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The Torreón of Machu Picchu: an astronomical observatory?

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Abstract: The Torreón is one of the most emblematic buildings of Machu Picchu. Since 1929, different archaeoastronomical studies have been carried out on this building to verify its function as an astronomical observatory. The authors of the present text analyse in detail these hypotheses using a thorough survey of the structure created from 3D scans and digitised models. The analysis concludes that we can take as established evidence that the builders of the tower designed it according to some solar orientations, but without the purpose of erecting an astronomical observatory as was apparent in the cases of Intimachay and Inkaraqay.

Keywords: Inca astronomy, Machu Picchu, 3D laser scanning

Introduction

This present analysis of the Torreón is part of a more comprehensive study dedicated to the supposed astronomical-calendar functions of some architectural structures of Machu Picchu. The authors decided to present the research results on this emblematic building as a monographic text due to the complexity of the hypotheses issued about it. The study is part of a larger project concerning the possible astronomical significance of the orientation of certain monuments of the Llaqta of Machu Picchu and some of its satellite sites. The results presented below, relating to the "Torreón", serve in particular for comparison with three structures previously analysed by the authors, namely Intimachay (Ziółkowski, Kościuk, Astete 2013), the Mirador de Inkaraqay (Astete, Ziółkowski, Kościuk 2017) and Coricancha (Ziółkowski Kościuk, 2018).

If the existence of astronomical orientations of some components of the Torreón is to be verified, the fundamental issue to be resolved is the following:

- Was the Torreón an observatory, properly speaking, similar in function to Intimachay or Inkaraqay?
- or were the astronomical orientations in question used only to achieve visual effects during some religious ceremonies performed in the Torreón?

The input data that we use in the analyses presented here are taken from a 3D laser scanning project carried out in cooperation with the Machu Picchu National Archaeological Park. In 2012, we set up a detailed geodetic network on Machu Picchu consisting of 59 measurement stations. Angle and distance between these stations were measured with the Leica TCRP1203 Total Station. To increase the accuracy, angular measurements were made twice, each time in two opposite positions of the lunette. The tachymetric data obtained in this way were adjusted using the least-squares method.

Additionally, static GPS measurements were made on eight points lying across the entire area. Based on the four reference points[1] of the official geodetic network, these data were also aligned using the least-squares method. The rigid survey network was then transformed (rotation and translation) from the local coordinates system into global geodetic UTM18S coordinates. The maximum errors were in the range of 20 mm or less[2].

In 2012, 3D laser scanning of the central part[3] of Machu Picchu also began[4]. Initially, a scanner of the Machu Picchu Park Directorate (Leica ScanStation 2) was in use, and in the following years (2014–2015)[5], courtesy of Leica Geosystems Poland, we used the Leica ScanStation C10 scanner. Finally (2016–2018), we brought to the site our own Leica P40 instrument. As the entire project is run on a pro bono basis, the annual scan sessions were limited to only two weeks. Nevertheless, more than 350 scan stations were completed, thus covering all the essential areas and buildings. Whenever possible, referencing to the survey network was done by placing HDS targets directly on the network points. In the areas from which no such points were visible, cloud-to-cloud registering was used with the least-squares method to minimise possible errors that did not extend 1 cm over the whole site. In the few cases when the errors turned out to be bigger, weighting was used.

Since the whole project's general orientation was based on global geodetic WGS-84 coordinates, it was necessary for archaeoastronomical analysis to introduce an adjustment for true north – the grid convergence correction. This was calculated with Walls Project Editor v2, and for Machu Picchu, which lies within the UTM 18S Zone, whose central meridian is 69°W, there was a 0.56° adjustment.

Although the whole project is not finished yet, the data derived from 3D laser scanning were intensively used for the archaeoastronomical analysis presented in this monograph. All the plans and sections are directly derived from the 3D point cloud, while all the computer simulations of the impact of the sun were made on 3D mesh models based on the scanning results.

For more precise orientations of particular buildings and linking those to the orientation of the horizon, direct observations of the Sun were used. The total station was set in front of the building, and several characteristic points were measured on the horizon (horizontal and vertical angles) and on the building itself (both the angles and the distance). For the latter, HDS targets for 3D laser scanning were often used as the reference. From the same total station location, up to 20 positions of the Sun were measured in 1–2 minute intervals and the true north direction was calculated with the help of Stellarium or Cartes de Ciel software alternately. Finally, using the same tripod position, the total station was replaced with a digital camera mounted on a panoramic head, and several overlapping pictures of the horizon were shot.

In most cases, we received good compatibility between our measurements and the official plan of Machu Picchu kindly provided by the Park Directorate. The differences did not exceed ±0.16° and can be explained mainly by the necessary simplification of the general plan of Machu Picchu, which did not take into consideration all the local irregularities of the sloping and often curved walls.

Finally, a few words must be dedicated to the chronology of the construction of the Torreón (and other structures of Machu Picchu), since this factor is also important in the archaeoastronomical analysis. Until recently, the construction of the entire site of Machu Picchu was usually placed in the second half of the 15th century, starting from 1450/60 AD. However, recent studies based on radiocarbon data indicate that construction began a few decades earlier, possibly in the early 15th century (Ziółkowski et al. 2020). Nevertheless, as most of the astronomical hypotheses formulated about the Torreón took either 1450 or 1500 AD as reference points, the authors decided to refer to these "traditional" dates in their comparative analysis. However, this possible chronological change has a marginal impact on the analysis of the positions of the Sun, but a slightly bigger impact on the observation of stars.

1 They were points Placa 149 Placa 150 Placa 167 and Placa 186.

2 All geodetic measurements were made by a team led by Bartłomiej Ćmielewski.

3 That is, within the limits available for visiting by tourists. The entire area of the Machu Picchu National Archaeological Park is over 300 km².

4 This part of the scanning project was coordinated jointly by the architect of the Machu Picchu Park, César Medina Alpaca, and Jacek Kościuk.

5 From that moment on, the entire scanning project was in the hands of Jacek Kościuk, the head of 3D Scanning and Modeling Laboratory at Wroclaw University of Science and Technology.

The Torreón or “Temple of the Sun”

The tower-like rotunda construction of the Torreón (Fig. 1) is one of Machu Picchu’s most unique and iconic buildings and enjoys much attention not only from tourists visiting the site but also from multiple scientific publications. The most significant of these publications will be discussed below while presenting archaeoastronomical interpretations related to this building.

Fig. 1. The Torreón of Machu Picchu as seen from the east (photo by J. Kościuk)

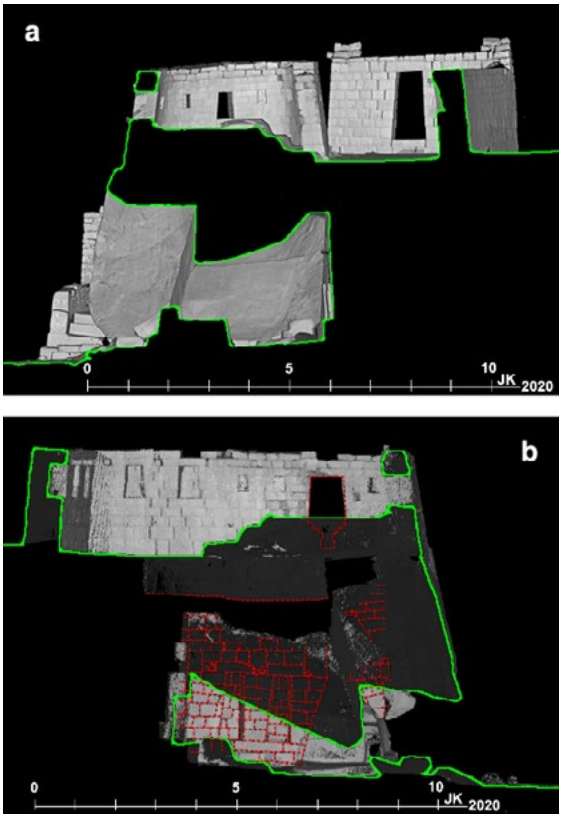

Fig. 2. Vertical sections across Window A (elaborated by J. Kościuk). a – looking south; b – looking north

A brief description of the building

The Torreón (Fig. 1) is built on top of a pile of big granite blocks that are the characteristic feature of the whole geomorphology of Machu Picchu. It is worth mentioning that some scientists see this as one of the reasons that this place was chosen by Inca builders.

Canuti and others (2009, p. 256) suggested that due to microcracks resulting from tensions inflicted by two tectonic faults running through the area, the granite blocks there are particularly easy to split and to process in planes parallel to these microcracks[6]. Further on, the authors state that … *the site of Machu Picchu could have been selected by Incas also because of the availability of two large block deposits, useful for constructions: one on the so-called ‘Cantera’ and the second in the paleo-landslide recently discovered.*

6 This might explain the slice-like destruction on the inner facade of the northern wall of the Torreón (Fig. 6). The stresses in the stone ashlars caused by the subsidence of the wall led to the detachment of the granite layers in the planes parallel to the microcracks and at the same time parallel to the face-processing plane chosen by the Inca masons.

The whole Torreón structure consists of two distinct parts: the lower part, often referred to as the *Tumba Torreón*, and the upper part, which will be the main subject of the following analysis.

The lower part occupies an irregular cave-like space between large lumps of granite wedged against each other. The gaps between the granite blocks are filled with the fine ashlar, Cusco-style masonry in which several trapezoid niches are arranged (Fig. 2). In some parts, the natural rock has been carefully carved in the form of stepped ledges, terraces and prisms.

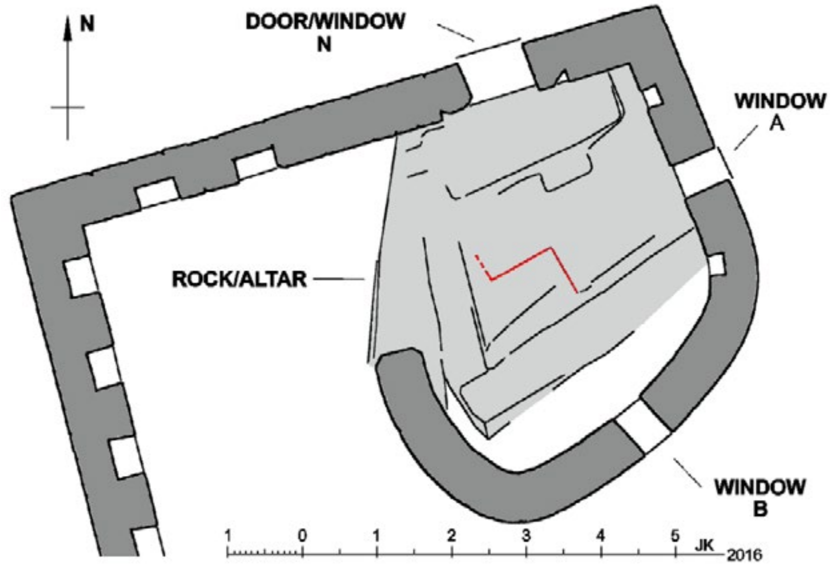

Fig. 3. The upper part of the Torreón according to 3D laser scanning results. The Z-like sharp edge on the top of the altar is marked in red (elaborated by J. Kościuk)

The upper part of the Torreón (often referred to as the Temple of the Sun) is built over oblong, artificially shaped rock (Fig. 1). It is surrounded by probably the best ashlar masonry one can find on Machu Picchu. The top of the rock is carved with several steps, horizontal platforms, seats(?) and sharp edges[7] forming a Z-like figure (Fig. 3). It is usually interpreted as an altar, or more often described as the rock/altar.

Fig. 4. Panoramic view of the upper part of the Torreón (elaborated by J. Kościuk)

In the walls surrounding the rock/altar, there are nine niches embedded (Fig. 4). These were carefully measured by Rolf Müller in 1929 (Müller 1929, 184), and he later concluded that the builders of Machu Picchu used a basic measuring unit of 7.3 cm (Müller 1972, 29). Although our 3D laser scanning fully confirmed the accuracy of his measurements, the metrological interpretation differs. Müller does not explain the basics of the applied calculation method. However, it is worth noting that Müller's estimations are perhaps the first attempt to study Machu Picchu metrology. Using his data and the *cosine quantogram* method (Kendall 1974; Pakkanen 2001), we get a unit of 13.4 cm rather than 7.3 cm (Fig. 5). This unit of 13.4 cm matches well with the Inca measurement

7 Today heavily damaged.

of *yuku*, which according to Anna Kubicka (2019), may belong to the alternative metrological system (13.5; 27; 54; 108; 162 cm). This system differs from the one postulated by Rostworowski de Diez Canseco (1978), which was based on a sequence of the following incaic units: *rikra* (approx. 164 cm), *sikya* (approx. 82 cm), *khocok* (approx. 42 cm), *k'apa* (approx. 20.5 cm) and *yuku* (approx. 10.5 cm). According to Anna Kubicka (2019, 171), the alternative system was mainly used in particularly prestigious buildings on Machu Picchu.

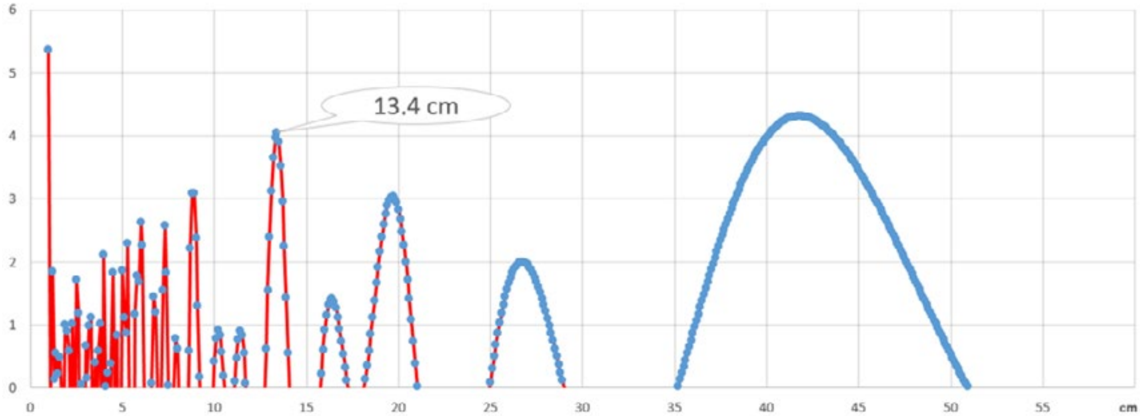

Fig. 5. *Cosine quantogram* estimation of niches and doors according to R. Müller's measurements (elaborated by J. Kościuk)

Fig. 6. Door/Window N of the Torreón. a – the northern facade of the Torreón as seen on September 22nd, 1911 (photo by H. Trucker, in: Machu Picchu. Catálogo de la colección 2011, 171); b – the lower part of Door/Window N as seen from the south (photo by J. Kościuk); the western jamb of Door/Window N as seen from the east (photo by J. Martusewicz)

The main feature of the upper part of the Torreón is a system of three openings in the walls pointing to characteristic directions – the east, south-east, and north. The eastern opening (Window A) has on its outer face elements that are unusual for this location. Four pegs are carved in stone blocks around the window corners (Fig. 1). Such elements are usually interpreted either as protrusions for the easy lifting of heavy blocks, or pins for attaching ropes stabilising the roof truss, or finally – particularly when placed above niches inside the buildings – as pegs to hang mats protecting the contents of niches. None of these interpretations convincingly fit this case. The outer face of the south-eastern opening (Window B) is even more peculiar – there are six such pegs, and four of them are arranged in a horizontal line below the window (Fig. 1). While their function is equally debatable, Dearborn and White offered in this case a compelling, it seems, explanation for the presence of the two additional pegs in the lower row. They assume (Dearborn and White 1983) that these are a remnant (window sill) of a planned, and ultimately moved more to the west, window. Since the curvature of the wall differs significantly in these two places, the already made and installed sill would have been useless for the window's new location. It was probably easier to leave it in place and carve out a new block for the new window sill. Nevertheless, the mystery of the pegs around the window corners remains unsolved.

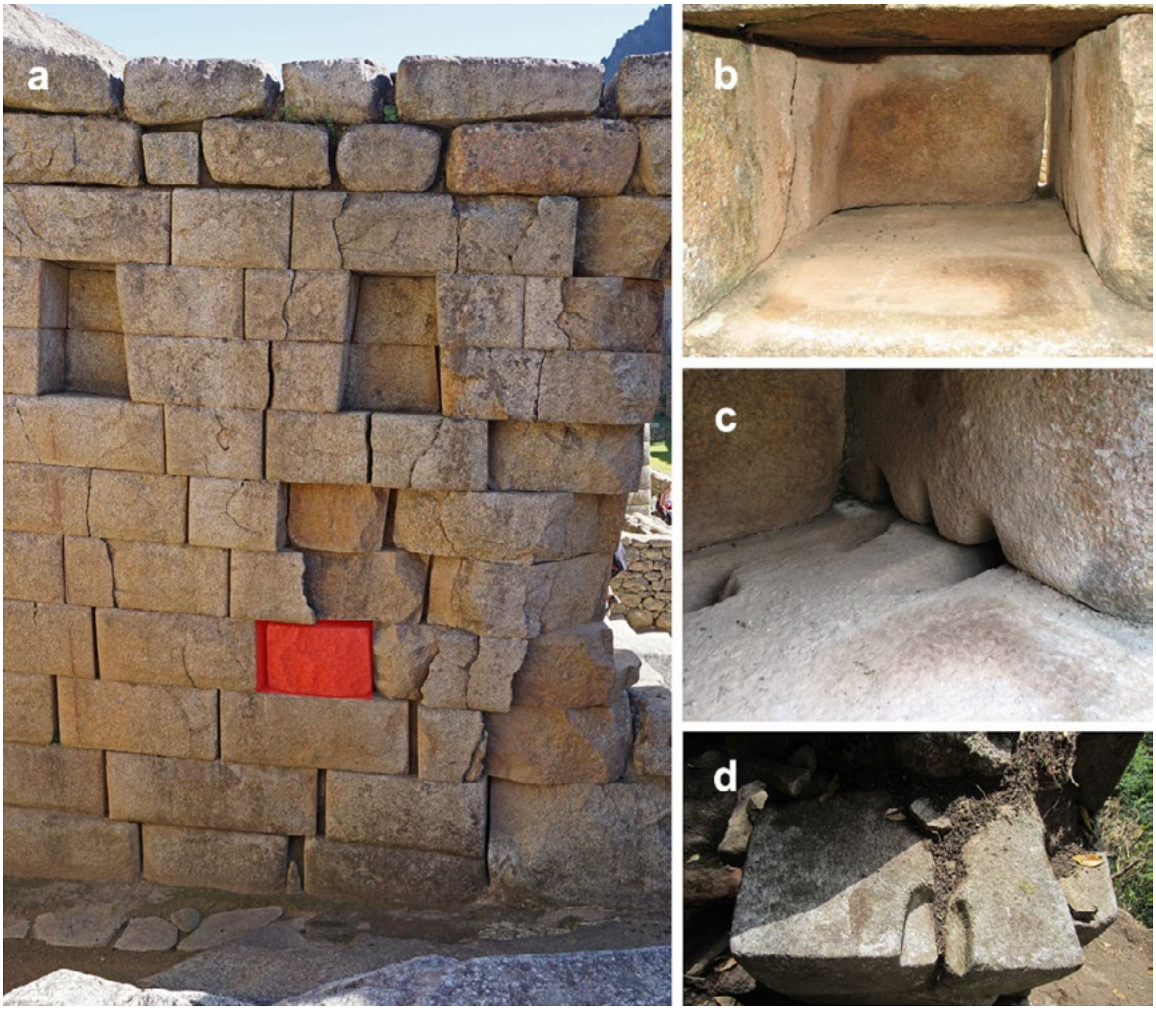

Fig. 7. The "cache" west of Door/Window N of the Torreón. a – the inner wall with the location of the "cache" highlighted red (photo by J. Kościuk); b – view of the "cache" interior (photo by J. Martusewicz); c – notches on the bottom and side surfaces of the "cache" (photo by J. Martusewicz); d – analogous notches on the north corner of the entrance to el Mirador de Inkaraqay (photo by J. Kościuk)

The last opening – the northern one – is the most difficult to interpret (Fig. 6). It is severely damaged and has proportions and a location more typical for a door than a window. The state of preservation, particularly of its lower part and the western jamb, does not allow for a reliable reconstruction. Neither its general dimensions nor the level of the threshold (or the sill) are clear. Therefore, it will be further referred to as Door/Window N. At the bottom part of this opening, there are several blocks with holes drilled in their vertical and horizontal faces. An association with a window in the facade of the so-called "Room of the Stars" in Coricancha may easily be imposed here (Ziółkowski M, Kościuk J 2018, 11, Fig. 4).

Although nowadays all the stones surrounding Door/Window N seem to be in the same place as in the times of Hiram Bingham (Fig. 6a), it is doubtful whether all of them are in their original position. Some of the holes do not have their counterparts in the adjacent stone blocks. Additionally, the stage of surface erosion (particularly on the edges of the blocks) differs considerably from the remaining part of the wall (Fig. 6b,c). Probably, during the Inca era, this part of the Torreón underwent some modifications due to structural problems that occurred, and the entire work was never completed. Thus, the present layout of the blocks does not necessarily reflect the original intentions of the ancient builders.

Another peculiarity can be found on the inner face of this wall of the Torreón – west of Door/Window N. One of the ashlars (Fig. 7a) can be easily pulled out from the wall, and behind it, there is a small hiding place – a kind of a "cache" (Fig. 7b). At the bottom and on the eastern side of this hiding place, there are oblong, inconsistent cuts, the function of which in this place is difficult to understand (Fig. 7c). They resemble similar cuts often found in door openings, which can be interpreted as traces of some mechanism securing the opening (Fig. 7d). However, there is no convincing evidence (or even coherent concept) that such a device could exist inside this "cache". In this situation, we tend to believe that the blocks around the hiding place come from some other, already dismantled building and have been reused here. Perhaps the same is true of at least some of the blocks at the bottom of Door/Window N.

The plan of the Torreón and its orientation towards true north and the horizon

When comparing the plan of the Torreón resulting from 3D laser scanning with plans published by our predecessors (Fig. 8), we noticed several discrepancies concerning the shape of the building itself, the positions of the windows, and the orientation of these elements relative to true north (Table 1).

Table 1. Torreón orientation according to various authors (elaborated by J. Kościuk)

	Angle	Müller 1972	Dearborn and White 1983	Kokocnik et al. 2013	Machu Picchu Park plan 2015	3D laser scan 2012–14	Difference Müller / 3D laser scan 2012–14	Difference Dearborn and White 1983 / 3D laser scan 2012–14	Difference Kokocnik et al. 2013 / 3D laser scan 2012–14	Difference Machu Picchu Park plan 2015 / 3D laser scan 2012–14
Plan	PW-A	–	85.0°	–	–	90.33°	–	-5.33°	–	–
	PW-B	–	152.0°	–	–	160.88°	–	-8.88°	–	–
	A-B	–	67.0°	–	68.62°	70.55°	–	-3.55°	–	-1.93°
Orientation	n-N	0.00°	4.03°	1.31°	0.16	0.00°	0,00°	4.03°	1.31°	0.16°
	Nwall-n	73.71°	69.58°	73.0°	73.13°	73.52°	0.58°	-3.94°	-0.52°	-0.39°
	n-PW	–	20.0°	–	–	23.71°	–	-3.71°	–	–
	n-A	–	65.0°	–	67.91°	66.62°	–	-1.62°	–	1.26°
	n-B	–	132.0°	–	136.53°	137.17°	–	-5.17°	–	-0.64°
	n-ab	–	65.0°	61.0°	60.70	60.58°	–	4.42°	0.42°	0.12°

Legend: PW – the axis of Door/Window N; A – the axis of Window A on Fig. 8e; the axis of Window B on Fig. 8e; Nwall – the northern wall of the Torreón; N – true north as on a 3D laser scan plan; n – true north as on the plan on Fig. 8 e; ab – the edge on the rock/altar between points "a" and "b" on Fig. 8e.

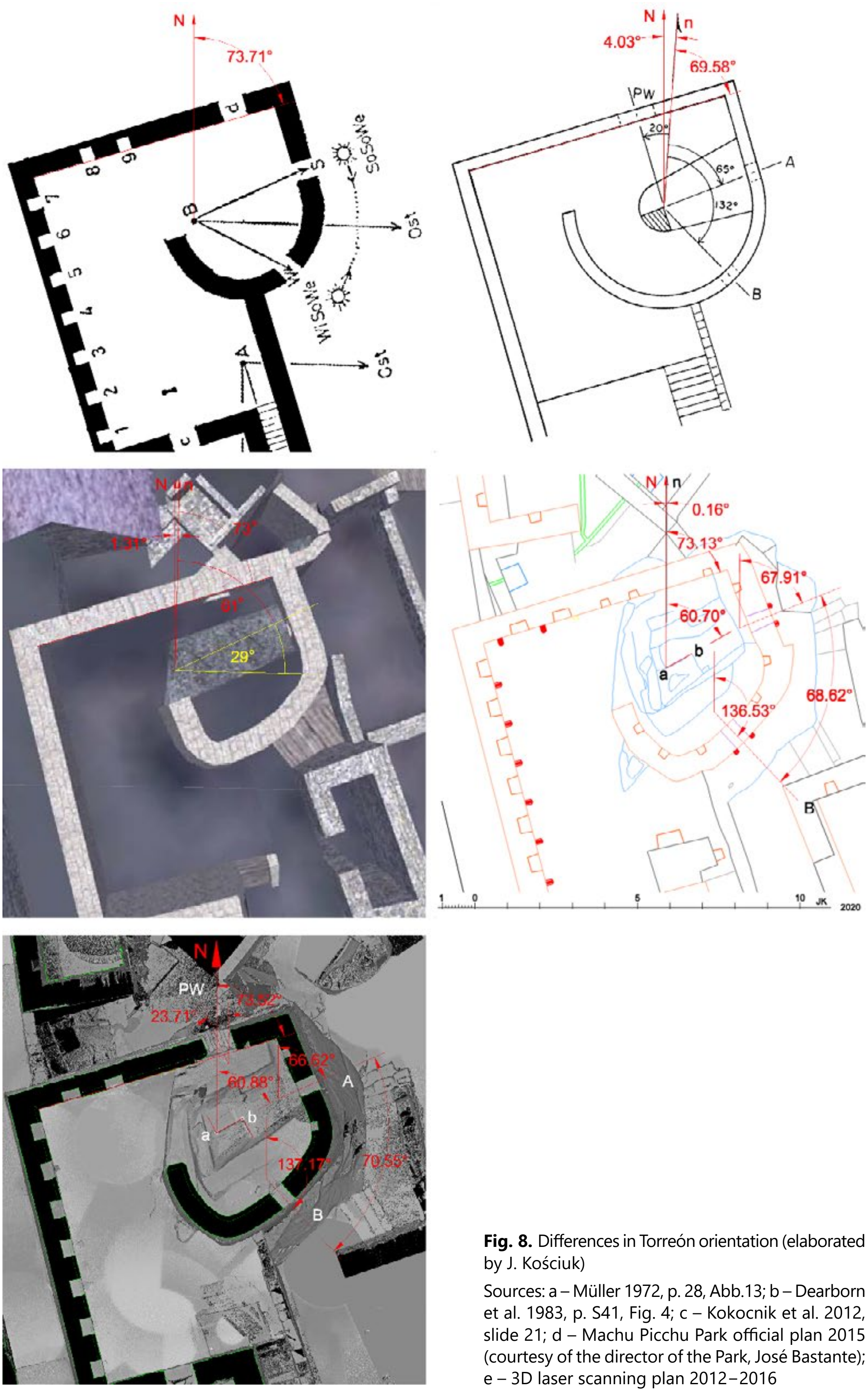

Fig. 8. Differences in Torreón orientation (elaborated by J. Kościuk)

Sources: a – Müller 1972, p. 28, Abb.13; b – Dearborn et al. 1983, p. S41, Fig. 4; c – Kokocnik et al. 2012, slide 21; d – Machu Picchu Park official plan 2015 (courtesy of the director of the Park, José Bastante); e – 3D laser scanning plan 2012–2016

Although the outline of the building does not play such an essential role in this case, the position of the window openings and their orientation towards north is of fundamental importance for further analyses.

To a large extent, the differences we found are due to the different methods and measuring techniques used by particular researchers. However, it is puzzling that the oldest of the plans analysed here, prepared in 1929 (Müller 1929; Müller 1972), shows a high degree of compliance with the current measurements made with the use of modern equipment and software. This is also true of the plans made for the Hiram Bingham expedition by US Army topographers in the early 20th century (Bingham 1912; Bingham 1930).[8]

We also noticed some minor differences between the results of 3D laser scanning and the Machu Picchu Archaeological Park survey team's official plan. The reasons for the differences lie in the different level of accuracy in mapping the details of the walls, and a different height at which the horizontal section was made. The latter differences have a particular impact, which is apparent when considering the inclination of all the walls of the Torreón. However, we have to highlight an essential fact that mainly concerns the data referring to the orientation of the supposed sightlines. For some reason, whose origin we do not know, the data differ between the different authors and sometimes in the same publication. This is revealed when comparing information provided in the texts with those on the plans (Table 2).

What may be of particular importance for the following discussion are the substantial differences between the June solstice direction in ca. 1500 offered by the different authors. We have not been able to find the source of such significant divergences. It is evident that at the June solstice around 1500, the Sun could not have emerged from beyond the horizon at azimuths of 64.5° or 65.0°. A horizon at approximately 14° results in the azimuth of 61.32° for the rising Sun's first ray. The azimuths of 64.5° and 65° also do not correspond to the 0° horizon, which could possibly explain the discrepancy. Therefore, to be sure that our calculations were correct, we used computer simulations for verification.

Table 2. Solstice orientation according to various authors (elaborated by J. Kościuk)

Source	Alignment method	Alignment of the straight edge cut into the rock/altar		June solstice alignment for ca. 1500**
		degree from N in the text	degree from N on the drawing	
Müller, 1972	direct Sun observations	64.50	63.74	64.50
Dearborn and White, 1983	direct Sun observations	65.00	64.97	65.00
Dearborn and Schreiber, 1986	direct Sun observations	65.00	57.63	65.00
Klokočník et al. 2012	magnetic compass	61.00	63.68	61.00
Machu Picchu Park 2015*	GPS	–	61.07	–
3D laser scan 2012–2014*	GPS corrected with direct Sun observations	60.91	60.91	61.32

* UTM grid convergence was applied as calculated by WALLS Project Editor v2.0 for 13° 9′ 52″ S. 72° 32′ 44″; h=2447 m; UTM grid convergence = 0.56°

** for Klokočník et al. 2012 at ca. Hz=14.6°; for 3D laser scan 2012–2014 at Hz=14°; there are no available data for the other authors.

A set of photos of the Torreón shot with digital, GPS-equipped cameras were used for the test. The exact GPS time stamp was read from the EXIF header of each photo, and the angles of incidence of sunlight were calculated in Stellarium for that exact moment. These values were then used to illuminate the 3D model of the Torreón resulting from laser scanning and oriented according to "our" north. Comparison of the obtained images with the original photos showed virtually no differences (Fig. 9). They would show up, especially in the case of small, single spots of sunlight, if the orientation of the 3D model in relation to true north was wrong by more than 3°.

8 Due to the very low quality of the copies that were available to us, we could not include them in this text.

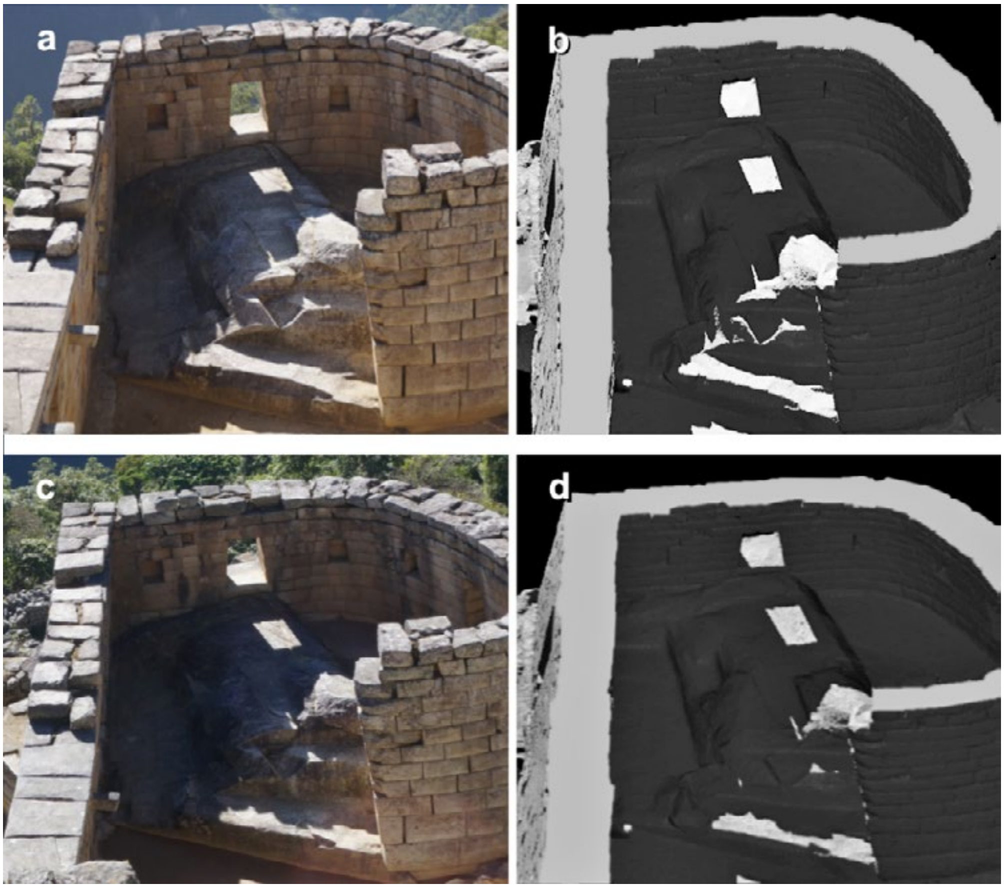

Fig. 9. Comparison of shadows on photos with recorded GPS time stamps with simulations on the Torreón 3D model (photos and simulations by J. Kościuk). a – photo from July 26th 2012 (GPS time stamp 13:37:19, local time 8:37:19); b – computer simulation on the 3D model for sunlight angles of incidence calculated for July 26th 2012, 8:37:19 with Stellarium software; c – photo from July 6th 2017 (GPS time stamp 13:37:19, local time 8:37:19); d – computer simulation on the 3D model for sunlight angles of incidence calculated for July 6th 2017, 8:37:19 with Stellarium software

The Torreón as astronomical observatory – summary of existing hypotheses

Several hypotheses regarding possible astronomical functions have been formulated about the Torreón, especially in relation to the chamber in its upper part. All these interpretations are based on the orientation of the three openings (Window A, Window B and Door/Window N) in the walls of the upper part of the structure.

Three of these hypotheses concern different methods of solar observations:

- horizontal, for the observation of the sunrise on the solstices of June and December (Müller 1972),
- gnomonic, with the use of the shadow of a plumb line in relation to the line on the rock/altar (Dearborn et al. 1983),
- gnomonic – of the simultaneous entry of sunlight in February and October through both windows (A and B) as anticipation of the sun's passage through the local zenith (Dearborn and Schreiber 1986).

An additional fourth hypothesis concerns the possibility of stellar observations through Windows A and B and perhaps Door/Window N. We will analyse each of these hypotheses, assessing their reliability by confronting them with the properly orientated 3D digital model of the Torreón. The model was used to reproduce and analyse all possible horizontal and gnomonical observations postulated by our predecessors. The astronomical calculations for these analyses were made with the use of Cartes du Ciel v. 4.0 and Stellarium v. 0.16.0 software.

Horizontal observations of the sunrise at the solstices

Undoubtedly the first (in chronological order) archaeoastronomical hypothesis concerning the Torreón was formulated by the German astronomer Rolf Müller in 1929 (Müller 1929), which was expanded and furnished with additional observations later (Müller 1972). As both studies were published only in German, they did not have the dissemination they deserved – instead they were almost entirely ignored by the main archaeoastronomical studies of Machu Picchu[9].

Müller's hypothesis is presented in the form of an oriented plan (Fig. 8a) and a description that we reproduce below literally in an English translation:

> *One immediately notices that the direction of view through these windows is south and north of the east direction so that an observer can see the sunrise through the Window. It was, therefore, reasonable to assume that the window openings were used to observe the rising points of the sun at the time of the solstices (summer and winter solstices). Subjecting this assumption to a computational check, it turns out that the angle that opens when looking through the Window to the places where the sun rises must be 51° on the days of the solstices. (In addition to the usual astronomical data, the mountain scenery, i.e. the elevation of the horizon, is also included in the calculation.) Therefore, if an observer positions himself at point B inside the rotunda, on the day of the winter solstice (WiSoWe), he will see the sun shining through Window W. Half a year later, the observer at B sees the same spectacle of the sun rising at the summer solstice in Window S (SoSoWe) (applies to the southern hemisphere)* (Müller 1972, 29; translated from German by J. Kościuk).

It is noteworthy that Müller did not pay much attention to the carved rock/altar in the central part of the structure's main room (Fig. 10).

Fig. 10. The carved rock/altar in the central part of the main Torreón room as seen from the north. Window B is visible in the rear (photo by J. Kościuk)

Our comparative analysis confirmed Müller's observations that indeed, there is a place within the structure, located in front of the western part of the rock/altar, from which the sunrise can be observed at the two solstices six months apart: that of June through Window A and that of December through Window B (Fig. 11).

9 For this reason, the merit of initiating archaeoastronomical studies at Machu Picchu is commonly and erroneously attributed to Dearborn and White: "The first investigations of astronomy at Machu Picchu were performed in 1980 by Earthwatch teams led by David Dearborn and Ray White (1982, 1983, 1989)" (Malville 2015, 885).

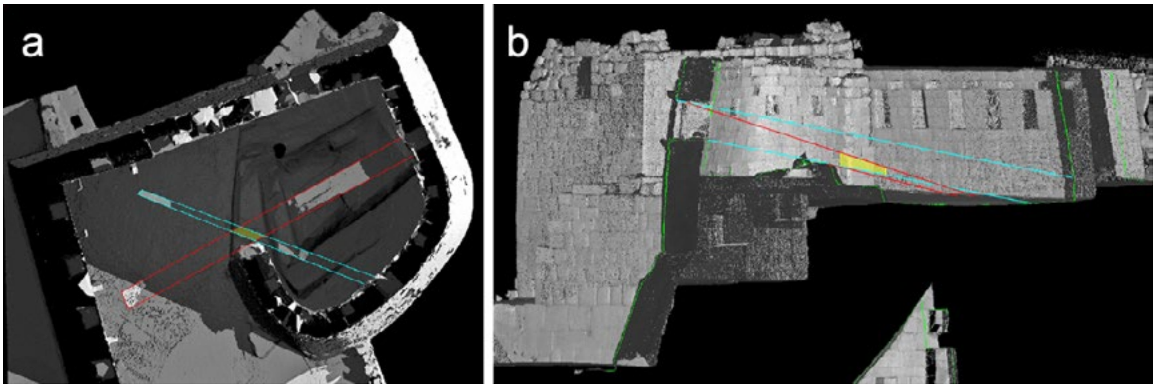

Fig. 11. The area (marked yellow) from which the sunrise can be observed at both solstices (elaborated by J. Kościuk). a – horizontal plan; b – vertical section along the December solstice direction)

However, the intersection point of the sunlight from the June and December solstices lies neither on the floor of the room nor on any of the walls. It is "suspended" in space, about 40 cm above the first western step of the rock/altar and about 20 cm from the nearest wall face. This makes direct observation from there somewhat impractical. Instead, the gnomonic observation of the sunlight in this place would be more likely, but as already indicated above, there is no element (lines, niches, or protrusions) that could have served as a precise marker, in particular for the sunrise on the December solstice.

Concluding: Müller's postulate of the possibility of the horizontal observation of the sunrises at both solstices from the same place within the Torreón is theoretically possible, but not very practical, because of the limitations imposed by the spatial arrangement of both the windows and the surrounding walls.

The supposed gnomonic observations of the June solstice sunlight on the rock/altar

This second hypothesis focuses on the carved rock/altar inside the Torreón and the supposed observations of sunlight illuminating it in a particular way at sunrise on the June solstice. The corresponding study, accompanied by some measurements, was started in 1980 by David Dearborn and Raymond White, with the support of Earthwatch volunteer teams.

The authors of the study published several texts in which they presented their hypothesis with different precision degrees (White 1981, Dearborn and White 1982, 1983, Dearborn, White and Schreiber 1986). The most detailed description is included in the 1983 text; therefore, we will refer mainly (but not exclusively) to that one. Here, particular attention is paid to a carved line (the "edge") in the rock/altar:

> *The altar stone in the Torreón stretches westward from the base of this Window [A] across most of the open chamber. One edge of the small platform on top of the altar stone (...) is straight about 0.9 m. long and points out the Window at an azimuths 60°.9510. Using the observed altitude of the apparent horizon at this azimuth, we found that the northwest edge of the platform points within 2′ (±5′) of the position of the rising winter (June) solstice Sun during the fifteenth century. The precision of this alignment is all the more remarkable when one considers that the angular diameter of the Sun is about 30′. (...) Furthermore, the height of the Window is such that, on dates near the winter solstice the far end of the altar stone is just illuminated by the*

10 In a following paper, the orientation of the north-eastern window of the Torreón is somewhat different – 21.6° (±0.6°) (Dearborn and Schreiber, 1986, 22). However, it is not clear what points they took as a reference to measure the orientation: the edge carved on the rock/altar or the mid-points (interior and exterior) of the window jambs? Please see the discussion in the text.

> *top of the Window at sunrise, and the northeast edge of the platform corresponds to the midpoint of the Window* (Dearborn and White 1983, 39–40)[11].

Further on, the authors propose the existence of a plummet hanging on a device tied to the protrusions on the outer side of Window A. The shadow of the plumb line at sunrise would have established an angle with a sharp edge cut into the rock/altar and oriented towards the June solstice. This way, the temporal distance to that event could have been calculated:

> *Given a fiducial line like the northwest edge of the altar platform, prediction of a solstice date could be done by observing the angle (with respect to the edge) at which the light enters the Window at sunrise. This angle can be observed simply and accurately by supporting a shadow-casting device (for example a plumb-bob) from the Windows' exterior pegs. During most of the year, the sunrise shadow of this device would fall across the altar. As the June solstice is approached the angle between the shadow and the edge are parallel* (Dearborn and White 1983, 42).

In any case, the authors are firmly convinced that the Torreón tower was designed for precise solar observations:

> *(...) the Torreón is designed for use as a precise instrument for observing the June solstice. In addition to this, it could be used to observe constellations and the approach of the zenith passage date* (Dearborn and White 1982, 253).

Leaving the discussion about possible stellar observations aside for the moment, let us look more closely at the factors put forward by the authors in support of the hypothetical reconstruction of the conditions of gnomonic observations in the main room of the Torreón. They are as follows:

- The measurements of the orientation of the windows and the edge carved on the rock/altar. The corresponding data are represented in schematic plans and also quoted in the texts.
- Some pictures of the projection of sunlight on the rock/altar in periods near the June solstice[12].
- A hypothetical reconstruction of a device that, according to the authors, would have been installed on the outer side of Window A, to tie a plummet, whose shadow projected on the rock would have allowed the temporal distance to the solstice to be defined.

As we pointed out at the beginning of this chapter, the main problem we faced in our comparative analysis was the noticeable difference in the orientation measurements towards Window A presented in the subsequent publications. It may be that these divergences are to some degree related to the problem of the height of the horizon seen through Window A, which obviously conditions the horizontal orientation of the point of sunrise at the solstice. Another problem is that the authors do not precisely explain what moment of sunrise they are referring to – to the first visible rays on the horizon, or the rise of the entire solar disk?

In any case, our colleagues' hypothesis deserved a detailed analysis, which we carried out using the 3D model mentioned above. In conclusion, we can confirm that the illumination of the rock/altar surface in the circum-solstitial period cannot be doubted. However, the hypothesis that the carved edge might have been used for precise observations needs further discussion.

First of all, the carved edge is relatively short (ca 90 cm), and its edges, in their present state of preservation, are far from regular, which today limits its potential use as a source to draw up precise conclusions. Secondly,

11 The authors suggest a similarity of the layout (and function) of the rock/altar of the Torreón with the Intihuatana of Pisac (Dearborn and White 1983, 24–25).

12 It is, however, to be noted that the dates and times at which these photos were taken are not precisely indicated. The one published in 1983 with the shadow cast by a plummet carries only the comment that it was taken "a week after the solstice" (Dearborn and White 1983, 42, Fig. 5). In the same text, there is information that the technique for predicting the moment of the solstice was tested by the authors between July 5th and 9th 1980, but this information is accompanied only by a graphic scheme and not by pictures (Dearborn and White 1983, 43, Fig. 6). In the photo published in 1986 in which no scales or plummet shadows are visible, there is only the comment that it represents the situation "on a day near the solstice" (Dearborn and Schreiber 1986, 23).

this hypothesis would imply that a device hung outside the window (in a wooden frame?) on the pegs. For obvious reasons, there are no physical traces of such an artefact. Also, no single mention exists in historical records about the use by the Incas of such an instrument for astronomical observations. Similar doubts concerning the accuracy of solar observations in the Torreón have also been expressed previously by other authors (Aveni 1988, Hyslop 2014, Malville 2015, 885–886).

Fig. 12. Schematic reconstruction of the edges cut into the top surface of the rock/altar (elaborated by J. Kościuk). red – preserved, original surfaces of the carefully treated rock faces; black lines – a schematic reconstruction of the original form

However, if one imagines the rock/altar's top surface in its original form (Fig. 12), perhaps there is no need to invent any additional instruments like the plumb-bob. The combination of the three edges carved on the top of the rock/altar and the sunlight coming through Window A creates a sufficiently interrelated system to observe the position of the Sun. Still, however, the question of the accuracy of such observations remains. The Sun's position on the horizon varies very little for ±4 days around the proper date in any solstice. In the days preceding and following the solstice, the relationship between the carved edges and the sunlight cast by Window A changes by a small degree that is difficult to measure (Fig. 13). Thus, the possibility of pointing to the exact date, even taking into account the subsequent reinterpretation of the observations, is very problematic in the case of the Torreón.

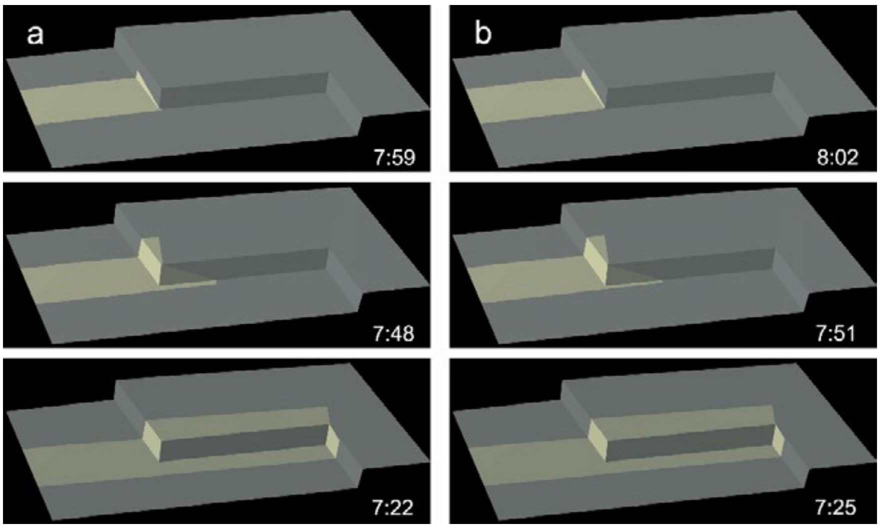

Fig. 13. Simulations of typical moments of sunlight falling on June 21st 2020 (column a) and June 10th 2020 (column b) through Window A on three edges carved on the top of the rock/altar. Notice only minimal shadow differences despite the 11 days' difference between the two simulations (elaborated by J. Kościuk)

An additional problem is imposed by the irregular edges of Window A, which are related to the nature of the stonework and result in a wavy-lined shadow. Therefore, if following in the footsteps of our colleagues, one looks for the use of four stone pegs projecting outside around the corners of Window A, it is possible to imagine, instead of the dubious plum-bob, a rectangular (or trapezoidal) frame surrounding the window and guaranteeing the sharp edges of the shadow. Even then, however, the interpretation of the Torreón as an instrument for precise gnomonic observations remains questionable.

Gnomonic observations of sunlight simultaneously entering Windows A and B in February and October, as anticipation of the passage of the Sun through the local zenith

Dearborn and White (1983) also formulated this hypothesis as a complement to their previous analysis of horizontal observations in the June solstice period. The authors state that for about five days on both sides of the zenith passages through Machu Picchu (February 14^{th} and October 29^{th}), the sun enters at sunrise through Windows A and B simultaneously:

> *We found the view of the two Windows to intersect along a 4° segment of horizon between azimuth 99° and 103°. The strip of sky that rises there lies in the range −11° > o > −15°. It is therefore centred on the rising point of the Sun on the days of zenith passage. From February to October the first rays of the rising Sun penetrate Window A. Then from October to February they illuminate the interior of the Torreon through Window B. Only for a period of five or six days on either side of the zenith passage dates will light penetrate both Windows at sunrise. Simply observing the illumination of the Torreon then clearly defines a period centred on the zenith passage dates. On the zenith passage dates themselves, the light from the rising Sun illuminates two nearly identical triangles on the interior walls of the Torreon. The similarity of the illuminated patches further helps to identify the precise date of zenith passage.*
>
> *The two Windows do not by themselves form a precise observing instrument; that is, they are not as accurate as the edge pointing at the rising point of the Sun on the solstice. The precision, however, could easily be improved by using a shadow-casting device mounted on the Window pegs, but it is also possible that the precise determination of zenith passage was done elsewhere* (Dearborn and White 1983, 46)[13].

To verify this hypothesis, we used the same 3D digital model as for the case study of the orientation of Window A towards the sunrise on the June solstice (Fig. 14).

Results of our 3D simulations led to the conclusion that the simultaneous entry of sunrays through Windows A and B in the period surrounding the sun's passage through the local zenith is a proven fact – the authors were right in their hypothesis. However, their assumptions have to be modified somewhat:

- The view from the two windows does not intersect along a 4° segment of the horizon between azimuths 99° and 103°, but in a space, corresponding to ca. 6°, between azimuths 98.7° and 104.85°.
- The periods of visibility of the incoming rays through both windows are not symmetric in length when related to the day of the Sun's passage through the local zenith. In the case of the passage through the zenith on February 14^{th}, the visibility of the two rays projected into the room begins about 12 days before the event, on February 2^{nd}, and continues until February 20^{th}. In the second zenith passage, on October 29^{th}, the situation is reversed: the period of visibility of sunlight from both windows before the event is approximately 7 days, and after it, 12 days. This asymmetry results from the particular shape of the horizon in the segment corresponding to the intersection of sightlines from Windows A and B (Fig. 15).
- The shapes of the patches projected in the morning of the Sun's passage through the local zenith differ. What can be seen is the change in the visibility of both patches and their respective dimensions (Fig. 14).

13 A slightly less detailed description is presented in the previous work of these authors (Dearborn and White 1982: 253).

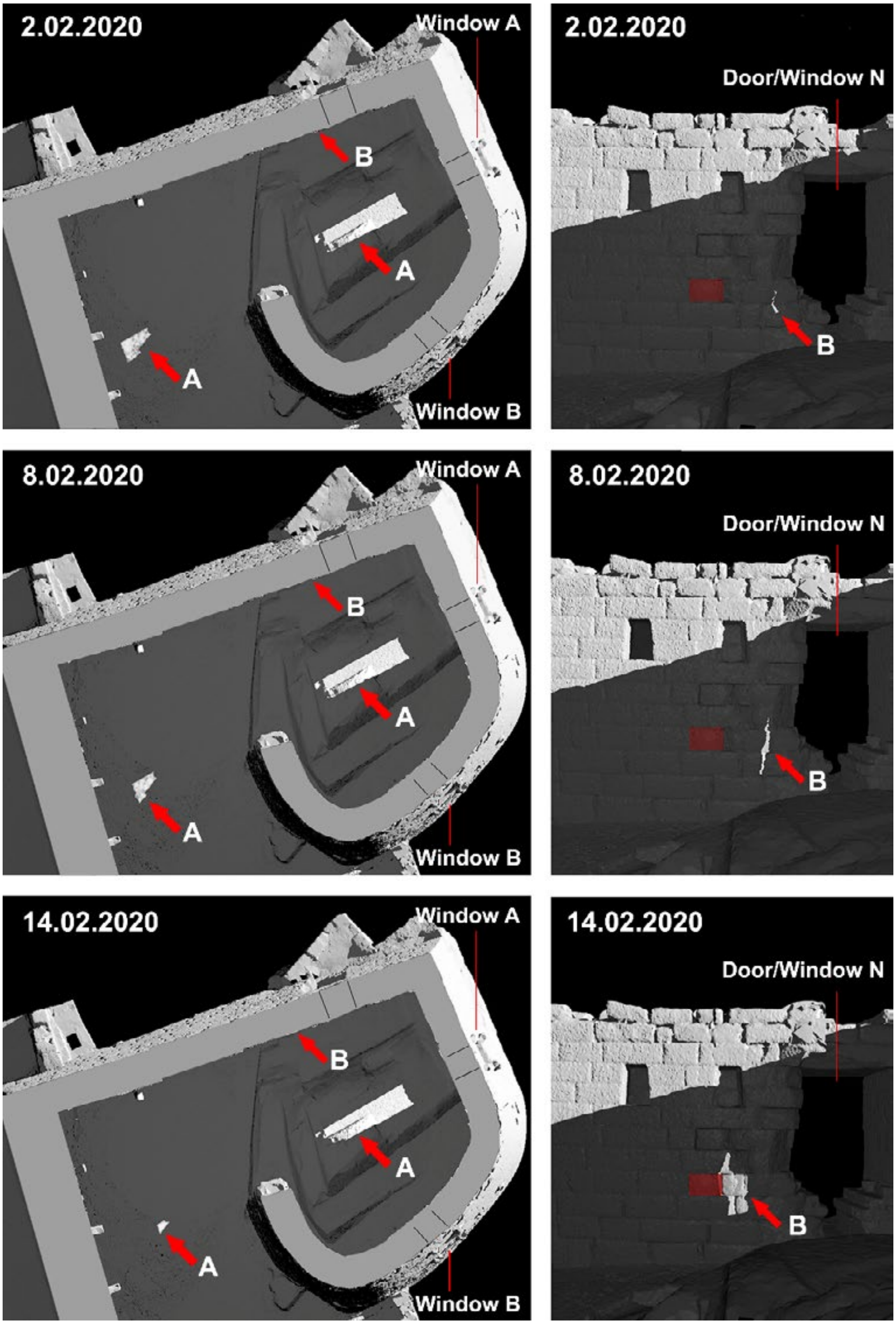

Fig. 14. Simulations of the sunlight passing simultaneously through Windows A and B in the period around the local zenith transition. Full solar disk over the horizon is taken as the simulation moment. Left – plan of the Torreón; right – view of the northern wall of the Torreón around Door/Window N (sunlight passing through Window B). The place of the "cache" is marked in red (calculations by M. Ziółkowski; computer simulation by J. Kościuk). A – sunlight spots entering through Window A; B – sunlight spots entering through Window B

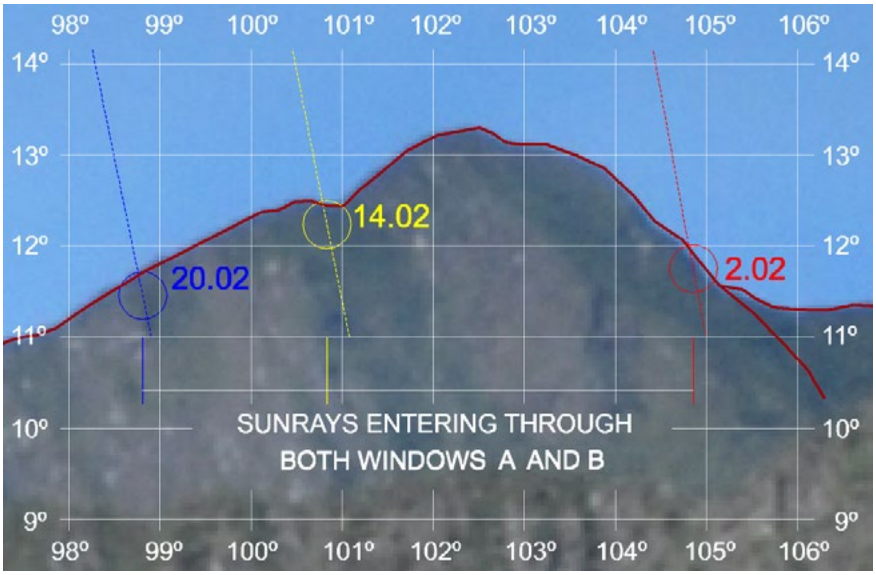

Fig. 15. Eastern horizon with a range of sunrises when the sunlight enters Windows A and B simultaneously (calculations by M. Ziółkowski; drawing by J. Kościuk)

Another result of our analysis that may be interesting for the general interpretation of the function of the Torreón is that during the 3–4 days around zenith transition, the sunlight that enter Window A illuminates a part of the interior wall of the room where a type of "cache" is located – a detail that appears when a loose stone is taken out of the wall (Fig. 14c). Did the Inca builders intentionally design this coincidence, or is it the result of pure chance? We do not have sufficient data to answer this question definitively.

The possibility of stellar observations from the Torreón

Some authors have hypothesised that apart from the observations of the Sun from the main room, observations of some stars important within the Inca (or more generally Andean) cosmovision were also made. In this case, the proposals made in this respect have to be examined in terms of four factors:

- the general orientation of the window,
- the shape and height of the horizon visible through that particular window,
- the position of the supposed observer, not only in terms of his exact location within the perimeter of the room but above all in terms of the height from which the observations are made,
- the likely date of observation, since unlike solar observations, because of the effect of the precession of Earth, the present positions of stars cannot be projected 500 years back.

Hypotheses formulated around each of the three openings of the upper room of the Torreón will be analysed separately.

Window A

According to several authors, this window could be used (in parallel to the observations of the sunrise on the June solstice) for the observation of the heliacal rising of the Pleiades – a group of stars significant in the Andean cosmovision for the prediction of the harvest of the forthcoming year (Dearborn and White 1983, 40). Salazar Garces also adds the Hyades and the star Aldebaran (α Tauri) to the list of stars that could be viewed from this window (Salazar 2014, 176). None of the cited authors specify from which exact location such observations could be made. This, as we will see below, is not as evident as it might seem at first sight, mainly because of the spatial limitations caused by the rock/altar in front of the window.

The main line of sight through Window A can be either of the following:

- the geometric centre of the window,
- looking along the carved edge of the rock.

Both orientations differ by 5.74° (Fig. 8e), but the most critical limitations result from the observer's position in relation to the height of Window A. A person of medium height (160 cm), standing in front of this window, will not see the horizon or the sky but the hillslope. Someone kneeling on the SW side of the rock/altar, with his/her head placed on its surface, will be able to glimpse the sky just below the window sill. The visible portion of the sky will then be in the range of only 1.5° vertically (Fig. 16a) and about 7° horizontally (Fig. 16b)[14].

This does not constitute a privileged situation for observing entire constellations, as one can hardly see a star or groups of stars, such as the Pleiades, with an observation time (resulting from the reduced vertical extension of the strip of the sky) of the order of 1.5 degrees. On the other hand, these limitations would allow a relatively exact determination of the day of the first visibility (heliacal rising) of, for example, the Pleiades mentioned above.

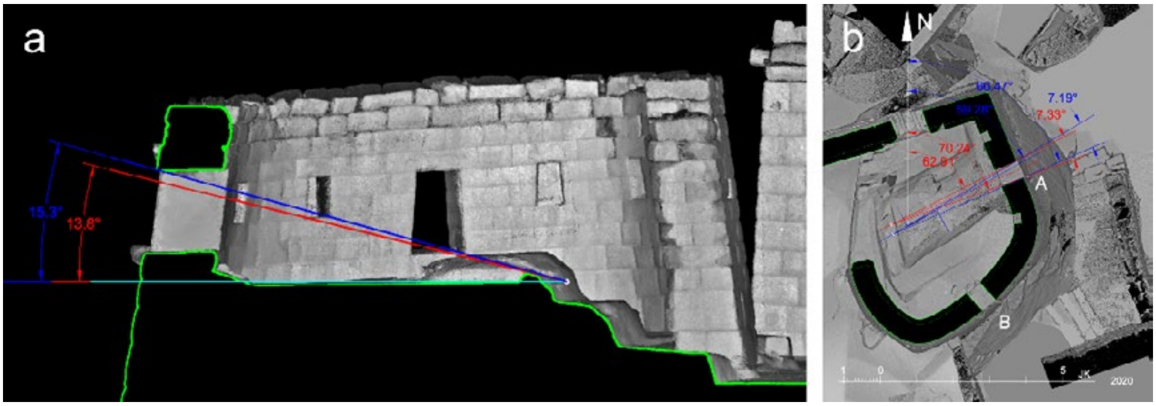

Fig. 16. Simulation of the sky's visibility over the horizon for an observer kneeling in front of the rock (elaborated by J. Kościuk). a – vertical extension of visibility (red line – angle at which the eastern horizon is visible; blue line – range of visibility limited by the upper edge of Window A); b – horizontal extension of visibility (red line – looking alongside the axis of Window A; blue line – looking alongside the edge carved on the top of the rock/altar)

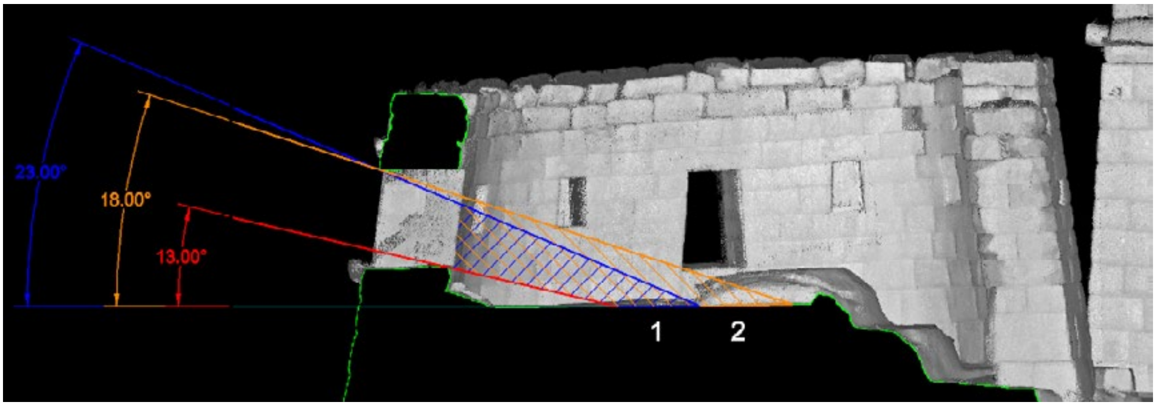

Fig. 17. Simulation of the sky's visibility over the horizon for an observer lying on the rock in zone 1 and 2 (elaborated by J. Kościuk). Red lines – visibility range limited by the bottom edge of Window A (for both observation zones); blue lines – visibility range limited by the upper edge of Window A for an observer in zone 1; orange lines – visibility range limited by the upper edge of Window A for an observer in zone 2

14 From 62.9° to 70.2° when the observer looks along the axis of Window A, and from 59.3° to 66.5° when the observer looks along the edge carved on the rock.

Finally, one has the best observation conditions when lying on the rock, with his/her head close to the window, and looking upwards. In such a situation, the observer would have a wide strip of the sky for observation – no less than 15° horizontally[15] and from 5° to 10° vertically depending on exact observer position (Fig. 17). The doubt is that although this kind of position for stellar observation is documented at an ethnographic level in some pre-industrial cultures of the Old World[16], there is no indication, to our knowledge, that it has also been used in the Andes.

Considering these limitations, we reconstructed, using Cartes du Ciel 4.0 software, the conditions of visibility through Window A, principally of the Pleiades, for 1450 AD and 1500 AD – the two moments indicated by Dearborn and White.

Let us first consider the observer kneeling on the W side of the rock/altar with his/her head placed on the latter and looking along the geometric axis of Window A (Fig. 16). It should be noted that in 1450 AD, visibility of the Pleiades would have been very limited – only part of the group would have appeared next to the left window jamb. Taking Taygeta as a reference and a height of the horizon of 14°, we observe that this star is rising at 62°19′ azimuth, which would have been invisible because the door jamb obscures it. The situation improves if the observer moves slightly south and looks along the edge carved on the top of the rock. In this case, the whole Pleiades group would be practically in the centre of his/her field of vision.

In 1500 AD, because of the terrestrial precession, when looking along the geometrical axis of Window A, the observer would no longer have been able to see the Pleiades (Taygeta rising at 62.12° would have been behind the window jamb) while still being able to observe the group from the second position looking along the edge (Fig. 16b).

Contrary to Salazar Garces's postulate, Aldebaran (α Tauri) and the Hyades would not have been visible in either 1450 AD or 1500 AD (Salazar 2014, 176) from either observation point. All these stars, and many others, would have been well visible in both 1450 AD and 1500 AD from the observer's position lying on the altar rock in zone 1 or 2 (Fig. 17). Then the celestial band determined by declinations between 60.5° and 72.5° and vertical range between 13° and 23° would have been within eyeshot.

Window B

As regards Window B, Dearborn and White put forward the following interpretation of its possible function, but, unlike the case of Window A, this time they postulated a more specific place for the observations:

> *The eastern slope of the mountain Machu Picchu makes the southerly horizon, as seen from Window B, very high. In fact, the sky is not visible to an observer looking through Window B from over the small platform of the altar stone. The sky can be seen through the Window if the observer sits on the floor of the Torreón with his back to the altar stone. Actually, such a position is quite comfortable as the stone is well shaped for such an exercise* (Dearborn and White 1983, 45).

From this place, one could observe the rising of several stars that were important for the Incas:

> *The band of sky visible to such an observer lies approximately within the declination strip $-57° < \delta < -37°$. This strip is well outside of the ecliptic plane, and so solar, lunar and planetary phenomena cannot be observed directly (straight) through Window B. (…) The Inca people recognised the dark lanes or clouds along the Milky Way, as well as the stars in their constellation mythology. The "Llama" is a dark region stretching from Scorpio to α and β Centauri (which form the Llama's eyes),*

15 For the observer position in the centre of zone 1 (ca. 0.7 m from the surface of the wall), from 56.2° to 76.8°, and for the observer position in the centre of zone 2 (ca. 1.2 m from the surface of the wall), from 57.4° to 72.4°.

16 Among others, technique observed personally by one of the Authors (Jacek Kościuk) among the Bedouins of the Western Desert in Egypt at ca. 1984.

> *and it rises through Window B. (…) Other objects which could be observed to rise through Window B include the stars Llamacnawin (α and β Centauri) and Pachapacariq Chaska (Canopus), as well as the dark clouds or constellations Unallamacha (the Baby Llama) and Machacuay (the Snake)…* (Dearborn, White 1983, 45)[17].

Unfortunately, the authors have not pointed out in their schematic plan of the Torreón (Dearborn and White 1983, 41, Fig. 4) where the observer should be sitting precisely, which leaves room for doubt when determining the visible strip of the sky.

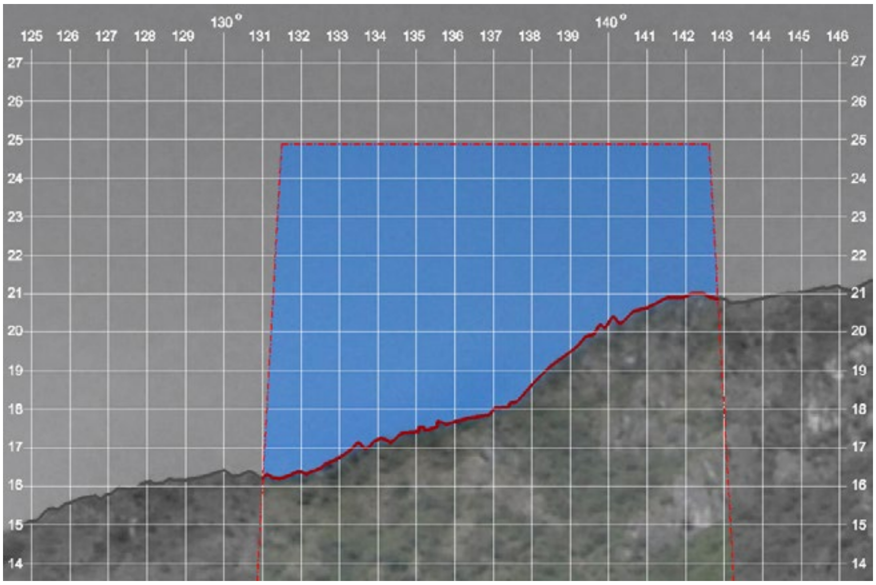

Fig. 18. The extent of the horizon as seen through the upper part of Window B from the position probably indicated by Dearborn and White (elaborated by J. Kościuk)

Following the description cited above, in our reconstruction, we have opted for a seated observer with his/her back to the altar rock and looking out along the axis of Window B. In this case, the visible part of the sky would cover approximately 14° of the horizon (Fig. 18).

The strip of visible sky would be limited on the left side by the intersection of the window jamb with the horizon line at the altitude of approximately 16° and the azimuth of 131°, which corresponds to the declination −40.63° (and not −37°). On the right side, this point of intersection would be at the altitude of ca. 21° and the azimuth of ca. 144°, which determines the declination of ca. −54.78° (and not – 57°). In other words, the width (expressed in declination) of the strip in the lower part of the window would be of the order of 14° and not 20°, as Dearborn and White postulated. In the upper part of the window, due to its trapezoidal shape, the visible strip of the sky narrows to 11°.

We also reconstructed visibility conditions through Window B for stars and parts of the Milky Way in 1450 AD that were indicated by the authors. The stars Llamacñawin (α and β Centauri) were rising above Machu Picchu mountain at the azimuth of ca. 148° and 147°, respectively. Therefore, to an observer sitting in the place described by Dearborn and White, they would be invisible, as they would be hidden by the window jamb. This limitation also concerned the dark stains in the Milky Way. On the other hand, the rising of Canopus (α Car) on the horizon above Machu Picchu mountain could be seen at the azimuth of approximately 141.5°.

However, the observation that Dearborn and White considered as being of particular interest is related to the rising of the tail of Scorpio:

> *The mask of the apparent horizon is shown positioned for sunset on the day of the solstice. It can be seen that the Incaic constellation "Collca" (the Store house) involving the tail of Scorpio lies parallel to and along the horizon when it rises. In the*

17 In a later study, Salazar Garces also places special emphasis on the possibility of observing the tail of Scorpio (Salazar Garces 2014, 176).

> *fifteenth century, this alignment occurred at sunset on the day of the winter (June) solstice. The association of the Tail of Scorpio with the Pleiades (also called the "Collca") apparently comes from their positions at nearly opposite ends of the sky. When one is observed to be rising at sunrise, the other will be rising at sunset. Even today some local villages observe these constellations to determine planting time and to divine the success of the coming season* (Dearborn and White 1983, 45).

This description is a commentary on a figure that is somewhat difficult to interpret (Fig. 19).

According to the reconstruction we made, about ten days before the June solstice in 1450 AD, a few minutes before the sunset, the tail of Scorpio's first stars were rising. However, from the place postulated by Dearborn and White, only two of them could be seen, Sargas (θ Sco) and η Sco, at about 130.67° azimuth, while the left window jamb hid the remaining stars of both the tail and the entire constellation of Scorpio.

To get better visibility corresponding to 20° horizontally, as postulated by Dearborn and White, an observer would have needed to sit closer to Window B (ca. 65 cm from the foot of the wall). From there, about an hour after sunset on the June solstice day, he/she would have been able to see almost the entire tail of Scorpio, but already at an altitude of 34° to 38°, not just above the horizon.

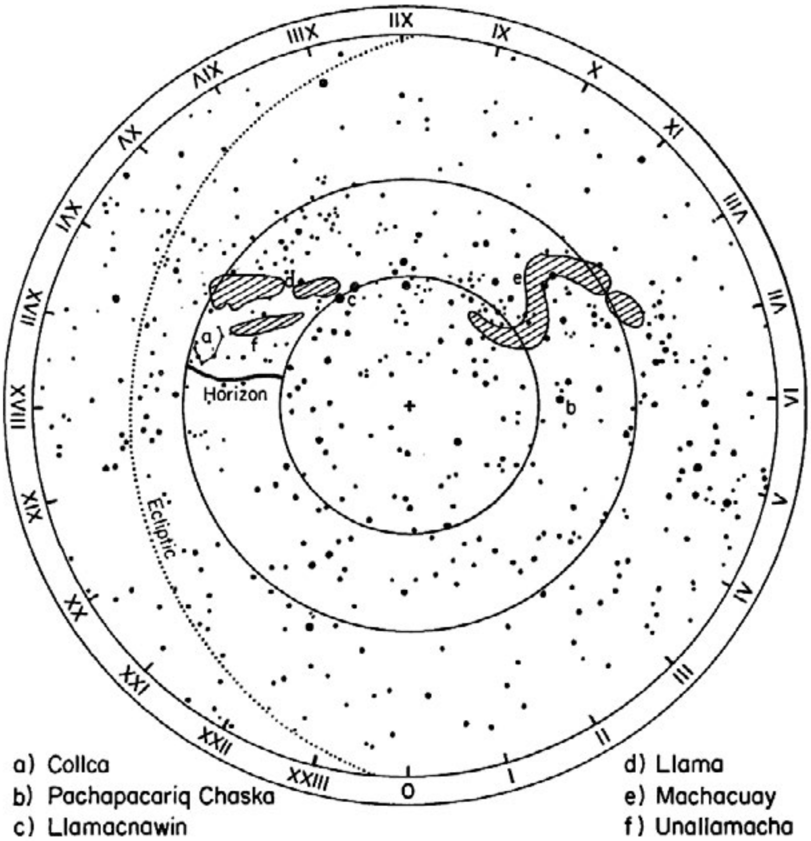

Fig. 19. A southern hemisphere starchart for 1450 AD according to Dearborn and White (1983, Fig. 7) as seen through Window B

To summarise: although changing the place of observation from the altar stone to a part closer to the window would have allowed some of the stellar observations mentioned by Dearborn and White, it does not seem that the design of this part of the Torreón was conditioned by astronomical considerations – at least, not for precise observations.

Door/Window N

It should be noted that the view through Door/Window N was limited by the roof of a house built opposite it. This seems to indicate that the visibility of a clear horizon was not the builders' primary intention. Regarding this opening, some hypotheses have been formulated about the possibility of observing circumpolar stars.

The most detailed (albeit somewhat imprecise) is Salazar Garces's proposal:

> *The window is oriented towards the NW, at 340 degrees azimuth (...) it is known as "The Window of the Snakes" (Reinhardt and others) and during the days of the solstice, at dawn, you can see the setting of the stars of the Ursa Major's tail on the horizon. (...)*
>
> *Somewhat earlier, between 2 and 3 a.m., the setting of the star Deneb (Alpha Cygni) can be seen through the same window, and near it the disappearance of the dark constellation of Paqo or black alpaca, which represents the other heavenly llama, the "masintin" of the southern llama: Yakana or Qatachillay". We made the corresponding analysis with Sky 5.0 and Guide 8.0 software for the year 1500 AD when, according to general opinion, Machu Picchu was at its peak* (Salazar Garces 2014, 175–76).

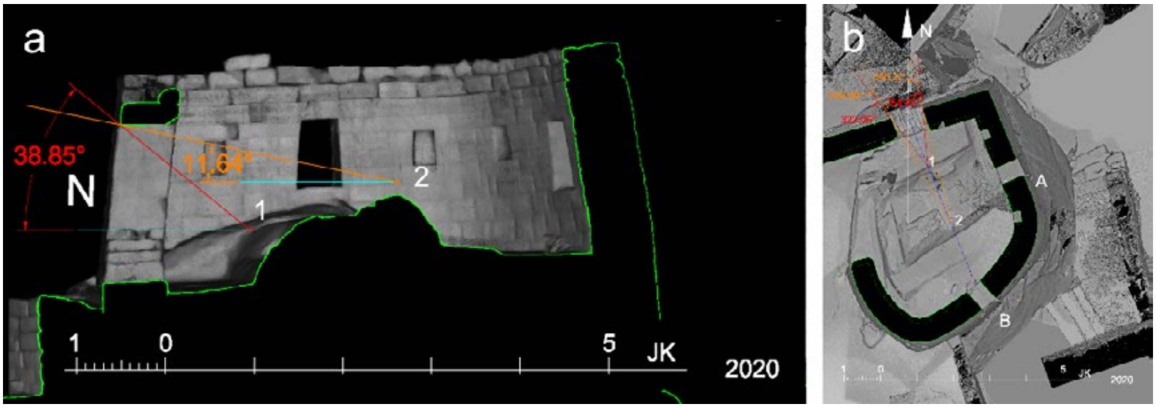

Fig. 20. Two possible observation points along the axis of Door/Window N. a – vertical extension of visibility; b – horizontal extension of visibility (elaborated by J. Kościuk)

Presumably, when speaking of *"solstice days"*, the author was referring to June, while the "*tail of the Big Dipper*" are the stars Alkaid (η UMa), Mizar (ζ UMa) and Alioth (ε UMa). Unfortunately, Salazar Garces does not precisely specify the supposed observation point or the observer's position (sitting, standing, lying on the rock/altar) that would determine the part of the sky visible through the window. Therefore, we have considered two possible observation points along the axis of this opening (Fig. 20). We are aware that this is a somewhat arbitrary decision, because any change in the observer's position to the right or left of this line significantly changes the visible part of the sky. Considering this limitation, on the 3D model, we have reconstructed visibility range from particular points (Fig. 21) and calculated the visibility of celestial bodies using Cartes du Ciel 4.0 software.

From this analysis, it appears that only point "1" (Fig. 20) with an observer sitting on the floor meets the condition of enabling the observation of the tail of the Ursa Major and the star Deneb:

- On the days of the June solstice in 1500 AD, one could indeed have seen the setting of the stars Alkaid, Mizar and Alioth, in a band of the sky delimited horizontally by the azimuths of 337.62° and 340.05° and vertically by the heights from 9° to 19.25°. However, this was possible not at dawn but at about 21:23 – that is, some three hours after sunset. These stars were visible through Door/Window N from about 19:00, starting with the appearance of Alioth on the horizon above Machu Picchu mountain shortly after sunset.

Other stars of the Big Dipper, Merak (β Uma), Megrez (δ UMa) and Phecda (γ Uma) were also visible, but not the most luminous one, Dubhe (α UMa), because it was hidden by the Huayna Picchu mountain.

- On the other hand, the star Deneb (α Cyg) was visible from approximately 2:40 in the morning when it appeared above the Machu Picchu mountain, at an altitude of 33° and disappeared behind the left window jamb at an altitude of about 11° – almost precisely at sunrise.

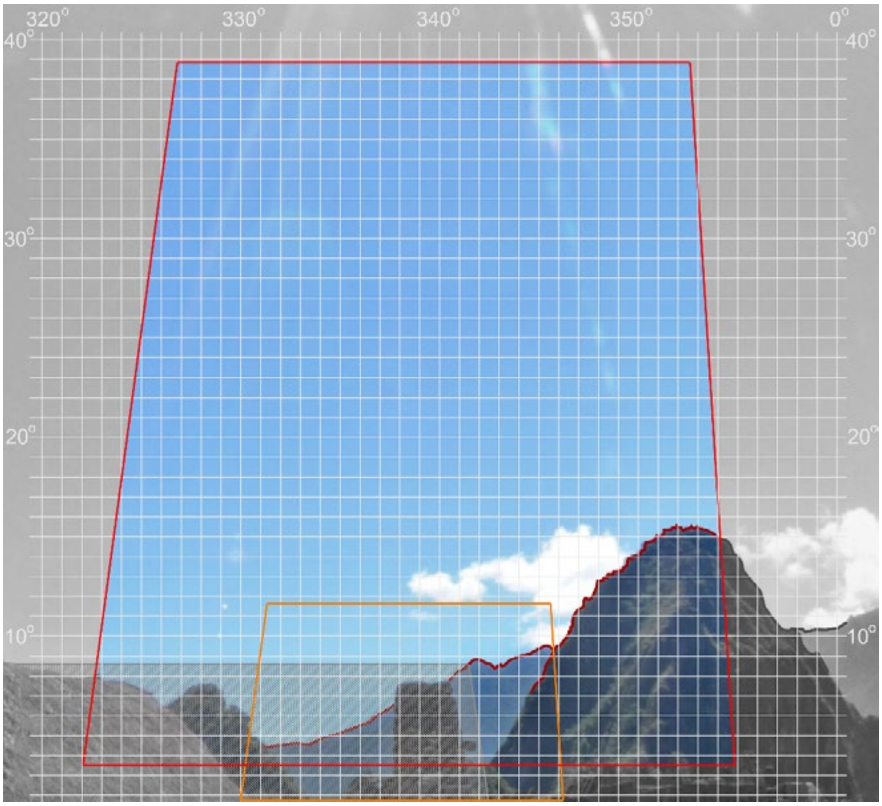

Fig. 21. The extent of the horizon as seen through Door/Window N from two reconstructed observer positions (elaborated by J. Kościuk). Red lines – position "1" Fig. x.20; orange lines – position "2" Fig. x.20; grey lines – part of the horizon obscured by the roof of the neighbouring building

The conditions of observation from the two remaining points that we have tentatively chosen are somewhat different:

- The star Deneb could not have been seen because it was hidden by the window sill.
- The setting of the tail of the Big Dipper would have been visible only from point "1" (Fig. 20). However, the period of visibility of these stars was shorter because of the reduced vertical width of the band of sky due to the Door/Window's trapezoid shape. Nevertheless, at least in theory, this situation allowed a more accurate observation of the stars in relation to sunrise and sunset times throughout the year.

Conclusions

It appears that the observations of the sun postulated by both Müller (1929 1972) and Dearborn, White and Scheiber (Dearborn and White 1982, 1983; Dearborn and Schreiber 1986) were possible but without the degree of accuracy required for a precise "astronomical" instrument. Therefore, we can assume that the entry of sunlight from Window B and in particular from Window A at different times of the year (in the case of the latter window – at the period around the June solstice) may have served more for ritual purposes than for astronomical calculations. Consequently, contrary to the postulates of the authors mentioned above, we disagree with the thesis that the Torreón was a precise solar observatory.

As far as stellar observations are concerned, which are dealt with in detail by the scholars cited above and by Salazar Garces (2014), these were in some cases possible (for example, the heliacal rising of the Pleiades through Window A). However, the interior arrangement of the upper room of the Torreón was apparently not designed with this particular function in mind.

To summarise: we can take as established evidence that the builders of the Torreón designed the building according to some solar orientations, but without the purpose of erecting an astronomical observatory as was apparent in the cases of Intimachay and Inkaraqay.

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