Astro-Ballistic Chronostratigraphic Sequencing III

From Event Geometry to Continents, Trenches, Mountains, and Basins

Global Plate-Boundary Formation, Inherited Motion, Continental Displacement, and Tectonic Reconstruction

Plate-Motion Inheritance and the Global Reconstruction Test

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Canonical Corpus Freeze Notice

This manuscript is part of the five-paper Canonical Corpus Freeze 1.0. Its freeze identifier is

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Declaration of Purpose

Paper I defines event-audit eligibility. Paper II defines event-level mechanical eligibility. Paper III addresses the distinct global reconstruction burden:

> Can one chronologically ordered sequence of mechanically eligible astro-ballistic events generate the observed global boundary, motion, structural, material-lineage, and deep-geophysical organization?

The objective is not to deny measured plate motion and not to compare final model superiority. It is to determine whether at least one complete shared global reconstruction exists.

Paper-III causal thesis.
Astro-Ballistic Chronostratigraphic Sequencing proposes that major plate boundaries, plate-motion directions, relative speeds, mountain systems, trenches, basins, fracture networks, volcanic provinces, and displaced terranes preserve a sequenced history of large astro-ballistic forcing. Present motion is modeled as a continuation of inherited event-created and event-modified conditions acted upon by gravity, buoyancy, mantle coupling, rheology, boundary interaction, and later events. This thesis remains conditional until a complete sequence-specific solution is produced.

Source Status and Citation Policy

External references support measurements, dated constraints, standard methods, regional context, comparison-model components, and reproducibility requirements. They do not independently verify an astro-ballistic event assignment, event sequence, causal interpretation, or replacement claim unless the cited source directly tests that claim. Internal Ontomics documents establish developmental provenance, not independent confirmation. Manuscript-derived values remain consequences of their declared inputs and methods. External chronology constrains observations and marker compatibility; it is not imported as a substitute causal narrative. The complete source taxonomy, verification fields, and conflict rules are maintained in Paper V.

Data, Evidence, and Provenance Convention

Every factual input, model input, reconstruction, simulation output, and calculated result must retain an explicit evidentiary origin. Scientific authority, publication status, or institutional custody does not by itself upgrade an item from model-derived to observed, from observed to causal, or from internally reproduced to independently validated.

The corpus uses the following evidence-origin classes:

Measurement-proximal
: A directly measured, sampled, mapped, or instrument-recorded quantity, together with its reported uncertainty and acquisition method.

Curated primary dataset
: A maintained collection of observations. The dataset may include processing, but its raw sources, version, and transformations must remain traceable.

Reference model
: A community or institutional model derived from observations and assumptions. It is not identical to the underlying measurements.

Reconstructed or inverted
: A past state, field, geometry, or parameter estimated through an explicit inversion or reconstruction method.

Author-declared input
: A coordinate, age, range, threshold, branch, or other value selected for the present investigation. It is a model input rather than an independent observation.

Internal provenance
: An Ontomics manuscript, author working document, or earlier source file establishing the developmental history of the hypothesis. Internal provenance is not independent confirmation.

Manuscript-derived result
: A reproducible consequence of declared inputs, equations, algorithms, and numerical conventions.

Simulated model output
: A quantity produced by an implemented physical or statistical model.

Interpretive inference
: A geological, causal, or historical interpretation assigned to one or more observations or model outputs.

Unverified, unavailable, or missing
: An item whose source, version, access path, lineage, uncertainty, or required observation has not yet been established.

For item i, the minimum provenance record is

$$\mathbf{P}_i = (\mathrm{ID}_i, \mathrm{origin}_i, \mathrm{custodian}_i, \mathrm{version}_i, \mathrm{locator}_i, \mathrm{acquisition}_i, \mathrm{hash}_i, \\ \mathrm{transformations}_i, \mathrm{units}_i, \mathrm{uncertainty}_i, \mathrm{use}_i, \mathrm{dependencies}_i, \mathrm{status}_i).$$

For a derived result R_j, the complete lineage must identify the exact input records and method version:

$$R_j = \mathcal{M}_j(\mathbf{D}_{j1}, \ldots, \mathbf{D}_{jn}; \boldsymbol{\theta}_j, \nu_j)\,,$$

where ν_j identifies the equation, code, solver, or calculation version. Rounding, unit conversion, coordinate transformation, filtering, interpolation, exclusion, and manual transcription are transformations and must be logged rather than treated as invisible clerical steps.

A located source is not automatically passage-verified. A verified passage is not automatically data-verified. A data-verified input does not by itself validate the causal interpretation built from it. Missing evidence remains explicitly missing; it may not be filled by a preferred reconstruction, model narrative, or uncited numerical convention.

The replacement claim is causal rather than observational.

The existence of moving plates is shared evidence.

The competing question is what primarily created and organized the global boundary-and-motion architecture.

Conditional Input Statement

Paper III does not assume that Paper II has already identified a physically viable Aegean–Himalayan–Mariana flagship candidate event.

The post-event fields supplied by Paper II are conditional model inputs.

If the event-specific Paper-II viable set is empty,

$$\mathcal{V}_{\mathrm{II},k} = \varnothing, \tag{1}$$

then event k cannot be treated as a mechanically admissible causal building block.

Paper III may still test the mathematics and architecture of a broader event sequence, but it must preserve the failed status of the flagship mechanism.

If one or more Paper-II mechanical branches survive, Paper III must use their actual outputs rather than an idealized event field selected independently.

Event-Indexed Mechanical Eligibility

Let the candidate event catalog be $\mathcal{E}$. The mechanically eligible subset is

$$\mathcal{E}_{\mathrm{mech}} = \{k \in \mathcal{E} : \mathcal{V}_{I,k} \neq \varnothing \text{ and } \mathcal{V}_{II,k} \neq \varnothing\}\,. \tag{2}$$

A candidate global sequence $\mathcal{S}$ is eligible only if

$$\mathcal{S} \subseteq \mathcal{E}_{\text{mech}}. \tag{3}$$

Failure of the flagship event removes the flagship from $\mathcal{E}_{\text{mech}}$. It does not automatically remove other events or reject every alternate sequence.

Paper-III Data and Provenance Snapshot

Table 1: Paper-III reconstruction data and provenance snapshot.

ID	Item	Origin and role	Current provenance status
P3-IN-001	Mechanically eligible event catalog	Author-defined registry constrained by Papers I and II	Candidate-model input; not an observed event catalog
P3-DAT-001	Digital plate-boundary geometry	External interpreted boundary model [5]	Reference dataset derived from mapped and interpreted boundaries, not raw observation alone
P3-DAT-002	Present plate-motion field	External geologically current motion model [4]	Comparison target with model and covariance assumptions
P3-DAT-003	Geodetic velocity and strain field	External geodetic model [6]	Measurement-constrained reference field; exact release and extraction must be frozen
P3-DAT-004	Deep-time plate and continental reconstructions	Model-derived reconstruction branches	Must retain rotation tree, plate polygons, uncertainty, and alternative branches; not treated as observations
P3-DAT-005	Gravity, magnetic, seismic, heat-flow, crustal, and lithospheric datasets	Required independent observational families	Required by the architecture but not yet assembled as one frozen release package
P3-RES-001	Predicted boundaries, velocities, surface fields, and lineage maps	Paper-III model outputs	Do not count as evidence until compared against frozen data not used to construct them

ID	Item	Origin and role	Current provenance status
P3-TEST-001	Internal and external holdout partitions	Preregistered validation design	Partitions, versions, and access dates remain to be frozen before confirmatory use

Epistemic Status and Claim-Language Convention

This paper distinguishes observation, curated data, reference model, author-declared input, manuscript-derived calculation, simulated output, interpretive inference, prediction, unresolved item, negative result, and falsified claim. These statuses are not interchangeable. Reproducible arithmetic does not establish historical causation; physical admissibility does not establish occurrence; and regional compatibility does not establish global replacement. Missing evidence is reported as unresolved rather than silently completed. Paper V contains the authoritative machine-readable status vocabulary and item-level records.

Prediction, Falsification, and Decision-Threshold Convention

Predictions must identify the claim tested, data required, comparison or null, uncertainty treatment, decision threshold, and bounded consequence. Thresholds are classified as physical-admissibility conditions (T0), measurement or convergence conditions (T1), exploratory working thresholds (T2), preregistered confirmatory thresholds (T3), or preregistered comparative thresholds (T4). A claim is rejected only after a valid, completed test crosses its frozen rejection rule. An unrun test, unavailable dataset, or unfrozen threshold is unresolved. Failure to earn superiority or replacement status is a comparative non-qualification, not retroactive falsification of every upstream result.

Causal-Chain, Assumption, and Alternative-Explanation Convention

Causal language follows a seven-level ladder: association (L0), temporal compatibility (L1), mechanical admissibility (L2), modeled contribution (L3), causal necessity (L4), primary or dominant causation (L5), and replacement qualification (L6). Each proposed transition must identify its assumptions, mediators, counterfactual intervention, and credible alternatives. For claim c with preregistered support paths $\mathcal{P}_c$, viability is

$$\mathcal{V}_{\text{causal},c} = \bigcup_{p \in \mathcal{P}_c} \bigcap_{e \in p} \mathcal{V}_e.$$

One failed edge rejects every path that requires that edge, but does not erase an independent surviving path. One failed branch, event, regional assignment, or event sequence therefore has only its registered downstream consequence. Confounding, equifinality, circular use of outputs as inputs, and unequal assumption burdens remain explicit audit failures. Paper V preserves the full causal-edge, assumption, alternative, and intervention registries.

Abstract

This paper defines the global reconstruction test for Astro-Ballistic Chronostratigraphic Sequencing . It receives only mechanically eligible, status-qualified event outputs from Paper II and assembles them into preregistered event catalogs and chronologically ordered event sequences. Plates are represented as evolving material domains; boundaries as time-dependent network elements; and motion through translational and rotational fields acted upon by inherited damage, density, thermal, phase, stress, gravity, buoyancy, mantle coupling, boundary interaction, and later events.

The paper specifies tests for boundary location, orientation, age, and type; plate direction, Euler poles, relative velocity, and speed hierarchy; continental and terrane displacement; mountains, trenches, ridges, basins, plateaus, and volcanic provinces; chronology and material lineage; and deep geophysical outputs. Present geography is not treated as an uncorrected proxy for event-time geometry, and modern plate names are not projected unchanged through deep time.

For each eligible sequence, one shared parameterization must generate the boundary, motion, structural, chronological, material-lineage, null-control, and predictive outputs. Failure of one sequence rejects that sequence only. The Paper-III astro-ballistic model family fails globally only if every frozen eligible sequence has an empty complete reconstruction set. A nonempty set is not a declaration of causal superiority: Paper III establishes reconstruction eligibility, while Paper IV alone determines whether a surviving model outperforms comparison and null models after held-out prediction, causal ablation, uncertainty, and complexity accounting. No complete global reconstruction is claimed here to have been executed.

Keywords

Astro-Ballistic Chronostratigraphic Sequencing; astro-ballistic reconstruction; astro-ballistic forensics; plate-motion inheritance; plate-boundary formation; continental displacement; tectonic reconstruction; mountain formation; trench formation; basin formation; event-created boundaries; Euler-pole reconstruction; Plate Tectonics replacement; forensic geophysics.

Contents

1 The Causal Replacement Burden

1.1 Canonical Corpus Terminology

The authoritative nomenclature registry is maintained in Paper V. Throughout this paper, *continental drift* and *plate motion* name observed motion classes, whereas Plate Tectonics names the competing causal model family. An *event catalog* is the registered set of candidate events; an *event sequence* is a chronologically ordered selection from that catalog. The *flagship candidate relationship* is the declared Aegean–Everest–Mariana geometry, while the *flagship candidate event* is its broader causal interpretation. *Midpoint* is geometric; *midpoint response* is physical. *Terminal response* is the general scientific term; *exit* is retained in the Paper-I title and only where a specific mechanism branch predicts literal outward passage. The *replacement thesis* is the proposition under test; a *replacement candidate* is an outcome that can be earned only through the complete Paper-IV comparison and replication program.

1.2 Measured Plate Motion Is Shared Evidence

Let the observed plate-motion dataset be

$$\mathbf{D}_V = \left\{ \mathbf{v}_i^{\text{obs}}(\mathbf{x}_j, t) \right\}, \tag{4}$$

where:

$$i = \text{plate or tectonic block index}, \tag{5}$$

$$j = \text{observation-site index}, \tag{6}$$

$$\mathbf{x}_j = \text{site position}, \tag{7}$$

$$\mathbf{v}_i^{\text{obs}} = \text{observed velocity in a declared reference frame}. \tag{8}$$

Both Plate Tectonics and Astro-Ballistic Chronostratigraphic Sequencing must explain these measurements. Plate rotations, present-day plate velocities, boundary geometry, and strain-rate fields have independent kinematic and geodetic literatures [1, 2, 3, 4, 5, 6].

The replacement framework does not gain support by disputing the existence of relative plate motion.

1.3 Continental Drift and Plate Tectonics

Continental drift and Plate Tectonics must be distinguished.

Continental drift describes the large-scale relative movement of continents through geological time.

Plate Tectonics is a broader causal and kinematic framework involving:

- lithospheric plates;
- plate boundaries;
- relative motion;

- oceanic spreading;
- subduction;
- continental collision;
- transform motion;
- mantle coupling;
- gravity-related forces; and
- long-term lithospheric recycling.

Paper III does not challenge the observation that continents and lithospheric plates have changed position.

It challenges the causal origin and organization of the boundary and motion system.

1.4 Three Levels of Explanation

The global problem contains three explanatory levels:

Observation
: Plates move relative to one another.

Kinematic organization
: The motion field can be represented through plate rotations, boundary velocities, deformation zones, and reconstructed positions.

Causal origin
: A physical model explains why the boundaries formed, why the plates move in their particular directions, and why the relative speeds possess their observed structure.

The replacement thesis operates primarily at the third level.

1.5 Plate-Tectonic Causal Model

Conventional plate-driving analyses distribute causal work among slab, gravitational, boundary, and mantle-coupling terms rather than treating "Plate Tectonics" as one undefined force [7, 8].

A generalized Plate-Tectonic model may be written as

$$\mathcal{M}_{\mathrm{PT}} : \{\mathbf{Q}_{\mathrm{mantle}}, \mathbf{Q}_{\mathrm{lith}}, \mathbf{F}_{\mathrm{gravity}}, \mathbf{F}_{\mathrm{boundary}}, \mathbf{F}_{\mathrm{buoyancy}}, \mathbf{F}_{\mathrm{coupling}}\} \to \{\mathcal{B}_{\mathrm{obs}}, \mathbf{V}_{\mathrm{obs}}\}, \tag{9}$$

where:

$$\mathcal{B}_{\mathrm{obs}} = \text{observed boundary network}, \tag{10}$$

$$\mathbf{V}_{\mathrm{obs}} = \text{observed plate-motion field}. \tag{11}$$

1.6 Astro-Ballistic Causal Model

The candidate replacement model is

$$\mathcal{M}_{\text{ABC}} : \{\mathcal{E}, \mathbf{Q}_{\text{inherit}}, \mathbf{F}_{\text{gravity}}, \mathbf{F}_{\text{boundary}}, \mathbf{F}_{\text{buoyancy}}, \mathbf{F}_{\text{coupling}}\} \to \left\{\widehat{\mathcal{B}}_{\text{ABC}}, \widehat{\mathbf{V}}_{\text{ABC}}\right\}, \tag{12}$$

where:

$$\mathcal{E} = \text{sequenced event catalog}, \tag{13}$$
$$\mathbf{Q}_{\text{inherit}} = \text{event-created and event-modified planetary state}, \tag{14}$$
$$\widehat{\mathcal{B}}_{\text{ABC}} = \text{predicted boundary network}, \tag{15}$$
$$\widehat{\mathbf{V}}_{\text{ABC}} = \text{predicted plate-motion field}. \tag{16}$$

The candidate model retains ongoing internal and gravitational forces.

Its replacement claim is that the event sequence supplies the primary historical organization and directional inheritance of the global system.

1.7 The Full Causal Chain

The replacement framework requires

$$\mathcal{E} \to \mathbf{Q}_{\text{post}} \to \mathcal{B}_{\text{inherit}} \to \mathbf{F}_{\text{ongoing}} \to \mathbf{V}_{\text{plates}}(t) \to \mathcal{G}_{\text{surface}}(t), \tag{17}$$

where:

$$\mathbf{Q}_{\text{post}} = \text{post-event state}, \tag{18}$$
$$\mathcal{B}_{\text{inherit}} = \text{inherited boundary and weakness network}, \tag{19}$$
$$\mathbf{F}_{\text{ongoing}} = \text{later and continuing forces}, \tag{20}$$
$$\mathbf{V}_{\text{plates}} = \text{plate-motion field}, \tag{21}$$
$$\mathcal{G}_{\text{surface}} = \text{mountains, trenches, ridges, basins, and terranes}. \tag{22}$$

Every arrow must be mathematically and physically specified.

1.8 Edge-by-Edge Global Causal Audit

The chain in equation (17) is not one test. Its minimum causal edges are:

Edge	Proposed transition	Minimum evidence	Principal alternatives
G1	Event sequence to post-event state	Mechanically admissible Paper-II output.	No event, different event, or unresolved handoff.
G2	Post-event state to inherited boundaries and material contrasts	Forward nucleation, damage, and persistence model.	Pre-existing weakness, internal emergence, or later creation.
G3	Inherited state to ongoing force and resistance architecture	Coupled constitutive and long-time evolution.	Unmodified mantle, gravity, buoyancy, and boundary forces.
G4	Force and resistance architecture to plate motion	Shared-parameter direction, speed, and Euler-pole prediction.	Plate-Tectonic driving, initial-state tuning, or hybrid control.
G5	Plate motion and inherited state to surface structures	Chronological forward model and held-out structural predictions.	Regional orogenesis, subduction, rifting, erosion, and reactivation.

A failure at G2 does not invalidate a valid Paper-II G1 calculation. A failure at G5 rejects the tested surface-structure path but does not by itself reject an independently tested motion path. Global primary causation requires at least one complete surviving path through all mandatory edges.

1.9 Replacement Is Not Addition

Adding astro-ballistic events to an otherwise unchanged Plate-Tectonic model does not automatically produce causal replacement.

The replacement claim requires that event-derived states explain a substantial portion of:

- boundary initiation;
- boundary placement;
- boundary orientation;
- initial relative-motion direction;
- later motion inheritance;
- mountain and trench localization;
- basin formation;
- crustal fragmentation;
- displaced terranes; and
- global chronological organization.

If the event sequence contributes only minor perturbations to a self-organized Plate-Tectonic system, it is not the primary replacement mechanism.

1.10 Replacement Success Standard

Paper III must ultimately show that the event-sequence model:

R1. predicts plate-boundary locations;

R2. predicts plate-boundary orientations;

R3. predicts boundary types or evolutionary transitions;

R4. predicts relative plate-motion directions;

R5. predicts relative plate speeds;

R6. predicts major continental displacements;

R7. predicts mountain-system placement;

R8. predicts trench and basin placement;

R9. preserves chronological consistency;

R10. produces unique advance predictions;

R11. survives independent reconstruction;

R12. remains compatible with Paper-II mechanics; and

R13. outperforms or materially improves the comparison framework after complexity penalties.

2 Scope and Central Questions

2.1 Primary Questions

Paper III asks:

Q1. Can event-created damage and rheological contrasts become persistent plate boundaries?

Q2. Can the event sequence predict why particular boundaries occupy their observed locations?

Q3. Can the event sequence predict why boundaries possess their observed orientations?

Q4. Can event-derived impulse and displacement fields predict plate-motion directions?

Q5. Can the model predict relative plate speeds without fitting each plate independently?

Q6. Can mountain systems be reconstructed as later expressions of inherited convergence, compression, uplift, or resistance nodes?

Q7. Can trenches be reconstructed as inherited excavation, weakening, bending, descent, or terminal-response zones?

Q8. Can ridges and basins be reconstructed as inherited extension, separation, uplift, collapse, decompression, or thermal-response structures?

Q9. Can successive events explain boundary reactivation, replacement, rotation, and continental fragmentation?

Q10. Does the complete chronology outperform coincidence and Plate-Tectonic comparison models?

2.2 Paper-III Output Classes

The paper must generate:

$$\mathbf{D}_{\text{III}}^{\text{pred}} = \left(\widehat{\mathcal{B}}, \widehat{\mathbf{V}}, \widehat{\mathbf{\Omega}}, \widehat{\mathcal{M}}, \widehat{\mathcal{T}}, \widehat{\mathcal{R}}, \widehat{\mathcal{S}}, \widehat{\mathcal{C}}\right), \tag{23}$$

where:

$$\widehat{\mathcal{B}} = \text{predicted boundary network}, \tag{24}$$
$$\widehat{\mathbf{V}} = \text{predicted plate velocities}, \tag{25}$$
$$\widehat{\mathbf{\Omega}} = \text{predicted plate rotations}, \tag{26}$$
$$\widehat{\mathcal{M}} = \text{predicted mountains}, \tag{27}$$
$$\widehat{\mathcal{T}} = \text{predicted trenches}, \tag{28}$$
$$\widehat{\mathcal{R}} = \text{predicted ridges and fracture systems}, \tag{29}$$
$$\widehat{\mathcal{S}} = \text{predicted basins and subsidence structures}, \tag{30}$$
$$\widehat{\mathcal{C}} = \text{predicted chronology}. \tag{31}$$

2.3 What Paper III Does Not Assume

Paper III does not assume that:

- every modern plate boundary was created by one event;
- every plate retains its original shape;
- an ancient impulse alone sustains modern speed;
- gravity and mantle coupling are absent;
- all mountain systems share one mechanism;
- all trenches are literal exit wounds;
- all ridges are literal entrance structures;
- the modern continents existed in their present configuration at each event time;
- every event in the source catalog is correct; or
- the replacement claim is established before model comparison.

3 Paper-II Handoff State

3.1 Conditional Post-Event State

Paper II defined the conditional event-indexed handoff vector

$$\mathbf{Q}_{\mathrm{III},0}^{(k)} = (\mathcal{B}_{\mathrm{ABC}}, \mathbf{J}_{\mathrm{plate}}, \Delta T, \Delta\rho, \mathbf{D}, \Delta\phi, \chi_m, \Delta\mathbf{C}, \Delta\boldsymbol{\sigma}, \mathbf{u}, \Delta\mathbf{g}, \Delta\boldsymbol{\omega}) \,. \tag{32}$$

Here:

$$\mathcal{B}_{\mathrm{ABC}} = \text{event-created or event-modified boundary field,} \tag{33}$$
$$\mathbf{J}_{\mathrm{plate}} = \text{plate-scale impulse field,} \tag{34}$$
$$\Delta T = \text{temperature perturbation,} \tag{35}$$
$$\Delta\rho = \text{density perturbation,} \tag{36}$$
$$\mathbf{D} = \text{damage and anisotropy state,} \tag{37}$$
$$\Delta\phi = \text{phase-state perturbation,} \tag{38}$$
$$\chi_m = \text{melt-fraction field,} \tag{39}$$
$$\Delta\mathbf{C} = \text{elastic and rheological property change,} \tag{40}$$
$$\Delta\boldsymbol{\sigma} = \text{residual-stress field,} \tag{41}$$
$$\mathbf{u} = \text{post-event velocity field,} \tag{42}$$
$$\Delta\mathbf{g} = \text{gravity perturbation,} \tag{43}$$
$$\Delta\boldsymbol{\omega} = \text{rotation-state perturbation.} \tag{44}$$

3.2 Material Handoff Rather Than Symbolic Handoff

Each handoff field must contain:

- a spatial coordinate system;
- a time;
- units;
- uncertainty;
- numerical resolution;
- material identity;
- preservation interval;
- constitutive assumptions;
- mechanism-branch identity; and
- conservation residuals.

A schematic path line or qualitative impulse arrow is not a sufficient Paper-III input.

3.3 Handoff Time

Let the Paper-II to Paper-III handoff occur at

$$t_h. \tag{45}$$

The handoff time must be late enough that the primary hypervelocity transient has decayed into a state suitable for long-duration geodynamic modeling.

It must be early enough to preserve:

- event-created momentum;
- damage;
- phase anomalies;
- density anomalies;
- displacement;
- residual stress;
- thermal structure; and
- material boundaries.

3.4 Handoff Uncertainty Ensemble

For candidate event k, Paper III must receive an uncertainty ensemble

$$\left\{\mathbf{Q}_{\mathrm{III},0}^{(k,r)}\right\}_{r=1}^{R_k}, \tag{46}$$

rather than one preferred field.

The ensemble should span:

- viable mechanical branches;
- event-energy uncertainty;
- impactor uncertainty;
- entrance-coordinate uncertainty;
- path uncertainty;
- Earth-model uncertainty;
- constitutive uncertainty;
- numerical uncertainty; and

- preservation uncertainty.

3.5 Handoff Admissibility

A handoff realization is admissible only if

$$\mathbf{Q}_{\mathrm{III},0}^{(k,r)} \in \mathcal{V}_{\mathrm{II},k}. \tag{47}$$

An inadmissible Paper-II state cannot be used as a Paper-III initial condition merely because it generates a favorable plate pattern.

3.6 Sequence-Level Handoff

For candidate sequence $\mathcal{S}$, the complete Paper-II input is

$$\mathbf{H}_{II\to III}(\mathcal{S}) = \left\{\mathbf{Q}_{\mathrm{III},0}^{(k,r)} : k \in \mathcal{S}, 1 \le r \le R_k\right\}. \tag{48}$$

A Paper-III realization must draw a physically compatible set of event states. It may not combine favorable fields from mutually incompatible Paper-II realizations without registering the combination as a new model version.

4 The Sequenced Event Catalog

4.1 One Event Is Not the Complete Framework

The Aegean–Himalayan–Mariana flagship candidate event is one candidate element within a wider event sequence.

Let the event catalog be

$$\mathcal{E} = \{\mathcal{E}_1, \mathcal{E}_2, \ldots, \mathcal{E}_{N_E}\}. \tag{49}$$

Each event is represented by

$$\mathcal{E}_k = \left(t_k, \mathcal{D}_{A,k}, \mathcal{P}_k, \mathcal{D}_{H,k}, \mathcal{D}_{M,k}, \mathbf{\Theta}_k, \mathbf{Q}_k^+, \mathbf{\Sigma}_k\right), \tag{50}$$

where:

$$
\begin{aligned}
t_k &= \text{event age}, && (51)\\
\mathcal{D}_{A,k} &= \text{entrance domain}, && (52)\\
\mathcal{P}_k &= \text{interior path or transmission structure}, && (53)\\
\mathcal{D}_{H,k} &= \text{midpoint response domain}, && (54)\\
\mathcal{D}_{M,k} &= \text{terminal domain}, && (55)\\
\mathbf{\Theta}_k &= \text{event parameters}, && (56)\\
\mathbf{Q}_k^+ &= \text{surviving post-event state}, && (57)\\
\mathbf{\Sigma}_k &= \text{uncertainty representation}. && (58)
\end{aligned}
$$

4.2 Chronological Ordering

The event sequence satisfies

$$t_1 > t_2 > \cdots > t_{N_E} \tag{59}$$

when age is expressed as time before present.

The planetary state immediately after event k is

$$\mathbf{Q}_k^+ = \mathcal{F}_k \left[\mathbf{Q}_k^-, \mathcal{E}_k \right], \tag{60}$$

where

$$\mathbf{Q}_k^- \tag{61}$$

is the pre-event state.

Between events,

$$\mathbf{Q}_{k+1}^- = \mathcal{U} \left[\mathbf{Q}_k^+, t_k \to t_{k+1} \right], \tag{62}$$

where $\mathcal{U}$ is the inter-event geodynamic evolution operator.

4.3 Event Superposition Is Not Linear by Default

The complete state is not assumed to be

$$\mathbf{Q} = \sum_k \mathbf{Q}_k^+. \tag{63}$$

Later events operate on a planet already modified by earlier events.

The state evolution is therefore generally

$$\mathbf{Q}_{N_E}^{+} = \mathcal{F}_{N_E} \circ \mathcal{U} \circ \mathcal{F}_{N_E-1} \circ \cdots \circ \mathcal{U} \circ \mathcal{F}_1 \left(\mathbf{Q}_0\right). \tag{64}$$

4.4 Event Interaction Classes

Successive events may:

- create new boundaries;
- reactivate old boundaries;
- terminate old boundaries;
- rotate existing blocks;
- fragment existing plates;
- merge blocks;
- redirect motion;
- accelerate or decelerate plates;
- deepen inherited basins;
- amplify inherited mountains;
- relocate deformation; or
- overprint earlier event evidence.

4.5 Event-Sequence Dependency

For boundary element b, define its event dependency set

$$\mathcal{K}_b = \{k : \mathcal{E}_k \text{ materially contributes to boundary } b\}. \tag{65}$$

For plate i, define motion dependency set

$$\mathcal{K}_{V,i} = \{k : \mathcal{E}_k \text{ materially contributes to plate } i\}. \tag{66}$$

The framework must identify which observed features are assigned to which events.

4.6 Catalog Completeness

The model must distinguish:

Known candidate events
: Events already identified within the source framework.

Required missing events
Events inferred because the current catalog cannot reconstruct a major observation.

Optional events
Events that improve a local fit but are not required globally.

Scope-reserved hypotheses
Directional or material-displacement event hypotheses intentionally withheld from the present corpus for separate later investigation. They are not counted as current explanatory successes, current free parameters, or current rescue mechanisms.

Rejected events
Events that fail geometry, chronology, mechanics, statistics, or global reconstruction.

A new event cannot be added without a complexity penalty and an independent forensic burden.

4.7 Current Catalog Is Not Claimed Exhaustive

The present manuscript intentionally does not enumerate every directional land-moving relationship, displaced-material hypothesis, or visually suspicious terrain association that may be investigated within the broader program. The current instantiated catalog is therefore not claimed to be the final catalog of all candidate astro-ballistic events.

This limitation creates a strict two-way firewall. First, a reserved hypothesis cannot be used to improve the current fit, explain a residual, or rescue an event sequence after results are known. Second, failure to model a feature that was explicitly declared outside the current scope is not itself a failed prediction of the current sequence. The exception is any observation class that the manuscript has already declared mandatory for a global replacement claim; such a class cannot be removed by relabeling it as future work.

Full replacement qualification therefore requires a later frozen catalog and a frozen mandatory-coverage vector. The present paper can test the architecture and declared sequences without pretending that all reserved terrain hypotheses have already been exposed or adjudicated.

No hidden-support rule.
Scope-reserved hypotheses have zero current evidentiary weight. They become scientific claims only when separately registered with their own coordinates or material domains, predicted directionality, chronology, mechanics, complexity cost, controls, and falsifiers.

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5 Global Coordinates and Reference Frames

5.1 Position Vector

For spherical latitude ϕ and longitude λ, the unit position vector is

$$\boldsymbol{\xi}(\phi, \lambda) = \begin{pmatrix} \cos\phi\cos\lambda \\ \cos\phi\sin\lambda \\ \sin\phi \end{pmatrix}. \tag{67}$$

The spherical surface position is

$$\mathbf{x} = R_{\oplus}\boldsymbol{\xi}. \tag{68}$$

Later models may replace the spherical Earth with an ellipsoid or three-dimensional geoid.

5.2 Reference-Frame Index

Let

$$\mathcal{R}_f, \qquad f = 1, \ldots, N_f, \tag{69}$$

denote candidate reference frames.

Each frame must specify:

- origin;
- orientation;
- rotation convention;
- time standard;
- mantle assumption;
- net-rotation constraint;
- uncertainty; and
- transformation to every other frame used.

5.3 Frame Transformation

Let position in frame a be

$$\mathbf{x}^{(a)}. \tag{70}$$

The position in frame b is

$$\mathbf{x}^{(b)} = \mathbf{R}_{ba}(t)\mathbf{x}^{(a)} + \mathbf{c}_{ba}(t), \tag{71}$$

where:

$$\mathbf{R}_{ba} = \text{rotation matrix}, \tag{72}$$
$$\mathbf{c}_{ba} = \text{translation vector}. \tag{73}$$

For Earth-centered rotational frames,

$$\mathbf{c}_{ba} = \mathbf{0}. \tag{74}$$

5.4 Velocity Transformation

The velocity transformation is

$$\mathbf{v}^{(b)} = \mathbf{R}_{ba}\mathbf{v}^{(a)} + \dot{\mathbf{R}}_{ba}\mathbf{x}^{(a)} + \dot{\mathbf{c}}_{ba}. \tag{75}$$

Plate-motion comparisons are invalid unless they use a declared common reference frame.

5.5 Finite Rotation

A finite plate rotation may be represented by matrix

$$\mathbf{R}_i\left(t_2, t_1\right). \tag{76}$$

A material point evolves as

$$\mathbf{x}_i(t_2) = \mathbf{R}_i\left(t_2, t_1\right)\mathbf{x}_i(t_1). \tag{77}$$

The inverse reconstruction is

$$\mathbf{x}_i(t_1) = \mathbf{R}_i^{-1}\left(t_2, t_1\right)\mathbf{x}_i(t_2). \tag{78}$$

5.6 Angular Velocity

For rigid plate i, let its instantaneous angular-velocity vector be

$$\boldsymbol{\omega}_i. \tag{79}$$

The predicted velocity at surface point $\mathbf{x}$ is

$$\mathbf{v}_i\left(\mathbf{x}\right) = \boldsymbol{\omega}_i \times \mathbf{x}. \tag{80}$$

The speed is

$$v_i = \left\|\boldsymbol{\omega}_i \times \mathbf{x}\right\|. \tag{81}$$

5.7 Euler Pole

Write

$$\boldsymbol{\omega}_i = \omega_i \widehat{\mathbf{e}}_i, \tag{82}$$

where $\widehat{\mathbf{e}}_i$ is the Euler-pole direction and ω_i is angular speed.

Paper III must predict or derive both.

5.8 Relative Motion

The relative velocity of plate i with respect to plate j is

$$\mathbf{v}_{ij} = (\boldsymbol{\omega}_i - \boldsymbol{\omega}_j) \times \mathbf{x}. \tag{83}$$

The relative angular velocity is

$$\boldsymbol{\omega}_{ij} = \boldsymbol{\omega}_i - \boldsymbol{\omega}_j. \tag{84}$$

5.9 Reference-Frame Robustness

A replacement result must remain stable across defensible frame choices.

For predicted quantity y,

$$\mathrm{Var}_f \left[y^{(f)} \right] \le \sigma^2_{y,\mathrm{frame}} \tag{85}$$

for a predeclared tolerance.

A result that exists only in one favorable frame is not robust.

6 Chronology, Paleogeography, and Material Lineage

6.1 Reconstruction Products Are Not Observations

Paper III separates measurement-proximal constraints from model-derived reconstructions. Dated samples, stratigraphic order, paleomagnetic measurements, provenance relations, pressure–temperature–time paths, and mapped present structures enter with explicit uncertainty. Plate polygons, rotation trees, restored coastlines, and inferred vanished boundaries are conditional outputs of declared models.

A model-derived reconstruction may be tested, used as one branch, or compared with another reconstruction. It is not treated as fixed causal ground truth merely because it is conventional.

6.2 Material-Lineage Graph

Define the global material-lineage graph

$$\mathcal{G}_L = (\mathcal{N}_L, \mathcal{E}_L, \tau_L), \tag{86}$$

where nodes are material domains and edges are typed transitions. Edge types include

- rotation and translation;
- distributed deformation;
- fragmentation and merger;
- accretion and terrane transfer;
- subduction, descent, and possible recycling;
- exhumation and erosion;
- event overprint; and
- later reactivation.

The map τ_L records the admissible age interval and uncertainty for each transition.

6.3 Present Response Domains and Event-Time Parcels

For present response domain Ω_j^0, candidate event-time parcel $n \in \mathcal{N}_L$, frame f, and reconstruction branch k, define

$$\mathbf{x}_{j,n}^{(k,f)}(a_e) = \mathcal{R}_{k,f}\left(a_e; \Omega_j^0, n, \mathcal{G}_L\right). \tag{87}$$

A modern place name is therefore a label for an observation domain, not proof of a unique deep-time material identity. The reconstruction must state whether a claim follows the present response domain, a crustal or lithospheric parcel, a mantle-relative corridor, or an Earth-fixed ballistic axis.

6.4 Flagship Initiating-Event Node

The flagship event is one specific node in the event catalog with nominal initiating age

$$a_{\text{init},F} = 256 \text{ Ma}. \tag{88}$$

A sequence containing this node must retain that identity. The event age may be propagated through a preregistered uncertainty model, but it may not be moved after the boundary, motion, mountain, trench, basin, or terrane fit is inspected. Other candidate events retain their own independently specified ages.

6.5 Sequence Chronology

For event sequence $\mathcal{S} = \{e_1, \ldots, e_N\}$, with age before present larger for older events, chronological order requires

$$a_{e_1} > a_{e_2} > \cdots > a_{e_N} \geq 0. \tag{89}$$

For structure s, define

$$\mathbf{C}_s = (a_{\text{seed},s}, a_{\text{react},s}, a_{\text{express},s}, \Delta a_s) \,. \tag{90}$$

An inherited interpretation requires

$$a_{\text{seed},s} > a_{\text{react},s} \geq a_{\text{express},s} \geq 0, \tag{91}$$

unless the seed and reactivation are the same dated event. The proposed carrier state between these ages must be represented in the material state or lineage graph.

6.6 Flagship Seed-to-Expression Ordering

For any structure s assigned to the flagship event, the chronology must satisfy

$$a_{\text{init},F} \geq a_{\text{seed},s} \geq a_{\text{react},s} \geq a_{\text{express},s} \geq 0. \tag{92}$$

A younger visible mountain, trench, basin, volcanic province, or boundary therefore tests the proposed carrier and reactivation lineage; it does not redefine the age of the initiating event.

6.7 Chronology and Lineage Closure

A reconstructed sequence is chronologically and materially closed only if every required event-to-structure path has:

1. a specific initiating-event age for each event, with uncertainty represented separately;
2. a connected material-lineage path;
3. no reversed cause-and-effect age relation;
4. an explicit treatment of missing or recycled material;
5. and a declared distinction between an older carrier state and a younger visible expression.

Define

$$I_{\text{closure},\mathcal{S}} = I_{\text{chron},\mathcal{S}} I_{\text{lineage},\mathcal{S}} I_{\text{frame},\mathcal{S}}. \tag{93}$$

A sequence with zero closure cannot qualify as a complete global reconstruction. Failure of one sequence does not remove other eligible sequences or independent regional claims.

A failure of the 256 Ma node rejects that flagship age assignment and every sequence that requires it. It does not automatically reject sequences built from independently specified events or regional claims that possess another complete support path.

7 Plates and Tectonic Blocks as Evolving Material Domains

7.1 Plate Domain

At time t, plate or tectonic block i occupies domain

$$\mathcal{P}_i(t) \subset \mathcal{S}_\oplus(t), \tag{94}$$

where $\mathcal{S}_\oplus$ is the lithospheric surface or shell.

The complete partition is

$$\mathcal{S}_\oplus = \bigcup_{i=1}^{N_P} \mathcal{P}_i \cup \mathcal{D}_{\text{deform}}, \tag{95}$$

where $\mathcal{D}_{\text{deform}}$ contains distributed deformation zones not represented as rigid plates.

7.2 Plate Boundary

The boundary of plate i is

$$\partial\mathcal{P}_i(t). \tag{96}$$

A shared boundary between plates i and j is

$$\mathcal{B}_{ij}(t) = \partial\mathcal{P}_i(t) \cap \partial\mathcal{P}_j(t). \tag{97}$$

7.3 Material Identity

A plate is not defined only by its present polygon.

Its material-state vector may include

$$\mathbf{Q}_{P_i} = (\rho_i, T_i, H_i, \eta_i, \mathbf{D}_i, \phi_i, \mathbf{C}_i, \boldsymbol{\sigma}_i, \mathbf{u}_i, \mathcal{A}_i)\,, \tag{98}$$

where:

$$H_i = \text{lithospheric thickness}, \tag{99}$$
$$\eta_i = \text{effective rheology}, \tag{100}$$
$$\mathbf{D}_i = \text{damage and anisotropy}, \tag{101}$$
$$\phi_i = \text{phase and composition state}, \tag{102}$$
$$\mathbf{C}_i = \text{elasticity tensor}, \tag{103}$$
$$\mathcal{A}_i = \text{age and inheritance fields}. \tag{104}$$

7.4 Rigid and Deforming Components

Decompose the velocity field within plate domain i as

$$\mathbf{v}_i(\mathbf{x}, t) = \boldsymbol{\omega}_i(t) \times \mathbf{x} + \mathbf{v}_{i,\mathrm{def}}(\mathbf{x}, t). \tag{105}$$

The first term is rigid rotation.

The second is internal deformation.

7.5 Internal Deformation Measure

Define the strain-rate tensor

$$\dot{\boldsymbol{\epsilon}}_i = \frac{1}{2}\left[\nabla \mathbf{v}_{i,\mathrm{def}} + (\nabla \mathbf{v}_{i,\mathrm{def}})^{\mathsf{T}}\right]. \tag{106}$$

A plate may be treated as approximately rigid where

$$\|\dot{\boldsymbol{\epsilon}}_i\| \leq \dot{\epsilon}_{\mathrm{rigid,crit}}. \tag{107}$$

7.6 Plate Birth, Fragmentation, and Merger

A plate may be created when a connected boundary network encloses a new material domain.

Define plate birth at time t_b when

$$\exists \mathcal{P}_i(t_b) : \partial \mathcal{P}_i(t_b) \text{ becomes mechanically connected.} \tag{108}$$

Fragmentation occurs when

$$\mathcal{P}_i \to \{\mathcal{P}_{i_1}, \mathcal{P}_{i_2}, \ldots\}. \tag{109}$$

Merger occurs when

$$\{\mathcal{P}_i, \mathcal{P}_j\} \to \mathcal{P}_{ij}. \tag{110}$$

7.7 Plate Identity Through Time

Let plate identity map be

$$\mathcal{I}_P\left(\mathcal{P}_i, t_1, t_2\right). \tag{111}$$

The identity map must account for:

- fragmentation;
- merger;
- accretion;
- subduction or descent;
- erosion;
- sediment addition;
- terrane transfer;
- internal deformation; and
- event overprint.

Modern plate names cannot be projected unchanged through all event times.

7.8 Material-Lineage Closure Across Plate Names

A plate name is a time-local organizational label. The lineage of a claimed event response must instead be traced through typed material transitions. Where the material record is destroyed, subducted, recycled, or unobserved, the corresponding lineage edge is marked `MISSING-EVIDENCE` rather than silently filled by a preferred reconstruction.

For present domain $\mathcal{P}_i(0)$, define the admissible ancestor set at age a as

$$\mathrm{Anc}\left[\mathcal{P}_i(0), a\right] = \left\{n \in \mathcal{N}_L : n \rightsquigarrow \mathcal{P}_i(0)\right\}. \tag{112}$$

The ancestor set may contain multiple parcels and may differ across lineage models. A causal claim that requires one unique ancestor must supply evidence that distinguishes it from the alternatives.

8 Global Boundary-Network Representation

8.1 Boundary Graph

Represent the global plate system as graph

$$\mathcal{G}_B(t) = (\mathcal{V}_B(t), \mathcal{E}_B(t)), \tag{113}$$

where:

$$\mathcal{V}_B = \text{plate or block nodes}, \tag{114}$$
$$\mathcal{E}_B = \text{shared-boundary edges}. \tag{115}$$

Each edge e_{ij} contains:

$$e_{ij} = (\mathcal{B}_{ij}, \tau_{ij}, \gamma_{ij}, \kappa_{ij}, a_{ij}, \mathbf{Q}_{ij}, \mathcal{K}_{ij}), \tag{116}$$

where:

$$\tau_{ij} = \text{boundary type}, \tag{117}$$
$$\gamma_{ij} = \text{boundary orientation}, \tag{118}$$
$$\kappa_{ij} = \text{boundary curvature}, \tag{119}$$
$$a_{ij} = \text{boundary age}, \tag{120}$$
$$\mathbf{Q}_{ij} = \text{boundary material state}, \tag{121}$$
$$\mathcal{K}_{ij} = \text{event dependency set}. \tag{122}$$

8.2 Boundary Types

The model may classify a boundary at time t as:

- opening;
- closing;
- convergent;
- divergent;
- transform or shear dominated;
- compressional interior;
- extensional interior;
- inherited weakness;
- inherited strength contrast;
- excavation boundary;
- collapse boundary;

- terminal-response boundary;
- reactivated boundary; or
- inactive inherited structure.

The classification must emerge from kinematics and mechanics rather than from modern naming alone.

8.3 Boundary Orientation

For boundary curve $\mathbf{b}_{ij}(u,t)$, the unit tangent is

$$\widehat{\mathbf{t}}_{ij} = \frac{\partial \mathbf{b}_{ij}/\partial u}{\|\partial \mathbf{b}_{ij}/\partial u\|}. \tag{123}$$

The local surface-normal direction perpendicular to the boundary is

$$\widehat{\mathbf{n}}_{ij} = \widehat{\mathbf{r}} \times \widehat{\mathbf{t}}_{ij}. \tag{124}$$

8.4 Normal and Tangential Relative Motion

The relative velocity across the boundary is

$$\mathbf{v}_{ij}^{\mathrm{rel}} = \mathbf{v}_i - \mathbf{v}_j. \tag{125}$$

Its normal component is

$$v_{ij,n} = \mathbf{v}_{ij}^{\mathrm{rel}} \cdot \widehat{\mathbf{n}}_{ij}, \tag{126}$$

and tangential component is

$$v_{ij,t} = \mathbf{v}_{ij}^{\mathrm{rel}} \cdot \widehat{\mathbf{t}}_{ij}. \tag{127}$$

These components determine whether the boundary is opening, closing, or shearing at that location.

8.5 Observed Boundary Dataset

The observed boundary dataset is

$$\mathbf{D}_B^{\mathrm{obs}} = \left(\mathbf{x}_B, \gamma_B, \kappa_B, \tau_B, a_B, v_n, v_t, \mathbf{Q}_B\right). \tag{128}$$

The replacement model must predict the same quantities.

8.6 Predicted Event-Derived Boundary Network

The predicted network is

$$\widehat{\mathcal{B}}_{\mathrm{ABC}}(t) = \mathcal{H}_B\left[\mathcal{E}, \mathbf{Q}_0, t\right]. \tag{129}$$

The boundary-generation operator $\mathcal{H}_B$ must include:

- event damage;
- displacement discontinuities;
- excavation and collapse margins;
- terminal-response zones;
- thermal contrasts;
- density contrasts;
- phase boundaries;
- residual stress;
- later gravitational evolution;
- later reactivation; and
- later events.

8.7 Boundary-Distance Residual

For observed boundary point $\mathbf{x}_{B,k}^{\mathrm{obs}}$, define distance to the predicted network

$$d_{B,k} = \min_{\mathbf{x}\in\widehat{\mathcal{B}}_{\mathrm{ABC}}} d_{\mathcal{S}}\left(\mathbf{x}_{B,k}^{\mathrm{obs}}, \mathbf{x}\right), \tag{130}$$

where $d_{\mathcal{S}}$ is surface geodesic distance.

The normalized residual is

$$\epsilon_{B,k} = \frac{d_{B,k}}{\sigma_{B,k}}. \tag{131}$$

8.8 Boundary-Orientation Residual

For observed axial orientation γ_k^{obs} and predicted orientation γ_k^{pred},

$$\epsilon_{\gamma,k} = \frac{1}{2}\,\mathrm{atan2}\left[\sin 2\left(\gamma_k^{\mathrm{obs}} - \gamma_k^{\mathrm{pred}}\right), \cos 2\left(\gamma_k^{\mathrm{obs}} - \gamma_k^{\mathrm{pred}}\right)\right]. \tag{132}$$

8.9 Boundary-Age Residual

For observed boundary age a_k^{obs} and predicted initiation or reactivation age a_k^{pred},

$$\epsilon_{a,k} = \frac{a_k^{\mathrm{obs}} - a_k^{\mathrm{pred}}}{\sigma_{a,k}}. \tag{133}$$

8.10 Boundary-Network Falsifier

Boundary falsifier B1.
If the sequenced event model cannot predict the locations, orientations, ages, and relative motions of the major boundary network without independently tuning each boundary, the event-derived global boundary claim is rejected.

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9 Event Impulse and Inheritance Fields

9.1 Impulse Density

For event k, define impulse density

$$\mathbf{J}_k(\mathbf{r}) = \int_{t_k^-}^{t_k^+} \mathbf{f}_k(\mathbf{r}, t)\, dt. \tag{134}$$

The total impulse delivered to material domain $\mathcal{P}_i$ is

$$\mathbf{I}_{ik} = \int_{\mathcal{P}_i} \mathbf{J}_k(\mathbf{r})\, dV. \tag{135}$$

9.2 Angular Impulse

The angular impulse is

$$\Delta\mathbf{L}_{ik} = \int_{\mathcal{P}_i} \mathbf{r} \times \mathbf{J}_k(\mathbf{r})\, dV. \tag{136}$$

The immediate angular-velocity perturbation is

$$\Delta\boldsymbol{\omega}_{ik} = \mathbf{I}_i^{-1} \Delta\mathbf{L}_{ik}, \tag{137}$$

for plate inertia tensor $\mathbf{I}_i$.

9.3 Linear Momentum Handoff

The immediate translational velocity perturbation of block i is

$$\Delta\mathbf{v}_{ik} = \frac{\mathbf{I}_{ik}}{M_i}. \tag{138}$$

This is an initial impulse response.

It is not assumed to equal the modern plate velocity.

9.4 Event-Generated Damage Field

Let event-generated damage be

$$\mathbf{D}_k(\mathbf{r}, t_k^+). \tag{139}$$

Its long-time evolution is

$$\frac{D\mathbf{D}_k}{Dt} = \mathcal{F}_D\left(\mathbf{D}_k, T, P, \boldsymbol{\sigma}, \dot{\boldsymbol{\epsilon}}, \chi_m, \phi\right). \tag{140}$$

9.5 Inherited Rheological Contrast

The event changes effective viscosity by

$$\Delta\eta_k = \eta_k^+ - \eta_k^-. \tag{141}$$

Define normalized weakness

$$W_{\eta,k} = \frac{\eta_k^-}{\eta_k^+}. \tag{142}$$

Values

$$W_{\eta,k} > 1 \tag{143}$$

represent weakening.

Values

$$W_{\eta,k} < 1 \tag{144}$$

represent strengthening.

9.6 Inherited Boundary Potential

Define a boundary-nucleation potential

$$\mathcal{N}_{B,k} = w_D\widetilde{D}_k + w_\eta\widetilde{W}_{\eta,k} + w_\sigma\widetilde{\|\Delta\boldsymbol{\sigma}_k\|} + w_T\left|\widetilde{\Delta T}_k\right| + w_\rho\left|\widetilde{\Delta\rho}_k\right| + w_\phi\left|\widetilde{\Delta\phi}_k\right| + w_u\left\|\widetilde{\Delta\mathbf{u}}_k\right\|, \tag{145}$$

with

$$\sum_j w_j = 1, \qquad w_j \geq 0. \tag{146}$$

The initial candidate boundary domain is

$$\mathcal{B}_k^0 = \{\mathbf{r} : \mathcal{N}_{B,k} \geq \mathcal{N}_{B,\text{crit}}\}. \tag{147}$$

9.7 Boundary Persistence

Let boundary strength be

$$S_{B,k}(t) = \int_{\mathcal{B}_k(t)} \mathcal{N}_{B,k}(\mathbf{r}, t)\, dV. \tag{148}$$

The normalized persistence is

$$\mathcal{P}_{B,k}(t) = \frac{S_{B,k}(t)}{S_{B,k}(t_k^+)}. \tag{149}$$

A candidate event-created boundary survives only if

$$\mathcal{P}_{B,k}(t_{\text{react}}) \geq \mathcal{P}_{B,\text{crit}}. \tag{150}$$

9.8 Reactivation Potential

For later stress tensor $\boldsymbol{\sigma}_{\text{later}}$, define resolved loading on an inherited boundary plane with normal $\widehat{\mathbf{n}}_B$:

$$\mathbf{t}_B = \boldsymbol{\sigma}_{\text{later}} \widehat{\mathbf{n}}_B. \tag{151}$$

Normal traction is

$$t_n = \mathbf{t}_B \cdot \widehat{\mathbf{n}}_B, \tag{152}$$

and shear traction is

$$\mathbf{t}_s = \mathbf{t}_B - t_n \widehat{\mathbf{n}}_B. \tag{153}$$

A reactivation function is

$$\mathcal{R}_B = \frac{\|\mathbf{t}_s\|}{C_B + \mu_B t_n}, \tag{154}$$

under an appropriate sign convention.

Reactivation is possible when

$$\mathcal{R}_B \geq 1. \tag{155}$$

9.9 Event Memory Kernel

The surviving influence of event k on plate i may be represented by memory kernel

$$K_{ik}\left(t - t_k\right). \tag{156}$$

A generalized inherited contribution is

$$\mathbf{v}_i^{\text{inherit}}(t) = \sum_k K_{ik}\left(t - t_k\right)\Delta\mathbf{v}_{ik}. \tag{157}$$

The kernel is not assumed to be simple exponential decay.

It may include:

- rapid relaxation;
- long-lived boundary guidance;
- gravity-driven amplification;
- delayed reactivation;
- later-event reinforcement;
- later-event cancellation; and
- changes in plate identity.

10 Long-Time Governing Equations

10.1 Continuum Momentum Equation

The long-time lithosphere–mantle system satisfies

$$\rho \frac{D\mathbf{u}}{Dt} = \nabla \cdot \boldsymbol{\sigma} + \rho\mathbf{g} - 2\rho\boldsymbol{\Omega}_{\oplus} \times \mathbf{u} - \rho\boldsymbol{\Omega}_{\oplus} \times \left(\boldsymbol{\Omega}_{\oplus} \times \mathbf{r}\right) + \mathbf{f}_{\text{event}} + \mathbf{f}_{\text{coupling}}. \tag{158}$$

On sufficiently long timescales or under creeping-flow approximations, the inertial term may be small.

That approximation must be stated rather than assumed.

10.2 Mass Conservation

Mass conservation is

$$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \mathbf{u}) = 0. \tag{159}$$

For an incompressible approximation,

$$\nabla \cdot \mathbf{u} = 0. \tag{160}$$

The approximation must not be applied through large phase or density changes without justification.

10.3 Thermal Evolution

The thermal equation is

$$\rho c_P \frac{DT}{Dt} = \nabla \cdot (k \nabla T) + \Phi_{\text{visc}} + \Phi_{\text{plastic}} + Q_{\text{phase}} + Q_{\text{internal}} + Q_{\text{event}}. \tag{161}$$

Every term on the right-hand side has units of volumetric power density, $\mathrm{W\,m^{-3}}$. In particular, Φ_{visc} and Φ_{plastic} are dissipation rates per unit volume, while the Q terms are volumetric heating or latent-power sources.

10.4 Composition and Phase Transport

For composition field C_a,

$$\frac{\partial C_a}{\partial t} + \mathbf{u} \cdot \nabla C_a = \nabla \cdot (\mathcal{D}_a \nabla C_a) + R_a. \tag{162}$$

For phase fraction ϕ_a,

$$\frac{D\phi_a}{Dt} = \mathcal{R}_{\phi,a} (P, T, \boldsymbol{\sigma}, C, t) . \tag{163}$$

10.5 Viscoelastic Stress Evolution

A generalized Maxwell-type deviatoric evolution is

$$\dot{\mathbf{s}} + \frac{1}{\tau_M} \mathbf{s} = 2G \dot{\boldsymbol{\epsilon}}_{\text{dev}} + \mathbf{S}_{\text{event}}, \tag{164}$$

where:

$$\tau_M = \frac{\eta}{G}, \tag{165}$$

$$\mathbf{S}_{\text{event}} = \text{event-derived stress source or initial condition.} \tag{166}$$

10.6 Damage and Healing

The inherited damage field evolves as

$$\frac{D\mathbf{D}}{Dt} = \mathcal{F}_{\text{damage}} - \mathcal{F}_{\text{heal}} + \mathcal{F}_{\text{react}} + \mathcal{F}_{\text{event}}. \tag{167}$$

This equation must preserve directional damage where the replacement model predicts directional boundary inheritance.

10.7 Gravity

The gravitational potential satisfies

$$\nabla^2 \Phi = 4\pi G \rho, \tag{168}$$

with

$$\mathbf{g} = -\nabla \Phi. \tag{169}$$

Event-driven density redistribution modifies:

- gravitational potential;
- isostatic response;
- buoyancy;
- plate-driving forces;
- basin subsidence;
- uplift;
- geoid structure; and
- mantle flow.

10.8 Plate-Integrated Linear Momentum

For plate domain $\mathcal{P}_i$,

$$\frac{d}{dt} \int_{\mathcal{P}_i} \rho \mathbf{u} \, dV = \mathbf{F}_i^{\text{event}} + \mathbf{F}_i^{\text{gravity}} + \mathbf{F}_i^{\text{buoyancy}} + \mathbf{F}_i^{\text{boundary}} + \mathbf{F}_i^{\text{mantle}} + \mathbf{F}_i^{\text{resist}}. \tag{170}$$

10.9 Plate-Integrated Angular Momentum

The plate angular momentum is

$$\mathbf{L}_i = \int_{\mathcal{P}_i} \mathbf{r} \times \rho \mathbf{u} \, dV. \tag{171}$$

Its evolution is

$$\frac{d\mathbf{L}_i}{dt} = \boldsymbol{\tau}_i^{\text{event}} + \boldsymbol{\tau}_i^{\text{gravity}} + \boldsymbol{\tau}_i^{\text{boundary}} + \boldsymbol{\tau}_i^{\text{mantle}} + \boldsymbol{\tau}_i^{\text{resist}}. \tag{172}$$

10.10 Rigid-Plate Rotational Equation

For approximately rigid plate i,

$$\mathbf{I}_i \frac{d\boldsymbol{\omega}_i}{dt} + \boldsymbol{\omega}_i \times (\mathbf{I}_i \boldsymbol{\omega}_i) = \boldsymbol{\tau}_{i,\text{net}}. \tag{173}$$

The net torque is

$$\boldsymbol{\tau}_{i,\text{net}} = \boldsymbol{\tau}_i^{\text{event}} + \boldsymbol{\tau}_i^{\text{gravity}} + \boldsymbol{\tau}_i^{\text{boundary}} + \boldsymbol{\tau}_i^{\text{mantle}} + \boldsymbol{\tau}_i^{\text{resist}}. \tag{174}$$

10.11 Boundary Traction

For plate i, boundary force is

$$\mathbf{F}_i^{\text{boundary}} = \int_{\partial \mathcal{P}_i} \boldsymbol{\sigma} \widehat{\mathbf{n}}_i \, dA. \tag{175}$$

The corresponding torque is

$$\boldsymbol{\tau}_i^{\text{boundary}} = \int_{\partial \mathcal{P}_i} \mathbf{r} \times (\boldsymbol{\sigma} \widehat{\mathbf{n}}_i) \, dA. \tag{176}$$

10.12 Mantle Coupling

A reduced basal traction law may be written as

$$\mathbf{t}_i^{\text{mantle}} = -\mathbf{K}_i^{\text{mantle}} (\mathbf{v}_i - \mathbf{v}_m), \tag{177}$$

where:

$$\mathbf{K}_i^{\text{mantle}} = \text{coupling tensor}, \tag{178}$$

$$\mathbf{v}_m = \text{mantle velocity beneath the plate}. \tag{179}$$

The tensor may depend on:

- viscosity;
- temperature;
- melt;
- damage;
- lithospheric thickness;
- anisotropy;
- inherited corridors; and
- event-modified mantle structure.

10.13 Resistance and Dissipation

The total mechanical dissipation rate is

$$\dot{E}_{\text{diss}} = \int_{\mathcal{V}_{\oplus}} \boldsymbol{\sigma} : \dot{\boldsymbol{\epsilon}}_{\text{irr}} \, dV. \tag{180}$$

Plate motion must satisfy

$$\frac{dE_{\text{kin}}}{dt} = \dot{W}_{\text{event}} + \dot{W}_{\text{gravity}} + \dot{W}_{\text{buoyancy}} + \dot{W}_{\text{mantle}} + \dot{W}_{\text{boundary}} - \dot{E}_{\text{diss}}. \tag{181}$$

11 Inherited Motion and Ongoing Force Decomposition

11.1 Ancient Impulse Alone Is Insufficient

A finite ancient impulse does not automatically sustain modern motion for hundreds of millions of years.

Paper III therefore decomposes plate motion into:

$$\mathbf{v}_i(t) = \mathbf{v}_i^{\text{inherit}}(t) + \mathbf{v}_i^{\text{gravity}}(t) + \mathbf{v}_i^{\text{mantle}}(t) + \mathbf{v}_i^{\text{boundary}}(t) + \mathbf{v}_i^{\text{later events}}(t). \tag{182}$$

This decomposition is conceptual until the coupled equations are solved.

11.2 Inherited Direction Versus Sustained Speed

The event sequence may contribute more strongly to direction than to modern speed.

Define directional inheritance fraction

$$f_{i,\text{dir}} = \frac{\mathbf{v}_i^{\text{obs}} \cdot \widehat{\mathbf{v}}_i^{\text{inherit}}}{\left\|\mathbf{v}_i^{\text{obs}}\right\|}. \tag{183}$$

Define inherited speed fraction

$$f_{i,\text{speed}} = \frac{\left\|\mathbf{v}_i^{\text{inherit}}\right\|}{\left\|\mathbf{v}_i^{\text{obs}}\right\|}. \tag{184}$$

The two quantities need not be equal.

11.3 Boundary Guidance

An inherited boundary may constrain motion direction even after the initial momentum has decayed.

Let boundary mobility tensor be

$$\mathbf{M}_B = M_{\parallel}\widehat{\mathbf{t}}_B \otimes \widehat{\mathbf{t}}_B + M_{\perp}\widehat{\mathbf{n}}_B \otimes \widehat{\mathbf{n}}_B. \tag{185}$$

If

$$M_{\parallel} \gg M_{\perp}, \tag{186}$$

motion is preferentially guided along the inherited boundary.

If

$$M_{\perp} \gg M_{\parallel}, \tag{187}$$

opening or closing across the boundary is favored.

11.4 Event-Modified Gravity

The event changes gravitational potential by

$$\Delta\Phi_k = -G \int \frac{\Delta\rho_k(\mathbf{r}')}{\|\mathbf{r} - \mathbf{r}'\|}\, dV'. \tag{188}$$

The corresponding force is

$$\Delta\mathbf{F}_{g,k} = -\int_{\mathcal{P}_i} \rho \nabla \Delta\Phi_k \, dV. \tag{189}$$

Thus, an event may contribute to later motion through a persistent density field rather than through surviving momentum alone.

11.5 Event-Modified Buoyancy

For density anomaly $\Delta\rho_k$, the buoyancy contribution is

$$\mathbf{F}_{B,k} = -\int_{\mathcal{V}} \Delta\rho_k \mathbf{g}\, dV. \tag{190}$$

Thermal, compositional, melt, and phase anomalies may therefore convert a short event into a long-lived force source.

11.6 Event-Modified Resistance

The event may reduce or increase resistance through

$$\eta^+ = \eta^- + \Delta\eta_k, \tag{191}$$

$$Y^+ = Y^- + \Delta Y_k, \tag{192}$$

and

$$\mathbf{D}^+ = \mathbf{D}^- + \Delta\mathbf{D}_k. \tag{193}$$

The same continuing force field can produce different motion when the boundary and rheological architecture changes.

11.7 Motion-Memory State

Define the motion-memory state of plate i as

$$\mathbf{M}_i(t) = (\mathbf{p}_i, \mathbf{L}_i, \mathbf{D}_i, \Delta\rho_i, \Delta T_i, \Delta\phi_i, \Delta\eta_i, \mathcal{B}_i)\,. \tag{194}$$

Its evolution is

$$\frac{D\mathbf{M}_i}{Dt} = \mathcal{F}_M\left[\mathbf{M}_i, \mathbf{F}_{\text{ongoing}}, \mathcal{E}_{\text{later}}\right]. \tag{195}$$

11.8 Primary Inheritance Test

Run the complete model with event-derived inheritance:

$$\mathbf{V}^+(t) = \mathcal{U}\left[\mathbf{Q}_{\text{inherit}}, \mathbf{F}_{\text{ongoing}}\right]. \tag{196}$$

Run the counterfactual without it:

$$\mathbf{V}^0(t) = \mathcal{U}\left[\mathbf{Q}_{\text{background}}, \mathbf{F}_{\text{ongoing}}\right]. \tag{197}$$

The event contribution is

$$\Delta \mathbf{V}^{\mathrm{ABC}} = \mathbf{V}^{+} - \mathbf{V}^{0}. \tag{198}$$

Inheritance falsifier I1.
If removing the event-created state leaves the predicted global boundary network and plate-motion field materially unchanged, the event sequence is not the primary causal framework of the plate system.

11.9 Mediator-Specific Inheritance Tests

The aggregate contrast in equation (198) must be decomposed so that one flexible inherited field cannot conceal the failure of another. Minimum coherent interventions include removal of:

1. residual linear and angular impulse;
2. event-created boundary geometry;
3. damage and rheological anisotropy;
4. density and buoyancy anomalies;
5. thermal and phase anomalies;
6. and event-modified mantle coupling.

Each intervention must preserve a valid background model and must be compared with the corresponding Plate-Tectonic and hybrid alternatives. When different mediators compensate for one another, the contribution must be reported as non-identifiable or interaction-dependent rather than assigned wholly to the event sequence.

12 Plate-Direction and Speed Prediction

12.1 Predicted Plate Velocity

For plate i, the model predicts

$$\widehat{\mathbf{v}}_i(\mathbf{x}, t) = \widehat{\boldsymbol{\omega}}_i(t) \times \mathbf{x} + \widehat{\mathbf{v}}_{i,\mathrm{def}}(\mathbf{x}, t). \tag{199}$$

12.2 Velocity Residual

The vector residual is

$$\boldsymbol{\epsilon}_{v,i} = \mathbf{v}_i^{\mathrm{obs}} - \widehat{\mathbf{v}}_i. \tag{200}$$

Its magnitude is

$$\epsilon_{v,i} = \|\boldsymbol{\epsilon}_{v,i}\|. \tag{201}$$

12.3 Directional Residual

The directional angular residual is

$$\Delta\theta_i = \arccos\left(\frac{\mathbf{v}_i^{\text{obs}} \cdot \widehat{\mathbf{v}}_i}{\left\|\mathbf{v}_i^{\text{obs}}\right\| \left\|\widehat{\mathbf{v}}_i\right\|}\right). \tag{202}$$

12.4 Speed Residual

The speed residual is

$$\Delta v_i = \left\|\mathbf{v}_i^{\text{obs}}\right\| - \left\|\widehat{\mathbf{v}}_i\right\|. \tag{203}$$

The normalized speed residual is

$$\epsilon_{s,i} = \frac{\Delta v_i}{\sigma_{v,i}}. \tag{204}$$

12.5 Euler-Pole Residual

For observed and predicted angular-velocity vectors,

$$\Delta\boldsymbol{\omega}_i = \boldsymbol{\omega}_i^{\text{obs}} - \widehat{\boldsymbol{\omega}}_i. \tag{205}$$

The Euler-pole angular separation is

$$\Delta\theta_{\omega,i} = \arccos\left(\widehat{\mathbf{e}}_i^{\text{obs}} \cdot \widehat{\mathbf{e}}_i^{\text{pred}}\right). \tag{206}$$

12.6 Global Velocity Misfit

For covariance matrix $\boldsymbol{\Sigma}_V$,

$$\chi_V^2 = \left(\mathbf{V}^{\text{obs}} - \widehat{\mathbf{V}}\right)^{\mathsf{T}} \boldsymbol{\Sigma}_V^{-1} \left(\mathbf{V}^{\text{obs}} - \widehat{\mathbf{V}}\right). \tag{207}$$

12.7 No Independent Plate-Speed Tuning

Let the event-sequence parameter count be

$$k_{\mathcal{E}}. \tag{208}$$

The model must not introduce one independent speed parameter for every plate unless those parameters are physically generated by the event and force model.

A prohibited direct fit would be

$$\widehat{v}_i = \theta_i \tag{209}$$

with one unconstrained θ_i per observed speed.

The required prediction is

$$\widehat{\mathbf{V}} = \mathcal{F}_V \left[\mathcal{E}, \mathbf{Q}_0, \mathbf{F}_{\text{ongoing}}\right]. \tag{210}$$

12.8 Shared-Parameter Requirement

Multiple plates must be predicted from shared event and material parameters.

For example,

$$\{\widehat{\mathbf{v}}_1, \ldots, \widehat{\mathbf{v}}_{N_P}\} = \mathcal{F}\left(\mathbf{\Theta}_{\text{global}}\right), \tag{211}$$

where

$$\dim\left(\mathbf{\Theta}_{\text{global}}\right) \ll 3N_P N_{\text{sites}} \tag{212}$$

for a genuinely constrained model.

12.9 Plate-Motion Prediction Falsifier

Motion falsifier V1.
If the sequenced event model cannot predict the observed relative plate directions and speeds from shared physical inputs without fitting each plate independently, the plate-motion inheritance claim is rejected.

13 Global Reconstruction Hierarchy

13.1 Stage 0: Observational Freeze

Before fitting the event sequence, freeze:

- plate and block definitions;
- boundary datasets;
- present velocity datasets;
- reconstruction time slices;
- reference frames;
- mountain and trench catalogs;
- basin and ridge catalogs;

- chronology datasets;
- uncertainty models; and
- comparison-model outputs.

13.2 Stage 1: Single-Event Boundary Test

For event k, calculate

$$\widehat{\mathcal{B}}_k(t) = \mathcal{H}_B\left[\mathcal{E}_k, \mathbf{Q}_k^-, t\right]. \tag{213}$$

This stage determines which boundaries one event can create, modify, or reactivate.

13.3 Stage 2: Single-Event Motion Test

Calculate the event-derived motion field

$$\widehat{\mathbf{V}}_k(t) = \mathcal{H}_V\left[\mathcal{E}_k, \mathbf{Q}_k^-, t\right]. \tag{214}$$

This tests:

- impulse direction;
- plate partition;
- rotation;
- relative motion;
- attenuation;
- boundary guidance; and
- persistent forcing.

13.4 Stage 3: Event-Sequence Assembly

The cumulative state is generated recursively through

$$\mathbf{Q}_{k+1}^- = \mathcal{U}\left[\mathcal{F}_k\left(\mathbf{Q}_k^-, \mathcal{E}_k\right)\right]. \tag{215}$$

This stage tests event interaction and overprint.

13.5 Stage 4: Plate and Boundary Reconstruction

At each time slice t_q, output

$$\left\{\widehat{\mathcal{P}}_i(t_q), \widehat{\mathcal{B}}_{ij}(t_q), \widehat{\mathbf{V}}_i(t_q)\right\}. \tag{216}$$

13.6 Stage 5: Surface-Structure Forward Model

The predicted surface structures are

$$\widehat{\mathcal{G}}_{\text{surface}} = \mathcal{O}_G \left[\widehat{\mathcal{P}}, \widehat{\mathcal{B}}, \widehat{\mathbf{V}}, \mathbf{Q} \right]. \tag{217}$$

The model must generate:

- mountains;
- trenches;
- ridges;
- basins;
- plateaus;
- volcanic provinces;
- fracture systems;
- continental margins;
- displaced terranes; and
- resource-bearing structural provinces.

13.7 Stage 6: Counterfactual Reconstruction

Run at least three model families:

$$\mathcal{M}_0 = \text{comparison model without astro-ballistic inheritance,} \tag{218}$$

$$\mathcal{M}_1 = \text{astro-ballistic inheritance model,} \tag{219}$$

$$\mathcal{M}_2 = \text{combined model with event inheritance and later geodynamics.} \tag{220}$$

The model comparison must determine whether the event sequence is:

- unnecessary;
- complementary;
- materially explanatory;
- causally dominant; or
- incompatible with observations.

13.8 Causal Identification Requirements for the Counterfactual Family

The three model families in Stage 6 must be executable, independently specified, and matched in observational opportunity. In particular:

- the no-event model must not be deliberately deprived of defensible initial heterogeneity;
- the astro-ballistic model must count every event, coordinate, transition, and inherited field selected after inspection;
- the combined model must demonstrate necessity of both parent components and any interaction term;
- and all families must be evaluated on the same held-out boundaries, motions, chronology, deep fields, and surface structures.

A fitted difference between two unmatched simulations is not a causal intervention. It is a model-configuration contrast and must be labeled accordingly.

13.9 Stage 7: Advance Prediction

The framework must identify observations not used in fitting.

These may include:

- unknown or poorly mapped boundary continuations;
- predicted subsurface corridors;
- predicted fracture orientations;
- predicted basin asymmetries;
- predicted terrane displacement paths;
- predicted gravity anomalies;
- predicted seismic anisotropy;
- predicted event-linked mineralization; and
- predicted chronological relationships.

14 Initial Paper-III Falsification Architecture

14.1 Primary Paper-III Falsifier

Paper-III primary falsifier.
If a completed search over the frozen eligible event-sequence family shows that every sequence has an empty integrated viable set for the major plate-boundary network, relative plate-motion directions, relative speeds, chronology, and principal surface structures, the global astro-ballistic organization claim developed in Paper III is rejected.
Before the eligible sequence family and its T3 thresholds are frozen and tested, the global status remains unresolved. Failure of one sequence rejects that sequence only.

14.2 Boundary Falsifier

If the event sequence predicts boundaries that are systematically mislocated, misoriented, mistimed, or absent, the global boundary-formation claim fails.

14.3 Direction Falsifier

If predicted plate directions do not match observed directions in a declared reference frame, directional inheritance fails.

14.4 Speed Falsifier

If speeds can be matched only through independent plate-specific tuning, the quantitative motion claim fails.

14.5 Chronology Falsifier

If predicted boundary initiation, reactivation, mountain building, trench development, and basin formation are chronologically incompatible with the geological record, the sequence fails.

14.6 Inheritance Falsifier

If removing the event-derived state does not materially alter the boundary and motion solution, the event sequence is not the primary organizer.

14.7 Complexity Falsifier

If the event model requires enough adjustable events, coordinates, paths, boundaries, and force parameters to reproduce arbitrary global patterns, it loses replacement force.

14.8 Mechanical-Consistency Falsifier

If Paper III requires event outputs outside the viable mechanical fields permitted by Paper II, the reconstruction is invalid.

14.9 Comparison-Model Falsifier

If the frozen comparison framework predicts the full held-out observation vector better after effective-complexity accounting, primary astro-ballistic replacement preference is not established. This comparative loss does not by itself reject independently viable regional or event-level contributions.

15 Global Reconstruction Framework Synthesis

This global-reconstruction synthesis records:

1. the causal replacement burden;
2. the distinction between continental drift and Plate Tectonics;
3. the acceptance of measured plate motion as shared evidence;
4. the Paper-II conditional handoff state;
5. the complete sequenced event-catalog structure;
6. nonlinear interaction among successive events;
7. the global coordinate and reference-frame architecture;
8. finite plate rotations and Euler-pole kinematics;
9. plates as evolving material domains;
10. rigid and internally deforming plate components;
11. plate birth, fragmentation, merger, and identity;
12. the global boundary-network graph;
13. boundary location, orientation, age, and motion residuals;
14. event impulse and angular-impulse fields;
15. inherited damage, rheology, gravity, and boundary potential;
16. long-time conservation and force equations;
17. the separation of inherited direction from sustained speed;
18. with-inheritance and without-inheritance counterfactuals;
19. quantitative direction, speed, and Euler-pole residuals;
20. the global reconstruction hierarchy; and
21. the initial Paper-III falsification architecture.

The following sections develop:

- event-derived boundary nucleation;
- fracture-network connectivity;

- plate fragmentation and enclosure;
- boundary reactivation by later events;
- convergent, divergent, transform, and collapse classifications;
- boundary propagation and termination;
- continental-margin inheritance;
- ocean-basin opening and closure;
- plate-identity tracking through successive events;
- topology and graph-comparison metrics; and
- complete boundary-network viability tests.

16 Event-Derived Boundary Nucleation

16.1 Boundary Nucleation as a Material-State Transition

A tectonic boundary is not defined only as a line drawn between modern plates.

Within Astro-Ballistic Chronostratigraphic Sequencing , a boundary begins as a spatially connected material-state transition capable of localizing later displacement.

For event k, define the post-event state perturbation

$$\Delta\mathbf{Q}_k = (\Delta T_k, \Delta\rho_k, \mathbf{D}_k, \Delta\phi_k, \chi_{m,k}, \Delta\eta_k, \Delta Y_k, \Delta\boldsymbol{\sigma}_k, \Delta\mathbf{u}_k, \Delta\mathbf{C}_k)\,. \tag{221}$$

A boundary-nucleation field is then constructed as

$$\mathcal{N}_{B,k}(\mathbf{r}, t) = \mathcal{F}_B\left[\Delta\mathbf{Q}_k(\mathbf{r}, t)\right]. \tag{222}$$

16.2 Normalized Boundary-Nucleation Functional

One explicit candidate is

$$\begin{aligned}\mathcal{N}_{B,k} = w_D\widetilde{D}_k + w_\eta\widetilde{\left(\frac{\eta_0}{\eta_k}\right)} + w_Y\widetilde{\left(\frac{Y_0}{Y_k}\right)} + w_\sigma\|\widetilde{\Delta\boldsymbol{\sigma}_k}\| \\ + w_T\left|\widetilde{\Delta T_k}\right| + w_\rho\left|\widetilde{\Delta\rho_k}\right| + w_\phi\left|\widetilde{\Delta\phi_k}\right| + w_u\left\|\widetilde{\Delta\mathbf{u}_k}\right\| + w_C\left\|\widetilde{\Delta\mathbf{C}_k}\right\|.\end{aligned} \tag{223}$$

The weights satisfy

$$w_j \geq 0, \qquad \sum_j w_j = 1. \tag{224}$$

The weights and normalization rules must be frozen before comparison with the observed boundary network.

16.3 Candidate Boundary Domain

The initial event-derived boundary domain is

$$\mathcal{B}_k^0 = \left\{ \mathbf{r} : \mathcal{N}_{B,k}(\mathbf{r}, t_k^+) \geq \mathcal{N}_{B,\mathrm{crit}} \right\}. \tag{225}$$

This domain may be volumetric.

Its surface projection is

$$\Pi_{\mathcal{S}} \left[\mathcal{B}_k^0 \right], \tag{226}$$

where $\Pi_{\mathcal{S}}$ maps the three-dimensional inherited structure onto the lithospheric surface or shell.

16.4 Boundary Skeleton

A volumetric weakness zone may be reduced to a center surface or centerline through skeletonization operator

$$\mathcal{S}_{B,k} = \mathrm{Skel} \left[\mathcal{B}_k^0 \right]. \tag{227}$$

The skeleton must preserve:

- connectivity;
- orientation;
- branching;
- thickness;
- depth;
- inherited material state; and
- uncertainty.

16.5 Boundary Thickness

For local boundary-normal coordinate ζ, define boundary thickness

$$H_{B,k} = \zeta_+ - \zeta_-, \tag{228}$$

where

$$\mathcal{N}_{B,k}(\zeta_\pm) = \mathcal{N}_{B,\text{crit}}. \tag{229}$$

The model must predict whether the inherited feature is:

- a narrow fault-like zone;
- a broad deformation belt;
- a deep lithospheric corridor;
- a crust–mantle transition;
- a thermal boundary;
- a compositional boundary; or
- a distributed plate-margin system.

16.6 Boundary Orientation From Material Tensors

Let the event-created damage tensor be

$$\mathbf{D}_k. \tag{230}$$

The principal weakness direction is

$$\widehat{\mathbf{n}}_{D,k} = \text{eigvec}_{\text{max}}\left(\mathbf{D}_k\right). \tag{231}$$

The predicted local boundary tangent may be defined as the surface direction orthogonal to the projected weakness normal:

$$\widehat{\mathbf{t}}_{B,k} = \frac{\widehat{\mathbf{r}} \times \widehat{\mathbf{n}}_{D,k}}{\|\widehat{\mathbf{r}} \times \widehat{\mathbf{n}}_{D,k}\|}. \tag{232}$$

Alternative orientation fields may derive from:

- maximum shear strain;
- maximum displacement gradient;
- phase-front geometry;
- excavation margins;
- collapse margins;
- terminal decompression;
- thermal gradients;
- density gradients; or

- stress discontinuities.

The selected orientation rule must be declared by mechanism class.

16.7 Boundary Initiation Time

The boundary initiation time is

$$t_{B,k}^{\text{init}} = \inf \left\{ t : \mathcal{N}_{B,k}(\mathbf{r}, t) \geq \mathcal{N}_{B,\text{crit}} \text{ over a connected domain} \right\}. \tag{233}$$

The time may differ from the event's nominal impact time because:

- damage may accumulate;
- collapse may be delayed;
- phase transformation may be delayed;
- thermal weakening may develop later;
- gravitational relaxation may localize deformation; or
- later events may reactivate a latent structure.

16.8 Boundary Maturity

Define normalized boundary maturity

$$\mathcal{M}_{B,k}(t) = \frac{S_{B,k}(t)}{S_{B,\text{mature}}}, \tag{234}$$

where

$$S_{B,k}(t) = \int_{\mathcal{B}_k(t)} \mathcal{N}_{B,k} \, dV. \tag{235}$$

A latent inherited structure may satisfy

$$0 < \mathcal{M}_{B,k} < 1 \tag{236}$$

before later loading turns it into an active plate boundary.

16.9 Boundary-Creation Classes

Event-derived boundary creation may occur through:

BC1. direct fracture;

BC2. shear localization;

BC3. compressional damage;

BC4. extensional separation;

BC5. excavation-margin formation;

BC6. terminal-collapse formation;

BC7. thermal weakening;

BC8. melt-assisted weakening;

BC9. density-contrast formation;

BC10. phase-boundary inheritance;

BC11. residual-stress localization; or

BC12. reactivation of an older structure.

Each class requires a distinct state signature.

16.10 Boundary-Nucleation Falsifier

Boundary-nucleation falsifier B2.
If mechanically admissible events do not generate connected material contrasts capable of becoming persistent deformation boundaries, the event-derived plate-boundary mechanism fails before global plate reconstruction begins.

---

17 Damage Connectivity and Plate Enclosure

17.1 Connected Boundary Components

For thresholded boundary domain $\mathcal{B}$, define connected components

$$\mathcal{B} = \bigcup_{c=1}^{N_C} \mathcal{B}_c. \tag{237}$$

Two points $\mathbf{x}_a$ and $\mathbf{x}_b$ belong to the same component if there exists a continuous path

$$\gamma : [0,1] \to \mathcal{B} \tag{238}$$

such that

$$\gamma(0) = \mathbf{x}_a, \qquad \gamma(1) = \mathbf{x}_b. \tag{239}$$

17.2 Surface Boundary Network

The surface-projected boundary network is

$$\mathcal{B}_{\mathcal{S}} = \Pi_{\mathcal{S}} \left[\bigcup_{k} \mathcal{B}_k \right]. \tag{240}$$

The complement of this network on the lithospheric surface is

$$\mathcal{S}_{\oplus} \setminus \mathcal{B}_{\mathcal{S}}. \tag{241}$$

Its connected components define candidate plate domains.

17.3 Candidate Plate Enclosure

A candidate plate domain $\mathcal{P}_i$ is a connected component satisfying

$$\partial \mathcal{P}_i \subseteq \mathcal{B}_{\mathcal{S}} \cup \mathcal{D}_{\text{distributed}}, \tag{242}$$

where $\mathcal{D}_{\text{distributed}}$ allows broad deformation zones.

17.4 Closure Defect

For candidate boundary loop Γ_i, define geometric closure defect

$$\delta_{\text{close},i} = d_{\mathcal{S}} \left(\mathbf{x}_{\text{start}}, \mathbf{x}_{\text{end}} \right). \tag{243}$$

The normalized defect is

$$\epsilon_{\text{close},i} = \frac{\delta_{\text{close},i}}{L_{\Gamma_i}}, \tag{244}$$

where L_{Γ_i} is loop length.

A candidate plate requires

$$\epsilon_{\text{close},i} \leq \epsilon_{\text{close,crit}}. \tag{245}$$

17.5 Boundary Completeness Fraction

Let the total perimeter of plate i be

$$L_{P_i}. \tag{246}$$

Let the perimeter supported by event-derived boundary state be

$$L_{P_i}^{\text{event}}. \tag{247}$$

Define boundary completeness

$$C_{P_i} = \frac{L_{P_i}^{\text{event}}}{L_{P_i}}. \tag{248}$$

A replacement model must specify the minimum completeness required for a plate to count as event organized.

17.6 Enclosure Confidence

Define plate-enclosure confidence

$$\mathcal{C}_i^{\text{enc}} = w_L C_{P_i} + w_{\text{close}} \left(1 - \epsilon_{\text{close},i}\right) + w_S \widetilde{S}_{B,i} + w_D \widetilde{D}_{B,i} + w_A \widetilde{A}_{B,i}, \tag{249}$$

with predeclared normalized components and weights.

17.7 Percolation Threshold

For threshold $\mathcal{N}_{B,\text{crit}}$, define largest connected-boundary fraction

$$P_\infty = \frac{L_{\text{largest component}}}{L_{\text{total boundary}}}. \tag{250}$$

A global boundary network may undergo a connectivity transition as the threshold changes.

The critical threshold is

$$\mathcal{N}_{B,\text{perc}} = \inf\left\{\mathcal{N}_{B,\text{crit}} : P_\infty \geq P_{\infty,\text{crit}}\right\}. \tag{251}$$

The threshold cannot be chosen solely because it produces the desired plate count.

17.8 Boundary Gaps

A gap between boundary segments a and b is

$$g_{ab} = \min_{\mathbf{x}_a \in \mathcal{B}_a, \mathbf{x}_b \in \mathcal{B}_b} d_{\mathcal{S}}\left(\mathbf{x}_a, \mathbf{x}_b\right). \tag{252}$$

A gap may be bridged only by:

- a predicted continuation;
- a distributed deformation zone;
- a later event;
- an independently mapped inherited structure; or
- a declared uncertainty interval.

17.9 No Arbitrary Boundary Bridging

A prohibited reconstruction is

$$\mathcal{B}_a \cup \mathcal{L}_{\text{manual}} \cup \mathcal{B}_b, \tag{253}$$

where $\mathcal{L}_{\text{manual}}$ is inserted only to close a preferred plate polygon.

Every connection must have a physical or observational basis.

17.10 Plate-Enclosure Falsifier

Plate-enclosure falsifier B3.
If the event-derived damage and material-state network cannot form stable connected boundaries enclosing a realistic set of tectonic domains without arbitrary gap filling, the global plate-partition claim is rejected.

18 Plate Fragmentation, Merger, and Terrane Transfer

18.1 Plate Lineage Graph

Plate identity through time is represented by directed graph

$$\mathcal{G}_P^{\text{lineage}} = \left(\mathcal{V}_P^{\text{time}}, \mathcal{E}_P^{\text{lineage}}\right). \tag{254}$$

Each node represents a plate or block at a specific time interval.

Edges represent:

- persistence;
- fragmentation;
- merger;
- accretion;
- transfer;
- descent;
- recycling; or
- uncertain identity.

18.2 Fragmentation Criterion

Plate i fragments when an internal connected boundary

$$\mathcal{B}_{i,\text{int}} \subset \mathcal{P}_i \tag{255}$$

separates the domain into at least two connected components:

$$\mathcal{P}_i \setminus \mathcal{B}_{i,\text{int}} = \bigcup_{a=1}^{N_f} \mathcal{P}_{i_a}, \qquad N_f \geq 2. \tag{256}$$

A mechanical fragmentation criterion may be

$$\mathcal{F}_{\text{frag},i} = w_D \widetilde{D} + w_\epsilon \widetilde{\epsilon}_{\text{eq}} + w_\sigma \widetilde{\sigma}_{\text{eq}} + w_\eta \widetilde{(\eta_0/\eta)} \geq \mathcal{F}_{\text{frag,crit}}. \tag{257}$$

18.3 Fragment Mass Conservation

Fragmentation requires

$$M_i^- = \sum_{a=1}^{N_f} M_{i_a}^+ + M_{\text{loss}} + M_{\text{transfer}}. \tag{258}$$

Angular momentum requires

$$\mathbf{L}_i^- + \Delta\mathbf{L}_{\text{event}} = \sum_{a=1}^{N_f} \mathbf{L}_{i_a}^+ + \mathbf{L}_{\text{loss}} + \mathbf{L}_{\text{transfer}}. \tag{259}$$

18.4 Fragment Velocity

For daughter fragment a,

$$\mathbf{v}_{i_a}^+ = \mathbf{v}_i^- + \Delta\mathbf{v}_{i_a}^{\text{event}} + \Delta\mathbf{v}_{i_a}^{\text{release}} + \Delta\mathbf{v}_{i_a}^{\text{gravity}}. \tag{260}$$

The model must predict differential daughter motion rather than simply assigning the modern velocities.

18.5 Merger Criterion

Two plate domains merge when:

1. their shared relative velocity becomes sufficiently small;
2. the intervening boundary loses mechanical activity;
3. their material-state contrast falls below a declared threshold; and
4. the combined domain behaves as one coherent kinematic unit.

Formally,

$$\left\| \mathbf{v}_{ij}^{\text{rel}} \right\| \leq v_{\text{merge,crit}}, \tag{261}$$

and

$$S_{B,ij} \leq S_{B,\text{inactive}}. \tag{262}$$

18.6 Terrane Domain

A terrane is represented as material domain

$$\mathcal{T}_q(t) \subset \mathcal{P}_i(t). \tag{263}$$

Its identity vector is

$$\mathbf{Q}_{T_q} = (\mathcal{C}_q, a_q, \mathbf{M}_q, \mathbf{S}_q, \mathbf{x}_q, \mathbf{R}_q), \tag{264}$$

where:

$$\mathcal{C}_q = \text{composition}, \tag{265}$$
$$a_q = \text{age structure}, \tag{266}$$
$$\mathbf{M}_q = \text{magnetic or paleomagnetic state}, \tag{267}$$
$$\mathbf{S}_q = \text{structural state}, \tag{268}$$
$$\mathbf{x}_q = \text{position}, \tag{269}$$
$$\mathbf{R}_q = \text{rotation state}. \tag{270}$$

18.7 Terrane Transfer

Terrane transfer from plate i to plate j is

$$\mathcal{T}_q \subset \mathcal{P}_i(t^-) \tag{271}$$

and

$$\mathcal{T}_q \subset \mathcal{P}_j(t^+). \tag{272}$$

The transfer requires:

- boundary crossing or boundary redefinition;
- material continuity;
- chronological continuity;
- displacement continuity;

- rotation continuity; and
- conservation of terrane identity.

18.8 Terrane Displacement Path

The reconstructed terrane path is

$$\mathbf{x}_{T_q}(t). \tag{273}$$

Its predicted displacement is

$$\Delta\mathbf{x}_{T_q} = \mathbf{x}_{T_q}(t_2) - \mathbf{x}_{T_q}(t_1). \tag{274}$$

The event-sequence model must predict this path from plate and boundary evolution.

18.9 Terrane-Fit Residual

For observed terrane property vector $\mathbf{Q}_{T_q}^{\text{obs}}$ and predicted vector $\widehat{\mathbf{Q}}_{T_q}$,

$$\boldsymbol{\epsilon}_{T_q} = \mathbf{Q}_{T_q}^{\text{obs}} - \widehat{\mathbf{Q}}_{T_q}. \tag{275}$$

The covariance-weighted residual is

$$\chi^2_{T_q} = \boldsymbol{\epsilon}_{T_q}^{\mathsf{T}} \boldsymbol{\Sigma}_{T_q}^{-1} \boldsymbol{\epsilon}_{T_q}. \tag{276}$$

18.10 Identity Falsifier

Plate-identity falsifier B4.
If the event sequence requires plate fragments, mergers, or terrane transfers that violate material, chronological, rotational, or geochemical continuity, the corresponding global reconstruction is rejected.

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19 Boundary Type From Relative Motion and Material State

19.1 Kinematic Boundary Components

For boundary $\mathcal{B}_{ij}$, the relative velocity is

$$\mathbf{v}_{ij}^{\text{rel}} = \mathbf{v}_i - \mathbf{v}_j. \tag{277}$$

Its boundary-normal and boundary-tangential components are

$$v_n = \mathbf{v}_{ij}^{\text{rel}} \cdot \widehat{\mathbf{n}}_{ij}, \tag{278}$$

$$v_t = \mathbf{v}_{ij}^{\text{rel}} \cdot \widehat{\mathbf{t}}_{ij}. \tag{279}$$

19.2 Kinematic Type Ratios

Define

$$\Pi_{nt} = \frac{|v_n|}{|v_t| + \epsilon_v}, \tag{280}$$

where ϵ_v prevents division by zero.

Define closing indicator

$$C_{ij} = -\frac{v_n}{v_{\text{ref}}}, \tag{281}$$

and opening indicator

$$O_{ij} = \frac{v_n}{v_{\text{ref}}}. \tag{282}$$

The sign convention must be frozen with the boundary-normal orientation.

19.3 Convergent Boundary

A boundary is kinematically convergent where

$$v_n < -v_{n,\text{crit}}. \tag{283}$$

Its mechanical expression may include:

- shortening;
- thickening;
- descent;
- underthrusting;
- folding;
- uplift;
- accretion;
- shear localization; and
- material recycling.

19.4 Divergent Boundary

A boundary is kinematically divergent where

$$v_n > v_{n,\text{crit}}. \tag{284}$$

Its mechanical expression may include:

- extension;
- lithospheric thinning;
- separation;
- decompression;
- melt production;
- subsidence;
- basin opening; and
- creation of new intervening material.

19.5 Transform or Shear-Dominated Boundary

A boundary is shear dominated where

$$|v_t| \geq v_{t,\text{crit}} \tag{285}$$

and

$$|v_n| < v_{n,\text{shear}}. \tag{286}$$

19.6 Oblique Boundary

A boundary is oblique where both components are significant:

$$|v_n| \geq v_{n,\text{oblique}} \tag{287}$$

and

$$|v_t| \geq v_{t,\text{oblique}}. \tag{288}$$

19.7 Collapse Boundary

A collapse boundary is identified not only by relative plate motion but by inward displacement toward an excavation, basin, terminal-response, or gravitationally unstable region.

Define collapse-center position

$$\mathbf{x}_c. \tag{289}$$

The radial collapse component is

$$v_{\text{coll}} = \mathbf{v} \cdot \frac{\mathbf{x}_c - \mathbf{x}}{\|\mathbf{x}_c - \mathbf{x}\|}. \tag{290}$$

A collapse boundary requires

$$v_{\text{coll}} > v_{\text{coll,crit}}. \tag{291}$$

19.8 Material-State Classification

Boundary kinematics alone do not determine mechanism.

Define material-state vector

$$\mathbf{Q}_B = \left(H_B, \rho_B, T_B, \eta_B, Y_B, D_B, \chi_{m,B}, \phi_B, \boldsymbol{\sigma}_B\right). \tag{292}$$

The complete boundary type is

$$\tau_B = \mathcal{C}_B\left(v_n, v_t, \mathbf{Q}_B, \mathcal{H}_B\right), \tag{293}$$

where $\mathcal{H}_B$ is boundary history.

19.9 Boundary-Type Transition

A boundary may evolve through

$$\tau_B(t_1) \to \tau_B(t_2). \tag{294}$$

Possible transitions include:

- fracture to extension;
- extension to spreading;
- extension to closure;
- convergence to collision;
- convergence to descent;
- transform to convergence;
- inactive inheritance to reactivation;

- excavation margin to later plate boundary; and
- terminal damage zone to later trench system.

19.10 Boundary-Type Confusion Matrix

For observed class a and predicted class b, define count

$$N_{ab}. \tag{295}$$

The normalized confusion matrix is

$$C_{ab} = \frac{N_{ab}}{\sum_b N_{ab}}. \tag{296}$$

The model must report systematic misclassification rather than only total accuracy.

19.11 Boundary-Type Falsifier

Boundary-type falsifier B5.
If the event-derived network predicts the wrong opening, closing, shearing, collapse, or inactive behavior across major boundaries, the global kinematic classification claim is rejected even when boundary locations appear similar.

---

20 Boundary Propagation, Branching, and Termination

20.1 Boundary Front

Let an evolving boundary front be represented by

$$F_B(\mathbf{r}, t) = 0. \tag{297}$$

The boundary-normal propagation speed is

$$V_{B,n} = -\frac{\partial F_B/\partial t}{\|\nabla F_B\|}. \tag{298}$$

20.2 Boundary Propagation Law

A general propagation law is

$$V_{B,n} = \mathcal{G}_B \left(G_{\text{drive}}, G_{\text{resist}}, D, T, P, \eta, Y, \chi_m, \phi, \boldsymbol{\sigma}, \mathcal{E}_{\text{later}}\right), \tag{299}$$

where:

$$G_{\text{drive}} = \text{mechanical driving energy or stress,} \tag{300}$$
$$G_{\text{resist}} = \text{fracture, yield, or rheological resistance.} \tag{301}$$

20.3 Propagation Criterion

Propagation occurs when

$$G_{\text{drive}} \geq G_{\text{crit}}. \tag{302}$$

Arrest occurs when

$$G_{\text{drive}} < G_{\text{arrest}}. \tag{303}$$

20.4 Propagation Direction

The boundary-propagation direction is

$$\widehat{\mathbf{d}}_B = \arg\max_{\widehat{\mathbf{d}}} \left[\mathcal{G}_B\left(\widehat{\mathbf{d}}\right)\right]. \tag{304}$$

It may be controlled by:

- principal stress;
- inherited weakness;
- event-path orientation;
- lithospheric thickness;
- thermal gradient;
- density gradient;
- pre-existing faults;
- plate curvature;
- topography; and
- later-event forcing.

20.5 Branching Criterion

A boundary branches when more than one propagation direction satisfies

$$G^{(a)}_{\text{drive}} \geq G_{\text{crit}}. \tag{305}$$

For branch a, define energy allocation

$$f_{B,a} = \frac{G_{\text{drive}}^{(a)}}{\sum_j G_{\text{drive}}^{(j)}}. \tag{306}$$

The branch angles and lengths must be predicted.

20.6 Junctions

At junction J, incident boundary tangents are

$$\left\{\widehat{\mathbf{t}}_{J,1}, \widehat{\mathbf{t}}_{J,2}, \ldots, \widehat{\mathbf{t}}_{J,n}\right\}. \tag{307}$$

The junction degree is

$$d_J = n. \tag{308}$$

The angular configuration is

$$\Theta_J = \{\theta_{ab}\}, \tag{309}$$

where

$$\theta_{ab} = \arccos\left(\widehat{\mathbf{t}}_{J,a} \cdot \widehat{\mathbf{t}}_{J,b}\right). \tag{310}$$

20.7 Boundary Termination

A boundary may terminate when:

- its driving stress falls below threshold;
- it encounters a stronger domain;
- it merges with another boundary;
- it reaches an event-created excavation margin;
- it reaches a plate edge;
- it is buried or consumed;
- it heals;
- later events redirect the deformation; or
- the plate identity changes.

The termination time is

$$t_B^{\text{term}} = \inf \{t : S_B(t) \leq S_{B,\text{term}}\} . \tag{311}$$

20.8 Boundary Lifetime

Boundary lifetime is

$$\tau_B = t_B^{\text{term}} - t_B^{\text{init}}. \tag{312}$$

The observed boundary chronology must be compatible with the predicted lifetime and any later reactivation.

20.9 Propagation Residual

For observed boundary tip path $\mathbf{x}_B^{\text{obs}}(t)$ and predicted path $\widehat{\mathbf{x}}_B(t)$,

$$\epsilon_{B,\text{tip}}(t) = d_{\mathcal{S}} \left[\mathbf{x}_B^{\text{obs}}(t), \widehat{\mathbf{x}}_B(t)\right] . \tag{313}$$

20.10 Propagation Falsifier

Boundary-propagation falsifier B6.
If event-derived boundaries must be extended, branched, or terminated independently of their calculated stress, material state, and event history to match the observed network, the propagation model is rejected.

---

21 Reactivation by Later Events

21.1 Latent Boundary State

A boundary may remain mechanically inherited while kinematically inactive.

Define latent boundary state

$$\mathbf{Q}_B^{\text{latent}} = (D_B, \eta_B, Y_B, \phi_B, \Delta\rho_B, \Delta T_B, \boldsymbol{\sigma}_{B,\text{res}}, \mathbf{C}_B) . \tag{314}$$

21.2 Later-Event Loading

For later event $m > k$, the incremental loading is

$$\Delta\boldsymbol{\sigma}_B^{(m)} = \boldsymbol{\sigma}_B^{(m,+)} - \boldsymbol{\sigma}_B^{(m,-)}. \tag{315}$$

The total post-event stress is

$$\boldsymbol{\sigma}_B^{\mathrm{tot}} = \boldsymbol{\sigma}_B^{\mathrm{background}} + \boldsymbol{\sigma}_{B,\mathrm{res}}^{(k)} + \sum_{m>k} \Delta\boldsymbol{\sigma}_B^{(m)}. \tag{316}$$

21.3 Reactivation Index

A general reactivation index is

$$\mathcal{R}_B^{(m)} = w_\tau \widetilde{\tau}_B^{(m)} + w_D \widetilde{D}_B + w_\eta \widetilde{(\eta_0/\eta_B)} + w_P \widetilde{\Delta P}_B^{(m)} + w_T \left|\widetilde{\Delta T}_B^{(m)}\right| + w_\phi \left|\widetilde{\Delta \phi}_B^{(m)}\right|. \tag{317}$$

Reactivation occurs when

$$\mathcal{R}_B^{(m)} \geq \mathcal{R}_{B,\mathrm{crit}}. \tag{318}$$

21.4 Reactivation Angle

Let inherited boundary normal be

$$\widehat{\mathbf{n}}_B^{(k)}. \tag{319}$$

Let maximum later compression direction be

$$\widehat{\mathbf{c}}^{(m)}. \tag{320}$$

Their angular relationship is

$$\theta_B^{(k,m)} = \arccos\left(\left|\widehat{\mathbf{n}}_B^{(k)} \cdot \widehat{\mathbf{c}}^{(m)}\right|\right). \tag{321}$$

The reactivation rule must predict whether the older boundary is:

- reopened;
- closed;
- sheared;
- inverted;
- bypassed;
- strengthened;
- rotated; or
- destroyed.

21.5 Boundary Inversion

Boundary inversion is a change in kinematic sense:

$$\operatorname{sign}\left[v_n(t_1)\right] \neq \operatorname{sign}\left[v_n(t_2)\right]. \tag{322}$$

Examples include:

- extension followed by compression;
- opening followed by closure;
- descent followed by uplift;
- normal displacement followed by reverse displacement; and
- basin formation followed by mountain building.

21.6 Boundary Overprint

The state after later event m is

$$\mathbf{Q}_B^{(m,+)} = \mathcal{F}_B^{(m)}\left[\mathbf{Q}_B^{(k,+)}, \mathcal{E}_m\right]. \tag{323}$$

The fraction of older boundary memory retained is

$$f_B^{(k\to m)} = \frac{\left\|\mathbf{Q}_B^{(m,+)} - \mathbf{Q}_{B,\mathrm{new}}^{(m)}\right\|}{\left\|\mathbf{Q}_B^{(k,+)}\right\|}. \tag{324}$$

The definition must be adapted to the normalized state variables used.

21.7 Event Attribution

For modern boundary b, define contribution weights

$$\alpha_{bk}, \qquad \alpha_{bk} \geq 0, \tag{325}$$

with

$$\sum_k \alpha_{bk} = 1. \tag{326}$$

A boundary may therefore be:

- primarily created by one event;
- reactivated by one or more later events;

- rotated by later plate motion;
- broadened by long-term deformation; or
- only weakly related to the event sequence.

21.8 Reactivation Falsifier

Reactivation falsifier B7.
If later events are invoked to reactivate older boundaries without predicting which boundaries reactivate, in what direction, at what time, and with what resulting motion, the sequenced reconstruction is non-falsifiable.

22 Continental-Margin and Ocean-Basin Inheritance

22.1 Continental Margin as a Material Transition

A continental margin is represented as domain

$$\mathcal{M}_C = \{\mathbf{r} : \mathcal{F}_C \left(H_{\text{crust}}, \rho, \mathcal{C}, T, \eta, D, \phi\right) = 0\}\,. \tag{327}$$

The event-sequence model must explain whether the margin was:

- directly fractured;
- thermally weakened;
- excavated;
- stretched;
- displaced;
- reactivated;
- inherited from an older margin; or
- produced by a combination of events and later deformation.

22.2 Margin-Nucleation Potential

Define margin-nucleation potential

$$\mathcal{N}_C = w_H \left|\widetilde{\nabla H_{\text{crust}}}\right| + w_D \widetilde{D} + w_\eta \widetilde{(\eta_0/\eta)} + w_\rho \left|\widetilde{\nabla\rho}\right| + w_T \left|\widetilde{\nabla T}\right| + w_{\mathcal{C}} \left|\widetilde{\nabla\mathcal{C}}\right|. \tag{328}$$

A candidate margin is

$$\mathcal{M}_C^{\text{pred}} = \{\mathbf{r} : \mathcal{N}_C \geq \mathcal{N}_{C,\text{crit}}\}\,. \tag{329}$$

22.3 Crustal Stretching

For extension direction $\widehat{\mathbf{n}}_e$, define extensional strain

$$\epsilon_e = \widehat{\mathbf{n}}_e \cdot \boldsymbol{\epsilon}\widehat{\mathbf{n}}_e. \tag{330}$$

The stretching factor is

$$\beta = \frac{L_f}{L_i}. \tag{331}$$

A basin-opening model requires

$$\beta > 1. \tag{332}$$

22.4 Crustal-Thinning Relation

A first geometric screening relation is

$$H_f \approx \frac{H_i}{\beta}, \tag{333}$$

before accounting for:

- magmatic addition;
- erosion;
- sedimentation;
- phase change;
- density change;
- dynamic support; and
- later compression.

22.5 Basin Domain

Define basin domain

$$\mathcal{S}_{\text{basin}}(t) = \left\{\mathbf{x} : z(\mathbf{x}, t) < z_{\text{reference}}(\mathbf{x}, t)\right\}. \tag{334}$$

Its area is

$$A_{\text{basin}} = \int_{\mathcal{S}_{\text{basin}}} dA. \tag{335}$$

Its accommodation volume is

$$V_{\text{accom}} = \int_{\mathcal{S}_{\text{basin}}} [z_{\text{reference}} - z] \, dA. \tag{336}$$

22.6 Basin Subsidence

The total subsidence is decomposed as

$$S_{\text{basin}}(t) = S_{\text{event}} + S_{\text{thermal}} + S_{\text{flexural}} + S_{\text{sed}} + S_{\text{dynamic}} + S_{\text{boundary}}. \tag{337}$$

The event contribution is

$$S_{\text{event}} = S_{\text{excavation}} + S_{\text{damage}} + S_{\text{density}} + S_{\text{phase}} + S_{\text{displacement}}. \tag{338}$$

22.7 Basin Opening Rate

For opposing margins $\mathcal{M}_1$ and $\mathcal{M}_2$, define opening width

$$W_B(t) = d_{\mathcal{S}} \left[\mathcal{M}_1(t), \mathcal{M}_2(t)\right]. \tag{339}$$

The opening rate is

$$\dot{W}_B = \frac{dW_B}{dt}. \tag{340}$$

22.8 New Intervening Material

Where separation produces new intervening lithosphere or crust, define production rate

$$\dot{A}_{\text{new}} = \int_{\Gamma_{\text{prod}}} v_n^+ \, d\ell, \tag{341}$$

where

$$v_n^+ = \max(v_n, 0). \tag{342}$$

The event model must reproduce the spatial and chronological pattern of new material where such production is observed.

22.9 Basin Closure

Basin closure occurs where

$$\dot{W}_B < 0. \tag{343}$$

The closure rate is

$$V_{\text{close}} = -\dot{W}_B. \tag{344}$$

Closure may generate:

- convergence;
- underthrusting;
- descent;
- crustal thickening;
- accretion;
- mountain building;
- basin inversion; and
- terrane transfer.

22.10 Margin Pairing

For margins a and b, define pairing score

$$\mathcal{P}_{ab} = w_G\mathcal{G}_{ab} + w_C\mathcal{C}_{ab} + w_A\mathcal{A}_{ab} + w_S\mathcal{S}_{ab} + w_T\mathcal{T}_{ab}, \tag{345}$$

where the terms compare:

- geometry;
- composition;
- age;
- structure; and
- chronology.

The event sequence must predict the separation and later relationship of paired margins.

22.11 Ocean-Basin Inheritance Chain

The proposed causal chain is

$$\mathcal{E}_k \to \mathcal{B}_{\text{weak}} \to \epsilon_{\text{ext}} \to H_{\text{crust}} \downarrow \to W_B \uparrow \to \mathcal{S}_{\text{basin}} \to \text{later basin evolution.} \tag{346}$$

Every step requires a forward calculation.

22.12 Margin and Basin Falsifier

Margin-and-basin falsifier B8.
If the event-derived boundary and displacement fields cannot reproduce the placement, paired geometry, opening history, crustal thinning, subsidence, and later closure of major continental margins and ocean basins, the global fragmentation claim is rejected.

23 Boundary-Network Topology and Graph Metrics

23.1 Observed and Predicted Graphs

Let the observed boundary graph be

$$\mathcal{G}_B^{\text{obs}} = \left(\mathcal{V}^{\text{obs}}, \mathcal{E}^{\text{obs}}\right), \tag{347}$$

and the predicted graph be

$$\widehat{\mathcal{G}}_B = \left(\widehat{\mathcal{V}}, \widehat{\mathcal{E}}\right). \tag{348}$$

23.2 Basic Graph Counts

The node-count residual is

$$\Delta N_V = N_V^{\text{obs}} - N_V^{\text{pred}}. \tag{349}$$

The edge-count residual is

$$\Delta N_E = N_E^{\text{obs}} - N_E^{\text{pred}}. \tag{350}$$

The connected-component residual is

$$\Delta N_C = N_C^{\text{obs}} - N_C^{\text{pred}}. \tag{351}$$

23.3 Degree Distribution

For graph node v, let degree be

$$d(v). \tag{352}$$

The observed degree distribution is

$$p_{\text{obs}}(d), \tag{353}$$

and the predicted distribution is

$$p_{\mathrm{pred}}(d). \tag{354}$$

A distributional residual may be

$$D_{\mathrm{degree}} = \frac{1}{2} \sum_{d} \left| p_{\mathrm{obs}}(d) - p_{\mathrm{pred}}(d) \right| . \tag{355}$$

23.4 Cycle Rank

For graph with N_E edges, N_V vertices, and N_C connected components, the cycle rank is

$$\mu_G = N_E - N_V + N_C. \tag{356}$$

This measures the number of independent graph cycles and therefore the topological capacity to enclose plate domains.

23.5 Plate-Enclosure Count

The predicted number of enclosed plate domains is

$$N_P^{\mathrm{pred}} = \mathcal{F}_{\mathrm{faces}} \left[\widehat{\mathcal{G}}_B \right] . \tag{357}$$

The residual is

$$\Delta N_P = N_P^{\mathrm{obs}} - N_P^{\mathrm{pred}}. \tag{358}$$

23.6 Boundary-Length Distribution

For boundary edge e, let length be

$$L_e. \tag{359}$$

The predicted and observed distributions are

$$p_{\mathrm{pred}}(L), \qquad p_{\mathrm{obs}}(L). \tag{360}$$

A normalized length residual is

$$D_L = \int \left| p_{\mathrm{pred}}(L) - p_{\mathrm{obs}}(L) \right| \, dL. \tag{361}$$

23.7 Hausdorff Distance

For observed boundary set $\mathcal{B}^{\text{obs}}$ and predicted set $\widehat{\mathcal{B}}$, the symmetric Hausdorff distance is

$$d_H\left(\mathcal{B}^{\text{obs}}, \widehat{\mathcal{B}}\right) = \max\left\{\sup_{x\in\mathcal{B}^{\text{obs}}} \inf_{y\in\widehat{\mathcal{B}}} d_{\mathcal{S}}(x,y),\ \sup_{y\in\widehat{\mathcal{B}}} \inf_{x\in\mathcal{B}^{\text{obs}}} d_{\mathcal{S}}(x,y)\right\}. \tag{362}$$

23.8 Average Symmetric Boundary Distance

A less outlier-sensitive measure is

$$d_{\text{ASD}} = \frac{1}{2}\left[\frac{1}{L_{\text{obs}}}\int_{\mathcal{B}^{\text{obs}}} d\left(x, \widehat{\mathcal{B}}\right)\, d\ell + \frac{1}{L_{\text{pred}}}\int_{\widehat{\mathcal{B}}} d\left(y, \mathcal{B}^{\text{obs}}\right)\, d\ell\right]. \tag{363}$$

23.9 Boundary-Type Agreement

Let observed boundary label be τ_e^{obs} and predicted label be τ_e^{pred}.

Weighted classification accuracy is

$$A_\tau = \frac{\sum_e L_e \mathbf{1}\left[\tau_e^{\text{obs}} = \tau_e^{\text{pred}}\right]}{\sum_e L_e}. \tag{364}$$

23.10 Orientation Agreement

The length-weighted orientation score is

$$A_\gamma = \frac{\displaystyle\int_{\mathcal{B}} \cos\left[2\left(\gamma^{\text{obs}} - \gamma^{\text{pred}}\right)\right]\, d\ell}{\displaystyle\int_{\mathcal{B}} d\ell}. \tag{365}$$

The factor of two treats orientations as axial.

23.11 Adjacency-Matrix Difference

Let observed and predicted adjacency matrices be

$$\mathbf{A}^{\text{obs}}, \qquad \mathbf{A}^{\text{pred}}. \tag{366}$$

The normalized Frobenius residual is

$$D_A = \frac{\left\|\mathbf{A}^{\text{obs}} - \mathbf{A}^{\text{pred}}\right\|_F}{\left\|\mathbf{A}^{\text{obs}}\right\|_F}. \tag{367}$$

23.12 Graph-Spectral Difference

Let graph Laplacians be

$$\mathbf{L}^{\text{obs}} = \mathbf{D}^{\text{obs}} - \mathbf{A}^{\text{obs}}, \tag{368}$$

and

$$\mathbf{L}^{\text{pred}} = \mathbf{D}^{\text{pred}} - \mathbf{A}^{\text{pred}}. \tag{369}$$

For ordered eigenvalues

$$\lambda_1, \lambda_2, \ldots, \tag{370}$$

define spectral distance

$$D_\lambda = \left[\sum_{j=1}^{N_\lambda} w_j \left(\lambda_j^{\text{obs}} - \lambda_j^{\text{pred}} \right)^2 \right]^{1/2}. \tag{371}$$

23.13 Event-to-Boundary Sparsity

Let

$$\mathbf{X}_{bk} = \begin{cases} 1, & \text{event } k \text{ contributes to boundary } b, \\ 0, & \text{otherwise.} \end{cases} \tag{372}$$

The total event-boundary assignments are

$$N_{EB} = \sum_{b,k} \mathbf{X}_{bk}. \tag{373}$$

A constrained model should not require every event to explain every boundary.

23.14 Composite Network Score

Define a composite network residual

$$\begin{aligned} \mathcal{J}_B = w_H \widetilde{d}_H + w_{\text{ASD}} \widetilde{d}_{\text{ASD}} + w_A \widetilde{D}_A + w_\lambda \widetilde{D}_\lambda + w_\tau \left(1 - A_\tau\right) \\ + w_\gamma \left(1 - A_\gamma\right) + w_N \widetilde{|\Delta N_P|} + w_C \widetilde{|\Delta N_C|}. \end{aligned} \tag{374}$$

All weights must be frozen before model evaluation.

24 Boundary-Network Model Comparison

24.1 Competing Model Families

The minimum comparison includes:

$$\mathcal{M}_{B,0} = \text{background geodynamic model without event inheritance}, \tag{375}$$
$$\mathcal{M}_{B,1} = \text{event-derived boundary model}, \tag{376}$$
$$\mathcal{M}_{B,2} = \text{event inheritance plus later geodynamics}, \tag{377}$$
$$\mathcal{M}_{B,3} = \text{spatial null or randomized event model}. \tag{378}$$

24.2 Boundary Data Vector

The complete boundary data vector is

$$\mathbf{D}_B = (\mathbf{x}_B, \gamma_B, \kappa_B, \tau_B, a_B, v_n, v_t, H_B, \mathbf{Q}_B, \mathcal{G}_B)\,. \tag{379}$$

24.3 Boundary Likelihood

For predicted boundary model $\widehat{\mathbf{D}}_B$,

$$\mathcal{L}_B = p\left(\mathbf{D}_B^{\mathrm{obs}} \mid \widehat{\mathbf{D}}_B, \mathbf{\Sigma}_B\right). \tag{380}$$

A Gaussian approximation may use

$$\ln \mathcal{L}_B = -\frac{1}{2}\boldsymbol{\epsilon}_B^{\top}\mathbf{\Sigma}_B^{-1}\boldsymbol{\epsilon}_B - \frac{1}{2}\ln|\mathbf{\Sigma}_B| + C. \tag{381}$$

Spatial topology and categorical boundary type may require non-Gaussian likelihood components.

24.4 Model Evidence

The evidence calculation must be interpreted together with effective complexity and predictive validation [9, 10, 11, 13].

For model $\mathcal{M}_{B,q}$,

$$\mathcal{Z}_{B,q} = \int \mathcal{L}_B p\left(\mathbf{\Theta}_{B,q} \mid \mathcal{M}_{B,q}\right) d\mathbf{\Theta}_{B,q}. \tag{382}$$

The Bayes factor is

$$K_{B,ij} = \frac{\mathcal{Z}_{B,i}}{\mathcal{Z}_{B,j}}. \tag{383}$$

24.5 Boundary Complexity

The boundary-model parameter count includes:

- event count;
- event ages;
- event coordinates;
- event paths;
- event energies;
- target domains;
- nucleation thresholds;
- propagation parameters;
- reactivation parameters;
- preservation parameters;
- manually assigned boundary-event links; and
- regional correction parameters.

24.6 Event-Count Penalty

For N_E events, define penalty

$$\mathcal{P}_{N_E} = \lambda_E N_E. \tag{384}$$

If newly added events are used only to cover unexplained boundaries, the penalty must include their complete forensic and mechanical burden.

24.7 Boundary-Assignment Penalty

For N_{EB} event-to-boundary assignments,

$$\mathcal{P}_{EB} = \lambda_{EB} N_{EB}. \tag{385}$$

A model with one manually selected event explanation per boundary is not strongly constrained.

24.8 Spatial Null Test

For randomized event catalog $\mathcal{E}^{(r)}$, calculate

$$\mathcal{J}_B^{(r)}, \qquad r = 1, \ldots, N_R. \tag{386}$$

The empirical probability of obtaining a score as favorable as the observed event sequence is

$$p_{\text{null}} = \frac{1 + \sum_{r=1}^{N_R} \mathbf{1}\left[\mathcal{J}_B^{(r)} \leq \mathcal{J}_B^{\text{obs}}\right]}{N_R + 1}. \tag{387}$$

24.9 Spatial Cross-Validation

Partition Earth into training regions

$$\mathcal{D}_{\text{train}} \tag{388}$$

and held-out regions

$$\mathcal{D}_{\text{test}}. \tag{389}$$

Fit or calibrate the model using

$$\mathbf{D}_B^{\text{train}}. \tag{390}$$

Then predict

$$\widehat{\mathbf{D}}_B^{\text{test}} \tag{391}$$

without regional retuning.

The held-out score is

$$\mathcal{J}_B^{\text{test}}. \tag{392}$$

24.10 Chronological Cross-Validation

A second validation trains on older time slices and predicts younger boundary development:

$$\mathcal{M}\left[t \geq t_q\right] \to \widehat{\mathcal{B}}\left[t < t_q\right]. \tag{393}$$

The reverse experiment may reconstruct older boundaries from younger constraints but must report the increased inverse-problem uncertainty.

24.11 Leave-One-Event-Out Test

For event k, remove it from the catalog:

$$\mathcal{E}_{-k} = \mathcal{E} \setminus \left\{\mathcal{E}_k\right\}. \tag{394}$$

Calculate the resulting network

$$\widehat{\mathcal{B}}_{-k}. \tag{395}$$

The event's marginal contribution is

$$\Delta\mathcal{J}_{B,k} = \mathcal{J}_{B,-k} - \mathcal{J}_{B,\text{full}}. \tag{396}$$

An event with

$$\Delta\mathcal{J}_{B,k} \approx 0 \tag{397}$$

is not required by the boundary reconstruction.

24.12 Comparison Decision

The event-derived model gains support only if it improves:

- spatial boundary fit;
- orientation fit;
- topology;
- boundary type;
- chronology;
- held-out prediction;
- physical interpretability; and
- causal compression of the data.

The improvement must survive complexity penalties.

25 Boundary Viability and Falsification

25.1 Boundary Parameter Vector

The complete boundary parameter vector is

$$\boldsymbol{\Theta}_B = (\mathcal{E}, \mathbf{Q}_0, \mathcal{N}_{B,\text{crit}}, \mathbf{w}_B, \mathcal{G}_B, \mathcal{R}_B, \mathcal{P}_B, \mathcal{H}_B)\,, \tag{398}$$

where:

$$\mathcal{G}_B = \text{propagation laws}, \tag{399}$$

$$\mathcal{R}_B = \text{reactivation laws}, \tag{400}$$

$$\mathcal{P}_B = \text{preservation laws}, \tag{401}$$

$$\mathcal{H}_B = \text{event-to-boundary handoff rules}. \tag{402}$$

25.2 Boundary Viable Set

Define

$$\mathcal{V}_B = \left\{ \mathbf{\Theta}_B : \begin{array}{l} \text{mechanical input admissible}, \\ \text{boundary nucleation successful}, \\ \text{connectivity successful}, \\ \text{plate enclosure successful}, \\ \text{boundary orientation compatible}, \\ \text{boundary type compatible}, \\ \text{chronology compatible}, \\ \text{propagation compatible}, \\ \text{reactivation compatible}, \\ \text{margin and basin inheritance compatible}, \\ \text{topology compatible}, \\ \text{held-out prediction successful} \end{array} \right\}. \tag{403}$$

25.3 Boundary Falsification Matrix

Table 3: Paper-III boundary-network falsification matrix.

ID	Boundary claim	Falsifying result	Consequence
B-F01	Boundary nucleation	Mechanically admissible events produce no persistent connected material-state boundaries.	Reject event-derived boundary formation.
B-F02	Boundary location	Predicted major boundaries are systematically displaced from observed boundaries beyond declared uncertainty.	Reject spatial reconstruction.
B-F03	Boundary orientation	Predicted orientations systematically disagree with observed boundary orientations.	Reject directional boundary inheritance.

ID	Boundary claim	Falsifying result	Consequence
B-F04	Plate enclosure	The predicted network does not enclose a realistic set of plate domains.	Reject event-derived plate partition.
B-F05	Boundary completeness	Large fractions of observed plate perimeters require manually inserted connections.	Reject network completeness.
B-F06	Boundary type	Predicted opening, closing, shear, or collapse behavior is incompatible with observed relative motion.	Reject kinematic classification.
B-F07	Boundary chronology	Predicted initiation or reactivation ages conflict with the geological record.	Reject the relevant event assignment.
B-F08	Boundary propagation	Required boundary growth cannot be generated by the declared stress and material model.	Reject propagation model.
B-F09	Boundary branching	Observed junctions require arbitrary branching angles or locations.	Reject branching model.
B-F10	Boundary termination	Predicted boundaries continue through regions where no corresponding structure exists.	Reject termination model.
B-F11	Reactivation	The model cannot predict which older boundaries later events reactivate.	Reject sequenced reactivation claim.
B-F12	Plate fragmentation	Predicted plate breakup violates material or chronological continuity.	Reject fragmentation history.
B-F13	Plate merger	Predicted mergers retain incompatible relative motion or boundary state.	Reject merger history.
B-F14	Terrane transfer	Predicted terrane paths violate age, composition, rotation, or structural evidence.	Reject transfer history.
B-F15	Continental margins	The model fails to predict paired margins and their separation history.	Reject continental-fragmentation claim.
B-F16	Ocean basins	The model fails to predict opening, subsidence, crustal thinning, or closure.	Reject basin-inheritance claim.

ID	Boundary claim	Falsifying result	Consequence
B-F17	Network topology	Predicted graph connectivity, plate count, cycles, and junction structure differ materially from observations.	Reject global topology.
B-F18	Spatial null	Randomized event catalogs reproduce the observed network equally well.	Reject special event-sequence significance.
B-F19	Held-out prediction	The model fits training regions but fails in withheld regions.	Reject general predictive validity.
B-F20	Leave-one-event-out necessity	Removing a claimed major event does not alter the reconstruction.	Reject that event as a necessary boundary organizer.
B-F21	Complexity	The model requires one event, correction, or assignment for nearly every boundary.	Reject causal compression.
B-F22	Mechanical consistency	Boundary-forming states are outside the viable outputs of Paper II.	Reject the reconstruction as mechanically unsupported.
B-F23	Comparison model	The non-astro-ballistic model reproduces the network more accurately with fewer parameters.	Reject boundary replacement claim.
B-F24	Complete boundary viability	The boundary viable set is empty.	Reject the global event-derived boundary network.

25.4 Boundary Success Standard

The event-derived boundary model survives only if one shared event sequence:

BS1. begins from mechanically admissible event states;

BS2. generates connected inherited material contrasts;

BS3. predicts major boundary locations;

BS4. predicts boundary orientations;

BS5. encloses a realistic plate and block partition;

BS6. predicts opening, closing, shear, and inactive behavior;

BS7. predicts boundary initiation and reactivation chronology;

BS8. predicts fragmentation, merger, and terrane transfer;

BS9. predicts continental-margin relationships;

BS10. predicts ocean-basin opening and closure;

BS11. reproduces network topology;

BS12. survives spatial and chronological cross-validation;

BS13. outperforms randomized event catalogs;

BS14. avoids independent fitting of each boundary; and

BS15. improves on the comparison model after complexity penalties.

Boundary-network decision rule.
The plate-boundary replacement claim survives only if a mechanically admissible sequence of astro-ballistic events generates one connected, chronologically consistent, materially persistent boundary network whose plate enclosure, topology, orientations, boundary types, margins, basins, and reactivation history match the observed Earth without manual boundary-by-boundary construction.

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26 Boundary-Network Synthesis

This boundary-network synthesis records:

1. the event-derived boundary-nucleation functional;
2. volumetric boundary domains and surface projections;
3. boundary thickness, orientation, maturity, and initiation time;
4. connected boundary components;
5. plate enclosure and closure-defect metrics;
6. boundary completeness and percolation thresholds;
7. restrictions against arbitrary boundary bridging;
8. plate-lineage graphs;
9. fragmentation, merger, and terrane-transfer rules;
10. mass and angular-momentum conservation during plate fragmentation;
11. boundary classification from relative normal and tangential motion;
12. convergent, divergent, transform, oblique, collapse, and inactive boundary classes;
13. boundary propagation, branching, junction, arrest, and termination laws;
14. later-event reactivation and boundary inversion;
15. event attribution and overprint;
16. continental-margin nucleation;

17. crustal stretching and thinning;
18. ocean-basin opening, subsidence, material production, and closure;
19. boundary-network graph and topology metrics;
20. Hausdorff, orientation, adjacency, and graph-spectral residuals;
21. spatial, chronological, randomized, and leave-one-event-out validation;
22. the boundary viable parameter set; and
23. the complete Paper-III boundary falsification matrix.

The following sections develop the quantitative motion problem:

- event impulse transfer into plate-scale translation and rotation;
- plate inertia tensors;
- Euler-pole prediction;
- force and torque decomposition;
- gravitational, buoyancy, boundary, and mantle contributions;
- inherited direction versus maintained speed;
- velocity-memory kernels;
- plate acceleration and deceleration;
- relative plate-motion prediction;
- global navigation-satellite and geological velocity datasets;
- present-day and deep-time velocity residuals;
- plate-speed hierarchy;
- motion counterfactuals; and
- complete plate-direction and speed falsification tests.

27 Event-to-Plate Impulse Mapping

27.1 Purpose

Paper II defines event-generated impulse as a spatial field.

Paper III must determine how that field is partitioned among plates, tectonic blocks, deforming boundary zones, mantle domains, oceans, atmosphere, ejecta, and bulk-Earth motion.

For event k, let the impulse-density field be

$$\mathbf{J}_k(\mathbf{r}) = \int_{t_k^-}^{t_k^+} \mathbf{f}_k(\mathbf{r}, t)\, dt. \tag{404}$$

The event impulse delivered to plate or block i is

$$\mathbf{I}_{ik} = \int_{\mathcal{P}_i(t_k)} \mathbf{J}_k(\mathbf{r})\, dV. \tag{405}$$

The associated angular impulse about Earth's center is

$$\Delta\mathbf{L}_{ik} = \int_{\mathcal{P}_i(t_k)} \mathbf{r} \times \mathbf{J}_k(\mathbf{r})\, dV. \tag{406}$$

27.2 Plate-Membership Field

At event time t_k, define material-membership function

$$\chi_i(\mathbf{r}, t_k) = \begin{cases} 1, & \mathbf{r} \in \mathcal{P}_i(t_k), \\ 0, & \mathbf{r} \notin \mathcal{P}_i(t_k). \end{cases} \tag{407}$$

For distributed or uncertain plate membership, replace the binary field with fractional membership

$$0 \le w_i(\mathbf{r}, t_k) \le 1, \tag{408}$$

subject to

$$\sum_i w_i(\mathbf{r}, t_k) + w_{\text{deform}}(\mathbf{r}, t_k) = 1. \tag{409}$$

The plate impulse becomes

$$\mathbf{I}_{ik} = \int_{\mathcal{V}_\oplus} w_i(\mathbf{r}, t_k)\mathbf{J}_k(\mathbf{r})\, dV. \tag{410}$$

27.3 Impulse Partition

The event impulse is partitioned as

$$\mathbf{I}_k^{\text{total}} = \sum_{i=1}^{N_P} \mathbf{I}_{ik} + \mathbf{I}_k^{\text{deform}} + \mathbf{I}_k^{\text{mantle}} + \mathbf{I}_k^{\text{ocean}} + \mathbf{I}_k^{\text{atm}} + \mathbf{I}_k^{\text{ejecta}} + \mathbf{I}_k^{\text{bulk}}. \tag{411}$$

Likewise, angular impulse satisfies

$$\Delta\mathbf{L}_k^{\text{total}} = \sum_{i=1}^{N_P} \Delta\mathbf{L}_{ik} + \Delta\mathbf{L}_k^{\text{deform}} + \Delta\mathbf{L}_k^{\text{mantle}} + \Delta\mathbf{L}_k^{\text{escape}} + \Delta\mathbf{L}_k^{\text{bulk}}. \tag{412}$$

27.4 Translation, Rotation, and Internal Deformation

For plate i, the event-delivered momentum is partitioned into:

$$\mathcal{K}_{ik} = \left(\Delta\mathbf{P}_{ik}^{\text{trans}}, \Delta\mathbf{L}_{ik}^{\text{rot}}, E_{ik}^{\text{def}}, E_{ik}^{\text{heat}}, E_{ik}^{\text{fract}}, E_{ik}^{\text{boundary}}\right). \tag{413}$$

The translational component changes center-of-mass velocity.

The rotational component changes angular velocity.

The remaining components modify internal deformation, temperature, damage, and future boundary mobility.

27.5 Immediate Translational Response

For plate mass M_i,

$$\Delta\mathbf{V}_{i,k}^{\text{CM}} = \frac{\mathbf{I}_{ik}}{M_i}. \tag{414}$$

This expression is an immediate momentum result.

It is not a prediction that modern plate velocity equals the initial event velocity.

27.6 Immediate Rotational Response

Let plate center of mass be

$$\mathbf{r}_{i,\text{CM}} = \frac{1}{M_i}\int_{\mathcal{P}_i} \rho\mathbf{r}\, dV. \tag{415}$$

The angular impulse about the plate center of mass is

$$\Delta\mathbf{L}_{ik}^{\text{CM}} = \int_{\mathcal{P}_i} (\mathbf{r} - \mathbf{r}_{i,\text{CM}}) \times \mathbf{J}_k\, dV. \tag{416}$$

The immediate angular-velocity change is

$$\Delta\boldsymbol{\omega}_{ik} = \mathbf{I}_i^{-1}\Delta\mathbf{L}_{ik}^{\text{CM}}, \tag{417}$$

where $\mathbf{I}_i$ is the plate inertia tensor.

27.7 Impulse Projection Into Rigid and Deforming Modes

Let the plate-response basis contain rigid translation modes, rigid rotation modes, and internal deformation modes:

$$\left\{\boldsymbol{\psi}_{i,1}, \ldots, \boldsymbol{\psi}_{i,N_m}\right\}. \tag{418}$$

The event response is

$$\Delta \mathbf{u}_{ik}(\mathbf{r}) = \sum_{a=1}^{N_m} c_{ik,a} \boldsymbol{\psi}_{i,a}(\mathbf{r}). \tag{419}$$

The modal coefficient is

$$c_{ik,a} = \frac{\displaystyle\int_{\mathcal{P}_i} \boldsymbol{\psi}_{i,a} \cdot \mathbf{J}_k \, dV}{\displaystyle\int_{\mathcal{P}_i} \rho \left\| \boldsymbol{\psi}_{i,a} \right\|^2 \, dV}. \tag{420}$$

This decomposition determines whether an event primarily:

- translates a block;
- rotates a block;
- fragments a block;
- deforms its interior;
- activates a margin;
- produces distributed strain; or
- transfers momentum into the underlying mantle.

27.8 Impulse-Direction Field

The normalized impulse direction is

$$\widehat{\mathbf{J}}_k = \frac{\mathbf{J}_k}{\|\mathbf{J}_k\|}, \tag{421}$$

where the denominator is nonzero.

For plate i, define mean impulse direction

$$\widehat{\mathbf{I}}_{ik} = \frac{\mathbf{I}_{ik}}{\|\mathbf{I}_{ik}\|}. \tag{422}$$

The directional dispersion is

$$\sigma_{I,ik}^2 = \frac{\displaystyle\int_{\mathcal{P}_i} \theta^2(\mathbf{r}) \, \|\mathbf{J}_k\| \, dV}{\displaystyle\int_{\mathcal{P}_i} \|\mathbf{J}_k\| \, dV}, \tag{423}$$

where

$$\theta(\mathbf{r}) = \arccos\left[\widehat{\mathbf{J}}_k(\mathbf{r}) \cdot \widehat{\mathbf{I}}_{ik}\right]. \tag{424}$$

A highly dispersed impulse may produce internal deformation rather than coherent plate motion.

27.9 Event-to-Plate Contribution Matrix

Define event-to-plate impulse matrix

$$\mathbf{A}^I_{ik} = \frac{\|\mathbf{I}_{ik}\|}{\sum_j \|\mathbf{I}_{jk}\|}. \tag{425}$$

For each event,

$$\sum_i \mathbf{A}^I_{ik} = 1 \tag{426}$$

after excluding or separately reporting non-plate impulse channels.

The angular-impulse matrix is

$$\mathbf{A}^L_{ik} = \frac{\|\Delta\mathbf{L}_{ik}\|}{\sum_j \|\Delta\mathbf{L}_{jk}\|}. \tag{427}$$

27.10 No Modern-Plate Projection Without Reconstruction

A modern plate polygon cannot be projected directly onto an ancient event without reconstructing its material ancestry.

The correct mapping is

$$\mathcal{P}_i(t_{\text{now}}) \to \{\mathcal{P}_{i_1}(t_k), \mathcal{P}_{i_2}(t_k), \ldots\}, \tag{428}$$

through the plate-lineage graph.

The ancient impulse assigned to a modern plate is

$$\mathbf{I}^{(k)}_{i,\text{now}} = \sum_a \mathcal{T}_{i_a \to i} \mathbf{I}_{i_a,k}, \tag{429}$$

where $\mathcal{T}_{i_a \to i}$ tracks material inheritance, merger, fragmentation, and terrane transfer.

27.11 Impulse-Mapping Falsifier

Impulse-mapping falsifier V2.
If the event impulse cannot be partitioned among reconstructed ancient material domains without using modern plate outlines retroactively, the derived plate-motion inheritance is not causally valid.

28 Plate Mass, Inertia, and Rotational Response

28.1 Plate Mass

For plate or block volume $\mathcal{P}_i$,

$$M_i = \int_{\mathcal{P}_i} \rho(\mathbf{r})\, dV. \tag{430}$$

For a thin-shell approximation with surface domain $\mathcal{A}_i$ and lithospheric thickness $H_i(\mathbf{x})$,

$$M_i \approx \int_{\mathcal{A}_i} \rho_i(\mathbf{x}) H_i(\mathbf{x})\, dA. \tag{431}$$

28.2 Plate Center of Mass

The center of mass is

$$\mathbf{r}_{i,\mathrm{CM}} = \frac{1}{M_i} \int_{\mathcal{P}_i} \rho \mathbf{r}\, dV. \tag{432}$$

Its velocity is

$$\mathbf{V}_{i,\mathrm{CM}} = \frac{1}{M_i} \int_{\mathcal{P}_i} \rho \mathbf{u}\, dV. \tag{433}$$

28.3 Plate Inertia Tensor

The inertia tensor about the center of mass is

$$\mathbf{I}_i = \int_{\mathcal{P}_i} \rho \left[\|\mathbf{r}'\|^2 \mathbf{1} - \mathbf{r}' \otimes \mathbf{r}' \right] dV, \tag{434}$$

where

$$\mathbf{r}' = \mathbf{r} - \mathbf{r}_{i,\mathrm{CM}}. \tag{435}$$

28.4 Principal Inertial Axes

The principal moments are the eigenvalues

$$I_{i,1}, \quad I_{i,2}, \quad I_{i,3} \tag{436}$$

of $\mathbf{I}_i$.

The corresponding principal axes are

$$\widehat{\mathbf{e}}_{i,1}, \quad \widehat{\mathbf{e}}_{i,2}, \quad \widehat{\mathbf{e}}_{i,3}. \tag{437}$$

Irregular plates respond differently to identical angular impulses depending on impulse direction relative to these axes.

28.5 Rigid Rotational Momentum

For rigid angular velocity $\boldsymbol{\omega}_i$,

$$\mathbf{L}_i^{\mathrm{rot}} = \mathbf{I}_i \boldsymbol{\omega}_i. \tag{438}$$

The rotational kinetic energy is

$$E_i^{\mathrm{rot}} = \frac{1}{2} \boldsymbol{\omega}_i^{\mathsf{T}} \mathbf{I}_i \boldsymbol{\omega}_i. \tag{439}$$

28.6 Immediate Event Rotation

Immediately after event k,

$$\mathbf{L}_i^{+} = \mathbf{L}_i^{-} + \Delta \mathbf{L}_{ik}. \tag{440}$$

If plate geometry is unchanged during the impulse interval,

$$\boldsymbol{\omega}_i^{+} = \boldsymbol{\omega}_i^{-} + \mathbf{I}_i^{-1} \Delta \mathbf{L}_{ik}. \tag{441}$$

28.7 Changing Inertia Tensor

Fragmentation, deformation, mass transfer, and crustal production change the inertia tensor:

$$\mathbf{I}_i^{+} = \mathbf{I}_i^{-} + \Delta \mathbf{I}_i^{\mathrm{event}} + \Delta \mathbf{I}_i^{\mathrm{transfer}} + \Delta \mathbf{I}_i^{\mathrm{deform}}. \tag{442}$$

The corresponding angular velocity is

$$\boldsymbol{\omega}_i^{+} = \left(\mathbf{I}_i^{+} \right)^{-1} \mathbf{L}_i^{+}. \tag{443}$$

28.8 Fragmentation Response

If plate i fragments into daughter blocks $i_1, \ldots, i_n$,

$$\mathbf{L}_i^- + \Delta\mathbf{L}_{ik} = \sum_{a=1}^{n} \left[\mathbf{r}_{i_a,\mathrm{CM}} \times M_{i_a}\mathbf{V}_{i_a,\mathrm{CM}} + \mathbf{I}_{i_a}\boldsymbol{\omega}_{i_a}\right] + \mathbf{L}_{\mathrm{loss}}. \tag{444}$$

The daughter velocities and rotations must satisfy this partition.

28.9 Rigid-Plate Adequacy

Define internal kinetic energy

$$E_i^{\mathrm{int}} = \frac{1}{2}\int_{\mathcal{P}_i} \rho \left\|\mathbf{u} - \mathbf{V}_{i,\mathrm{CM}} - \boldsymbol{\omega}_i \times \mathbf{r}'\right\|^2 dV. \tag{445}$$

The rigid-motion fraction is

$$f_i^{\mathrm{rigid}} = \frac{E_i^{\mathrm{trans}} + E_i^{\mathrm{rot}}}{E_i^{\mathrm{trans}} + E_i^{\mathrm{rot}} + E_i^{\mathrm{int}}}. \tag{446}$$

A rigid-plate representation is adequate only if

$$f_i^{\mathrm{rigid}} \geq f_{\mathrm{rigid,crit}}. \tag{447}$$

28.10 Plate-Mass and Inertia Uncertainty

The plate mass and inertia ensemble is

$$\left\{M_i^{(q)}, \mathbf{I}_i^{(q)}\right\}_{q=1}^{N_Q}. \tag{448}$$

It must reflect uncertainty in:

- plate boundaries;
- lithospheric thickness;
- crustal thickness;
- density;
- subducted or descended material;
- attached terranes;
- deforming margins;
- mantle coupling depth; and
- reconstructed plate identity.

28.11 Inertia Falsifier

Inertial-response falsifier V3.
If the angular impulse required to generate the predicted plate rotations is incompatible with reconstructed plate mass, geometry, inertia, fragmentation, or total angular-momentum conservation, the event-derived rotation claim fails.

29 Euler-Pole Generation

29.1 Euler Poles as Model Outputs

For approximately rigid plate i, the velocity field is

$$\mathbf{v}_i(\mathbf{x}, t) = \boldsymbol{\omega}_i(t) \times \mathbf{x}. \tag{449}$$

The Euler vector

$$\boldsymbol{\omega}_i(t) \tag{450}$$

must emerge from event impulse, plate inertia, later torque, boundary interaction, and mantle coupling.

It must not be inserted directly from the observed velocity solution when evaluating causal prediction.

29.2 Initial Euler Vector

Immediately after event k,

$$\boldsymbol{\omega}_{i,k}^{+} = \boldsymbol{\omega}_{i,k}^{-} + \mathbf{I}_{i,k}^{-1} \Delta \mathbf{L}_{ik}. \tag{451}$$

For multiple events,

$$\boldsymbol{\omega}_{i}^{+} = \boldsymbol{\omega}_{i}^{-} + \sum_k \mathbf{I}_{i,k}^{-1} \Delta \mathbf{L}_{ik}, \tag{452}$$

only when the events act on the same material domain and the inertia changes are negligible.

In the general case, the update must be performed recursively.

29.3 Euler-Vector Evolution

The Euler vector evolves according to

$$\mathbf{I}_i \frac{d\boldsymbol{\omega}_i}{dt} + \dot{\mathbf{I}}_i \boldsymbol{\omega}_i + \boldsymbol{\omega}_i \times (\mathbf{I}_i \boldsymbol{\omega}_i) = \boldsymbol{\tau}_{i,\mathrm{net}}. \tag{453}$$

The net torque includes:

$$\boldsymbol{\tau}_{i,\mathrm{net}} = \boldsymbol{\tau}_i^{\mathrm{event}} + \boldsymbol{\tau}_i^{\mathrm{gravity}} + \boldsymbol{\tau}_i^{\mathrm{buoyancy}} + \boldsymbol{\tau}_i^{\mathrm{boundary}} + \boldsymbol{\tau}_i^{\mathrm{mantle}} + \boldsymbol{\tau}_i^{\mathrm{resist}}. \tag{454}$$

29.4 Finite Rotation

The orientation matrix $\mathbf{R}_i(t)$ satisfies

$$\frac{d\mathbf{R}_i}{dt} = [\boldsymbol{\omega}_i]_\times \mathbf{R}_i, \tag{455}$$

where

$$[\boldsymbol{\omega}]_\times = \begin{pmatrix} 0 & -\omega_z & \omega_y \\ \omega_z & 0 & -\omega_x \\ -\omega_y & \omega_x & 0 \end{pmatrix}. \tag{456}$$

For constant angular velocity over interval Δt,

$$\mathbf{R}_i(t + \Delta t) = \exp\left[(\boldsymbol{\omega}_i)_\times \Delta t\right] \mathbf{R}_i(t). \tag{457}$$

29.5 Time-Dependent Finite Rotation

For time-varying angular velocity,

$$\mathbf{R}_i(t_2, t_1) = \mathcal{T} \exp\left[\int_{t_1}^{t_2} [\boldsymbol{\omega}_i(t)]_\times \, dt\right], \tag{458}$$

where $\mathcal{T}$ denotes chronological ordering.

29.6 Predicted Euler Pole

The predicted pole direction is

$$\hat{\mathbf{e}}_i^{\mathrm{pred}} = \frac{\boldsymbol{\omega}_i^{\mathrm{pred}}}{\left\|\boldsymbol{\omega}_i^{\mathrm{pred}}\right\|}. \tag{459}$$

Its angular speed is

$$\omega_i^{\mathrm{pred}} = \left\|\boldsymbol{\omega}_i^{\mathrm{pred}}\right\|. \tag{460}$$

29.7 Relative Euler Pole

For plates i and j,

$$\boldsymbol{\omega}_{ij} = \boldsymbol{\omega}_i - \boldsymbol{\omega}_j. \tag{461}$$

The relative Euler-pole direction is

$$\widehat{\mathbf{e}}_{ij} = \frac{\boldsymbol{\omega}_{ij}}{\|\boldsymbol{\omega}_{ij}\|}. \tag{462}$$

29.8 Euler-Pole Drift

The pole-drift rate is

$$\dot{\widehat{\mathbf{e}}}_i = \frac{1}{\omega_i} \left[\mathbf{1} - \widehat{\mathbf{e}}_i \otimes \widehat{\mathbf{e}}_i \right] \dot{\boldsymbol{\omega}}_i. \tag{463}$$

Pole drift may result from:

- changing torque;
- changing plate geometry;
- changing inertia;
- boundary reorganization;
- mantle-flow evolution;
- plate fragmentation;
- terrane accretion;
- or later events.

29.9 Euler-Pole Residuals

The angular pole residual is

$$\Delta\theta_{\text{pole},i} = \arccos \left[\widehat{\mathbf{e}}_i^{\text{obs}} \cdot \widehat{\mathbf{e}}_i^{\text{pred}} \right]. \tag{464}$$

The angular-speed residual is

$$\Delta\omega_i = \omega_i^{\text{obs}} - \omega_i^{\text{pred}}. \tag{465}$$

The covariance-weighted Euler residual is

$$\chi^2_{\omega,i} = \left(\boldsymbol{\omega}_i^{\text{obs}} - \boldsymbol{\omega}_i^{\text{pred}} \right)^{\mathsf{T}} \boldsymbol{\Sigma}_{\omega,i}^{-1} \left(\boldsymbol{\omega}_i^{\text{obs}} - \boldsymbol{\omega}_i^{\text{pred}} \right). \tag{466}$$

29.10 No Independent Euler-Pole Fitting

The event model must generate

$$\{\boldsymbol{\omega}_1, \ldots, \boldsymbol{\omega}_{N_P}\} = \mathcal{F}_\omega \left[\mathcal{E}, \mathbf{Q}_0, \mathcal{B}, \mathbf{F}_{\text{ongoing}}\right]. \tag{467}$$

A reconstruction that assigns one independent Euler vector to every plate and then attributes the fitted vectors to events does not test causal generation.

29.11 Euler-Pole Falsifier

Euler-pole falsifier V4.
If the event sequence cannot generate the observed Euler-pole directions and angular speeds from shared physical parameters, plate inertia, and calculated torques, the rotational inheritance claim is rejected.

30 Force and Torque Decomposition

30.1 Plate Net Force

For plate i,

$$\mathbf{F}_{i,\text{net}} = \mathbf{F}_i^{\text{event}} + \mathbf{F}_i^{\text{gravity}} + \mathbf{F}_i^{\text{buoyancy}} + \mathbf{F}_i^{\text{boundary}} + \mathbf{F}_i^{\text{mantle}} + \mathbf{F}_i^{\text{topography}} + \mathbf{F}_i^{\text{resist}}. \tag{468}$$

The center-of-mass acceleration is

$$M_i \frac{d\mathbf{V}_{i,\text{CM}}}{dt} = \mathbf{F}_{i,\text{net}}. \tag{469}$$

30.2 Plate Net Torque

The torque about Earth's center is

$$\boldsymbol{\tau}_{i,\text{net}} = \int_{\mathcal{P}_i} \mathbf{r} \times \mathbf{f}_{\text{net}}\, dV + \int_{\partial\mathcal{P}_i} \mathbf{r} \times (\boldsymbol{\sigma}\hat{\mathbf{n}})\; dA. \tag{470}$$

It is decomposed as

$$\boldsymbol{\tau}_{i,\text{net}} = \boldsymbol{\tau}_i^{\text{event}} + \boldsymbol{\tau}_i^{\text{gravity}} + \boldsymbol{\tau}_i^{\text{buoyancy}} + \boldsymbol{\tau}_i^{\text{boundary}} + \boldsymbol{\tau}_i^{\text{mantle}} + \boldsymbol{\tau}_i^{\text{resist}}. \tag{471}$$

30.3 Force and Torque Registry

Table 4: Paper-III plate force and torque registry.

Component	Physical origin	Required output
Event	Direct impulse, displacement, damage, density, and stress change	Initial momentum, angular momentum, boundary state
Gravity	Mass redistribution, topography, density anomalies	Horizontal force, restoring force, torque
Buoyancy	Thermal, phase, melt, and compositional density contrasts	Vertical and lateral force, long-time maintenance
Boundary	Normal and shear traction at plate edges	Convergence, divergence, shear, resistance
Mantle	Basal traction and mantle-flow interaction	Driving or resisting force and torque
Topography	Gravitational potential-energy gradients	Down-gradient force and lateral pressure
Resistance	Viscosity, friction, yielding, damage, bending, deformation	Dissipation and deceleration

30.4 Power by Force Component

For force component a, the translational power is

$$\dot{W}_{i,a}^{\mathrm{trans}} = \mathbf{F}_{i,a} \cdot \mathbf{V}_{i,\mathrm{CM}}. \tag{472}$$

The rotational power is

$$\dot{W}_{i,a}^{\mathrm{rot}} = \boldsymbol{\tau}_{i,a} \cdot \boldsymbol{\omega}_i. \tag{473}$$

The total plate power is

$$\dot{W}_{i,\mathrm{net}} = \sum_a \left(\dot{W}_{i,a}^{\mathrm{trans}} + \dot{W}_{i,a}^{\mathrm{rot}} \right). \tag{474}$$

30.5 Driving and Resisting Components

Define positive driving power

$$\dot{W}_i^{+} = \sum_a \max\left(\dot{W}_{i,a}, 0 \right), \tag{475}$$

and resisting power

$$\dot{W}_i^- = -\sum_a \min\left(\dot{W}_{i,a}, 0\right). \tag{476}$$

The net kinetic-energy change is

$$\frac{dE_i^{\text{kin}}}{dt} = \dot{W}_i^+ - \dot{W}_i^-. \tag{477}$$

30.6 Force Attribution Fraction

The fractional contribution of component a to positive power is

$$f_{i,a}^+ = \frac{\max\left(\dot{W}_{i,a}, 0\right)}{\dot{W}_i^+}. \tag{478}$$

The fraction may vary through time.

A plate may begin with event-dominated motion and later become gravity-, boundary-, or mantle-dominated.

30.7 Torque Attribution Fraction

The magnitude-based torque fraction is

$$f_{\tau,i,a} = \frac{\|\boldsymbol{\tau}_{i,a}\|}{\sum_b \|\boldsymbol{\tau}_{i,b}\|}. \tag{479}$$

Because opposing torques may cancel, both vector sums and component magnitudes must be reported.

30.8 Action–Reaction Across Shared Boundaries

For shared boundary $\mathcal{B}_{ij}$,

$$\mathbf{F}_{i\leftarrow j}^B = -\mathbf{F}_{j\leftarrow i}^B \tag{480}$$

when both forces are evaluated consistently on the same interface.

The corresponding torques need not be equal in magnitude about different plate centers.

30.9 Force-Balance Residual

Define normalized force residual

$$\epsilon_{F,i} = \frac{\left\|M_i \dot{\mathbf{V}}_{i,\text{CM}} - \mathbf{F}_{i,\text{net}}\right\|}{F_{i,\text{ref}}}. \tag{481}$$

Define normalized torque residual

$$\epsilon_{\tau,i} = \frac{\left\| \dot{\mathbf{L}}_i - \boldsymbol{\tau}_{i,\text{net}} \right\|}{\tau_{i,\text{ref}}}. \tag{482}$$

30.10 Force-Decomposition Falsifier

Force-decomposition falsifier V5.
If the predicted plate directions and speeds require unbalanced forces, unaccounted torques, or power exceeding the available event, gravitational, buoyancy, boundary, and mantle budgets, the motion solution is rejected.

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31 Gravitational and Buoyancy Maintenance

31.1 Event-Modified Gravitational Potential

For event-created density anomaly $\Delta\rho_k$,

$$\Delta\Phi_k(\mathbf{x}, t) = -G \int_{\mathcal{V}_\oplus} \frac{\Delta\rho_k(\mathbf{r}, t)}{\|\mathbf{x} - \mathbf{r}\|} \, dV. \tag{483}$$

The resulting acceleration perturbation is

$$\Delta\mathbf{g}_k = -\nabla\Delta\Phi_k. \tag{484}$$

31.2 Plate Gravitational Force

The force on plate i from event-created potential is

$$\mathbf{F}^g_{i,k} = -\int_{\mathcal{P}_i} \rho\nabla\Delta\Phi_k \, dV. \tag{485}$$

The associated torque is

$$\boldsymbol{\tau}^g_{i,k} = -\int_{\mathcal{P}_i} \mathbf{r} \times \rho\nabla\Delta\Phi_k \, dV. \tag{486}$$

31.3 Gravitational Potential Energy

The plate gravitational potential energy is

$$U_{g,i} = \int_{\mathcal{P}_i} \rho\Phi \, dV. \tag{487}$$

The generalized force along displacement coordinate q_i is

$$F_{g,i}^{(q)} = -\frac{\partial U_{g,i}}{\partial q_i}. \tag{488}$$

31.4 Topographic Potential Energy

For surface elevation $h(\mathbf{x})$, define a regional gravitational potential-energy density

$$\mathcal{U}_{\text{topo}} = \int_{z_{\text{ref}}}^{z_{\text{surf}}} \rho g z \, dz. \tag{489}$$

The lateral force scale is related to

$$-\nabla_{\mathcal{S}} \mathcal{U}_{\text{topo}}, \tag{490}$$

where $\nabla_{\mathcal{S}}$ is the surface gradient.

An event-created mountain, plateau, basin, or trench may therefore produce long-lived gravitational forcing after the original impulse decays.

31.5 Buoyancy Force

For density anomaly $\Delta\rho$,

$$\mathbf{F}_B = -\int_{\mathcal{V}} \Delta\rho \mathbf{g} \, dV. \tag{491}$$

The density anomaly may arise from:

- temperature;
- composition;
- phase state;
- melt;
- fracture porosity;
- displaced crust;
- dense event-derived material; or
- pressure-dependent transformation.

31.6 Thermal Buoyancy

For thermal expansion coefficient α_T,

$$\Delta\rho_T \approx -\rho_0 \alpha_T \Delta T \tag{492}$$

within its applicable linear range.

The thermal buoyancy force is

$$\mathbf{F}_{B,T} = -\int \Delta\rho_T \mathbf{g}\, dV. \tag{493}$$

31.7 Compositional Buoyancy

For composition variables C_a,

$$\Delta\rho_C = \sum_a \frac{\partial\rho}{\partial C_a} \Delta C_a. \tag{494}$$

The compositional buoyancy force is

$$\mathbf{F}_{B,C} = -\int \Delta\rho_C \mathbf{g}\, dV. \tag{495}$$

31.8 Phase Buoyancy

For phase fractions ϕ_a,

$$\Delta\rho_\phi = \sum_a \rho_a \Delta\phi_a. \tag{496}$$

The corresponding force is

$$\mathbf{F}_{B,\phi} = -\int \Delta\rho_\phi \mathbf{g}\, dV. \tag{497}$$

31.9 Buoyancy-Decay Kernel

Let event-created buoyancy contribution evolve as

$$\mathbf{F}_{B,k}(t) = K_{B,k}\,(t - t_k)\,\mathbf{F}_{B,k}(t_k^+), \tag{498}$$

where the kernel may include:

- thermal diffusion;
- compositional persistence;
- phase relaxation;
- melt migration;
- advective transport;
- mixing;

- gravitational reorganization; and
- later-event modification.

31.10 Maintenance Fraction

The fraction of modern plate power supplied by persistent event-modified gravity and buoyancy is

$$f_i^{gB} = \frac{\max\left[\left(\mathbf{F}_i^g + \mathbf{F}_i^B\right) \cdot \mathbf{v}_i, 0\right]}{\dot{W}_i^+}. \tag{499}$$

31.11 Impulse Versus Persistent Forcing

Define event-impulse contribution to present motion as

$$\mathbf{v}_i^I(t) \tag{500}$$

and persistent event-modified forcing contribution as

$$\mathbf{v}_i^{gB}(t). \tag{501}$$

The combined event inheritance is

$$\mathbf{v}_i^{\mathrm{ABC}} = \mathbf{v}_i^I + \mathbf{v}_i^{gB} + \mathbf{v}_i^{B,\mathrm{inherit}}. \tag{502}$$

31.12 Maintenance Falsifier

Maintenance falsifier V6.
If the initial impulse decays while event-created gravity, buoyancy, boundary guidance, and later reinforcement provide insufficient power to maintain the predicted plate-motion field, the long-duration inheritance claim fails.

32 Boundary and Mantle Coupling

32.1 Boundary Traction

For boundary $\mathcal{B}_{ij}$, traction on plate i is

$$\mathbf{t}_{ij} = \boldsymbol{\sigma}_{ij}\widehat{\mathbf{n}}_{ij}. \tag{503}$$

Its normal component is

$$t_{ij,n} = \mathbf{t}_{ij} \cdot \widehat{\mathbf{n}}_{ij}, \tag{504}$$

and its tangential component is

$$\mathbf{t}_{ij,t} = \mathbf{t}_{ij} - t_{ij,n}\widehat{\mathbf{n}}_{ij}. \tag{505}$$

32.2 Boundary Force

The total force on plate i from plate j is

$$\mathbf{F}^{B}_{i\leftarrow j} = \int_{\mathcal{B}_{ij}} \mathbf{t}_{ij}\, dA. \tag{506}$$

The torque is

$$\boldsymbol{\tau}^{B}_{i\leftarrow j} = \int_{\mathcal{B}_{ij}} \mathbf{r} \times \mathbf{t}_{ij}\, dA. \tag{507}$$

32.3 Boundary Mobility Tensor

Define local boundary mobility

$$\mathbf{M}^{B}_{ij} = M_n\widehat{\mathbf{n}}_{ij} \otimes \widehat{\mathbf{n}}_{ij} + M_t\widehat{\mathbf{t}}_{ij} \otimes \widehat{\mathbf{t}}_{ij} + M_z\widehat{\mathbf{z}}_{ij} \otimes \widehat{\mathbf{z}}_{ij}. \tag{508}$$

The relative velocity may be expressed as

$$\mathbf{v}^{\text{rel}}_{ij} = \mathbf{M}^{B}_{ij}\mathbf{t}_{ij} + \mathbf{v}^{\text{plastic}}_{ij}. \tag{509}$$

32.4 Inherited Boundary Anisotropy

Event-created damage modifies mobility:

$$\mathbf{M}^{B,+}_{ij} = \mathbf{M}^{B,0}_{ij} + \Delta\mathbf{M}^{B,\text{event}}_{ij}. \tag{510}$$

The event contribution may favor:

- opening;
- closure;
- strike-parallel motion;
- underthrusting;
- descent;
- uplift;
- or distributed deformation.

32.5 Boundary Dissipation

The local boundary-dissipation rate is

$$\dot{E}_{ij}^{B} = \int_{\mathcal{B}_{ij}} \mathbf{t}_{ij} \cdot \mathbf{v}_{ij}^{\mathrm{rel}} \, dA. \tag{511}$$

For a passive dissipative boundary,

$$\dot{E}_{ij}^{B} \geq 0 \tag{512}$$

under the adopted sign convention.

32.6 Basal Mantle Traction

At plate base $\mathcal{A}_i^{\mathrm{base}}$,

$$\mathbf{t}_i^{m} = \boldsymbol{\sigma}_m \widehat{\mathbf{n}}_i^{\mathrm{base}}. \tag{513}$$

A reduced anisotropic coupling law is

$$\mathbf{t}_i^{m} = -\mathbf{K}_i^{m} \left(\mathbf{v}_i - \mathbf{v}_m \right), \tag{514}$$

where $\mathbf{K}_i^m$ is positive semidefinite for purely resistive coupling.

32.7 Mantle Force and Torque

The basal force is

$$\mathbf{F}_i^{m} = \int_{\mathcal{A}_i^{\mathrm{base}}} \mathbf{t}_i^{m} \, dA. \tag{515}$$

The basal torque is

$$\boldsymbol{\tau}_i^{m} = \int_{\mathcal{A}_i^{\mathrm{base}}} \mathbf{r} \times \mathbf{t}_i^{m} \, dA. \tag{516}$$

32.8 Event-Modified Mantle Flow

The mantle velocity is decomposed as

$$\mathbf{v}_m = \mathbf{v}_m^{0} + \sum_k \Delta \mathbf{v}_{m,k}^{\mathrm{event}}. \tag{517}$$

Event-created thermal, density, phase, and damage fields may alter both the magnitude and direction of basal traction.

32.9 Coupling Regimes

The model should distinguish:

Plate-driven mantle coupling
Plate motion drags the underlying mantle.

Mantle-driven plate coupling
Mantle flow provides positive power to the plate.

Mutual coupling
Plate and mantle exchange power through a coupled transient.

Weak decoupling
A low-viscosity or damaged layer reduces traction.

Anisotropic coupling
Event-created structure allows easier motion in selected directions.

32.10 Coupling Power

The power transferred from mantle to plate is

$$\dot{W}_i^m = \int_{\mathcal{A}_i^{\text{base}}} \mathbf{t}_i^m \cdot \mathbf{v}_i \, dA. \tag{518}$$

The power extracted from relative motion is

$$\dot{E}_i^{m,\text{diss}} = \int_{\mathcal{A}_i^{\text{base}}} (\mathbf{v}_i - \mathbf{v}_m) \cdot \mathbf{K}_i^m (\mathbf{v}_i - \mathbf{v}_m) \, dA. \tag{519}$$

32.11 Coupling Falsifier

Coupling falsifier V7.
If the model requires boundary or mantle coupling with the wrong sign, unphysical negative dissipation, or unconstrained directional traction to reproduce plate velocities, the coupling solution is rejected.

---

33 Velocity Memory and Directional Inheritance

33.1 Velocity Memory Tensor

For event k acting on plate ancestry i, define memory tensor

$$\mathbf{K}_{ik}^V (t, t_k) \, . \tag{520}$$

The inherited velocity contribution is

$$\mathbf{v}_{ik}^{\text{inherit}}(t) = \mathbf{K}_{ik}^{V}(t, t_k)\,\Delta\mathbf{v}_{ik}. \tag{521}$$

A tensor is required because inherited structure may preserve one direction more strongly than another.

33.2 Directional and Magnitude Memory

Decompose

$$\mathbf{K}_{ik}^{V} = K_{\parallel}\widehat{\mathbf{d}}_{ik} \otimes \widehat{\mathbf{d}}_{ik} + K_{\perp,1}\widehat{\mathbf{n}}_{ik,1} \otimes \widehat{\mathbf{n}}_{ik,1} + K_{\perp,2}\widehat{\mathbf{n}}_{ik,2} \otimes \widehat{\mathbf{n}}_{ik,2}. \tag{522}$$

If

$$K_{\parallel} \gg K_{\perp,1}, K_{\perp,2}, \tag{523}$$

the event direction is preferentially preserved.

33.3 Scalar Speed-Memory Kernel

A scalar speed-memory model may be written as

$$K_{s,ik}(\Delta t) = \sum_{a=1}^{N_K} A_{ik,a} \exp\left[-\left(\frac{\Delta t}{\tau_{ik,a}}\right)^{p_{ik,a}}\right] + K_{ik}^{\text{persist}}, \tag{524}$$

where:

$$\tau_{ik,a} = \text{relaxation timescale}, \tag{525}$$

$$p_{ik,a} = \text{decay-shape exponent}, \tag{526}$$

$$K_{ik}^{\text{persist}} = \text{persistent boundary- or force-guidance component}. \tag{527}$$

The expression is a flexible test form, not an assumed physical law.

33.4 Directional Persistence Angle

Let the initial event-derived direction be

$$\widehat{\mathbf{d}}_{ik}^{0}. \tag{528}$$

The plate-motion direction at time t is

$$\widehat{\mathbf{v}}_i(t) = \frac{\mathbf{v}_i(t)}{\|\mathbf{v}_i(t)\|}. \tag{529}$$

The directional memory angle is

$$\theta_{ik}^{V}(t) = \arccos\left[\widehat{\mathbf{d}}_{ik}^{0} \cdot \widehat{\mathbf{v}}_i(t)\right]. \tag{530}$$

33.5 Direction-Persistence Statistic

Define

$$P_{ik}^{\mathrm{dir}}(t) = \cos\theta_{ik}^{V}(t). \tag{531}$$

Values near 1 indicate alignment.

Values near 0 indicate orthogonality.

Values near -1 indicate reversal.

33.6 Speed-Persistence Statistic

The speed-memory fraction is

$$P_{ik}^{\mathrm{speed}}(t) = \frac{\left\|\mathbf{v}_{ik}^{\mathrm{inherit}}(t)\right\|}{\|\Delta\mathbf{v}_{ik}\|}. \tag{532}$$

Direction may remain inherited even when this fraction becomes small.

33.7 Boundary-Guided Direction

Let inherited boundary tangent be

$$\widehat{\mathbf{t}}_B. \tag{533}$$

The plate-motion alignment with that boundary is

$$A_{iB}^{V} = \left|\widehat{\mathbf{v}}_i \cdot \widehat{\mathbf{t}}_B\right|. \tag{534}$$

The normal-motion alignment is

$$A_{iB}^{N} = \left|\widehat{\mathbf{v}}_i \cdot \widehat{\mathbf{n}}_B\right|. \tag{535}$$

The event framework must predict whether each inherited boundary guides parallel, normal, or oblique motion.

33.8 Later-Event Reinforcement

For later event m, define directional reinforcement

$$R_i^{(k,m)} = \widehat{\mathbf{I}}_{ik} \cdot \widehat{\mathbf{I}}_{im}. \tag{536}$$

If

$$R_i^{(k,m)} > 0, \tag{537}$$

the events reinforce direction.

If

$$R_i^{(k,m)} < 0, \tag{538}$$

they oppose direction.

If

$$R_i^{(k,m)} \approx 0, \tag{539}$$

the later event may rotate the motion field.

33.9 Cumulative Directional Inheritance

The cumulative inherited vector is

$$\mathbf{V}_i^{\text{inherit}}(t) = \sum_{k \in \mathcal{K}_{V,i}} \mathbf{K}_{ik}^{V}(t, t_k) \Delta \mathbf{v}_{ik}. \tag{540}$$

The normalized cumulative direction is

$$\widehat{\mathbf{V}}_i^{\text{inherit}} = \frac{\mathbf{V}_i^{\text{inherit}}}{\|\mathbf{V}_i^{\text{inherit}}\|}. \tag{541}$$

33.10 Inherited Direction Fraction

The directional agreement with observed velocity is

$$f_i^{\text{dir}} = \widehat{\mathbf{V}}_i^{\text{inherit}} \cdot \widehat{\mathbf{V}}_i^{\text{obs}}. \tag{542}$$

The inherited speed fraction is

$$f_i^{\mathrm{mag}} = \frac{\left\|\mathbf{V}_i^{\mathrm{inherit}}\right\|}{\left\|\mathbf{V}_i^{\mathrm{obs}}\right\|}. \tag{543}$$

33.11 Directional-Inheritance Counterfactual

Run the model with the inherited anisotropic boundary and memory fields:

$$\mathbf{V}^{+} = \mathcal{U}\left[\mathbf{Q}_{\mathrm{inherit}}, \mathbf{F}_{\mathrm{ongoing}}\right]. \tag{544}$$

Run the model after isotropizing the inherited state:

$$\mathbf{V}^{\mathrm{iso}} = \mathcal{U}\left[\mathrm{Iso}\left(\mathbf{Q}_{\mathrm{inherit}}\right), \mathbf{F}_{\mathrm{ongoing}}\right]. \tag{545}$$

The directional inheritance contribution is

$$\Delta\mathbf{V}^{\mathrm{dir}} = \mathbf{V}^{+} - \mathbf{V}^{\mathrm{iso}}. \tag{546}$$

33.12 Memory Falsifier

Velocity-memory falsifier V8.
If the observed motion directions arise equally well after removing or isotropizing the event-created impulse, damage, boundary, density, and phase fields, the proposed directional memory is not required.

---

34 Plate Acceleration, Deceleration, and Speed Hierarchy

34.1 Plate Speed

For plate i, define representative speed

$$\bar{v}_i(t) = \frac{\displaystyle\int_{\mathcal{A}_i} w_i(\mathbf{x}) \left\|\mathbf{v}_i(\mathbf{x}, t)\right\| \, dA}{\displaystyle\int_{\mathcal{A}_i} w_i(\mathbf{x}) \, dA}. \tag{547}$$

The weighting may reflect area, mass, observational coverage, or a predeclared reference-site distribution.

34.2 Tangential Acceleration

The plate acceleration field is

$$\mathbf{a}_i = \frac{D\mathbf{v}_i}{Dt}. \tag{548}$$

The acceleration along the velocity direction is

$$a_{i,\|} = \mathbf{a}_i \cdot \widehat{\mathbf{v}}_i. \tag{549}$$

The turning acceleration is

$$\mathbf{a}_{i,\perp} = \mathbf{a}_i - a_{i,\|}\widehat{\mathbf{v}}_i. \tag{550}$$

34.3 Speed Evolution

The speed derivative is

$$\frac{d\bar{v}_i}{dt} = \bar{a}_{i,\|}. \tag{551}$$

Acceleration occurs where

$$\bar{a}_{i,\|} > 0. \tag{552}$$

Deceleration occurs where

$$\bar{a}_{i,\|} < 0. \tag{553}$$

34.4 Characteristic Relaxation Time

A velocity-relaxation time is

$$\tau_{v,i} = \frac{M_i}{C_{i,\text{eff}}}, \tag{554}$$

for effective linear resistance coefficient $C_{i,\text{eff}}$.

For rotational motion,

$$\tau_{\omega,i} = \frac{I_{i,\text{eff}}}{C_{\omega,i,\text{eff}}}. \tag{555}$$

These quantities may be tensorial in an anisotropic system.

34.5 Reduced Speed Equation

A reduced one-dimensional speed equation is

$$M_i \frac{dv_i}{dt} = F_i^+(t) - C_i(t)v_i - Q_i(t)v_i\left|v_i\right|, \tag{556}$$

where:

$$F_i^+ = \text{net driving force along motion,} \tag{557}$$
$$C_i = \text{linear resistance,} \tag{558}$$
$$Q_i = \text{quadratic or nonlinear resistance.} \tag{559}$$

The reduced equation is a diagnostic approximation.

The full solution remains vectorial and coupled.

34.6 Quasi-Steady Speed

Where acceleration is small,

$$F_i^+ \approx C_i v_i + Q_i v_i |v_i| . \tag{560}$$

For negligible quadratic resistance,

$$v_i^{\text{qs}} \approx \frac{F_i^+}{C_i}. \tag{561}$$

For negligible linear resistance,

$$v_i^{\text{qs}} \approx \sqrt{\frac{F_i^+}{Q_i}}. \tag{562}$$

34.7 Speed-Hierarchy Prediction

Let the observed ordering be

$$\bar{v}_{(1)}^{\text{obs}} \geq \bar{v}_{(2)}^{\text{obs}} \geq \cdots \geq \bar{v}_{(N_P)}^{\text{obs}}. \tag{563}$$

The model predicts ordering

$$\bar{v}_{(1)}^{\text{pred}} \geq \bar{v}_{(2)}^{\text{pred}} \geq \cdots \geq \bar{v}_{(N_P)}^{\text{pred}}. \tag{564}$$

A valid model should explain the hierarchy through shared variables such as:

- event impulse;
- angular impulse;
- plate mass;
- plate inertia;

- boundary mobility;
- mantle coupling;
- density anomalies;
- gravitational gradients;
- plate geometry;
- resistance;
- and later-event reinforcement.

34.8 Speed-Rank Residual

Let observed rank be r_i^{obs} and predicted rank be r_i^{pred}.

The rank residual is

$$\Delta r_i = r_i^{\text{obs}} - r_i^{\text{pred}}. \tag{565}$$

A normalized rank score is

$$\mathcal{R}_v = 1 - \frac{6 \sum_i (\Delta r_i)^2}{N_P (N_P^2 - 1)}. \tag{566}$$

34.9 Speed-Scale Residual

The logarithmic speed residual is

$$\epsilon_{\log v, i} = \log \left(\frac{\bar{v}_i^{\text{pred}}}{\bar{v}_i^{\text{obs}}} \right). \tag{567}$$

This penalizes proportional rather than absolute errors.

34.10 Acceleration Chronology

For reconstructed time slices t_q, define

$$\Delta \bar{v}_{i,q} = \bar{v}_i(t_{q+1}) - \bar{v}_i(t_q). \tag{568}$$

The event sequence should predict when a plate:

- accelerates;
- decelerates;
- reverses;
- rotates;

- fragments;
- changes boundary regime; or
- becomes dynamically coupled to a different mantle or plate domain.

34.11 Speed-Hierarchy Falsifier

Speed-hierarchy falsifier V9.
If relative plate speeds and their ordering can be reproduced only by assigning independent resistance, force, or memory parameters to each plate, the claimed shared event-derived speed law is rejected.

---

35 Relative Motion Across the Global Boundary Network

35.1 Boundary Relative Velocity

For plates i and j,

$$\mathbf{v}_{ij}^{\mathrm{rel}}(\mathbf{x}) = (\boldsymbol{\omega}_i - \boldsymbol{\omega}_j) \times \mathbf{x} + \mathbf{v}_{i,\mathrm{def}} - \mathbf{v}_{j,\mathrm{def}}. \tag{569}$$

35.2 Opening, Closing, and Shear Rates

At boundary point $\mathbf{x}$,

$$v_{ij,n} = \mathbf{v}_{ij}^{\mathrm{rel}} \cdot \widehat{\mathbf{n}}_{ij}, \tag{570}$$
$$v_{ij,t} = \mathbf{v}_{ij}^{\mathrm{rel}} \cdot \widehat{\mathbf{t}}_{ij}. \tag{571}$$

Define opening rate

$$v_{ij}^{\mathrm{open}} = \max\left(v_{ij,n}, 0\right), \tag{572}$$

closing rate

$$v_{ij}^{\mathrm{close}} = \max\left(-v_{ij,n}, 0\right), \tag{573}$$

and shear rate

$$v_{ij}^{\mathrm{shear}} = \left|v_{ij,t}\right|. \tag{574}$$

35.3 Plate-Circuit Closure

For a closed plate circuit

$$i_1 \to i_2 \to \cdots \to i_m \to i_1, \tag{575}$$

the relative Euler vectors must satisfy

$$\sum_{a=1}^{m} \boldsymbol{\omega}_{i_a i_{a+1}} = \mathbf{0}, \tag{576}$$

where $i_{m+1} = i_1$.

The closure residual is

$$\boldsymbol{\epsilon}_{\text{circ}} = \sum_{a=1}^{m} \boldsymbol{\omega}_{i_a i_{a+1}}. \tag{577}$$

35.4 Velocity-Circuit Closure

At a common point or consistently transformed locations,

$$\sum_{a=1}^{m} \mathbf{v}_{i_a i_{a+1}}^{\text{rel}} = \mathbf{0}. \tag{578}$$

Failure indicates inconsistent plate velocities, reference frames, or boundary assignments.

35.5 Triple-Junction Compatibility

At junction among plates i, j, and k, the relative velocities satisfy

$$\mathbf{v}_{ij}^{\text{rel}} + \mathbf{v}_{jk}^{\text{rel}} + \mathbf{v}_{ki}^{\text{rel}} = \mathbf{0}. \tag{579}$$

The junction velocity $\mathbf{v}_J$ must satisfy the kinematic conditions of all incident boundaries.

For boundary a,

$$(\mathbf{v}_J - \mathbf{v}_{B,a}) \cdot \widehat{\mathbf{n}}_{B,a} = 0 \tag{580}$$

under a boundary-preserving condition.

35.6 Global Motion Constraint Matrix

Stack plate angular velocities into

$$\boldsymbol{\Omega} = \begin{pmatrix} \boldsymbol{\omega}_1 \\ \boldsymbol{\omega}_2 \\ \vdots \\ \boldsymbol{\omega}_{N_P} \end{pmatrix}. \tag{581}$$

Boundary observations produce linearized system

$$\mathbf{H}_V \boldsymbol{\Omega} = \mathbf{d}_V + \boldsymbol{\epsilon}_V, \tag{582}$$

where:

$$\mathbf{H}_V = \text{boundary-geometry and reference-frame operator}, \tag{583}$$

$$\mathbf{d}_V = \text{observed relative-motion data}. \tag{584}$$

The causal model must predict $\boldsymbol{\Omega}$ before using this system for residual evaluation.

35.7 Network Kinematic Residual

The covariance-weighted network residual is

$$\chi^2_{\text{rel}} = \left(\mathbf{d}_V - \mathbf{H}_V \boldsymbol{\Omega}^{\text{pred}}\right)^{\mathsf{T}} \boldsymbol{\Sigma}_V^{-1} \left(\mathbf{d}_V - \mathbf{H}_V \boldsymbol{\Omega}^{\text{pred}}\right). \tag{585}$$

35.8 Boundary Work Consistency

For each boundary,

$$\dot{W}^B_{ij} = \int_{\mathcal{B}_{ij}} \mathbf{t}_{ij} \cdot \mathbf{v}^{\text{rel}}_{ij} \, dA. \tag{586}$$

The global boundary power is

$$\dot{W}^{\text{global}}_B = \frac{1}{2} \sum_i \sum_{j \neq i} \dot{W}^B_{ij}. \tag{587}$$

The factor of one-half prevents double counting.

35.9 Global Area Consistency

Let total surface area be

$$A_{\oplus}. \tag{588}$$

The sum of plate-domain areas plus distributed deformation must satisfy

$$\sum_i A_i(t) + A_{\mathrm{deform}}(t) = A_\oplus(t). \tag{589}$$

Area production and destruction must be tracked consistently with opening, closing, descent, and new-material generation.

35.10 Relative-Motion Falsifier

Relative-motion falsifier V10.
If the event-derived plate velocities violate plate-circuit closure, triple-junction compatibility, shared-boundary kinematics, global area accounting, or action–reaction constraints, the global motion field is rejected.

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36 Present-Day and Deep-Time Velocity Datasets

36.1 Observational Hierarchy

The velocity test must distinguish among:

Present-day direct kinematics
: Modern position and velocity observations in declared reference frames.

Recent geological kinematics
: Displacement rates averaged over intervals longer than direct instrumental observation.

Finite-rotation reconstructions
: Plate or block rotations inferred between geological time slices.

Paleomagnetic constraints
: Reconstructed orientation and latitude information with explicit uncertainty.

Boundary-production records
: Age and geometry of material created or consumed at evolving boundaries.

Terrane and structural displacement
: Material identities, rotations, offsets, and transfer histories.

Indirect geodynamic constraints
: Stress, strain, subsidence, uplift, seismic anisotropy, and mantle structure used to constrain motion.

36.2 Global Navigation Satellite System Data

Let the Global Navigation Satellite System (GNSS) observation at site j be

$$\mathbf{v}_j^{\mathrm{GNSS}} \tag{590}$$

with covariance

$$\mathbf{\Sigma}_j^{\text{GNSS}}. \tag{591}$$

The complete present-day dataset is

$$\mathbf{D}_{\text{GNSS}} = \left\{\mathbf{x}_j, \mathbf{v}_j^{\text{GNSS}}, \mathbf{\Sigma}_j^{\text{GNSS}}, \mathcal{R}_{f,j}, t_j\right\}. \tag{592}$$

36.3 Plate-Interior and Boundary Sites

The observation set must distinguish:

- stable plate-interior sites;
- broad deformation-zone sites;
- active boundary sites;
- volcanic or subsiding sites;
- postseismic or transient sites;
- anthropogenically disturbed sites; and
- sites with uncertain plate membership.

36.4 Site Prediction

For site j assigned to plate i,

$$\widehat{\mathbf{v}}_j = \boldsymbol{\omega}_i^{\text{pred}} \times \mathbf{x}_j + \mathbf{v}_{i,\text{def}}^{\text{pred}}(\mathbf{x}_j). \tag{593}$$

The residual is

$$\boldsymbol{\epsilon}_j^V = \mathbf{v}_j^{\text{obs}} - \widehat{\mathbf{v}}_j. \tag{594}$$

36.5 Finite-Interval Velocity

For reconstructed position $\mathbf{x}_i(t)$, the mean velocity over interval $[t_1, t_2]$ is

$$\overline{\mathbf{v}}_i(t_1, t_2) = \frac{\mathbf{x}_i(t_2) - \mathbf{x}_i(t_1)}{t_2 - t_1}, \tag{595}$$

after consistent treatment of spherical geometry and reference frames.

36.6 Finite-Rotation Observation

For reconstructed rotation matrix

$$\mathbf{R}_i^{\mathrm{obs}}(t_2, t_1), \tag{596}$$

the predicted residual may be expressed through relative rotation

$$\mathbf{R}_i^{\mathrm{res}} = \left[\mathbf{R}_i^{\mathrm{pred}}\right]^{-1} \mathbf{R}_i^{\mathrm{obs}}. \tag{597}$$

The residual rotation angle is

$$\Delta\theta_{R,i} = \arccos\left[\frac{\mathrm{tr}\left(\mathbf{R}_i^{\mathrm{res}}\right) - 1}{2}\right]. \tag{598}$$

36.7 Paleomagnetic Observation Vector

A generalized paleomagnetic constraint is

$$\mathbf{D}_i^{\mathrm{PM}} = \left(\widehat{\mathbf{m}}_i, \lambda_i, \alpha_i, t_i, \boldsymbol{\Sigma}_i^{\mathrm{PM}}\right), \tag{599}$$

where:

$$\widehat{\mathbf{m}}_i = \text{measured remanence direction}, \tag{600}$$

$$\lambda_i = \text{reconstructed latitude-related constraint}, \tag{601}$$

$$\alpha_i = \text{rotation-related constraint}. \tag{602}$$

The event model must propagate predicted plate rotations into the corresponding observation space.

36.8 Boundary-Age Kinematic Constraint

For material-age field $a(\mathbf{x})$, the model predicts

$$\widehat{a}(\mathbf{x}) = \mathcal{F}_a\left[\mathcal{B}(t), \mathbf{V}(t), \mathcal{P}(t)\right]. \tag{603}$$

The age residual is

$$\epsilon_a(\mathbf{x}) = a^{\mathrm{obs}}(\mathbf{x}) - \widehat{a}(\mathbf{x}). \tag{604}$$

36.9 Timescale Separation

The data constrain different temporal averages:

$$\mathbf{v}_{\Delta t}^{\text{obs}} = \frac{1}{\Delta t} \int_{t-\Delta t}^{t} \mathbf{v}(t')\, dt'. \tag{605}$$

A present-day velocity cannot be directly compared with a hundred-million-year average without forward averaging the model over the same interval.

36.10 Observation Covariance

The complete covariance must include:

- measurement error;
- reference-frame error;
- plate-membership error;
- temporal averaging;
- reconstruction uncertainty;
- correlated site error;
- model-resolution error;
- inherited-structure uncertainty; and
- event-age uncertainty.

36.11 No Double Counting

Several datasets may derive from the same underlying observations or reconstruction assumptions.

Let data groups a and b have covariance

$$\text{Cov}\left(\mathbf{D}_a, \mathbf{D}_b\right) \neq \mathbf{0}. \tag{606}$$

They cannot be treated as independent likelihood factors without including that covariance.

36.12 Training and Validation Split

Define calibration data

$$\mathbf{D}_V^{\text{train}} \tag{607}$$

and held-out data

$$\mathbf{D}_V^{\text{test}}. \tag{608}$$

The model is calibrated on the first and evaluated on the second.

Possible held-out structures include:

- selected plates;
- selected boundaries;
- selected geographic regions;
- selected time intervals;
- selected data types; or
- selected event consequences.

36.13 Velocity-Data Falsifier

Velocity-data falsifier V11.
If the model matches one velocity timescale or reference frame but fails independent present-day, finite-rotation, paleomagnetic, boundary-age, or terrane-displacement constraints, the motion reconstruction is not globally coherent.

37 Velocity Inversion, Counterfactuals, and Model Comparison

37.1 Forward Model

The predicted global velocity field is

$$\widehat{\mathbf{D}}_V = \mathcal{F}_V \left[\mathcal{E}, \mathbf{Q}_0, \mathcal{B}_0, \mathbf{\Theta}_F, \mathbf{\Theta}_C, t\right], \tag{609}$$

where:

$$\mathbf{\Theta}_F = \text{force and torque parameters}, \tag{610}$$

$$\mathbf{\Theta}_C = \text{boundary and mantle coupling parameters}. \tag{611}$$

37.2 Inversion Target

The inversion estimates event and physical parameters:

$$\mathbf{\Theta}_V = \left(\mathbf{\Theta}_{\mathcal{E}}, \mathbf{\Theta}_F, \mathbf{\Theta}_C, \mathbf{\Theta}_M, \mathbf{\Theta}_R\right). \tag{612}$$

It must not directly estimate one unconstrained modern velocity vector per plate and then treat those vectors as predictions.

37.3 Velocity Likelihood

For observation vector $\mathbf{D}_V^{\text{obs}}$,

$$\ln \mathcal{L}_V = -\frac{1}{2}\left(\mathbf{D}_V^{\text{obs}} - \widehat{\mathbf{D}}_V\right)^{\mathsf{T}} \boldsymbol{\Sigma}_V^{-1}\left(\mathbf{D}_V^{\text{obs}} - \widehat{\mathbf{D}}_V\right) - \frac{1}{2}\ln|\boldsymbol{\Sigma}_V| + C. \tag{613}$$

37.4 Posterior Distribution

The posterior is

$$p\left(\boldsymbol{\Theta}_V \mid \mathbf{D}_V^{\text{obs}}\right) \propto \mathcal{L}_V p\left(\boldsymbol{\Theta}_V\right). \tag{614}$$

The prior must enforce:

- Paper-II mechanical admissibility;
- event chronology;
- conservation;
- nonnegative dissipation;
- defensible coupling;
- plate-lineage continuity;
- boundary-network viability; and
- parameter bounds independent of the velocity fit.

37.5 Regularization

A penalized objective may be

$$\mathcal{J}_V = \chi_V^2 + \lambda_E \mathcal{P}_E + \lambda_B \mathcal{P}_B + \lambda_F \mathcal{P}_F + \lambda_C \mathcal{P}_C + \lambda_S \mathcal{P}_S. \tag{615}$$

The penalties may include:

- event count;
- event-to-plate assignments;
- force complexity;
- coupling complexity;
- spatial roughness;
- excessive memory timescales;
- unphysical parameter values;
- and regional correction terms.

37.6 Counterfactual Model Family

The minimum counterfactuals are:

$$\mathcal{M}_{V,0} = \text{no astro-ballistic inheritance,} \tag{616}$$
$$\mathcal{M}_{V,1} = \text{impulse only,} \tag{617}$$
$$\mathcal{M}_{V,2} = \text{boundary inheritance only,} \tag{618}$$
$$\mathcal{M}_{V,3} = \text{density and buoyancy inheritance only,} \tag{619}$$
$$\mathcal{M}_{V,4} = \text{full event inheritance,} \tag{620}$$
$$\mathcal{M}_{V,5} = \text{randomized or spatially shuffled events,} \tag{621}$$
$$\mathcal{M}_{V,6} = \text{full comparison geodynamic model.} \tag{622}$$

37.7 No-Impulse Counterfactual

Set

$$\mathbf{J}_k = \mathbf{0} \tag{623}$$

while preserving other event-created fields.

The resulting difference is

$$\Delta\mathbf{V}^I = \mathbf{V}^{\text{full}} - \mathbf{V}^{\text{no impulse}}. \tag{624}$$

37.8 No-Boundary-Inheritance Counterfactual

Replace event-created mobility and damage fields with background values:

$$\mathbf{M}_B^+ \to \mathbf{M}_B^0, \qquad \mathbf{D}^+ \to \mathbf{D}^0. \tag{625}$$

The difference is

$$\Delta\mathbf{V}^B = \mathbf{V}^{\text{full}} - \mathbf{V}^{\text{no boundary inheritance}}. \tag{626}$$

37.9 No-Density-Inheritance Counterfactual

Set

$$\Delta\rho_k = 0, \qquad \Delta T_k = 0, \qquad \Delta\phi_k = 0 \tag{627}$$

after the primary event interval.

The difference is

$$\Delta \mathbf{V}^{gB} = \mathbf{V}^{\text{full}} - \mathbf{V}^{\text{no density inheritance}}. \tag{628}$$

37.10 Leave-One-Event-Out Motion Test

For event k,

$$\mathcal{E}_{-k} = \mathcal{E} \setminus \{\mathcal{E}_k\}. \tag{629}$$

The event's marginal velocity contribution is

$$\Delta \mathcal{J}_{V,k} = \mathcal{J}_{V,-k} - \mathcal{J}_{V,\text{full}}. \tag{630}$$

An event with negligible marginal contribution is not required for the motion solution.

37.11 Randomized Event Test

Generate randomized event catalogs

$$\left\{\mathcal{E}^{(r)}\right\}_{r=1}^{N_R} \tag{631}$$

that preserve declared nuisance properties while randomizing relevant geometry, chronology, or orientation.

The empirical probability is

$$p_{V,\text{null}} = \frac{1 + \sum_{r=1}^{N_R} \mathbf{1}\left[\mathcal{J}_V^{(r)} \leq \mathcal{J}_V^{\text{obs}}\right]}{N_R + 1}. \tag{632}$$

37.12 Model Evidence

For model $\mathcal{M}_{V,q}$,

$$\mathcal{Z}_{V,q} = \int \mathcal{L}_V \, p\left(\boldsymbol{\Theta}_{V,q} \mid \mathcal{M}_{V,q}\right) d\boldsymbol{\Theta}_{V,q}. \tag{633}$$

The evidence ratio is

$$K_{V,ij} = \frac{\mathcal{Z}_{V,i}}{\mathcal{Z}_{V,j}}. \tag{634}$$

37.13 Held-Out Prediction

For test data

$$\mathbf{D}_V^{\text{test}}, \tag{635}$$

the predictive likelihood is

$$p\left(\mathbf{D}_V^{\text{test}} \mid \mathbf{D}_V^{\text{train}}, \mathcal{M}_{V,q}\right) = \int p\left(\mathbf{D}_V^{\text{test}} \mid \boldsymbol{\Theta}_{V,q}\right) p\left(\boldsymbol{\Theta}_{V,q} \mid \mathbf{D}_V^{\text{train}}\right) \, d\boldsymbol{\Theta}_{V,q}. \tag{636}$$

37.14 Parameter Identifiability

The parameter-information matrix is

$$\mathbf{F}_\Theta = \left(\frac{\partial \widehat{\mathbf{D}}_V}{\partial \boldsymbol{\Theta}_V}\right)^{\mathsf{T}} \boldsymbol{\Sigma}_V^{-1} \left(\frac{\partial \widehat{\mathbf{D}}_V}{\partial \boldsymbol{\Theta}_V}\right). \tag{637}$$

Poorly constrained parameter combinations correspond to small eigenvalues of $\mathbf{F}_\Theta$.

The effective identifiable rank is

$$r_{\text{ident}} = \operatorname{rank}\left(\mathbf{F}_\Theta\right) \tag{638}$$

under a declared numerical threshold.

37.15 Causal Contribution Fraction

For observation component y, define event contribution

$$f_y^{\text{ABC}} = \frac{\left|y^{\text{full}} - y^{\text{no ABC}}\right|}{|y^{\text{obs}}| + \epsilon_y}. \tag{639}$$

The replacement claim requires substantial contribution across the global observation vector, not isolated regional improvements.

37.16 Inversion Falsifier

Velocity-inversion falsifier V12.
If event and inheritance parameters are non-identifiable, require plate-specific tuning, fail held-out prediction, or provide no material improvement over the no-event and comparison models, the quantitative motion-replacement claim fails.

38 Plate-Motion Viability and Falsification

38.1 Complete Motion Parameter Vector

The motion parameter vector is

$$\boldsymbol{\Theta}_M = (\mathcal{E}, \mathbf{Q}_{\mathrm{II}}, \mathcal{G}_P, \mathbf{I}_P, \mathbf{K}_B, \mathbf{K}_m, \mathbf{K}_V, \boldsymbol{\Theta}_F, \boldsymbol{\Theta}_R, \mathcal{R}_f), \tag{640}$$

where:

$$\mathbf{Q}_{\mathrm{II}} = \text{mechanically admissible Paper-II handoff,} \tag{641}$$
$$\mathcal{G}_P = \text{plate-lineage graph,} \tag{642}$$
$$\mathbf{I}_P = \text{plate inertia tensors,} \tag{643}$$
$$\mathbf{K}_B = \text{boundary coupling tensors,} \tag{644}$$
$$\mathbf{K}_m = \text{mantle coupling tensors,} \tag{645}$$
$$\mathbf{K}_V = \text{velocity-memory tensors,} \tag{646}$$
$$\boldsymbol{\Theta}_F = \text{force and torque parameters,} \tag{647}$$
$$\boldsymbol{\Theta}_R = \text{resistance parameters,} \tag{648}$$
$$\mathcal{R}_f = \text{reference-frame architecture.} \tag{649}$$

38.2 Plate-Motion Viable Set

Define

$$\mathcal{V}_V = \left\{ \boldsymbol{\Theta}_M : \begin{array}{l} \text{Paper-II mechanics satisfied,} \\ \text{plate lineage satisfied,} \\ \text{impulse partition satisfied,} \\ \text{mass conservation satisfied,} \\ \text{momentum conservation satisfied,} \\ \text{angular momentum satisfied,} \\ \text{force balance satisfied,} \\ \text{torque balance satisfied,} \\ \text{nonnegative dissipation satisfied,} \\ \text{Euler poles compatible,} \\ \text{directions compatible,} \\ \text{speeds compatible,} \\ \text{boundary-relative motion compatible,} \\ \text{deep-time motion compatible,} \\ \text{held-out prediction successful} \end{array} \right\}. \tag{650}$$

38.3 Motion Falsification Matrix

Table 5: Paper-III plate-motion falsification matrix.

ID	Motion claim	Falsifying result	Consequence
V-F01	Ancient plate mapping	Event impulse can be assigned only by projecting modern plate outlines backward without lineage reconstruction.	Reject impulse attribution.
V-F02	Impulse partition	Plate, mantle, deformation, ejecta, and bulk-Earth momentum do not close.	Reject event momentum handoff.
V-F03	Angular impulse	Required plate rotations violate angular-momentum conservation.	Reject rotational inheritance.
V-F04	Plate inertia	Predicted Euler vectors require incompatible plate masses or inertia tensors.	Reject rotational response.
V-F05	Euler-pole generation	Observed Euler poles must be inserted directly rather than generated.	Reject causal pole prediction.
V-F06	Force balance	Predicted accelerations do not match the sum of modeled forces.	Reject plate dynamics.
V-F07	Torque balance	Predicted rotational evolution does not match the modeled torque.	Reject plate rotation model.
V-F08	Power budget	Maintained motion requires more mechanical power than the model supplies.	Reject speed maintenance.
V-F09	Gravitational maintenance	Event-created density and topographic fields provide insufficient or incorrectly directed force.	Reject gravitational inheritance branch.
V-F10	Buoyancy maintenance	Thermal, phase, or compositional anomalies decay before contributing meaningfully.	Reject buoyancy inheritance branch.
V-F11	Boundary guidance	Inherited boundary mobility does not predict the observed direction of motion.	Reject directional guidance.
V-F12	Mantle coupling	Required mantle traction has the wrong sign, magnitude, or dissipation.	Reject mantle-coupling solution.

ID	Motion claim	Falsifying result	Consequence
V-F13	Velocity memory	Directional agreement disappears when the event-derived state is forward evolved.	Reject long-time motion memory.
V-F14	Counterfactual necessity	Removing or isotropizing event inheritance leaves the velocity field materially unchanged.	Reject primary causal inheritance.
V-F15	Plate direction	Predicted plate-motion directions systematically disagree with observations.	Reject directional prediction.
V-F16	Plate speed	Predicted speeds systematically disagree with observations.	Reject speed prediction.
V-F17	Speed hierarchy	The observed plate-speed ordering requires independent plate-specific parameters.	Reject shared speed law.
V-F18	Euler-pole drift	Predicted pole evolution conflicts with finite-rotation history.	Reject rotational chronology.
V-F19	Relative motion	Predicted opening, closing, and shear rates conflict with shared-boundary observations.	Reject boundary kinematics.
V-F20	Plate-circuit closure	Relative Euler vectors fail closed-circuit consistency.	Reject global velocity field.
V-F21	Triple junctions	Predicted motions are incompatible at major junctions.	Reject local network kinematics.
V-F22	Global area accounting	Plate production, destruction, and deformation do not preserve global surface accounting.	Reject global reconstruction.
V-F23	Present-day data	The model fails independent Global Navigation Satellite System velocity constraints.	Reject modern motion prediction.
V-F24	Deep-time data	The model fails finite rotations, paleomagnetic constraints, terrane paths, or boundary-age histories.	Reject temporal motion reconstruction.
V-F25	Reference-frame robustness	Agreement exists only in one favorable reference frame.	Reject frame-robust motion claim.

ID	Motion claim	Falsifying result	Consequence
V-F26	Randomized-event null	Randomized event catalogs reproduce the velocity field equally well.	Reject special causal significance.
V-F27	Leave-one-event-out necessity	Removing a claimed major event does not change the motion solution.	Reject that event as a necessary motion organizer.
V-F28	Held-out prediction	The model fits calibration plates or times but fails held-out data.	Reject predictive generality.
V-F29	Identifiability	Multiple incompatible event sequences fit the velocity field equally well.	Reject unique causal reconstruction.
V-F30	Complexity	The model requires independent force, resistance, coupling, or memory parameters for nearly every plate.	Reject causal compression.
V-F31	Comparison model	The no-event or comparison model reproduces motion better with fewer parameters.	Reject motion replacement claim.
V-F32	Complete motion viability	The plate-motion viable set is empty.	Reject global plate-motion inheritance.

38.4 Plate-Motion Success Standard

The motion model survives only if one shared event sequence:

VS1. begins from mechanically admissible Paper-II event states;

VS2. maps impulse onto reconstructed ancient material domains;

VS3. conserves mass, momentum, energy, and angular momentum;

VS4. predicts plate mass and inertia consistently;

VS5. generates Euler-pole directions and angular speeds;

VS6. predicts force and torque evolution;

VS7. distinguishes initial impulse from sustained forcing;

VS8. predicts boundary and mantle coupling;

VS9. explains directional memory;

VS10. predicts acceleration and deceleration histories;

VS11. predicts the relative speed hierarchy;

VS12. predicts opening, closing, and shear across boundaries;

VS13. satisfies plate-circuit and triple-junction closure;

VS14. matches present-day direct velocity observations;

VS15. matches deep-time finite-rotation and material-displacement evidence;

VS16. remains stable across reference frames;

VS17. survives leave-one-event-out and randomized-event tests;

VS18. predicts held-out plates, regions, and time intervals;

VS19. avoids independent plate-by-plate tuning; and

VS20. outperforms or materially improves the comparison model after complexity penalties.

Plate-motion decision rule.
The plate-motion inheritance claim survives only if a mechanically admissible sequence of astro-ballistic events generates plate-scale linear and angular momentum, persistent directional boundaries, event-modified gravity and buoyancy, and physically valid boundary and mantle coupling that together predict the observed global hierarchy of Euler poles, plate directions, relative speeds, boundary motions, and deep-time displacements.
Measured motion may not be used as the input that supposedly proves its own event-derived cause.

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39 Plate-Motion Synthesis

This plate-motion synthesis records:

1. event-to-plate impulse mapping;
2. fractional ancient plate-membership fields;
3. translation, rotation, and internal-deformation partition;
4. event-to-plate impulse and angular-impulse matrices;
5. lineage-based transfer of ancient impulse into modern plate ancestry;
6. plate mass and center-of-mass calculations;
7. full plate inertia tensors;
8. principal moments and principal axes;
9. immediate angular-velocity response;
10. inertia changes caused by fragmentation and deformation;
11. rigid-motion adequacy tests;
12. Euler vectors as generated model outputs;

13. finite rotations and time-dependent Euler-pole drift;
14. force, torque, power, and dissipation decomposition;
15. event-modified gravity and buoyancy;
16. persistent force-maintenance kernels;
17. boundary traction and anisotropic mobility;
18. basal mantle traction and power exchange;
19. tensorial velocity memory;
20. directional inheritance distinct from speed persistence;
21. later-event reinforcement, opposition, and rotation;
22. acceleration and deceleration equations;
23. quasi-steady speed limits;
24. shared prediction of the plate-speed hierarchy;
25. global boundary-relative motion;
26. plate-circuit and triple-junction closure;
27. present-day Global Navigation Satellite System observations;
28. finite-rotation, paleomagnetic, boundary-age, and terrane constraints;
29. velocity inversion and identifiability;
30. impulse, boundary, density, and no-event counterfactuals;
31. randomized and leave-one-event-out motion tests;
32. the complete plate-motion viable set; and
33. the Paper-III motion falsification matrix.

The following sections develop the major surface-expression problem:

- inherited compression and mountain localization;
- mountain-system orientation and growth;
- inherited terminal zones and trench development;
- descent, bending, underthrusting, and excavation alternatives;
- ridge and spreading-system inheritance;
- basin subsidence and inversion;
- continental plateaus and uplift nodes;
- volcanic-province localization;

- displaced terranes and orogenic sutures;
- surface-structure chronology;
- structure-by-structure counterfactuals;
- mountain, trench, ridge, and basin prediction matrices; and
- complete surface-expression falsification tests.

40 Inherited Compression and Mountain-System Localization

40.1 Mountain Systems as Forward-Modeled Responses

A mountain system cannot be assigned to an event merely because it lies near a proposed path, midpoint, boundary, or convergence zone.

The predicted mountain domain must emerge from the coupled evolution of:

- inherited damage;
- inherited strength contrasts;
- event-created displacement;
- event-created density contrasts;
- residual stress;
- phase-state changes;
- thermal anomalies;
- plate convergence;
- crustal shortening;
- lithospheric thickening;
- underthrusting;
- isostatic response;
- erosion;
- sediment redistribution; and
- later event overprint.

40.2 Mountain-System State Vector

For candidate mountain system m, define

$$\mathbf{Q}_{M_m} = (z_m, H_{c,m}, H_{\ell,m}, \boldsymbol{\epsilon}_m, \boldsymbol{\sigma}_m, D_m, \rho_m, T_m, \phi_m, \mathbf{A}_m, \mathcal{C}_m, t_m)\,, \tag{651}$$

where:

$$z_m = \text{surface elevation field,} \tag{652}$$

$$H_{c,m} = \text{crustal thickness,} \tag{653}$$

$$H_{\ell,m} = \text{lithospheric thickness,} \tag{654}$$

$$\mathbf{A}_m = \text{anisotropy and preferred orientation,} \tag{655}$$

$$\mathcal{C}_m = \text{composition and terrane structure,} \tag{656}$$

$$t_m = \text{chronological state.} \tag{657}$$

40.3 Inherited Compression Field

For event k, define the inherited compressive-stress contribution

$$\Delta\boldsymbol{\sigma}_k^{\text{comp}} = \mathcal{P}_{\text{comp}}\left[\Delta\boldsymbol{\sigma}_k\right], \tag{658}$$

where $\mathcal{P}_{\text{comp}}$ extracts the compressive portion under the declared stress convention.

Let the maximum compressive principal stress be

$$\sigma_{1,k} = \lambda_{\max}\left(-\Delta\boldsymbol{\sigma}_k\right). \tag{659}$$

The corresponding principal direction is

$$\widehat{\mathbf{c}}_k = \text{eigvec}_{\max}\left(-\Delta\boldsymbol{\sigma}_k\right). \tag{660}$$

40.4 Convergence Field

For plates or blocks i and j, the convergence rate across their shared boundary is

$$v_{ij}^{\text{conv}} = \max\left(-v_{ij,n}, 0\right). \tag{661}$$

The cumulative convergence is

$$C_{ij}\left(t_1, t_2\right) = \int_{t_1}^{t_2} v_{ij}^{\text{conv}}(t)\, dt. \tag{662}$$

40.5 Shortening Tensor

The horizontal strain-rate tensor is

$$\dot{\boldsymbol{\epsilon}}_h = \mathbf{P}_h \dot{\boldsymbol{\epsilon}} \mathbf{P}_h, \tag{663}$$

where

$$\mathbf{P}_h = \mathbf{1} - \widehat{\mathbf{r}} \otimes \widehat{\mathbf{r}} \tag{664}$$

projects onto the local tangent plane.

The compressional strain-rate magnitude is

$$\dot{\epsilon}_{\text{comp}} = \sum_{\lambda_a < 0} \left| \lambda_a \left(\dot{\boldsymbol{\epsilon}}_h \right) \right| . \tag{665}$$

40.6 Cumulative Shortening

The cumulative shortening field is

$$\mathcal{S}_{\text{short}}(\mathbf{x}) = \int_{t_1}^{t_2} \dot{\epsilon}_{\text{comp}} \left(\mathbf{x}, t \right) \, dt. \tag{666}$$

A predicted orogenic domain requires

$$\mathcal{S}_{\text{short}} \geq \mathcal{S}_{\text{short,crit}}. \tag{667}$$

40.7 Inherited Orogenic Susceptibility

Define an inherited orogenic-susceptibility field

$$\begin{aligned} \mathcal{N}_O = {} & w_C \widetilde{\mathcal{S}}_{\text{short}} + w_D \widetilde{D} + w_\eta \widetilde{(\eta_0/\eta)} + w_\sigma \widetilde{\sigma}_1 \\ & + w_\rho \left| \widetilde{\Delta\rho} \right| + w_\phi \left| \widetilde{\Delta\phi} \right| + w_H \left| \widetilde{\Delta H_c} \right| + w_B \widetilde{\mathcal{B}}_{\text{inherit}}. \end{aligned} \tag{668}$$

The weights satisfy

$$w_a \geq 0, \qquad \sum_a w_a = 1. \tag{669}$$

40.8 Predicted Orogenic Domain

The predicted orogenic domain is

$$\mathcal{O}_m^{\text{pred}} = \left\{ \mathbf{x} : \mathcal{N}_O(\mathbf{x}) \geq \mathcal{N}_{O,\text{crit}} \right\} . \tag{670}$$

Its surface area is

$$A_{O,m} = \int_{\mathcal{O}_m^{\text{pred}}} dA. \tag{671}$$

Its response-weighted centroid is

$$\mathbf{x}_{O,m}^{\text{cent}} = \frac{\int_{\mathcal{O}_m^{\text{pred}}} \mathbf{x}\mathcal{N}_O(\mathbf{x})\, dA}{\int_{\mathcal{O}_m^{\text{pred}}} \mathcal{N}_O(\mathbf{x})\, dA}. \tag{672}$$

40.9 Mountain-Location Residual

For observed mountain-system domain $\mathcal{O}_m^{\text{obs}}$, define intersection-over-union

$$\text{IoU}_{O,m} = \frac{\text{Area}\left(\mathcal{O}_m^{\text{pred}} \cap \mathcal{O}_m^{\text{obs}}\right)}{\text{Area}\left(\mathcal{O}_m^{\text{pred}} \cup \mathcal{O}_m^{\text{obs}}\right)}. \tag{673}$$

The centroid residual is

$$d_{O,m} = d_{\mathcal{S}}\left(\mathbf{x}_{O,m}^{\text{cent}}, \mathbf{x}_{O,m}^{\text{obs}}\right). \tag{674}$$

40.10 Mountain-Specific Event Attribution

For mountain system m, let event contribution weights be

$$\alpha_{mk}, \qquad \alpha_{mk} \geq 0, \tag{675}$$

with

$$\sum_k \alpha_{mk} + \alpha_{m,\text{background}} = 1. \tag{676}$$

The framework permits:

- one dominant event;
- multiple reinforcing events;
- one initiating event and later amplification;
- an inherited structure reactivated by ordinary convergence;
- or a mountain system primarily unrelated to the event catalog.

40.11 No Prominence Selection

A mountain may not be selected because it is the tallest, most famous, or visually compelling candidate.

The target set must be frozen using objective criteria such as:

- regional elevation;
- relief;
- crustal thickness;
- shortening;
- structural continuity;
- chronological coherence;
- reconstructed material identity; and
- subsurface response.

40.12 Mountain-Localization Falsifier

Mountain-localization falsifier S5.
If the event-derived stress, boundary, motion, density, and inheritance fields do not predict the locations of major mountain systems before those systems are selected as targets, the global orogenic-localization claim is rejected.

41 Mountain Growth, Orientation, and Structural Amplification

41.1 Surface-Elevation Evolution

Let surface elevation be

$$z(\mathbf{x}, t). \tag{677}$$

Its evolution may be written as

$$\frac{Dz}{Dt} = U_{\text{tect}} + U_{\text{iso}} + U_{\text{dyn}} + U_{\text{mag}} - E_{\text{eros}} - S_{\text{subs}}, \tag{678}$$

where:

$$U_{\text{tect}} = \text{tectonic uplift}, \tag{679}$$
$$U_{\text{iso}} = \text{isostatic uplift}, \tag{680}$$
$$U_{\text{dyn}} = \text{dynamic support}, \tag{681}$$
$$U_{\text{mag}} = \text{magmatic or thermal uplift}, \tag{682}$$
$$E_{\text{eros}} = \text{erosional lowering}, \tag{683}$$
$$S_{\text{subs}} = \text{subsidence}. \tag{684}$$

41.2 Crustal Thickening

For horizontal velocity $\mathbf{u}_h$ and crustal thickness H_c, a depth-integrated mass-balance form is

$$\frac{\partial H_c}{\partial t} + \nabla_h \cdot (H_c \mathbf{u}_h) = S_c - L_c, \tag{685}$$

where:

$$S_c = \text{crustal addition}, \tag{686}$$

$$L_c = \text{crustal removal or transfer}. \tag{687}$$

41.3 Shortening-to-Thickening Screening

Under a simplified volume-conserving column model,

$$H_{c,f} \approx \frac{H_{c,i}}{1 - \epsilon_{\text{short}}}, \tag{688}$$

for

$$0 \leq \epsilon_{\text{short}} < 1. \tag{689}$$

The full model must include lateral escape, underthrusting, erosion, phase change, magmatism, and lower-crustal flow.

41.4 Isostatic Response

A generalized isostatic response is

$$z_{\text{iso}} = \mathcal{I}_{\text{iso}}\left[H_c, \rho_c, H_\ell, \rho_\ell, \rho_m, L_{\text{surface}}\right]. \tag{690}$$

The event model must distinguish:

- direct event displacement;
- later convergence-driven thickening;
- buoyant uplift;
- dynamic support;
- flexural support;
- erosion-driven rebound; and
- magmatic addition.

41.5 Orogenic Orientation

Let observed mountain-axis tangent be

$$\widehat{\mathbf{t}}_O^{\mathrm{obs}}. \tag{691}$$

Candidate predicted orientations include:

$$\widehat{\mathbf{t}}_O^{\mathrm{boundary}} = \widehat{\mathbf{t}}_B, \tag{692}$$

$$\widehat{\mathbf{t}}_O^{\mathrm{strain}} = \mathrm{eigvec}_\perp\left(\dot{\boldsymbol{\epsilon}}_h\right), \tag{693}$$

$$\widehat{\mathbf{t}}_O^{\mathrm{stress}} = \mathrm{eigvec}_\perp\left(\boldsymbol{\sigma}_h\right), \tag{694}$$

$$\widehat{\mathbf{t}}_O^{\mathrm{event}} = \Pi_{\mathcal{S}}\left[\widehat{\mathbf{d}}_{\mathrm{event}}\right]. \tag{695}$$

The physical mechanism must specify which orientation rule applies.

41.6 Orientation Residual

The axial orientation residual is

$$\epsilon_{\gamma,O} = \frac{1}{2}\,\mathrm{atan2}\left[\sin 2\left(\gamma_O^{\mathrm{obs}} - \gamma_O^{\mathrm{pred}}\right), \cos 2\left(\gamma_O^{\mathrm{obs}} - \gamma_O^{\mathrm{pred}}\right)\right]. \tag{696}$$

41.7 Mountain-Length and Width Metrics

For predicted orogenic skeleton Γ_O, define length

$$L_O = \int_{\Gamma_O} d\ell. \tag{697}$$

Define mean width

$$\bar{W}_O = \frac{A_O}{L_O}. \tag{698}$$

The model must predict:

- system length;
- width;
- curvature;
- segmentation;
- branching;
- elevation distribution;

- crustal-root geometry; and
- along-strike variation.

41.8 Structural Amplification

Let the initial event-created structural amplitude be

$$A_{O,0}. \tag{699}$$

The later amplitude is

$$A_O(t) = \mathcal{G}_O\left[A_{O,0}, \mathbf{F}_{\text{later}}, \mathbf{Q}_{O,0}\right]. \tag{700}$$

Define amplification factor

$$G_O(t) = \frac{A_O(t)}{A_{O,0} + \epsilon_A}. \tag{701}$$

41.9 With-Inheritance Counterfactual

The with-inheritance mountain solution is

$$\mathbf{Q}_O^+(t) = \mathcal{U}_O\left[\mathbf{Q}_{O,0}^{\text{event}}, \mathbf{F}_{\text{later}}\right]. \tag{702}$$

The counterfactual is

$$\mathbf{Q}_O^0(t) = \mathcal{U}_O\left[\mathbf{Q}_{O,0}^{\text{background}}, \mathbf{F}_{\text{later}}\right]. \tag{703}$$

The event contribution is

$$\Delta\mathbf{Q}_O^{\text{ABC}} = \mathbf{Q}_O^+ - \mathbf{Q}_O^0. \tag{704}$$

41.10 Orogenic Necessity Score

For observed mountain data $\mathbf{D}_O^{\text{obs}}$, define

$$\Delta\mathcal{J}_O = \mathcal{J}_O^0 - \mathcal{J}_O^+. \tag{705}$$

A positive value means the inherited event state improves the fit.

The improvement must be evaluated after complexity penalties.

41.11 Mountain Chronology

For mountain system m, define chronological vector

$$\mathbf{T}_{O,m} = (t_{\text{init}}, t_{\text{short}}, t_{\text{uplift}}, t_{\text{met}}, t_{\text{exhum}}, t_{\text{react}}) \,, \tag{706}$$

where the entries represent initiation, shortening, uplift, metamorphism, exhumation, and reactivation intervals.

The event model predicts

$$\widehat{\mathbf{T}}_{O,m}. \tag{707}$$

The chronological residual is

$$\chi^2_{T,O,m} = \left(\mathbf{T}^{\text{obs}}_{O,m} - \widehat{\mathbf{T}}_{O,m}\right)^{\mathsf{T}} \mathbf{\Sigma}^{-1}_{T,O,m} \left(\mathbf{T}^{\text{obs}}_{O,m} - \widehat{\mathbf{T}}_{O,m}\right). \tag{708}$$

41.12 Mountain-Growth Falsifier

Mountain-growth falsifier S6.
If the inherited state does not improve the predicted location, orientation, width, shortening, uplift, crustal thickness, or chronology of a mountain system relative to the no-inheritance model, the event is not required for that orogen.

42 Terminal Zones, Trench Development, and Descent

42.1 Trench-System State Vector

For trench system q, define

$$\mathbf{Q}_{T_q} = (z_q, W_q, \kappa_q, \gamma_q, H_q, D_q, \rho_q, T_q, \mathbf{v}_q, \mathbf{S}_q, t_q) \,, \tag{709}$$

where:

$$z_q = \text{bathymetric or topographic depth}, \tag{710}$$
$$W_q = \text{width}, \tag{711}$$
$$\kappa_q = \text{curvature}, \tag{712}$$
$$\gamma_q = \text{orientation}, \tag{713}$$
$$H_q = \text{lithospheric geometry}, \tag{714}$$
$$\mathbf{S}_q = \text{deep seismic and structural state}. \tag{715}$$

42.2 Candidate Terminal-Inheritance Field

For event k, define terminal-inheritance potential

$$\begin{aligned}\mathcal{N}_{T,k} = w_D \widetilde{D}_k + w_z \left|\widetilde{\Delta z_k}\right| + w_\rho \left|\widetilde{\Delta\rho_k}\right| + w_\eta \widetilde{(\eta_0/\eta_k)} \\ + w_\phi \left|\widetilde{\Delta\phi_k}\right| + w_\sigma \left\|\widetilde{\Delta\boldsymbol{\sigma}_k}\right\| + w_I \left\|\widetilde{\mathbf{J}}_k\right\|.\end{aligned} \tag{716}$$

The candidate terminal boundary is

$$\mathcal{T}_k^0 = \{\mathbf{x} : \mathcal{N}_{T,k} \geq \mathcal{N}_{T,\mathrm{crit}}\}. \tag{717}$$

42.3 Descent Velocity

Let local vertical or inward radial velocity be

$$v_r = \mathbf{v} \cdot \widehat{\mathbf{r}}. \tag{718}$$

Define inward descent rate

$$v_{\mathrm{desc}} = \max(-v_r, 0). \tag{719}$$

For a dipping material surface with normal $\widehat{\mathbf{n}}_d$, descent across that surface is

$$v_{d,n} = \mathbf{v} \cdot \widehat{\mathbf{n}}_d. \tag{720}$$

42.4 Descent Mass Flux

The mass flux through descent surface $\mathcal{S}_d$ is

$$\dot{M}_{\mathrm{desc}} = \int_{\mathcal{S}_d} \rho v_{d,n}^+ \, dA, \tag{721}$$

where

$$v_{d,n}^+ = \max(v_{d,n}, 0) \tag{722}$$

under the declared normal convention.

42.5 Inherited Weakness and Descent Initiation

A descent zone may initiate where

$$\mathcal{F}_{\mathrm{desc}} = w_\rho \widetilde{\Delta\rho_+} + w_D \widetilde{D} + w_\eta \widetilde{(\eta_0/\eta)} + w_C \widetilde{v}_{\mathrm{conv}} + w_B \widetilde{\mathcal{B}}_{\mathrm{inherit}} \geq \mathcal{F}_{\mathrm{desc,crit}}. \tag{723}$$

Here $\Delta\rho_+$ denotes the density component favoring descent.

42.6 Trench-Depth Evolution

The trench-depth field evolves as

$$\frac{Dz_T}{Dt} = S_{\text{bend}} + S_{\text{desc}} + S_{\text{event}} + S_{\text{collapse}} + S_{\text{dynamic}} - S_{\text{sed}} - S_{\text{rebound}}. \tag{724}$$

42.7 Trench Axis

For bathymetric or structural field z_T, the trench axis may be defined by ridge-extraction or minimum-line operator

$$\Gamma_T = \text{Axis}_{\text{min}} \left[z_T(\mathbf{x}) \right]. \tag{725}$$

The predicted axis must be generated before comparison with the modern or reconstructed trench.

42.8 Trench Curvature

For trench-axis curve $\mathbf{x}_T(s)$, geodesic curvature is

$$\kappa_{g,T} = \left\| \mathbf{P}_{\mathcal{S}} \frac{d\widehat{\mathbf{t}}_T}{ds} \right\|. \tag{726}$$

The model must predict:

- trench length;
- curvature;
- segmentation;
- depth;
- width;
- asymmetry;
- descent orientation;
- deep continuation; and
- chronological evolution.

42.9 Terminal Exit Versus Later Trench

The immediate event terminal state is

$$\mathbf{Q}_T^+. \tag{727}$$

The later trench state is

$$\mathbf{Q}_T^{\text{now}} = \mathcal{U}_T\left[\mathbf{Q}_T^{+}, \mathbf{F}_{\text{later}}, \mathcal{H}_{\text{regional}}\right]. \tag{728}$$

The event contribution is

$$\Delta\mathbf{Q}_T^{\text{ABC}} = \mathbf{Q}_T^{\text{now}} - \mathbf{Q}_T^{0,\text{now}}, \tag{729}$$

where the counterfactual omits the terminal inheritance.

42.10 Terminal Necessity Score

Define

$$\Delta\mathcal{J}_T = \mathcal{J}_T^0 - \mathcal{J}_T^{+}. \tag{730}$$

A positive value indicates improved prediction with terminal inheritance.

42.11 Trench-System Falsifier

Trench-system falsifier S7.
If the event terminal state does not improve the predicted trench location, curvature, depth, descent geometry, chronology, or deep structure relative to the model without terminal inheritance, the event is not required for that trench system.

---

43 Underthrusting, Bending, and Excavation Alternatives

43.1 Competing Trench-Formation Branches

The framework must distinguish among at least four possible trench branches:

Inherited excavation
A terminal event creates an initial depression, damage zone, or structural margin.

Later descent
Dense or mechanically weakened lithosphere descends along an inherited boundary.

Underthrusting
One lithospheric domain advances beneath another.

Elastic–viscous bending
Plate loading and descent generate a flexural trench.

These branches may combine, but each contribution must be quantified.

43.2 Underthrusting Velocity

For upper plate u and lower plate l, define relative velocity

$$\mathbf{v}_{lu} = \mathbf{v}_l - \mathbf{v}_u. \tag{731}$$

For interface tangent $\widehat{\mathbf{t}}_d$, the underthrusting rate is

$$v_{\text{under}} = \max\left[\mathbf{v}_{lu} \cdot \widehat{\mathbf{t}}_d, 0\right]. \tag{732}$$

The cumulative underthrust distance is

$$D_{\text{under}} = \int v_{\text{under}}\, dt. \tag{733}$$

43.3 Bending Curvature

For plate midsurface $\mathbf{x}(s)$, curvature is

$$\kappa_b = \left\| \frac{d\widehat{\mathbf{t}}}{ds} \right\|. \tag{734}$$

The bending strain at distance ζ from the neutral surface is

$$\epsilon_b = \zeta \kappa_b. \tag{735}$$

43.4 Flexural Rigidity

A reference flexural rigidity is

$$D_f = \frac{E H_{\text{eff}}^3}{12\left(1 - \nu^2\right)}, \tag{736}$$

where:

$$E = \text{effective elastic modulus}, \tag{737}$$

$$H_{\text{eff}} = \text{effective elastic thickness}, \tag{738}$$

$$\nu = \text{Poisson-type elastic parameter}. \tag{739}$$

43.5 Flexural Response

A reduced plate-flexure equation is

$$D_f \nabla_h^4 w + \Delta\rho g w = q(\mathbf{x}), \tag{740}$$

where:

$$w = \text{vertical deflection}, \tag{741}$$

$$q = \text{applied load}. \tag{742}$$

The full spherical, nonlinear, damaged, and viscoelastic calculation may differ from this screening relation.

43.6 Bending Energy

The bending energy is

$$E_{\text{bend}} = \frac{1}{2}\int_{\mathcal{A}} D_f \kappa_b^2 \, dA. \tag{743}$$

The energy must be supplied by gravitational, boundary, mantle, or event-derived forcing.

43.7 Excavation Contribution

Let the immediate event-created depression be

$$w_{\text{exc}}(\mathbf{x}). \tag{744}$$

Let later bending and descent contribute

$$w_{\text{bend}}(\mathbf{x}, t), \qquad w_{\text{desc}}(\mathbf{x}, t). \tag{745}$$

The complete trench displacement is

$$w_T = w_{\text{exc}} + w_{\text{bend}} + w_{\text{desc}} + w_{\text{dyn}} + w_{\text{sed}} + w_{\text{other}}. \tag{746}$$

43.8 Contribution Fractions

For trench-depth amplitude A_T, define component fractions

$$f_{\text{exc}} = \frac{A_{\text{exc}}}{A_T}, \qquad f_{\text{bend}} = \frac{A_{\text{bend}}}{A_T}, \qquad f_{\text{desc}} = \frac{A_{\text{desc}}}{A_T}. \tag{747}$$

The fractions may be time dependent and need not sum linearly when the mechanisms interact nonlinearly.

43.9 Mechanism-Specific Predictions

Table 6: Trench-mechanism prediction classes.

Mechanism	Primary predicted structure	Direct failure
Excavation	Immediate cavity, damaged margins, ejecta or terminal material, radial or asymmetric fracture	No compatible ancient terminal structure or markers
Bending	Flexural curvature, outer-rise response, stress reversal, elastic-thickness dependence	Observed geometry incompatible with predicted flexure
Underthrusting	Overlapping material domains, shortening, crustal duplication, interface shear	No reconstructed material overlap or compatible kinematics
Descent	Dense dipping structure, mass flux, deep continuation, gravity and seismic signature	No compatible descending material or deep structure
Hybrid	Interacting excavation, bending, underthrusting, and descent	Requires unconstrained component switching or double counting

43.10 Branch-Selection Rule

A trench branch is retained only if it predicts:

- geometry;
- motion;
- stress;
- gravity;
- seismic structure;
- chronology;
- material identity;
- and preserved markers

better than its alternatives after complexity penalties.

43.11 Trench-Mechanism Falsifier

Trench-mechanism falsifier S8.
If excavation, bending, underthrusting, descent, and hybrid branches cannot be distinguished through independent predicted structures, the claimed terminal explanation is underdetermined and cannot support causal replacement.

44 Ridge, Rift, and Spreading-System Inheritance

44.1 Extensional Boundary Field

For plate or block pair i, j, extension occurs where

$$v_{ij,n} > v_{\text{ext,crit}}. \tag{748}$$

The cumulative opening is

$$D_{ij}^{\text{open}} = \int v_{ij}^{\text{open}}\, dt. \tag{749}$$

44.2 Inherited Rift Potential

Define rift-nucleation field

$$\begin{aligned}\mathcal{N}_R = w_D\widetilde{D} + w_\eta\widetilde{(\eta_0/\eta)} + w_\epsilon\widetilde{\epsilon}_{\text{ext}} + w_T\widetilde{\Delta T}_+ \\ + w_m\widetilde{\chi_m} + w_H\widetilde{(H_0/H_\ell)} + w_B\widetilde{\mathcal{B}}_{\text{inherit}}.\end{aligned} \tag{750}$$

The predicted rift domain is

$$\mathcal{R}_{\text{rift}} = \{\mathbf{x} : \mathcal{N}_R \geq \mathcal{N}_{R,\text{crit}}\}. \tag{751}$$

44.3 Rift-Axis Orientation

Candidate rift-axis tangent is perpendicular to maximum extension:

$$\widehat{\mathbf{t}}_R = \text{eigvec}_\perp(\dot{\boldsymbol{\epsilon}}_h). \tag{752}$$

The event-derived damage orientation may modify this direction:

$$\widehat{\mathbf{t}}_R^{\text{eff}} = \mathcal{F}_{R,\gamma}\left[\widehat{\mathbf{t}}_R, \widehat{\mathbf{t}}_D, \mathbf{M}_B\right]. \tag{753}$$

44.4 Lithospheric Thinning

The lithospheric-thickness evolution is

$$\frac{\partial H_\ell}{\partial t} + \nabla_h \cdot (H_\ell \mathbf{u}_h) = S_\ell - L_\ell. \tag{754}$$

The thinning factor is

$$\beta_\ell = \frac{H_{\ell,i}}{H_{\ell,f}}. \tag{755}$$

44.5 Decompression and Melt Potential

Let vertical mantle velocity be

$$w_m = \mathbf{v}_m \cdot \hat{\mathbf{r}}. \tag{756}$$

A decompression-melt source may be represented as

$$\dot{\chi}_m = \mathcal{F}_m \left(P, T, C, \frac{DP}{Dt}, w_m \right). \tag{757}$$

44.6 New-Material Production

For productive ridge axis Γ_R,

$$\dot{A}_{\text{new}} = \int_{\Gamma_R} v_{\text{open}} \, d\ell. \tag{758}$$

The new-material volume rate is

$$\dot{V}_{\text{new}} = \int_{\Gamma_R} H_{\text{new}} v_{\text{open}} \, d\ell. \tag{759}$$

44.7 Age-Distance Prediction

For material moving away from a ridge axis at normal speed $v_n(t)$, the predicted age at distance x_n satisfies

$$x_n = \int_{t_{\text{form}}}^{t_{\text{now}}} v_n(t) \, dt. \tag{760}$$

The age prediction is

$$\hat{a}(x_n) = t_{\text{now}} - t_{\text{form}}(x_n). \tag{761}$$

44.8 Symmetry and Asymmetry

For opposing ridge flanks $+$ and $-$, define age asymmetry

$$\Delta a_R(x) = a_+(x) - a_-(x). \tag{762}$$

Define width asymmetry

$$\Delta W_R = W_+ - W_-. \tag{763}$$

The event-sequence model must predict whether a ridge is:

- approximately symmetric;
- directionally asymmetric;
- offset;
- segmented;
- propagating;
- dying;
- reactivated; or
- inherited from an older event boundary.

44.9 Transform Offsets

For ridge segments a and b, define along-axis offset

$$D_{ab}^{\text{offset}} = d_{\mathcal{S}}\left(\Gamma_{R,a}, \Gamma_{R,b}\right) \tag{764}$$

measured along the transform-compatible direction.

The event model must predict the fracture or boundary inheritance producing the offset.

44.10 Ridge Counterfactual

The with-inheritance solution is

$$\mathbf{Q}_R^+ = \mathcal{U}_R\left[\mathbf{Q}_{R,0}^{\text{event}}, \mathbf{F}_{\text{later}}\right]. \tag{765}$$

The no-inheritance solution is

$$\mathbf{Q}_R^0 = \mathcal{U}_R\left[\mathbf{Q}_{R,0}^{\text{background}}, \mathbf{F}_{\text{later}}\right]. \tag{766}$$

44.11 Ridge-System Falsifier

Ridge-system falsifier S9.
If the event-derived weakness, extension, displacement, and thermal fields do not predict ridge and rift locations, orientations, opening rates, age-distance patterns, segmentation, and new-material production, the event-derived spreading-system claim is rejected.

---

45 Basin Formation, Subsidence, and Inversion

45.1 Basin State Vector

For basin b, define

$$\mathbf{Q}_{B_b} = \left(z_b, A_b, V_b, H_{s,b}, H_{c,b}, \dot{S}_b, \rho_b, T_b, D_b, \boldsymbol{\epsilon}_b, t_b\right), \tag{767}$$

where:

$$H_{s,b} = \text{sedimentary thickness}, \tag{768}$$

$$\dot{S}_b = \text{subsidence rate}. \tag{769}$$

45.2 Event-Created Basin Components

The event contribution may include:

$$S_{\text{event}} = S_{\text{exc}} + S_{\text{stretch}} + S_{\text{damage}} + S_\rho + S_\phi + S_{\text{thermal}} + S_{\text{collapse}}. \tag{770}$$

45.3 Total Subsidence Evolution

The total basin subsidence is

$$S_b(t) = S_{\text{event}} + S_{\text{thermal}} + S_{\text{flex}} + S_{\text{load}} + S_{\text{dynamic}} + S_{\text{comp}} + S_{\text{eros}} + S_{\text{boundary}}. \tag{771}$$

45.4 Subsidence Rate

The basin subsidence rate is

$$\dot{S}_b = \frac{dS_b}{dt}. \tag{772}$$

The acceleration of subsidence is

$$\ddot{S}_b = \frac{d^2 S_b}{dt^2}. \tag{773}$$

45.5 Accommodation Space

For reference surface z_{ref}, accommodation is

$$A_c(\mathbf{x}, t) = z_{\text{ref}}(\mathbf{x}, t) - z_b(\mathbf{x}, t). \tag{774}$$

The accommodation volume is

$$V_c(t) = \int_{\mathcal{B}_b} \max\left[A_c(\mathbf{x}, t), 0\right] \, dA. \tag{775}$$

45.6 Sediment Balance

Sediment thickness evolves as

$$\frac{\partial H_s}{\partial t} + \nabla_h \cdot (H_s \mathbf{u}_s) = Q_{\text{sed}} - E_{\text{sed}} - C_{\text{sed}}. \tag{776}$$

45.7 Basin Shape Tensor

For basin area $\mathcal{A}_b$, define second moment

$$\mathbf{J}_b = \frac{\int_{\mathcal{A}_b} (\mathbf{x} - \bar{\mathbf{x}}) \otimes (\mathbf{x} - \bar{\mathbf{x}}) \, w_b(\mathbf{x}) \, dA}{\int_{\mathcal{A}_b} w_b(\mathbf{x}) \, dA}. \tag{777}$$

Its principal axes determine predicted basin orientation and aspect ratio.

45.8 Basin Orientation

Let eigenvalues be

$$\lambda_{b,1} \geq \lambda_{b,2}. \tag{778}$$

The basin aspect ratio is

$$\mathcal{R}_b = \sqrt{\frac{\lambda_{b,1}}{\lambda_{b,2}}}. \tag{779}$$

The principal basin direction is

$$\widehat{\mathbf{t}}_b = \text{eigvec}_{\max}\left(\mathbf{J}_b\right). \tag{780}$$

45.9 Basin Inversion

A basin is inverted when prior extensional or subsidence structure undergoes later shortening or uplift.

Define inversion onset

$$t_{\text{inv}} = \inf \left\{ t : \dot{S}_b(t) < 0 \text{ or } \dot{\epsilon}_{\text{comp}}(t) > \dot{\epsilon}_{\text{inv,crit}} \right\}. \tag{781}$$

The inversion amplitude is

$$A_{\text{inv}} = S_b(t_{\max}) - S_b(t_{\text{now}}) \tag{782}$$

under the declared sign convention.

45.10 Event-Sequence Inversion

For earlier event k and later event m, define inversion relation

$$\mathcal{E}_k \to \mathcal{B}_b^{\text{ext}} \to \mathcal{E}_m \to \mathcal{B}_b^{\text{comp}} \to \text{basin inversion.} \tag{783}$$

The model must predict:

- which basin inverts;
- when inversion begins;
- inversion direction;
- magnitude;
- structural localization;
- sediment deformation;
- and whether uplift or mountain building follows.

45.11 Basin Chronology Vector

Define

$$\mathbf{T}_b = (t_{\text{init}}, t_{\text{rapid subs}}, t_{\text{thermal}}, t_{\text{fill}}, t_{\text{inv}}, t_{\text{react}}). \tag{784}$$

The event-sequence prediction is

$$\widehat{\mathbf{T}}_b. \tag{785}$$

45.12 Basin Counterfactual

The event contribution is

$$\Delta \mathbf{Q}_{B_b}^{\text{ABC}} = \mathbf{Q}_{B_b}^{+} - \mathbf{Q}_{B_b}^{0}. \tag{786}$$

The basin-necessity score is

$$\Delta \mathcal{J}_{B_b} = \mathcal{J}_{B_b}^{0} - \mathcal{J}_{B_b}^{+}. \tag{787}$$

45.13 Basin Falsifier

Basin falsifier S10.
If the event sequence cannot predict basin location, shape, orientation, subsidence history, sediment accommodation, thermal evolution, and inversion chronology without assigning independent mechanisms after observing each basin, the basin-inheritance claim is rejected.

46 Continental Plateaus and Persistent Uplift Nodes

46.1 Plateau State

For plateau p, define

$$\mathbf{Q}_{P_p} = \left(z_p, A_p, H_{c,p}, H_{\ell,p}, \rho_p, T_p, \phi_p, D_p, \mathbf{v}_p, \boldsymbol{\sigma}_p, t_p\right). \tag{788}$$

46.2 Persistent Uplift Potential

Define uplift-node potential

$$\begin{aligned} \mathcal{N}_U = w_\rho \widetilde{(-\Delta\rho)} + w_T \widetilde{\Delta T} + w_\phi \widetilde{\Delta\phi}_{\text{buoyant}} + w_H \widetilde{\Delta H_c} \\ + w_\sigma \widetilde{\sigma}_{\text{comp}} + w_D \widetilde{D}_{\text{react}} + w_g \widetilde{\Delta g} + w_m \widetilde{\chi_m}. \end{aligned} \tag{789}$$

The predicted uplift-node domain is

$$\mathcal{U}_p = \left\{\mathbf{x} : \mathcal{N}_U \geq \mathcal{N}_{U,\text{crit}}\right\}. \tag{790}$$

46.3 Plateau Elevation Budget

The plateau elevation is decomposed as

$$z_p = z_{\text{crust}} + z_{\text{thermal}} + z_{\text{dynamic}} + z_{\text{phase}} + z_{\text{event}} + z_{\text{eros}} + z_{\text{sed}}. \tag{791}$$

46.4 Dynamic Support

A generalized dynamic-topography contribution is

$$z_{\mathrm{dyn}} = \mathcal{D}_z \left[\mathbf{v}_m, \eta_m, \Delta\rho_m, \boldsymbol{\sigma}_m \right]. \tag{792}$$

The event model must determine whether the event:

- directly creates uplift;
- creates a long-lived buoyant anomaly;
- redirects mantle flow;
- thickens crust;
- creates a resistant block;
- localizes later compression; or
- contributes negligibly.

46.5 Plateau Persistence

Let plateau amplitude be

$$A_p(t) = \int_{\mathcal{U}_p} \max \left[z(\mathbf{x}, t) - z_{\mathrm{ref}}, 0 \right] \, dA. \tag{793}$$

The persistence fraction is

$$P_p(t) = \frac{A_p(t)}{A_p(t_{\mathrm{form}})}. \tag{794}$$

46.6 Plateau Edge Prediction

The predicted plateau edge is

$$\Gamma_p = \partial \mathcal{U}_p. \tag{795}$$

The edge may correspond to:

- inherited damage boundaries;
- crustal-thickness transitions;
- density transitions;
- event-created displacement margins;
- later compressional boundaries; or

- erosional truncation.

46.7 Plateau Counterfactual

The event contribution is

$$\Delta z_p^{\mathrm{ABC}} = z_p^{+} - z_p^{0}. \tag{796}$$

The structural contribution is

$$\Delta \mathbf{Q}_{P_p}^{\mathrm{ABC}} = \mathbf{Q}_{P_p}^{+} - \mathbf{Q}_{P_p}^{0}. \tag{797}$$

46.8 Plateau Falsifier

Plateau falsifier S11.
If the event-derived density, thermal, phase, damage, and compression fields do not improve the predicted position, extent, elevation, crustal root, edge geometry, or persistence of a plateau, the event is not required for that uplift system.

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47 Volcanic-Province and Melt-Path Localization

47.1 Volcanic-Province State Vector

For volcanic province v, define

$$\mathbf{Q}_{V_v} = \left(\mathcal{D}_v, V_{m,v}, \dot{V}_{m,v}, \mathcal{C}_{m,v}, t_v, \Gamma_v, D_v, T_v, P_v, \mathbf{A}_v\right), \tag{798}$$

where:

$$\mathcal{D}_v = \text{province domain}, \tag{799}$$

$$V_{m,v} = \text{melt or erupted volume}, \tag{800}$$

$$\dot{V}_{m,v} = \text{production or eruption rate}, \tag{801}$$

$$\mathcal{C}_{m,v} = \text{composition}, \tag{802}$$

$$\Gamma_v = \text{melt-path network}. \tag{803}$$

47.2 Melt-Generation Potential

Define melt-generation potential

$$\mathcal{N}_m = \mathcal{F}_m\left(P, T, C, \Delta P, \Delta T, \phi, \mathbf{v}_m, D, \eta\right). \tag{804}$$

A normalized form may be

$$\mathcal{N}_m = w_T\widetilde{\Delta T}_+ + w_P\widetilde{(-\Delta P)}_+ + w_D\widetilde{D} + w_\eta\widetilde{(\eta_0/\eta)} \\ + w_u\widetilde{w}_{m,+} + w_\phi\widetilde{\Delta\phi}_m + w_C\widetilde{\mathcal{C}}_{\text{fus}}. \tag{805}$$

47.3 Melt Production Rate

The local melt-production rate is

$$\dot{m} = \rho\frac{D\chi_m}{Dt}. \tag{806}$$

The integrated melt rate is

$$\dot{M}_m = \int_{\mathcal{V}_m} \dot{m}\, dV. \tag{807}$$

47.4 Melt Migration

A reduced melt-segregation velocity is

$$\mathbf{v}_{m\ell} - \mathbf{v}_s = -\frac{k_{\text{perm}}}{\mu_m}\left(\nabla P_m - \rho_m\mathbf{g}\right), \tag{808}$$

where:

$$\mathbf{v}_{m\ell} = \text{melt velocity}, \tag{809}$$
$$\mathbf{v}_s = \text{solid velocity}, \tag{810}$$
$$k_{\text{perm}} = \text{effective permeability}, \tag{811}$$
$$\mu_m = \text{melt viscosity}. \tag{812}$$

47.5 Damage-Guided Melt Transport

The permeability tensor may be

$$\mathbf{k}_{\text{perm}} = k_\parallel\widehat{\mathbf{d}}\otimes\widehat{\mathbf{d}} + k_\perp\left(\mathbf{1} - \widehat{\mathbf{d}}\otimes\widehat{\mathbf{d}}\right), \tag{813}$$

where $\widehat{\mathbf{d}}$ is an inherited damage or fracture direction.

If

$$k_\parallel \gg k_\perp, \tag{814}$$

melt preferentially follows the inherited corridor.

47.6 Melt-Path Network

Define predicted melt-path network

$$\Gamma_m^{\text{pred}} = \text{Stream}\left[\mathbf{v}_{m\ell}\right]. \tag{815}$$

The surface-emergence domain is

$$\mathcal{D}_m^{\text{surf}} = \Pi_{\mathcal{S}}\left[\Gamma_m^{\text{pred}}\right]. \tag{816}$$

47.7 Volcanic Localization Score

For observed volcanic domain $\mathcal{D}_v^{\text{obs}}$, define overlap

$$\text{IoU}_v = \frac{\text{Area}\left(\mathcal{D}_m^{\text{surf}} \cap \mathcal{D}_v^{\text{obs}}\right)}{\text{Area}\left(\mathcal{D}_m^{\text{surf}} \cup \mathcal{D}_v^{\text{obs}}\right)}. \tag{817}$$

47.8 Volcanic Chronology

Define volcanic chronology vector

$$\mathbf{T}_v = \left(t_{\text{init}}, t_{\text{peak}}, t_{\text{pulse},1}, \ldots, t_{\text{pulse},n}, t_{\text{end}}\right). \tag{818}$$

The event sequence predicts

$$\widehat{\mathbf{T}}_v. \tag{819}$$

47.9 Event-Volcanism Lag

For event time t_k and volcanic initiation time $t_{v,\text{init}}$, define lag

$$\Delta t_{v,k} = t_{v,\text{init}} - t_k. \tag{820}$$

The lag must emerge from:

- pressure release;
- thermal diffusion;
- melt generation;
- melt migration;
- boundary reactivation;
- lithospheric thinning;

- and preservation uncertainty.

47.10 Volcanic Counterfactual

The event contribution is

$$\Delta \mathbf{Q}_{V_v}^{\mathrm{ABC}} = \mathbf{Q}_{V_v}^{+} - \mathbf{Q}_{V_v}^{0}. \tag{821}$$

47.11 No Universal Volcanic Assignment

The framework does not require every volcanic province to be an event entrance, exit, midpoint, or corridor.

Each candidate province must pass:

- spatial prediction;
- chronological prediction;
- melt-volume prediction;
- compositional prediction;
- subsurface-path prediction;
- and comparison-model evaluation.

47.12 Volcanic-Province Falsifier

Volcanic-province falsifier S12.
If event-derived pressure, temperature, damage, permeability, and flow fields do not predict volcanic-province location, timing, volume, composition, and subsurface melt pathways better than the comparison model, the event-volcanism assignment is rejected.

48 Displaced Terranes, Sutures, and Orogenic Assembly

48.1 Terrane Identity

For terrane q, define identity vector

$$\mathbf{Q}_{\mathcal{T}_q} = \left(\mathcal{C}_q, \mathbf{A}_q, \mathbf{M}_q, \mathbf{S}_q, \mathbf{F}_q, \mathbf{x}_q, \mathbf{R}_q, t_q\right), \tag{822}$$

where:

$$\mathcal{C}_q = \text{composition}, \tag{823}$$
$$\mathbf{A}_q = \text{age structure}, \tag{824}$$
$$\mathbf{M}_q = \text{magnetic state}, \tag{825}$$
$$\mathbf{S}_q = \text{structural state}, \tag{826}$$
$$\mathbf{F}_q = \text{fossil or environmental assemblage where applicable}, \tag{827}$$
$$\mathbf{R}_q = \text{rotation}. \tag{828}$$

48.2 Terrane Trajectory

The terrane trajectory is

$$\mathbf{x}_q(t) = \mathcal{U}_{\mathcal{T}}\left[\mathbf{x}_q(t_0), \mathbf{V}_P(t), \mathbf{V}_{\text{def}}(t), \mathcal{B}(t)\right]. \tag{829}$$

The terrane rotation is

$$\mathbf{R}_q(t_2, t_1) = \mathcal{R}_{\mathcal{T}}\left[\boldsymbol{\omega}_P, \boldsymbol{\omega}_{\text{local}}, \boldsymbol{\epsilon}_{\text{rot}}\right]. \tag{830}$$

48.3 Terrane Transfer Event

Terrane transfer from plate i to plate j occurs at time t_q^{trans} when

$$\mathcal{T}_q \subset \mathcal{P}_i(t^-) \tag{831}$$

and

$$\mathcal{T}_q \subset \mathcal{P}_j(t^+). \tag{832}$$

The transfer must preserve material identity within declared uncertainty.

48.4 Suture Definition

A suture is represented as boundary domain

$$\mathcal{S}_{ij}^{\text{suture}} = \partial\mathcal{T}_i \cap \partial\mathcal{T}_j \tag{833}$$

after collision, transfer, merger, or assembly.

Its state vector is

$$\mathbf{Q}_S = \left(\gamma_S, D_S, \boldsymbol{\sigma}_S, \mathcal{C}_S, \mathbf{M}_S, \phi_S, t_S\right). \tag{834}$$

48.5 Suture-Formation Condition

A suture forms where:

$$v_n < 0, \tag{835}$$

$$C_{ij} \geq C_{\text{suture,crit}}, \tag{836}$$

and the intervening domain is removed, transferred, underthrust, or incorporated.

48.6 Suture Orientation

The predicted suture orientation is derived from:

- pre-collision boundary orientation;
- convergence vector;
- inherited damage;
- terrane geometry;
- rotation;
- shear partitioning;
- and later deformation.

Formally,

$$\hat{\mathbf{t}}_S = \mathcal{F}_{S,\gamma}\left[\hat{\mathbf{t}}_B^-, \mathbf{v}_{ij}^{\text{rel}}, \mathbf{D}, \mathbf{R}_i, \mathbf{R}_j\right]. \tag{837}$$

48.7 Orogenic Assembly Graph

Represent terrane and continental assembly as graph

$$\mathcal{G}_{\text{asm}} = (\mathcal{N}_{\text{terr}}, \mathcal{E}_{\text{contact}}), \tag{838}$$

where:

$$\mathcal{N}_{\text{terr}} = \text{terranes or crustal blocks}, \tag{839}$$

$$\mathcal{E}_{\text{contact}} = \text{predicted sutures and transfer contacts}. \tag{840}$$

48.8 Assembly Chronology

For contact e_{ij}, define

$$\mathbf{T}_{ij}^{\text{assembly}} = (t_{\text{approach}}, t_{\text{contact}}, t_{\text{closure}}, t_{\text{met}}, t_{\text{exhum}}) \,. \tag{841}$$

The event model must predict the sequence of contacts rather than only the final assembled geometry.

48.9 Material-Identity Residual

For observed and predicted terrane identity,

$$\boldsymbol{\epsilon}_{\mathcal{T},q} = \mathbf{Q}_{\mathcal{T},q}^{\text{obs}} - \widehat{\mathbf{Q}}_{\mathcal{T},q}. \tag{842}$$

The covariance-weighted residual is

$$\chi_{\mathcal{T},q}^2 = \boldsymbol{\epsilon}_{\mathcal{T},q}^{\mathsf{T}} \boldsymbol{\Sigma}_{\mathcal{T},q}^{-1} \boldsymbol{\epsilon}_{\mathcal{T},q}. \tag{843}$$

48.10 Terrane-Path Residual

For trajectory observations $\mathbf{x}_q^{\text{obs}}(t_a)$,

$$\chi_{x,q}^2 = \sum_a \frac{d_{\mathcal{S}}^2 \left[\mathbf{x}_q^{\text{obs}}(t_a), \widehat{\mathbf{x}}_q(t_a) \right]}{\sigma_{x,q,a}^2}. \tag{844}$$

48.11 Assembly Counterfactual

Run the assembly with event-derived boundary and motion inheritance:

$$\mathcal{G}_{\text{asm}}^{+} = \mathcal{U}_A \left[\mathcal{E}, \mathbf{Q}_{\text{inherit}} \right]. \tag{845}$$

Run without event inheritance:

$$\mathcal{G}_{\text{asm}}^{0} = \mathcal{U}_A \left[\mathbf{Q}_{\text{background}} \right]. \tag{846}$$

The event contribution is evaluated through differences in:

- terrane paths;
- contact order;
- suture locations;
- rotations;
- mountain assembly;
- and chronology.

48.12 Terrane and Suture Falsifier

Terrane-and-suture falsifier S13.
If the event-derived plate and boundary history cannot reproduce terrane identities, displacement paths, rotations, transfer histories, suture locations, and assembly chronology without violating material continuity, the proposed orogenic assembly is rejected.

49 Surface-Structure Chronology and Counterfactuals

49.1 Unified Structure Catalog

Let the surface-structure catalog be

$$\mathcal{G}_S = \{\mathcal{O}_m, \mathcal{T}_q, \mathcal{R}_r, \mathcal{B}_b, \mathcal{P}_p, \mathcal{V}_v, \mathcal{S}_s, \mathcal{TR}_u\}, \tag{847}$$

where the elements represent:

$$\mathcal{O}_m = \text{mountains and orogens}, \tag{848}$$

$$\mathcal{T}_q = \text{trenches and descent zones}, \tag{849}$$

$$\mathcal{R}_r = \text{ridges and rifts}, \tag{850}$$

$$\mathcal{B}_b = \text{basins}, \tag{851}$$

$$\mathcal{P}_p = \text{plateaus and uplift nodes}, \tag{852}$$

$$\mathcal{V}_v = \text{volcanic provinces}, \tag{853}$$

$$\mathcal{S}_s = \text{sutures}, \tag{854}$$

$$\mathcal{TR}_u = \text{terranes and displaced blocks}. \tag{855}$$

49.2 Structure Chronology Vector

For structure g, define

$$\mathbf{T}_g = (t_{\text{inherit}}, t_{\text{init}}, t_{\text{growth}}, t_{\text{peak}}, t_{\text{react}}, t_{\text{decline}}, t_{\text{modern}}). \tag{856}$$

The event model predicts

$$\widehat{\mathbf{T}}_g. \tag{857}$$

49.3 Event-to-Structure Dependency Matrix

Define

$$\mathbf{X}_{gk} = \begin{cases} 1, & \mathcal{E}_k \text{ materially contributes to structure } g, \\ 0, & \text{otherwise.} \end{cases} \tag{858}$$

A weighted version is

$$0 \leq \alpha_{gk} \leq 1, \tag{859}$$

subject to

$$\sum_k \alpha_{gk} + \alpha_{g,0} = 1. \tag{860}$$

49.4 Chronological Precedence

If event k creates an inherited state required for structure g,

$$a_k \geq a_{g,\text{inherit}} \geq a_{g,\text{init}} \tag{861}$$

where $a \geq 0$ denotes age before present, so larger values are older. In the forward coordinate τ, the equivalent ordering is $\tau_k \leq \tau_{g,\text{inherit}} \leq \tau_{g,\text{init}}$.

49.5 Chronological Lag

Define event-to-structure lag

$$\Delta\tau_{gk} = \tau_{g,\text{init}} - \tau_k \geq 0 \tag{862}$$

in forward-time coordinates.

The lag must be physically accounted for through:

- stress relaxation;
- boundary reactivation;
- thermal evolution;
- melt generation;
- convergence accumulation;
- underthrusting;
- erosion;
- sedimentation;
- phase transitions;

- and later events.

49.6 Chronological Likelihood

For structure chronology observations $\mathbf{T}_g^{\text{obs}}$,

$$\mathcal{L}_{T,g} = p\left(\mathbf{T}_g^{\text{obs}} \mid \widehat{\mathbf{T}}_g, \boldsymbol{\Sigma}_{T,g}\right). \tag{863}$$

The complete chronology likelihood is

$$\mathcal{L}_T = p\left(\left\{\mathbf{T}_g^{\text{obs}}\right\} \mid \mathcal{E}, \mathbf{Q}_0\right). \tag{864}$$

49.7 Structure-by-Structure Counterfactual

For structure g, the full model is

$$\mathbf{Q}_g^+ = \mathcal{U}_g\left[\mathbf{Q}_{g,0}^{\text{event}}, \mathbf{F}_g^{\text{later}}\right]. \tag{865}$$

The no-event counterfactual is

$$\mathbf{Q}_g^0 = \mathcal{U}_g\left[\mathbf{Q}_{g,0}^{\text{background}}, \mathbf{F}_g^{\text{later}}\right]. \tag{866}$$

The event contribution is

$$\Delta\mathbf{Q}_g^{\text{ABC}} = \mathbf{Q}_g^+ - \mathbf{Q}_g^0. \tag{867}$$

49.8 Leave-One-Event-Out Surface Test

For event k, remove it:

$$\mathcal{E}_{-k} = \mathcal{E} \setminus \{\mathcal{E}_k\}. \tag{868}$$

The surface-score change is

$$\Delta\mathcal{J}_{S,k} = \mathcal{J}_{S,-k} - \mathcal{J}_{S,\text{full}}. \tag{869}$$

An event with negligible score change is not required for the surface reconstruction.

49.9 Leave-One-Structure-Out Prediction

Remove structure g from model calibration.

Fit the model using

$$\mathcal{G}_{S,-g}. \tag{870}$$

Then predict

$$\widehat{\mathbf{Q}}_g^{\text{test}} \tag{871}$$

without tuning to that structure.

49.10 Randomized Event-Structure Test

For randomized event catalog $\mathcal{E}^{(r)}$, calculate surface score

$$\mathcal{J}_S^{(r)}. \tag{872}$$

The empirical null probability is

$$p_{S,\text{null}} = \frac{1 + \sum_{r=1}^{N_R} \mathbf{1}\left[\mathcal{J}_S^{(r)} \leq \mathcal{J}_S^{\text{obs}}\right]}{N_R + 1}. \tag{873}$$

49.11 Structure Complexity Penalty

The surface-model complexity includes:

- event count;
- structure-specific event assignments;
- independent response thresholds;
- independent preservation parameters;
- structure-specific correction forces;
- manually assigned delays;
- manually inserted boundaries;
- and mechanism switching.

Define

$$\mathcal{P}_S = \lambda_E N_E + \lambda_{GS} N_{GS} + \lambda_{\text{corr}} N_{\text{corr}} + \lambda_{\text{switch}} N_{\text{switch}}. \tag{874}$$

49.12 Composite Surface Score

Define

$$\mathcal{J}_S = w_O\mathcal{J}_O + w_T\mathcal{J}_T + w_R\mathcal{J}_R + w_B\mathcal{J}_B + w_P\mathcal{J}_P + w_V\mathcal{J}_V + w_{\mathcal{T}}\mathcal{J}_{\mathcal{T}} + w_C\mathcal{J}_{\text{chron}} + \mathcal{P}_S. \tag{875}$$

All weights must be frozen before final evaluation.

49.13 Chronology and Counterfactual Falsifier

Surface chronology falsifier S14.
If the event sequence predicts the correct modern structure only by violating initiation, growth, reactivation, or preservation chronology, or if the same structure develops equally well without the event state, the event assignment is rejected.

---

50 Surface-Expression Viability and Falsification

50.1 Complete Surface Parameter Vector

The surface-expression parameter vector is

$$\mathbf{\Theta}_S = \left(\mathcal{E}, \mathbf{Q}_{\text{II}}, \mathcal{B}, \mathbf{V}, \mathbf{F}, \mathbf{\Theta}_O, \mathbf{\Theta}_T, \mathbf{\Theta}_R, \mathbf{\Theta}_B, \mathbf{\Theta}_P, \mathbf{\Theta}_V, \mathbf{\Theta}_{\mathcal{T}}, \mathbf{\Theta}_{\text{pres}}\right). \tag{876}$$

50.2 Surface Viable Set

Define

$$\mathcal{V}_S = \left\{ \mathbf{\Theta}_S : \begin{array}{l} \text{Paper-II event mechanics admissible,} \\ \text{boundary network admissible,} \\ \text{plate-motion field admissible,} \\ \text{mountain locations compatible,} \\ \text{mountain growth compatible,} \\ \text{trench locations compatible,} \\ \text{trench mechanisms compatible,} \\ \text{ridges and rifts compatible,} \\ \text{basins compatible,} \\ \text{plateaus compatible,} \\ \text{volcanic provinces compatible,} \\ \text{terranes and sutures compatible,} \\ \text{structure chronology compatible,} \\ \text{counterfactual necessity demonstrated,} \\ \text{held-out prediction successful} \end{array} \right\}. \tag{877}$$

50.3 Nested Global Viability

The current Paper-III viable intersection is

$$\mathcal{V}_{\mathrm{III}}^{(4)} = \mathcal{V}_B \cap \mathcal{V}_V \cap \mathcal{V}_S. \tag{878}$$

The model remains viable only if

$$\mathcal{V}_{\mathrm{III}}^{(4)} \neq \varnothing. \tag{879}$$

50.4 Surface-Expression Falsification Matrix

Table 7: Paper-III surface-expression falsification matrix.

ID	Surface claim	Falsifying result	Consequence
S-F01	Mountain localization	Predicted inherited compression and boundary fields miss major mountain systems.	Reject global orogenic localization.
S-F02	Mountain orientation	Predicted mountain axes systematically disagree with observed structural orientation.	Reject directional orogenic inheritance.
S-F03	Mountain growth	Predicted shortening, uplift, width, crustal thickness, or elevation is incompatible with observations.	Reject the relevant mountain mechanism.
S-F04	Mountain chronology	Predicted inheritance, shortening, uplift, or reactivation timing is incompatible with the geological record.	Reject the event assignment.
S-F05	Mountain necessity	The mountain system develops equally well without event inheritance.	Reject event necessity for that mountain.
S-F06	Trench localization	Predicted terminal and descent fields miss major trench systems.	Reject global terminal localization.
S-F07	Trench geometry	Predicted curvature, depth, width, segmentation, or orientation is incompatible.	Reject the relevant trench model.
S-F08	Trench deep structure	Predicted descent, underthrusting, or inherited terminal structure is absent.	Reject the relevant trench branch.

ID	Surface claim	Falsifying result	Consequence
S-F09	Trench necessity	The trench develops equally well without terminal inheritance.	Reject event necessity for that trench.
S-F10	Ridge localization	Predicted extensional and weakness fields miss major ridges and rifts.	Reject ridge inheritance.
S-F11	Ridge kinematics	Predicted opening rates, age-distance relations, segmentation, or offsets are incompatible.	Reject spreading-system reconstruction.
S-F12	New-material production	Predicted production or destruction of lithospheric area conflicts with the reconstructed material record.	Reject ridge-production model.
S-F13	Basin localization	Predicted subsidence and extension fields miss major basins.	Reject basin localization.
S-F14	Basin evolution	Predicted subsidence, sediment accommodation, thermal evolution, or inversion history is incompatible.	Reject basin-inheritance model.
S-F15	Plateau localization	Predicted uplift and buoyancy fields miss major plateaus.	Reject uplift-node localization.
S-F16	Plateau support	Predicted crustal, thermal, phase, or dynamic support is insufficient.	Reject the relevant plateau mechanism.
S-F17	Volcanic localization	Predicted melt-generation and migration paths miss the volcanic province.	Reject event-volcanism assignment.
S-F18	Volcanic chronology	Predicted melt-generation, migration, and eruption timing is incompatible.	Reject event-volcanism chronology.
S-F19	Volcanic composition	Predicted source and transport history conflicts with observed composition.	Reject the relevant melt-path model.
S-F20	Terrane paths	Predicted terrane trajectories and rotations conflict with material identity.	Reject displacement reconstruction.
S-F21	Suture assembly	Predicted contacts, closure order, and suture chronology are incompatible.	Reject orogenic assembly history.

ID	Surface claim	Falsifying result	Consequence
S-F22	Surface chronology	Modern structures are matched only by violating their recorded temporal sequence.	Reject event-sequence reconstruction.
S-F23	Counterfactual necessity	Removing event inheritance leaves the surface structure materially unchanged.	Reject primary event causation.
S-F24	Leave-one-event-out necessity	Removing a claimed major event does not alter its assigned structures.	Reject that event as necessary.
S-F25	Leave-one-structure-out prediction	The model cannot predict a withheld structure without retuning.	Reject predictive generality.
S-F26	Randomized-event null	Randomized event catalogs reproduce the surface structures equally well.	Reject special event-sequence significance.
S-F27	Complexity	The model requires independent events, lags, thresholds, or mechanisms for nearly every structure.	Reject causal compression.
S-F28	Mechanical consistency	The surface reconstruction requires event states excluded by Paper II.	Reject the reconstruction.
S-F29	Boundary consistency	Surface structures require boundaries outside the viable boundary network.	Reject structural reconstruction.
S-F30	Motion consistency	Surface structures require plate motions outside the viable motion field.	Reject structural reconstruction.
S-F31	Comparison-model performance	The comparison model predicts the surface catalog better with fewer parameters.	Reject surface-expression replacement.
S-F32	Complete surface viability	The surface-expression viable set is empty.	Reject global event-derived surface organization.

50.5 Surface-Expression Success Standard

The surface-expression model survives only if one shared event sequence:

SS1. begins from mechanically admissible event outputs;

SS2. uses the viable event-derived boundary network;

SS3. uses the viable plate-motion field;

SS4. predicts mountain locations and orientations;

SS5. predicts shortening, uplift, and crustal thickening;

SS6. predicts trench locations and deep structure;

SS7. distinguishes excavation, bending, underthrusting, and descent;

SS8. predicts ridge and rift locations;

SS9. predicts opening rates and material-age patterns;

SS10. predicts basin subsidence and inversion;

SS11. predicts plateaus and persistent uplift nodes;

SS12. predicts volcanic provinces and melt pathways;

SS13. predicts terrane paths, sutures, and assembly;

SS14. predicts structure chronology;

SS15. demonstrates event contribution through counterfactuals;

SS16. survives leave-one-event-out tests;

SS17. predicts held-out structures;

SS18. outperforms randomized event catalogs;

SS19. avoids independent structure-by-structure tuning; and

SS20. improves on the comparison model after complexity penalties.

Surface-expression decision rule.
The global surface-expression claim survives only if the same mechanically admissible event sequence and inherited boundary-and-motion solution predicts the locations, orientations, dimensions, material states, and chronologies of mountains, trenches, ridges, basins, plateaus, volcanic provinces, sutures, and displaced terranes.
A catalog assembled by assigning a different event or mechanism after examining each structure is not a causal reconstruction.

---

51 Surface-Structure Synthesis

This surface-structure synthesis records:

1. mountain systems as forward-modeled material and kinematic responses;
2. inherited compression and cumulative-shortening fields;
3. an objective orogenic-susceptibility function;
4. predicted mountain domains, centroids, orientations, lengths, and widths;

5. crustal-thickening and elevation-evolution equations;
6. mountain amplification and with-inheritance counterfactuals;
7. terminal-zone and trench-state representations;
8. descent velocity and mass-flux calculations;
9. terminal inheritance and modern-trench evolution;
10. excavation, bending, underthrusting, descent, and hybrid trench branches;
11. flexural rigidity, curvature, and bending energy;
12. event-derived ridge and rift nucleation;
13. lithospheric thinning, decompression, and melt generation;
14. new-material production and age-distance prediction;
15. ridge symmetry, asymmetry, segmentation, and transform offsets;
16. complete basin state and subsidence decomposition;
17. basin shape, orientation, sediment accommodation, and inversion;
18. continental-plateau and persistent-uplift-node prediction;
19. plateau elevation, edge, and persistence tests;
20. volcanic-province and melt-path localization;
21. anisotropic damage-guided permeability;
22. volcanic timing, volume, and composition tests;
23. terrane trajectory, rotation, transfer, and material-identity constraints;
24. suture formation and orogenic-assembly graphs;
25. unified structure chronology;
26. event-to-structure dependency matrices;
27. structure-by-structure and leave-one-event-out counterfactuals;
28. randomized event-structure tests;
29. the complete surface-expression viable set; and
30. the Paper-III surface-expression falsification matrix.

The following sections develop the global chronological and predictive integration:

- the complete event chronology;
- event initiation, expression, inheritance, and overprint intervals;
- global plate-reconstruction time slices;

- continental displacement and paleogeographic residuals;
- event-path reconstruction in moving reference frames;
- predicted gravity, seismic, magnetic, and heat-flow fields;
- resource and mineralization predictions;
- sequence-wide statistical null models;
- multiple-testing and selection-bias controls;
- global advance predictions;
- the Paper-III claim ledger;
- the complete integrated falsification matrix;
- independent replication protocol;
- discussion;
- limitations;
- conclusions; and
- the formal handoff to Paper IV.

52 Global Event Chronology and Time-Slice Architecture

52.1 Chronology as a Causal Constraint

A sequenced event framework requires more than a collection of spatial alignments.

Each proposed event must occupy a defensible position within a global chronology.

Let the ordered event catalog be

$$\mathcal{E} = \{\mathcal{E}_1, \mathcal{E}_2, \ldots, \mathcal{E}_{N_E}\}, \tag{880}$$

with ages before present

$$a_1 > a_2 > \cdots > a_{N_E} \tag{881}$$

for a catalog ordered from older to younger events.

52.2 Forward-Time Coordinate

For numerical evolution, define forward time

$$\tau = a_{\text{start}} - a, \tag{882}$$

where a_{start} is the oldest modeled age and a is age before present. Thus

$$\frac{d\tau}{da} = -1. \tag{883}$$

All chronological inequalities must state whether they use age before present or forward time.

52.3 Event Phase Vector

Each event is divided into phases

$$\mathbf{T}_{E,k} = \left(t_k^{\text{approach}}, t_k^{\text{contact}}, t_k^{\text{transient}}, t_k^{\text{handoff}}, t_k^{\text{relax}}, t_k^{\text{react}}\right). \tag{884}$$

These represent:

- pre-contact approach;
- initial contact;
- short-duration mechanical transient;
- handoff to long-time evolution;
- structural and thermal relaxation; and
- possible later reactivation.

52.4 Event-State Update

The planetary state immediately after event k is

$$\mathbf{Q}_k^+ = \mathcal{F}_{E,k}\left[\mathbf{Q}_k^-, \mathcal{E}_k\right]. \tag{885}$$

Between events,

$$\mathbf{Q}_{k+1}^- = \mathcal{U}\left[\mathbf{Q}_k^+, \tau_k^+, \tau_{k+1}^-\right]. \tag{886}$$

The complete state at present is

$$\mathbf{Q}_{\text{now}} = \mathcal{U} \circ \mathcal{F}_{E,N_E} \circ \cdots \circ \mathcal{U} \circ \mathcal{F}_{E,1}\left[\mathbf{Q}_0\right]. \tag{887}$$

52.5 Time-Slice Grid

Define reconstruction times

$$\mathcal{T}_R = \{\tau_0, \tau_1, \ldots, \tau_{N_T}\}. \tag{888}$$

At time slice τ_q, the model outputs

$$\mathbf{Q}(\tau_q) = (\mathcal{P}(\tau_q), \mathcal{B}(\tau_q), \mathbf{V}(\tau_q), \mathbf{Q}_m(\tau_q), \mathcal{G}_S(\tau_q)), \tag{889}$$

where:

$$\mathcal{P} = \text{plate and block domains,} \tag{890}$$
$$\mathcal{B} = \text{boundary network,} \tag{891}$$
$$\mathbf{V} = \text{velocity and rotation fields,} \tag{892}$$
$$\mathbf{Q}_m = \text{mantle and lithospheric state,} \tag{893}$$
$$\mathcal{G}_S = \text{surface-structure catalog.} \tag{894}$$

52.6 Adaptive Temporal Resolution

Time-step size must respond to physical changes.

Let

$$\Delta\tau_q = \tau_{q+1} - \tau_q. \tag{895}$$

A reduced adaptive criterion is

$$\Delta\tau_q \leq C_\tau \min(\tau_{\text{event}}, \tau_{\text{boundary}}, \tau_{\text{rotation}}, \tau_{\text{thermal}}, \tau_{\text{damage}}, \tau_{\text{phase}}). \tag{896}$$

Shorter time steps are required around:

- event initiation;
- plate fragmentation;
- boundary activation;
- boundary inversion;
- rapid acceleration;
- collision;
- ridge initiation;
- trench initiation;
- basin inversion; and
- major volcanic pulses.

52.7 Event Overlap

Events k and m overlap mechanically or geodynamically where

$$\left[t_k^{\text{influence,start}}, t_k^{\text{influence,end}}\right] \cap \left[t_m^{\text{influence,start}}, t_m^{\text{influence,end}}\right] \neq \varnothing. \tag{897}$$

The overlap operator is

$$\mathcal{O}_{km}^{E} = \text{Duration}\left(\mathcal{I}_k \cap \mathcal{I}_m\right). \tag{898}$$

Overlapping events cannot be modeled as independent additions when they modify the same material domains.

52.8 Chronological Dependency Graph

Represent event and structure chronology as directed acyclic graph

$$\mathcal{G}_T = \left(\mathcal{N}_T, \mathcal{E}_T\right). \tag{899}$$

Nodes include:

- events;
- boundary initiation;
- plate fragmentation;
- plate merger;
- mountain initiation;
- trench initiation;
- basin opening;
- basin inversion;
- volcanic pulses;
- terrane contacts; and
- later reactivation.

An edge

$$a \to b \tag{900}$$

states that process a must precede or causally condition process b.

52.9 Chronological Violation Count

For dependency edge $a \to b$, define violation

$$I_{ab}^{T} = \begin{cases} 1, & \tau_a > \tau_b \text{ under forward-time ordering,} \\ 0, & \text{otherwise.} \end{cases} \tag{901}$$

The total violation count is

$$N_{T,\text{viol}} = \sum_{a \to b} I_{ab}^{T}. \tag{902}$$

A causally valid reconstruction requires

$$N_{T,\text{viol}} = 0 \tag{903}$$

after accounting for declared uncertainties.

52.10 Chronological Residual

For observed age t_j^{obs} and predicted age t_j^{pred},

$$\epsilon_{T,j} = \frac{t_j^{\text{obs}} - t_j^{\text{pred}}}{\sigma_{T,j}}. \tag{904}$$

The complete chronological misfit is

$$\chi_T^2 = \boldsymbol{\epsilon}_T^{\mathsf{T}} \mathbf{C}_T^{-1} \boldsymbol{\epsilon}_T, \tag{905}$$

where $\mathbf{C}_T$ contains correlated age and reconstruction uncertainties.

52.11 Temporal Cross-Validation

Fit the model using events and structures older than a cutoff τ_c:

$$\mathbf{D}_T^{\text{train}} = \{\mathbf{D}_T : \tau \leq \tau_c\}. \tag{906}$$

Then predict younger development:

$$\widehat{\mathbf{D}}_T^{\text{test}} = \mathcal{F}_T\left[\mathbf{D}_T^{\text{train}}\right]. \tag{907}$$

This prevents younger structures from silently determining the older event sequence.

52.12 Chronology Falsifier

Global chronology falsifier C1.
If the proposed event order requires structures to form before their assigned causal events, violates plate lineage, or matches modern geometry only by violating independently constrained ages, the event sequence is rejected.

---

53 Continental Displacement and Paleogeographic Reconstruction

53.1 Continents as Evolving Material Domains

A continent or continental block is represented as

$$\mathcal{C}_i(t) \subset \mathcal{P}_i(t), \tag{908}$$

with state

$$\mathbf{Q}_{C_i} = \left(\mathcal{A}_i, H_{c,i}, \rho_i, \mathcal{X}_i, \mathbf{M}_i, \mathbf{S}_i, \mathbf{R}_i, \mathbf{x}_i\right), \tag{909}$$

where:

$$\mathcal{A}_i = \text{continental area and geometry}, \tag{910}$$
$$\mathcal{X}_i = \text{composition and age structure}, \tag{911}$$
$$\mathbf{M}_i = \text{magnetic or paleomagnetic state}, \tag{912}$$
$$\mathbf{S}_i = \text{structural state}. \tag{913}$$

53.2 Material-Point Evolution

For material point $\mathbf{x}_{i,a}$ within continent i,

$$\frac{d\mathbf{x}_{i,a}}{dt} = \mathbf{v}_i\left(\mathbf{x}_{i,a}, t\right). \tag{914}$$

For approximately rigid motion,

$$\mathbf{x}_{i,a}(t_2) = \mathbf{R}_i(t_2, t_1)\mathbf{x}_{i,a}(t_1). \tag{915}$$

For deformation,

$$\mathbf{x}_{i,a}(t_2) = \mathbf{R}_i(t_2, t_1)\mathbf{x}_{i,a}(t_1) + \mathbf{u}_{i,\text{def}}. \tag{916}$$

53.3 Continental Displacement

The displacement of reference point a is

$$\Delta \mathbf{x}_{i,a} = \mathbf{x}_{i,a}(t_2) - \mathbf{x}_{i,a}(t_1). \tag{917}$$

The surface path length is

$$L_{i,a} = \int_{t_1}^{t_2} \|\mathbf{v}_{i,h}\| \, dt. \tag{918}$$

53.4 Shape Evolution

Let the continental boundary be

$$\Gamma_{C_i}(t). \tag{919}$$

The shape-change operator is

$$\Gamma_{C_i}(t_2) = \mathcal{U}_C \left[\Gamma_{C_i}(t_1), \mathbf{V}_i, \boldsymbol{\epsilon}_i, \mathcal{B}, \mathcal{E}\right]. \tag{920}$$

Shape change may include:

- rigid rotation;
- internal deformation;
- fragmentation;
- terrane accretion;
- margin erosion;
- sedimentary growth;
- volcanic addition;
- underthrusting;
- descent; and
- later event overprint.

53.5 Area Accounting

Continental area evolves as

$$\frac{dA_{C_i}}{dt} = \dot{A}_{\text{accretion}} + \dot{A}_{\text{magmatic}} + \dot{A}_{\text{sedimentary}} - \dot{A}_{\text{erosion}} - \dot{A}_{\text{descent}} - \dot{A}_{\text{transfer}}. \tag{921}$$

The model must not treat present coastlines as permanent material boundaries.

53.6 Reconstructed Continental Dataset

At time slice t_q, the observed or independently reconstructed continental dataset is

$$\mathbf{D}_C(t_q) = (\Gamma_C, \mathcal{A}_C, \mathbf{x}_C, \mathbf{R}_C, \mathbf{M}_C, \mathbf{X}_C, \mathcal{N}_C), \tag{922}$$

where $\mathcal{N}_C$ contains continental adjacency relationships.

53.7 Centroid Residual

For predicted and observed continental centroids,

$$d_{C,i} = d_{\mathcal{S}}\left(\mathbf{x}_{C,i}^{\text{pred}}, \mathbf{x}_{C,i}^{\text{obs}}\right). \tag{923}$$

53.8 Shape-Overlap Residual

The continental overlap score is

$$\text{IoU}_{C,i} = \frac{\text{Area}\left(\mathcal{C}_i^{\text{pred}} \cap \mathcal{C}_i^{\text{obs}}\right)}{\text{Area}\left(\mathcal{C}_i^{\text{pred}} \cup \mathcal{C}_i^{\text{obs}}\right)}. \tag{924}$$

53.9 Boundary Distance

The average symmetric continental-boundary distance is

$$d_{C,\text{ASD}} = \frac{1}{2}\left[\frac{1}{L_{\text{obs}}}\int_{\Gamma_C^{\text{obs}}} d\left(x, \Gamma_C^{\text{pred}}\right) d\ell + \frac{1}{L_{\text{pred}}}\int_{\Gamma_C^{\text{pred}}} d\left(y, \Gamma_C^{\text{obs}}\right) d\ell\right]. \tag{925}$$

53.10 Adjacency Matrix

Define continental adjacency matrix

$$\mathbf{A}_{C,ij}(t) = \begin{cases} 1, & \mathcal{C}_i \text{ and } \mathcal{C}_j \text{ share a declared contact,} \\ 0, & \text{otherwise.} \end{cases} \tag{926}$$

The adjacency residual is

$$D_{A,C} = \frac{\left\|\mathbf{A}_C^{\text{obs}} - \mathbf{A}_C^{\text{pred}}\right\|_F}{\left\|\mathbf{A}_C^{\text{obs}}\right\|_F}. \tag{927}$$

53.11 Paleomagnetic Residual

For predicted and observed orientation or latitude constraint $\mathbf{d}_i^{\text{PM}}$,

$$\chi^2_{C,i,\mathrm{PM}} = \left(\mathbf{d}_i^{\mathrm{obs}} - \mathbf{d}_i^{\mathrm{pred}}\right)^{\mathsf{T}} \mathbf{\Sigma}_{i,\mathrm{PM}}^{-1} \left(\mathbf{d}_i^{\mathrm{obs}} - \mathbf{d}_i^{\mathrm{pred}}\right). \tag{928}$$

53.12 Reconstruction Ensemble

Paper III must evaluate multiple reconstruction realizations

$$\left\{\mathcal{R}_C^{(q)}\right\}_{q=1}^{N_R}, \tag{929}$$

spanning:

- alternative reference frames;
- alternative plate lineages;
- uncertain boundaries;
- uncertain terrane identities;
- internal deformation;
- paleomagnetic uncertainty;
- coastline uncertainty;
- and missing material.

53.13 Continental Reconstruction Score

Define

$$\begin{aligned} \mathcal{J}_C = w_x \widetilde{d}_C + w_S \left(1 - \mathrm{IoU}_C\right) + w_B \widetilde{d}_{C,\mathrm{ASD}} + w_A \widetilde{D}_{A,C} \\ + w_{\mathrm{PM}} \widetilde{\chi}^2_{C,\mathrm{PM}} + w_T \widetilde{\chi}^2_{C,T} + w_M \widetilde{\chi}^2_{C,\mathrm{material}}. \end{aligned} \tag{930}$$

The score weights must be predeclared.

53.14 Continental-Displacement Falsifier

Continental-displacement falsifier C2.
If the event-derived boundary and motion system cannot reconstruct continental positions, rotations, shapes, adjacencies, material identities, and displacement chronology within uncertainty, the global continental-reconstruction claim is rejected.

---

54 Event Paths in Moving Plates and Reference Frames

54.1 Present Coordinates Are Not Event Coordinates

The modern coordinates of a proposed entrance, midpoint, or terminal structure are not automatically the coordinates of the relevant material at event time.

For modern material point $\mathbf{x}_0$, the reconstructed position at event time t_k is

$$\mathbf{x}_k = \mathcal{R}^{-1}\left[\mathbf{x}_0, t_k, t_{\text{now}}\right]. \tag{931}$$

The reconstruction operator must include plate identity, finite rotation, deformation, transfer, and uncertainty.

54.2 Material Target Domains

For event k, define reconstructed entrance, middle, and terminal material domains

$$\mathcal{D}_{A,k}(t_k), \qquad \mathcal{D}_{H,k}(t_k), \qquad \mathcal{D}_{M,k}(t_k). \tag{932}$$

Each domain must identify:

- material ancestry;
- plate or block membership;
- surface and subsurface extent;
- uncertainty;
- preservation;
- and later displacement.

54.3 Inertial Event Path

Let the event carrier or disturbance path in an inertial frame be

$$\mathbf{r}_{I,k}(t). \tag{933}$$

The Earth-fixed path is

$$\mathbf{r}_{E,k}(t) = \mathbf{R}_{EI}(t)\left[\mathbf{r}_{I,k}(t) - \mathbf{r}_{\oplus}(t)\right], \tag{934}$$

where:

$$\mathbf{R}_{EI}(t) = \text{inertial-to-Earth rotation}, \tag{935}$$

$$\mathbf{r}_{\oplus}(t) = \text{Earth-center inertial position}. \tag{936}$$

54.4 Rotating-Earth Velocity

The Earth-fixed velocity is

$$\mathbf{v}_E = \mathbf{R}_{EI} (\mathbf{v}_I - \mathbf{v}_\oplus) - \boldsymbol{\Omega}_\oplus \times \mathbf{r}_E. \tag{937}$$

The rotating-frame acceleration includes:

$$\mathbf{a}_E = \mathbf{a}_{\text{physical}} - 2\boldsymbol{\Omega}_\oplus \times \mathbf{v}_E - \boldsymbol{\Omega}_\oplus \times (\boldsymbol{\Omega}_\oplus \times \mathbf{r}_E) - \dot{\boldsymbol{\Omega}}_\oplus \times \mathbf{r}_E. \tag{938}$$

54.5 Material Motion During the Event

For short-duration events, plate motion during the transient may be small but must be estimated.

For target material point

$$\mathbf{x}_T(t) = \mathbf{x}_T(t_k) + \int_{t_k}^{t} \mathbf{v}_T(t')\, dt'. \tag{939}$$

The targeting condition is

$$\min_t \|\mathbf{r}_{E,k}(t) - \mathbf{x}_T(t)\| \le d_{T,\text{crit}}. \tag{940}$$

54.6 Path Through a Moving Interior

For interior material velocity $\mathbf{u}(\mathbf{r}, t)$, the relative path velocity is

$$\mathbf{v}_{\text{rel}} = \dot{\mathbf{r}}_{E,k} - \mathbf{u}\left[\mathbf{r}_{E,k}(t), t\right]. \tag{941}$$

The relative trajectory affects:

- momentum transfer;
- attenuation;
- shear;
- thermal deposition;
- path curvature;
- and the final terminal location.

54.7 Event-Path Transport to the Present

Let the event create path-state field

$$\mathbf{Q}^{+}_{P,k}(\mathbf{r}, t_k). \tag{942}$$

Its present state is

$$\mathbf{Q}_{P,k}^{\text{now}} = \mathcal{U}_P \left[\mathbf{Q}_{P,k}^{+}, t_k, t_{\text{now}} \right]. \tag{943}$$

The modern surface projection of the path is

$$\Gamma_{P,k}^{\text{now}} = \Pi_{\mathcal{S}} \left[\mathbf{Q}_{P,k}^{\text{now}} \right]. \tag{944}$$

A modern line between selected surface features is not automatically the preserved path.

54.8 Path-to-Boundary Intersection

For path-state domain $\mathcal{P}_k^{\text{inherit}}$ and boundary network $\mathcal{B}(t)$, define intersection

$$\mathcal{I}_{PB,k}(t) = \mathcal{P}_k^{\text{inherit}}(t) \cap \mathcal{B}(t). \tag{945}$$

The path may:

- nucleate a boundary;
- reinforce a boundary;
- cross a boundary;
- terminate at a boundary;
- redirect later motion;
- or leave no detectable boundary expression.

54.9 Path Uncertainty Ensemble

The reconstructed event-path ensemble is

$$\left\{ \mathcal{P}_k^{(q)} \right\}_{q=1}^{N_P}, \tag{946}$$

spanning uncertainty in:

- entrance material;
- exit material;
- event age;
- reference frame;
- Earth rotation;
- path curvature;
- internal heterogeneity;

- plate reconstruction;
- and preservation.

54.10 Path-Target Residual

For predicted path center $\mathbf{x}_{P,k}^{\mathrm{pred}}$ and reconstructed target domain $\mathcal{D}_k$,

$$d_{P,k} = \min_{\mathbf{x}\in\mathcal{D}_k} \left\| \mathbf{x}_{P,k}^{\mathrm{pred}} - \mathbf{x} \right\|. \tag{947}$$

54.11 Moving-Frame Falsifier

Moving-frame falsifier C3.
If a proposed event path aligns only in present coordinates but fails when the relevant material domains are reconstructed to event time in defensible moving reference frames, the path assignment is rejected.

---

55 Global Gravity, Seismic, Magnetic, and Heat-Flow Predictions

55.1 Global Prediction Vector

The global geophysical prediction vector is

$$\widehat{\mathbf{D}}_G = \left(\widehat{\mathbf{g}}, \widehat{\Phi}, \widehat{V}_P, \widehat{V}_S, \widehat{Q}^{-1}, \widehat{\mathbf{A}}_{\mathrm{seis}}, \widehat{\mathbf{B}}, \widehat{q}_H, \widehat{\rho}, \widehat{\eta}\right). \tag{948}$$

55.2 Gravity Field

The event-derived density perturbation is

$$\Delta\rho_{\mathrm{ABC}}(\mathbf{r}, t). \tag{949}$$

The predicted gravitational-potential perturbation is

$$\Delta\Phi_{\mathrm{ABC}}(\mathbf{x}) = -G \int \frac{\Delta\rho_{\mathrm{ABC}}(\mathbf{r})}{\|\mathbf{x} - \mathbf{r}\|}\, dV. \tag{950}$$

The acceleration anomaly is

$$\Delta\mathbf{g}_{\mathrm{ABC}} = -\nabla\Delta\Phi_{\mathrm{ABC}}. \tag{951}$$

55.3 Geoid Prediction

The event-derived geoid-height perturbation is represented as

$$\Delta N_{\mathrm{ABC}} = \mathcal{G}_N \left[\Delta\Phi_{\mathrm{ABC}}, \Phi_0, \mathbf{Q}_{\oplus}\right]. \tag{952}$$

The model must distinguish event-derived anomalies from:

- present mantle structure;
- topography;
- crustal thickness;
- ocean loading;
- sediment;
- ice;
- and later tectonic evolution.

55.4 Seismic Velocity

For elastic moduli K and G,

$$V_P = \sqrt{\frac{K + \frac{4}{3}G}{\rho}}, \tag{953}$$

and

$$V_S = \sqrt{\frac{G}{\rho}}. \tag{954}$$

The moduli depend on

$$K, G = \mathcal{F}\left(P, T, C, \phi, \chi_m, D, \mathbf{A}\right). \tag{955}$$

55.5 Seismic Anisotropy

The predicted elasticity tensor is

$$\mathbf{C}_{\mathrm{ABC}} = \mathbf{C}_0 + \Delta\mathbf{C}_{\mathrm{event}} + \Delta\mathbf{C}_{\mathrm{strain}} + \Delta\mathbf{C}_{\mathrm{phase}}. \tag{956}$$

The anisotropy prediction includes:

- fast directions;
- slow directions;
- anisotropy magnitude;
- depth variation;
- boundary alignment;
- path alignment;

- and later strain overprint.

55.6 Attenuation

A generalized attenuation prediction is

$$Q^{-1} = \mathcal{F}_Q\left(T, P, \chi_m, D, \phi, C, \omega_{\text{seis}}\right). \tag{957}$$

55.7 Tomographic Forward Operator

The synthetic observation is

$$\widehat{\mathbf{d}}_{\text{tomo}} = \mathcal{O}_{\text{tomo}}\left[V_P, V_S, Q^{-1}, \mathbf{A}_{\text{seis}}\right]. \tag{958}$$

The comparison must occur in observation space or through resolution-matched inversion products.

55.8 Magnetic Field

The event-modified magnetization is

$$\mathbf{M}_{\text{ABC}} = \mathcal{F}_M\left[\mathbf{M}_0, T_{\max}, P_{\max}, D, \chi_m, \phi, \mathbf{B}(t)\right]. \tag{959}$$

The predicted magnetic anomaly is

$$\widehat{\mathbf{B}}_{\text{ABC}} = \mathcal{O}_B\left[\mathbf{M}_{\text{ABC}}, \mathbf{Q}_{\text{crust}}, \mathbf{Q}_{\text{mantle}}\right]. \tag{960}$$

55.9 Heat Flow

The conductive heat flux is

$$\mathbf{q}_H = -k\nabla T. \tag{961}$$

The surface-normal heat flow is

$$q_{H,n} = -\mathbf{q}_H \cdot \widehat{\mathbf{n}}_{\mathcal{S}}. \tag{962}$$

The event-derived heat-flow perturbation is

$$\Delta q_H^{\text{ABC}} = q_H^+ - q_H^0. \tag{963}$$

55.10 Global Observation Residual

Let observed geophysical vector be

$$\mathbf{D}_G^{\text{obs}}. \tag{964}$$

The residual is

$$\boldsymbol{\epsilon}_G = \mathbf{D}_G^{\text{obs}} - \widehat{\mathbf{D}}_G. \tag{965}$$

The covariance-weighted misfit is

$$\chi_G^2 = \boldsymbol{\epsilon}_G^{\mathsf{T}} \boldsymbol{\Sigma}_G^{-1} \boldsymbol{\epsilon}_G. \tag{966}$$

55.11 Corridor Detection Statistic

For predicted event corridor field $\widehat{\mathcal{T}}_{\text{ABC}}$ and observed residual field $\mathcal{T}_{\text{obs}}$, define normalized correlation

$$\mathcal{C}_G = \frac{\int \widehat{\mathcal{T}}_{\text{ABC}} \mathcal{T}_{\text{obs}} \, dV}{\sqrt{\int \widehat{\mathcal{T}}_{\text{ABC}}^2 \, dV} \sqrt{\int \mathcal{T}_{\text{obs}}^2 \, dV}}. \tag{967}$$

55.12 Resolution Test

Let the observation-resolution operator be

$$\mathcal{R}_G. \tag{968}$$

The event prediction must be filtered as

$$\widehat{\mathbf{D}}_G^{\text{res}} = \mathcal{R}_G \left[\widehat{\mathbf{D}}_G \right] \tag{969}$$

before comparison with resolution-limited data.

55.13 Geophysical Falsifier

Global geophysical falsifier G1.
If the event sequence predicts gravity, seismic, magnetic, anisotropy, attenuation, or heat-flow structures that are absent at adequate resolution, or requires anomalies incompatible with the observed fields, the relevant event and inheritance branches are rejected.

---

56 Resource Provinces and Mineralization as Advance Predictions

56.1 Secondary Predictive Status

Resource and mineralization predictions are secondary tests.

They cannot establish the global replacement framework by themselves.

They can provide high-value advance predictions because they combine:

- deep structure;
- fluid pathways;
- heat;
- pressure;
- fracture networks;
- melt migration;
- basin development;
- chemical transport;
- and preservation.

56.2 Mineral-System State Vector

For candidate resource province r, define

$$\mathbf{Q}_{R_r} = (\mathbf{S}_r, \mathbf{P}_r, \mathbf{T}_r, \mathbf{F}_r, \mathbf{C}_r, \mathbf{H}_r, \mathbf{D}_r, \mathbf{K}_r, t_r)\,, \tag{970}$$

where:

$$\mathbf{S}_r = \text{source-material state,} \tag{971}$$
$$\mathbf{P}_r = \text{pressure history,} \tag{972}$$
$$\mathbf{T}_r = \text{temperature history,} \tag{973}$$
$$\mathbf{F}_r = \text{fluid or melt transport,} \tag{974}$$
$$\mathbf{C}_r = \text{chemical components,} \tag{975}$$
$$\mathbf{H}_r = \text{host-rock and trap state,} \tag{976}$$
$$\mathbf{D}_r = \text{damage and permeability,} \tag{977}$$
$$\mathbf{K}_r = \text{preservation and sealing.} \tag{978}$$

56.3 Event-Derived Prospectivity Field

Define prospectivity

$$\begin{aligned}\mathcal{P}_R = {} & w_S\widetilde{\mathcal{S}}_{\text{source}} + w_T\widetilde{\mathcal{T}}_{\text{thermal}} + w_F\widetilde{\mathcal{F}}_{\text{fluid}} + w_D\widetilde{D} \\ & + w_K\widetilde{k}_{\text{perm}} + w_H\widetilde{\mathcal{H}}_{\text{host}} + w_C\widetilde{\mathcal{C}}_{\text{chem}} + w_P\widetilde{\mathcal{P}}_{\text{pres}}.\end{aligned} \tag{979}$$

The weights must be calibrated independently or frozen before blind testing.

56.4 Predicted Province Domain

The predicted province is

$$\mathcal{D}_R^{\text{pred}} = \{\mathbf{x} : \mathcal{P}_R(\mathbf{x}) \geq \mathcal{P}_{R,\text{crit}}\}\,. \tag{980}$$

56.5 Resource-Type Classification

The predicted resource class is

$$\tau_R = \mathcal{C}_R\left[\mathbf{Q}_{R_r}\right]. \tag{981}$$

Possible outputs include classes associated with:

- magmatic concentration;
- hydrothermal transport;
- sedimentary basins;
- structural traps;
- metamorphic remobilization;
- brine migration;
- fracture-controlled deposition;
- and deep-fluid pathways.

The manuscript does not assume that all resource classes share one event mechanism.

56.6 Blind Prediction Requirement

A valid advance test must:

1. freeze the event model;
2. freeze the prospectivity function;
3. exclude known target locations from calibration;
4. publish predicted regions and depths;
5. publish predicted resource class;
6. publish uncertainty;
7. and evaluate the prediction against withheld exploration or geological data.

56.7 Hit and False-Positive Rates

For predicted province cells, define:

$$N_{\mathrm{TP}} = \text{true positives}, \tag{982}$$

$$N_{\mathrm{FP}} = \text{false positives}, \tag{983}$$

$$N_{\mathrm{FN}} = \text{false negatives}, \tag{984}$$

$$N_{\mathrm{TN}} = \text{true negatives}. \tag{985}$$

Precision is

$$\text{Precision} = \frac{N_{\mathrm{TP}}}{N_{\mathrm{TP}} + N_{\mathrm{FP}}}. \tag{986}$$

Recall is

$$\text{Recall} = \frac{N_{\mathrm{TP}}}{N_{\mathrm{TP}} + N_{\mathrm{FN}}}. \tag{987}$$

56.8 Area-Normalized Enrichment

Let predicted target area be A_{pred} and total search area be A_{tot}.

Define target-area fraction

$$f_A = \frac{A_{\mathrm{pred}}}{A_{\mathrm{tot}}}. \tag{988}$$

If fraction of validated occurrences inside the target is f_O, enrichment is

$$\mathcal{E}_R = \frac{f_O}{f_A}. \tag{989}$$

56.9 Resource-Prediction Falsifier

Resource-prediction falsifier G2.
If prospectivity maps generated before target disclosure do not enrich for the predicted resource class above spatial, geological, and comparison-model baselines, the event-derived resource prediction is rejected.

---

57 Sequence-Wide Statistical Null Models

57.1 Null Models Must Preserve Relevant Structure

A useful null model should randomize the proposed causal relationship while preserving nuisance structure.

The sequence-wide null family is

$$\mathfrak{N} = \{\mathcal{N}_0, \mathcal{N}_1, \ldots, \mathcal{N}_{N_N}\}\,. \tag{990}$$

57.2 Uniform Spatial Null

Under $\mathcal{N}_0$, event locations are sampled from the permitted global domain:

$$\mathbf{x}_{E,k}^{(r)} \sim p_{\text{uniform}}\left(\mathcal{S}_{\oplus}\right). \tag{991}$$

57.3 Geological-Opportunity Null

Under $\mathcal{N}_1$, event locations are sampled from regions with comparable preservation, exposure, sampling, or structural complexity:

$$\mathbf{x}_{E,k}^{(r)} \sim p\left(\mathbf{x} \mid \mathcal{O}_{\text{geol}}\right). \tag{992}$$

57.4 Boundary-Conditioned Null

Under $\mathcal{N}_2$, event targets are sampled near existing geological boundaries to test whether boundary proximity alone creates apparent success:

$$\mathbf{x}_{E,k}^{(r)} \sim p\left(\mathbf{x} \mid d\left(\mathbf{x}, \mathcal{B}\right) \leq d_{B,\max}\right). \tag{993}$$

57.5 Chronology-Permutation Null

Under $\mathcal{N}_3$, event geometries are retained while ages are permuted:

$$\left\{t_k^{(r)}\right\} = \text{Permute}\left[\{t_k\}\right]. \tag{994}$$

57.6 Orientation Null

Under $\mathcal{N}_4$, event directions are randomized while locations and ages are retained:

$$\widehat{\mathbf{d}}_k^{(r)} \sim p_{\text{orient}}\left(\widehat{\mathbf{d}}\right). \tag{995}$$

57.7 Event-Count Null

Under $\mathcal{N}_5$, synthetic catalogs contain the same number of events and comparable parameter ranges but randomized assignments:

$$N_E^{(r)} = N_E. \tag{996}$$

57.8 Plate-Preserving Null

Under $\mathcal{N}_6$, event locations are shuffled within reconstructed plate domains:

$$\mathbf{x}_{E,k}^{(r)} \sim p\left(\mathbf{x} \mid \mathcal{P}_{i(k)}(t_k)\right). \tag{997}$$

57.9 Complete Sequence Statistic

Define composite global score

$$\begin{aligned}\mathcal{J}_{\mathrm{III}} = w_B\mathcal{J}_B + w_V\mathcal{J}_V + w_S\mathcal{J}_S + w_C\mathcal{J}_C + w_T\mathcal{J}_T \\ + w_G\mathcal{J}_G + w_R\mathcal{J}_R + \mathcal{P}_{\mathrm{complexity}} + \mathcal{P}_{\mathrm{physical}}.\end{aligned} \tag{998}$$

Lower scores indicate better penalized fit.

57.10 Empirical Null Probability

For null realizations

$$\mathcal{J}_{\mathrm{III}}^{(r)}, \qquad r = 1, \ldots, N_R, \tag{999}$$

the empirical probability is

$$p_{\mathrm{III,null}} = \frac{1 + \sum_{r=1}^{N_R} \mathbf{1}\left[\mathcal{J}_{\mathrm{III}}^{(r)} \leq \mathcal{J}_{\mathrm{III}}^{\mathrm{obs}}\right]}{N_R + 1}. \tag{1000}$$

57.11 Feature-Level Statistics

For observation class g, calculate

$$p_{g,\mathrm{null}} = \frac{1 + \sum_r \mathbf{1}\left[\mathcal{J}_g^{(r)} \leq \mathcal{J}_g^{\mathrm{obs}}\right]}{N_R + 1}. \tag{1001}$$

This prevents one favorable global score from hiding systematic failure in one observation class.

57.12 Null-Model Falsifier

Sequence-null falsifier N1.
If randomized, permuted, boundary-conditioned, or opportunity-matched event catalogs reproduce the global boundary, motion, structure, chronology, and geophysical scores as well as the proposed sequence, the claimed special causal organization is rejected.

58 Multiple Testing, Selection Bias, and Model Flexibility

58.1 Search-Space Disclosure

The complete search space must report:

- number of event candidates;
- number of entrance candidates;
- number of exit candidates;
- number of midpoint or response candidates;
- number of tested ages;
- number of reference frames;
- number of reconstruction models;
- number of mechanism branches;
- number of boundary thresholds;
- number of structure assignments;
- number of statistical metrics;
- and number of revised models.

58.2 Selection Ledger

For candidate selection s, record

$$\mathbf{L}_s = (\text{candidate}, \text{selection time}, \text{selection rule}, \text{data viewed}, \text{alternatives}, \text{status})\,. \tag{1002}$$

The ledger must distinguish:

- predeclared targets;
- exploratory targets;
- post hoc targets;
- revised targets;
- and rejected targets.

58.3 Family-Wise Error

For m independent tests with per-test level α_{ind}, the family-wise error probability is

$$\alpha_{\text{FWER}} = 1 - (1 - \alpha_{\text{ind}})^m\,. \tag{1003}$$

A conservative Bonferroni threshold is

$$\alpha_{\text{ind}} = \frac{\alpha_{\text{family}}}{m}. \tag{1004}$$

Dependence among tests requires an appropriate alternative procedure.

58.4 False-Discovery Control

The selected false-discovery procedure and dependence assumptions must be declared [12].

For ordered p-values

$$p_{(1)} \leq p_{(2)} \leq \cdots \leq p_{(m)}, \tag{1005}$$

a false-discovery-rate screening threshold may retain the largest k satisfying

$$p_{(k)} \leq \frac{k}{m} q. \tag{1006}$$

The dependence assumptions and selected method must be declared.

58.5 Effective Degrees of Freedom

Let fitted prediction vector be

$$\widehat{\mathbf{y}} = \mathcal{F}\left[\mathbf{y}\right]. \tag{1007}$$

An effective flexibility measure is

$$k_{\text{eff}} = \operatorname{tr}\left(\frac{\partial \widehat{\mathbf{y}}}{\partial \mathbf{y}}\right). \tag{1008}$$

This may exceed the obvious parameter count when the model includes manual selection, branch switching, or regional correction.

58.6 Model Revision Penalty

For N_{rev} major revisions after examining outcomes, define

$$\mathcal{P}_{\text{rev}} = \lambda_{\text{rev}} N_{\text{rev}}. \tag{1009}$$

A revision may be scientifically appropriate, but it creates a new model that requires new validation data.

58.7 Mechanism-Switching Penalty

For structure-specific mechanism switches

$$N_{\text{switch}}, \tag{1010}$$

define

$$\mathcal{P}_{\text{switch}} = \lambda_{\text{switch}} N_{\text{switch}}. \tag{1011}$$

58.8 Coordinate-Flexibility Penalty

For target domain area A_T relative to global admissible area A_{global}, define spatial flexibility

$$f_{\text{coord}} = \frac{A_T}{A_{\text{global}}}. \tag{1012}$$

Larger target domains increase the probability of accidental alignment.

58.9 Age-Flexibility Penalty

For allowed age interval Δt_T within complete search interval Δt_{search},

$$f_{\text{age}} = \frac{\Delta t_T}{\Delta t_{\text{search}}}. \tag{1013}$$

58.10 Combined Flexibility Volume

A simplified flexibility volume is

$$\mathcal{V}_{\text{flex}} = f_{\text{coord}} f_{\text{age}} f_{\text{orient}} f_{\text{mechanism}} f_{\text{target}} f_{\text{reconstruction}}. \tag{1014}$$

The exact factors must reflect the actual search process.

58.11 Training-Data Reuse

Data used to:

- discover the event;
- select the coordinates;
- choose the age;
- choose the mechanism;
- choose the target structure;
- or choose the scoring rule

cannot simultaneously serve as fully independent validation data.

58.12 Selection-Bias Falsifier

Selection-bias falsifier N2.
If apparent event-sequence performance disappears after accounting for the number of tested coordinates, ages, structures, mechanisms, reference frames, revisions, and post hoc assignments, the statistical support for the causal sequence is rejected.

---

59 Global Advance-Prediction Program

59.1 Purpose

A candidate replacement framework requires observations that were not used to construct it.

The advance-prediction program converts the event sequence into registered forecasts.

59.2 Prediction Record

Each prediction is recorded as

$$\mathbf{P}_j = (\text{claim}, \text{location}, \text{depth}, \text{orientation}, \text{magnitude}, \text{age}, \text{uncertainty}, \text{test}, \text{falsifier})\,. \qquad (1015)$$

59.3 Prediction Classes

The program should include predictions of:

AP1. previously unmapped boundary continuations;

AP2. subsurface damage corridors;

AP3. gravity anomalies;

AP4. seismic-velocity anomalies;

AP5. seismic-anisotropy orientations;

AP6. magnetic resetting or remanence patterns;

AP7. heat-flow anomalies;

AP8. basin asymmetry;

AP9. terrane displacement paths;

AP10. concealed sutures;

AP11. melt pathways;

AP12. resource-province enrichment;

AP13. chronological relationships;

AP14. and explicit absence of predicted features outside selected domains.

59.4 Positive and Negative Predictions

A positive prediction states

$$\mathcal{F}_j \in \mathcal{D}_j \tag{1016}$$

within declared uncertainty.

A negative prediction states

$$\mathcal{F}_j \notin \mathcal{D}_j^0 \tag{1017}$$

for a declared control region.

Negative predictions reduce the ability to claim that every observed feature supports the model.

59.5 Blind Geographic Validation

Partition the globe into:

$$\mathcal{D}_{\text{visible}} \tag{1018}$$

and

$$\mathcal{D}_{\text{blind}}. \tag{1019}$$

Model construction uses only

$$\mathcal{D}_{\text{visible}}. \tag{1020}$$

Predictions are frozen for

$$\mathcal{D}_{\text{blind}}. \tag{1021}$$

59.6 Blind Depth Validation

Where surface data are known but deep data are withheld, the model predicts:

- anomaly depth;
- anomaly sign;
- orientation;

- thickness;
- continuity;
- and relationship to surface structures.

59.7 Prediction Scoring

For continuous observation y_j,

$$z_j = \frac{y_j^{\text{obs}} - y_j^{\text{pred}}}{\sigma_j}. \tag{1022}$$

For binary prediction,

$$\ell_j = y_j \log p_j + (1 - y_j) \log (1 - p_j). \tag{1023}$$

The total predictive score is

$$\mathcal{S}_{\text{pred}} = \sum_j w_j \mathcal{S}_j. \tag{1024}$$

59.8 Prediction Freeze

Every advance prediction must record:

- freeze date;
- model version;
- source data cutoff;
- parameter values;
- uncertainty;
- validation authority;
- and whether the result was previously known to the author.

59.9 Advance-Prediction Falsifier

Advance-prediction falsifier N3.
If registered predictions fail at rates incompatible with their stated uncertainties or perform no better than comparison and spatial-null models, the predictive extension of the framework is rejected.

60 Integrated Paper-III Viability

60.1 Component Viable Sets

The Paper-III component sets are defined in a common lifted parameter space. Event-catalog and material-lineage constraints are included in the continental, chronology, and boundary sets; event-to-domain impulse and angular-momentum constraints are included in the motion set. This prevents the same requirement from being counted twice under different short symbols.

$$\mathcal{V}_B = \text{boundary-network viable set,} \tag{1025}$$
$$\mathcal{V}_V = \text{plate-motion viable set,} \tag{1026}$$
$$\mathcal{V}_S = \text{surface-expression viable set,} \tag{1027}$$
$$\mathcal{V}_C = \text{continental-reconstruction viable set,} \tag{1028}$$
$$\mathcal{V}_T = \text{chronology viable set,} \tag{1029}$$
$$\mathcal{V}_G = \text{global-geophysical viable set,} \tag{1030}$$
$$\mathcal{V}_N = \text{statistical and null-model viable set,} \tag{1031}$$
$$\mathcal{V}_P = \text{advance-prediction viable set.} \tag{1032}$$

60.2 Complete Paper-III Viable Set

For one frozen eligible event sequence $\mathcal{S}$, define its mechanical-event intersection as

$$\mathcal{V}_{\text{mech},\mathcal{S}} = \bigcap_{k\in\mathcal{S}} \left(\mathcal{V}_{I,k} \cap \mathcal{V}_{II,k}\right). \tag{1033}$$

The sequence-specific complete viable set is

$$\begin{aligned} \mathcal{V}_{\text{III},\mathcal{S}} = \mathcal{V}_{\text{mech},\mathcal{S}} \cap \mathcal{V}_{B,\mathcal{S}} \cap \mathcal{V}_{V,\mathcal{S}} \cap \mathcal{V}_{S,\mathcal{S}} \cap \mathcal{V}_{C,\mathcal{S}} \\ \cap\, \mathcal{V}_{T,\mathcal{S}} \cap \mathcal{V}_{G,\mathcal{S}} \cap \mathcal{V}_{N,\mathcal{S}} \cap \mathcal{V}_{P,\mathcal{S}}. \end{aligned} \tag{1034}$$

Let $\mathfrak{S}_{\text{elig}}$ be the preregistered family of eligible candidate sequences. The global Paper-III model-family viable set is

$$\mathcal{V}_{\text{III}} = \bigcup_{\mathcal{S}\in\mathfrak{S}_{\text{elig}}} \mathcal{V}_{\text{III},\mathcal{S}}. \tag{1035}$$

The global reconstruction family remains viable only if

$$\mathcal{V}_{\text{III}} \neq \varnothing. \tag{1036}$$

Failure of one sequence rejects that sequence. The global model family fails only when every preregistered eligible sequence has an empty complete viable set.

60.3 Shared Event-Sequence Requirement

All component solutions must use one shared event catalog

$$\mathcal{E}^*. \tag{1037}$$

A prohibited result is

$$\mathcal{E}_B \neq \mathcal{E}_V \neq \mathcal{E}_S \neq \mathcal{E}_C \tag{1038}$$

when the differences are introduced only to improve separate fits.

60.4 Shared Parameter Requirement

For global parameter θ_j, define component-compatible intervals

$$\Theta_{B,j}, \Theta_{V,j}, \Theta_{S,j}, \Theta_{C,j}, \Theta_{T,j}, \Theta_{G,j}. \tag{1039}$$

The common interval is

$$\Theta_j^* = \Theta_{B,j} \cap \Theta_{V,j} \cap \Theta_{S,j} \cap \Theta_{C,j} \cap \Theta_{T,j} \cap \Theta_{G,j}. \tag{1040}$$

If

$$\Theta_j^* = \varnothing, \tag{1041}$$

the complete reconstruction fails for parameter j.

60.5 Posterior Overlap

Let component posterior distributions be

$$p_q(\boldsymbol{\Theta}), \qquad q \in \{B, V, S, C, T, G\}. \tag{1042}$$

Define overlap

$$\mathcal{O}_{\text{III}} = \int \min_q [p_q(\boldsymbol{\Theta})] \, d\boldsymbol{\Theta}. \tag{1043}$$

A near-zero value indicates that different observation classes require incompatible models.

60.6 Integrated Model Score

Define

$$\begin{aligned}\mathcal{S}_{\text{III}} = & -2\ln\mathcal{L}_{\text{global}} + \mathcal{P}_{\text{events}} + \mathcal{P}_{\text{assign}} + \mathcal{P}_{\text{mechanism}} \\ & + \mathcal{P}_{\text{revision}} + \mathcal{P}_{\text{physical}} + \mathcal{P}_{\text{numerical}} + \mathcal{P}_{\text{missing}}.\end{aligned} \tag{1044}$$

60.7 Replacement Contribution

Let global observation vector be

$$\mathbf{D}_{\text{global}}. \tag{1045}$$

The full event model predicts

$$\widehat{\mathbf{D}}_{\text{ABC}}. \tag{1046}$$

The no-event model predicts

$$\widehat{\mathbf{D}}_{0}. \tag{1047}$$

Define normalized event contribution

$$f_{\text{ABC}} = \frac{\left\|\widehat{\mathbf{D}}_{\text{ABC}} - \widehat{\mathbf{D}}_0\right\|_{\Sigma}}{\left\|\mathbf{D}_{\text{global}} - \widehat{\mathbf{D}}_0\right\|_{\Sigma} + \epsilon}. \tag{1048}$$

The norm is covariance weighted.

60.8 Outcome Classes

Paper III permits four broad outcomes:

Outcome A: Globally incompatible
Every preregistered eligible event sequence has an empty complete viable set.

Outcome B: Regional
Some events explain limited regions but not the global system.

Outcome C: Complementary
Event inheritance improves portions of the global model but is not the primary organizer.

Outcome D: Causal replacement candidate
One shared event sequence materially predicts the global boundary, motion, structure, chronology, and geophysical system better than the comparison model after penalties.

60.9 Integrated Decision Rule

Paper-III integrated decision rule.
A candidate sequence qualifies for direct Paper-IV global comparison only if one mechanically admissible, chronologically ordered astro-ballistic event sequence generates a common plate-boundary network, plate-motion field, continental reconstruction, surface-structure catalog, and deep geophysical state that is physically admissible, statistically distinguishable from the frozen null family, and reproducible under the declared numerical tests.
Held-out predictive superiority over strong competing model families is a Paper-IV replacement criterion. Failure to establish that superiority prevents replacement qualification but does not retroactively erase a nonempty Paper-III reconstruction set.

---

61 Paper-III Claim Ledger

Table 8: Paper-III claim ledger.

ID	Class	Claim	Current status
P3-C01	Shared observation	Continental and plate motion are accepted as observations requiring causal explanation.	Framework position
P3-C02	Causal thesis	Major global boundaries and motion directions may preserve sequenced astro-ballistic inheritance.	Unverified
P3-C03	Mechanical dependency	Paper-III event inputs must belong to the Paper-II viable set.	Requirement defined
P3-C04	Boundary requirement	Events must generate persistent connected material-state boundaries.	Untested
P3-C05	Topology requirement	The event-derived boundary network must enclose a realistic plate partition.	Untested
P3-C06	Motion requirement	Event impulse and later forcing must generate plate translation and rotation.	Untested
P3-C07	Euler-pole claim	Euler-pole directions and speeds can be generated from shared physical inputs.	Untested
P3-C08	Direction claim	Inherited boundaries and event-modified forces contribute to plate-motion directions.	Untested
P3-C09	Speed claim	Relative plate speeds can be predicted without independent tuning of each plate.	Untested
P3-C10	Mountain claim	Inherited event fields contribute to mountain localization and later amplification.	Untested

ID	Class	Claim	Current status
P3-C11	Trench claim	Some trench systems may preserve terminal-event or event-modified descent inheritance.	Untested
P3-C12	Ridge claim	Some ridge and rift systems may follow inherited extensional or damaged boundaries.	Untested
P3-C13	Basin claim	Some basins may preserve event-derived excavation, extension, damage, or density inheritance.	Untested
P3-C14	Volcanic claim	Event-created thermal, pressure, and permeability fields may localize some volcanic provinces.	Untested
P3-C15	Terrane claim	The event-derived motion system may predict terrane transfer and suture assembly.	Untested
P3-C16	Continental claim	The event sequence can be tested against continental positions, rotations, shapes, and adjacencies.	Test architecture defined
P3-C17	Chronology claim	The event sequence must predict the temporal order of boundaries, motions, and surface structures.	Test architecture defined
P3-C18	Moving-frame claim	Event geometry must be evaluated using reconstructed material targets at event time.	Requirement defined
P3-C19	Geophysical claim	A completed event-sequence model would generate gravity, seismic, magnetic, anisotropy, and heat-flow fields.	Untested
P3-C20	Resource claim	The event model may generate blind resource-province predictions.	Secondary and untested
P3-C21	Statistical claim	The proposed event sequence must outperform randomized and opportunity-matched catalogs.	Untested
P3-C22	Counterfactual claim	Removing event inheritance must materially alter the reconstructed global system.	Untested
P3-C23	Prediction claim	The framework can issue registered predictions not used in model construction.	Program defined
P3-C24	Replacement dependency	A nonempty complete Paper-III viable set exists.	Unknown

ID	Class	Claim	Current status
P3-C25	Paper-IV dependency	The full event model can be compared directly with Plate Tectonics.	Reserved for Paper IV

62 Complete Paper-III Falsification Matrix

Table 9: Complete integrated Paper-III falsification matrix.

ID	Global claim	Falsifying result	Consequence
P3-F01	Paper-II handoff	Required event states lie outside the mechanically admissible Paper-II set.	Reject the affected reconstruction.
P3-F02	Event chronology	Assigned structures precede their required causal events.	Reject event sequence.
P3-F03	Plate lineage	Modern and ancient plate identities cannot be connected consistently.	Reject impulse and displacement mapping.
P3-F04	Moving-frame geometry	Proposed alignments fail in reconstructed event-time material coordinates.	Reject event assignment.
P3-F05	Boundary nucleation	Events generate no persistent connected boundary state.	Reject event-derived boundary formation.
P3-F06	Plate enclosure	The predicted network fails to enclose realistic tectonic domains.	Reject global plate partition.
P3-F07	Boundary topology	Connectivity, cycles, junctions, and plate count conflict with the observed network.	Reject boundary topology.
P3-F08	Boundary chronology	Boundary initiation and reactivation ages are incompatible.	Reject boundary sequence.
P3-F09	Impulse mapping	Momentum cannot be partitioned among reconstructed ancient domains.	Reject motion inheritance.
P3-F10	Angular momentum	Predicted plate rotations violate angular-momentum conservation.	Reject Euler-pole generation.
P3-F11	Force and torque	Predicted motion requires unbalanced force, torque, or power.	Reject plate dynamics.

ID	Global claim	Falsifying result	Consequence
P3-F12	Direction	Predicted plate-motion directions systematically fail.	Reject directional inheritance.
P3-F13	Speed	Relative speeds require independent plate-specific tuning.	Reject shared speed law.
P3-F14	Kinematic closure	Plate circuits or triple junctions fail closure.	Reject global motion field.
P3-F15	Present motion	Predictions fail independent modern velocity observations.	Reject present-day reconstruction.
P3-F16	Deep-time motion	Predictions fail finite rotations, paleomagnetism, or terrane paths.	Reject temporal reconstruction.
P3-F17	Continental displacement	Predicted positions, shapes, rotations, or adjacencies fail.	Reject paleogeographic reconstruction.
P3-F18	Mountains	Predicted orogenic locations, orientations, growth, or chronology fail.	Reject global mountain inheritance.
P3-F19	Trenches	Predicted terminal, bending, descent, or underthrusting structures fail.	Reject global trench inheritance.
P3-F20	Ridges	Predicted ridge locations, opening rates, and age patterns fail.	Reject spreading-system inheritance.
P3-F21	Basins	Predicted basin location, subsidence, fill, or inversion fails.	Reject basin inheritance.
P3-F22	Plateaus	Predicted uplift nodes and support structures fail.	Reject plateau inheritance.
P3-F23	Volcanism	Predicted melt locations, timing, pathways, or composition fail.	Reject event-volcanism assignment.
P3-F24	Terranes and sutures	Predicted trajectories, identities, contacts, or chronology fail.	Reject assembly reconstruction.
P3-F25	Gravity	Required density structure predicts incompatible gravity or geoid signals.	Reject density-inheritance branch.
P3-F26	Seismic structure	Required velocity, attenuation, or anisotropy structures are absent.	Reject deep inheritance branch.
P3-F27	Magnetics	Predicted resetting or remanence conflicts with observations.	Reject thermal or shock history.
P3-F28	Heat flow	Predicted thermal inheritance conflicts with observed heat flow.	Reject thermal branch.

ID	Global claim	Falsifying result	Consequence
P3-F29	Resource prediction	Blind prospectivity maps fail to outperform baselines.	Reject secondary resource claim.
P3-F30	Statistical null	Randomized or opportunity-matched catalogs perform equally well.	Reject special sequence significance.
P3-F31	Selection bias	Performance disappears after search-space and multiple-testing correction.	Reject statistical support.
P3-F32	Counterfactual necessity	Removing event inheritance leaves the global solution unchanged.	Reject primary causal organization.
P3-F33	Leave-one-event-out	Claimed major events have negligible marginal contribution.	Reject those events as necessary.
P3-F34	Held-out prediction	The model fails withheld regions, structures, data types, or time intervals.	Reject predictive generality.
P3-F35	Advance prediction	Registered predictions fail beyond stated uncertainty.	Reject predictive extension.
P3-F36	Identifiability	Many incompatible event sequences fit equally well.	Reject unique causal reconstruction.
P3-F37	Complexity	The model requires structure-by-structure events, lags, thresholds, or corrections.	Reject causal compression.
P3-F38	Numerical robustness	The solution changes materially with mesh, timestep, solver, or reconstruction choice.	Reject numerical result.
P3-F39	Independent replication	Independent teams cannot reproduce the principal results.	Reject reproducibility claim.
P3-F40	Comparison model	The comparison model explains the global observation vector better with fewer assumptions.	Reject replacement preference.
P3-F41	Complete global viability	Every preregistered eligible sequence has an empty complete Paper-III viable set.	Reject the global astro-ballistic organization claim while retaining independently viable regional event claims.

ID	Global claim	Falsifying result	Consequence
P3-F42	Paper-IV global eligibility	No common global event model survives for direct comparison.	Paper IV records failure of the global replacement model family; regional and complementary comparisons remain separately eligible.

62.1 Global Non-Detection and Comparison Rule

Absence of a predicted boundary, deep anomaly, motion change, or surface structure becomes a hard falsifier only when the feature was frozen with a minimum detectable magnitude and the held-out observation had adequate resolution. Comparative underperformance removes or reduces replacement preference; it rejects the underlying event or regional claim only when a mandatory prediction of that exact claim is directly contradicted.

62.2 No Cross-Compensation

A successful resource prediction cannot compensate for failed plate motion.

A favorable mountain alignment cannot compensate for failed chronology.

A regional trench fit cannot compensate for an empty global boundary set.

A statistically favorable pattern cannot compensate for mechanical impossibility.

62.3 Compartmentalized Failure

Failure of one event does not automatically reject every proposed event.

Failure of one regional structure does not automatically reject every regional event contribution.

A completed empty union across all frozen eligible sequences rejects the global astro-ballistic organization claim developed in Paper III. An uncomputed set, an unfrozen threshold, or incomplete observation coverage remains unresolved rather than empty.

63 Independent Replication Protocol

63.1 Replication Levels

63.1.1 Level R1: Event and Source Audit

The reviewer reproduces:

- event catalog;
- event coordinates;

- event ages;
- target definitions;
- source provenance;
- selection history;
- and rejected alternatives.

63.1.2 Level R2: Paleogeographic Reconstruction

The reviewer reproduces:

- plate lineages;
- finite rotations;
- continental domains;
- terrane identities;
- event-time coordinates;
- reference-frame transformations;
- and reconstruction uncertainty.

63.1.3 Level R3: Boundary Network

The reviewer reproduces:

- boundary-nucleation fields;
- thresholding;
- connectivity;
- plate enclosure;
- boundary types;
- propagation;
- reactivation;
- and topology scores.

63.1.4 Level R4: Plate Motion

The reviewer reproduces:

- event-to-plate impulse mapping;
- plate masses;
- inertia tensors;

- Euler poles;
- force and torque budgets;
- speed hierarchy;
- relative motion;
- and kinematic closure.

63.1.5 Level R5: Surface Structures

The reviewer reproduces:

- mountain predictions;
- trench predictions;
- ridge predictions;
- basin predictions;
- plateau predictions;
- volcanic predictions;
- terrane paths;
- and suture assembly.

63.1.6 Level R6: Global Geophysics

The reviewer reproduces:

- gravity;
- geoid;
- seismic velocities;
- attenuation;
- anisotropy;
- magnetics;
- heat flow;
- and resolution-filtered observables.

63.1.7 Level R7: Statistics and Null Models

The reviewer reproduces:

- randomized catalogs;
- chronology permutations;

- opportunity-matched nulls;
- multiple-testing corrections;
- complexity penalties;
- cross-validation;
- and empirical probabilities.

63.1.8 Level R8: Integrated Viability

The reviewer reproduces:

- component viable sets;
- common parameter intersections;
- posterior overlap;
- complete model score;
- event marginal contributions;
- outcome classification;
- and Paper-IV handoff state.

63.2 Repository Structure

```
abc-paper-iii/
|
|-- manuscript/
|   |-- main.tex
|   `-- figures/
|
|-- sources/
|   |-- source-ledger.csv
|   |-- selection-ledger.csv
|   `-- chronology-ledger.csv
|
|-- inputs/
|   |-- event-catalog/
|   |-- plate-lineages/
|   |-- paleogeography/
|   |-- boundaries/
|   |-- velocities/
|   |-- structures/
|   |-- geophysics/
|   `-- resource-validation/
|
```

```
|-- models/
|   |-- boundary-network/
|   |-- plate-motion/
|   |-- surface-structures/
|   |-- chronology/
|   |-- geophysics/
|   `-- null-models/
|
|-- validation/
|   |-- spatial-holdout/
|   |-- temporal-holdout/
|   |-- leave-one-event-out/
|   |-- leave-one-structure-out/
|   |-- randomized-catalogs/
|   `-- cross-solver/
|
|-- outputs/
|   |-- raw/
|   |-- processed/
|   |-- figures/
|   |-- tables/
|   `-- prediction-registry/
|
|-- ledgers/
|   |-- claim-ledger.csv
|   |-- equation-registry.csv
|   |-- parameter-registry.csv
|   |-- falsification-matrix.csv
|   |-- event-boundary-map.csv
|   |-- event-structure-map.csv
|   `-- dependency-graph.json
|
`-- README.md
```

63.3 Required Metadata

Every reconstruction must report:

- model version;
- data version;
- reference frame;
- coordinate system;
- time convention;

- plate definitions;
- event definitions;
- mechanism branches;
- parameter priors;
- numerical method;
- mesh and time step;
- random seed;
- uncertainty method;
- selection cutoff;
- training data;
- validation data;
- and all failed runs.

63.4 Replication Statuses

Allowed statuses are:

Reproduced
Principal outputs agree within declared tolerances.

Partially reproduced
Some components agree, but one or more global dependencies fail.

Not reproduced
Results do not follow from the declared inputs.

Reference-frame dependent
Results disappear under defensible frame changes.

Selection dependent
Results depend on undisclosed or post hoc choices.

Numerically unstable
Results change under resolution, solver, or timestep tests.

Statistically non-distinct
Null models perform equally well.

Falsified
A predeclared Paper-III rejection condition is triggered.

64 Reconstruction Eligibility Versus Replacement Qualification

A nonempty Paper-III sequence-level viable set establishes only that the registered reconstruction has not yet failed its own mandatory boundary, motion, structural, chronology, and lineage conditions. It does not by itself establish causal dominance or replacement of Plate Tectonics.

Paper IV may classify a surviving sequence as regionally useful, complementary, hybrid-dependent, equivalent, disfavored, or a replacement candidate. Those comparative outcomes do not retroactively empty the Paper-III viable set unless the comparison exposes a genuine Paper-III hard-condition violation or incompatible shared parameter state.

Likewise, one highly favorable regional score cannot compensate for a failed global transfer condition. Eligibility, comparative preference, and replacement qualification remain separate registered states.

65 Integrated Discussion

65.1 Paper III Addresses Organization Rather Than Motion Denial

The existence of continental drift and present plate motion is not the principal dispute.

Paper III asks whether the global placement and directional structure of plates and boundaries can be reconstructed as historical inheritance from a sequenced astro-ballistic event catalog.

65.2 The Replacement Burden Is Global

One compelling regional feature is insufficient.

A replacement framework must connect:

$$\begin{aligned}\text{event mechanics} \to \text{boundary creation} \to \text{plate partition}\\ \to \text{motion} \to \text{surface structures} \to \text{modern observations.}\end{aligned} \tag{1049}$$

Failure at one required link breaks the corresponding causal chain.

65.3 Ancient Impulse Is Not Treated as Perpetual Motion

Paper III does not assume that an ancient impulse remains undiminished for hundreds of millions of years.

The proposed inheritance may persist through:

- directional damage;
- boundary mobility;
- density anomalies;
- thermal anomalies;
- phase anomalies;

- topographic potential;
- buoyancy;
- mantle-flow modification;
- and reinforcement by later events.

Each contribution must be forward modeled.

65.4 Boundary Generation Is the First Global Test

If mechanically admissible events do not create persistent connected material contrasts, the framework cannot generate plates.

Boundary placement, orientation, type, chronology, and topology are therefore primary tests rather than decorative outputs.

65.5 Motion Must Be Generated Rather Than Reassigned

Observed Euler poles and velocities may be used to evaluate the model.

They cannot be inserted as free parameters and then attributed to the event sequence.

The strongest motion test is simultaneous prediction of multiple plates from shared event, inertia, force, resistance, and coupling parameters.

65.6 Surface Structures Are Conditional Outputs

Mountains, trenches, ridges, basins, plateaus, volcanic provinces, terranes, and sutures are not independent confirmation points when they are selected after examining the event geometry.

They become meaningful tests only when generated from the same boundary-and-motion state and evaluated against frozen catalogs.

65.7 Chronology Can Reject Attractive Geometry

A spatially persuasive pattern fails if the material domains were not in the required positions at the proposed time.

Moving-frame paleogeographic reconstruction is therefore decisive.

65.8 Global Geophysics Creates Independent Burdens

A proposed event history modifies:

- density;
- gravity;
- elastic properties;
- seismic velocities;

- anisotropy;
- attenuation;
- magnetization;
- and heat flow.

These fields provide tests independent of surface appearance.

65.9 The Model Must Compress Rather Than Multiply Explanations

A powerful causal model should explain many observations with a limited shared parameter set.

If nearly every boundary, plate, mountain, trench, basin, or volcanic province requires a separate event or correction, the model loses causal compression.

65.10 Regional Success Remains Scientifically Useful

The global replacement claim may fail while individual event-derived hypotheses remain testable.

Possible surviving regional contributions include:

- an inherited boundary;
- a localized damage corridor;
- a basin precursor;
- a volcanic pathway;
- a terrane displacement;
- or a mineralization pathway.

These must be reported as regional findings rather than global replacement.

65.11 Paper III Is an Architecture, Not a Completed Demonstration

The manuscript establishes:

- state variables;
- governing equations;
- reconstruction operators;
- observation vectors;
- counterfactuals;
- null models;
- prediction standards;
- and falsification conditions.

It does not claim that a complete successful numerical reconstruction has already been produced.

66 Limitations of Paper III

66.1 No Validated Complete Event Catalog

The proposed global event sequence remains provisional.

The number, ages, coordinates, directions, and mechanical states of candidate events are not yet independently established.

66.2 Conditional Dependence on Paper II

Paper III depends on mechanically admissible event states from Paper II.

No event excluded by Paper II may be restored solely because it improves the global reconstruction.

66.3 Paleogeographic Uncertainty

Ancient positions, plate identities, terrane locations, internal deformation, and reference frames remain uncertain.

66.4 Boundary Nonuniqueness

Different damage, thermal, stress, and phase fields may produce similar surface boundary patterns.

66.5 Motion Nonuniqueness

Different combinations of gravity, buoyancy, mantle coupling, boundary traction, and inherited impulse may produce similar plate velocities.

66.6 Computational Scale

A complete model requires coupled evolution across:

- planetary dimensions;
- short event timescales;
- long geological timescales;
- nonlinear material behavior;
- changing plate topology;
- and uncertain initial conditions.

66.7 Constitutive Uncertainty

Long-term damage, healing, rheology, phase evolution, permeability, anisotropy, and mantle coupling remain incompletely constrained.

66.8 Observation Dependence

Many geological reconstructions depend on shared datasets and assumptions.

Apparent agreement across multiple outputs may not represent fully independent evidence.

66.9 Preservation Bias

Older event structures may be buried, metamorphosed, deformed, subducted, eroded, or destroyed.

Preservation models remain essential and uncertain.

66.10 Selection Risk

The large number of global features creates substantial risk of post hoc matching.

The selection ledger and blind-prediction program are therefore mandatory.

66.11 Resource-Prediction Limitation

Resource-province prediction is a secondary application and must not be used to bypass failed global mechanics, chronology, or plate reconstruction.

66.12 Replacement Limitation

Paper III tests whether a coherent event-derived global reconstruction can exist.

Direct adjudication against the full explanatory content of plate tectonics belongs to Paper IV.

66.13 Reserved Directionality and Terrain Scope

Additional directionality and material-displacement hypotheses are intentionally reserved for later studies so that the present reconstruction can be judged on its declared event sequence rather than on an expanding set of map correspondences. This is a limitation on current coverage, not an invitation to infer missing events. Reserved hypotheses provide no support until preregistered, and mandatory observation classes for eventual global replacement remain mandatory.

67 Conclusions

67.1 Conclusion 1: Plate Motion Is Accepted

The framework accepts measured continental and plate motion.

The causal challenge concerns the historical origin and organization of the global plate-boundary and motion system.

67.2 Conclusion 2: Mechanical Admissibility Comes First

Every Paper-III event input must survive Paper II.

A favorable global fit cannot validate a mechanically excluded event.

67.3 Conclusion 3: Boundaries Must Emerge

Astro-ballistic forcing must generate persistent connected material contrasts capable of enclosing realistic plate and block domains.

67.4 Conclusion 4: Motion Must Be Predicted

Plate translations, Euler poles, relative directions, and speed hierarchies must emerge from event impulse, plate inertia, force, torque, boundary mobility, gravity, buoyancy, and mantle coupling.

67.5 Conclusion 5: Ancient Impulse Is Only One Contribution

Long-duration inheritance may persist through event-modified boundary, density, thermal, phase, and mantle states.

The model does not rely on unattenuated ancient momentum.

67.6 Conclusion 6: Surface Structures Are Coupled Outputs

Mountains, trenches, ridges, basins, plateaus, volcanic provinces, terranes, and sutures must be generated by the same viable boundary and motion solution.

67.7 Conclusion 7: Paleogeography Is Decisive

Event paths and target relationships must be tested using reconstructed material domains at event time.

Present-coordinate alignment alone is insufficient.

67.8 Conclusion 8: Chronology Can Falsify the Sequence

Boundary formation, plate fragmentation, mountain growth, trench development, basin evolution, volcanism, and terrane assembly must occur in a causally consistent temporal order.

67.9 Conclusion 9: Deep Geophysics Supplies Independent Tests

A completed event-sequence model would generate gravity, geoid, seismic-velocity, attenuation, anisotropy, magnetic, and heat-flow outputs.

Once frozen before validation, those outputs can test and potentially reject visually persuasive surface reconstructions.

67.10 Conclusion 10: Statistical Flexibility Must Be Penalized

The number of tested coordinates, ages, structures, mechanisms, reference frames, and revisions must be included in model evaluation.

67.11 Conclusion 11: Advance Predictions Are Required

The framework must predict withheld structures, subsurface corridors, geophysical anomalies, chronology, or resource provinces before those observations are revealed.

67.12 Conclusion 12: Global Viability Requires One Shared Model

For one frozen eligible sequence $\mathcal{S}$, the decisive object is

$$\begin{aligned} \mathcal{V}_{\mathrm{III},\mathcal{S}} = & \left[\bigcap_{k\in\mathcal{S}} (\mathcal{V}_{I,k} \cap \mathcal{V}_{II,k})\right] \cap \mathcal{V}_{B,\mathcal{S}} \cap \mathcal{V}_{V,\mathcal{S}} \cap \mathcal{V}_{S,\mathcal{S}} \\ & \cap \mathcal{V}_{C,\mathcal{S}} \cap \mathcal{V}_{T,\mathcal{S}} \cap \mathcal{V}_{G,\mathcal{S}} \cap \mathcal{V}_{N,\mathcal{S}} \cap \mathcal{V}_{P,\mathcal{S}}. \end{aligned} \tag{1050}$$

The Paper-III model-family viable set is the union over preregistered eligible sequences. Separate regional successes do not constitute one global causal solution, and failure of one sequence does not reject an independently specified surviving sequence.

67.13 Final Paper-III Statement

Astro-Ballistic Chronostratigraphic Sequencing remains a global causal-replacement candidate only if one chronologically ordered and mechanically admissible event sequence generates the observed plate-boundary network, plate-motion field, continental displacement history, mountains, trenches, ridges, basins, plateaus, volcanic provinces, terrane assemblies, and deep geophysical structure from shared physical inputs.

A particular sequence fails the Paper-III global reconstruction test if its sequence-specific viable intersection is empty. The Paper-III astro-ballistic model family fails globally only if

$$\mathcal{V}_{\mathrm{III}} = \bigcup_{\mathcal{S}\in\mathfrak{S}_{\mathrm{elig}}} \mathcal{V}_{\mathrm{III},\mathcal{S}} = \varnothing. \tag{1051}$$

If that model-family set is nonempty, Paper IV must determine whether the surviving astro-ballistic model explains the total evidence more accurately, parsimoniously, and predictively than the comparison models.

AI-Assisted Research Disclosure

Artificial-intelligence systems were used as analytical, organizational, equation-formatting, and editorial-assistance tools during manuscript development.

Justin B Fine is the sole human author and is responsible for the selection of claims, scientific framing, interpretation, revisions, source verification, and final publication decisions.

Artificial-intelligence systems are not authors and do not assume scientific responsibility.

Paper V is designed as an AI-supported companion atlas for equation tracking, claim dependencies, data requirements, reproducibility, and falsification.

A Global Time and State Registry

Table 10: Minimum chronology and state registry.

Field	Symbol	Required content
Event age	t_k	Central value, uncertainty, dating basis
Forward time	τ_k	Numerical time coordinate
Pre-event state	$\mathbf{Q}_k^-$	Plates, boundaries, motion, mantle, surface
Post-event state	$\mathbf{Q}_k^+$	Mechanically admissible event output
Handoff time	$t_{h,k}$	Short-time to long-time transition
Reactivation time	$t_{r,k}$	Later loading or event interaction
Time-slice output	$\mathbf{Q}(\tau_q)$	Complete reconstructed planetary state
Uncertainty	$\mathbf{\Sigma}_{T,k}$	Age and correlation structure

B Continental Reconstruction Metric Registry

Table 11: Continental and paleogeographic reconstruction metrics.

Metric	Symbol	Purpose
Centroid distance	$d_{C,i}$	Tests continental position
Shape overlap	$\mathrm{IoU}_{C,i}$	Tests reconstructed geometry
Boundary distance	$d_{C,\mathrm{ASD}}$	Tests perimeter agreement
Adjacency residual	$D_{A,C}$	Tests continental contacts
Rotation residual	$\Delta\theta_{R,i}$	Tests finite rotation
Paleomagnetic residual	$\chi^2_{C,i,\mathrm{PM}}$	Tests orientation and latitude constraints
Material residual	$\chi^2_{C,\mathrm{material}}$	Tests terrane and crustal identity
Chronological residual	$\chi^2_{C,T}$	Tests displacement timing

C Complete Global Observation Vector

The complete Paper-III observation vector is

$$\mathbf{D}_{\mathrm{global}} = (\mathbf{D}_B, \mathbf{D}_V, \mathbf{D}_C, \mathbf{D}_S, \mathbf{D}_T, \mathbf{D}_G, \mathbf{D}_R)\,. \tag{1052}$$

The components contain:

Boundary data
: Location, orientation, type, age, curvature, thickness, motion, and topology.

Motion data
: Present velocities, Euler poles, finite rotations, plate circuits, paleomagnetic constraints, and terrane paths.

Continental data
: Positions, shapes, adjacencies, rotations, material identities, and reconstructed margins.

Surface data
: Mountains, trenches, ridges, basins, plateaus, volcanic provinces, sutures, and terranes.

Chronology data
: Event, boundary, motion, deformation, uplift, descent, volcanism, and assembly ages.

Geophysical data
: Gravity, geoid, seismic velocity, attenuation, anisotropy, magnetics, density, rheology, and heat flow.

Resource-validation data
: Blind mineral-system, basin, fluid-path, and structural-target outcomes.

D Sequence-Wide Null-Simulation Pseudocode

```
INPUT:
    frozen observed datasets
    frozen event catalog
    frozen scoring functions
    frozen model penalties
    number of simulations N

CALCULATE:
    J_observed = score(full proposed event sequence)

FOR r = 1 TO N:

    choose declared null family

    randomize only the causal variables assigned to that null

    preserve required nuisance structure:
        event count
        accessible geological regions
        preservation opportunity
        age distribution where applicable
        plate membership where applicable
```

```
        parameter ranges
        observation masks

    reconstruct:
        event-time geometry
        boundary network
        plate motion
        continental positions
        surface structures
        geophysical fields

    apply:
        identical model fitting rules
        identical penalties
        identical holdout sets
        identical failure rules

    calculate:
        J_null[r]

END FOR

p_null =
    (1 + count(J_null <= J_observed)) / (N + 1)

REPORT:
    full null-score distribution
    feature-specific null distributions
    random seeds
    failed simulations
    sensitivity to null family
```

E Claim, Source, and Selection Audit Template

Table 12: Minimum claim and provenance audit.

ID	**Claim**	**Source or derivation**	**Selection status**	**Test status**
Example	Boundary created by event k	Paper-II state and boundary calculation	Predeclared or exploratory	Untested, supported, or falsified

Every claim must record:

- original source;
- author-derived calculation;
- model prediction;
- external observation;
- uncertainty;
- selection history;
- dependence on other claims;
- and direct falsifier.

F Figure and Table Production Registry

Table 13: Minimum Paper-III visual-production registry.

ID	Planned visual	Required input
F3-01	Five-paper series architecture	Frozen paper dependency structure
F3-02	Event chronology and dependency graph	Event and structure age ledger
F3-03	Event-derived global boundary network	Boundary-nucleation outputs
F3-04	Plate-lineage graph	Fragmentation, merger, and transfer data
F3-05	Predicted and observed Euler poles	Motion-model outputs
F3-06	Plate-speed hierarchy	Predicted and observed plate speeds
F3-07	Continental reconstruction time slices	Paleogeographic ensemble
F3-08	Mountain, trench, ridge, and basin maps	Surface forward models
F3-09	Global geophysical anomaly maps	Gravity, seismic, magnetic, heat-flow outputs
F3-10	Null-model score distributions	Randomized sequence simulations
F3-11	Component viable-set intersection	Parameter and posterior outputs
F3-12	Paper-IV comparison handoff	Frozen Paper-III result state

G Paper-IV Handoff

G.1 Purpose

Paper IV performs the direct causal comparison between

$$\mathcal{M}_{\mathrm{ABC}} \tag{1053}$$

and

$$\mathcal{M}_{\mathrm{PT}}. \tag{1054}$$

Paper IV must not compare a fully specified Plate-Tectonic model with an undefined astro-ballistic narrative.

It must compare declared model families using shared observations, uncertainties, complexity penalties, and falsification rules.

G.2 Paper-III Output Package for Paper IV

The Paper-III output package delivered to Paper IV is

$$\mathbf{H}_{III\to IV} = \left(\mathcal{E}^*, \mathcal{V}_{\mathrm{III}}, \widehat{\mathcal{B}}, \widehat{\mathbf{V}}, \widehat{\mathcal{P}}, \widehat{\mathcal{G}}_S, \widehat{\mathbf{D}}_G, \mathcal{J}_{\mathrm{III}}, \mathbf{L}_{\mathrm{claims}}, \mathbf{F}_{\mathrm{fals}}\right). \tag{1055}$$

Here:

$$\mathcal{E}^* = \text{surviving event sequence,} \tag{1056}$$

$$\mathcal{V}_{\mathrm{III}} = \text{complete viable parameter set,} \tag{1057}$$

$$\widehat{\mathcal{B}} = \text{predicted boundary network,} \tag{1058}$$

$$\widehat{\mathbf{V}} = \text{predicted plate-motion field,} \tag{1059}$$

$$\widehat{\mathcal{P}} = \text{predicted continental and plate history,} \tag{1060}$$

$$\widehat{\mathcal{G}}_S = \text{predicted surface structures,} \tag{1061}$$

$$\widehat{\mathbf{D}}_G = \text{predicted geophysical fields,} \tag{1062}$$

$$\mathcal{J}_{\mathrm{III}} = \text{integrated penalized score,} \tag{1063}$$

$$\mathbf{L}_{\mathrm{claims}} = \text{claim ledger,} \tag{1064}$$

$$\mathbf{F}_{\mathrm{fals}} = \text{falsification status.} \tag{1065}$$

G.3 Paper-IV Comparison Questions

Paper IV must determine:

IV-Q1. Which model predicts observed boundaries more accurately?

IV-Q2. Which model predicts relative motion more accurately?

IV-Q3. Which model predicts chronology more accurately?

IV-Q4. Which model predicts mountains, trenches, ridges, and basins more accurately?

IV-Q5. Which model explains deep geophysical fields more accurately?

IV-Q6. Which model makes stronger advance predictions?

IV-Q7. Which model uses fewer effective degrees of freedom?

IV-Q8. Which model requires fewer post hoc assignments?

IV-Q9. Which model better satisfies conservation and physical consistency?

IV-Q10. Does a hybrid model outperform both?

IV-Q11. Is astro-ballistic inheritance primary, complementary, regional, or unnecessary?

IV-Q12. Does the formal replacement thesis survive?

G.4 Causal and Alternative-Model Handoff Record

The Paper-IV handoff must include, for every principal output:

- the highest causal level actually reached;
- the surviving support paths and rejected paths;
- the assumptions and mediator fields required;
- the strongest Plate-Tectonic, regional, null, and hybrid alternatives tested;
- the intervention-validity status;
- and the holdout data not used to construct the event sequence.

Paper IV compares these registered causal objects. It may not infer causal dominance from an aggregate Paper-III fit score that lacks the edge and alternative records above.

G.5 Handoff Failure

If

$$\mathcal{V}_{\mathrm{III}} = \varnothing, \tag{1066}$$

Paper IV must record that no preregistered eligible global sequence survived for direct replacement comparison.

This rejects the global replacement model family evaluated by Paper III, not every regional event hypothesis, mechanism branch, or alternate future model version. Regional event hypotheses may still be compared separately.

H Paper-III Production Checklist

Before release, Paper III requires:

1. complete LaTeX compilation;
2. equation-reference audit;
3. notation audit;
4. consistency audit against Papers I and II;
5. verified event catalog;
6. verified chronology ledger;
7. paleogeographic reconstruction ensemble;
8. plate-lineage dataset;
9. frozen boundary catalog;
10. frozen velocity catalog;
11. frozen surface-structure catalog;
12. frozen global geophysical datasets;
13. source and selection ledger;
14. complete parameter registry;
15. complete numerical model;
16. convergence and conservation tests;
17. null-model simulation;
18. spatial and temporal cross-validation;
19. leave-one-event-out testing;
20. registered advance predictions;
21. independent replication;
22. external literature verification;
23. integrated model comparison preparation;
24. final claim-status update;
25. and frozen Paper-IV handoff package.

Paper-III Freeze Status and Handoff

Corpus Freeze 1.0 fixes the Paper-III reconstruction architecture and its handoff contract. A complete global numerical reconstruction remains unresolved.

The downstream adjudication paper in the frozen series is:

Astro-Ballistic Chronostratigraphic Sequencing IV

Astro-Ballistic Chronostratigraphic Sequencing Versus Plate Tectonics

Direct Causal Comparison, Explanatory Coverage, Model Complexity, Prediction, and Replacement Adjudication

Paper IV defines the adjudication required to determine whether the event-derived framework is:

- mechanically incompatible;
- regionally useful;
- complementary to Plate Tectonics;
- a causal organizer of selected global structures;
- or a defensible primary replacement candidate.

References

The external references below support conventional scientific context, standard methods, and comparison requirements. Their inclusion does not imply endorsement or independent verification of Astro-Ballistic Chronostratigraphic Sequencing.

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