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## ► To cite this version:

Anaïs Lamesa. Methods for rock-hewn worksite analysis: case study of Göreme's n°4b (Cappadocia) "thwarted" worksite. *Anatolia antiqua = Eski anadolu*, 2020. halshs-04407944v1

**HAL Id: halshs-04407944**

**<https://hal.science/halshs-04407944v1>**

Submitted on 20 Apr 2021 (v1), last revised 24 Jan 2024 (v2)

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## Methods for rock-hewn worksite analysis: case study of Göreme's n°4b (Cappadocia) "thwarted" worksite<sup>1</sup>.

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Some rock-hewn structures present oddities in their layout, far from the models shared by the majority of similar monuments. These particularities challenge and question the very process of their design. While a technical survey may explain part of these singular cases, a careful comparative selection of the available methods remains paramount to draw a clearer picture of the progress and organisation of these peculiar worksites.

Göreme n°4b is a rock-hewn church located on a ridge on the East side of the road leading to the Göreme Open Air Museum. The obvious difficulties encountered during its excavation make it an ideal case study. Its analysis sheds light on the choices made by the patron, the master builder, as well as the workers' behaviour during the digging phase. It also unearths clues of the church's subsequent occupation phases and highlights the change with the initial project.

Combining multiple methods provides different approaches to address the technical, economic and sociological issues of rock-hewn church worksites. A first method consists of defining sequences of the *chaîne opératoire* through the careful analysis of tool marks<sup>2</sup>. Extending this first approach, an anthropological study involving recording teams of stonemasons working traditionally will be the core of the second method. In Cappadocia, only a few workers use non-mechanised-tools. The third method experiments a technique proposed by E. Harris in order to determine phasing<sup>3</sup>. Currently this approach is used in excavations and in the archaeology of buildings<sup>4</sup>. Sharing the intuition of a set of researchers working on African Studies, we believe that the concept may also apply to the study of structures excavated in rock<sup>5</sup>. To carry out this analysis, we use the results obtained by the software developed by B. Desachy, Le Stratifiant. This computerized tool permits semi-automation of the reading process and produces visuals such as diagrams<sup>6</sup>. At the crossroad where these three methods meet will the decisions of the project manager and the workers come to light, and a chronology of the rock-hewn worksite emerge.

On their own, these methods do not provide a complete picture of the church's project. They are limited to the definition of digging and finishing actions, albeit as complete as possible. All aspects of the commission – choice of site, financing, initial choice of church plan – cannot be addressed without the gathering of a comprehensive collection of written or oral sources. Data

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<sup>1</sup> I would like to extend my sincere gratitude to the Turkish Ministry of Culture and Tourism for having authorised the survey in the province of Nevşehir in 2010 (n°07375590) as well as to the members of the French Institute of Anatolian Studies for the logistical support provided during my doctoral research, under a TÜBİTAK contract. I would also like to thank Jean-Pierre Gély, Bruno Desachy and Marie-Laure Derat for their careful proofreading and Néhémie Strupler for his support.

<sup>2</sup> See Bessac, 2007.

<sup>3</sup> Harris, 2019.

<sup>4</sup> We refer to the methodological article by E. Rouger (1998) dealing with the application of Harris's principles to archaeology of buildings.

<sup>5</sup> The relevance of the method applied to rock art has been debated: Russell, 2000; Russell, 2012 contra Pearce, 2010. Method convincingly applied by the team working at the Lalibela site: Fauvelle et al., 2010.

<sup>6</sup> Djindjian & Desachy, 1990; Desachy, 2008a; Desachy, 2008b. See also Le Stratifiant software page: <https://abp.hypotheses.org/3965>.

which is currently unavailable for Cappadocia. In this analysis, we limit ourselves to the study of the excavation and finishing of the church's main structural shell, excluding the realisation of the sculptured elements and monolithic elements.

### Local Geology

Like any worksite, the choice of raw materials is fundamental. Indeed, the rock in which the church has been excavated had a considerable impact on the organisation of the worksite and played an essential role in the choice of tools, digging strategies and in the final appearance of the monument. The church Göreme n°4b has been excavated above nowadays ground level in a fairy chimney formed by a volcanic rock, called ignimbrite. These are deposits of solidified pyroclastic flow.

From the characteristics of the rock, the church appears to be clearly carved out of the so-called Zelve ignimbrite, one of the oldest ignimbrites in Cappadocia. Its colour ranges from white to yellow and it displays numerous lithic pyroclasts (inclusions), notably andesites or basalt<sup>7</sup>. Its source of emission was located between the cities of Nevşehir and Derinkuyu<sup>8</sup>.

The volcano's proximity - source of the Zelve ignimbrite - explains the size of the inclusions observed in the church. Pyroclastic clouds consist of rock fragments and ashes. Once emitted by the volcano, this fiery matter gradually falls down, cools and eventually hardens. The pieces of rock or pyroclasts, heavier than the ashes, settle first on the ground.

Many pyroclasts, dark and of centimetric scale, can be seen on the church's walls. Three are particularly remarkable: the first inclusion, of decimetric scale, can be seen on the North wall of the nave. The second and third inclusions, of metric scale, are in the nave, near the vault and pew respectively. As we will see, all three inclusions had an impact during the excavation **[Insérer Fig. 1]**.

### General Description and Dating Elements

The rock's heterogeneous nature altered the course of the hewing process and considerably modified the church's final shape. A simple observation of the nave confirms this. The monument has a transversal nave **[Insérer Fig. 2]**, but the shape of its vault is unusual. On the South side, a very regular barrel vault suddenly stops giving way to a kind of flat ceiling on the north side. In this part of the roof, delimitation with the walls of the nave is not clearly defined **[Insérer Fig. 3]**<sup>9</sup>. The presence of the first metric scaled inclusion explains this interruption. Similarly, a bench runs along the northern and eastern walls. This bench is of irregular aspect and widens towards the North-West of the nave. Coincidentally, we find the second metric inclusion of hard stone **[Insérer Fig. 4]** near this irregularity.

The presence of rooms under the church could indicate that steps used to lead to a now destroyed doorway in front of the present monument **[Insérer Fig. 5]**<sup>10</sup>. The nave is in an awful state of conservation. It has been completely gutted. Part of its western wall and the whole of its southern wall have fallen into the valley down below **[Insérer Fig. 6]**. Three alcoves were

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<sup>7</sup> Le Pennec et al, 1994, p. 66-67. The dating of this ignimbrite layer is still being discussed: Le Pennec et al. 2005 ; Viereck-Goette et al. 2010.

<sup>8</sup> A. Temel *et al.*, 1998, p. 451.

<sup>9</sup> This alteration was first noted by S.-A. Wallace (1991, II p. 532), who explains the irregularity of the covering by the presence of inclusion.

<sup>10</sup> About these underground rooms, see Jolivet-Lévy & Lemaigre Demesnil, 2015, p. 33.

carved into the nave. The first one is on the North wall, at man's height. It is wide and flat-bottomed. The other two alcoves are excavated at the bottom of the eastern wall. They have curved bottoms and have been identified as seats **[Insérer Fig. 7]**<sup>11</sup>. A panel near the flat-bottomed niche on the northern wall adorns a painting depicting a holy warrior. Its execution has been dated to the 11th century<sup>12</sup>.

The church has a single apse in its northern part, with a flat bottom and an irregular shape, accessible by three steps. Its entrance is highlighted by a frame materialised by a relief side on the East wall of the nave. A monolithic altar flanks the eastern wall. A single alcove with a curved bottom can be found to the South of the sanctuary. A small step seems to allow one to climb to its level. This niche could therefore also be a seat. Two coats of paint on plaster cover the whole of the walls and the barrel vault of the apse. The paintings are very damaged, but some of them could still be successfully identified. Of the first painted layer, a gemmed cross is the only remaining element<sup>13</sup>. It is visible near the barrel vault. Surrounded by two saints that cannot be identified, the bust of Christ appears on the last layer. The face of the Christ surmounts a small alcove that was later transformed into a window. In the recessed seat, St Basil has been identified by means of a fragment of an inscription<sup>14</sup>.

At the southern end of what remains of the nave, an irregular room, collapsed on its southern half, opens to the East. It has never been noticed before - yet it seems essential to the understanding of the church's architectural organisation and its initial projected design **[Insérer Fig. 8]**.

Typo-chronologies of the painted ornamentations and the church's layout help identify the phases of excavation and occupation of the monument. According to C. Jolivet-Lévy and N. Lemaigre Demesnil's hypothesis, the digging would have been carried out shortly before the first phase of painted ornamentation - between the 7th and 9th centuries. The second layer of paintings in the apse took place between the 9th and 10th centuries<sup>15</sup>. The last painted panel in the nave, seems to have been painted sometime during the 11th century.

Other phases of occupation can be deduced. The military saint's panel, dated to the 11th century, has been obviously destroyed by the large niche dug in the North-East corner of the nave's northern wall **[Insérer Fig. 9]**. The destruction of the painted panel is evidence of a late occupation phase, as the devotional object that this particular military saint used to represent got forgotten.

#### Using Tool Marks to Reveal the Chaîne Opératoire in Place

Understanding the phase sequence of the church Göreme n°4b worksite brings to light the master builder's first intentions and its probable successive adaptations. A first method focuses on defining the sequencing of the church's building through a *chaîne opératoire*. This theoretical model, mainly used in ethnology, aims to characterise the technical changes and the social organisation of work<sup>16</sup>. Its use in our study derives from the absence of written or oral sources to describe the excavation of rock-hewn monuments in Cappadocia.

The tasks (first degree of the *chaîne opératoire*), the stages (second degree) and the phases (third and last degree) describe the work sequence. Tool marks on the wall constitute the

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<sup>11</sup> Jolivet-Lévy, 1991, p. 90.

<sup>12</sup> Jolivet-Lévy, 1991, p. 90.

<sup>13</sup> Jolivet-Lévy, 1991, p. 90.

<sup>14</sup> Jolivet-Lévy & Lemaigre Demesnil, 2015, p. 33.

<sup>15</sup> Jolivet-Lévy & Lemaigre Demesnil, 2015, p. 33.

<sup>16</sup> Martinelli, 1991, p. 66.

*princeps* element by which the model can be constructed. They emanate from a tool that is used for a specific task. They form a tool cut, a grouping of tool marks (i.e. salvo), which represents the action the tool performed on the wall to complete that task. They can be broken down into two elements: the longitudinal mark and the final mark. The longitudinal mark (i.e. groove) corresponds to the tool mark left by the tool when it is in motion. The final mark (i.e. impact) is made by the tool's cutting edge.

A first sequence of the *chaîne opératoire* can be deduced by identifying the marks of the three main tools used during the excavation:

The predominant tool marks on the church's wall originate from a tool with a short handle **[Insérer Fig. 10]**<sup>17</sup>. The grooves they typically leave behind are narrow, short, and evenly spaced. They form a distinctive radial and slanted cut, a feature of the short-handled pick. This cutting process is used to straighten up walls. The salvo of the longitudinal impacts forms an arc. The stonecutter operates in profile, and the marks result from the movement of his tool. This cutting is carried out voluntarily for functional or aesthetic purposes.

A second type of marks also result from longitudinal impacts of a thrown tool, a long-handled pick<sup>18</sup> in this case. These differ from the short-handled pick tool marks with distinctive wide and long grooves and cuttings of various types - radial, slanted, linear - may be observed throughout the monument. For the radial type, the quarryman handles his tool parallel to the wall. The longitudinal impact salvo forms an arc. The quarryman operates on the bed rock he aims to remove in front of him. This cutting is often associated with linear cutting. These are the final impressions left on the rock mass by the worker. This cutting leaves round or square impacts (depending on the tool's cutting edge wear) in vertical line patterns. Both types of cuttings can be classified as destructive<sup>19</sup>. In the church Göreme n°4b, tool marks of long-handled picks can be seen in the south-eastern hall and at the bottom of the nave's western wall **[Insérer Fig. 11]**.

The third type of tool marks also results from a thrown percussion tool: an axe with two cutting edges (one vertical and the other horizontal) named polka or a carving axe<sup>20</sup>. It is not easy to distinguish these two tools by their marks. In the church Göreme no. 4b, some of these tool marks are clearly visible on the relief side of the apse frame on the nave's eastern wall **[Insérer Fig. 12]**. The tool marks are distributed horizontally, trademarks of a polka. The chosen cutting is of the slanted type. This tool was exclusively used on the eastern parts of the nave, the cornice running along the nave, the intrados and mouldings of the triumphal arch, and the upper part (covered with paintings) of the apse **[Insérer Fig. 13]** to finish the flattening of the walls. The layers' superimposition makes a hewing chronology possible: the tool marks of the long-handled pick are covered by the impacts of the short-handled pick **[Insérer Fig. 14]**. The tool marks of the polka very clearly overlap those of the short-handled pick.

This sequence of tasks, stages and phases may be translated as follows:

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<sup>17</sup> We have distinguished the picks according to the length of their handle because in Cappadocia, two variants of this tool have been observed. See Lamesa, 2011, p. 184; Lamesa, 2018, p. 79.

<sup>18</sup> Bessac, 1986, p. 14–24 for the long-handled pick or stonecutter pick.

<sup>19</sup> On radial, slanted and linear cutting: Bessac, 1986, p. 19–20.

<sup>20</sup> Bessac, 1986, p. 39–52 and 53–59.

Phases	Stages	Tasks	Actions	Tools	Location
Realising the project	Roughing out the structural work	- Roughing out the wall	Destructive radial and slanted cutting	Long-handled pick	Western wall of the nave and eastern room
Finishing the project	Finishing the structural work	- Straightening the wall	Radial and slanted cutting	Short-handled pick	West and North walls of the nave
		- Flattening the wall	Skewed slanted cutting	Polka	Eastern wall of the nave

The observation of hewing accidents further details this first sequence of *chaîne opératoire*. In the case of the church Göreme n°4b, the workers carved an ignimbrite with many hard inclusions. Some of them could be removed when the wall was straightened with a short-handled pick. Others had to be levelled, perhaps using a carving axe or a polka. Two, however, could not be removed and show tool marks on their surface, which allows us to further define the stone workers toolbox.

On the North's wall inclusion of decimetric scale, two types of marks are clearly visible. The first are around 0.5 to 0.7 cm in diameter. These marks come from the cutting edge of the long-handled pick. The second type does not correspond to a tool that has already been observed: they are composed of coarse lines caused by the bursting of the rock [Insérer Fig. 15]. These tool marks result from the use of a sledgehammer to remove the inclusion. The use of this tool is explained by the very nature of the inclusion – a hard stone (basalt?) and the inefficiency of the traditional tools used for carving – in this case the long-handled pick.

On the inclusions of metric scale, visible both on the ceiling and floor of the church, the tool marks are less clear, but the shape of the longitudinal impacts seems to confirm bursting by sledgehammer. The lines are coarse and irregular, the angles sharp [Insérer Fig. 16].

The second sequence of the *chaîne opératoire* therefore concerns the treatment of inclusions, which the workers had to take into consideration during the carving process. This sequence completes the relative chronology<sup>21</sup>.

This second sequence also highlights the difficulties encountered by the workers during the excavation process and the technical solutions implemented to get around them. It illustrates the choice of the master builder who modified the final appearance of the work by leaving three hard inclusions in place.

Phases	Stages	Tasks	Actions	Tools	Location
Realising the project	Roughing out the structural work	- Roughing out the wall	Destructive radial and slanted cutting	Long-handled pick	Western wall of the nave and eastern room
		- Removing hard inclusions	Burst cutting	Sledgehammer	Inclusions of decimetric

<sup>21</sup> Additions to the table are indicated by the colour grey.

					and metric scale
		- Managing the two hard inclusions	Abandonment of the destruction attempt	–	North wall of the nave and vault
Finishing the project	Finishing the structural work	- Straightening the wall	Radial and slanted cutting	Short-handled pick	West and North walls of the nave
		- Removing hard inclusions	Destructive cutting	Short-handled pick	Inclusions of centimetric scale
		- Flattening hard inclusions	–	Polka	Inclusions of centimetric scale
		- Flattening the wall	Skewed slanted cutting	Polka	Eastern wall of the nave

A first limitation to sequencing a *chaîne opératoire* is the impossibility to establish what types of measuring or drawing tools were used by the workers on the site. However, the vault's perfect cradle shape seems to indicate the use of a tool able to carry out perfect semicircles.

The second limit derives from specific tasks in the *chaîne opératoire*, the purpose of which is precisely to make tool marks disappear. An example is the fine smoothing of walls: this technique is commonly used in Cappadocia, where the rough/smooth contrast can be played with [Insérer Fig. 17]<sup>22</sup>. This fine finishing of the walls was applied around the nave's alcoves and passages (see Fig. 13).

Thanks to the very accurate observation of protected spaces (e.g. under a moulding), it is possible to detect the use of a rasp or of an abrasive<sup>23</sup>. It is difficult to distinguish the two tools as they both leave fine grooves on the wall<sup>24</sup>. In Cappadocia, we were able to observe some of these marks on a moulding of a monumental tomb in the Davutlu Valley Bucağı [Insérer Fig. 18]<sup>25</sup>. However, these finishing techniques do not seem to have been used in the case of the church Göreme n°4b. The space to be smoothed is far too large. Abrasives or rasps are typically used for mouldings and no streaks could be found.

#### Ethnoarchaeology in Cappadocia: Possible Tracks to Explore

In order to identify the motions associated with these finishing stages, we have chosen to call upon ethnoarchaeology, through an experimental approach and the observation of practices<sup>26</sup>. Alain Gallay stressed the need to set up a quantitative study<sup>27</sup>. This is difficult to carry out in Cappadocia since rock art is no longer practised. However, a couple of stonemasons still hew conservation deposits or rock rooms (rooms, refectories) for luxury hotels using traditional tools

<sup>22</sup> On this church: Lemaigre, 2010, p. 69–72; Jolivet-Lévy 2007, p. 52–60; Jolivet-Lévy & Lemaigre Demesnil, 2015, p. 118.

<sup>23</sup> Bessac, 1986, p. 264 for the abrasive and p. 203 for the rasp.

<sup>24</sup> Bessac, 1986, p. 207.

<sup>25</sup> Lamesa, 2016, p. 416.

<sup>26</sup> Gallay, 2011, p. 298–299.

<sup>27</sup> Gallay, 2011, p. 301.

at certain stages<sup>28</sup>. We therefore focused on a qualitative study using direct observation and interview techniques. This is a case study and the collected data must be considered as possible solutions.

We followed the stonemasons' team led by Kemal Manap. For a smooth rendering of a block used in a wall, the master/*usta* uses the blade of the straight edge as a scraper to remove the roughness left by the tool's impact [Insérer Fig. 19]. He then finishes smoothing with an artificial abrasive (sandpaper). This straight-edged scraped cut can also be performed using a wide chisel with a sharp, straight edge<sup>29</sup>. The resultant effect matches what could be observed on the church's walls. The tool marks of the straight edge are still visible depending on the incidence of light, but from the front, the wall appears smooth.

We therefore propose to insert this solution into the hewing process of church Göreme n°4b, but we should stress that for now this remains a hypothesis:

Phases	Stages	Tasks	Actions	Tools	Localisation
Realising the project	Roughing out the structural work	- Roughing out the wall	Destructive radial and slanted cutting	Long-handled pick	Western wall of the nave and eastern room
		- Removing hard inclusions	Burst cutting	Sledgehammer	Inclusions of decimetric and metric scale
		- Managing the two hard inclusions	Abandonment of the destruction attempt	–	North wall of the nave and vault
Finishing the project	Finishing the structural work	- Straightening the wall	Radial and slanted cutting	Short-handled pick	West and North walls of the nave
		- Removing hard inclusions	Destructive cutting	Short-handled pick	Inclusions of centimetric scale
		- Flattening hard inclusions	–	Polka	Inclusions of centimetric scale
		- Flattening the wall	Skewed slanted cutting	Polka	Eastern wall of the nave
			Scraped cutting	Polka or chisel	Eastern wall of the nave

We also point out three other pieces of information obtained through ethnoarchaeology that will later be useful for our demonstration's purposes.

<sup>28</sup> Öztürk, 2009; Lamesa, 2011; Öztürk, 2017; Lamesa, 2018. It should be noted that stone workers most often use a pneumatic hammer for hewing and cutting the bedrock.

<sup>29</sup> J. Cl. Bessac (1986, p. 190) mentions the replacement of the squeegee with a very sharp chisel. See also Lamesa 2011, p. 185.



Thanks to the photographs published by F. Öztürk<sup>30</sup> or collected during interviews, we notice that (1) the rubble allowed the stone worker to climb to ceiling level. In the picture **[Insérer Fig. 20]**, the tool marks (2) are distributed horizontally at the level of the wall's upper part (slanted cutting) and follow an arc at the centre of the wall (radial cutting). The extremities of the room (ceiling, corners and floor) require a precise and meticulous cutting to be carried out, which is impossible with slanted and radial cutting. It appears that (3) the stonemason's work was carried out in sections, as reserves of rock were gradually being removed<sup>31</sup>.

Data collection through interviews and experimentation is still in its infancy in Cappadocia. Hence the need to combine this information with other archaeological methods to confirm or disprove it. The hypotheses formulated thanks to ethnoarchaeology can be discussed in a relevant way only by cross-matching with other methods.

#### The Phasing of a Wall: a Complex but Incomplete Vision of the Work

A stratigraphic reading of the tool marks left on the walls further refines the church's build sequence and confirms archaeologically the data collected in ethnoarchaeology. This third method, based on the principles advocated by E. Harris, needs to be adapted to the characteristics of the rock-hewn space. Unlike stratigraphic units, layers accumulate one on top of the other according to the Law of Superposition (the oldest layers being covered by the latest). The newest tool marks destroy the oldest ones by physically removing a layer from the wall. We therefore propose to call these layers Negative Units instead of Stratigraphic Unit<sup>32</sup>. This is a particularly time-consuming method to deploy over the entire rock-hewn monument. It should therefore only be used in very specific and carefully selected promising areas. In our case, we chose the western wall of the nave, of which only the northern part remains<sup>33</sup>. This wall is essential insofar as it has not received the same finishing touches as its eastern counterpart. Moreover, it is located at the junction of the two ceilings, separated by the metric scale inclusion of hard rock and at the level of the metric inclusion of the floor.

To properly define the phasing of the Negative Units, it is necessary to delimit and correctly describe the test wall by identifying the type of tool marks, their orientation and their spacing **[Insérer Fig. 21]** :

To this stratification, we add a few scattered or grouped tool marks that do not perform proper salvos.

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<sup>30</sup> Öztürk, 2009, res.17-18.

<sup>31</sup> Öztürk, 2009, including res.17.

<sup>32</sup> I wish to thank B. Desachy for our discussions on the application of Le Stratifiant software to rock cutting. Fauvelle-Aymar *et al.*, 2010, 1138 it applies this technique of reverse sequencing by studying the superimposition of impacts or 'anomalies' (in the words of the authors) on the site of the rock-hewn churches of Lalibela.

<sup>33</sup> Wall measurements: 172 cm long, 214 cm high (measurement taken on the step) and 246 cm high (at the foot of the step).

By mechanically applying the Principle of Stratification of Negative Units, an automation made possible by Le Stratifiant software, a striking pattern emerges. While nine phases appear on the Harris matrix, Negative Units 1 and 8 do not seem to correspond to the same period. A lost chronological relationship is therefore revealed between these two units **[Insérer Fig. 22]**.

Can these results be cross-matched with the sequencing of *chaîne opératoire* data and the information obtained by ethnoarchaeology?

Units 1 and 9 form two separate floors. Both cases are related to the straightening of the wall after excavation, as shown by the extremely regular cutting made by a short-handled pick. The two layers' overlapping to the North is explained by the proximity of the North wall. The worker wanted to accurately shape the junction between the North and West walls. He therefore reworked this critical and delicate area of the wall. The floor-by-floor breakdown shows that a clearance operation was carried out between the two floors. These two units represent two different tasks chronologically distinct in time.

After completing unit 1, the stone worker seems to have taken over the centre of the wall. This is visible at the level of units 4 and 5, which appear to us to be synchronous. The greater depth of tool marks at Negative Unit 6's level and the change in the marks' angle prove that this is a distinct third level in the phase. This last unit seems to be leftovers of a task, which was then subsequently covered by unit 9. Could it be the presence of a first floor formed by the rubble? The presence of an important inclusion? In any case, the wall was cut again, and this action required the worker to turn around and slightly change position.

Several indications tend to prove that negative units 2, 3 and 7 were carried out between two tasks of straightening the wall, represented mainly by units 1 and 9. The mason did not intervene at the ceiling level, demonstrating that he had completed the ceiling's shaping. The stone worker's position, inferred from the radial and slanted cuttings, proves that he was slightly elevated from the current floor. The clearance of the space had therefore not been fully completed. It is difficult to explain the reasons that led the stonemason to take up the wall in the opposite direction: the need to straighten the wall? The levelling of imperfections due to inclusions? The linear cut at unit 3 could indicate the presence of an obstacle to the South. Could it be the hard inclusion in the ceiling that prevented the worker from easily manipulating his tool? The distorted unit 7 indicates in any case that the worker had encountered some kind of difficulties in cutting at this level of the wall.

Unit 11's tool marks do not share the same spacing as those of negative unit 9. However, the same tool has been used, indicating that the cutting has been resumed consecutively to the previous task. The lengthening of the worker's movement and the significant penetration of the tool into the wall at the level of negative unit 11 further demonstrate that the worker was performing his action close to ground level. The change of tool, a long-handled pick, at the level of negative unit 12 confirms this hypothesis. After this first ground level, the worker used a long-handled pick to shape a step in the immediate vicinity of the hard inclusion of metric proportion. This allowed him to make the bench appear. It is certain that at this point the space had been completely cleared.

Finally, negative unit 10 also shows signs of resuming work. The change of tool, a long-handled pick, could indicate the presence of a reserve of rock, close to the North wall. The need to protect the wall junctions as much as possible in order to avoid any irreversible work-related

accident explains this strategic choice. The worker therefore favoured cutting the lower northern corner of the wall in a second step, once the entire area had been cleared.

In the case of units A, B, C, D, this could be a one-time intervention to remove inclusions. This hypothesis is supported by the presence of inclusions of centimetre scale near A, B and C. For D, there is no guarantee, but the use of the short-handled pick seems to be associated with this task. Moreover, the traces are oriented in the same way as C, contrary to those of the negative unit 8. We believe that the work of levelling unit D has been carried out in the same continuity as unit C. The interpretation of unit E is more delicate, the use of the polka in the centre of the wall could also indicate a flattening of inclusions.

The relationship between Negative Unit 1 and Negative Unit 8 remains to be explained. The latter predates units 7, 9 (and therefore Negative Unit 11). The use of a long-handled pick could be the key to this mystery, the unit would be a reminiscence of a first phase of excavation, prior to all the other units visible on the wall. The fact that the worker is facing South to carry out this digging seems to indicate that a space had already been created.

One could thus define a *chaîne opératoire* thanks to this stratification of tool marks. It is however not possible to place unit 11 and unit 10 in a chronological stratigraphic sequence since the worker could first work on the task of unit 10 or on the task of unit 11. Arbitrarily, and for convenience, we will place task 11 before task 10 in the table below.

Phases	Stages	Tasks	Actions	Tools
Realising the project	Roughing out the structural work	- Roughing out the wall, unit 8	Destructive radial and slanted cutting	Long-handled pick
Finishing the project	Finishing the structural work	- Straightening the wall, unit 1	Radial and slanted cutting	Short-handled pick
		- Removing hard inclusions, unit A	Destructive cutting	Short-handled pick
		- Straightening the wall, units 4 et 5	Radial and slanted cutting	Short-handled pick
		- Straightening the wall at the ground floor, unit 6	Radial and slanted cutting	Short-handled pick
		- Removing the rubble	Removing the rubble	Basket, shovel
		- Straightening the wall, unit 2	Radial and slanted cutting	Short-handled pick
		- Straightening the wall, unit 3	Linear cutting	Short-handled pick
		- Distorted area, unreadable reading, unit 7	–	–
		- Removing hard inclusions, unit C et D	–	Short-handled pick

		- Removing the rubble	Removing the rubble	Basket, shovel
		- Straightening the wall, unit 9	Radial and slanted cutting	Short-handled pick
		- Removing hard inclusions, unit E	–	Polka
		- Removing hard inclusions, unit B	–	
		- Straightening the wall at the ground floor, unit 11	Radial and slanted cutting	Short-handled pick
Realising the project	Roughing out the structural work	- Roughing out the wall, unit 10	Destructive radial and slanted cutting	Long-handled pick
		- Roughing out the wall, unit 10	Destructive radial and slanted cutting	Long-handled pick

Thanks to the phasing in the Le Stratifiant software, a new Harris diagram organized according to the previously mapped chronology may be proposed [Insérer Fig. 23].

Phasing by stratigraphy reading has many advantages. The first is to systematically record the salvos on a wall. Recording the observations in Le Stratifiant then makes it possible to verify the reading of these Negative Units by pointing out redundancies and logic problems. With quick access to a graphical representation of the data, the software helps the archaeologist's reasoning and streamlines the formulation of new hypotheses which could potentially lead current field work to be redirected on the spot.

In the framework of a study specific to rock-hewn monuments, the case of Negative Unit 8 is particularly interesting. It is commonly accepted that the salvos on the wall are evidence of the masons' work from top to bottom. The archaeologist therefore tends to consider the high salvo as the oldest. In this case, it is not unit 1 but unit 8, in the centre of the wall, which is the oldest. This fact gives a different orientation to the view of the space under survey. The transcription by means of graphs reveals the divergent hypotheses and opens up a new field of questioning: why did the worker not take over the wall completely and leave part of it in its most unfinished phase? Does this mean that the area further to the South, now destroyed, was waiting for a finishing phase when the church was delivered to the patron? Did the presence of the hard inclusion in the ceiling, still represent, during the finishing of this wall, an obstacle to the good progress of the worksite?

For the church Göreme n°4b, applying a stratigraphic reading at wall scale illustrates the masons' working process. The limits of the different levels of ground reached during excavation, the organisation of the site (the stonecutter has to stop clearing) and the work sequences (the tools used are visible on the graph) are thus highlighted. In the same vein, this very accurate reading of the wall reveals the difficulties that a worker encountered and the solutions he implemented to solve them while shaping the space.

However, this automated stratigraphic work remains incomplete. Without the ethnoarchaeological study, it would have been impossible to understand the clearing tasks during excavation, which are essential to draw a full *chaîne opératoire*. Similarly, the focus on a given space obscures the plurality of tools used by the stonemason and the singularity of each worker. Phasing by stratigraphic reading cannot therefore do without other methods such as tracer analysis and ethnoarchaeology. This method allows the setting of limits (in a deductive study) which by crossing information obtained by other approaches becomes an inductive study.

#### The Worksite of Church Göreme n°4b: a Modified Initial Project?

We now wish to take a broader look at the final architectural aspect of the monument, which is rare. Articulating this aspect with the results obtained previously argues in favour of a final project amended during the building process [see Fig. 2]<sup>34</sup>.

A simple observation of the monument reveals an uncommon layout and suggests a first modification of the project. The unnatural transition between a particularly well-made transverse vault and the irregular shape of the ceiling to the North of the nave is obvious. Thanks to the technical study, it could be proved that the hard inclusions of decimetric and metric scale were subject to attempts of destruction by the stone workers. The efforts made and the result shows that a decision, taken by the master builder, stopped the work and initiated a reflection on the integration of these hard inclusions in the final project.

As R. Ousterhout notices, the plan of the apse is peculiar<sup>35</sup>. Rectangular on the North side, it is curved on the South side. This irregularity links to a second modification, decided by the master mason who favoured avoiding the hard inclusion altogether by considering its oblique disposition into the rock. He therefore had a straight wall made on the North side, a precaution that was superfluous over on the South side.

The unfinished rooms' presence to the church's South-East finally pleads in favour of a third modification decided upon during hewing process. We believe that this room is a part of the church project. The apse's frame has been perfectly executed and the first task in the finishing stage of the work (slanted cutting with a polka) overflows back [see Fig. 12]. This shows that the protruding framing is anterior to the finishing of the church. The entrance of the unfinished room is made during hewing. In addition, its entrance is marked by a pediment surmounted by a rectangular corbel and is inscribed in an opening in the shape of an arc [Insert Fig. 24]. The corner of the door can also be seen. Paradoxically, we observe a destructive radial and slanted cutting and a linear cutting characteristic of the use of a long-handled pick on its interior walls. This tool and the cuttings associated with it were identified during the hewing process. The workman stopped while he was obviously shaping the room. The entrance had already been regularised and was in the process of being finished. This can be seen by the levelling of the inclusion at the level of the pediment and by the partial destruction of the nearby inclusion [Insert Fig. 25]. Similarly, the mouldings surrounding the door are well done. It is impossible to define what could have been the role of this South-East room: a second apse? A parekklesion (annexe chapel)?

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<sup>34</sup> Refer lastly to Jolivet-Lévy & Lemaigre Demesnil, 2015, p. 33.

<sup>35</sup> Ousterhout, 2017, p. 430.

The choice to focus on the northern part of the church seems surprising at first glance; it would, in fact, have been more logical not to continue digging beyond the hard metric scaled inclusion of the ceiling and to make do with the spaces already available, namely the southern part of the church. However, geological problems also prevented the workmen from properly shaping the southern space, which would explain the master builder's plan to have the two metric scaled inclusions removed in order to obtain a finalised part in the north.

Thanks to all the data collected, the sequence of the workers' actions and the modifications decided by the master builder can be chronologically sequenced. (1) The workers first completed the southern part of the nave, a process that was part of the initial project. As they moved northwards, they encountered several metric scale inclusions that prevented them from progressing. (2) While the shaping of the southern part is well advanced but before the finishing of the naves' walls, a workman begins the realisation of the South-Eastern room. Unfortunately, the quality of the rock stops him and this room is left unfinished. (3) The decision is made to amend the original plan of the church, i.e. a transverse nave covered with a barrel vault. The team then concentrates on the northern part of the nave. (4) After having succeeded getting through the metric inclusions to the north-west of the nave, an operation that must have required at least a two-person team, (5) a space is created, and hewing is resumed. (6) Then a worker heads East, and a second worker begins the phase of making the space to the West; the quantity of rubble had to be sufficient and the space between the inclusion of the ceiling and the North wall of the nave sufficient to start the ceiling. (7) The worker digging eastwards then finds the inclusion again. (8) The master builder then makes the decision to change the shape of the apse to avoid the hard vein, which explains the unusual shape of the apse. He chooses to carry out the enhancement of the naves' north-eastern part. (9) At the same time, the protruding framing in the middle of the nave is decided in order to customise and visually identify the northern part of the church as the sacred part of the monument. (10) The remaining of the naves' eastern wall is taken over before the finishing and sculpting phases are carried out. The localisation of the finishing tasks, observed on the North and North-East walls of the nave and vault, confirms the importance attributed by the master builder to the northern part. This additional indication tends to prove that at the end of the worksite, the southern part of the church had lost all its appeal.

## Conclusion

The detailed study of the church Göreme n°4b has shown that these rock-hewn structures retain the memory of the changes they have undergone over time. Thanks to the rocky nature of the monument, these changes can be included in the succession of the worksite phases, more precisely than those observed in a built monument. They highlight the decisions made by the master builder when problems were encountered during the shaping of the church, as well as the organisation of the team and the distribution of their work in the hewn space<sup>36</sup>.

A part of the church n°4b was left unfinished: this is not exceptional, other churches such as the church n°28 of Göreme (northern apse) or the church of Bahçeli (western part of the northern nave) have the same characteristic<sup>37</sup>. Delivering a monument to the patron does not imply that all the finishing touches have to be carried out or that certain areas have to be completed<sup>38</sup>. The choice to proceed with the painted ornamentation while the monument was yet to be completed suggests that this "abandonment" of the excavation was not decided by the

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<sup>36</sup> This idea was highlighted earlier by Fauvelle-Aymar *et al.*, 2010, 1138–1139.

<sup>37</sup> Lamesa, 2016, plates 5 et 15.

<sup>38</sup> On the question of unfinished works and sculptures, see the recent reflections of Vidya Dehejia & Peter Rockwell (2016).

master builder but rather by the patron himself. In the case of church no. 4b, was the final choice to carry out the delicate finishing touches on the north-eastern part of the church not made by the patron? Saving in human resources for a saving in costs - the initial contract having most certainly been subject to "amendments" - the patron also influenced the project manager in these decisions. In any case, this explains the dichotomy between the northern and southern parts.

The methods proposed in this paper and the resulting reflections could be extended to other monuments. The traceology approach also needs to be cross-referenced with other methods that are more anthropologically centric. In Cappadocia, there is a need to collect more testimonies of stonemasons, to carry out experimental archaeology on ignimbrite and to observe the carving of supply sites and rock-hewn hotels. Although partly lost, the knowledge and skills related to traditional stone-cutting techniques need to be collected.

Finally, other areas, such as Ethiopia, where rock church sites are still being hewn, require special attention. The establishment of comparative analytical grids will, I hope, in the future, provide new elements that will most certainly broaden the scope of our reflection<sup>39</sup>.

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<sup>39</sup> On a first example of comparative work, see Lamesa & Gervers 2020 (forthcoming).

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