Building 6J2-Sub2	Follow-up excavation	3	3	
	24/02/2015	Building 6J2-Sub2	Follow-up excavation	3	6	
		Building 6J2-Sub2 - Structure 1	Follow-up excavation	3		
	26/02/2015	Building 6J2-Sub2	Follow-up excavation	7	7	
	27/02/2015	Building 6J2-Sub2	Follow-up excavation	4	4	
	04/03/2015	Building 6J2-Sub2	Room 1 opened	7	7	
	06/03/2015	Building 6J2-Sub2	Follow-up excavation - last operations	4	8	
		Building 6J2-Sub2 - Structure 1	Interior Graffiti	4		
	07/03/2015	Building 6J2-Sub2	Final State - Season Closure	4	4	
2016						
	03/04/2016	Building 6J2-Sub2	Season Starting	7	7	116
	04/04/2016	Building 6J2-Sub2	Structure 1 open, Structures 2 & 3 excavation on-going	8	8	
	05/04/2016	Building 6J2-Sub2	Structure 1 excavation, Structures 2 & 3 excavation	8	8	
	06/04/2016	Building 6J2-Sub2	Structure 1 excavation, Structure 3 excavation	4	4	
	07/04/2016	Building 6J2-Sub2	Structure 1 excavation, Structures 2 & 3 excavation	6	6	
	08/04/2016	Building 6J2-Sub2	Structure 1 excavation, Structure 3 excavation	6	6	
	09/04/2016	Building 6J2-Sub2	Structure 2 excavation, Structure 3 vault problems	9	9	
	10/04/2016	Building 6J2-Sub2	Structure 3 vault consolidated	2	2	
	11/04/2016	Building 6J2-Sub2	Structure 2 excavation, Structure 3 excavation	5	5	
	12/04/2016	Building 6J2-Sub2	Structure 2 excavation, Structure 3 excavation	5	5	
	13/04/2016	Building 6J2-Sub2	Structure 2 excavation, Structure 3 excavation	7	7	
	14/04/2016	Building 6J2-Sub2	Structure 2 excavation	2	2	
	15/04/2016	Building 6J2-Sub2	Structure 3 excavation	6	6	
	16/04/2016	Building 6J2-Sub2	Structure 2 excavation, Structure 3 excavation	4	4	
	17/04/2016	Building 6J2-Sub2	Structure 2 excavation, Structure 3 excavation	5	5	
	18/04/2016	Building 6J2-Sub2	Structure 2 excavation, Structure 3 excavation	4	4	
	19/04/2016	Building 6J2-Sub2	Structure 3 excavation	4	4	
	20/04/2016	Building 6J2-Sub2	Structure 3 excavation completed / not consolidated	7	7	
	21/04/2016	Building 6J2-Sub2	Structure 1 complete, Structure 2 excavation	5	5	
	24/04/2016	Building 6J2-Sub2	Structure 2 max excavation in2016	4	4	
	25/04/2016	Building 6J2-Sub2	Final State, vault structure 3 consolidated	8	8	
2017						
	17/04/2017	Building 6J2-Sub2	Starting campaign	7	7	36
	21/04/2017	Building 6J2-Sub2 - Structure 2	Filling Acces 1. Follow-up excavation	2	2	
	24/04/2017	Building 6J2-Sub2 - Structure 2	Filling, accesses 1 & 2. Follow-up excavation	4	4	
	27/04/2017	Building 6J2-Sub2 - Structure 2	Filling Steructure 2. Follow-up excavation	2	2	
	01/05/2017	Building 6J2-Sub2 - Structure 2	Filling Structure 2. Follow-up excavation	3	3	
	04/05/2017	Building 6J2-Sub2 - Structure 2	Filling accesses 2 & 3 / Folllow-up excavation	3	3	
	07/05/2017	Building 6J2-Sub2 - Structure 2	Filling Structure 2. Follow-up excavation	4	4	
	09/05/2017	Building 6J2-Sub2 - Structure 2	Filling Structure 2. Follow-up excavation	3	3	
	11/05/2017	Building 6J2-Sub2	Final State 2017 campaign	8	8	
2018						
	04/05/2018	Building 6J2-Sub2	Starting campaign	20	20	125
	23/05/2018	Building 6J2-Sub2 - Structure 2	Fillig access 3. Follow-up Excavation	7	16	
		Building 6J2-Sub2 - Structure 2	Fillig access 3. Follow-up Excavation	4		
		Subop. 369	Stanchions Protective Roof 6J2.Sub2. Follow-up	5		
	24/05/2018	Subop.371-372	Stanchions Protective Roof 6J2.Sub2. Follow-up	8	8	
	25/05/2018	Building 6J2-Sub2 - Structure 2	Fillig Structure 2. Follow-up Excavation Vault	9	14	
		Subop.369 (final)	Stanchions Protective Roof 6J2.Sub2. Follow-up	5		
	26/05/2018	Building 6J2-Sub2 - Structure 2	Fillig Structure 2. Follow-up Excavation Vault	9	19	
		Subop. 370	Stanchions Protective Roof 6J2.Sub2. Follow-up	6		
		Subop. 377	Stanchions Protective Roof 6J2.Sub2. Follow-up	4		
	27/05/2018	Building 6J2-Sub2 - Structure 1	Central Borehole. Floor 1. Follow-up Excavation	5	25	
		Building 6J2-Sub2 - Structure 1	Central Borehole. Floor 2. Follow-up Excavation	5		
		Subop. 373	Stanchions Protective Roof 6J2.Sub2. Follow-up	5		
		Subop. 374	Stanchions Protective Roof 6J2.Sub2. Follow-up	5		
		Subop. 375	Stanchions Protective Roof 6J2.Sub2. Follow-up	5		
	28/05/2018	Building 6J2-Sub2 - Structure 2	Fillig Structure 2. Follow-up Excavation Vault	12	23	
		Subop. 376	Stanchions Protective Roof 6J2.Sub2. Follow-up	5		
		Subop. 377	Stanchions Protective Roof 6J2.Sub2. Follow-up	6		
2019						
	24/05/2019	Building 6J2-Sub2	Final State - Closure Project	12	35	35
	25/05/2019	Building 6J2-Sub2	Final State - Closure Project + Connection with 6J2 build.	23		
					TOTAL	**420**

Table 1 - Data collected by laser scanning from 2013 to 2019 field seasons.

This progressive range-based survey was always complemented by photogrammetric data collections that permitted us to obtain high accurate chromatic surveys. Hence, we documented by digital photogrammetry the three rooms of the 6J2-Sub2 at the end of each season, all the remains that had to be reburied to ensure their preservation, and the ones that were dismantled to continue excavation.

In five survey campaigns, we collected almost 7000 photographs using various digital cameras and complementary tools. In this paper we show the data collection that permitted us to obtain photogrammetric 3D models of the 6J2-Sub2 building in the final state after excavation (Fig. 6). We documented the interior space of the first structure in 2018. The interior room of the second structure was documented in 2019, after the plaster and mural painting remains were consolidated. Finally, we surveyed the entire façade of the 6J2-Sub2 building, including the half-preserved room of the third structure.

We planned and conducted the photogrammetric data collection adapting the usual methodology for photographs acquisition (Remondino, 2014) to the lighting conditions of the various parts of the building, that we previously studied. All the photographic sets necessary to document the 6J2-Sub2 building were acquired with a Canon EOS 5D Mark III reflex camera equipped with an EF 24-105 mm f/3.5-5.6 IS STM lens. The photographs were processed following the *Agisoft Metashape* workflow that leads first to the alignment of all pictures with each other, then to the construction of a point cloud model and finally to the creation of a textured polygonal 3D model (Fig. 6, Table 2).

All the models obtained during the excavation, including these last three, were scaled and aligned to the Architectural Digital Database. We identified common points which we labelled as targets in the range-based model and as markers in the photogrammetric models. The coordinates of

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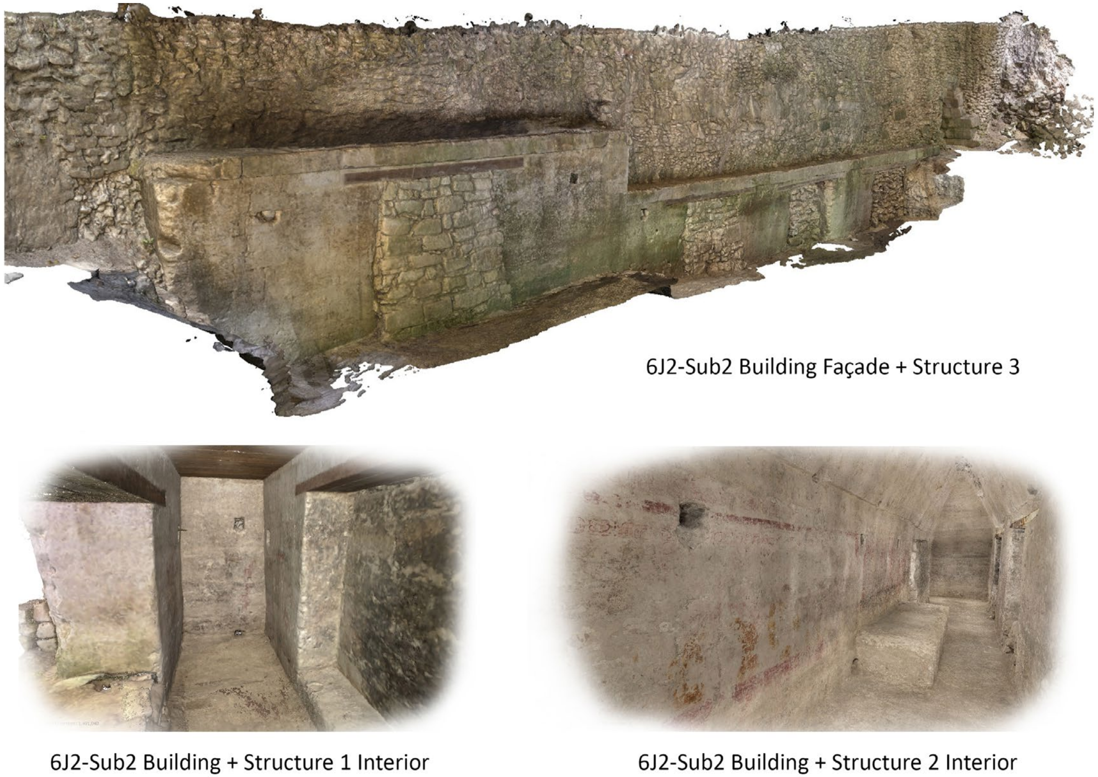

Fig. 6 - Photogrammetric 3d models of the 6J2-Sub2 building.

Table 2 - Specifications of the photogrammetric models obtained between 2018 and 2019.

PHOTOGRAMMETRIC SURVEY OF THE BUILDING 6J2-Sub2	
Carhacteristics of the Digital Camera	
Camera	Canon EOS 5D Mark III
Lens	EF 24-105 mm f/3.5-5.6 IS STM
Collection parameters	
Pictures Resolution	6000 x 4000 px
Collection format	RAW *(Canon CR2)*
Focal Distance	24 mm
Superposition	60% horizontal - 60% vertical
Complementary tools used	
Color checker OPCARD 202	white balance *a posteriori*
LED Panel Pixel Sonnon DL-913	illumination interior of the rooms
Tripod Manfrotto	photo collection interior of the rooms
BUILDING 6J2-Sub2 - STRUCTURE 1 ROOM	
Data collection	
Field Season	2018
Nº of Photographs collected	275
Resultant Point Cloud Model	
Nº of Points	$37x10^6$ pt
Resultant Poligonal Model	
Nº of polygons	$2000x10^3$ pl
Size of the .obj file	212 MB
Texture applied to the Poligonal Model	
Size of the texture	8192 x 8192 px
Size of the .jpeg file	11,1 MB
BUILDING 6J2-Sub2 - STRUCTURE 2 ROOM	
Data collection	
Field Season	2019
Nº of Photographs collected	870
Resultant Point Cloud Model	
Nº of Points	$118x10^6$ pt
Resultant Poligonal Model	
Nº of polygons	$10000x10^3$ pl
Size of the .obj file	730 MB
Texture applied to the Poligonal Model	
Size of the texture	16384 x 16384 px
Size of the .jpeg file	57,8 MB
BUILDING 6J2-Sub2 - FAÇADE + STRUCTURE 3 ROOM	
Data collection	
Field Season of the data collection	2019
Nº of Photographs collected	671
Resultant Point Cloud Model	
Nº of Points	$121x10^6$ pt
Resultant Poligonal Model	
Nº of polygons	$4941x10^3$ pl
Size of the .obj file	420 MB
Texture applied to the Poligonal Model	
Size of the texture	32768x 32768 px
Size of the .jpeg file	176,4 MB

the targets were exported and fed into *Agisoft Metashape*, so that the photogrammetric models were automatically scaled, oriented, and referenced to the laser scanner reference system.

4. RESULTS

As a result of the application and improvement of this excavation follow-up methodology, we developed an Architectural Digital Database that contains in a common reference system all the architectural remains of the building 6J2-Sub2 that were digitized from 2013 to 2019, and the Acropolis surveyed between 2012 and 2015 (Fig. 7). This repository is organized by layers and stored in a 146 gigabyte *.imp* file.

Besides serving as a storage for survey results, this digital database is the starting point for generating a variety of 2D and 3D outputs. It also offers the possibility to exploit all data collected as a whole for architectural analysis, comparisons and different kinds of studies. The integration of these data with the photogrammetric data, already aligned into the general reference system, allows us to obtain a high-quality documentation of Building 6J2-Sub2.

We have already discussed what outputs can be extracted from this type of database and what are the advantages of storing, in a common refer-

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ence system, all the architectural data collected to document the long-term excavation of a Maya former building (Montuori et al., 2022, 89-91). In this section, we can finally show the complete Architectural Digital Database of building 6J2-Sub2 (Fig. 7) and present some of the outputs we obtained to study this pre-existing building.

4.1 DOCUMENTATION OF THE 6J2-SUB2 BUILDING.

The exploitation of the data included in our Architectural Digital Database and in the season specialized databases allowed us to extract a complete set of plans representing the 6J2-Sub2 building as it was at the end of each campaign. These plans were helpful to analyse in depth the architectural remains unveiled during the season, monitor the state of conservation of the exposed buildings and plan the following excavation campaigns, identifying the priorities for future campaigns according to the research questions raised. In Figure 8, we show some of the plans extracted after the 2019 season to document accurately the 6J2-Sub2 building as it was at the end of the research project. Thanks to the use of this repository, we also represented elements that, after being excavated and documented, were reburied, i.e. the sculptural relief placed in front of the first structure of the 6J2-Sub2 building. Thus, we were able to relate to each other all the remains we observed and documented through this long-

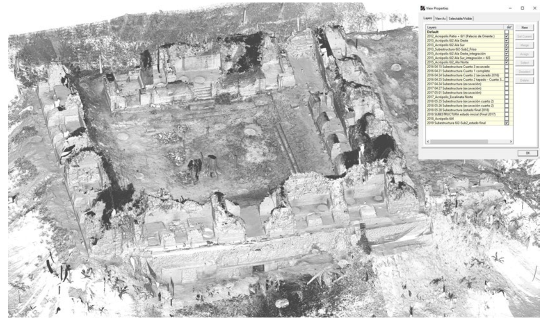
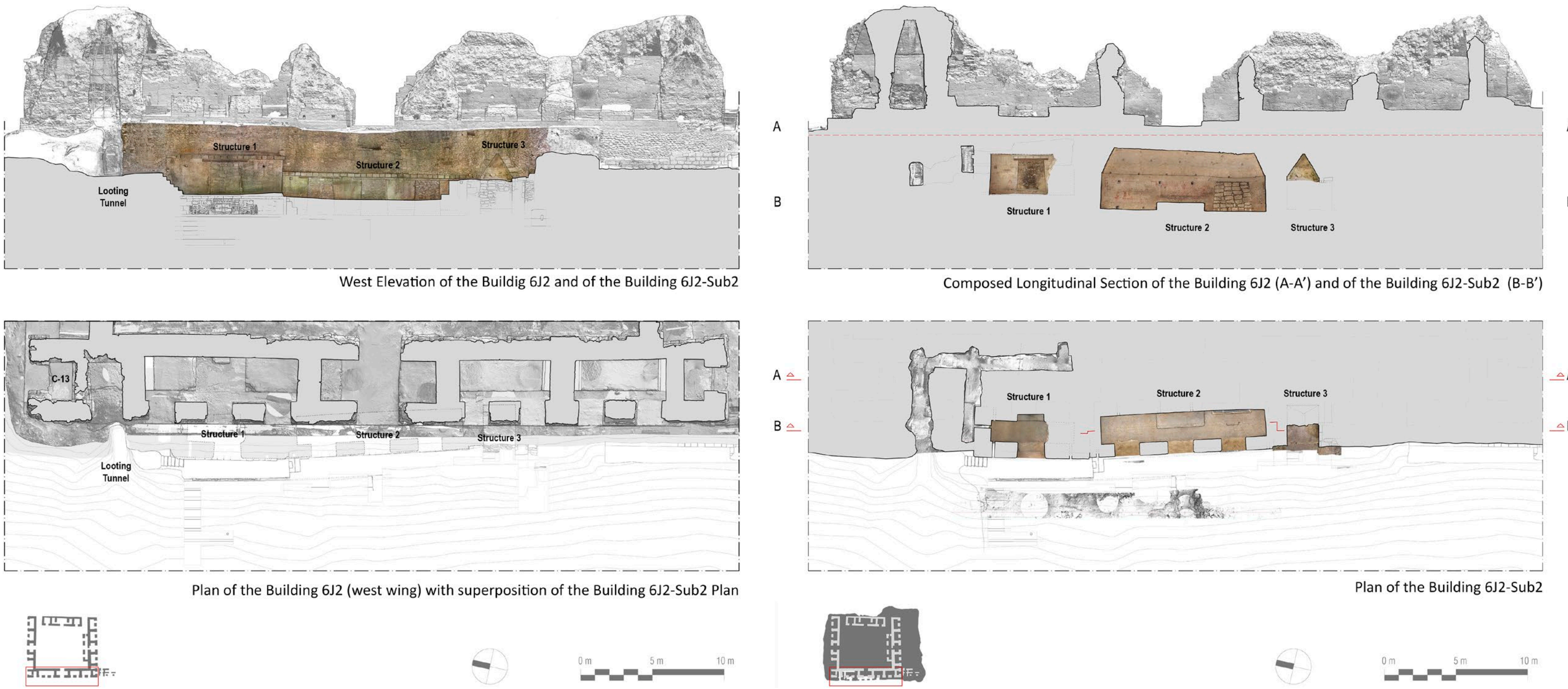


Fig. 7 - Architectural Digital Database of the Acropolis with the 6J2-Sub2 building.

Fig. 8 - Plans, Longitudinal Section and Elevation of the 6J2-Sub2 building, in scale 1:50.



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term excavation.
We extracted all the plans at 1:50 scale by exporting slices of the point cloud acquired by TLS (Terrestrial Laser Scanning) and drawing them into a vector design software. The projection areas were completed by cutting the point cloud according to the section planes set and generating rendered snapshots (Fig. 8). The accurate 3D photogrammetric models allowed us to complete our plans with ortophotos showing the true chromatic data of this previous building. We represented the former structure with a different chromatic treatment to emphasize its position and spatial relationship with the superimposed Acropolis building. We extracted the orthophotos with a resolution of 0.503 mm/pix and scaled to 1:50.
The accurate photogrammetric survey was crucial because it also allowed us to accurately document the interior ambiences of Building 6J2-Sub2 that still preserve the remains of plaster and polychrome mural paintings. In this case, we extracted orthophotos with a resolution of 0.708 mm/pix and scaled to 1:20 (Fig. 9). Although after the last fieldwork campaign, the access to building 6J2 Sub2 was blocked, these pictorial remains can be analysed in depth in the laboratory thanks to this digital photogrammetric documentation.

4.2 THE 3D MODEL OF THE ACROPOLIS WITH THE 6J2-SUB2 BUILDING

The data we acquired between 2012 and 2015 were used to build a reality-based mesh model of the Acropolis. For this purpose, we applied reverse engineering techniques using *3D System Geomagic Design X*. This software allowed us to obtain a mesh model by processing a point cloud model. We developed a specific workflow and methodology to integrate the parts not correctly detected by the laser scanner (Montuori et al., 2020). The resultant 3D model showing the Acropolis at the end of the 2015 field season (Fig. 10) is formed by 6.043.072 polygons and contained in an *.obj* file of 278 MB. A 3D printed copy of this model in scale 1:100 was placed in the Visitors Centre of La Blanca as a resource for dissemination (Montuori et al., 2020).
After the excavation was completed in 2019, we decided to update the 3D model of the Acropolis by introducing the 6J2-Sub2 building. For this purpose, we firstly selected from our Architectural Digital Database the parts of the point clouds showing each element of this previous building after it was completely unveiled (Fig. 11). Secondly, we exported them to *3D System Geomagic Design X* and processed them to obtain several 3D mesh models already georeferenced to the Acropolis model. Finally, we mixed all these meshes. As a result, we obtained a 3D mesh model of 10.225.268 polygons and stored in an *.obj* file of 431 MB that represents the Acropolis at the end of the excavation project and that allows us to enjoy an overall view of the 6J2-Sub2 building in context (Fig. 12). This digital replica shows the 6J2-Sub2 building in the ideal state of full excavation: it contains in only one 3D model all the remains that were unveiled during a long-term excavation, that were reburied and that were never visible at the same time all together.
Moreover, this updated replica of the Acropo-

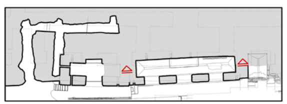

Fig. 9 - Longitudinal section the 6J2-Sub2 building room 2, scale 1:20

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lis permits us to extract all the images, sections (Fig.13) and plans that we need to study the geometries, the architectural features, and the spatial relationship between the 6J2-Sub2 building and the superimposed buildings of this architectural complex. This model can be the basis for digital reconstructions. It can also be used to extract pictures and videos for dissemination purposes or optimized models for VR (Virtual Reality) or AR (Augmented Reality) applications. Finally, it can be printed in 3D as an updated scaled replica of the Acropolis for dissemination purposes.

4.3 THE CONSTRUCTIVE FILLINGS OF THE 6J2-SUB2 BUILDING

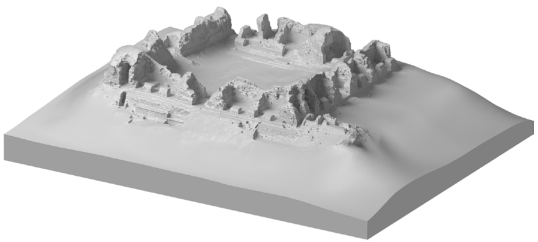


Fig. 10 - 3D model of the Acropolis of La Blanca in 2015.

Fig. 11 - Construction of the final 3D model of the Acropolis after the excavation of the 6J2-Sub2 building.

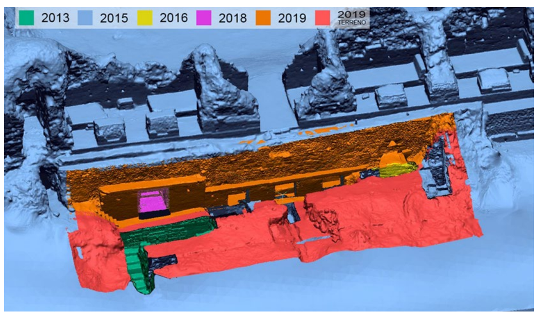
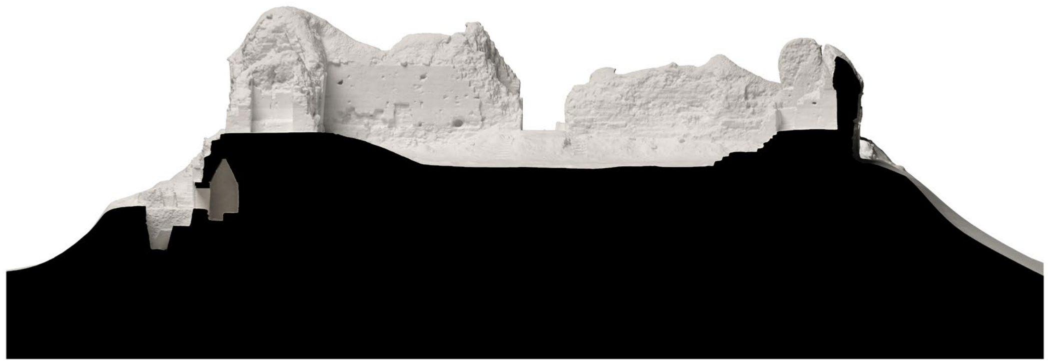


Fig. 12 - 3D model of the Acropolis of La Blanca with the 6J2-Sub2 building.

The exploitation of data contained in our Architectural Digital Database allowed us to analyse in depth the construction fillings the Maya builders placed inside the three interior ambiences of Building 6J2-Sub2 to reinforce it before erecting the superimposed structures. Thanks to the use of this repository, we could move back in time and select the excavation data relevant for the analysis of the emptying process in the three rooms. Thus, we obtained a diachronic visualization of 6J2-Sub2 interior ambiences (Fig. 14).

Fig. 13 - Section of the 3D model of the Acropols with the 6J2-Sub2 building.



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We identified and classified the parts of these construction fillings. Then, we represented them in specific plans and formulated hypotheses about the filling and closing process. In Figure 15, we show the plans we developed to study filling up of the second room, in which the Maya builders erected three compartment walls with ashlars mixed with mud. The first wall was 1 m tall above floor level. The other two had a height of 2.44 m above floor level, corresponding to the vault starting level. The rest of the filling consisted of stones of variable size mixed with lime mortar but river stones were also included in some layers. The Maya blocked the three entrances to the building with three retaining walls built in rough stone masonry. Located in the rear wall of the room, the fourth opening was blocked by reused large limestone ashlars. We also observed that the Maya builders removed some capstone and disassembled several dowels from the vault, probably to complete the vault fill from above. We located two holes in the vault, one to the north of the room, and the other, larger, to the south. The rest of a cross wood beam [5] was found in the vault filling. The proximity to the south hole of the vault suggests that it may have been left in its position to be used as a support point for entering and exiting the room during the filling process.

5. CONCLUSIONS

“Building upon the built” was one of the most common practices in Maya architecture. Most of these buildings were the result of multiple remodelling processes with the superposition of different construction phases. Many structures preserve the remains of earlier buildings, previously closed and filled up. Studying this practice is crucial to obtain a deeper understanding of Maya architecture. However, investigating the architectural evolution of buildings with a large architectural evolution is an intricate endeavour. Excavations inside these volumes are complex. Understanding the correlation between architectural remains of different buildings that appear under solid masonry fillings and which can be only partially exposed, is difficult. Digital technologies can offer numerous advantages for the survey and analysis of these complexes.

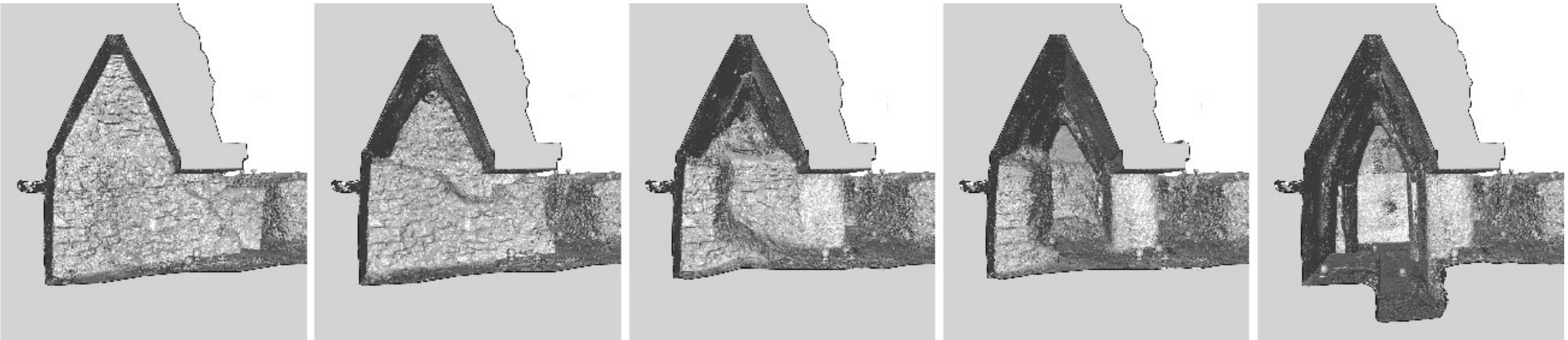
Documentation with digital survey techniques for following-up the excavation of Building 6J2-Sub2 was a pioneering experience in the research on Maya former buildings. Specific workflows and methodologies to record and study these structures were developed for the first time in the Maya area.

The range-based follow-up methodology, which we developed and applied, allowed us to register accurately the entire long-term excavation process and all the architectural remains as they appeared in context. The introduction of all data collected into the Architectural Digital Database permitted us to store, in a common reference system, vestiges from different periods and locations, and to extract high quality 2D and 3D outputs for documentation, research and dissemination.

Digitization allowed us to relate to each other all the remains that are no longer visible because they had to be reburied to ensure their preservation. We also analysed in depth elements that were definitively lost as they were dismantled to advance the excavation, as in our study of 6J2-Sub2 building’s construction fillings. Thanks to the use of these methodologies and workflows it is possible to exploit and analyse as a whole all the vestiges by combining datasets from several field seasons. It is also possible to regress to any specific moment of an excavation to obtain detailed plans of each excavation stage.

Finally, we want to emphasize the importance of digitization in Maya architecture. We believe that

Fig. 14 - Diachronic section of the 6j2-Sub2 building room 2.



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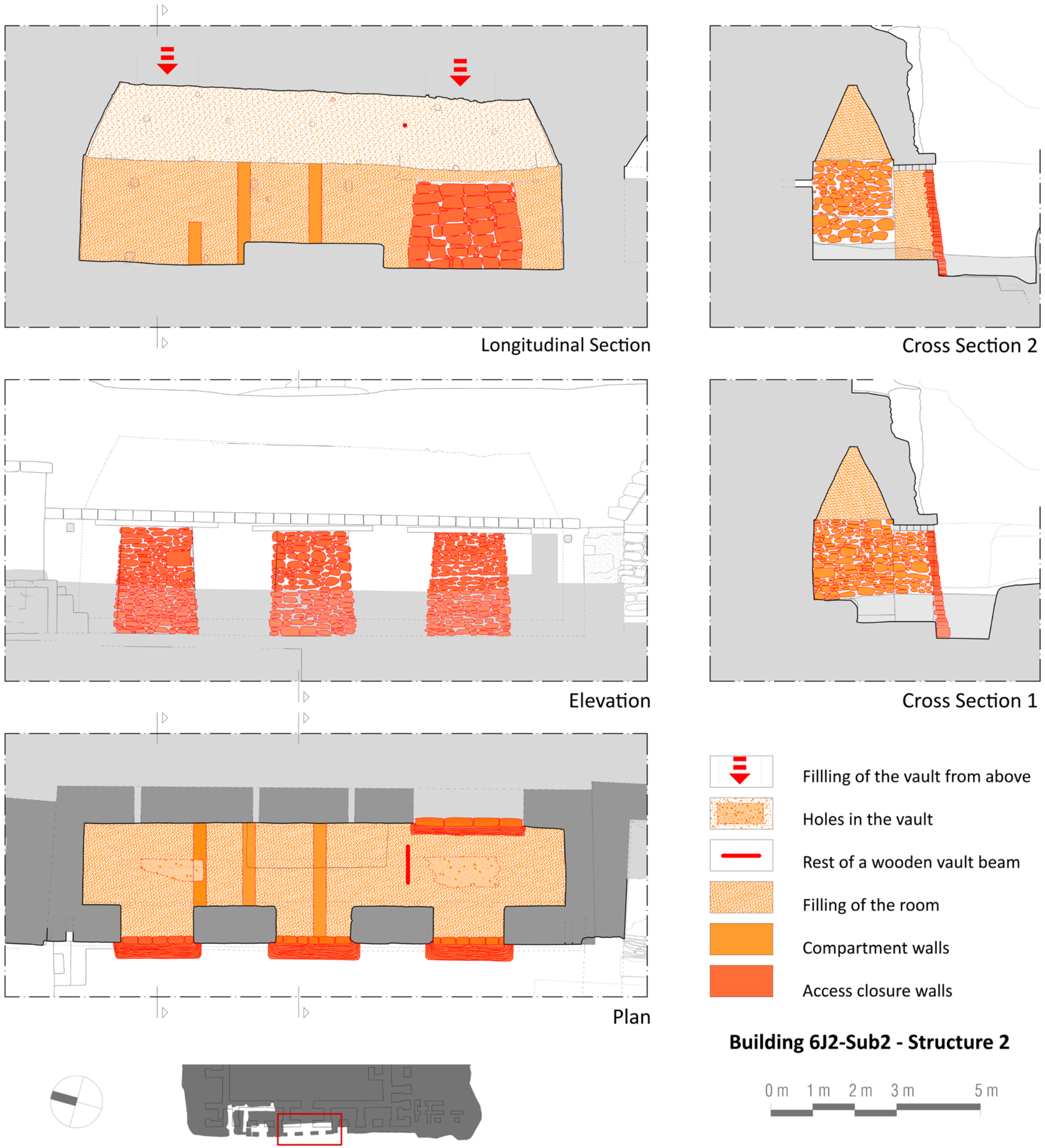

the application of methodologies for following-up the excavation of an earlier building and of workflows for storing in the same reference system all data collected is crucial for studying Maya architectural complexes built with one or more superpositions. Moreover, the use of a Digital Repository containing all data allows analysing the remains right after excavation or for many years after the closure of a research project.

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Fig. 15 - Study of the filling in the room of the second structure of the 6J2-Sub2 building.

NOTE

[1] In the scientific literature in Spanish these former buildings are usually known as *"subestructuras"*, a word that can be used to identify both the preexisting buildings and the pyramidal and stepped platforms that usually support Maya buildings (Gendrop, 1997, 188-190).

[2] The La Blanca Project, led by Cristina Vidal Lorenzo (Universitat de València) and Gaspar Muñoz Cosme (Universitat Politècnica de València), started excavations in La Blanca in 2004 and studied the site through 15 field seasons up to 2019.

[3] Further information about the introduction of this methodology for the follow-up of the 6J2-Sub2 building excavation can be found in Merlo et al. (2017) and Montuori et al. (2022).

[4] A set of daily plans and elevations can be seen in Montuori et al. (2022, p. 88).

[5] Check Gilabert-Sansalvador (2021, 91-97) for more information about vault beams in Maya architecture.

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