The Size of a Crater Records Almost Nothing of the Violence That Made It

— Where gravity governs, the diameter grows only as the **1/3.4** power of the energy: a millionfold energy gives **58.170913** times the diameter, and a billionfold only **443.668733** times — the separator is whether gravity or strength governs — [Paper 681]

Yuuki YAMAGISHI (山岸 勇輝)
Yamagishi Complexity Torus Lab, Japan
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— *From thinking to syncing.* —

Abstract

A crater is taken to record an impact. But its diameter grows only as the 1/3.4 power of the energy, so a millionfold difference shows up as a factor of fifty-eight.What is recorded and what is lost is counted here from the exponent.No new theorem or law is claimed. First, and this is the core. The diameter keeps almost none of the difference in energy——a millionfold energy gives 58.170913 times the diameter and a billionfold only 443.668733 times (Section 2). **Second, read backwards, a slightly larger hole costs an enormous energy——doubling the diameter takes 10.556063 times the energy, tripling it 41.899830 times, and a tenfold diameter 2511.886432 times** (Section 2). **Third, geometry does not fix the exponent——were the excavated volume simply proportional to the energy it would be 1/3, but where gravity governs it is 1/3.4, that is 0.294118** (Section 2). **Fourth, the two exponents drift apart as the scale grows——at a thousandfold energy the two predictions stand in a ratio of 1.311134, at a millionfold 1.719072, at a billionfold 2.253934 and at a trillionfold 2.955209** (Section 3). **Fifth, so a relation fitted on small craters must not be carried upward——a difference of 0.039216 in the exponent becomes a discrepancy of more than a factor of two over nine decades of extrapolation** (Section 3). **Sixth, the separator is whether gravity or strength governs——whether the digging is resisted by the strength of the material or by the weight of what must be lifted out. That difference changes the exponent** (Section 4). **Keywords**: impact crater, scaling relation, gravity regime, strength regime, power-law exponent, risk of extrapolation.

> **Scope of this paper (scope note)**: **No new theorem or law is claimed——crater scaling and the distinction between the gravity and strength regimes are standard (Melosh 1989, Holsapple 1993).No real crater is identified——the age, distribution and origin of particular craters are not treated.No impact calculation of my own is made——the exponent $1/3.4$ is taken as a representative value and moves with the properties of the target, the gravity and the angle of impact.Morphology is not discussed——the transition to complex craters with central peaks and terraced walls, and the collapse of rims, are not the subject.No hazard is assessed——probabilities of impact and estimates of damage are not made.Relation to earlier papers**: **Paper 326 showed that the square-cube "law" is not a law but an identity, the exponent $2/3$ following from geometry alone——there geometry fixed the exponent; here the $1/3$ that geometry offers does not hold, and the exponent is fixed by the mechanism, gravity or strength.**What is added is **tabulating factors of energy against factors of diameter**, **inverting that to the energy a given diameter costs**, **setting the two predictions against each other at each scale**, **putting the difference of 0.039216 in the exponent into numbers under extrapolation**, and **placing the separator on whether gravity or strength governs**.

1. Notation and the Question

Setting: **let the diameter D of a crater grow as a power of the impact energy E. Where gravity governs the exponent is about $1/3.4$; where the strength of the material governs it is $1/3$.**

$$D \propto E^{\,\alpha}, \qquad \alpha_{\text{gravity}} = \frac{1}{3.4} = 0.294118, \qquad \alpha_{\text{strength}} = \frac{1}{3} = 0.333333$$

Multiplying the energy by k multiplies the diameter by k^{α}; multiplying the diameter by m costs $m^{1/\alpha}$ in energy.

Question: **how much of what does the diameter of a crater actually record?**

2. The Diameter Keeps Almost Nothing

Computation 2.1: **the factor in diameter was derived for each factor in energy.**

energy	diameter (gravity)	diameter (strength)
10	1.968419	2.154435
100	3.874675	4.641589
1000	7.626986	10.000000
10^6	58.170913	100.000000
10^9	443.668733	1000.000000

> **Observation 2.2**
>
> this is the core: the diameter records the energy compressed in decades.Nine decades of energy appear as about two and a half decades of diameter——whoever reads the size of a hole for “how violent it was” has already lost most of the decades.

Computation 2.3: inverted, doubling the diameter costs 10.556063 times the energy, tripling it 41.899830 times and a tenfold diameter 2511.886432 times. In the strength regime the same three cost 8.000000, 27.000000 and 1000.000000 times.

> **Observation 2.4**
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> geometry does not fix the exponent.Were the excavated volume simply proportional to the energy, the diameter would grow as $E^{1/3}$. It is $1/3.4$ under gravity because the material dug out must also be lifted, and the larger the hole the more that costs——a small difference in the exponent is where the mechanism is written down.

3. The Two Exponents Drift Apart

Computation 3.1: the ratio between the two predictions was derived at each energy.

energy	gravity	strength	ratio
1000	7.626986	10.000000	1.311134
10^{6}	58.170913	100.000000	1.719072
10^{9}	443.668733	1000.000000	2.253934
10^{12}	3383.855153	10000.000000	2.955209

Observation 3.2

a difference of 0.039216 in the exponent acts in proportion to the distance extrapolated.Disagreements between powers open with the number of decades, not with the factor——three decades give 1.311134 and twelve decades give 2.955209.

Observation 3.3

a relation fitted on the small side must not be carried to the large.Craters made in a laboratory are small, and there strength governs; the large craters on planetary surfaces are governed by gravity——outside the fitted range, which exponent was used changes the answer by more than a factor of two.

4. The Separator

Observation 4.1

the separator is whether gravity or strength governs.If the digging is resisted by the strength of the material the exponent is $1/3$; if by the weight of what must be lifted out it approaches $1/3.4$——the single phrase “crater scaling” names two mechanisms at once.

Observation 4.2

beside Paper 326.Paper 326 showed the square-cube “law” to be an identity, its exponent $2/3$ following from geometry alone——there geometry fixed the exponent; here the $1/3$ offered by geometry does not hold and the mechanism fixes it instead. An exponent that is an identity and an exponent that records a mechanism are different objects.

Observation 4.3

what is not said.No real crater is identified, no complex morphology is treated and no hazard is assessed——what is shown is what follows from the exponent departing slightly from $1/3$.

5. Roll Call and Closing

1. **58.170913 at a millionfold** (Computation 2.1): **the core.**
2. **443.668733 at a billionfold** (Computation 2.1): **decades compressed.**
3. **doubling costs 10.556063** (Computation 2.3): **the price inverted.**
4. **tenfold costs 2511.886432** (Computation 2.3): **suddenly expensive.**
5. **the gravity exponent 0.294118** (Section 1): **one over 3.4.**
6. **strength gives exactly 8 for doubling** (Computation 2.3): **as geometry says.**
7. **ratio 1.311134 at a thousandfold** (Computation 3.1): **still close.**
8. **ratio 1.719072 at a millionfold** (Computation 3.1): **drifting.**
9. **ratio 2.955209 at a trillionfold** (Computation 3.1): **do not extrapolate.**
10. **gravity or strength** (Observation 4.1): **the separator; Paper 326.**

Closing: **The size of a crater records almost nothing of the violence that made it.A millionfold energy gives 58.170913 times the diameter, a billionfold only 443.668733 times——nine decades folded into about two and a half.Read backwards, doubling the diameter costs 10.556063 times the energy and a tenfold diameter 2511.886432 times.Geometry does not fix the exponent——volume alone would give $1/3$, but under gravity it is $1/3.4$, that is 0.294118.The two exponents drift apart with the decades extrapolated: a ratio of 1.311134 at a thousandfold becomes 2.955209 at a trillionfold——a relation fitted on small craters must not be carried to large ones.The separator is whether gravity or strength governs.Placed among the earlier papers——in Paper 326 the exponent was**

an identity of geometry; here it is a record of a mechanism.To be honest——the exponent $1/3.4$ is a representative value and no impact calculation of my own was made.

References

1. Holsapple, K. A. (1993). The scaling of impact processes in planetary sciences. *Annual Review of Earth and Planetary Sciences*.
2. Melosh, H. J. (1989). *Impact Cratering: A Geologic Process*. Oxford University Press.
3. Yamagishi, Y. (2026). *The Square-Cube "Law" Is Not a Law but an Identity* [Paper 326]. Zenodo. 10.5281/zenodo.22209992

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Yuuki YAMAGISHI (山岸 勇輝)

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