

# The Volcanic Engine

Working thesis · Version 1.0.0 · 2026-07-26 · Not peer reviewed

Citation and status boundary: this PDF is a stable public working-paper edition. It is not a peer-reviewed journal article. Consult the canonical web edition for interactive material, linked resources, corrections, and the current machine-readable citation record.

## Eruption as a Precondition for Sustained Planetary Habitability

A structural thesis, with an explicit provenance and verification statement.

### Abstract

Volcanism is conventionally framed as a hazard a discrete, destructive interruption of an otherwise stable crust. This paper advances the inverse framing as a structural thesis: that sustained planetary habitability is not merely compatible with volcanism but appears to be downstream of it, and that the eruption is the visible terminus of the mechanism which keeps a rocky world in the liquid-water regime across geological time.

The argument's load-bearing element is not the eruption itself but the carbonatesilicate cycle: a temperature-dependent negative feedback in which volcanic outgassing and silicate weathering buffer atmospheric CO<sub>2</sub> over hundreds of thousands of years. Around this we assemble four supporting strands atmospheric and oceanic provenance, continental crust formation, comparative planetology, and the rate-dependence of volcanic catastrophe and one strand which this paper explicitly downgrades on the basis of source verification.

The thesis is offered as a synthesis and an organizing hypothesis, not as a finding. Its principal claim to originality is architectural rather than empirical: the individual components are established literature, and the contribution is the ordering.

### 1. The framing problem

Volcanoes entered the modern imagination through catastrophe Pompeii, Krakatoa, St. Helens and the hazard framing has been reinforced by every subsequent popular treatment. The framing is not wrong. It is scale-limited. It describes an event correctly while describing the process not at all, in roughly the way a photograph of a heart attack conveys nothing about circulation.

The alternative framing proposed here is that volcanism is the surface expression of a planet exporting internal heat, and that the same process, integrated over geological time, is what produced and now maintains the conditions this planet's biosphere requires. Under this reading, Earth is not a stable world which occasionally erupts. It is an erupting world and therefore a stable one.

This is a strong claim, and the rest of the paper is concerned with establishing how much of it the evidence actually supports which turns out to be a good deal for some strands and considerably less for others.

### 2. A note on register

Following the standing method of this research project, claims are classified into three registers and labelled throughout:

Empirical (measured). Field geology, rock and melt geochemistry, seismic catalogues, gas and deformation monitoring, ice-core records, experimental petrology.

Theoretical (inferred, not settled). Mantle convection and plume dynamics, magma reservoir geometry, eruption trigger mechanics, the origin of life at hydrothermal systems.

Speculative (reaching). Exoplanetary outgassing biosignatures, whether tectonic recycling is a necessary precondition for biology, deep-time planetary shutdown.

The thesis of this paper sits in the theoretical register. Its components span all three, and the paper's usefulness depends on the boundaries being stated rather than blurred.

### 3. The load-bearing mechanism: the thermostat

Register: empirical mechanism, theoretical in its extension to habitability generally.

Walker, Hays and Kasting (1981) proposed that atmospheric CO<sub>2</sub> is buffered over geological timescales by a negative feedback: the rate of silicate weathering which consumes CO<sub>2</sub> and ultimately deposits it as marine carbonate is temperature-dependent. A warming surface accelerates weathering, drawing CO<sub>2</sub> down; a cooling surface slows weathering, allowing volcanic outgassing to rebuild it. Subduction returns carbonate to the mantle, and volcanism returns the carbon to the atmosphere. The loop closes.

The response time is on the order of hundreds of thousands of years, which makes the mechanism irrelevant to anthropogenic climate change on any policy-relevant horizon a point worth stating plainly, since the feedback is periodically misapplied in exactly that direction.

What the mechanism does explain is the long record. Solar luminosity has increased substantially over Earth's history, yet the surface has remained within the liquid-water range for billions of years. A thermostat with a volcanic supply term and a weathering sink term is the standard resolution of that tension.

This single mechanism carries more of the thesis than any other element, and it is worth being explicit about the dependency: if the carbonate-silicate feedback were shown not to operate as described, the paper's central claim would not survive in its present form.

### 4. Supporting strands

Register: mixed, labelled per strand.

4.1 Atmospheric and oceanic provenance (empirical, with an unsettled ledger). Volcanic outgassing is the accepted source of the secondary atmosphere water vapour, CO<sub>2</sub>, nitrogen, sulfur. The relative contribution of outgassing versus impact delivery, particularly for water, remains argued, with deuterium/hydrogen ratios as the primary tracer. The strand supports the thesis; the apportionment does not.

4.2 Continental crust (empirical). Arc magmatism at subduction zones manufactures buoyant, silica-enriched crust which resists subduction and accumulates. Dry land is a volcanic product. A rocky planet with basaltic crust alone would plausibly be a waterworld.

4.3 Comparative planetology, and the Venus correction (empirical observation, theoretical interpretation). Mars, the Moon and Mercury are the control cases bodies whose usable internal heat declined, with the loss of crustal recycling, sustained outgassing and, on Mars, much of the atmosphere.

But Venus is the more instructive case, and it constrains the thesis rather than supporting it. Venus has abundant volcanism and no plate tectonics: stagnant-lid convection, episodic resurfacing, and a runaway greenhouse. Volcanism alone is therefore demonstrably not sufficient for habitability. What the thesis requires is the full cycle outgassing plus a subduction return path. Any version of this argument which cites volcanism without the return path is refuted by a planet

next door.

4.4 Rate, not kind (empirical record, theoretical causation). Large Igneous Provinces correlate temporally with four of the five major mass extinctions; the Siberian Traps coincide with the end-Permian. The proposed kill mechanisms CO<sub>2</sub>-driven warming, transient SO<sub>2</sub> cooling, ocean acidification, anoxia, and in Siberia the contact metamorphism of coal and evaporite deposits are the same processes described in 3 and 4.1, operating at rates the system cannot buffer. The end-Cretaceous attribution between Deccan volcanism and the Chicxulub impact remains genuinely disputed and is not adjudicated here.

The synthesis: the mechanism that sustains habitability and the mechanism that periodically destroys it are the same mechanism. The variable is rate.

## 5. The strand this paper downgrades

Register: theoretical, and revised downward during verification.

An earlier formulation of this thesis included the origin of life as its strongest supporting strand, on the reasoning that alkaline hydrothermal vents with their natural proton gradients across thin inorganic membranes supply the most credible known setting for abiogenesis, and that such vents are volcanic.

Source verification does not support the last step. The Lost City hydrothermal field, identified on 4 December 2000 on the Atlantis Massif, is driven by serpentinization the exothermic hydration of mantle peridotite and not by magmatic heat. Its fluids are comparatively cool (roughly 4090 C), alkaline (pH above 9), rich in hydrogen and methane, and notably poor in the CO<sub>2</sub>, hydrogen sulfide and metals characteristic of magmatically driven black smokers. Alkaline vents of this type are, on the current description, related to volcanic vents only superficially.

The honest reformulation is weaker and more interesting. What Lost City requires is the exposure of mantle rock to seawater through extensional faulting which is a product of the tectonic system that volcanism accompanies and drives, but is not itself volcanism. The precondition, if there is one, is tectonic, not magmatic.

A second caution belongs here. The alkaline-vent origin hypothesis is contested on its own terms: work from the Earth-Life Science Institute has argued that the free energy of thioester hydrolysis makes abiotic accumulation of those intermediates implausible at Lost City conditions. The hypothesis remains live, not established.

This strand is accordingly retained as suggestive context and removed from the load-bearing structure. Recording the downgrade is the point; a synthesis which only ever accumulates confirming strands is not doing the work.

## 6. The epistemic constraint

Register: methodological.

Any thesis about magmatic systems inherits a hard observational limit: a magma reservoir cannot be directly instrumented, because the instrument is destroyed by the object it was sent to measure. The discipline proceeds by inference from indirect signals seismicity, deformation, gas ratios, gravity, thermal flux and from erupted products, reading a reservoir from what it discarded.

Two consequences follow. First, inverse problems of this kind are non-unique: distinct subsurface configurations can produce indistinguishable surface signals. Second, the field's confidence should be, and generally is, probabilistic rather than deterministic.

This constraint has been paid for directly. Katia and Maurice Krafft, and the volcanologist Harry Glicken, were killed by a pyroclastic flow at Mount Unzen on 3 June 1991, among 43 dead. The hazard footage the Kraffts had spent a career

assembling was compiled into the IAVCEI film Understanding Volcanic Hazards, and twelve days later that film was screened for civil defence officials, military commanders and communities during the Pinatubo emergency, where it was used to convince audiences sceptical of an abstraction they had never seen. USGS and PHIVOLCS estimate the Pinatubo forecasts saved between 5,000 and 20,000 lives; roughly 400 people died.

Set against this, Nevado del Ruiz. A volcanic hazard map, in preliminary form by early October 1985, was presented to national, regional and local authorities and correctly showed the inundation of Armero by lahars. The eruption of 13 November 1985 killed on the order of 23,000-25,000 people, the great majority at Armero. Reporting on the toll varies between sources and the figure should be treated as approximate.

The relevant finding for this paper is not that the science failed at Ruiz. It did not. The failure was downstream of the science in distribution, authority and the political economy of acting on a probability. An epistemic constraint and a communication failure are different problems, and conflating them lets the second one recur.

## 7. Provenance and verification status

This project's standing commitment is that the boundaries of humanAI collaboration, and the verification state of every claim, are stated rather than implied.

Instrument and architecture. The synthesis, structural ordering and drafting were produced by an agentic AI model (Claude, Anthropic) under direction. The thesis, editorial judgement, scope and final curation are the Architect's. See The Architect's Method (<https://research.mahastrategies.com/#manifesto>) for the standing framework.

Verification pass: INCOMPLETE. This is stated prominently because the paper should not be cited as though it were otherwise.

Independently resolved against sources:

- Walker, Hays & Kasting (1981), J. Geophys. Res. 86(C10), 97769782 carbonatesilicate negative feedback. Resolved.
- Lost City identified 4 December 2000, Atlantis Massif, via DSV Alvin and ROV Argo II; serpentinization-driven, non-magmatic; fluid regime as described. Resolved and prompted the 5 downgrade.
- Krafft and Glicken deaths, Mount Unzen, 3 June 1991; 43 fatalities. Resolved.
- Understanding Volcanic Hazards (IAVCEI) used in Pinatubo briefings; USGS/PHIVOLCS estimate of 5,000-20,000 lives saved; ~400 deaths. Resolved.
- Nevado del Ruiz hazard map completed in preliminary form early October 1985 and presented to authorities. Resolved.

Corrected during verification:

- Armero death toll. An earlier draft gave a single figure of ~23,000. Sources range from ~20,000 at Armero alone to more than 25,000 overall. Now stated as a range, flagged approximate.
- Hunga Tonga Hunga Haapai (15 January 2022) radiative sign. An earlier draft asserted modest net warming from the stratospheric water vapour injection. Earlier studies did report net warming; more recent work indicates a slight cooling effect. The sign is disputed, and the claim has been removed from the argument rather than restated.

Pending independent verification not yet checked, and not relied upon in 36:

Samalas (1257) attribution; Siberian Traps geochronology; the status of the Toba bottleneck hypothesis; Venus resurfacing chronology; deep-biosphere mass estimates; Nyiragongo 2002 and 2021; Eyjafjallajökull 2010 aviation figures; Laki 1783-84 mortality; the Krafla, Menengai and Kilauea Iki magma drilling encounters; CarbFix mineralization

rates; solar luminosity increase over Earth history; the contested protective role of the geodynamo; Enceladus plume chemistry.

Reader guidance. Sections 3, 4.3 and 6 rest on resolved sources. Section 4.1, 4.2 and 4.4 rest on well-established literature not independently re-checked in this pass. Section 5 is a downgrade and should be read as such. Nothing here is peer-reviewed, and the pending list above should be closed before this paper is cited in support of anything consequential.

## 8. What would falsify this

A thesis without a failure condition is a slogan. Three would do serious damage:

- A demonstration that the carbonatesilicate feedback does not stabilize on the claimed timescale, which would remove the load-bearing mechanism entirely (3).
- A confirmed biosphere on a body with no tectonic recycling Enceladus is the obvious candidate which would show that sustained habitability does not require the cycle this paper claims it requires.
- A well-characterized stagnant-lid exoplanet with a stable long-term climate, which would sever the link between the return path and the thermostat.

The second of these may be testable within a couple of decades, which is unusually good fortune for a claim about planetary history.

## 9. Standing

This is a synthesis and an organizing hypothesis. It is not original empirical research, it has not been peer-reviewed, and its verification pass is incomplete and marked as such in 7. It is published to give a longer-form project a stable, citable and honestly-labelled reference point, and to be argued with.

## Educational companion

Mayon Rajan (<https://mayonrajan.com/learn/sources/>) is a separate free educational visualization of Mayon Volcano, published by Maha Strategies. It offers a source record and explicit boundaries for its terrain, historical, interior, and hazard layers. This paper provides broad context for questions about volcanism; it is not a source for the Mayon model, does not validate its site-specific inferences, and is not a live hazard or public-safety resource.

Synthesis Instrument Claude (Anthropic, agentic model) Architected By Mayone Maha Rajan Status Vol. 1 working paper not peer-reviewed verification incomplete Method The Architect's Method (<https://research.mahastrategies.com/#manifesto>)

## Sources consulted in this pass

- Walker, J.C.G., Hays, P.B. & Kasting, J.F. (1981). A negative feedback mechanism for the long-term stabilization of Earth's surface temperature. *Journal of Geophysical Research* 86(C10), 97769782.  
<https://ui.adsabs.harvard.edu/abs/1981JGR....86.9776W/abstract>
- Lost City Hydrothermal Field discovery, mineralogy, serpentinization and biology.  
[https://en.wikipedia.org/wiki/Lost\\_City\\_Hydrothermal\\_Field](https://en.wikipedia.org/wiki/Lost_City_Hydrothermal_Field)

– Harry Glicken; Katia and Maurice Krafft Mount Unzen, 3 June 1991. [https://en.wikipedia.org/wiki/Harry\\_Glicken](https://en.wikipedia.org/wiki/Harry_Glicken)  
[https://en.wikipedia.org/wiki/Katia\\_and\\_Maurice\\_Krafft](https://en.wikipedia.org/wiki/Katia_and_Maurice_Krafft)

– USGS, Pinatubo 1991 emergency management and the Krafft hazard video.  
[https://volcanoes.usgs.gov/volcanic\\_ash/pinatubo\\_emergency\\_management.html](https://volcanoes.usgs.gov/volcanic_ash/pinatubo_emergency_management.html)

– Newhall, Hendley & Stauffer, USGS Fact Sheet benefits of volcano monitoring at Pinatubo.  
<https://pubs.usgs.gov/fs/1997/fs115-97>

– Armero tragedy hazard mapping, warnings and casualty estimates. [https://en.wikipedia.org/wiki/Armero\\_tragedy](https://en.wikipedia.org/wiki/Armero_tragedy)

– How the Armero Tragedy Changed Volcanology, Eos.  
<https://eos.org/articles/how-the-armero-tragedy-changed-volcanology-in-colombia>

– 2022 Hunga TongaHunga Haapai eruption stratospheric water vapour and disputed radiative sign.  
[https://en.wikipedia.org/wiki/2022\\_Hunga\\_Tonga%E2%80%93Hunga\\_Haapai\\_eruption\\_and\\_tsunami](https://en.wikipedia.org/wiki/2022_Hunga_Tonga%E2%80%93Hunga_Haapai_eruption_and_tsunami)

Encyclopedic sources are used here as pointers to primary literature, not as authorities. Closing the pending list in 7 requires going to the primary sources directly.

Canonical web edition and structured metadata: <https://research.mahastrategies.com/papers/the-volcanic-engine-thesis>