Preliminary Report on the Absolute Dating of the Khufu Pyramid Using the Relative Erosion Method (REM)

Alberto Donini

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Abstract
In this article, Engineer Alberto Donini presents an innovative method, the "Relative Erosion Method" (REM), which he developed to determine the construction date of ancient structures. He applies this method to the Khufu pyramid on the Giza Plateau. Is it possible that the current archaeological dating of this ancient Egyptian monuments is incorrect? Is it also possible that the alternative dates proposed by various researchers are likewise incorrect? To address these questions, the author analyses the Khufu pyramid from an unconventional perspective in order to determine the most probable period of its construction. The REM is based on the ratio between two types of erosion affecting the same type of rock in the same location: one with a known date and the other with a date to be determined. This ratio is then used to calculate the age of the stone block under examination.

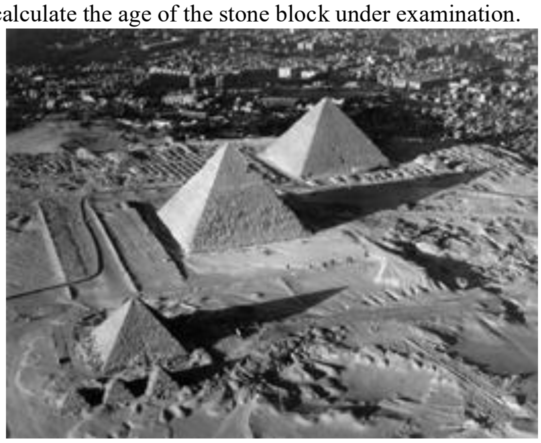

Fig. 1 The Giza Plateau with its famous pyramids.

(*)Note: the small numbers in red and green refer to the sources and references listed on page 10.

I. Brief illustration of the 'Relative Erosion Method' (REM)

In order to obtain a correct order of magnitude for the construction period of ancient buildings, and in particular for the pyramid of Khufu, I conceived the "Relative Erosion Method" (REM).

The idea is as follows: since some of the casing stones of the pyramids of Giza collapsed during catastrophic events, and since the time of their collapse and removal is known (on average, about 675 years ago the limestone casing of the pyramids was removed and reused to construct several buildings in Cairo), I measured the surface erosion of the stones that had been covered by the casing and compared it with that of the adjacent stones, which have remained exposed to atmospheric agents since they were laid at the time of the construction of the monument. The volume of disintegrated material should be proportional to the duration of exposure to erosive processes. From the ratio between these two types of erosion, it is therefore possible to calculate a plausible construction date for the structure.

II. Main causes of erosion

The principal agents of rock erosion are:

- Water: surface runoff and freeze–thaw processes (water freezes in cracks, expands, and fractures the rock).
- Wind: transports sand and dust, progressively abrading rock surfaces (aeolian erosion).
- Temperature: thermal expansion and contraction caused by temperature fluctuations lead to rock fragmentation.
- Gravity: induces landslides, collapses, and rockfalls, causing debris to move downslope.
- Water and gas: slightly acidic rainwater (containing dissolved carbon dioxide) reacts chemically with rock minerals, dissolving them or transforming them into more friable compounds.

- Acids: acid rain, often related to pollution, accelerates corrosion, particularly in carbonate rocks such as limestone.
- Living organisms: plant roots penetrating cracks, lichens, burrowing animals, and acid-producing microorganisms contribute to rock disintegration (biological erosion).
- Salt crystallisation: salts dissolved in water crystallise as evaporation occurs, generating pressure within cracks and causing the rock to fracture; this is especially common in coastal and arid environments.
- Human activity: the passage of people, causing wear of pavements and stone surfaces through abrasion.

III. Morphology of eroded rocks

Pitting erosion

Pitting erosion (or pitting) in rock is a form of point-like degradation that produces small cavities or blind holes on the surface. It is caused primarily by chemical agents (such as salts or acids) and physical agents (including freeze–thaw cycles and plant root action), and is often promoted by the presence of water and dissolved salts. This process typically manifests as clusters of closely spaced holes that can progressively deepen, leading to significant deterioration of the stone material. Pitting erosion represents a type of localized corrosion that affects specific points on the surface, resulting in material loss, and is commonly observed in exposed marble, sandstone, and limestone, particularly in coastal or humid environments.

Uniform erosion

This type of erosion manifests as a smooth or polished surface, or, in some cases, as a layered appearance of the eroded or worn rock.

Fig. 2 Pitting erosion on limestone rock.

Fig. 3 Uniform erosion on limestone rock.

IV. Erosion rate "k"

Rock erosion is directly proportional to the time elapsed when the process occurs at a constant rate, according to the mathematical relationship

$$E = kt$$

in which k represents the "erosion rate" or proportionality constant. This k constant is not universal but depends strictly on the physical properties of the rock and on the climatic context. The main influencing factors include:
- Mineral hardness: for example, rocks such as granite exhibit very low erosion rates.
- Climate: for instance, an increase in the frequency or intensity of precipitation leads to an increase in the value of k
- Exposure: the exposure of the rock surface and its orientation significantly influence the rate of erosion.
- Interpretation of the linear model: if the data are plotted on a Cartesian graph with time t on the x-axis and erosion on the y-axis, a straight line originating at the origin is obtained. The slope of this line is determined by the coefficient k. A steeper slope indicates a faster and more aggressive erosion process over time.

The degradation of a rock is therefore directly proportional to time when the erosion rate k remains constant, resulting in a linear increase in the mass or thickness of material removed, as expressed by the formula

$$E = kt$$

V. Time of demolition of the outer cladding of the pyramids of Giza

Herodotus, in his Histories (Book II) (circa 450 B.C.), describes the Pyramid of Cheops (Khufu) as being covered with smooth limestone slabs that made it shine.

Diodorus Siculus, who lived shortly after the beginning of the Christian era, wrote in his Bibliotheca Historica that the polished white limestone cladding of the Great Pyramid of Cheops was still intact and in perfect condition, with smooth slabs extending down to ground level. The cladding stones were described as "complete and without the slightest decay."

The 13th-century Arab historian Abd al-Latif al-Baghdadi wrote in his works, such as Kitab al-ifada wa al-i‘tibar (Book of the Useful and the Instructive), that the polished white limestone cladding of the Great Pyramid of Cheops was engraved with inscriptions. He described the pyramids as being covered with finely worked white limestone that shone in the sunlight, bearing engraved inscriptions.
The earthquake of Crete on 8 August 1303, an event of approximately magnitude 8.0 with its epicentre between Crete and Rhodes, also affected Cairo and Alexandria in Egypt, causing severe damage and generating a tsunami that devastated the coasts. The seismic tremors loosened and caused some of the white limestone blocks forming the smooth cladding of the pyramids to fall. Several cladding stones broke, and the local population reused these fallen stones as raw material for rebuilding Cairo.
The Mamluk sultan Al-Nasir Hasan (1334–1361) subsequently initiated the systematic removal of the facing stones of the Giza pyramids, using them as building material for palaces and for the decoration of mosques in Cairo.
There is evidence that by the reign of Sultan Barkuk (1382–1399 AD), the pyramids had already been stripped of most of their limestone cladding.
At present, only a few original casing blocks remain: at the base of the Pyramid of Khufu and near the summit of the Pyramid of Khafra.
Thus, the limestone cladding of the Giza pyramids was removed and reused as quarry stone from approximately 1303 to 1400 AD and beyond. On average, therefore, the casing blocks of the Giza pyramids were removed about 675 years ago (as of 2025 AD) and used in the reconstruction of Cairo.

VI. Basic principles of the "REM" method and uncertainty factors

A. I assume linear erosion, i.e. erosion progressing proportionally with elapsed time, and therefore a constant erosion rate k. In other words, the volume of rock removed is assumed to be linearly proportional to the time of exposure to erosive agents. An analysis of the possible causes of erosion shows that this assumption may not be strictly accurate. For example, when erosion creates a small hollow, wind erosion or sand abrasion tends to be less intense at the bottom of the hollow than on the more exposed, uneroded parts of the rock, whereas water erosion, salt crystallisation, or acid rain may be more effective in the hollow. Erosion also varies locally depending on rock morphology, exposure to atmospheric agents, and chemical impurities within the rock. These sources of uncertainty are taken into account in the statistical calculation method.

B. I assume the average date of removal of the limestone casing stones of the Giza pyramids to be approximately 675 years ago. The first casing stones to be removed were those at the base of the pyramids, which are of primary interest for this analysis, followed later by those at higher levels. Clearly, the fall of upper stones onto the base could have caused damage, scratching, or partial removal of material. However, such macroscopic breakages are easily identifiable, and the points selected for analysis appear to have been affected by gradual wear and erosion due to atmospheric or chemical agents, rather than by mechanical breakage.

C. One cause of wear and erosion of the paving is foot traffic. In modern times, thousands of visitors walk on these surfaces every day. Although reliable data for earlier periods are unavailable, foot traffic was most likely far less intense in the past. Consequently, erosion caused by pedestrian activity in recent centuries may have been significantly greater than in ancient times. This factor introduces a variation in the erosion rate k and may lead to an underestimation of the age of the structure.

D. A wetter climate in ancient times, compared to the extremely arid climate of recent centuries, represents another source of uncertainty and may have led to an overestimation of the age of the building.

E. Acid rain, which is essentially a modern phenomenon, may have increased erosion rates in recent times relative to earlier periods, causing a variation in k and potentially leading to an underestimation of the age of the structure to which the method is applied.

F. Measuring average erosion at different points proved challenging, as the rock exhibited substantial variability even within the same block. This factor must therefore be accounted for by adopting a wide tolerance range in the calculated values.

G. An additional source of uncertainty is whether the rock surfaces on which erosion measurements were taken were covered by other rocks or by sand at various times in the past, which would have reduced the effectiveness of the erosive agents considered. Such coverage may have occurred during the dismantling of the limestone casing of the pyramids, i.e. in relatively recent times, but could also have taken place in much earlier periods. For example, the body of the Sphinx was buried under desert sand for many centuries. Similarly, the slopes and contours at the base of the pyramids may have been partially covered for centuries or even millennia.

H. For greater accuracy, erosion should ideally be measured at two different points on the same stone block, assuming substantial constancy or only slow and continuous variation in the physical and chemical properties of the stone subjected to REM analysis. Relative erosion was measured on the same limestone block or in nearby blocks at all analysed points. All blocks on which erosion measurements were performed occupy the same horizontal position (at least originally), that is, they share the same orientation of the rock surface.

I. REM uses the ratio between two types of erosion affecting the same type of rock in the same location—one with a known exposure time and the other with an exposure time to be determined—to calculate the age of the block in question, assuming that the rock surface was initially smooth and un-eroded. In this way, the specific form or mechanism of erosion can be disregarded. Indeed, even if the dominant erosion process were chemical, for example due to dew infiltrating the pores of limestone by capillary action and, upon evaporation, leaving behind crystallising minerals capable of detaching small fragments of rock, this type of erosion—as well as erosion caused by wind, rain, or the trampling of visitors—should be distributed equally over adjacent areas of the same block. It is highly unlikely that dew would form 10 cm to the right but not 10 cm to the left, that wind would erode one side of the same block but not the other at such a small distance, or that rain and foot traffic would selectively affect only one portion of the block. Therefore, regardless of the specific erosive agent responsible for the degradation of the rock, the ratio between the erosion accumulated since the block was initially laid and the erosion accumulated since a known date (675 years ago in the case of the Giza pyramids), measured on the same block, provides a value proportional to the age of the structure under investigation. All these considerations, of course, are subject to the uncertainty factors listed in this chapter.

L. Given the presence of several imponderable factors in the REM that may have altered the erosion rate k over time, I consider the calculated results to be indicative only of the order of magnitude of the construction period, rather than of a precise date. The numerous variables involved may act either in the same direction or in opposition to one another. This implies that, at some of the analysed points, the calculated date may be significantly overestimated or underestimated (when the uncertainty factors act in concert). At other points, however, a correct order of magnitude is obtained (when the uncertainty factors act in opposition and partially cancel each other out). Consequently, a wide variability in the results between individual measurement points is to be expected. The arithmetic mean of a large number of analysed points significantly reduces this error. REM therefore does not provide an exact age, but rather indicates the order of magnitude of the construction period of a building. I also performed a statistical analysis, limited to the two largest pyramids, by determining the standard deviation of each measured value and constructing a Gaussian curve to estimate the probability that the construction date falls within a given time interval. Rather than identifying a precise date, REM is thus useful for determining the order of magnitude of the construction age of a structure with an associated probability.

VII. Criteria for selecting the analysed points

The points analysed using REM were selected in such a way as to allow a direct and close comparison—preferably within the same stone block—between the erosion experienced by the rock since the time of the pyramid's construction and the erosion experienced by the rock since a specific, known date. Where no points were selected on certain sides of the pyramid bases, this was due solely to the impossibility of performing reliable measurements in those areas.

VIII. The points analysed

Fig. 4 Paving at the base of the Pyramid of Khufu at point 1.

Fig. 5 Base of Akhet Khufu with the few remaining limestone blocks of the cladding.

Fig. 4 illustrates one of the analysed points, corresponding to a portion of the northern pavement at the base of the Pyramid of Khufu. The left-hand side of the pavement was originally covered by limestone casing blocks, which were removed approximately 675 years ago, whereas the right-hand side has remained continuously exposed to atmospheric agents since the time of construction and consequently exhibits significantly greater surface erosion. The ratio between the erosion observed on these two adjacent surfaces provides the basis for estimating the construction date of the pyramid.

Fig. 6 The G1 pyramid of Akhet Khufu, with the points where I measured relative erosion marked in red (picture from Googleearth)

IX. Calculation of the construction period based on the volume eroded at each point

At analysis point no. 1 on the Pyramid of Khufu, I calculated the relative erosion of the surface characterised by pronounced roughness and pitting-type erosion by estimating the volume of the eroded recesses. This was done by taking measurements at closely spaced points, some of which had been exposed to erosive agents since the time of construction, and others that were exposed only after the removal of the limestone facing blocks.

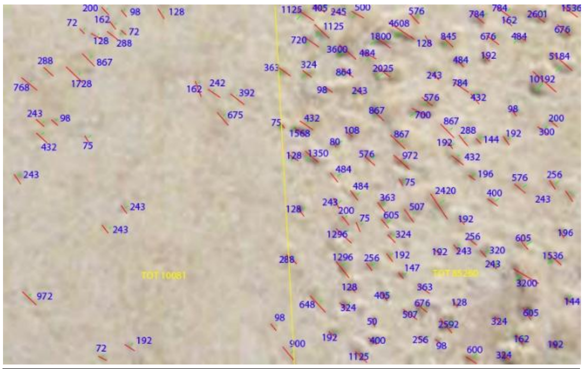

Fig. 7 Calculation of erosion (volume of holes) at point 1: on the left, the part of the limestone paving exposed to erosive agents for approximately 675 years; on the right, the part exposed since the time of construction.

In this image, I calculated the volume, expressed in mm^3, of each erosion cavity, and then the total volume of eroded rock at point 1. The right-hand side has been exposed to erosive agents since the beginning of construction, while the left-hand side has been exposed to erosive agents for approximately 675 years.

1) Calculation of the construction period based on the volume of eroded recesses at Point 1

Total volume of eroded recesses in the continuously exposed section: 85,260 mm^3

Total volume of eroded recesses exposed since 675 years B.P.: 10,081 mm^3

Estimated construction date: 85,260 × 675 / 10,081 = 5,708 years B.P. [1]

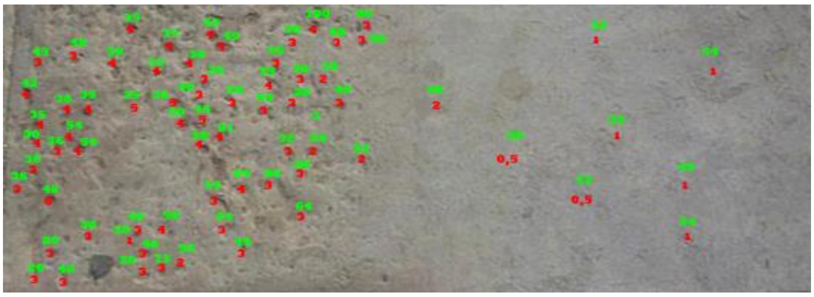

Fig. 8 Calculation of erosion (volume of holes) in point 2: on the right, the part of the limestone pavement exposed to erosive agents for approximately 675 years; on the left, the part exposed since the time of construction.

In this image, the area (highlighted in green) and the depth (highlighted in red) of each recess were calculated and expressed in square millimetres and millimetres, respectively. The total volume of eroded rock at analysis point 2 was then determined. The left-hand side corresponds to the surface that has been exposed to erosive agents since the time of construction, whereas the right-hand side represents the surface that has been exposed to erosive agents for approximately 675 years.

2) Calculation of construction period based on volume of eroded recesses, point 2

Total volume of eroded recesses in exposed part: 9,124 mm3

Total volume of eroded recesses in exposed part 675 years B.P.: 343 mm3

Date of construction: 9,124 x 675 / 343 = 17,955 years B.P.

At point 3, I measured the average erosion of the pyramid paving immediately outside the area formerly covered by the removed casing blocks, and compared it with the average erosion of the paving that lay beneath the removed cladding.

Figs. 9 and 10 Wear of the paving immediately outside the cladding blocks at point 3, in Fig. 11 highlighted in the red rectangle.

A few metres apart, points 3, 4 and 5 show uniform erosion with a smooth or undulating appearance. For these points, I considered the average decrease in thickness, noting wear or erosion of the part of the pavement immediately outside the paving blocks, varying from approximately 15 mm to approximately 45 mm.

3) Calculation of construction period with point 3 consumption

Average erosion over 675 years B.P.: average 1 mm

Average erosion since the beginning: 3 cm = 30 mm

Construction date: 675 x 30 / 1 = 20,250 years B.P.

4) Calculation of construction period with point 4 consumption

Average erosion over 675 years B.P.: average 1 mm

Average erosion since the beginning: 1.5 cm = 15 mm

Date of construction: 675 x 15 / 1 = 10,125 years B.P.

5) Calculation of construction period with point 5 consumption

Average erosion from 675 years B.P.: average 1 mm

Average erosion since the beginning: 4.5 cm = 45 mm

Construction date: 675 x 45 / 1 = 30,375 years B.P.

The procedure described above, together with the corresponding calculations, was applied to each of the twelve analysed points on the Pyramid of Khufu, with each point yielding different yet mutually compatible results. The arithmetic mean of these twelve values represents the most probable estimate for the age of the Pyramid of Khufu.

Fig. 12 Wear on the paving immediately outside the paving blocks at point 6, highlighted in the red oval, and in Fig. 13 in the red rectangle.

6) Calculation of construction period with consumption point 6

Average erosion from 675 years B.P.: 1 – 4 mm, average 2.5 mm

Average erosion since the beginning: 11 cm = 110 mm

Construction date: 675 x 110 / 2.5 = 29,700 years B.P.

Figs. 14 and 15 Wear or erosion of the paving immediately outside the cladding blocks at point 7.

7) Calculation of construction period with consumption point 7

Average erosion from 675 years B.P.: 1 – 4 mm, average 2.5 mm

Average erosion since the beginning: 10 cm = 100 mm

Date of construction: 675 x 100 / 2.5 = 27,000 years B.P.

Fig. 16 Wear or erosion of the paving immediately outside the cladding blocks at point 8, and, in Fig. 17, at point 9.

8) Calculation of construction period with consumption point 8

Average erosion from 675 years B.P.: 1 – 4 mm, average 2.5 mm

Average erosion since the beginning: 17 cm = 170 mm

Date of construction: 675 x 170 / 2.5 = 45,900 years B.P.

9) Calculation of construction period with consumption point 9

Average erosion from 675 years B.P.: 1 – 4 mm, average 2.5 mm

Average erosion since the beginning: 20 cm = 200 mm

Date of construction: 675 x 200 / 2.5 = 54,000 years B.P.

10) Calculation of construction period with consumption point 10

Average erosion from 675 years B.P.: average 1 mm

Average erosion from the beginning: 2 cm = 20 mm

Date of construction: 675 x 20 / 1 = 13,500 years B.P.


Fig. 18 Wear or erosion of the paving immediately outside the cladding blocks at point 10, and, in Fig. 19, at point 11.

11) Calculation of construction period with consumption point 11

Average erosion from 675 years B.P.: 1–5 mm, average 3 mm

Average erosion since the beginning: 10 cm = 100 mm

Date of construction: 675 x 100 / 3 = 22,500 years B.P.


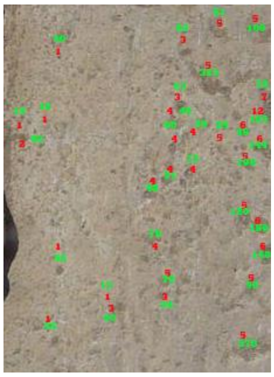

Fig. 20 The difference in erosion at point 12 between the right side (which has been exposed since the pyramid was built) and the left side.
Fig. 21 Calculation of erosion (recess volume) at point 12.

12) Calculation of construction period based on volume of eroded recesses at point 12

Total volume of eroded recesses in exposed part: 13,072 mm3

Total volume of eroded recesses in exposed part 675 years B.P.: 396 mm3

Date of construction: 13,072 x 675 / 396 = 22,281 years B.P.

Arithmetic mean μ of the 12 values calculated for the G1 pyramid of Akhet Khufu

μ = (5,708 + 17,955 + 20,250 + 10,125 + 30,375 + 29,700 + 27,000 + 45,900 + 54,000 + 13,500 + 22,500 + 22,281) / 12 = 24,941 years B.P. = 22,941 B.C.

Standard deviation σ = 13,962   Z score: (x - μ) / σ

-1,37	-0,50	-0,33	-1,06	0,38	0,34	0,14	1,50	2,08	-0,81	-0,17	-0,19

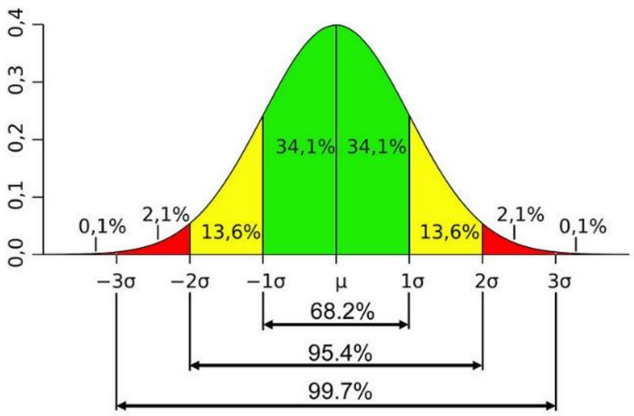

Fig. 22 Gaussian curve showing the 68.2% probability that the value will fall within plus or minus one standard deviation [1]

Therefore, regarding the dating of the G1 pyramid of Akhet Khufu calculated based on REM, I have a 68.2% probability that it is between (μ - σ) and (μ + σ), i.e. (24,941 - 13,962) and (24,941 + 13,962).

There is a 68.2% probability that the construction period of the G1 pyramid of Akhet Khufu is between 10,979 and 38,903 years B.P., with an average of 24,941 years B.P.

68.2% probability that the G1 pyramid of Akhet Khufu was built between 8,954 B.C. and 36,878 B.C., with an average of 22,916 B.C.

X. Conclusions of the Preliminary Report

These conclusions are preliminary and will be further investigated through additional measurements, extended to all structures and buildings on the Giza plateau. It is always possible to improve measurement accuracy, the determination of eroded volumes, and the overall precision of the results.

Alberto Donini intends to continue his research and invites archaeologists from around the world to collaborate in future studies.

REM is not intended to determine a precise construction date for an ancient building; rather, it identifies a temporal interval and assigns a probability to it. Although the resulting date ranges are wide, the conclusions indicate a low probability for the official archaeological dating of 2,560 B.C. For these reasons, it is likely that the pyramids of Akhet Khufu (G1) date back to approximately 23,000 B.C. It is therefore plausible that the pharaoh Cheops merely renovated the Khufu pyramid, attributing its authorship to themselves.

On the basis of this preliminary report on relative erosion measurements (REM) carried out on the Khufu pyramid, it can be concluded that around 20,000 years before Christ there existed a civilisation in Egypt capable of constructing at least the Khufu pyramid (G1).

20/01/2026

Alberto Donini

Sources

[1] https://www.senhormercado.com.br/bolsa-de-valores-e-videogames/curva-de-gauss-bovespa/

References

[1] B.P. = Before Present.

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