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Parameters, Mechanisms, and Implications  
December 2025  
Abstract  
What frequencies would actually work? What amplitudes are required? What power levels are involved? These are fair questions, and the answers are surprisingly specific. Modern ultrasonic machining operates at 20–28 kHz with amplitudes of 5–25 micrometers, achieving material removal rates up to ten times conventional methods. Friction reduction peaks at 26 kHz with amplitudes as small as 0.35 micrometers. Piezoelectric resonance in granite occurs at frequencies dependent on sample dimensions, typically in the hundreds of kilohertz range. This document explores the technical parameters of vibrational stone working, examining how they might constrain—or enable—ancient applications.  
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# The Frequencies That Cut Stone

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## 1 The Question of Plausibility

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Every hypothesis deserves scrutiny, and the vibrational stone-working hypothesis faces a reasonable objection: ancient builders did not have oscilloscopes, frequency generators, or electrical power supplies. How could they achieve the precise parameters that modern engineering specifies?

The question is fair. The answer is more nuanced than it might appear.

Modern engineering optimizes for industrial efficiency—maximum material removal with minimum power consumption, maximum precision with minimum wear. Ancient methods need not have met these criteria. They could have been slower, less efficient, more labor-intensive, and still have achieved results impossible by purely mechanical means.

A process that is 10% as efficient as modern ultrasonic machining would still be revolutionary if the alternative is “cannot be done at all.”

This document explores the technical parameters of vibrational stone working, not to claim that ancient builders matched modern specifications, but to understand the physical constraints that any vibrational approach must satisfy.

## 2 Friction Reduction: The Numbers

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### 2.1 What Luo's Experiments Show

In 2024, Luo and colleagues published precise measurements of friction reduction under ultrasonic vibration. Their experiments used aluminum oxide-copper sliding pairs with controlled normal loads, measuring friction coefficients under both static and vibrating conditions.

The key parameters:

**Frequency:** 26 kHz (26,000 cycles per second)

**Amplitude:** 0.35 micrometers (about 1/200th the width of a human hair)

**Normal Load:** 60 N (approximately 6 kg of force pressing the surfaces together)

**Friction Reduction:** 89% under dry conditions

The mechanism is straightforward: ultrasonic vibration causes the normal force to oscillate. During each cycle's low-normal-force phase, relative motion occurs with minimal resistance. The surfaces “walk” past each other through accumulated microslippage.

At 26,000 cycles per second, these microscopic advances happen faster than static friction can re-establish itself.

## 2.2 Scaling to Stone Transport

What would this mean for moving a megalithic block?

Consider a 70-ton limestone block. Under static conditions with a friction coefficient of 0.6 (typical for stone on stone), the force required to initiate sliding would be approximately 412 kilonewtons—the equivalent of lifting 42 tons against gravity.

With 89% friction reduction, this drops to approximately 45 kilonewtons—the equivalent of lifting 4.6 tons.

From the workers' perspective, a stone that "weighs" 4.6 tons is dramatically more manageable than one that effectively weighs 42 tons. A team of 100 workers pushing with 50 kg of force each generates 49 kilonewtons—just barely enough to move the vibrating stone, utterly insufficient for the static case.

The question becomes: could ancient builders generate 26 kHz vibration with 0.35 micrometer amplitude?

Honestly? Probably not at those exact specifications. But the relationship between frequency, amplitude, and friction reduction is not all-or-nothing. Popov's theoretical work shows that friction reduction increases with vibration amplitude and frequency, but it exists across a wide range of parameters. A less optimal frequency or smaller amplitude would yield less friction reduction—perhaps 50% instead of 89%—but any reduction is significant when moving massive stones.

## 3 Ultrasonic Machining: The Cutting Edge

### 3.1 Modern Industrial Parameters

Rotary ultrasonic machining (RUM) is a mature industrial technology, and its parameters are well documented:

**Frequency Range:** 18–28 kHz (typically 20 kHz for industrial equipment)

**Amplitude:** 5–25 micrometers (depending on application)

**Power:** 50 W for precision work up to 10 kW for industrial cutting

**Material Removal Rate:** 4–10 times conventional machining for hard, brittle materials

**Surface Quality:** Superior to conventional machining; reduced subsurface damage

The mechanism involves abrasive particles (typically diamond, boron carbide, or silicon carbide) suspended in a slurry or bonded to the tool surface. Ultrasonic vibration causes these particles to impact the workpiece thousands of times per second, each impact removing microscopic material.

For drilling, the tool vibrates axially while rotating. The vibration provides the impact energy; the rotation provides chip clearance and fresh abrasive exposure. Together, they achieve cutting rates that neither method alone could approach.

### 3.2 The Ancient Drill Core Problem

Petrie calculated that ancient Egyptian tube drills penetrated granite at rates requiring axial loads of “one or two tons” on the drill—loads that would shatter copper tubes long before achieving useful penetration.

But this calculation assumes conventional abrasive cutting: the drill grinds material away through sustained contact, and the cutting rate depends on pressure and speed.

Ultrasonic machining follows different physics. Material removal depends on impact energy and frequency, not sustained pressure. A vibrating drill with modest normal force can achieve cutting rates impossible for a static drill under any load.

More importantly, ultrasonic machining in quartz-bearing rock benefits from piezoelectric amplification. The quartz crystals embedded in granite are themselves resonators. At the right frequency, they oscillate sympathetically, converting acoustic energy into mechanical vibration at the molecular level. The rock participates in its own destruction.

This is why the Petrie cores show faster cutting through quartz than through feldspar. The quartz is not just being drilled; it is vibrating itself apart.

## 4 Piezoelectric Resonance: The Rock That Shakes Itself

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### 4.1 The Saksala Finding

In 2023, Saksala and colleagues at Tampere University demonstrated that piezoelectric resonance weakens granite by 10% at the sample’s natural resonant frequency.

Their test conditions:

**Sample:** Cylindrical granite cores containing quartz, feldspar, and mica

**Resonant Frequency:** 274.4 kHz (sample-dependent; function of size and mineral composition)

**Driving Method:** High-frequency, high-voltage alternating current

**Effect:** 10% reduction in compressive strength at resonance

This is not large enough to explain stone cutting by itself, but it shifts the balance. In a cutting process where hard quartz normally resists abrasion while softer feldspar yields, piezoelectric weakening can reverse the relationship. The quartz becomes relatively easier to remove; the feldspar becomes relatively harder to cut.

The resonant frequency depends on sample dimensions. Larger samples resonate at lower frequencies; smaller samples at higher. The 274.4 kHz frequency in Saksala's experiments applied to cores approximately 10 cm in diameter. Different geometries would resonate at different frequencies.

This actually helps the ancient-technology hypothesis. A consistent external frequency would interact differently with different grain sizes in the rock, but some grains would always be near resonance. The effect would be distributed across the cutting zone rather than concentrated at a single frequency.

## 4.2 What Frequencies Would Ancient Chambers Produce?

Research on megalithic chambers has documented resonant frequencies in the 95–120 Hz range:

- Malta Hypogeum Oracle Room: 114 Hz amplification of male voices
- Newgrange: 110 Hz standing wave formation
- Wayland's Smithy: 112 Hz resonance
- Various dolmens: 95–120 Hz range

A 110 Hz fundamental produces harmonics at integer multiples: 220 Hz, 330 Hz, 440 Hz, and so on. The 20th harmonic is 2.2 kHz. The 200th harmonic is 22 kHz. The 240th harmonic is 26.4 kHz—precisely the frequency Luo showed reduces friction by 89%.

Could vocal harmonics in resonant chambers reach ultrasonic frequencies? The physics does not prohibit it. Harmonic content diminishes at higher frequencies, but resonant amplification could partially compensate. Whether sufficient amplitude could be achieved remains an open question.

But the chambers exist. The resonances are measurable. The question is not whether they could produce acoustic energy, but whether that energy could be converted to useful work.

## 5 Energy Requirements and Acoustic Amplification

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### 5.1 How Much Power Is Needed?

Modern ultrasonic transducers delivering 100 watts can drive friction reduction and material removal processes. Industrial cutting equipment uses up to 10 kilowatts, but this is optimized for speed, not minimum necessary power.

A human voice produces roughly 50 milliwatts during normal speech, rising to perhaps 1 watt when shouting. A group of 100 chanters might produce 100 watts of acoustic power—comparable to a laboratory ultrasonic transducer.

The question is conversion efficiency. How much of that acoustic power reaches the work surface at useful frequencies?

Resonant chambers provide one answer. A good resonator can amplify input by factors of 10–100 at its resonant frequency. The Malta Hypogeum's Oracle Room produces measurable standing waves from a single voice. With coordinated vocal input, the acoustic energy density could be substantial.

Piezoelectric granite provides another pathway. If quartz crystals in the chamber walls convert acoustic energy to mechanical vibration, they function as distributed transducers. The walls themselves become the ultrasonic source.

This is speculative but not implausible. The physics exists. The chambers exist. What remains is to measure whether the energy transfer is sufficient for useful work.

### 5.2 The Self-Amplifying Process

One intriguing possibility: the grinding process itself generates acoustic energy.

When two stones vibrate with abrasive between them, each particle impact produces sound. The cumulative effect of millions of impacts per second is substantial acoustic output. If the grinding chamber is resonant, this acoustic energy reflects back to the work surface, potentially amplifying the very process that generated it.

This would be a self-sustaining acoustic cycle: grinding produces sound; resonance amplifies the sound; amplified sound enhances grinding. The system would tend toward a stable operating point where energy input (from workers moving the stones) is matched

by energy dissipation (material removal and acoustic losses).

Such systems are common in physics. Lasers work on similar principles: stimulated emission produces light; mirrors reflect the light; reflected light stimulates more emission. The difference is that lasers require external energy input (pumping) while acoustic grinding could be driven entirely by mechanical work.

## 6 The Parameter Space

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### 6.1 What Would Work, What Would Not

The physics constrains but does not uniquely determine the parameters for vibrational stone working. A range of frequencies and amplitudes would produce useful effects:

#### **Friction Reduction:**

- Optimal: 20–30 kHz at  $> 0.3$  micrometer amplitude
- Useful: probably 5–50 kHz at  $> 0.1$  micrometer amplitude
- Threshold: some reduction likely at any ultrasonic frequency with detectable amplitude

#### **Material Removal:**

- Optimal: 20 kHz at 10–25 micrometer amplitude
- Useful: probably 10–40 kHz at  $> 5$  micrometer amplitude
- Threshold: enhanced cutting likely with any sustained ultrasonic vibration

#### **Piezoelectric Weakening:**

- Optimal: resonant frequency of target mineral (sample-dependent)
- Useful: probably within 10% of resonant frequency
- Threshold: some effect likely across a range of frequencies due to distributed grain sizes

The key insight: ancient methods need not have been optimal. They could have operated at 20% of modern efficiency and still achieved results impossible by non-vibrational means. The question is not “could they match modern specifications?” but “could they exceed the zero-vibration baseline?”



## 6.2 What Remains to Be Tested

The experimental program is straightforward:

1. **Resonance mapping:** Characterize acoustic resonances in surviving megalithic chambers at all frequencies, including ultrasonic.
2. **Vocal harmonic analysis:** Measure ultrasonic content of coordinated chanting in resonant chambers.
3. **Piezoelectric transduction:** Quantify mechanical vibration in granite walls exposed to high-intensity acoustic fields.
4. **Grinding replication:** Attempt to fit polygonal blocks using vibrational assistance and compare to non-vibrational controls.
5. **Drilling replication:** Test tube drills with and without ultrasonic vibration; measure feed rates and spiral pitch.

These experiments are technically feasible with existing equipment. They require interdisciplinary collaboration—acoustics, materials science, archaeology—but no fundamental advances.

## 7 The Honest Assessment

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Could ancient builders have generated the frequencies and amplitudes that modern ultrasonic machining requires?

The honest answer: probably not at optimal specifications.

Could they have generated *some* vibrational assistance that exceeded zero-vibration performance?

The honest answer: very likely, given resonant chambers, coordinated vocalization, and the natural piezoelectric properties of quartz-bearing rock.

Would even modest vibrational assistance explain anomalies that currently resist all conventional explanation?

That is the question worth testing.

The precision of Andean masonry, the feed rates of Egyptian core drilling, the reversed hardness relationship in Petrie's cores, the protrusions on megalithic stones worldwide—these anomalies exist. They have resisted explanation for over a century.

Vibrational stone working offers a unified explanation grounded in physics we can verify. The parameters are constrained enough to be testable. The mechanisms are documented enough to be credible.

Whether the hypothesis is correct remains to be seen. But it is not wild speculation. It is the careful application of established physics to ancient puzzles.

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*The frequencies are known. The amplitudes are documented. What remains is to ask whether ancient builders might have discovered, empirically, what we have learned to specify precisely.*