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ILLUMINATING THE PARTHENON

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The Parthenon's structure suggests a thought-out design particularly attentive to light. This includes the orientation of the building towards the rising sun, the placement of windows, the use of barriers and grilles, the translucent marble ceilings, the skylights, and even 'reflective' pools of various liquid. These are all devices that, alongside bright materials, may have been used to enhance the experience of visitors to the temple and their encounter with the colossal gold and ivory statue of the goddess Athena. To test the validity and the effect that each of these purported design strategies produced, this article proposes an experiment using advanced 3D digital technologies, along with physically based lighting simulations, to recreate the ambient and architectural conditions that existed in the original temple design. The results suggest that this temple, contrary to long-standing beliefs that imagined the interior as a 'bright marble space', was generally quite dark and dim. The subsequent discussion and concluding remarks suggest that the illumination of the chryselephantine statue's materials through the glow of a lamp, and on rare occasions from the sun, probably represented the pinnacle of the viewing encounters.

INTRODUCTION

The modes in which classical Greek temples were illuminated have fascinated scholars for the past three centuries. Whereas the earlier Archaic architecture of Doric temples, with its sturdy walls and thick columns, has frequently been considered heavy and dark, designed to elicit fear and reverence from worshippers (Marconi 2004, 222), the temples of the Classical period appear to have been more conscious of light and brilliance. This shift can be attributed in part to the increasing incorporation of gleaming marble, the enlargement of door thresholds, and several other distinctive architectural elements that suggest deliberate light effects within the temple's interior, which will be discussed below.

Out of all the Greek temples, the Parthenon has garnered the most attention regarding the way in which it may have been illuminated. This heightened interest is largely due to its enduring status as a symbol of the refinement of Classical style or, as stated by R.E. Wycherley (1978, 111) and then reiterated by the head of the Acropolis Restoration Service (YSMA), Manolis Korres (1999, 85–101), the 'refinement of the refinements' of Classical architecture. Consequently, it has been of paramount importance for scholars to understand not only how the building was constructed but also how it was experienced (Mylonopoulos 2023).

Among the features related to the visual experience within the Parthenon, the most prominent was the chryselephantine statue of Athena – an extraordinary statue whose size and materials were unmatched at the time (Lapatin 2001, 63 and 78; van Rookhuijzen 2020, 10). Through the adroit incorporation of unconventional dimensions, standardised iconographies, and large-scale use of gold and ivory, the colossal statue acquired epiphanic potential, meant to symbolise the god's sacred presence on earth. The golden Athena also acted as an 'icon' of the Athenian community and beyond, as copies of this particular statue spread across the Greek world for centuries after construction of the original (Platt 2011, 88–9; Fig. 1).

Post-Classical writers lauded the statue's 'beauty and magnitude', which inspired religious reverence, a feeling akin to what the Greeks knew as *thauma idesthai*: a 'wonder to behold' (e.g. Dio Chrysostom, *Oration* 12.49–52; Pliny, *Natural History* 36.18–9).[1] The combination of

[1] See also Tanner 2001, 260–2; 2006, 48–54; Lapatin 2001, 95. *Thauma* in relation to art has recently been commented on by Lightfoot 2021, 31–41; see also Platt 2011, 105–6. On *thauma* relating to statues, both miniature

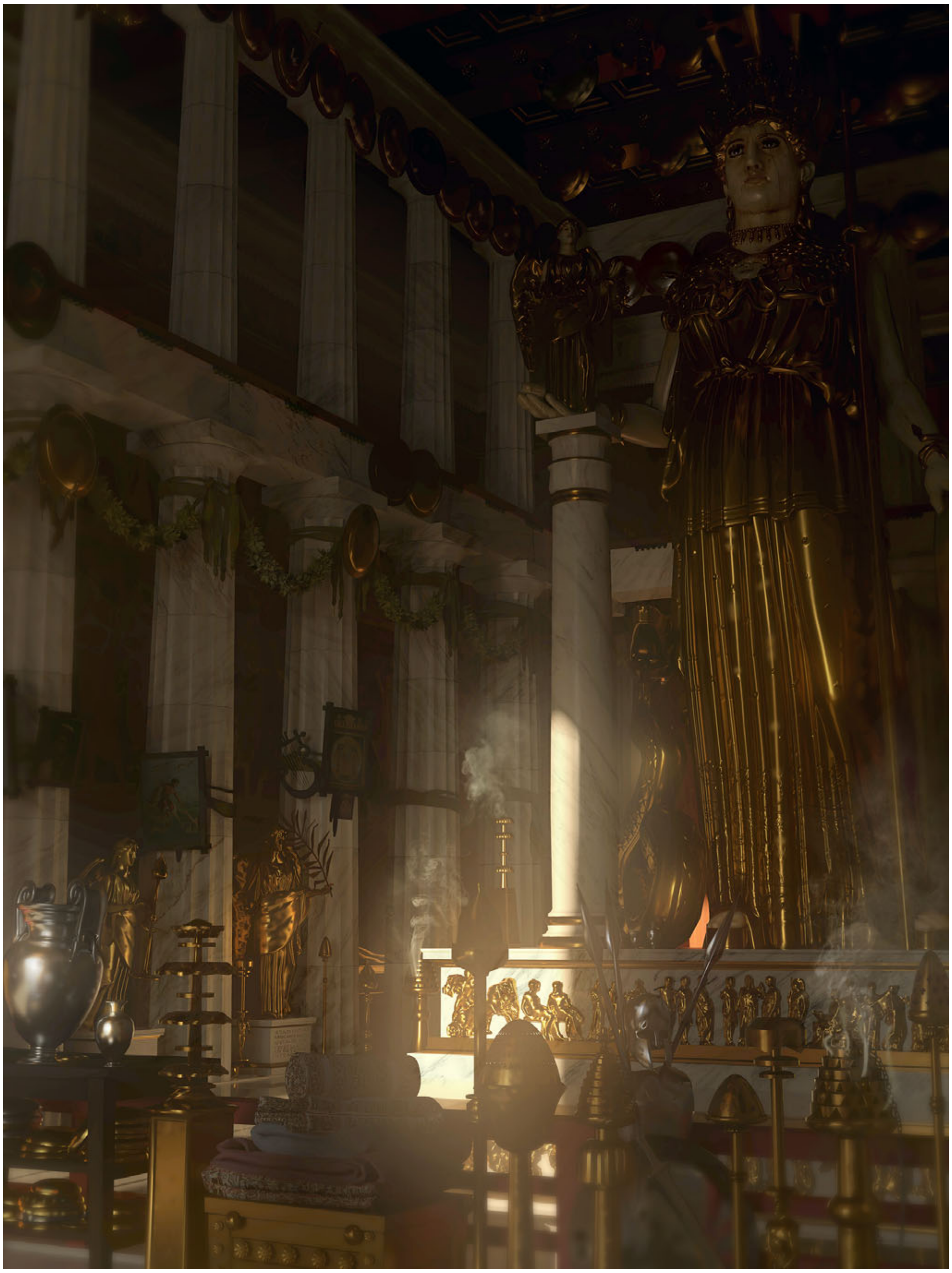

Fig. 1. Hypothetical reconstruction of the Parthenon interior, enriched with elements documented in ancient inventories, including numerous incense burners, shields, gold statues of Nikai, and various items such as panoplies, musical instruments, tables, and libation bowls. Render: Juan de Lara.

beauty, grandeur, wonder, and *charis* in a single creation was undoubtedly one of Phidias' greatest triumphs. But the placement of this statue in the presumably dark abode of the temple invites us to ponder under what lighting conditions the artist and architect conceived the space that housed this

and colossal, see Neer 2020, 14–16. Prier 1989 continues to be the key piece of research on *thauma* and vision in Archaic Greek poetry; see also Hunzinger 1993; 1994; 2015; 2018. On how *thauma* was a sensorial experience elicited by novelty and dazzling light, see D'Angour 2011, 134 and 148–50. See also McEwen 1993, 54–7.

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statue, and in which way it may have maximised its grandeur and the visual encounter.[2] Therefore, this paper aims to investigate and evaluate the feasibility of a range of visual techniques and strategies related to allowing both natural and artificial light into the Parthenon.

A number of techniques are presumed to have been intentionally linked to illumination in this and other temples, and include windows, reflective pools of water, skylights, translucent roofs of marble, solar alignments during the morning hours, lamps, and torches. Until now, it has only been possible to approximate and hypothesise most of these elements and their corresponding theories, leading to both misinterpretations and assumptions, which wider scholarship has recycled and taken at face value. To avoid these pitfalls, a full methodology has been crafted to produce a three-dimensional replica model of the Parthenon, which was then subjected to advanced simulations of natural and artificial light. The final observation of the behaviour of these lighting systems over the complex volumetric spaces of the temple will assist us in the validation or disproval of these theories, and help us gain a better understanding of the visual experience within the temple.

ILLUMINATION STRATEGIES

These discussions on illumination have been a subject of interest since the European Enlightenment.[3] The earliest study was conducted by the pre-eminent art historian, architect and archaeologist of his era, Antoine Chrysostome Quatremère de Quincy (1755–1849). In 1815, Quatremère de Quincy published his seminal work, *Le Jupiter Olympien*, an investigation of sculpture and toreutics which sought to distance itself from the idealised and colourless portrayal of ancient Greece advocated by J.J. Winckelmann (1717–68). Quatremère de Quincy strove to offer innovative solutions by visualising descriptions based on Pausanias' writings (such as 1.24.5–7). Pausanias' words were not the sole influence on Quatremère de Quincy's perception of the temples' interior. Drawing inspiration from Vitruvius' descriptions of roofless spaces (i.e. hypaethral temples), and acknowledging the inherent darkness of Greek temples, Quatremère de Quincy imagined and visualised Greek temples with statues beneath open skylights (3.2.8; cf. Fig. 2). This preliminary investigation on the subject of light led Quatremère de Quincy (1818) to publish a second piece of research exclusively on this same topic of light.

After this, one of the most comprehensive and daring investigations of the illumination of the Parthenon was carried out by architect James Fergusson between 1849 and 1883.[4] Fergusson contested the notion that light coming from the main entrance or lamplight alone was sufficient to illuminate both the statue and the interior. Instead, he proposed a structural arrangement inspired by the hypostyle halls found in Egyptian temples, and argued that the Parthenon might have included a series of clerestory windows above the cella to enhance illumination (Fig. 3).[5] While

[2] On the topic of access to Greek temples see Hewitt 1909; Corbett 1970; Gawlinski 2015; and Sneed 2020. Access to a temple was dependent upon the deity housed therein and the type of ritual associated with its cult. Generally, Greek temples were communal spaces where a devotee could interact with the divine via libations, prayers, singing, sacrifices and offerings. Our knowledge regarding permission to enter a temple is limited, but the idea that temples were often not accessible is an erroneous, yet persistent, trope in archaeology. It is possible that entrance in some temples was allowed only during major festivals. It is also a possibility that some temples were open upon request by a visitor or worshiper. Access was restricted in some specific temples devoted to one or another cult. There were even areas within the cella where entrance was strictly forbidden (e.g. the adyton). On other occasions, some restrictions dictated that the interior of a temple could only be seen from the threshold. There is no information on access to the Parthenon, but its large size and the need for inventories suggest that some transit occurred. The topic deserves an article of its own, and has briefly been covered in de Lara 2023a, 22 and 219.

[3] In terms of Classical writers, Vitruvius (4.5), for example, only devotes one paragraph to discuss the light of temples. See Bouchareb 2011.

[4] Fergusson had already delved into this concept in 1849, then in 1861 in a paper at the Royal Institute of British Architects, followed by a chapter in 1865 (260–4).

[5] Also proposed by Hittorff (1870, pl. 87). A similar idea had been proposed by Chipiez (1878) for the Temple of Aphaia on the island of Aegina.

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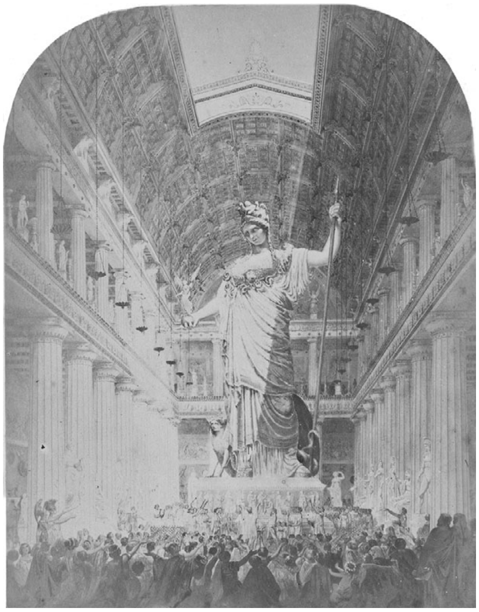

Fig. 2. View of the interior of the cella of the Parthenon, following Quatremère de Quincy models, by Edward Falkener (British, 1814–96). J. Paul Getty Museum, Los Angeles, 84. XB.944.4.1. Photo: Falkener 1861.

innovative, this hypothesis has since been discredited due to its inconsistency with archaeological evidence, and the issue of a lack of any practical drainage system for the water that would have accumulated in the clerestories (Orlandos 1949; 1976–7).

In 1897, when a life-size replica of the Parthenon was completed in Nashville for the *Tennessee Centennial Exposition*, the dark nature of this Greek temple interior became apparent. Architects and

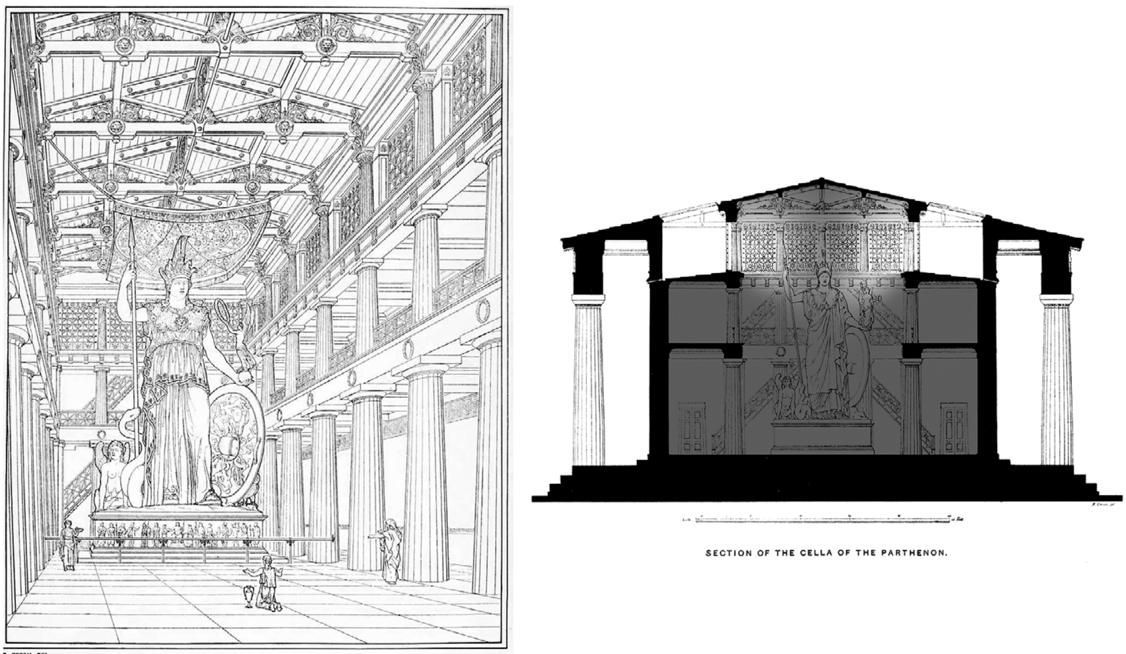

Fig. 3. View of the interior of the cella of the Parthenon, by Fergusson and Groom. Photo: Fergusson 1883, 144 and pl. IV.

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historians of this epoch struggled to fathom the possibility of such seemingly dimly lit spaces housing intricate gold and ivory statues of colossal dimensions. This data somehow contested the first-hand accounts of ancient travellers, which suggested that the counterpart of the Parthenon, the temple of Zeus in Olympia – built in 479 BCE by Libon and refurbished around 432 BCE by Phidias – appeared to be relatively well lit. Pausanias (5.11.1–5.12.8) provides descriptions of the temple indicating a discernible level of visibility, where all details were evidently perceivable, even those found in the innermost part of the temple.

Since the nineteenth century, the issue of how temples were illuminated has continuously piqued academic interest (e.g. Partida 2020; Williamson 2018; Miles 2016a; Schneider and Wulf-Rheidt 2011; Hennemeyer 2011; Varanese 2011; Bettini 2010; Saget 2005; Berard 2002; Williamson 1993; Dörpfeld 1913). Notably, the contributions of scholars such as Wolf-Dieter Heilmeyer and Wolfram Hoepfner (1990), as well as Arnd Hennemeyer (2011; 2015), have enriched research in this field. The author of the present article has recently joined in the efforts to gain a better understanding of the illumination of ancient Greek temples (de Lara 2023a; 2023b).

Now, back to the mode by which temples may have been illuminated: scholars have consistently identified a number of hypothetical tools and methods of illumination, which are succinctly elaborated upon below.

Solar alignments and *hierophanies*

The Parthenon, like many other Greek temples, was oriented towards the east.[6] A widely accepted view among researchers and scholars is that the primary motivation behind the cardinal alignment of Greek temples towards the east was symbolic.[7] Some scholars have assumed this arrangement facilitated the flow of morning light into the building, and functioned as a visual axis that guided light towards the cult statue.[8] Because of this, attempts have been made to link the morning sun with the phenomenon of a beam of sunlight entering the interior of the temple at dawn and illuminating the statue – in a mode that evokes Aeschylus' 'sun-facing gods' (*Agamemnon* 519).[9]

This alignment of the temple entrance with the cult statue has been considered as a way in which to communicate the manifestation of the divine, also termed *hierophany* by some authors.[10] The effect is common in other cultures, and can be observed, for example, in pharaonic Egypt (Fig. 4). In the case of the Parthenon, and due to the unobstructed eastward view of the temple towards the hills

6 On this topic see Vitruvius (4.5.1–2), who advised a western orientation. The first systematic studies of temple orientations in ancient Greece were carried out by Nissen (1906) and Dinsmoor (1939). Doxiades (1937, chapter 3) argued that the apparent layout and orientation of Greek temple sites can be explained by 'unified composition' of the visible landscape and visual angles (Doxiades 1972; Tsiambaos 2009). Recent reviews of the orientation of Greek temples reveal that there is a great variety in axial directions (Ruggles 2005, 419–20; Boutsikas 2011). See also Bouchareb 2011; Ranieri 2014; Pantazis 2014; Magli 2017, 269; Castro, Liritzis and Nyquist 2016; Miles 2016b, 155–6.

7 The act of orienting a building has held profound religious significance across diverse cultures. This practice involves aligning a structure with a revered topographical and celestial landmark, thereby establishing connections between the edifice and cardinal points as well as the cosmic order of the sky. See Eliade 1958/9, 32–5 and 79–81.

8 Metzler 1995, 61–5; Hahn 2001, 86–95. Boutsikas (2017, 48) argues that the widespread assumption that east-facing structures are preferable for optimal sunlight is incorrect. A west-facing entrance does not necessarily result in insufficient or inconsistent illumination. Instead, the orientation of a temple's façade underscores the specific time of day during which the building is illuminated.

9 Bouchareb 2011, 329–32; Boutsikas and Ruggles 2011, 57. A hierophany has also been hypothesised for the temple of Apollo in Bassai (Cooper 1968), although this idea has been challenged by the present author (de Lara 2023a, 358–78).

10 The term itself is versatile, as it means a manifestation of the sacred, in its broadest sense; see Eliade 1958/9. In the context of this article, Barbara Weightman's definition is used, which relates to the effect and therefore manifestation of the divine via illumination. See Weightman 1996, 66–7. In antiquity, references to this effect can be found in Rufinus of Aquilea (*Historia Ecclesiastica*, 11.23, cited by Platt 2011, 303), who refers to it as a 'kiss of the sun', describing a religious event: 'for the moment had been rigorously calculated – a captive sun's ray lights up through this opening', touching the lips of the statue of Serapis in Alexandria (see also the Roccabruna tower at Hadrian's Villa in De Franceschini and Veneziano 2018).

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Fig. 4. The 'hierophany' in the inner room of the main temple of Abu Simbel at dawn on 22 February 2004. Photo: courtesy of Enrico Sandorini.

of Mount Hymettos, it is not surprising that this specific phenomenon has been widely assigned to this building.[11]

Studies of temple entrances have revealed a trend over the Archaic and Classical periods: that the style of these openings gradually widened over time (Williamson 1993, 13). This evolution could, of course, indicate advancements in building techniques, allowing for better distribution of weight in the walls and therefore larger openings, but it could also reflect a growing desire to allow more natural light into the temple.

Fergusson (1883, 109) also noted that the door of the Parthenon did not open directly to a wide-open sky – indeed, the distance between the door and the beginning of the stylobate was more than 12 meters, and was covered by a roof. For this reason, he has expressed reservations regarding the extent to which light managed to penetrate the interior from the main door. To make matters worse, it must be emphasised that the porch that extended over the main door was also walled by some sort of wooden lattice or fence, which probably would have filtered and blocked light.[12]

To date, no study has effectively quantified the volume of morning light that entered this building, nor have the resulting effects, their duration and their implications been examined. The acquisition of this data, broken down in the second part of this article, contributes to a better understanding of the visual experience within the interior and the effects of these phenomena.

Translucent roofs

Around the same time Fergusson was working on his study, another unconventional theory took root when Francis Penrose (1851, 46, note 3) noted the thickness of the marble roof tiles of the Parthenon. He came to believe that they were, in reality, translucent, and he pondered whether their purpose may have been to diffuse light in the cella: as sunlight passed through the tiles, the transmitted light was scattered in all directions through the interior, creating a bright and diaphanous space. Penrose was convinced that the original tiles of the building were carved out of Parian marble, as opposed to the local Pentelic marble used in the rest of the structure. This particular choice would have entailed the additional cost of shipping and land transportation from the Cyclades, significantly raising the net total cost of the construction project. If such cost was incurred, there must have been something special about this material: one possible reason is that Parian marble offered superior translucency compared to other types of marble (Fig. 5).[13]

In later years, translucent roofs were also attributed to other buildings, notably some Cycladic temples (Hoepfner 2001) and the temple of Zeus in Olympia, which was equipped with marble roof tiles that Pausanias (5.10.3), in the Roman era, identified as made of 'Pentelic' marble. This choice

[11] The door as preferred illumination tool has been proposed by Quatremère de Quincy 1815, 262; 1818, 170; Dörpfeld 1891, 334; Miles 2016a, 206; Partida 2020, 179.

[12] Stevens 1942. A particularly evocative visualisation of this feature is recounted by McKean (1997).

[13] Heile 1990, 27–8; Hoepfner 2001. For a full synthesis of the problem, see de Lara 2023a, 135–9; 2023b.

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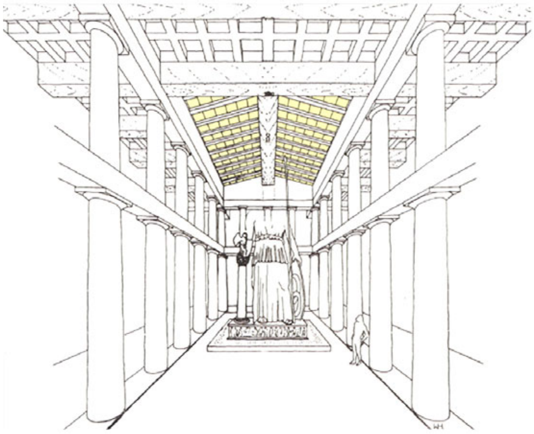

Fig. 5. View of the interior of the Parthenon with a suggested arrangement of the roof with visible translucent roof tiles (in yellow). Image: Hoepfner 2001, 505.

suggests once again a deliberate intention, which some authors have linked to translucency (Hennemeyer 2015; 2013; 2011; Patay-Horváth 2014).

Ohnesorg (2011) has argued against the existence of a configuration in which the roof tiles would have been visible for most of these temples: structural limitations demonstrate the presence of a ceiling over the cella. However, Ohnesorg (2011; 2017, 60) did note that in some temples from the island of Naxos, like the temple of Sangri, the effect may have been possible. In more recent times, Ohnesorg (2021) has questioned and raised doubts on whether achieving optimal lighting was the ultimate goal of such a design.

The major proponent of this lighting strategy in the Parthenon has been Kozo Ike (2006, 117–35; Ike and Otaki 1998) (Figs 6 and 7). His studies aimed to show the translucency levels of various marble samples, and the effect that Parian marble, in particular, had in the Parthenon. The experimental reconstruction calculated the translucency values of different marble samples and measured the amount of light that was therefore blocked when passing through the material.

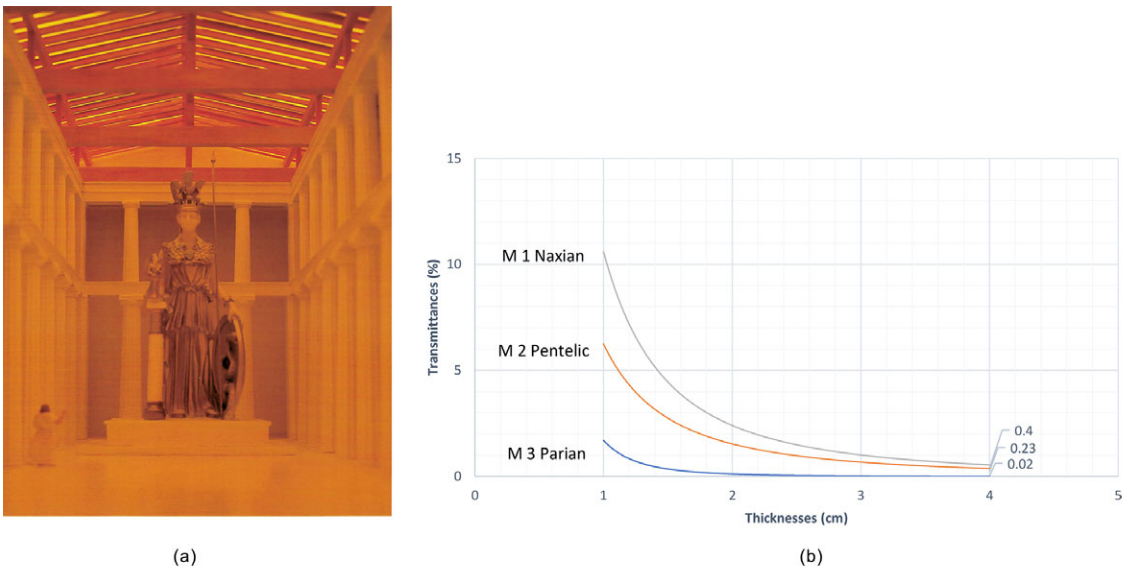

Fig. 6. (a) Scale model of the Parthenon showing red-tinted light coming through the marble tiles (photo: Ike and Otaki 1998, 239). (b) Variation graph of the transmittance values in proportion to the thickness for the three marble specimens of M1 Naxian, M2 Pentelic and M3 Parian marble (image: Juan de Lara, after Ike and Otaki 1998, 239).

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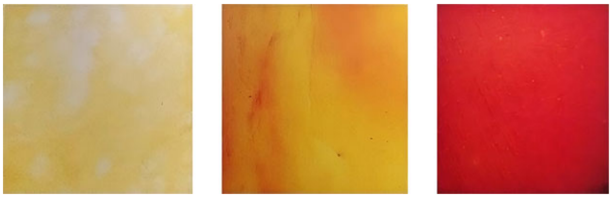

Fig. 7. Variation of the visible transmittance in three marble specimens of Naxian, Pentelic and Paros marble. Image: Ike and Otaki 1998, 239.

The results showed that Naxian marble had the highest translucency, followed by Pentelic and finally Parian. While Ike's methodology initially may seem sound, his resulting scale model of the temple, which featured an exceptionally translucent roof and a remarkably luminous interior, did not account for other elements that might have affected interior illumination. This raises questions about the accuracy of his metrics and prompts a re-evaluation of his findings (de Lara 2023b).

In addition to Ike's work, we must also mention a recent study that has suggested the tiles of the Parthenon were not of Parian but of Pentelic marble (T.L. Shear 2016, 91). This new attribution challenges the aforementioned assumptions regarding the intentionality of using tiles as translucent devices to channel natural light into the interior (cf. Ohnesorg 1993; 2011; 2021). Weigand, García Campos Acosta and Storch de Gracia (2015) have attempted to obtain more data on the translucency of marble samples that may have been used in the similar roof conceived for the temple of Zeus in Olympia. Their research challenges Ike's results (shown in Fig. 5b), as it shows that the translucency of Parian marble on a 1 cm thick sample is very high, and particularly good at transmitting the red spectrum of colour, but when the sample thickness is over 2.8 cm, it falls below the factor of Pentelic marble (Fig. 8).

In conclusion, these two research pieces now reveal that Parian marble was indeed the type of marble with the highest translucency, but only for very thin samples. If a roof tile was to be carved with a thickness of 4 cm, as is the case of the Parthenon, Naxian marble would have been the best choice, with the highest translucency index. However, the historical evidence confirms that the roof tiles of the Parthenon were actually made of Pentelic marble, a material with mid-translucency, and consistent with the rest of the building. Moving forward, we will evaluate the impact of this material on the overall interior viewing experience and determine whether its effect, a persistent trope in recent scholarship, was indeed achievable (Berard 2002; Saget 2005, 32; Malacrino 2010, 18; García Pastor 2013, 200–22; Weigand, García Campos Acosta and Storch de Gracia 2015; Barry 2020, 15–33; Barringer 2021, 131; Anguissola 2021).

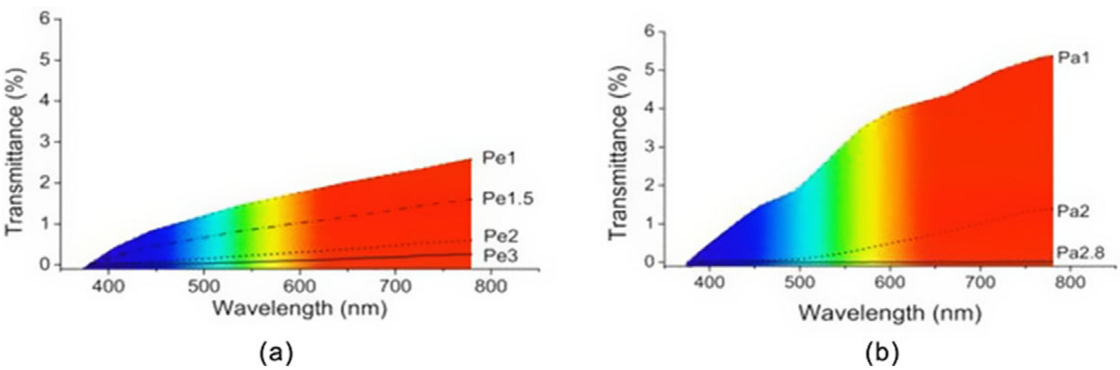

Fig. 8. Total spectral transmittance measurements for samples of Pentelic (a) and Parian (b) marble, sampled by thickness (Pe1, Pe1.5, Pe2, Pe3 and Pa1, Pa2, Pa2.8). Image: Juan de Lara, after Weigand, García Campos Acosta and Storch de Gracia 2015.

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Skylights and apertures in the ceilings

As noted earlier, one of the illumination methods that scholars initially argued in favour of was open roofs. This type of temple configuration, known as hypaethral, was primarily documented by Vitruvius (1.2.5, 3.2.1, and 8), and gave rise to the historical 'hypaethral question', a complex and intricate debate on whether certain temples were intentionally designed to be open to the sky (Herrmann 1844; Ross 1846; Boetticher 1847; Falkener 1860, 1–24; 1861; Clarke 1879; Hellmann, Fraisse and Cazalas 1982).

Today, the accepted answer to this question is that some sacred structures were indeed designed as open-air spaces, but this peculiarity was largely concentrated in sanctuaries in Sicily and Asia Minor.[14] In the case of the Parthenon, the notion of a hypaethral design was considered by figures such as Cockerell (1860) and Falkener (1860). However, this hypothesis of an open roof (as with Fergusson's clerestories) now needs to be discarded due to the lack of archaeological and structural evidence to support such an arrangement (Wikander 1983, 96).

There is another pertinent theory associated with openings in the ceiling, involving the presence of smaller apertures in the roof. In 1860, Cockerell identified in certain marble pan tiles from the Acropolis – presumably originating from the Parthenon itself – some irregularities, namely cuts that seemed to outline the edges of an opening, a shape referred to as *opaia* (Fig. 9). Historically, tiles bearing such cuts and with such shapes were not confined to any specific type of structure; they have been discovered in a plethora of contexts, including stoas, private residences, kitchens and temples

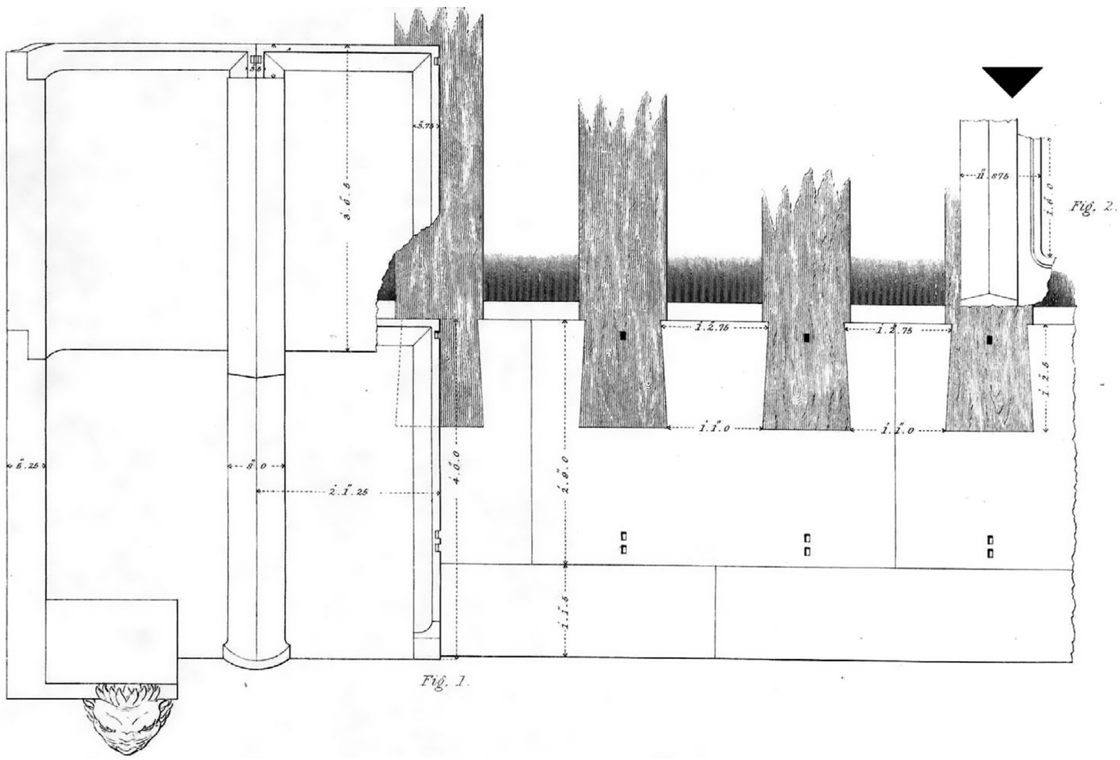

Fig. 9. Drawing showing the architectural roof structure of marble slabs in the rooftiles of the Parthenon. The arrow shows the *opaion*. Image: Cockerell 1860, pl. VII:2.

[14] For instance, the temple 'G' in Akragas (second half of the fifth century BCE); the temple 'G' in Selinus (530–460 BCE); the temple of Artemis in Ephesos (fourth century BCE); the temple of Apollo at Didyma (*c.* 300 BCE). See Hodge 1960, 73; Bammer 1974, 204. For a selected list see Hellmann 1993, 78.

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Table 1. Selection of pierced stone roof tiles found in temple contexts.

	Place	Notes	Reference
	Kerkyra, temple of Artemis	A normal pan tile with a 30 cm opening from the temple of Artemis, 6th c. BCE	Schleif, Romaios and Klaffenbach 1940, 43
	Olympia, temple of Zeus	From the temple of Zeus, dated *c.* 460 BCE Opening of 75 × 62 cm	Dörpfeld 1891, 17
	Epipoli, near Syracusa	From an unknown building	Hodge 1960, pl. XIII
	Acropolis of Athens	Fragments found on the Acropolis, maybe from the Parthenon (?)	Cockerell 1860, pl. VII Fergusson 1883, 74 Dörpfeld 1891, 17
	Tegea, temple of Athena Alea	Marble tile dated to the middle of the 4th c. BCE	Dörpfeld 1891, 338

(Table 1). In these settings, opaia could have improved lighting conditions and increased air circulation. In kitchens, providing outlets for smoke would have been a primary concern. In temples, the burning of large quantities of incense or the use of lamps and fires produced significant smoke, making ventilation outlets a necessity (Fitchen 1981, 496). But in addition to this, we could imagine that these small holes might have created shafts of light that enhanced the ambient lighting within a temple (compare with Fig. 10).

While this theory is intriguing, archaeologists and artists involved in meticulous reconstructions have encountered the challenge of physically locating the fragments of opaia in modern storehouses. For instance, this is the case of the temples of Zeus in Olympia and Apollo in Bassai, where similar tiles were documented in the previous century, but all of which are currently missing from the records, and efforts to locate them have been fruitless (including the present author's). Consequently, archaeologists are working with highly speculative material, as for an accurate reconstruction, a number of tiles will need to be placed to test and determine the quantity of apertures required for an effective lighting effect.[15]

Pools of water as reflective tools

In the second century, Pausanias (5.11.10–1) documented the presence of a pool filled with water in the Parthenon's interior (Fig. 11). Its existence was later confirmed by Stevens (1955, 267–70), who identified marks in front of the statue of Athena that once fixed the curb that contained water. It is worth mentioning that Pausanias had also seen a similar pool in the temple of Zeus, filled with oil (Fig. 12), which was incorporated into the temple following an intricate readaptation process undertaken by Phidias around 432 BCE, parting from the older temple

[15] Damgaard (2017) has attempted a reconstruction of the effect in Roman temples, but the light shafts are only indicated by an outline, and the scene is not illuminated with real-world physical light properties.

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Fig. 10. View of the barrel vault in the Hephaistion in Athens. During the later medieval reconstruction of the building, holes were added in the new vault, possibly to improve illumination or air circulation. Courtesy of ancient-greece.org.

designed by Libon of *c.* 470 BCE (Hennemeyer 2015). It has been argued that the pool in Athens was a direct response to or influenced by the design of the pool in the temple of Zeus in Olympia, and finished shortly after the one in Olympia was completed (Hurwit 2005, 142; Taraporewalla 2011, 42–4).

But what were these pools for? The *periegetes* remarked that they were installed to regulate humidity within the interior spaces: the water in the Parthenon helped to preserve the ivory and wooden core of the statue in the dry environment of Athens, while the oil in the temple of Zeus helped to regulate the humidity coming up from the marshy ground in which the structure was built. For Kenneth Lapatin (2001, 86), the authority on chryselephantine statuary and ivory sculpture in antiquity, neither of these purposes can be ruled out.

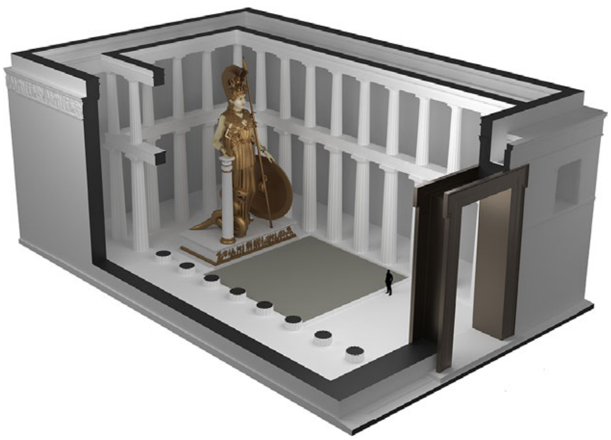

Fig. 11. Cutaway view of the cella of the Parthenon, with the area for the pool shown in dark grey. Render: Juan de Lara.

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Fig. 12. Cutaway view of the cella of the temple of Zeus in Olympia, with the area for the pool shown in dark grey, surrounded by a hypothesised reconstruction of the parapets described by Pausanias. Render: Juan de Lara.

In addition to these properties, in 1967 Boardman proposed that these pools and their liquids could have been used to better illuminate the statues, acting as mirrors to redirect sunlight onto them. The potential aesthetic effect of this pool becomes more pronounced in Phidias' refurbishing of the old Olympian temple. Here the artist had to disassemble and reassemble part of the older temple to accommodate for the new chryselephantine statue. But the artist went a step further – he incorporated a novel basin, quite sophisticated and complex, lined with dark stone and placed it in front of the statue (Taraporewalla 2011, 44). In the eyes of other scholars, this choice of a dark material was presumably to enhance reflectivity (Gaugler and Hamill 1989).

In 1989, an experiment led by Gaugler and Hamill aimed to measure how much the presence of oil or water affected the humidity of an enclosed room, and whether the reflected image of the statue would have been visible to an observer standing at the edge of the pool. Both authors used environmental chambers that could simulate dry and hot versus cold and damp climates. Strips of ivory glued to cedar were placed in these chambers in order to determine any preservative effect over them. But upon observation of the results, Gaugler and Hamill eliminated any practical benefits over the material. In their view, water could help to keep the glue more elastic, but the contribution was marginal. In the case of oil, no effect on the relative humidity was noted other than providing a suitable reflective surface. Therefore, they concluded the pools may have had an aesthetic function. Another experiment led by Claudia Wölfel (1990) also aimed to demonstrate a reflective function, but due to the use of inaccurate surface materials – such as cardboard and tinfoil attempting to replicate marble and water – the results lack accuracy, as these materials do not have the same reflective indexes as marble or gold.

As a result of all these experiments and debates, the practical function of these pools for reflecting light remains widely accepted within current scholarship (Leipen 1971; Lapatin 2001, 134; Barry 2007, 639–40; 2020, 32–3; Boutsikas 2020, 14). However, there are some who have questioned this idea. For instance, Hennemeyer (2011) challenged the efficacy of this theory and proposed an alternative interpretation for the temple of Zeus, suggesting that the pool's purpose was to reflect light from skylights and not from the main entrance. The consideration of the pools as reflecting mirrors for light is further complicated by recent reinterpretations of fences or barriers that might have been positioned in front of the pools in both the Parthenon and the temple in Olympia. If such barriers of unknown height and unknown shape did exist in the Parthenon, they could have blocked sunlight coming from the door from reaching the pools (Fig. 13; Stevens 1955, 267–71; Mattern 2006; 2007, 152–3; Mylonopoulos 2008, 272–5; de Lara 2023a, 193–212).

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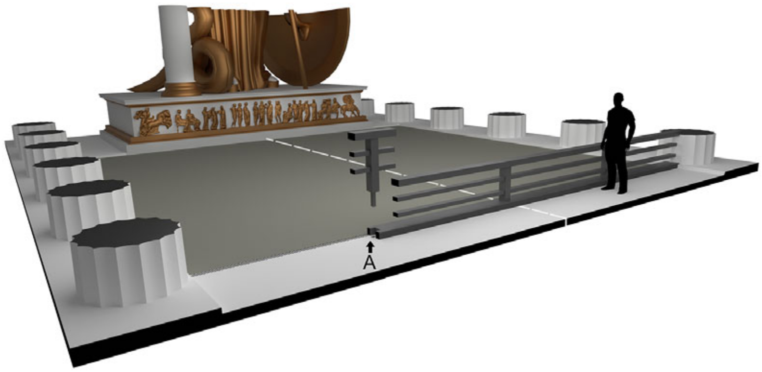

Fig. 13. Pool area (light grey) contained within the rim of the cella colonnade and curbs. Stevens' (1955, 268) dowel location marked as 'A'. The fence has been reconstructed as railed, following ancient Greek models. Render: Juan de Lara.

Windows

One of the most important discoveries in relation to light in the Parthenon involved the identification of two windows flanking the east-facing door (Figs 14 and 15; Korres 1984; see also Herbig 1929; Skrabei 1990; Williamson 1993, 25; Bankel 1993; Montel 2018, 43). Each of these openings was 2.5 m wide and 2.5–3 m high, and no marks for grilles or shutters were found.[16]

These windows were positioned in line with and above the lateral aisles formed by the interior colonnade of the temple. Lighting was presumably needed in these lateral corridors, as they accommodated a vast number of votive offerings, many of which could be considered artworks of some significance (Harris 1991; 1995). In addition, recent archaeological investigations led by Vasileia Manidaki (2022) have brought to light the existence of a decorative band on the upper segment of the interior wall, likely a carved or painted narrative frieze. Both the ritual equipment and the frieze would have required additional ambient light, as the sturdy pi-shaped colonnade blocked light coming from the door. In this context, the windows seem to have been a convenient solution.

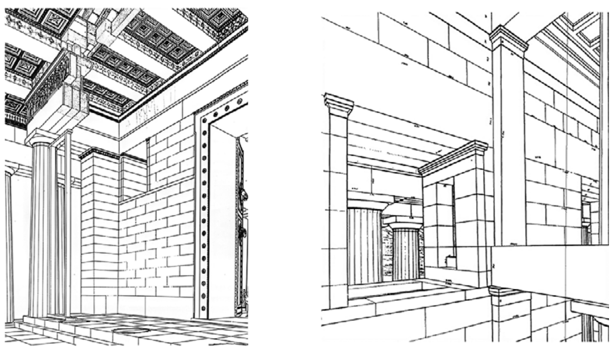

Fig. 14. Perspective drawings of the north window containing the staircase found in the Parthenon. Image: Korres 1984.

[16] Korres 1984, 47 and 51. An interesting observation made by Stevens (1940, 67) and Korres (1984, 52–3) regarding the door and windows in the pronaos is that the columns in this area are 7 cm slimmer in diameter than those in the opisthodomos. They both consider this to possibly have been for better ventilation, either for when incense was burned or for optimal exposure to lighting. While the difference in diameter might be considered too subtle to have any impact in the illumination, as indicated in the test models below, it may reflect an attempt to expand the intercolumnar area of the pronaos area, albeit minimally, without disrupting the harmony of the architectural style.

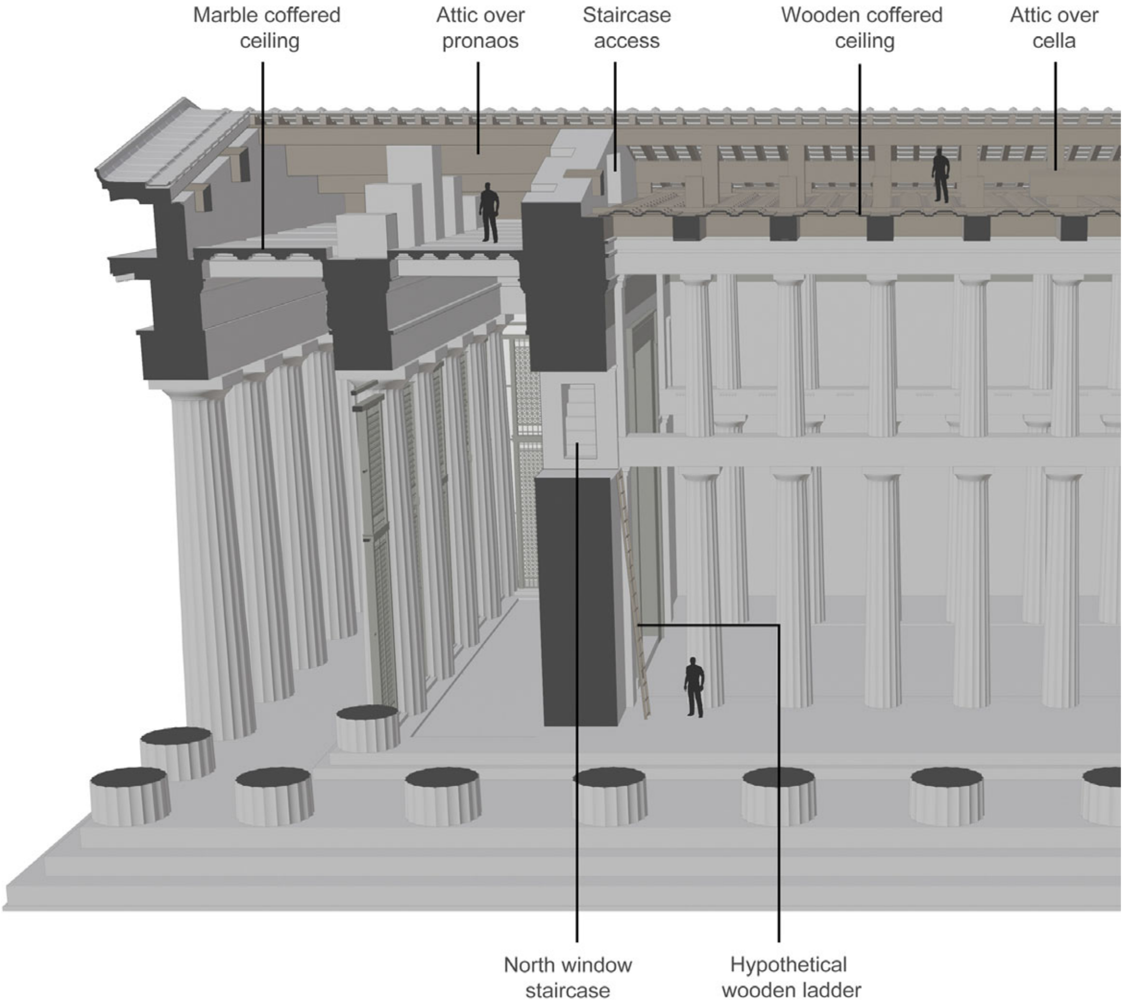

Fig. 15. Cross-section view of the Parthenon from the north, showing the concealed areas above the cella. Render: Juan de Lara.

Lamps

When considering an interior with limited natural light, a logical solution to this shortcoming is to resort to artificial illumination through lamps and/or fire. However, an archaeological quandary arises in relation to lamps: Pausanias' descriptions of sacred enclosures scarcely reference them (2.17.7; 1.26.6–7; 7.22.2), with only three instances in which they are mentioned among the numerous temples he visited. Given this insignificant representation, one might question whether lamps were a commonplace fixture within temples and taken for granted, or on the contrary, whether they were a rarity.

Archaeological evidence primarily supports the existence of small portable and votive lamps, in many cases not meant to be lit, as was the case with a silver boat-shaped lamp found at the Erechtheion (Wachsmann 2012, 248). Other equipment, such as lampstands, candelabra and lamps/torch holders were not characteristic of the Classical period in the Aegean, though they were used in the Italian peninsula (Testa and Sannibale 1989; Ambrosini 2021). The evaluation of more permanent fixtures, such as hanging lamps, presents greater challenges.

Hanging lamps made of marble were common in the Archaic period, and a number were found in the Acropolis (Fig. 16; Schrader 1939, 330, no. 451; Beazley 1940, 38; Payne and Mackworth-Young 1950, pl. 17). Nonetheless, marble lamps fell into disuse in the fifth century, after which

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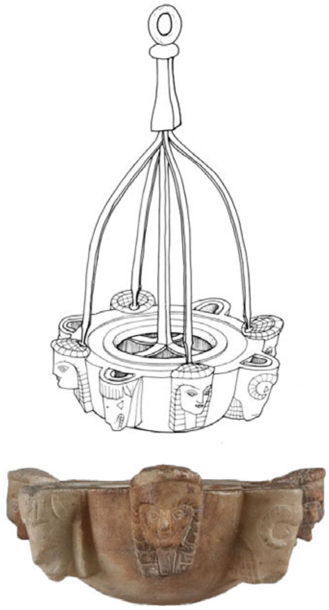

Fig. 16. A multi-nozzle marble lamp, probably from Naxos, found on the Acropolis of Athens and dating to the 6th century BCE. Acropolis Museum (Ακρ. 190). Photo: courtesy of the Acropolis Museum.

Fig. 17. Bronze hanging lamp with decorative heads of youths, from a house in ancient Phagres, Kavala Museum, mid-5th century BCE. Photo: Schuppi, Wikicommons.

archaeological records no longer provide further examples (Bailey 1975, 24; Beazley 1940, 29, 33, 34). That hanging lamps made of metal existed is evidenced by a number of them found in archaeological contexts. The most remarkable example, for instance, is a monumental fifth- or fourth-century lamp found in a tomb in Cortona (Italy), measuring 60 cm in diameter.[17] That similar lamps existed in mainland Greece between the fifth and fourth centuries is demonstrated by the discovery of one example in Phagres, now in the Kavala Museum, dated to the mid-fifth century (Fig. 17). On this same topic, Pliny (*Natural History* 34.8.14) describes a suspended sacred lamp, in the form of a hanging tree, which Alexander the Great had seized during his attack on Thebes (335 BCE) and dedicated to Apollo at Kyme (Carey 2003, 83; Castoldi 2014). 'Arboreal' lamps of this sort, like the golden palm tree crafted by Callimachus within the cella of the Erechtheion in the Acropolis (Pausanias 1.26.6–7), may have been a common configuration, as tree-shaped lamps became a popular theme in later Roman times (Castoldi 2014, 7–23). Bearing in mind all this data, it is possible to hypothesise that lamps of precious metals may have once existed, before being melted down in some later period, and this might explain their absence in archaeological contexts.

[17] Van der Meer 2014; see also Rastrelli 1993, 351 for other examples. Some of these lamps might have originally been found in tomb contexts. However, Beazley (1940) suggests that their origin could have been ritual, possibly from a temple, and that they were later transferred into tombs.

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In the case of the Parthenon, only two small lamps – one of gold (weighing 38 drachmas) and one of silver (of 22 drachmas) – were documented in an inventory of the pronaos of the temple, but not in the cella (Harris 1995, 66–7). The general absence of these in the inventories is peculiar, and there might be three reasons why these were not documented (or even found within the archaeological record). One, as said, is that they were taken for granted, and therefore not included. Alternatively, it is possible that they were made of bronze, in which case their inclusion in the inventories was unnecessary. A final possibility, which cannot be ruled out, is that lamps were not a common element of Greek temples. This was the opinion of Quatremère de Quincy (1818, 176–80), who considered that the smell of burnt fat and the smoke produced by the sheer quantity of lamps that would have been needed to illuminate a temple as big as the Parthenon would have been overwhelming and that therefore artificial light was not desired within these spaces.

We may also want to contemplate the notion proposed by Dorina Mollou; she suggests that a solitary flame, likely positioned near the statue, was a more likely custom in Greek temples.[18] Assessing the evidence within a broader context that draws parallels from the religious landscape of different cultures, the arrangement of a single lamp can be proven a popular and effective practice, with clear spiritual purposes behind its use. The feature has been commonly called 'the eternal flame', an allegorical element with meanings beyond mere illumination.[19] For example, in the Bible the *menorah* is mentioned as the sacred lamp of the western section of the Temple of Jerusalem (Exodus 27:20–1 and Leviticus 24:2). In Jewish synagogues there is a lamp, the *ner tamyd*, which perpetually burns near the Ark of the Law (Yarden 1971, s.v. Eternal Light). In Ireland, remnants of a pagan practice survived Christendom. An example is the flame of St Brigid in Kildare, a fire that remained alight until it was extinguished by Henry de Loundres, archbishop of Dublin, in 1220 CE (Bray 1992).

In a similar context, a fire was also often equated to the divine presence. This was, for instance, the case of the perpetual sacred fire of Vesta in Rome, a symbol of the goddess and her protection over the city (Frazer 1885). In Iran, the Achaemenids had three ever-burning Great Flames distributed across different temples within their Empire, one of which was extinguished by Alexander after the death of Hephaestion (Boyce 1979, 87 and 108). In a much later period, the early Muslim dynasties equipped their mosques with a symbolic single lamp hanging in front of the concave *mihrab* niche, its light meant to symbolise God's brilliant presence on earth (Bonnéric 2019). Considering these tropes and the importance of a single perpetual flame in many sanctuaries of antiquity throughout various cultures, and with some records that appear to associate the practice with the ancient Greek world (e.g. Pausanias 1.26.6–7), the possibility that a similar tradition existed in Greek temples cannot be dismissed.

Digital reconstruction and experimental methodology

In order to assess all the aforementioned light strategies, a new methodology that can account for the physical properties of light and materials is needed. However, the current condition of the Parthenon hinders the examination of any of these phenomena on site. For this reason, the original conditions in this temple must be recreated in a spatially explicit form, modelled rather than imagined, so that they can be treated under physical simulations of static and dynamic natural laws of light and optics.[20]

[18] This is inferred from the one single lamp in the temple of Hera at Argos (Pausanias 2.17.7) and Callimachus' lamp in the cella of the Erechtheion (Pausanias 1.26.6–7). Personal communication with Dorina Mollou.

[19] The main reference is still Simons 1949. On Greek temples, see Quatremère de Quincy 1818, 179.

[20] Gooding 2004, 278; Vergnieux 2011, 39; Bielfeldt et al. 2022; Campanaro 2023. While this experiment with the Parthenon primarily focuses on its visual aspects, the author acknowledges its potential to inspire a broader archaeology of the senses. This future approach could one day enable the reconstruction of a multisensory experience in the temple, where scents, perfumes, and a carefully crafted soundscape are integrated into the space (see Day 2013).

Fig. 18. Model of the Parthenon interior by Chipiez and Jolly, 1883. Photo: courtesy of Electrum Magazine.

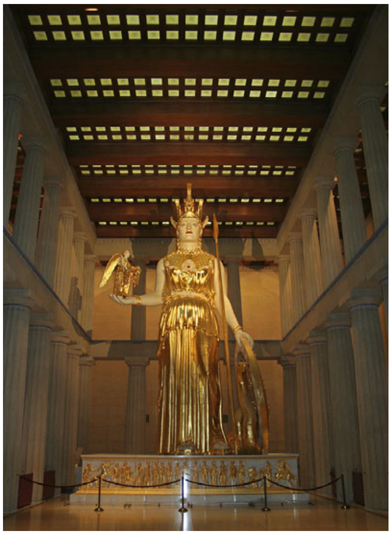

Fig. 19. Interior view of the Parthenon from Nashville, built in 1897. Photo: Aaron Archuleta, Wikicommons.

Fig. 20. Maquette of the Parthenon interior by Leipen and Hahn, 1962. Photo: Wikicommons.

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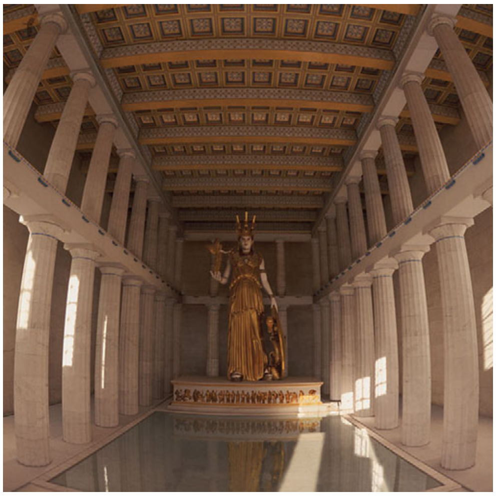

Fig. 21. 3D model of the Parthenon interior, 2004. Photo: Paul Devebec – VEL3D.

Such an approach, using physical spaces, has been embraced by archaeologists and artists since the late nineteenth century. For instance, Fergusson's theory was put to test by a scale model funded by the Willard Architectural Commission and created by Adolfe Jolly and French architect Charles Chipiez in 1883 (Fig. 18). Later on, in 1897, when the Parthenon replica was constructed in Nashville, the dimness of its interior strengthened earlier suspicions concerning the actual aspect of the classical temple. In fact, the lighting in the building was so subdued that in 1930 electric lights had to be installed in the coffers to improve the interior illumination (Fig. 19), perhaps evoking the translucent tiles argued for by Penrose (1851; Stair and Tathwell 1930). In 1962, the Royal Ontario Museum created a scale model of the interior of the temple to evaluate the lighting conditions with an incorporated pool (Fig. 20; Graham 1963; Leipen 1971). Finally, there is the aforementioned maquette used by Ike and Otaki, which was aimed at demonstrating the effect of translucent tiles in the Parthenon (Fig. 6; Ike and Otaki 1998; see also Ike 2006). As already noted, their approach aimed to provide photometric values such as colour hues and luminous intensity within the cella.

In 1985, the advent of 3D technology and computer graphics (CG) marked a gradual departure from relying on physical maquettes for experimentation.[21] This technological advancement enabled the creation of photorealistic images of historical sites, subsequently allowing the visualisation of realistic ambient effects. The 3D render of the Parthenon's interior created by Paul Devebec in 2004 is remarkable for portraying a brightly illuminated cella (Fig. 21). However, the issue with this specific image is that it has been accepted by general media as an absolute historical snapshot, without contextualisation or rigorous critical assessment to accompany it.

As we have seen, for centuries, antiquarians, architects and archaeologists alike based their comprehension of the material past on linear, pictorial reconstructions, heavily relying on textual descriptions over actual scientific data. Such an approach calls for a revised methodology that benefits from the latest technology while also providing a proper critical framework to re-evaluate the way the Parthenon was illuminated. To this end, new three-dimensional models of the Parthenon and the statue of Athena were created (Figs 22–26) and subsequently subjected to physically corrected lighting, an approach that seeks to render graphics in a way that accurately

[21] For further information on the first archaeological 3D reconstructions of monuments, see Frischer and Dakouri-Hild 2008, vii.

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models not only the flow of light but also the surface material qualities of objects. This process, called *physically based rendering* (PBR), has been adopted as it observes physical and optical phenomena while respecting as much as possible the photometric qualities of a scene, that is, the mathematical formulas used in the propagation of light through space and materials (Pharr, Jakob and Humphreys 2016). This method also recognises that all surfaces in the real world reflect light in small degrees. For this reason, each material of the scene was assigned appropriate reflectance values[22] and colours to match as closely as possible their real-world counterparts.[23]

The Seville Principles and the London Charter have established the guidelines for best practices in creating digital models of historical monuments such as the Parthenon.[24] These principles ensure transparency in the reconstruction process, mitigating the presence of 'black boxes' – a term denoting concealed methodologies, where the internal processes to obtain a desired outcome are not readily visible to researchers (Wilson and Edwards 2015, 98; Marwick 2016; Marwick et al. 2017). Furthermore, these principles outline a complete list of sources as well as the processes that guided the choice of one reconstruction hypothesis over others (Alusik and Sovarova 2015). Consequently, the reconstruction remains aligned with the available evidence and contradictions are avoided.

The metric data for the model of the Parthenon were obtained mostly from the works of Anastasios Orlandos (1949; 1976–7; Orlandos and Vranouses 1973), Manolis Korres (1983; 1989a; 1989b; 1994a; 1994b; 1994c; 1994d; 1994e; 1994f; 1994g; 1994h; 1994i; 1996) and Vasileia Manidaki (2015; 2019; 2022). Other studies, such as those by Penrose (1851) and Stevens (1940; 1942; 1943; 1955; 1957; 1961), were also consulted.[25]

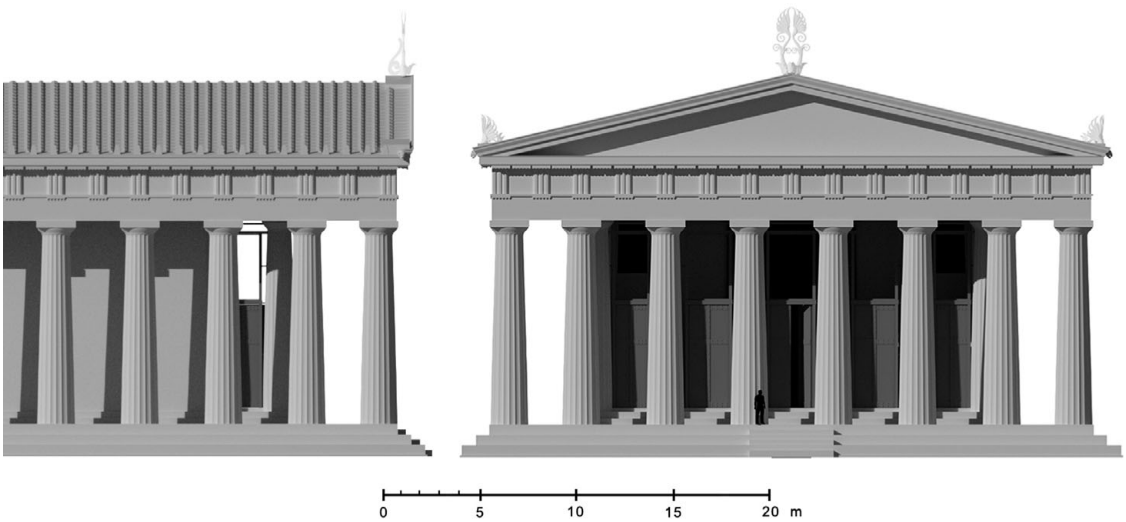

Fig. 22. Restored lateral and front elevation of the Parthenon. Render: Juan de Lara.

[22] Defined as a universal scale that measures the amount of visible and usable light that is reflected from a surface when illuminated by a light source.

[23] This is a difficult process, so for a full and comprehensive breakdown of it, see de Lara 2023a, 126–38.

[24] Denard 2012; Bendicho 2013; Beacham and Niccolucci 2020. For a detailed reconstruction of the Parthenon model, readers can refer to de Lara 2023a, 161–219.

[25] This combination of measurements has been necessary while anticipating a final publication from the Acropolis Restoration Service (YSMA). Further artistic and architectural choices are listed in de Lara 2023a, 216–17. On the reconstruction of the statue of Athena, see de Lara 2023a, 211–16. In this particular reconstruction, the column under Athena's right hand has been retained as an original feature. Similarly, the serpent-statue of Erichthonious has been placed under the right hand. Recent studies suggest that Erichthonious' original position, as conceived by Phidias, was on her right, and only in Roman times was it changed to her left (under the shield, as seen in the so-called Varvakaion copy of the Athena). This arrangement can be seen in a coin from Priene (illustrated in Stevens 1961,

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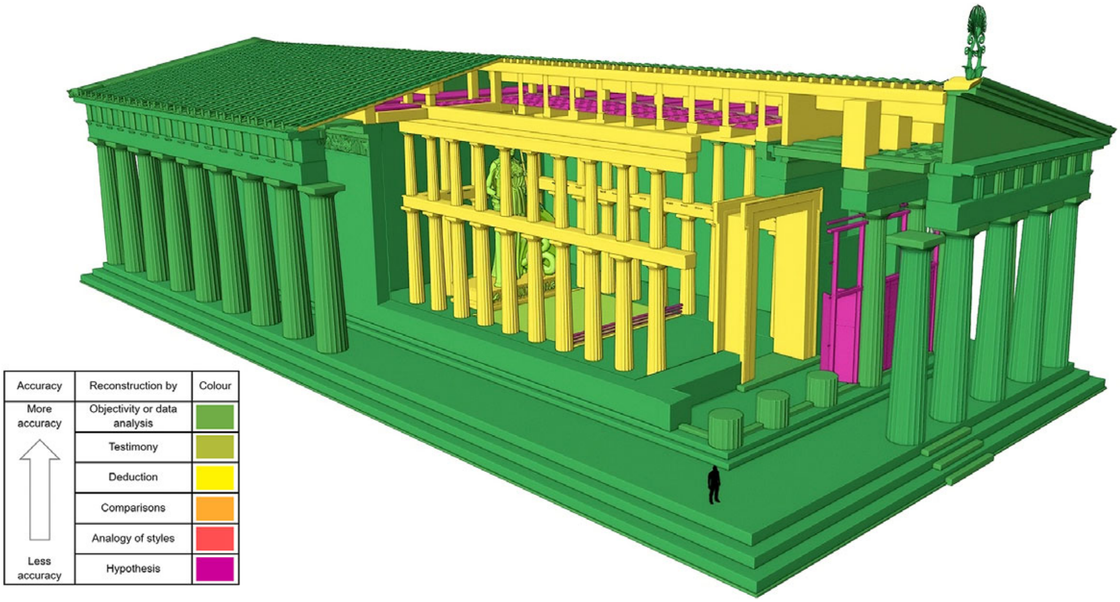

Fig. 23. Uncertainty visualisation of various architectural elements in the restored Parthenon. Render: Juan de Lara.

Fig. 24. A 3D reconstruction of the chryselephantine statue of Athena. Render: Juan de Lara.

pl. 1). These changes have been argued in Lapatin (forthcoming) and Stevens (1961). Lapatin and other scholars (see for example Palagia 2019, 336) consider that the column was a later Roman addition. Nonetheless, based on some graphic evidence, such as the aforementioned coin, the author argues that the column must have been necessary to support the weight of the Nike statue, as a simple cantilever system would have been inadequate given Athens' high seismic activity. Furthermore, the column would not seem out of place optically, as it was placed strategically to overlap with the colonnade in the background, as seen from the entrance (Fig. 33).

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Fig. 25. Cross-section elevation of the Parthenon. Render: Juan de Lara.

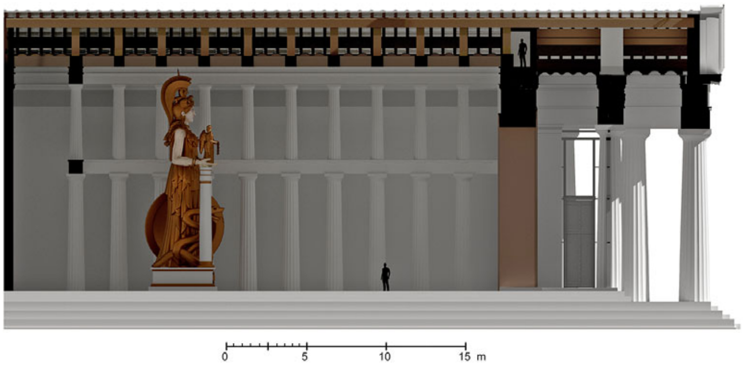

Fig. 26. Restored lateral cross-section elevation of the Parthenon's cella and pronaos. Render: Juan de Lara.

The digital Parthenon was placed on a digital space and oriented using the most recent azimuth measurements.[26] To this scene, a 3D model of the profile of the perceptible horizon (the skyline) was added (Fig. 27).[27] The horizon plays a significant role in the amount of sunlight allowed into the building – high mountains dictate the angle of light available and delay the appearance of the sun on the horizon, and this reduces the amount of time the temple interior is exposed to sunlight.

Another significant challenge was addressing the Earth's axial tilt, or obliquity. This means that the imagined axis running through the Earth oscillates between 22.1 and 24.5 degrees over a 41,000-year cycle. This leads to a slight deviation of approximately 2 degrees (as observed from Earth) in the sun's position from the time of the Parthenon's construction to the present. For the experiment, the year 430 BCE was used as a reference year, and to determine the sun's position in that year, data were extracted from ephemeris software.

Finally, with the scene set, the resulting analyses are presented below as observations on the distribution of natural and artificial illuminance levels. Illuminance is a photometric parameter measured in *lux* that assesses the spatial distribution of light on a surface. Colours have been assigned to different lux levels on each surface (or 'false colour scale'). This technique

[26] Pantazis 2014. The azimuth is the direction of a celestial object from the observer, presented as the angular distance from the north point of the horizon to the point at which a vertical circle passing through the object intersects the horizon.

[27] Perceptible horizon can be defined as the projection of the outline of hills, mountains or buildings situated around an observer standing at a certain position; see Pantazis and Papathanassiou 2005, 68; also Pantazis et al. 2004. An area of 16 km radius is enough to obtain the outline of the horizon that is relevant to the Parthenon's east-facing side. To learn about the process of obtaining a digital model of such an area, see de Lara 2023a, 138–48.

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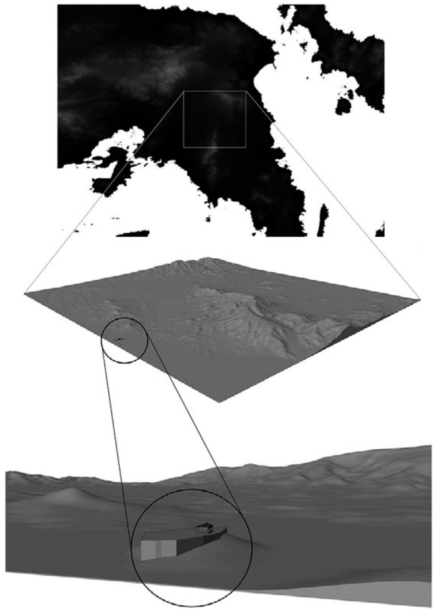

Fig. 27. Portion of Attica surrounding the Acropolis of Athens and exported as a 3D Digital Elevation Map. Render: Juan de Lara.

was employed in order to better visualise the illuminance levels, through a day and throughout the year; the sunbeams were tracked as they were admitted in the temple and collided with solids.

THE RESULTING EFFECT OF SOLAR ALIGNMENTS AND HIEROPHANIES

An initial physically based experiment, designed to observe the average ambient illumination within the structure during daylight, revealed that in cases where direct sunlight did not penetrate the cella, the interior remained dim throughout the year (average 100–150 lux, measured in the centre of the cella). This result implied that with such levels of illuminance, the entirety of the statue would have been visible enough to perceive some colours and shapes.[28]

A major observation was also that the amount of ambient light coming into the cella was limited by whatever was the configuration of the grilles installed in the pronaos. The pronaos of many temples, including the Parthenon, were equipped with high fences composed of solid or latticed panels of wood covered with metal sheets.[29] Experiments with two different arrangements were carried out (Fig. 28). Regardless of whether the spaces were pierced, both configurations significantly reduced the illuminance in the cella (from 150 lux to 300 lux). Of course, if light was a concern, the leaves of these intercolumnar parapets could be opened on special occasions, but the architects only designed three out of the five sets of doors in the pronaos to be opened – the centre one and the ones on each side. This reveals that light was then not a concern when placing the grilles, as otherwise all the door leaves would have been designed to be opened (Fig. 29). Additionally, the

[28] It must also be noted that the resulting images are close enough to human perception, but do not account for the eye's ability to adapt to various lighting conditions (photopic, mesopic, and scotopic vision); see Papadopoulos and Earl 2009; Gallardo 2000, 448–9. It is not currently possible to fully capture or represent the eye's organic adaptation to light and darkness in a single static image. When in bright spaces, the eye cone cells mimic the way in which camera sensors respond to light. However, in dark environments, the human eye adjusts to dark conditions (scotopic vision) in a much better way than a camera can capture it due to the eyes' heightened levels of sensitivity (Moullou 2015, 210).

[29] For a description of these fences, see de Lara 2023a, 196–212.

Fig. 28. Restored elevation view of the barriers of the pronaos, with lattice (left) and solid (right) walls installed between the columns. The pteron columns have been removed for better visualisation. Render: Juan de Lara.

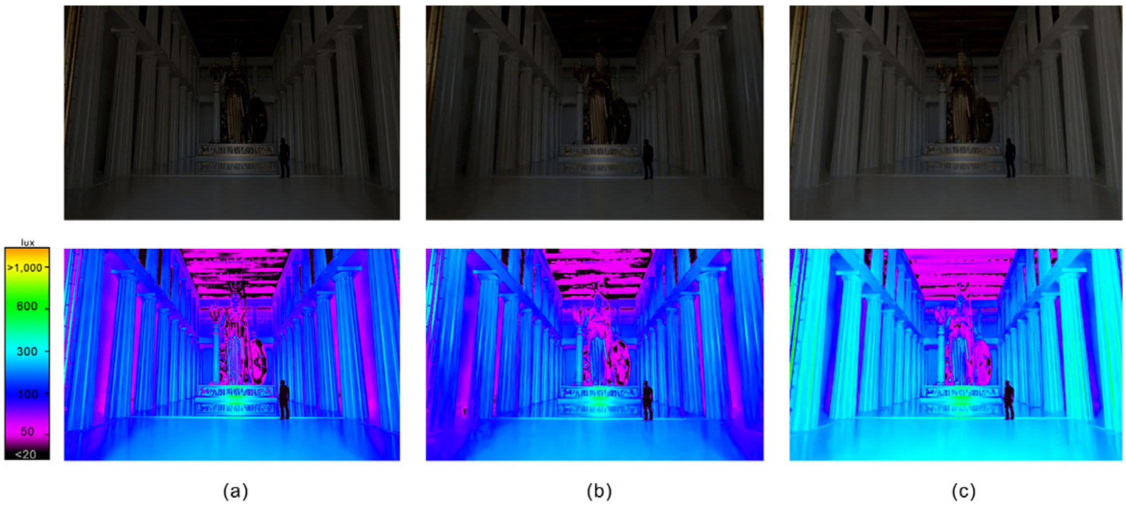

Fig. 29. Comparative physically based renderings depicting the cella at 10 a.m. on 1 August 430 BCE with different types of grilles in the pronaos and illuminance level analysis shown as false colour. (a) The cella viewed with normal latticed screens raised up to the architrave of the pronaos. (b) The cella with a screen featuring a solid lower parapet and an open upper portion. (c) The cella with no grilles in the pronaos. Render: Juan de Lara.

presence of curtains and sunshield at the door – as seen in other temples (Schrenk 2011, 152–3; Brøns 2017, 78) – remains uncertain and warrants consideration, but should not distract us here.

Sun rays reached directly into the cella's interior between March and November, starting around 5.30 a.m., continuing until approximately 10.00 a.m. (Figs 30–32).[30] The sun's azimuth aligned with the long axis of the Parthenon twice a year, around 25 April and 30 August, at approximately 5.30 a.m., as the sun made its first appearance over the horizon behind Mount Hymettus. At this time, the statue was subjected to what we describe as a 'hierophany', and was bathed in sunlight. However, an unanticipated realisation from this experiment is that the statue was not illuminated by this direct sunlight at its full height, as the isolation angle (2°) of the sun (determined by the altitude of both the Parthenon [158 m] and Mount Hymettus in front

30 All times mentioned in this paper are based on standard time, which is one hour earlier than Daylight Saving Time in Greece during summer.

Fig. 30. Time-lapse view of the cella, top-down perspective, depicting the morning sun's hourly movement from 5 a.m. to 9 a.m. in 430 BCE. Render: Juan de Lara.

[approximately 674 m]) only allowed for the statue's legs and waist to be illuminated, never the entirety of the statue.

Regardless of whether the statue was pushed back to the colonnade or remained in its current position (closer to the centre of the cella), the area of illumination during these dates did not change much. This observation is important because it has been claimed that the positioning of Athena towards

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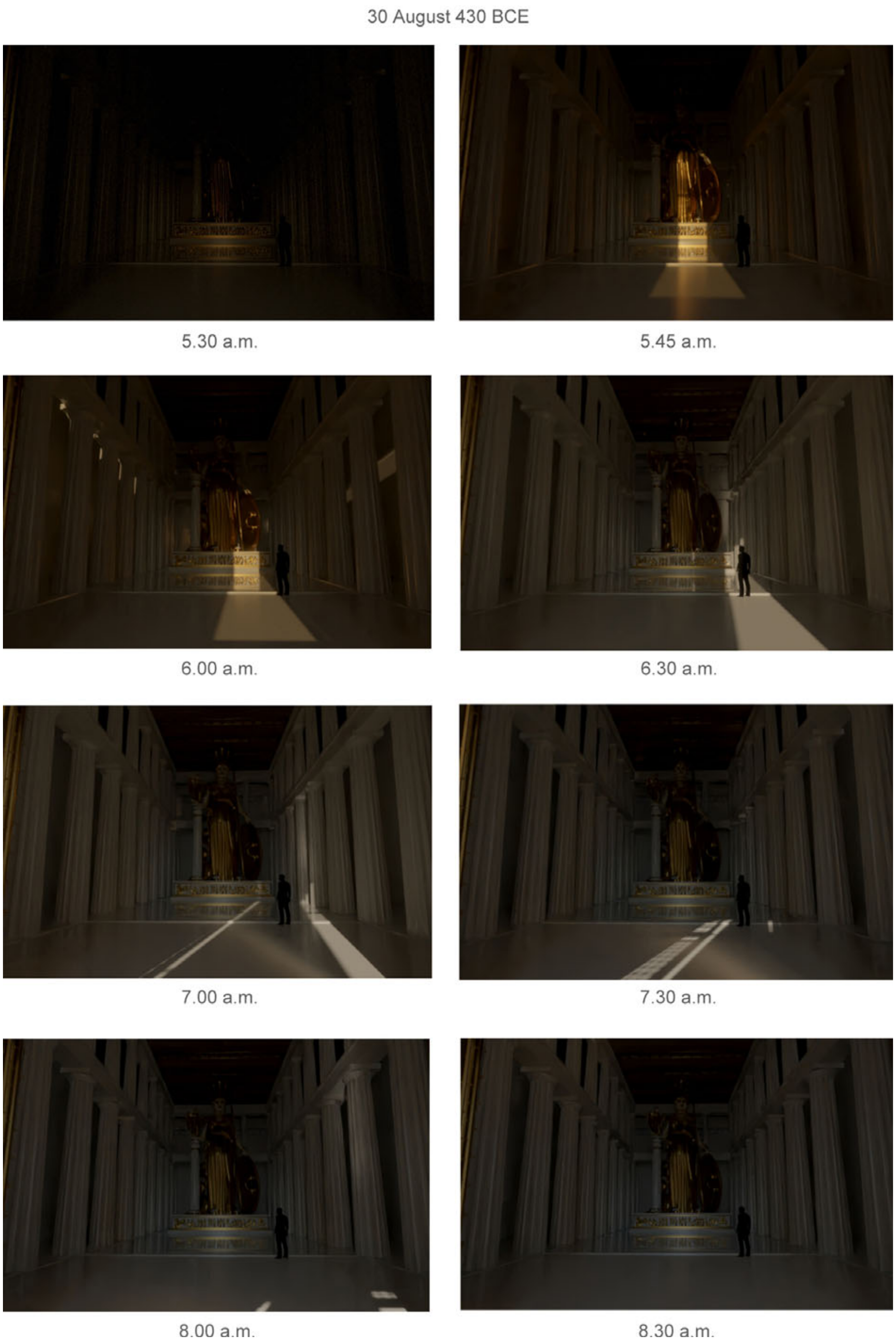

Fig. 31. Time-lapse view of the cella captured from the perspective of an observer standing at the door threshold, showing the effect and movement of the sun's rays on the statue from 5.30 a.m. to 8.30 a.m. of 30 August 430 BCE. Render: Juan de Lara.

the centre of the cella, and not to the back, was to benefit from better solar exposure, a claim that this experiment does not support (Winter 1915, 12–14; Schrader 1924, 39; Dörpfeld 1935, 2.16).

Furthermore, Phidias' statues in the Parthenon and the temple of Zeus in Olympia were both placed at the same distance – 17 meters – from the cella door, as first noted in modern scholarship by Ferdinand Noack (1927, 294–8). We are uncertain about the reason for such measurements. While the distance from the door to the statue was the same in both temples, the distance from the door to the border of the stylobate differed, and hence illumination may not have been the reason for this placement.

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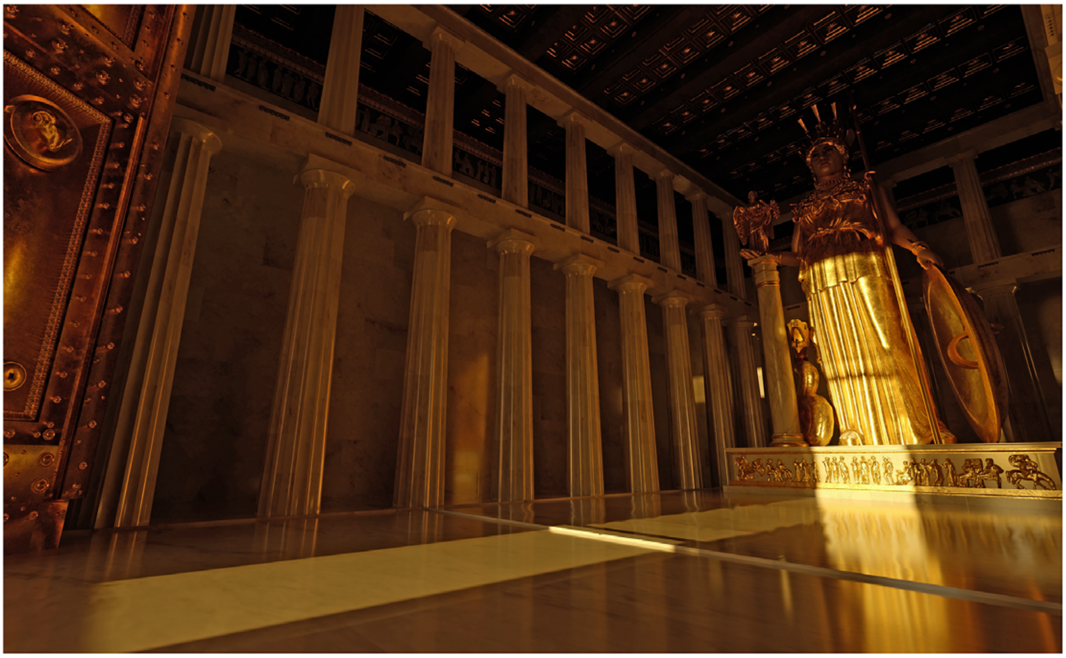

Fig. 32. Physically based render of the cella on 30 August 430 BCE at 5.45 a.m. The image shows the alignment between the sun behind Mount Hymettus, the temple threshold, and the statue; the sun beam's maximum reach is only up to the statue's waist. Render: Juan de Lara.

It should also be noted that at the moment of this solar hierophany, the light was not too intense. This was because at this time photons had to travel through a longer distance in the atmosphere, causing them to scatter and lose luminous intensity. This means that at dawn, the face of Athena would be observed under 50 lux. Now, if a visitor wanted to have an optimal view of Athena's ivory face, a recommended time for a visit would have been at 7.00–7.30 a.m. during the summer months. This was the time when the sun's rays would have directly hit the marble pavement of the cella, just in front of the pool, and which would have been relatively reflective due to the crystalline matrix of the stone, acting like a mirror and reflecting light onto Athena's face (300 lux) (Fig. 33).

This observation emphasises the importance of determining the extent of the polishing applied to the marble surfaces within the Parthenon. However, this task is hindered by weathering and the poor condition of the remaining stone pavement, although it has been noted that certain marble floor surfaces, such as the stylobate of the opisthonaos, south of the medieval staircase, were deliberately treated via a soft chiselling. Korres thinks these markings were performed after the final smoothing of the surface, only on the floor and not on the columns. Manidaki also wonders if the marks had any impact on the lighting of the cella and whether they reduced reflection, and leans towards the idea that the marks are simply remnants of the tools used for smoothing the surface.[31]

Nevertheless, it is reasonable to assume that some form of buffing could have been employed – the temple of Nemesis in Rhamnous serves as a noteworthy example, where the marble blocks had an extremely fine polished finish, as noted by Margaret Miles (1989, 147). The surfaces of walls and floors may have also been treated with a technique akin to *ganōsis*, a polishing method used in sculpture to safeguard paint and enhance lustre.[32]

To further illustrate the importance of determining polishing degrees to calculate the reflection of marble, tests were conducted to adjust various indexes for the stone materials in the 3D software, revealing distinct illuminance levels corresponding to the different variances. This proves that the difference between polished or unpolished marble could vary the illuminance of the interior by up to

[31] Personal correspondence with Vasileia Manidakis.

[32] Pliny (*Natural History* 36.22 and 36.9), Vitruvius (7.3.9–10) and Plutarch (*Moralia* 201). For more insights, refer to sources such as Deonna and de Ridder 1927, 129; Bourgeois 2016; Abbe 2020, 8.

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Fig. 33. Physically based render of the statue of Athena on 1 July 430 BCE at 7.30 a.m. The image shows minimal direct sunlight admitted into the cella at this time, with only atmospheric illumination remaining. The illumination is enough to make the statue and the interior perceptible. The light coming through the large door is reflected on the pedestal and particularly in the ceiling. Render: Juan de Lara.

±100 lux – a quite relevant figure. Due to challenges in determining the level of polishing present in the original Parthenon of Iktinos, a mid-range reflectance value (65% Light Reflectance Value) was employed in the subsequent figures (Fig. 34).[33]

[33] For a larger discussion on the issue of reflection and stone polishing, along with the rationales for determining the values for the Parthenon, see de Lara 2023a, 430–44.

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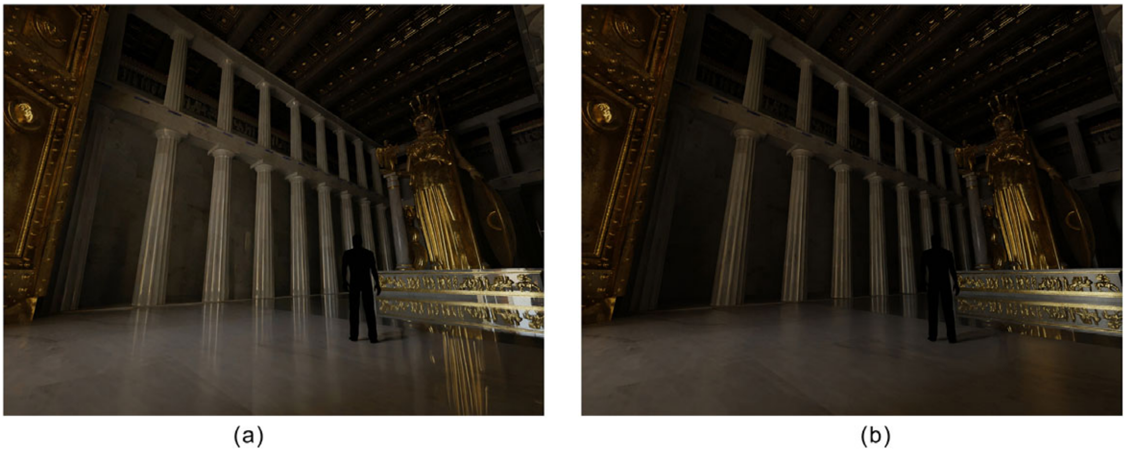

Fig. 34. Render showing the interior of the Parthenon sometime at noon with (a) marble being treated and polished (65% Light Reflectance Value) and (b) the same stone left rough (20% Light Reflectance Value). Render: Juan de Lara.

In conclusion, a solar alignment might not initially strike us as an awe-inspiring feature, as it would have illuminated only Athena's skirt. In light of these finds, we might ponder on the different purposes associated to the effect. For example, we could explore a practical timekeeping tool for marking important events on the calendar (Ruggles 2005, 419; Hannah 2013). Let us take for instance the 30 August date, which as has been discussed was one of the two dates in which an alignment occurred. This date roughly coincided with the summer procession of the Greater Panathenaia festival celebrated on the 27/28 of the Attic month of Hekatombaion (Proklos, *Commentary on Plato's Timaeus* 17b and *Scholia on Plato's Republic* 327a; see Greene 1938, 187–8; Parker 2005, 257; Håland 2017, 306–10).

Hekatombaion 27/28 was erroneously associated with Athena's birthday by modern scholars,[34] and identified by Dinsmoor as occurring on 31 August in the years *c.* 490–480 BCE, when the foundation of the pre-Parthenon was established (Dinsmoor 1939, 120–2; see Hannah 2013 for further insights). However, if the same effect was sought every year afterwards, this posed the problem of matching a solar effect to the lunisolar calendar. In the lunisolar Attic calendar, Hekatombaion began with the visible new moon after the summer solstice, around July/August (Meritt 1928, 112). Therefore, an exact alignment could not have been the prime concern of the architects, as a solar event could not be synchronised with a lunar calendar annually. Its lunar aspect meant that in some years 28 Hekatombaion would begin in early August, and in other cases, at the end of August. Thus, the position of the sun on this specific date of the Attic calendar would differ slightly each year. A possible solution to the problem of matching calendars and times is to consider that the solar alignment with the building axis did not necessarily mark a specific day, but rather a timeframe (July–August), which could have coincided with the festival of the goddess.[35]

VISUALISING REFLECTIONS IN POOLS OF LIQUID

The pool of water in the cella of the Parthenon covered an area of roughly 90 m^2. During solar alignments with the statue, the beam of light that fell on the pool covered one-third of the pool's total area (23 m^2). This area shrank as the sun transited throughout the morning from 5.30 to 7.00 a.m.

34 Anghelina (2017, 176) dismisses any association between the birthday and the Panathenaia.

35 Cf. Anghelina 2017, 180–1. This would not mean that there was any ritual relationship between the Parthenon and the festival, other than helping worshipers to identify when the festival approached.

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Fig. 35. Top-down perspective view of the cella's interior, showing superimposed sunlight over the pool for one hour (from 6 to 7 a.m.) on 1 August 430 BCE. Render: Juan de Lara.

Such a result challenges, a priori, the proposed use of the pool as a mirror, as such a large area would not have been needed: a smaller one would have sufficed for the 'special effect' without the need to sacrifice such a large area from the cella (Fig. 35).

Furthermore, the efficacy of the reflected light on the pool as a lighting mechanism for the statue has here been tested with negative results. In this experiment, the reflected light from the pool falls short of adequate, as it only reaches up to Athena's shins (Fig. 36). It is also crucial to dispel the notion that water hugely amplifies reflection on an already polished surface. The thin layer of water, just 3 cm deep, has a negligible effect on the reflection index of the overall layout of the temple interior. This layer primarily refracts the light rays, which then encounter the marble underneath the water's surface, and subsequently they are reflected by the marble stone (rather than the water). This means that in essence, the reflection on the polished marble basin is realised by the reflection index of the marble and not by the water.[36]

Lastly, it is essential to consider the conjectural parapets located in the Parthenon, contrasted against the better-evidenced ones at the temple of Zeus in Olympia. Such structures, often missing from reconstructions, would have presumably blocked any sunlight coming through the doors. For this experiment, parapets have been reconstructed using a standard type of fence found in several temples (e.g. the monument of the Eponymous Heroes in the Athenian Agora, *c.* 350–300 BCE; the temple of Nemesis in Rhamnous, fifth century BCE; or the fences in the temple of Despoina in Lykosoura, second century BCE).[37] As Fig. 37 shows, such an arrangement would have decreased the intensity of the light coming through. If we were to consider larger and more solid parapets, like those in the temple of Zeus in Olympia (Fig. 38),[38] it becomes evident that these pools were not designed to augment the illumination of the chryselephantine statues.

[36] I thank Dr Johannes Hinrichs for his input and observation. To confirm that a thin layer of water does not reflect more light than the marble underneath, a practical experiment was conducted. The same test was then repeated, this time using unrefined oil, which produced comparable outcomes, with the only noticeable difference being a change in colour.

[37] A more expanded discussion on the shape and form of these parapets is given in de Lara 2023a, 196–205 and 248–54.

[38] See the description of those parapets in de Lara 2023a, 248–53.

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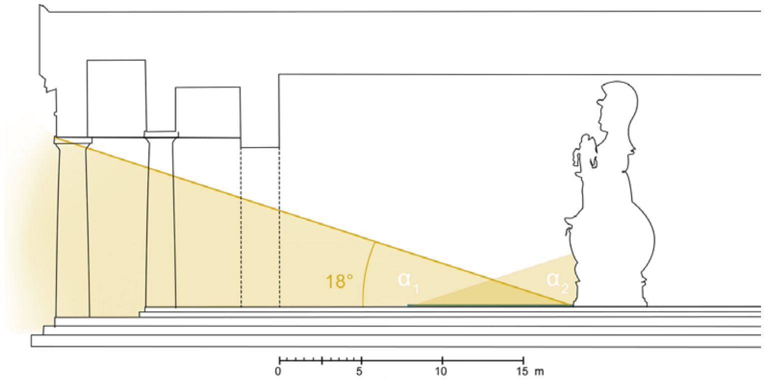

Fig. 36. Side elevation of the Parthenon showing the ideal solar altitude angle (α1) for impact on the pool, and the reflection angle (α2). Render: Juan de Lara.

Fig. 37. Top-down perspective view of the cella's interior showing superimposed sun streaks over the pool for one hour (from 6 to 7 a.m.) on 1 August 430 BCE. A low fence has been placed to demonstrate the blocked surface of sun light over the pool area. Render: Juan de Lara.

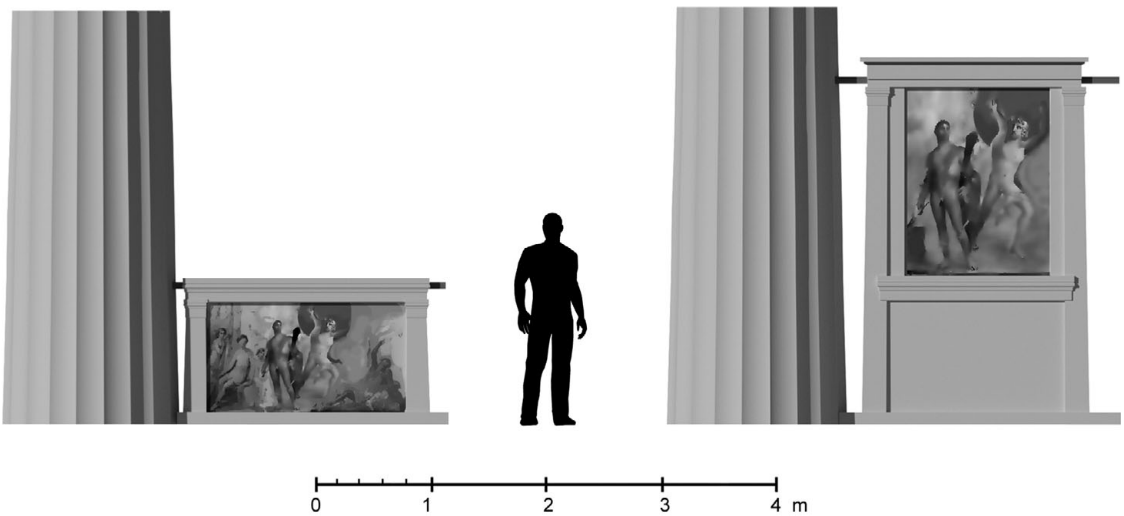

Fig. 38. Elevation showing hypothetical arrangements for the parapets surrounding the pool in the temple of Zeus in Olympia. The left side of the image depicts a low parapet, while the right side shows a high parapet, the most likely option when looking at the evidence. Render: Juan de Lara.

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ILLUMINATION LEVELS FROM WINDOWS AND OPAIA

As anticipated, the renders reveal that the openings of the windows have a notable impact on the overall ambient lighting of the continuous frieze positioned atop the walls and the aisles. Ritual equipment and the frieze may have required additional ambient light as the pi-shaped colonnade significantly blocked the light coming from the door (Fig. 39).[39] These windows managed to increase the illuminance levels on the lateral walls of the temple from 50–100 to 300 lux in the morning (Figs 40 and 41). However, it is important to note that due to the colonnade, the windows did not contribute to the illumination of Athena's statue.

Regarding the roof opaia, a hypothetical set-up with pierced tiles was laid out in our 3D model, demonstrating that the inclusion of sporadic opaia (i.e. one hole per flat tile) in the roof tiles of the Parthenon would have provided only minimal illumination (Fig. 42). An experiment was done with two arbitrary values for comparison. The first test was conducted with a small quantity, 14 pierced tiles over the statue, whereas a second experiment incorporated a hundred openings. The results showed that only one hundred of them would increase the overall illumination of the interior to perceptible illuminance values. Yet the idea of having one hundred, or even hundreds, of tiles with openings goes against the rationale of roofs as impermeable surfaces, and contradicts the archaeological evidence: such pierced tiles cannot be found in modern inventories at Olympia, Athens, or Bassai, despite nineteenth-century travellers documenting their existence. Had they been used extensively, the number of extant finds would have been much higher. Therefore, based on the results, it is unlikely that dozens of opaia were used in this temple. The most logical

Fig. 39. Hypothetical reconstruction of a Doric temple segment, with wall paintings and votive militaria hanging from the wooden beams and the walls. Render: Juan de Lara.

[39] These were likely furniture, storage units, and votive offerings, such as ceremonial crowns and militaria; see Harris 1991; 1995.

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(a) (b)

Fig. 40. Physically based render of the cella's interior on 30 August at 10.00 a.m. showing the amounts of light allowed into the building (a) with windows and (b) without windows. Render: Juan de Lara.

(a) (b)

Fig. 41. Comparative illuminance analysis of Fig. 40. Render: Juan de Lara.

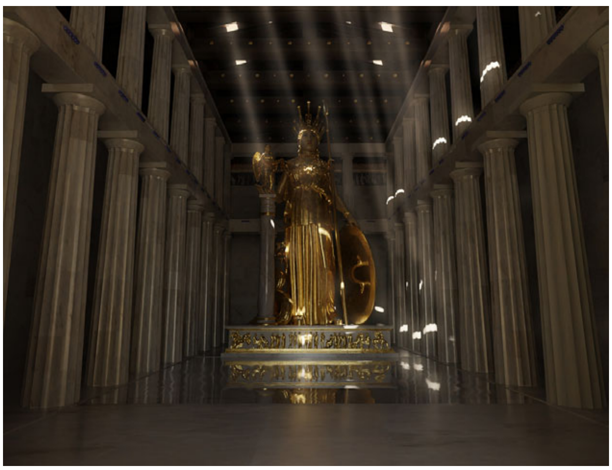

Fig. 42. Physically based render of the cella's interior on 30 August at 10.00 a.m. showing opaia on the ceiling of the temple (coffers have been removed). Render: Juan de Lara.

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interpretation is to think that a few of them existed to illuminate a wooden attic above the cella that was used for storage (Fig. 15), as lamps and fires could not be bought to this area due to the flammability of the construction material.

LIGHT THROUGH MARBLE TILES

The results of the experimentation on translucent marble roof tiles have been more broadly addressed elsewhere, but a summary is provided here (see de Lara 2023b).

An experiment, set solely as a working hypothesis to assess an old theory, tested the illuminance levels under natural light conditions at 11.00 a.m. on 1 August 440 BCE with a cella with coffered ceilings (Fig. 43).[40] In this scene, the main light source was unidirectional from the door and the windows. The physically based render shows a relatively lit interior, where the back of the cella is gradually enshrouded in shadows. The illuminance at the centre of the cella (ambient) was calculated at 200–250 lux.

Simultaneously, further calculations were made under the same conditions but removing the coffered ceiling just for experimental purposes, and bearing in mind the long tradition of arguments that favoured visible roof tiles from the interior. The transmittance level of the Pentelic marble tiles in the roof was set at 0.23 per cent, a figure sourced from the research from Ike and Otaki (1998) and Weigand, García Campos Acosta and Storch de Gracia (2015). The colour of the transmitted light was set at a red tone, in accord with the data provided by the same authors.[41]

The result in this case was that the light transmitted through the tiles increased the illuminance at the centre of the cella from 200–250 lux to approximately 270–280 lux. This is barely a meaningful contribution for the purpose of illumination. It is also worth noting that the little light coming through translucent tiles creates an effect known in rendering as ambient occlusion, which blurs the shadows in the interior, creating a diaphanous space (Figs 44 and 45). Such an effect has the shortcoming of reducing the contrast between light and shadows (*chiaroscuro*), which is unlikely to

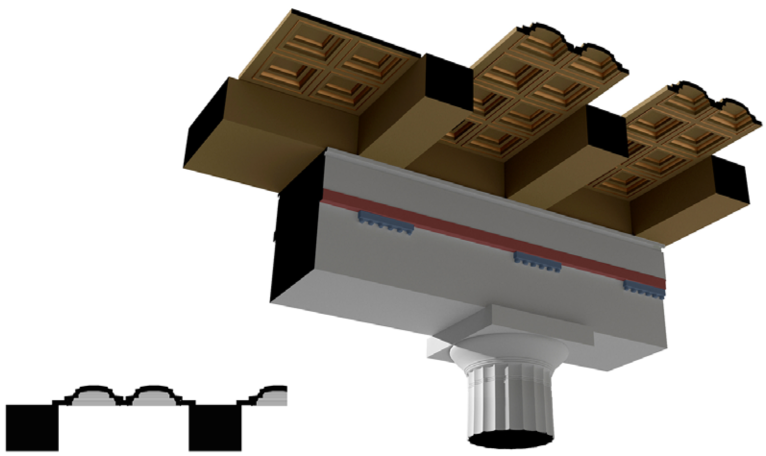

Fig. 43. Perspective view section of the architrave and column segment from the interior colonnade, complete with wooden beams and coffer slabs on top. Render: Juan de Lara.

[40] The time has been set at 11.00 a.m. as this is when the light is sufficient and consistently ambient. Any earlier time could cast sunlight streaks inside the Parthenon, which might confound the resulting render.

[41] RGB (236, 122, 4). This colour model was obtained from the Chromaticity Diagram CIE x=0.57 and y=0.40, determined by Ike and Otaki 1998, 240. See also Weigand, García Campos Acosta and Storch de Gracia 2015.

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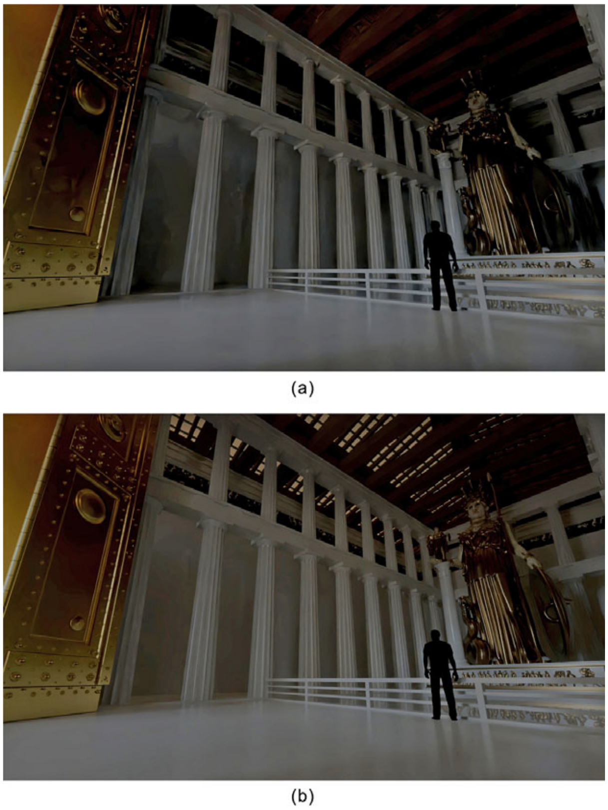

Fig. 44. Physically based render of the cella's interior on 30 May 430 BCE at 8 a.m., captured from the north-east side of the central nave. (a) The interior rendered with a ceiling with coffers. (b) Same as previous but with a ceiling without coffers, exposing marble tiles set up with the equivalent transmittance factor of Pentelic marble. Render: Juan de Lara.

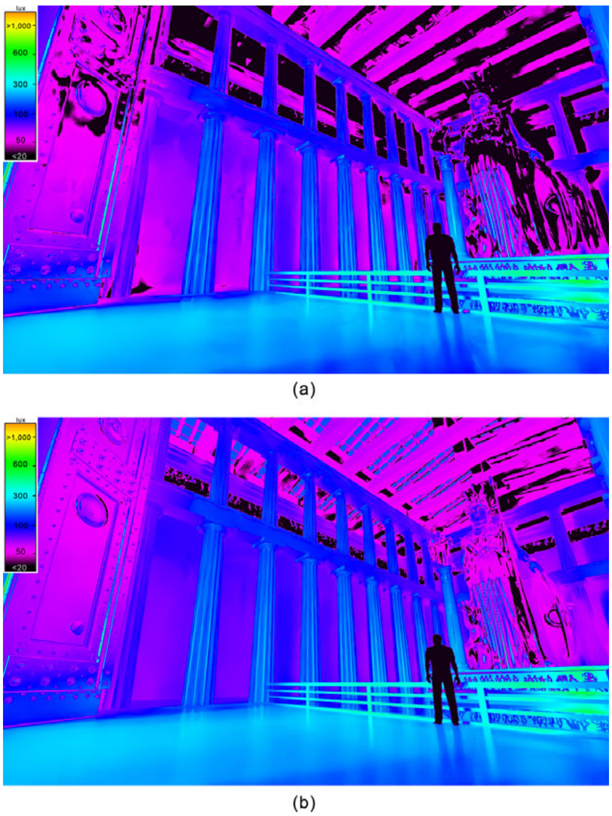

Fig. 45. Illuminance analysis of Fig. 44. Render: Juan de Lara.

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have been a desired effect over the carefully sculpted creases and folds of the statue. Therefore, these marginal results seem to suggest that the use of translucent tiles made of Pentelic marble was not effective to enhance the light within the interior, and contests the bright result achieved by Ike and Otaki.

LAMPS AND OTHER FIRES INSIDE THE PARTHENON

The final experiment assessed the potential impact of artificial light through the use of lamps and torches. This is one of the more contentious and debated issues within this article. And this is because of the scarcity of archaeological evidence and the speculative nature of the use of lamps and torches in temple interiors.

As there is no data on the number of lamps that could have been used in a temple of the size of the Parthenon, only assumptions can be made. Undoubtedly, lamps would have made the interior brighter and more luminous. However, more lamps would have also produced more, and at some point uncontrollable, amounts of smoke and soot. Therefore, a working hypothesis consisted in strategically placing a total of 12 lamps, each with a diameter of 40 cm, with eight nozzles each along the main nave. Ten lamps would be distributed across the long axis, and two would be positioned at the head level of the statue.[42] The lamps were suspended at a height of eight meters above the pavement of the cella. This arrangement, again, is purely speculative and greatly relied on observation of temples in other cultures.[43]

The wicks chosen for the experiment were made of 2 cm width twisted flax, the material that would have been available that has emits the strongest power of visible light (lumens). This choice also determined the light attenuation, or decay factor over distance, a figure that can be obtained from other studies (Moullou and Topalis 2017; Doulos, Moullou and Topalis 2015, 124). The resulting render illustrated the potential illumination achieved by this configuration, encompassing the head of Athena's statue, with an average brightness ranging from 10 to 50 lux, extending to her face. The lower part of the cella remained dimly lit. However, it is important to emphasise that despite the low levels of illumination, this level would have been sufficient to facilitate safe human transit through the cella.

The digital scene was then modified to accommodate torches brought in by a hypothetical group of visitors. Whereas the multitude of lamp flames provided consistent and even illumination, eliminating shadows and reducing contrasts, the torchlight offered a more captivating result. In particular, it generated a highly uplifting effect and a more intense and directional light, capable of casting deeper shadows and highlighting intricacies in the statue's features (Figs 46 and 47). In this case, the surfaces closer to the flame could receive up to 80 lux. Torches were found to have a more pronounced effect on the statue's face than lamps.

Assessing whether the scenario with torches was even plausible is undoubtedly challenging. It could be hypothesised that such visits could have occurred during night vigils for a select group of citizens (see next subchapter). But even if these did occur, they must have been of brief duration: there would have been a need to allow for dispersal of the fumes from the torches. If such visits ever happened, this is perhaps one of the reasons why windows were incorporated, assuming the doors had to be closed for religious purposes.

All in all, the experiment has proven to be of use to demonstrate the potential of an effect, but limited data exists to prove that anything was ever a real scene in such a space.

[42] For a longer discussion on the rationale of such numbers, both for lamps and nozzles, see de Lara 2023a, 344–50.

[43] For example, Indian temples, in which a statue is often a central part of a temple interior, and light is procured in a variety of ways (Eck 1998).

(a)

(b)

Fig. 46. (a) Interior view of the cella with a hypothetical configuration of hanging lamps strategically distributed across the central nave. (b) Closeup of statue of Athena in the cella showing the effect of the same lamp arrangement. Render: Juan de Lara.

LIGHT AND DARKNESS IN GREEK RELIGIOUS EXPERIENCE

The previous physically based three-dimensional reconstructions have revealed that the interior of the Parthenon maintained a subdued illumination during daytime.[44] On a sunny day, the ambient light coming from the door was sufficient to accentuate the fundamental outlines and spatial forms within the interior, namely the colonnade and the statue. This unidirectional light arrangement allowed the ivory veneers and gold plating of Phidias' monumental statue to interact with the incoming light through the doorway on the opposite side. This effect must have given rise to the sensation that the deity, bedecked in her golden attire, emerged from the shrouding darkness.

This analysis has also demonstrated that spectacle-making in the interior of the Parthenon was relatively modest, and was not as sophisticated as modern works have attempted to portray. Firstly, the presence of liquid pools might have been related to rituals rather than illumination –

[44] This atmospheric dimness had already been anticipated by several earlier scholars: Quatremère de Quincy 1818, 170; Fergusson 1883; Korres 1989a; McKean 1997; Williamson 2018.

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(a)

(b)

Fig. 47. (a) Interior of the cella with an imagined gathering of people in the entrance of the cella, some of them holding torches. The scene is meant to illustrate the potential visual impact of torches on the interior illumination of the temple. (b) Closeup view of the statue of Athena and the effect of the illumination by torchbearers. Render: Juan de Lara.

perhaps activities related to the maintenance of the statue, such as washing and anointing (de Lara 2023a, 478–86). Furthermore, Korres sees no reason to doubt the existence of a coffered ceiling,[45] so translucent tiles or opaia were more relevant in the use of the dark attic of this particular structure. In either case, we have demonstrated how opaia could not have contributed to the general illumination of such a large temple. Additionally, the windows served to illuminate areas of the cella where works of art were located, such as the shadowy aisles laden with valuables and decorative friezes. Nonetheless, these windows may have also operated as ventilation channels, addressing the need to extract the copious amounts of smoke from the incense (and/or perhaps lamps) burned in the temple. Of course, ultimately these two functions were not mutually exclusive.

In summation, most of the strategies that have been historically attributed to temple lighting in the Parthenon did not fulfil the function of enhancing the lighting of the temple. Confirmation of the Parthenon as a dimly lit temple introduces a fresh perspective on approaching Greek sacred structures. To provide an analogy for the way in which Greek temples could be studied, a parallel could be drawn with the doctrines of mystical darkness in Egyptian and Indian sacred architecture. These temples have been identified as symbols of the sacred cave, a persistent religious trope replicated across time and

[45] Personal communication with Vasileia Manidaki.

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space as a symbol of creation and the point of emergence of celestial bodies (Eliade 1958/9, 37; Smith 2012, 118). In the Egyptian context, revelatory practices held great significance, as seen in instances where deities were believed to emerge from a primeval dark ocean-womb, acting as the source of light and divine beings (Quirke 1992, 80; Smith 2012, 117; Magli 2017). The expulsion of darkness by light also held profound social, religious and emotional implications within Egyptian religious beliefs (Strong 2018, 185 and 251; 2021, 63–96; Hosny 2020, 37–42).

Scholars have recently highlighted how light and darkness played a role in the worshiping routines of the ancient Greeks, emotionally manipulating the observer's perception (Christopoulos, Karakantza and Levaniouk 2010; Boutsikas 2017). In Boutsikas' view, darkness was an integral element that shaped mystical and religious atmospheres in all sorts of acts of piety. In fact, many Greek acts of worship occurred at night. Ritual observation of cult proceedings during night-time were termed *pannychis*: these ceremonies appear to have shared characteristics with later Christian vigils. Such festivities could be held in the name of various deities, such as Demeter (IG II^2 1363, 17), Dionysos (IG XII 2 499), Artemis (Pausanias 6.22.9), and Athena (at the Panathenaia, including a second vigil that followed the sacrifice and dedication of Athena's new peplos; see IG II^3 1, 447; Shapiro 1992, 56; Lefkowitz 1996, 79; Boutsikas 2020, 51; J.L. Shear 2021). Even though the *pannychides* took place at night, a characteristic that may suggest their mystical nature, they do not seem to have been associated with the negative undertones of darkness. On the contrary, darkness seems to have provided the ritual a sought-after concealment, with the atmosphere being enhanced by the assistance of artificial light (Boutsikas 2020, 51). Other rituals, too, such as the Athenian Arrephoria (Pausanias 1.27.3), or Partheneion in Sparta at the shrine of Artemis Orthia, occurred at night-time (Alcman, *Partheneion* 61, 87).

Certain nocturnal ceremonies relied extensively on torches and lamps, although the evidence is limited.[46] If torches and lamps were indeed introduced into the temple, the internal environment and the magnificent statues must have been radically altered, transforming the visual experience into a radiant spectacle, albeit momentarily, as we have shown. Then, the break of dawn could have signalled the commencement or conclusion of one or another part of the ritual (as seen in Euripides' *Ion* 45, for instance).

To conclude, the experiments and literature discussed here suggest that whenever access was granted to the temple, the vision of the divine statue was filtered through a variety of material and immaterial veils, such as diaphanous grilles, gate thresholds, curtains, parapets, and ultimately darkness. Both natural and artificial light shone and gleamed in the darkness. The occasional shining of the repoussé gold, alongside the reflections of the stone, and the colours, drifting shadows, and kinetic occlusion of smoke, would have created a sensorial stage apt for epiphanies. Within this space, gods were revealed in a multitude of experiences that marked liminal transitions, culminating in the temple's core dramatic experience: the charm in realising the unseen – the gods (Fig. 48).

CONCLUSION

The present study has demonstrated the utility of 3D modelling for assessing questions of illumination and visibility. The result of such a line of inquiry has addressed and illustrated theories related to light that have previously been only approximated. The study reveals that many of these purported tools did not serve to effectively illuminate an interior, which, under natural conditions, was in a rather dim state.

Greek temples have stereotypically been assessed as highly illuminated, highly rational, pristine spaces, with unbroken daylight – the canonical structures of Western civilisation and European Enlightenment. However, these are not accurate reflections but rather tropes of certain eras projected onto ancient Greek realities, in which one can sense the enduring presence of

[46] Parisinou 2000, 136–40. Torchlight in mysteries is more abundant. However, as there is limited knowledge of the rites associated with the Parthenon, and there is no indication of them being considered mysteries, it was a conscious choice not to explore evidence in this context.

Fig. 48. Physically based render reconstruction of the close-up view of Athena holding Nike in her right hand. Render: Juan de Lara.

Winckelmann's neo-classical scholarship and his idealised world of pure light on gleaming surfaces (Stolow and Meyer 2021; Lindberg 1986; Spelman 1997, 12–15; Schützinger, Paparella and Howell 2013; Zwi Werblowsky and Iwersen 2005, 5450). Winckelmann conceived an immaculate world of 'white marble, since white is the colour that reflects the most rays of light, and thus is most easily perceived' (Pater 1837; Winckelmann 2006, 195; Hodne 2020), and believed that the ideal quality of Classical sculpture was best reflected in its marmoreal whiteness (Bruel 1958, 182–3; cf. Dates, Logan and Knudstrup 1945). And it is under these parameters of aesthetic purity that Greek temples seem to have been replicated and copied over centuries.

But we can now have a better grasp at the dynamic and complex conditions of a temple interior such as that in the Parthenon (Fig. 49). Analyses of this nature underscore the significance and benefits of experimentation, particularly through digital means, as a potent tool for exploring the experiential dimensions of architectural spaces. Quatremère de Quincy's words written in 1829 have never resonated as much as they do today:

> [A reconstruction,] far from treating of the intrinsic beauty of the building, has no other purpose than to enable the reader to understand how it was built, and the effect it has on the senses, and to eliminate the prejudices of modern taste […]. (Antoine Chrysostome Quatremère de Quincy 1829, IV)

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Fig. 49 Enriched reconstruction of the interior of the Parthenon. Render: Juan de Lara.

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Φωτίζοντας τον Παρθενώνα

Η αρχιτεκτονική του Παρθενώνα μαρτυρά έναν προσεκτικό σχεδιασμό με ιδιαίτερη μέριμνα για τη χρήση του φωτός. Σε αυτόν τον σχεδιασμό συμπεριλαμβάνονται ο προσανατολισμός του οικοδομήματος, η τοποθέτηση των παραθύρων, η χρήση κιγκλιδωμάτων, οι διαπερατές από το φως μαρμάρινες οροφές, οι φεγγίτες ή ακόμα και οι "αντανακλαστικές" δεξαμενές. Με αυτές τις κατασκευαστικές τεχνικές, σε συνδυασμό και με υλικά που διευκολύνουν τη διάχυση του φωτός στον χώρο, θα μπορούσε να επηρεαστεί η αισθητηριακή εμπειρία των επισκεπτών του ναού και η επαφή τους με το κολοσσιαίο χρυσελεφάντινο άγαλμα της θεάς Αθηνάς. Αποσκοπώντας στον έλεγχο του αποτελέσματος αυτών των υποτιθέμενων μεθόδων φωτισμού, το παρόν άρθρο προτείνει ένα πείραμα που κάνει χρήση προηγμένων ψηφιακών τεχνολογιών, τρισδιάστατης ψηφιακής αναπαράστασης μαζί με προσομοιώσεις φωτισμού βασισμένες σε πραγματικά δεδομένα, για την ανασύνθεση και αναπαράσταση των συνθηκών που επικρατούσαν εντός του ναού. Τα αποτελέσματα του πειράματος, σε αντίθεση με τις προϋπάρχουσες απόψεις που παρουσιάζουν το εσωτερικό του μνημείου ως έναν "φωτεινό μαρμάρινο χώρο", υποδηλώνουν πως ο ναός εσωτερικά ήταν στην πραγματικότητα ένας ιδιαίτερα σκοτεινός με αμυδρό φως χώρος. Τα τελικά συμπεράσματα υποδεικνύουν ότι το αντίκρυσμα του χρυσελεφάντινου αγάλματος υπό το φως ενός λυχναριού και, σε σπάνιες περιπτώσεις, το φως του ήλιου αποτελούσε πιθανότατα το απόγειο της επίσκεψης στον ναό.

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