

Lifting the Stones of a Pyramid Is Not the Bottleneck

— Raising **2.3** million blocks to a height of **146.6** m takes **2.0666×10^{12}** J, which over twenty years averages **3274.3759** W — In people, that is **127.57** — The friction of a ramp costs **3** times the lifting, and that ratio is the closed form μ/s — [Paper 362]

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— *From thinking to syncing.* —

Abstract

The puzzle of the pyramids is posed as “how did they lift the stones”. This paper asks how much work lifting them takes—the answer is surprisingly little, and that is not where the bottleneck is. No new mathematical theorem and no new law is claimed. First, 2.3×10^6 blocks of 2500 kg give a total mass of **5.75×10^9** kg (Section 2). Second, a pyramid’s centroid sits at $H/4 = 36.65$ m, giving a potential energy of **2.0666×10^{12}** J (Section 2). Third, this is the core of the paper. Over twenty years that averages **3274.3759** W, which in people is only **127.57** (Section 3). Fourth, dragging up a ramp of slope 0.10 with friction 0.3 costs **3.0000** times the lifting (Section 4). Fifth, that ratio is the closed form μ/s and does not depend on the pyramid’s size at all (Section 4). Sixth, the separator is conservative work against path-dependent work (Section 5).

Scope of this paper (scope note): No new mathematical theorem and no new law is claimed——potential energy, the centroid of a pyramid, and frictional work are all standard. We do not build archaeology——which construction method was used (straight ramp, spiral ramp, internal ramp) is not judged. They are named and no more. We do not argue dates——estimating the construction period is not the subject. Twenty years is used as an assumption, stated. We do not discuss labour——the status, diet, and organisation of workers are not the subject. Stonework is not treated——quarrying, dressing, and haulage technique are not the subject. Only sizes of work are compared. Structure is not treated——stresses and stability are not the subject. Relation to earlier papers: Paper 357 showed maximum power and maximum efficiency to be different points——there the question was where an effect acts; here it is where the bottleneck is. Paper 359 showed the gyroscope to be orders too small——there an explanation failed on magnitude; here the question itself does. Paper 300 showed whether two things share a root is decidable——by that test, lifting work and dragging work have distinct roots. Paper 354 showed a mismatched ruler producing a divergence——here a mismatched question produces a “mystery”. What is added is giving the total potential energy as a number, converting the average power into 127.57 people, showing that the ratio to frictional work is the closed form μ/s , confirming the formula by the exact doubling that a mistaken $H/2$ centroid would give, and putting the separator on conservative against path-dependent.

1. Notation and the Question

Setting: Take $N = 2.3 \times 10^6$ blocks of mass $m = 2500$ kg and a height $H = 146.6$ m.

$$M = Nm, \quad E = Mg\frac{H}{4}, \quad \bar{P} = \frac{E}{T}$$

using the fact that a pyramid’s centroid lies at $H/4$ above the base. T is the construction period.

Observation 1.1

The centroid is not at $H/2$. A pyramid narrows upward, so its mass is weighted low——the centroid of a uniform pyramid is at $H/4$.

Observation 1.2

Lifting work does not depend on the path. Gravity is conservative, so any route costs $Mg\Delta h$ ——ramp or vertical, the same.

Observation 1.3

Frictional work is not like that. The longer the path, the more it costs—that difference is the content of Section 4.

Question: How much work is it to lift the stones?

2. The Potential Energy Is 2.0666×10^{12} J

Calculation 2.1: Total mass and potential energy (computed in this paper).

Quantity	Value
Number of blocks	2.3×10^6
Mass per block	2500 kg
Total mass M	5.7500×10^9 kg
Centroid height $H/4$	36.6500 m
Potential energy E	2.0666×10^{12} J

Observation 2.2

2.0666×10^{12} J looks like a large number. 574063.58 kWh, or 493.9362 tonnes of TNT—changing units changes the impression. So divide by time.

Observation 2.3

574063.58 kWh is a 100 W bulb left on for 654.9 years. 5.7406×10^6 hours—that is the total of twenty years of stacking.

Observation 2.4

The centroid matters. Take it as $H/2$ and the answer doubles exactly—a check that the formula is doing the work.

3. In People, 127.57

Calculation 3.1: Average power, and its conversion into people (computed in this paper).

Quantity	Value
Construction period (assumed)	20 years = 6.3115×10^8 s
Average power $\bar{P}$	3274.3759 W
Mechanical output while working	75 W
Duty (10 h/day, 300 days/year)	annual mean 25.6674 W
People required	127.57

Observation 3.2

This is the core of the paper. 127.57 people—take only the lifting out of a project thought to have mobilised tens of thousands, and this is all that is left.

Observation 3.3

So “how did they lift them” is not the centre of the puzzle. The total work is comfortably available—if there is a puzzle, it is somewhere else.

Observation 3.4

The force per block is a separate matter. Lifting 2500 kg takes 24517 N—a small total energy and a light single action are different things. Power and force are not to be mixed.

Observation 3.5

The same shape as Paper 359. There the gyroscopic explanation failed on order of magnitude—here the “lifting puzzle” does. In both, a conversation continued without anyone checking the size.

4. Friction Costs Three Times the Lifting

Calculation 4.1: Dragging up a ramp of slope $s = 0.10$ with friction $\mu = 0.3$ (computed in this paper).

Quantity	Value
Lifting work E	2.0666×10^{12} J
Frictional work E_{fric}	6.1999×10^{12} J
Ratio	3.0000
Closed form	μ/s

Observation 4.2

The ratio equals μ/s exactly. $0.3/0.10 = 3$ —independent of the number of blocks, their mass, and the height. The size of the pyramid cancels.

Observation 4.3

A gentler ramp is worse. At 0.05 the frictional work exactly doubles—an “easier” slope lengthens the path and raises the total work.

Observation 4.4

Here is a design trade. A gentler ramp lowers the force needed at any moment and raises the total work—the same shape as maximum power and maximum efficiency sitting at different points in Paper 357.

Observation 4.5

It is also why reducing friction pays. Taking μ from 0.3 to 0.1 takes the ratio from 3 to 1—wetting the sand, using sledges, laying timber: each cuts the total work to a third.

Observation 4.6

To be stated honestly— $\mu = 0.3$ and $s = 0.10$ are assumptions made here. The actual values are not known—what can be said is the structure: the ratio is fixed by μ/s and does not depend on size.

5. The Separator: Conservative, or Path-Dependent?

Observation 5.1

The separator—whether the work is independent of the path or proportional to its length.

	Path dependence	Size	How to reduce it
Lifting (gravity)	none	2.0666×10^{12} J	cannot (fixed by height)
Dragging (friction)	proportional	6.1999×10^{12} J	lower μ , steepen the ramp

Observation 5.2

The rightmost column is the whole of practice. The top row cannot be reduced—the bottom row can, so every technique aims at the bottom row.

Observation 5.3

Distinct roots by the criterion of Paper 300. Both are measured in joules and both are called “work”—but one is a difference of a state function and the other a path integral. The same shape as P and Q differing in Paper 356.

Observation 5.4

The separator can be moved. Lift vertically and the friction term vanishes——at the cost of the largest instantaneous force. Which to take is decided by the limits of hands and tools.

Observation 5.5

To be stated honestly——127.57 people and the factor 3.0000 are values on assumptions stated explicitly. Change the block count, the period, or the working hours and other numbers follow——what does not move is that lifting work is path-independent and that the ratio to friction is μ/s .

Observation 5.6

One last thing——before asking “how”, it is worth computing “how much”. The lifting totals 127.57 people, and there was no mystery there——pose a question without checking the size and you can dig for decades in a place that was never the bottleneck.

6. The Census and the Close

1. Total mass 5.7500×10^9 kg (Calculation 2.1): 2.3×10^6 blocks of 2500 kg.
2. Centroid 36.65 m above the base (Observation 1.1): $H/4$, not $H/2$.
3. Potential energy 2.0666×10^{12} J (Calculation 2.1): 574063.58 kWh.
4. Average 3274.3759 W (Calculation 3.1): divided over twenty years.
5. 127.57 people (Calculation 3.1): for the lifting alone.
6. 24517 N per block (Observation 3.4): total and single action are different.
7. Friction 6.1999×10^{12} J (Calculation 4.1): 3.0000 times the lifting.
8. The ratio is μ/s (Observation 4.2): independent of size.
9. Halving the slope doubles friction (Observation 4.3): an easier slope costs more.
10. A mistaken $H/2$ doubles it exactly (Observation 2.4): the formula is doing the work.

Closing: The puzzle of the pyramids is posed as “how did they lift the stones”——but it is worth computing how much work that is first. 2.3×10^6 blocks of 2500 kg give a total mass of 5.75×10^9 kg——a pyramid narrows upward, so its centroid lies not at $H/2$ but at $H/4 = 36.65$ m, and the potential energy is 2.0666×10^{12} J, or

574063.58 kWh. Take the centroid as $H/2$ and the answer doubles exactly. Over twenty years that averages only **3274.3759 W**——a person working at 75 W for 10 hours a day, 300 days a year, averages 25.6674 W over the year, so the lifting alone needs **127.57** people. Take only the lifting out of a project thought to have mobilised tens of thousands, and this is all that is left. The force per block is a separate matter — lifting 2500 kg takes 24517 N — and power and force are not to be mixed. The bottleneck is in the dragging——up a ramp of slope 0.10 with friction 0.3, the frictional work is **6.1999×10^{12} J**, **3.0000** times the lifting. And that ratio equals μ/s exactly: independent of the number of blocks, their mass, and the height. The size of the pyramid cancels. A gentler slope of 0.05 exactly doubles the frictional work — an “easier” ramp lengthens the path and raises the total. Conversely, taking μ from 0.3 to 0.1 takes the ratio from 3 to 1, so wetting the sand, using sledges and laying timber each cut the total work to a third. One thing separates them——whether the work is independent of the path or proportional to its length. Lifting work is fixed by height and cannot be reduced; frictional work can, so every technique aims there. Both are measured in joules and both are called “work”, but one is a difference of a state function and the other a path integral — distinct roots by the criterion of Paper 300. To be said honestly—— $\mu = 0.3$, $s = 0.10$ and the twenty years are assumptions made here, and the actual values are not known. What does not move is that lifting work is path-independent and that the ratio to friction is μ/s . One last thing——before asking “how”, it is worth computing “how much”. The lifting totals **127.57** people, and there was no mystery there. Pose a question without checking the size and you can dig for decades in a place that was never the bottleneck.

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