Three Electrostatic Hypotheses, Tested

Quartz veins, Martian saltation and Titan dunes, against published measurements

Compiled: 31 October 2026 **Prepared for:** Toby Mikle **Source batch:** *29 New Hypotheses — Unconventional Sources* (31 Oct 2026), entries H15, H12, H18 **Status:** three tests run; one partly supported, one conditionally supported, one refuted

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0. What this is

Three hypotheses from the newest bundle were selected because each makes a number that can be checked against published measurements without a new instrument. Each was turned into a model with explicit parameters, run as a Monte Carlo over the published ranges, and judged against its own falsifier. The code, the parameter registry and the results are in this folder.

The short answer: **the Martian claim survives, the quartz claim survives only in the strongest ruptures, and the Titan claim does not survive at all.**

Test	Hypothesis	Decisive number	Verdict
01	H15 Quartz Lightning Rod	0.57 MV/m median; 17 MPa needed	Conditional
02	H12 Mars Dust Battery	4.0×10^{-7} W/m² median	Partly supported
03	H18 Titan Dune Capacitor	0.05 s retention	Refuted

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1. H15 · The Quartz Lightning Rod

> *Piezoelectric quartz veins in fault zones generate charge during rupture. The charge concentrates at vein tips and triggers corona discharges in the surrounding air, producing earthquake lights.*

The claim, as a number

If a rupture drops the shear stress on a quartz vein by Δτ, the piezoelectric polarization is P = d26 Δτ. The bound charge on the vein faces is σ_b = P, and the field in the air just outside a charged face is the sheet field

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E_air = g · σ_b / (2 ε₀)  =  g · d26 · Δτ / (2 ε₀),
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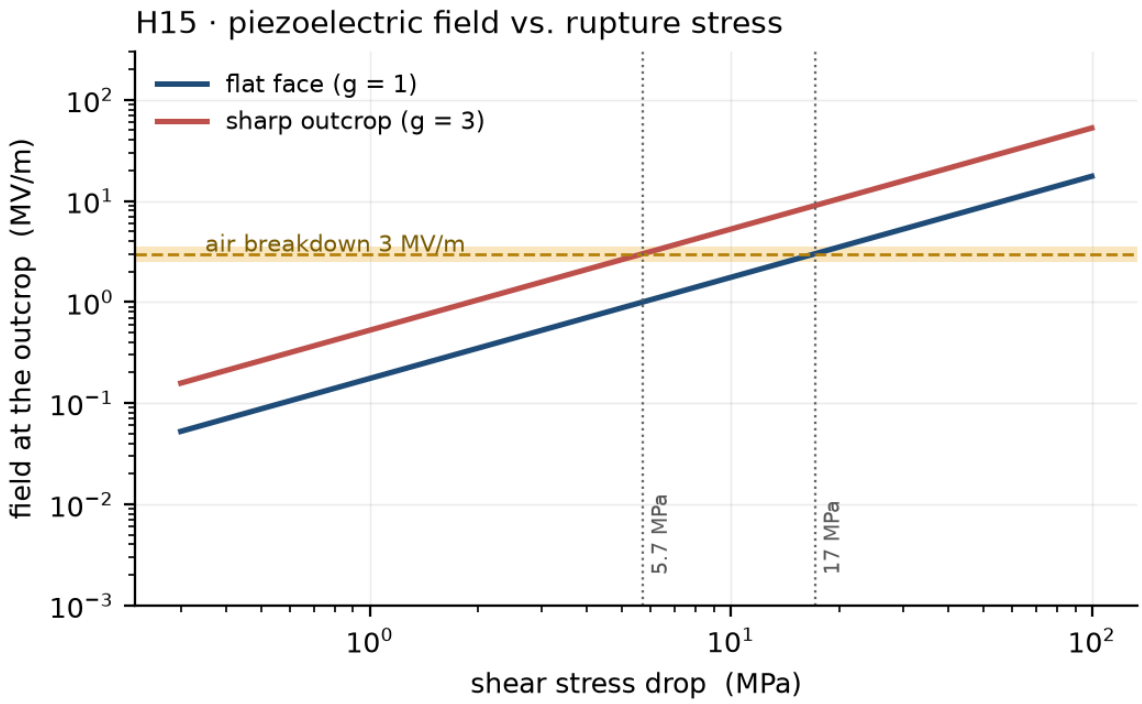
where g is a geometric concentration factor (g = 1 for a flat face, up to ~3 for a sharp outcrop). The hypothesis is met if E_air reaches the breakdown field of air, 3 MV/m.

Parameters

Quantity	Value used	Source
d26, quartz	3.1 pC/N (range 2.3–4.6)	Bechmann (1958); class-32 relation d26 = −2d11
Stress drop	log-normal, median 3 MPa, σ_ln = 0.8	Allmann & Shearer (2009)
Breakdown, air at 1 atm	3.0 MV/m (2.5–3.5)	standard
Geometry factor g	1 (flat) to 3 (sharp outcrop)	bounding assumption

The d26 range carries a real ambiguity: the class-32 piezoelectric matrix gives |d26| = 2|d11| = 4.6 pC/N, while thickness-shear values near 3.1 pC/N are also in use. The test runs the whole 2.3–4.6 pC/N range rather than choosing.

Result



Quartz field versus stress drop

- Median field at a flat outcrop: **0.57 MV/m** — a factor of five below breakdown.
- 95th percentile: 2.2 MV/m; only **2.3%** of ruptures exceed 3 MV/m.
- **17 MPa** of stress drop is needed at a flat face. The stress-drop distribution puts only **1.4%** of ruptures above that.
- A sharp outcrop (g = 3) lowers the requirement to **5.7 MPa**; **21%** of ruptures exceed it and **12.9%** of the sampled cases cross breakdown.
- Deterministic check: 3 MPa → 0.52 MV/m; 10 MPa → 1.75 MV/m; 30 MPa → 5.25 MV/m.

Verdict: conditionally supported

The mechanism is not generic. For the median earthquake it fails by a factor of five. It works only where a rupture is strong ($\Delta\tau \gtrsim 6$–17 MPa, depending on outcrop sharpness) *and* the vein tip is sharp. That combination is rare but not unphysical: the stress-drop tail above 10 MPa is populated, and quartz veins do outcrop as ridges and slickensided faces.

Two things push the result down, and both are conservative in the right direction. First, the charge is bound, not mobile: unlike a lightning rod, a quartz vein cannot redistribute charge to a tip, so g cannot be arbitrarily large. Second, the surrounding rock and the finite vein thickness reduce the external field relative to the sheet estimate. The g = 3 case should therefore be read as an upper bound.

What would settle it

A field or corona measurement at a real quartz outcrop during a $M \gtrsim 5$ rupture, or a laboratory shear test on a quartz vein analog at 10–30 MPa with a field probe at the tip. The hypothesis predicts a threshold, so a null result at 30 MPa would kill it cleanly.

Scope note: this test checks the mechanism, not the hypothesis's statistical half — the claim that light flashes correlate with quartz-vein abundance and slip rate. That needs an earthquake-light catalog, which is not machine-readable here.

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2. H12 · The Mars Dust Battery

> *A grounded conductor in a Martian dust devil can harvest triboelectric charge. The current scales with saltation flux and grain size, producing >10 nW m^{-2} during a vortex passage.*

The claim, as a number

Treat the saltation layer as a weakly conducting slab of height h with conductivity σ and vertical field E. Charge is supplied by the grains at $j_{charge} = \chi\Phi$ (charge-to-mass ratio times mass flux) and carried by the plasma at $j_{cond} = \sigma E$. In steady state the smaller current limits what a grounded plate can draw:

$$j = \min(\chi\,\Phi,\ \sigma\,E), \qquad P/A = \eta \cdot j \cdot E \cdot h.$$

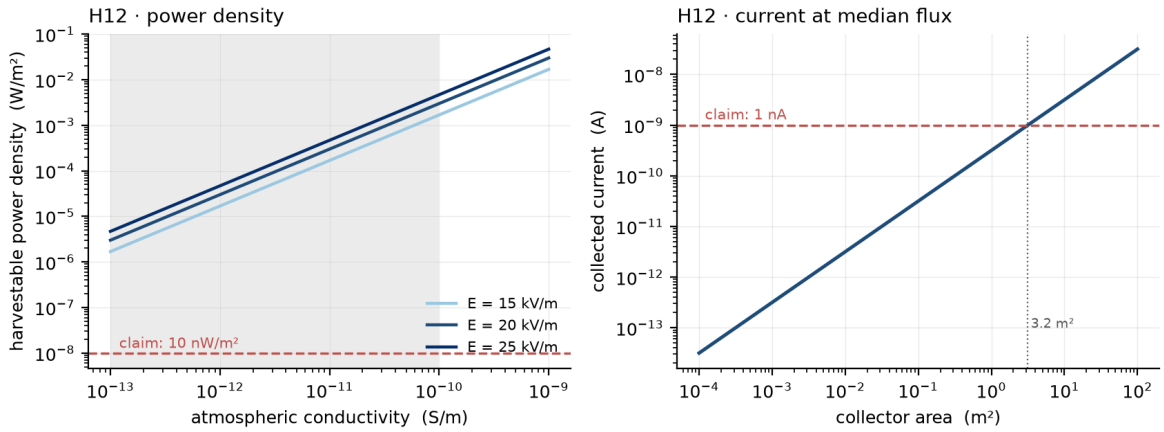
Kok & Renno (2009) showed that the field in Martian saltation self-limits at **15–20 kV/m**: field ionisation raises the conductivity, which bleeds the charge away. That number, not the Paschen limit of 43 kV/m, is the ceiling. The hypothesis is met if $P/A > 10$ nW/m² (and its own falsifier asks for >1 nA).

Parameters

Quantity	Value used	Source
Field E	15–25 kV/m	Kok & Renno (2009)
Conductivity σ	10^{-13}–10^{-10} S/m, nominal 10^{-12}	Kok & Renno (2009); Farrell et al. (2021)
Layer height h	0.1–0.5 m (z_{cat} = 30 cm)	Kok & Renno (2009)

Quantity	Value used	Source
Charge-to-mass χ	10^{-6}–10^{-4} C/kg	laboratory saltation range
Mass flux Φ	10^{-6}–10^{-3} kg m^{-2} s^{-1}	saltation range
Load fraction η	0.10–0.40	matched load

Result



Mars power and current

- Median current density: **3.2×10^{-10} A/m²** (5–95%: 5.9×10^{-12} – 1.2×10^{-8}).
- Median harvestable power density: **4.0×10^{-7} W/m²** — forty times the claimed 10 nW/m². **92.7%** of sampled conditions clear the claim; the 5th percentile (6.8×10^{-9} W/m²) does not.
- Current through a 0.01 m² benchtop plate: **3.2 pA**. Only **0.05%** of cases reach 1 nA. A 1 nA current at the median flux density needs **3.2 m²** of collector.
- Energy per 100 s vortex passage at 1 m²: **4×10^{-5} J** — enough to run a micro-power sensor for a fraction of a second, not to charge a battery quickly.

Verdict: partly supported

The power-density half of the claim passes with a wide margin. The current half does not, at any benchtop scale: the hypothesis's own 1 nA detection threshold requires a collector of several square metres. That is a real engineering constraint, not a technicality — a 1 cm² plate sees picoamps, which is at the edge of low-leakage electrometry.

There is also a physical tension inside the hypothesis. It says the current "scales with saltation flux", but the field self-limits because the conductivity rises with E. In the high-flux regime the current is set by the plasma, not by the sand; the scaling flattens. The model reproduces that: above $\chi\Phi \approx \sigma E$ the current stops growing.

What would settle it

A Mars-pressure saltation experiment that measures χ for the relevant grain size, and a field measurement in a Martian dust devil. The power margin is large enough that the remaining question is collection geometry, not physics.

Scope note: this test checks the energy budget, not the claim that "the discharge rate, not the dust density, is the controlling variable". Testing that needs the time-resolved current during a vortex passage, which no published Mars dataset has.

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3. H18 · The Titan Dune Capacitor

> *Titan's dune sands are charged to 10^5–10^6 V m^{-1} and retain charge for months. The dunes act as giant capacitors.*

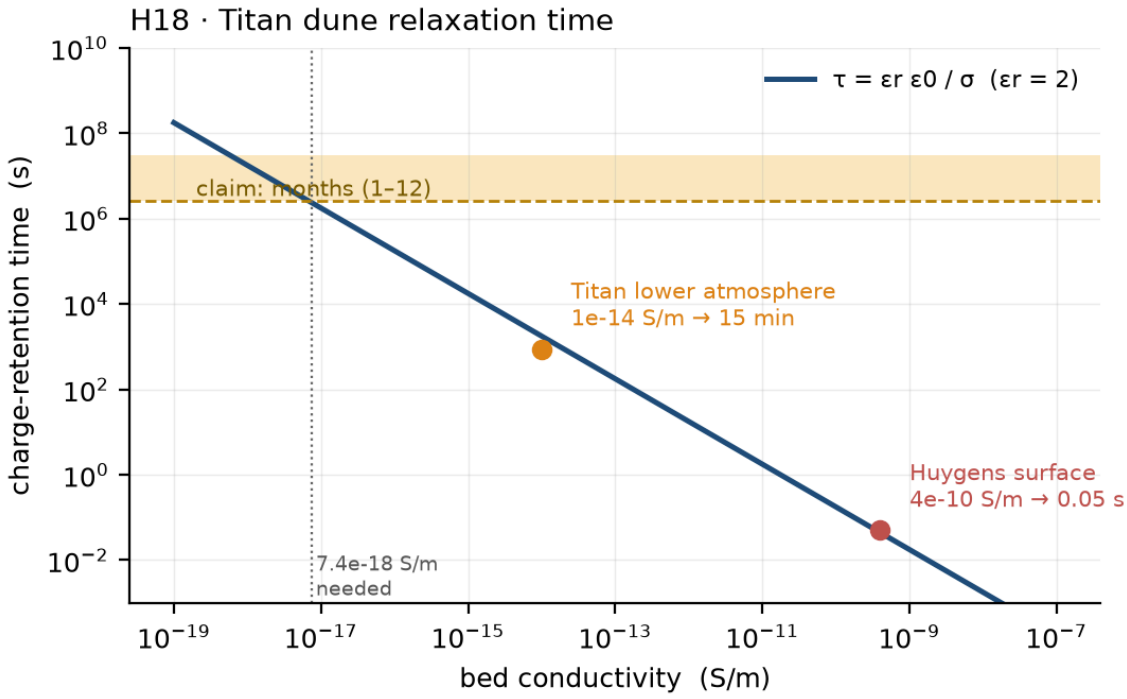
The claim, as a number

A bed of permittivity ε_r and conductivity σ relaxes free charge with the dielectric time $\tau = \varepsilon_r \varepsilon_0 / \sigma$. The field decays as $E(t) = E_0 \exp(-t/\tau)$. The hypothesis needs $\tau \gtrsim 1$ month $= 2.6 \times 10^6$ s at 10^5–10^6 V/m.

Parameters

Quantity	Value used	Source
Surface conductivity	4×10^{-10} S/m (10^{-11}–10^{-9})	Grard et al. (2006), Huygens PWA
Surface permittivity	~2 (1.8–2.6)	Huygens PWA
Lower-atmosphere conductivity	10^{-14} S/m (10^{-16}–10^{-12})	Lorenz (2021)
Claimed retention	1–12 months	H18

Result



Titan relaxation time

- At the measured surface conductivity: τ = **0.049 s** (5–95%: 0.024–0.11 s). The field is gone before a dust devil could cross the dune.
- Even using the atmosphere as the leakage channel, with a conductivity ten times lower than Earth's: τ = **887 s ≈ 15 min**. The 5th percentile is 70 s, the 95th 2.1 h.
- Retention for one month requires **$\sigma < 7.4 \times 10^{-18}$ S/m**. The measured surface value is **7.7 orders of magnitude** above that.
- The surviving fraction after a month at the measured conductivity is $\exp(-5.3 \times 10^{7})$, i.e. zero to any measurable precision.

Verdict: refuted

There is no version of the measured Titan surface that holds a field for months. The nuance worth stating is that the Huygens value is itself contested: Lorenz (2021) argues the high conductivity and its sudden drop 11 minutes after landing were caused by the probe's radioisotope heater units ionising the air around it. That caveat does not rescue the hypothesis. If the surface is as insulating as clean ice, the atmosphere above it still relaxes charge in minutes; to reach months the *atmosphere* would have to be below 10^{-18} S/m, which is far below any measured planetary atmosphere.

The capacitor analogy fails for a second reason: the dunes are not being continuously charged. Titan's surface winds are ~1 m/s, near or below the saltation threshold, so there is no sustained charging current to replace what leaks away. A dune that both leaks in seconds and is not being charged cannot accumulate a seasonal charge.

What would settle it

A laboratory measurement of the conductivity of Titan dune analog (tholin-coated organic sand) at 94 K and low pressure. If it came out below 10^{-18} S/m the claim would reopen; nothing measured so far is within seven orders of that.

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4. What the three tests say together

All three hypotheses are about the same competition: charge separation versus relaxation. The differences are in the medium.

Setting	Conductivity (S/m)	$\tau = \varepsilon\varepsilon_0/\sigma$	Is the field driven?	Outcome
Quartz vein	~10^{-16} (dry insulator)	~5 days	yes, during rupture	charge survives, but is too small
Mars saltation layer	~10^{-12}	~9 s	yes, continuously	steady field at 15–20 kV/m
Titan dune	4×10^{-10}	0.05 s	no	charge cannot accumulate

The Mars case passes because the charging is continuous: a 9-second relaxation time is irrelevant when grains are delivering charge every second. The Titan case fails because the claim is about *storage*: a 0.05-second relaxation time destroys any seasonal capacitor, and the wind is too weak to replenish it. The quartz

case sits in between: the medium holds charge for years, but the piezoelectric charge density at ordinary stresses is simply too small to break down air.

That is the useful generalisation from this batch: **a charge-separation hypothesis needs both a long relaxation time and a charge source matched to the observation time.** H18 has neither; H15 has the first but not the second at typical stress; H12 has both because it never needs to store anything.

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5. Limits

- These are **models**, not experiments. Each verdict follows from published parameters and a stated mechanism; none of them measures a vein, a dust devil or a dune.
- The Monte Carlo propagates *parametric* uncertainty only. Model uncertainty (the geometry factor in H15, the load fraction in H12, the leakage channel in H18) is stated in each dossier and is the dominant uncertainty in H15.
- The H15 result depends on d26, which is quoted in two conventions. The 2.3–4.6 pC/N range is carried through; choosing 4.6 pC/N would move the threshold from 17 MPa to ~11 MPa without changing the verdict class.
- The H18 result depends on one in-situ measurement that is itself disputed. The test therefore reports the atmosphere channel separately, and the verdict holds under both.
- The H12 charge-to-mass range is laboratory-derived, not Mars-derived. It is the parameter most worth measuring.

6. Files

File	What it is
`tests/01-quartz-vein/code/model.py`	H15 model: analytic field, Monte Carlo, deterministic table
`tests/02-mars-saltation/code/model.py`	H12 model: current-limited harvest, Monte Carlo
`tests/03-titan-dune/code/model.py`	H18 model: relaxation time, required conductivity
`tests/*/out/results.json`	every number quoted above
`shared/params.json`	parameter registry with source keys
`shared/make_figures.py`	rebuilds the three figures
`figures/`	fig01 quartz, fig02 mars, fig03 titan
`literature/`	the source papers used