Astro-Ballistic Chronostratigraphic Sequencing V

Claims, Equations, Data, and Falsification Atlas

An AI-Supported Companion for Verification, Reproducibility, Dependency Tracking, and Independent Testing

A Companion to Papers I Through IV

Not an Additional Causal Argument

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Series: Astro-Ballistic Chronostratigraphic Sequencing

Paper: V of V

Function: Verification and reproducibility companion

Authorship: Sole human author: Justin B Fine

AI status: Analytical and organizational assistance only

Version: Canonical Corpus Freeze 1.0

Freeze ID: ABC-CF1-2026-08-07

Date: August 7, 2026

Canonical Corpus Freeze Notice

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

`ABC-CF1-2026-08-07`

and its freeze date is August 7, 2026. The freeze fixes the current manuscript wording, equations, citations, epistemic statuses, dependencies, falsifiers, and declared scope. It does not upgrade any item marked unresolved, not established, disfavored, not yet executed, draft, or to-be-preregistered into empirical support. Any substantive scientific revision requires a new corpus version and a new freeze identifier.

Declaration of Function

Papers I–IV contain the scientific claims, equations, model outputs, comparisons, and replacement criteria. Paper V does not create a separate fifth causal case. It creates the inspection system through which that four-paper scientific core is audited inside the five-paper corpus.

Its governing relationship is

$$\boxed{\text{Claim} \rightarrow \text{Equation} \rightarrow \text{Assumption} \rightarrow \text{Parameter} \rightarrow \text{Data} \rightarrow \text{Test} \rightarrow \text{Falsifier}} \tag{1}$$

The atlas must show what each item is, where it appears, what supports it, which dependencies it requires, how it is tested, what would change its status, and which downstream claims would be affected by failure.

Paper-V mandate.
The atlas may organize, trace, calculate, cross-reference, and expose missing or contradictory dependencies. It may not transform an assumption into an observation, a model output into evidence, a geometric relationship into a causal result, an unresolved item into a supported conclusion, or a machine summary into final scientific judgment.

Source Status and Citation Policy

External references in this manuscript support standard measurements, regional geological context, governing methods, comparison-model components, and reproducibility requirements. They do not independently verify the proposed astro-ballistic event assignments, event sequence, or replacement thesis unless a source is explicitly identified as a direct test of those claims.

Internal Ontomics manuscripts and author working documents establish provenance for the development of the hypothesis. They are not treated as independent scientific confirmation. Calculations derived in this manuscript are cited to their declared inputs and equations rather than to an external authority. External chronology is used to constrain dated observations and marker compatibility; it is not imported as a substitute causal narrative. A potential conflict that would materially alter the framework is registered for explicit author review before it is promoted into the manuscript as a conclusion.

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

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

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.

Corpus-Wide Epistemic Status

At the current corpus freeze:

- selected present-coordinate calculations are `CALCULATION-VERIFIED`;
- source passages may be `SOURCE-VERIFIED` without independently supporting the source hypothesis;
- mechanical, historical, reconstruction, replacement, and advance-prediction claims remain `UNRESOLVED` or `UNTESTED` unless a more specific record states otherwise;
- architecture and requirement statuses record completed model specification, not empirical validation; and
- Paper V records and propagates status but may not upgrade it.

The authoritative status of any item is its complete multiaxial record, not a single favorable adjective in narrative prose.

Prediction, Falsification, and Decision-Threshold Convention

This manuscript distinguishes a failed prediction, a triggered falsifier, failure to establish a preferred model, and lack of adequate data. Those outcomes are not interchangeable.

Prediction Classes

Model outputs are classified as:

Reconstruction or retrodiction

The output is fitted to, selected with, or evaluated against evidence already available during model construction.

Internal holdout prediction
: A portion of the existing corpus is withheld before fitting and is evaluated only after the model version, parameters, and score are frozen.

External holdout prediction
: The model is frozen before an independently maintained dataset is opened or supplied to the analysis.

Prospective prediction
: The model specifies an outcome before the relevant observation is collected or becomes available.

Negative prediction
: The model declares where, when, or in which observation class the predicted structure should not occur.

Only frozen internal holdouts, external holdouts, and prospective tests may contribute to confirmatory predictive status. A known observation cannot become an advance prediction through later relabeling.

Threshold Classes

Every threshold must be assigned one of the following classes:

T0: physical identity or hard admissibility condition
: A conservation law, sign condition, bounded state variable, or other mandatory physical relationship. A numerical tolerance used to test the identity must still be justified by solver and measurement error.

T1: measurement or resolution threshold
: A threshold derived from instrument sensitivity, observational uncertainty, numerical convergence, or a verified detection limit.

T2: exploratory or source-working threshold
: A historical, illustrative, sensitivity, or screening value. It may organize analysis but cannot by itself support a confirmatory claim.

T3: confirmatory claim threshold
: A claim-specific threshold frozen before the confirmatory data are inspected and justified by uncertainty, calibration, power, or a declared loss function.

T4: comparative decision threshold
: An equivalence, superiority, necessity, complexity, or replication threshold frozen before final model ranking.

An unspecified T3 or T4 threshold remains `TO-BE-PREREGISTERED`. This manuscript does not invent a numerical cutoff merely to complete a decision table.

Decision States

The allowed evidentiary outcomes are:

Unresolved
: The test has not been completed, the threshold is not frozen, or the available data are insufficient.

Not established
: The evidence does not meet the burden for confirmation, preference, necessity, or replacement. This does not by itself prove the model false.

Disfavored
: Valid comparative evidence shifts support away from the target, but no mandatory contradiction has yet been demonstrated.

Rejected or falsified
: A valid completed test crosses a frozen rejection threshold for a mandatory condition of the declared target.

Failure to reject a null is not confirmation. Failure to achieve superiority is not automatically falsification. Absence of a predicted feature is a hard negative result only when the model predicted sufficient detectability and the observation had adequate sensitivity.

Hard-Rejection Gate

For target claim or model node i, hard rejection requires

$$I_i^{\text{hard}} = I_{\text{tested}} I_{\text{valid}} I_{\text{mandatory}} I_{\text{threshold frozen}} I_{\text{adequate sensitivity}} = 1 \tag{2}$$

and the frozen rejection condition must be crossed. If any factor is zero, the appropriate state is unresolved, data-insufficient, or not established rather than falsified.

Scoped Consequence Rule

Every falsifier must identify:

1. the exact target;
2. the scope of the test;
3. the prediction or requirement being evaluated;
4. the threshold class and frozen threshold;
5. the direct consequence;
6. the required downstream dependencies that inherit the result;
7. and the neighboring claims, branches, events, sequences, or model versions that remain unaffected.

A failed branch does not reject alternate branches. A failed event does not reject independent events. A failed sequence does not reject every eligible sequence. Failure to qualify as a global replacement does not erase surviving calculations, regional claims, or complementary model contributions.

Causal-Chain, Assumption, and Alternative-Explanation Convention

This manuscript treats a causal claim as a chain of separately auditable edges rather than as one indivisible narrative. Reproducible geometry, chronological compatibility, physical admissibility, modeled contribution, causal necessity, causal dominance, and replacement qualification are distinct evidentiary levels.

Causal-Claim Levels

The corpus uses the following causal ladder:

`CAUSAL-L0`: association or pattern
: A reproducible spatial, temporal, kinematic, or statistical relationship exists. This level does not establish a mechanism.

`CAUSAL-L1`: temporal compatibility
: The proposed cause can precede the proposed effect within declared age and reconstruction uncertainty.

`CAUSAL-L2`: mechanistic admissibility
: At least one physically specified mechanism survives conservation, constitutive, numerical, and planetary constraints.

`CAUSAL-L3`: modeled contribution
: Controlled intervention, ablation, or counterfactual analysis shows that the proposed component materially changes the target output.

`CAUSAL-L4`: causal necessity
: The target performance cannot be recovered by a coherent model in which the proposed component is removed or replaced by a declared alternative.

`CAUSAL-L5`: primary or dominant causation
: The proposed component supplies the principal explanatory work under shared data, uncertainty, physical constraints, and complexity accounting.

`CAUSAL-L6`: replacement qualification
: The frozen model family satisfies the complete Paper-IV replacement standards, including held-out prediction and replication.

A claim may not inherit a higher causal level merely because a later paper discusses a larger model. Each level requires its own evidence.

Causal-Edge Record

For a proposed edge from state or claim node u to node v, define

$$\mathbf{e}_{u\to v} = \left(u, v, \mathcal{M}_{uv}, \mathbf{A}_{uv}, \mathbf{D}_{uv}, \mathbf{T}_{uv}, \mathbf{X}_{uv}, s_{uv}\right), \tag{3}$$

where $\mathcal{M}_{uv}$ is the proposed mechanism or transformation, $\mathbf{A}_{uv}$ is its assumption set, $\mathbf{D}_{uv}$ is the data used to test it, $\mathbf{T}_{uv}$ is the test and threshold record, $\mathbf{X}_{uv}$ is the registered alternative-explanation set, and s_{uv} is the edge status.

Allowed edge statuses include `PROPOSED`, `FORMULATED`, `SIMULATED`, `SUPPORTED`, `NOT-ESTABLISHED`, `DISFAVORED`, `REJECTED`, and `UNRESOLVED`.

Multiple Causal Paths and Non-Domino Failure

For claim c, let $\mathfrak{P}_c$ be the preregistered set of admissible support paths. Its causal viable set is

$$\mathcal{V}_{\text{causal},c} = \bigcup_{p \in \mathfrak{P}_c} \bigcap_{e \in p} \mathcal{V}_e. \tag{4}$$

Failure of one mandatory edge rejects the path that requires it. It does not reject a separately specified path whose required edges remain viable. A claim-level causal mechanism is rejected only after every frozen admissible path has been validly tested and the union is empty. An untested edge produces an unresolved path, not an empty set by assumption.

Assumption Classes and Intervention Validity

Every assumption must be classified as structural, physical, constitutive, initial or boundary state, chronological, measurement, preservation or detectability, statistical, computational, selection related, or comparison related.

For a loss $\mathcal{L}$, where lower is better, the formal ablation contrast for assumption or component a_i is

$$\Delta\mathcal{L}^{\text{abl}}_{a_i} = \mathcal{L}\left(\mathcal{M} \setminus a_i\right) - \mathcal{L}\left(\mathcal{M}\right). \tag{5}$$

This contrast is interpretable only when $\mathcal{M} \setminus a_i$ remains a coherent model with valid initial conditions and governing equations. Removing a defining physical law and leaving an impossible residual system is not a valid causal intervention. Such a result is labeled `ABLATION-INVALID`, not evidence of necessity.

Alternative-Explanation Requirement

Every principal causal claim must register, where applicable:

- a selection-aware coincidence or null explanation;
- a measurement, reconstruction, or target-definition artifact;
- a regional non-event geological explanation;
- a strongest defensible Plate-Tectonic explanation;
- an event-compatible but non-unique explanation;
- a pre-existing-structure or reactivation explanation;

- and a hybrid explanation combining inherited event effects with later geodynamics.

Alternatives must use the same observation domain, uncertainty rules, data partition, physical constraints, and effective-complexity audit. A weak or undefined comparison model cannot establish causal superiority. Conversely, unresolved questions in a comparison model do not supply positive evidence for the target model.

Confounding, Equifinality, and Circularity

A fitted pattern may be produced by multiple causal histories. The audit must therefore identify confounders, mediator variables, interchangeable mechanisms, and parameter compensation. Observations used to select an event, coordinate, boundary, or mechanism may test internal fit but may not be counted again as independent predictive confirmation.

No causal arrow is completed by spatial proximity, chronological compatibility, an equation written without calibrated inputs, or a simulation that was tuned to the same target it is said to predict.

Authorship and AI-Assistance Disclosure

Justin B Fine is the sole human author of the five-paper series.

Artificial-intelligence systems were used as:

- organizational tools;
- equation-formatting tools;
- analytical-assistance tools;
- consistency-checking tools;
- drafting and editorial-assistance tools;
- registry-design tools;
- and research-navigation tools.

Artificial-intelligence systems are not scientific authors.

They do not assume responsibility for:

- source accuracy;
- scientific validity;
- model selection;
- interpretation;
- claim approval;
- publication;
- or final conclusions.

Every AI-assisted entry remains subject to:

- human review;
- source verification;
- mathematical verification;
- computational reproduction;
- and independent scientific evaluation.

Abstract

This paper presents the Claims, Equations, Data, and Falsification Atlas for the five-paper Astro-Ballistic Chronostratigraphic Sequencing corpus and serves as the audit companion to the scientific core in Papers I–IV. It does not add a fifth causal argument. It makes every claim, equation, assumption, parameter, dataset, source, transformation, model output, prediction, test, decision, dependency, and falsifier inspectable at item level.

Paper V defines stable identifiers, provenance and epistemic-status vocabularies, claim and equation schemas, parameter and assumption ledgers, data and source records, prediction and falsification records, causal and dependency graphs, contradiction and supersession rules, bounded failure propagation, and human-readable and machine-readable navigation. It preserves the distinction between source provenance and scientific support: an internally derived item may be reproducible but unsupported; an externally sourced item may remain unverified; a calculation may be correct under an unestablished assumption; and a specified prediction may remain untested.

The atlas grants no validity by inclusion and performs no automated final judgment. Its purpose is to expose what is observed, declared, calculated, simulated, inferred, predicted, unresolved, disfavored, or falsified; what each status depends upon; and what evidence would change it. Local failure remains local unless a registered dependency makes the failed item mandatory for a broader claim. The companion is therefore both the reproducibility layer for the current corpus and the operating specification for a later AI-assisted reader, while final scientific interpretation remains human-controlled.

Keywords

Astro-Ballistic Chronostratigraphic Sequencing; claims atlas; equation registry; assumption ledger; parameter registry; data provenance; source verification; prediction registry; falsification atlas; dependency graph; scientific reproducibility; AI-supported research; causal auditing; Plate Tectonics.

Contents

1 The Companion Mandate

1.1 Canonical Corpus Nomenclature

Paper V treats the following distinctions as authoritative for registry construction:

- *continental drift* and *plate motion* are observation classes;
- Plate Tectonics is the competing causal model family, with *Plate-Tectonic* as the adjectival form;
- an *event catalog* is a registered set of candidate events, whereas an *event sequence* is one chronologically ordered model realization;
- the *flagship candidate relationship* is the Aegean–Everest–Mariana geometry, whereas the *flagship candidate event* is the broader Aegean–Himalayan–Mariana causal assignment;
- *midpoint* denotes geometry, while *midpoint response* denotes a modeled physical or inherited state;
- *terminal response* is the general term; *exit* is retained only as title or source shorthand, or for a branch that explicitly reaches a surface-exit condition;
- *replacement thesis* denotes the proposition under test, while *replacement candidate* denotes a possible post-test classification.

Canonical corpus thesis.
Astro-Ballistic Chronostratigraphic Sequencing accepts observed continental drift and plate motion while challenging Plate Tectonics as the primary causal framework of global crustal organization. The framework proposes that major plate boundaries, plate-motion directions, relative plate velocities, mountain systems, trenches, basins, fracture networks, volcanic provinces, and displaced terranes are inherited and continuing consequences of a sequenced history of large astro-ballistic events.

1.2 Paper V Is an Atlas

Paper V is designed as a structured scientific atlas rather than a continuous fifth argument.

Its primary objects are:

$$\mathfrak{A} = \{\mathfrak{C}, \mathfrak{E}, \mathfrak{AS}, \mathfrak{P}, \mathfrak{D}, \mathfrak{S}, \mathfrak{M}, \mathfrak{R}, \mathfrak{F}, \mathfrak{G}\}\,, \tag{6}$$

where:

$$
\begin{aligned}
\mathfrak{C} &= \text{claim registry}, && (7)\\
\mathfrak{E} &= \text{equation registry}, && (8)\\
\mathfrak{AS} &= \text{assumption registry}, && (9)\\
\mathfrak{P} &= \text{parameter registry}, && (10)\\
\mathfrak{D} &= \text{data registry}, && (11)\\
\mathfrak{S} &= \text{source registry}, && (12)\\
\mathfrak{M} &= \text{model and method registry}, && (13)\\
\mathfrak{R} &= \text{prediction and result registry}, && (14)\\
\mathfrak{F} &= \text{falsification registry}, && (15)\\
\mathfrak{G} &= \text{dependency graph}. && (16)
\end{aligned}
$$

1.3 Inspection Questions

For every principal claim, the atlas should answer:

Q1. What is the exact claim?

Q2. Which paper and section contains it?

Q3. Is it foundational, derived, conditional, comparative, methodological, or negative?

Q4. What is its provenance?

Q5. What is its present epistemic status?

Q6. Has its source been verified?

Q7. Which equations support it?

Q8. Which assumptions does it require?

Q9. Which parameters control it?

Q10. Which data evaluate it?

Q11. Which model version produced it?

Q12. Was it calibrated, reconstructed, predicted, or observed?

Q13. What uncertainty applies?

Q14. What would falsify it?

Q15. Which downstream claims depend on it?

Q16. Has it been independently reproduced?

1.4 No Validity by Inclusion

The presence of an item in the atlas means only that it has been registered.

It does not mean that the item is:

- correct;
- verified;
- independently observed;
- physically admissible;
- statistically significant;
- or accepted.

1.5 No Silent Completion

The companion may not infer or reconstruct deliberately reserved directional, terrain, or material-displacement hypotheses from partial hints in the corpus. It must distinguish an undocumented gap from an intentionally scope-reserved item and may not convert either into supporting evidence.

When a source, derivation, parameter, uncertainty, or test is missing, the atlas must record the missing item.

It must not silently fill the gap with general knowledge or an AI-generated approximation.

1.6 Companion Success Standard

Paper V succeeds when an independent reader can move from any principal claim to:

$$(\text{location}, \text{provenance}, \text{derivation}, \text{inputs}, \text{evidence}, \text{test}, \text{falsifier}, \text{status}) \tag{17}$$

without depending on an undocumented interpretation.

2 Scope and Non-Scope

2.1 Included Functions

Paper V includes:

- exact claim extraction;
- cross-paper claim mapping;
- equation indexing;
- dimensional and symbolic audit;
- assumption extraction;
- parameter tracking;
- source and dataset provenance;
- numerical-result reproduction status;

- prediction registration;
- falsification mapping;
- dependency analysis;
- contradiction detection;
- supersession tracking;
- failure propagation;
- replication status;
- and reader navigation.

2.2 Excluded Functions

Paper V does not itself:

- validate the flagship event;
- validate transmission through Earth;
- establish the global event catalog;
- prove that events created plate boundaries;
- prove that events generated plate motion;
- prove that events generated mountains, trenches, or basins;
- establish causal replacement;
- replace independent simulation;
- replace peer review;
- or replace source verification.

2.3 Reserved-Hypothesis Firewall

The corpus intentionally reserves some additional directional and material-displacement hypotheses for later research. Paper V records the existence and governance of that reserved class without requiring disclosure of coordinates, directions, event identities, or terrain assignments that are not part of the frozen public corpus.

For reserved item q, the minimum governance record is

$$\begin{aligned}\mathbf{R}_q^{\text{reserve}} = \big(&\text{ID}_q, \text{domain class}_q, \text{disclosure level}_q, \text{current dependency}_q,\\ &\text{rescue allowed}_q, \text{current credit}_q, \text{release trigger}_q, \text{status}_q\big).\end{aligned} \tag{18}$$

For the present corpus, scope-reserved items satisfy

$$\text{rescue allowed} = 0, \qquad \text{current credit} = 0, \qquad \text{status} = \texttt{SCOPE-RESERVED}. \tag{19}$$

A reserved item may not be used by the companion to fill a causal gap, infer a missing event, or answer a current claim as though the hypothesis were already published. The companion should return `SCOPE-RESERVED` or `OUTSIDE-CURRENT-CORPUS` instead.

This status is not a scientific result. It is a scope-control state. When a reserved hypothesis is later released, it must receive a new frozen claim record, provenance record, complexity cost, predictions, and falsifiers before it can affect the evidentiary graph.

2.4 Separation From Paper IV

Paper IV defines the formal adjudication between:

$$\mathcal{M}_{\mathrm{PT}}, \qquad \mathcal{M}_{\mathrm{ABC}}, \qquad \mathcal{M}_{\mathrm{HYB}}. \tag{20}$$

Paper V records:

- what Paper IV compares;
- which criteria it uses;
- which evidence enters each criterion;
- which decisions remain unresolved;
- and which results would change the final classification.

2.5 No Automated Final Judgment

The atlas may calculate or display a declared decision rule.

It may not replace scientific judgment with an unexplained automated label.

Any automated status must retain:

- the input record;
- the rule used;
- the threshold used;
- the model version;
- the date;
- and the human approval status.

3 Series Corpus and Authority Order

3.1 Five-Paper Corpus

The atlas covers:

Table 1: Five-paper series corpus.

ID	Paper	Primary burden
P1	*Aegean Entrance, Everest Midpoint, Mariana Exit*	Flagship geometry, chronology, source evidence, statistical structure, and falsification
P2	*Transmission Through a Differentiated Earth*	Entrance coupling, deep-Earth transmission, midpoint-response inheritance, terminal response, survival, and mechanical viability
P3	*From Event Geometry to Continents, Trenches, Mountains, and Basins*	Event-derived plate boundaries, motion, relative velocity, continental displacement, structures, and global reconstruction
P4	*Astro-Ballistic Chronostratigraphic Sequencing Versus Plate Tectonics*	Direct causal comparison, model evidence, complexity, prediction, hybrid testing, and replacement adjudication
P5	*Claims, Equations, Data, and Falsification Atlas*	Verification, dependency tracking, reproduction status, contradiction audit, and independent-test navigation

3.2 Paper-IV Handoff Package

Paper V receives the frozen ledger and dependency package defined by Paper IV:

$$\mathbf{Q}_{V,0} = \left(\mathbf{L}_C, \mathbf{L}_E, \mathbf{L}_D, \mathbf{L}_S, \mathbf{L}_P, \mathbf{L}_F, \mathbf{G}_{\text{dep}}, \mathbf{Q}_{\text{status}}\right). \tag{21}$$

The package is an atlas intake state. It does not upgrade the status of any claim. Every ledger entry must retain the paper, model version, event or sequence index, provenance, uncertainty, and falsification scope from which it was inherited.

3.3 Authority Classes

Define corpus authority levels:

A0: Frozen canonical manuscripts
The approved versions of Papers I through V.

A1: Primary data and primary external sources
Original datasets, measurements, maps, surveys, experiments, and authoritative source publications.

A2: Verified numerical and computational outputs
Reproducible calculations, scripts, simulations, and output ledgers.

A3: Author source documents
White papers, research notes, event catalogs, and internal working documents written or approved by the author.

A4: Superseded manuscript drafts
Earlier versions retained for revision and provenance auditing.

A5: AI-assisted working material
Draft language, organizational suggestions, provisional equations, summaries, and analytical assistance not yet independently verified.

A6: Conversation and process records
Decision history, drafting discussions, unresolved questions, and production notes.

3.4 Authority Does Not Equal Truth

A frozen manuscript has authority over the wording and status of its own claims.

It does not automatically override:

- primary data;
- a verified numerical contradiction;
- a source correction;
- or a failed experiment.

3.5 Conflict Rules

When materials conflict:

CR1. The conflict must be registered.

CR2. The conflicting statements must remain visible.

CR3. The source and version of each statement must be recorded.

CR4. No silent harmonization is permitted.

CR5. A resolution requires an explicit decision record.

CR6. The superseded item remains traceable.

3.6 Source-Control Rule

For an externally sourced factual statement, the verified source controls the factual content.

For an author-derived model statement, the canonical manuscript controls the approved formulation.

For a calculated value, the reproducible calculation controls the number.

For a model status, the frozen decision rule and evidence control the classification.

3.7 Corpus-Freeze Record

The series freeze record is

$$\mathbf{F}_{\text{corpus}} = (v_{P1}, v_{P2}, v_{P3}, v_{P4}, v_{P5}, v_{\text{data}}, v_{\text{code}}, t_{\text{freeze}}) . \tag{22}$$

4 Atlas Ontology

4.1 Typed Atlas Node

Every registered item is a node

$$v_i = (\text{ID}_i, \tau_i, \mathbf{Q}_i, \mathbf{S}_i) , \tag{23}$$

where:

$$\text{ID}_i = \text{stable identifier}, \tag{24}$$
$$\tau_i = \text{entity type}, \tag{25}$$
$$\mathbf{Q}_i = \text{content and metadata}, \tag{26}$$
$$\mathbf{S}_i = \text{status vector}. \tag{27}$$

4.2 Entity Types

The primary entity-type set is

$$\mathcal{T}_V = \{\text{CLM}, \text{EQN}, \text{ASM}, \text{PAR}, \text{DAT}, \text{SRC}, \text{MOD}, \text{MET}, \text{RES}, \text{PRD}, \text{FAL}, \text{FIG}, \text{TAB}, \text{DEC}, \text{REV}\} . \tag{28}$$

These represent:

Table 2: Paper-V atlas entity types.

Code	**Entity**	**Function**
CLM	Claim	A scientific, mathematical, methodological, comparative, or procedural statement
EQN	Equation	A mathematical relationship, operator, definition, or decision rule
ASM	Assumption	A condition accepted for a derivation or model but not derived within that step
PAR	Parameter	A fixed, fitted, inferred, bounded, or uncertain quantity
DAT	Dataset	Measurements, observations, maps, reconstructions, or computational input

Code	Entity	Function
SRC	Source	Publication, document, archive, dataset authority, or provenance item
MOD	Model	A complete or partial physical, statistical, geometric, or comparative model
MET	Method	A calculation, simulation, scoring, inversion, reconstruction, or audit procedure
RES	Result	A calculated, simulated, measured, or comparative output
PRD	Prediction	A frozen claim about evidence not used to construct the model
FAL	Falsifier	A declared condition that rejects a claim, branch, model, or paper
FIG	Figure	A visual representation with traceable data and production method
TAB	Table	A structured presentation of values, classifications, or relationships
DEC	Decision	A human-approved status change, model choice, or adjudication outcome
REV	Revision	A tracked change between document, model, source, or registry versions

4.3 Typed Atlas Edge

A dependency edge is

$$e_{ij} = (v_i, v_j, \tau_{ij}, \mathbf{Q}_{ij}), \tag{29}$$

where τ_{ij} is the relationship type.

4.4 Relationship Types

The primary relationship set is

$$\mathcal{T}_E = \left\{ \begin{array}{l} \mathrm{DERIVES\_FROM}, \mathrm{REQUIRES}, \mathrm{PARAMETERIZED\_BY}, \mathrm{USES\_DATA}, \\ \mathrm{SOURCED\_BY}, \mathrm{CALCULATED\_BY}, \mathrm{PREDICTS}, \mathrm{TESTED\_BY}, \\ \mathrm{FALSIFIED\_BY}, \mathrm{SUPPORTS}, \mathrm{CONFLICTS\_WITH}, \\ \mathrm{SUPERSEDES}, \mathrm{REVISES}, \mathrm{REPLICATES}, \mathrm{DEPENDS\_ON} \end{array} \right\}. \tag{30}$$

4.5 No Untyped Relationship

The statement

Claim A is related to Claim B

is insufficient.

The relationship must be typed.

For example:

- Claim A `REQUIRES` Assumption B;
- Equation A `USES_DATA` Dataset B;
- Result A `SUPPORTS` Claim B;
- Falsifier A `FALSIFIED_BY` Test B;
- Claim A `CONFLICTS_WITH` Claim B.

4.6 Atlas Record

The minimum atlas record is

$$\mathbf{R}_i^A = (\mathrm{ID}, \mathrm{type}, \mathrm{title}, \mathrm{exact\ content}, \mathrm{location}, \mathrm{provenance}, \mathrm{status}, \mathrm{dependencies}, \mathrm{test}, \mathrm{falsifier})\,. \tag{31}$$

5 Stable Identifier System

5.1 Canonical Identifier Grammar

The canonical identifier is

$$\boxed{\texttt{ABC-Pn-TYP-NNN}} \tag{32}$$

where:

- `ABC` identifies the series;
- `Pn` identifies Paper I through Paper V;
- `TYP` identifies the entity class;
- `NNN` is a zero-padded stable sequence number.

5.2 Examples

Table 3: Example canonical atlas identifiers.

Identifier	**Meaning**
`ABC-P1-CLM-001`	First registered Paper-I claim
`ABC-P2-EQN-014`	Fourteenth registered Paper-II equation
`ABC-P3-ASM-006`	Sixth registered Paper-III assumption
`ABC-P4-PRD-009`	Ninth registered Paper-IV prediction
`ABC-P5-FAL-003`	Third registered Paper-V falsification rule
`ABC-X-DAT-001`	Cross-paper dataset used by more than one paper

Identifier	Meaning
ABC-X-DEC-001	Cross-paper decision or supersession record

5.3 Entity Codes

The identifier codes are:

$$\begin{array}{lll} \text{CLM} = \text{claim}, & \text{EQN} = \text{equation}, & \text{ASM} = \text{assumption}, \\ \text{PAR} = \text{parameter}, & \text{DAT} = \text{dataset}, & \text{SRC} = \text{source}, \\ \text{MOD} = \text{model}, & \text{MET} = \text{method}, & \text{RES} = \text{result}, \\ \text{PRD} = \text{prediction}, & \text{FAL} = \text{falsifier}, & \text{FIG} = \text{figure}, \\ \text{TAB} = \text{table}, & \text{DEC} = \text{decision}, & \text{REV} = \text{revision}. \end{array} \tag{33}$$

5.4 Identifier Permanence

Once assigned, an identifier must not be reused.

If an item is removed, it is marked:

$$\texttt{RETIRED} \tag{34}$$

or

$$\texttt{SUPERSEDED}. \tag{35}$$

Its identifier remains reserved.

5.5 Revision Identifiers

A revised item retains its canonical identifier and receives a version:

$$\texttt{ABC-P2-CLM-014-v2}. \tag{36}$$

The previous version remains accessible.

5.6 Cross-Paper Items

An item genuinely shared across papers uses:

$$\texttt{ABC-X-TYP-NNN}. \tag{37}$$

A cross-paper identifier must not be used merely because similar wording appears in multiple papers.

The item must have one shared definition and one shared provenance record.

5.7 Human-Readable Short Form

Within tables, a short form may be used:

$$\texttt{P2-C014}, \quad \texttt{P3-E027}, \quad \texttt{P4-F009}. \tag{38}$$

The canonical machine identifier remains authoritative.

6 Claim Registry

6.1 Claim Definition

A claim is any statement that may affect:

- interpretation;
- model construction;
- evidence classification;
- physical viability;
- prediction;
- falsification;
- or final adjudication.

6.2 Claim Classes

Each claim receives one primary class:

Foundational
A statement required by large portions of the framework.

Observational
A statement about measured or mapped evidence.

Geometric
A statement about distance, angle, path, topology, or spatial relationship.

Mechanical
A statement about force, energy, momentum, material response, or viability.

Chronological
A statement about age, ordering, delay, or historical sequence.

Kinematic
A statement about displacement, velocity, rotation, or strain.

Structural
A statement about mountains, trenches, ridges, basins, plateaus, volcanic provinces, terranes, or boundaries.

Geophysical
: A statement about gravity, seismic structure, magnetics, or heat flow.

Statistical
: A statement about likelihood, significance, null models, or model evidence.

Comparative
: A statement comparing model families.

Methodological
: A statement defining how an analysis must be performed.

Negative result
: A result that excludes, disfavors, limits, or fails to establish a branch.

Procedural
: A statement governing production, verification, replication, or decision rules.

6.3 Exact Claim Requirement

The claim registry must preserve the exact approved claim text.

A summary may be included, but it must not replace the exact statement.

6.4 Claim Record Schema

Each claim record contains:

$$\begin{aligned}\mathbf{C}_i = \big(&\mathrm{ID}_i, \text{exact statement}_i, \text{summary}_i, \text{paper}_i, \text{section}_i,\\ &\text{scope}_i, \text{class}_i, \text{provenance}_i, \text{status}_i, \text{verification}_i,\\ &\text{dependencies}_i, \text{support}_i, \text{uncertainty}_i, \text{test}_i, \text{falsifier}_i,\\ &\text{downstream}_i, \text{replication}_i, \text{notes}_i\big).\end{aligned} \tag{39}$$

6.5 Claim Scope

Scope must be one of:

- local;
- regional;
- multi-regional;
- global;
- branch-specific;
- paper-specific;
- cross-paper;
- or series-level.

6.6 Claim Polarity

Each claim is marked as:

- positive;
- negative;
- conditional;
- comparative;
- or procedural.

6.7 Conditional Claim

A conditional claim must specify its antecedent:

$$A \Rightarrow C. \tag{40}$$

The claim cannot be listed as supported if condition A remains unestablished unless the status explicitly states:

$$\texttt{CONDITIONALLY-SUPPORTED}. \tag{41}$$

6.8 Claim Support Vector

Define

$$\mathbf{S}_{C_i} = (s_{\text{source}}, s_{\text{derivation}}, s_{\text{data}}, s_{\text{test}}, s_{\text{falsifier}}, s_{\text{replication}})_i \,. \tag{42}$$

Each component is reported separately.

The components must not be collapsed into one favorable label when one critical component is absent.

6.9 Claim Completeness Indicator

A registry-complete claim satisfies

$$I_{C_i}^{\text{complete}} = I_{\text{location}} I_{\text{provenance}} I_{\text{dependencies}} I_{\text{test}} I_{\text{falsifier}}. \tag{43}$$

This indicator measures registry completeness, not scientific truth.

6.10 Orphan Claim

A claim is an orphan when it has:

- no source or derivation path;

- no declared assumption path;
- no test;
- or no falsifier.

An orphan claim receives:

$$\texttt{DEPENDENCY-INCOMPLETE}. \tag{44}$$

6.11 Claim Upgrade Rule

A claim status may be upgraded only through a decision record that identifies:

- the previous status;
- the new evidence;
- the new calculation or test;
- the approving human reviewer;
- the date;
- and the new status.

7 Equation Registry

7.1 Equation Scope

The equation registry includes:

- governing equations;
- geometric definitions;
- constitutive laws;
- conservation equations;
- likelihoods;
- score functions;
- decision rules;
- diagnostic ratios;
- scaling relationships;
- and numerical substitutions.

7.2 Equation Record

Each equation record is

$$\begin{aligned}\mathbf{E}_i = \big(&\mathrm{ID}_i, \mathrm{LaTeX}_i, \mathrm{paper}_i, \mathrm{label}_i, \mathrm{role}_i,\\ &\mathrm{source}_i, \mathrm{derivation}_i, \mathrm{assumptions}_i, \mathrm{variables}_i, \mathrm{units}_i,\\ &\mathrm{domain}_i, \mathrm{limits}_i, \text{numerical use}_i, \mathrm{verification}_i,\\ &\text{supported claims}_i, \mathrm{conflicts}_i, \mathrm{notes}_i\big).\end{aligned} \tag{45}$$

7.3 Equation Roles

Equation role is classified as:

- definition;
- identity;
- governing law;
- constitutive model;
- approximation;
- scaling diagnostic;
- likelihood;
- score;
- decision rule;
- or illustrative calculation.

7.4 Dimensional Audit

For equation

$$\mathcal{L} = \mathcal{R}, \tag{46}$$

dimensional consistency requires

$$[\mathcal{L}] = [\mathcal{R}]\,. \tag{47}$$

Each equation receives:

- unit system;
- dimensions of every variable;
- dimensional audit status;
- and any nondimensionalization rule.

7.5 Symbol Uniqueness

A symbol must have one declared meaning within its stated scope.

If a symbol is reused, the registry must distinguish:

$$x^{(P1)}, \qquad x^{(P2)}, \qquad x^{(P3)}, \qquad x^{(P4)}. \tag{48}$$

7.6 Domain of Validity

Each equation must state the conditions under which it applies.

Examples include:

- small deformation;
- rigid plate;
- continuum approximation;
- hydrostatic background;
- constant density;
- incompressible flow;
- Gaussian likelihood;
- independent observations;
- or linear response.

7.7 Limiting-Case Audit

Where applicable, an equation must be checked under:

- zero forcing;
- zero event energy;
- zero damage;
- zero viscosity;
- infinite viscosity;
- zero relative velocity;
- small angle;
- large distance;
- and no-event limits.

7.8 Numerical Reproduction

For numerical result

$$y_i = f(x_1, x_2, \ldots, x_n), \tag{49}$$

the equation registry must include:

- input values;
- units;
- source of each input;
- code or calculation method;
- precision;
- output;
- uncertainty;
- and reproduction status.

7.9 Equation Verification States

Allowed equation-verification states are:

- `TRANSCRIBED`;
- `SYMBOL-AUDITED`;
- `DIMENSION-AUDITED`;
- `DERIVATION-CHECKED`;
- `NUMERICALLY-REPRODUCED`;
- `INDEPENDENTLY-REPRODUCED`;
- `CONDITIONAL`;
- `INCONSISTENT`;
- `SUPERSEDED`.

7.10 Equation Does Not Establish Its Inputs

A mathematically valid equation does not establish that:

- its assumptions apply;
- its parameters are correct;
- its boundary conditions are physical;
- or its model describes the event.

The equation and its input validity must be recorded separately.

8 Assumption and Parameter Registries

8.1 Assumption Definition

An assumption is any condition accepted without being derived within the current analytical step.

8.2 Assumption Classes

Assumptions are classified as:

- physical;
- geometric;
- chronological;
- constitutive;
- statistical;
- computational;
- observational;
- preservation-related;
- comparison-related;
- or procedural.

8.3 Assumption Record

$$\begin{aligned}\mathbf{A}_i = \big(&\mathrm{ID}_i, \mathrm{statement}_i, \mathrm{class}_i, \mathrm{scope}_i, \mathrm{source}_i,\\ &\mathrm{justification}_i, \mathrm{alternatives}_i, \mathrm{sensitivity}_i, \mathrm{dependent\ claims}_i,\\ &\mathrm{test}_i, \mathrm{status}_i, \mathrm{notes}_i\big).\end{aligned} \tag{50}$$

8.4 Explicit and Hidden Assumptions

Every assumption is marked:

- explicit;
- inherited from another paper;
- inherited from a source model;
- discovered during audit;
- or unresolved.

A discovered hidden assumption must be added to the registry rather than silently incorporated.

8.5 Assumption Necessity and Intervention Validity

For a declared loss $\mathcal{L}$, where lower is better, remove or replace assumption a only if the resulting model remains coherent:

$$N_{A,a} = \mathcal{L}_{-a} - \mathcal{L}_{+a}. \tag{51}$$

A positive value indicates that the assumption or its represented component contributes to the registered score. It does not by itself establish that the assumption is true or uniquely causal.

Every intervention is classified as:

- `VALID-REMOVAL`;
- `VALID-REPLACEMENT`;
- `VALID-MEDIATOR-ABLATION`;
- `INVALID-STRUCTURAL-REMOVAL`;
- `INVALID-INITIAL-STATE`;
- `NUMERICALLY-INVALID`;
- or `UNRESOLVED`.

The result then records whether the assumption is essential, influential, weakly influential, redundant, compensable, non-identifiable, or not validly testable by ablation.

8.6 Parameter Definition

A parameter is a quantity whose value influences a model, calculation, test, or decision.

8.7 Parameter Classes

Parameters are classified as:

- measured;
- source-derived;
- calculated;
- fixed by convention;
- physically bounded;
- inferred;
- fitted;
- nuisance;
- branch-specific;

- or exploratory.

8.8 Parameter Record

$$\begin{aligned}\mathbf{P}_i = \big(&\mathrm{ID}_i, \mathrm{symbol}_i, \mathrm{name}_i, \mathrm{definition}_i, \mathrm{units}_i,\\ &\mathrm{value}_i, \mathrm{range}_i, \mathrm{uncertainty}_i, \mathrm{prior}_i, \mathrm{source}_i,\\ &\text{fitted to}_i, \text{shared scope}_i, \mathrm{sensitivity}_i, \mathrm{status}_i,\\ &\text{dependent claims}_i, \mathrm{notes}_i\big).\end{aligned} \tag{52}$$

8.9 Shared Versus Local Parameters

Each parameter is marked as:

- global across the series;
- shared across multiple papers;
- paper-specific;
- model-branch-specific;
- region-specific;
- event-specific;
- or structure-specific.

8.10 Parameter Freeze

A frozen parameter record contains:

$$\mathbf{F}_{P,i} = (\mathrm{value}, \mathrm{range}, \mathrm{prior}, \mathrm{version}, t_{\mathrm{freeze}})\,. \tag{53}$$

8.11 Parameter-Change Rule

Changing a parameter after validation data are examined creates a new model version.

The change must record:

- former value;
- new value;
- reason;
- data visible;
- affected claims;
- and new validation requirement.

8.12 Sensitivity

For output y and parameter θ_i,

$$S_{y,\theta_i} = \frac{\partial \ln y}{\partial \ln \theta_i}. \tag{54}$$

The registry must identify parameters that dominate:

- viability;
- uncertainty;
- model ranking;
- or falsification.

8.13 No Silent Parameter Retuning

The same parameter cannot take different values in different observation classes unless:

- the difference is physically defined;
- the scope is explicit;
- the values are independently constrained;
- and the added flexibility is counted.

9 Causal-Edge, Causal-Path, and Alternative Registries

9.1 Causal-Edge Record

Each causal edge is stored as

$$\begin{aligned}\mathbf{C}_e = \big(&\text{ID}, \text{source}, \text{target}, \text{mechanism}, \text{causal level}, \\ &\text{assumptions}, \text{mediators}, \text{confounders}, \text{datasets}, \text{tests}, \\ &\text{alternatives}, \text{interventions}, \text{thresholds}, \text{status}, \text{version}\big).\end{aligned} \tag{55}$$

A claim that contains multiple arrows must reference multiple edge records. One supported edge cannot silently upgrade its neighbors.

9.2 Causal-Path Record

A path record identifies the ordered edge set, mandatory and optional edges, alternate support paths, path status, failed cut sets, and direct consequence of failure. A path is `SUPPORTED` only when all mandatory edges reach their declared causal level.

9.3 Alternative-Explanation Record

The alternative record is

$$\begin{aligned}\mathbf{X}_j = \big(&\text{ID}, \text{target}, \text{model family}, \text{exact explanation}, \text{scope}, \\ &\text{shared data}, \text{unique predictions}, \text{parameters}, \text{assumptions}, \text{complexity}, \\ &\text{discriminating tests}, \text{ablation tests}, \text{status}, \text{version}\big).\end{aligned} \tag{56}$$

The registry must include null, regional, Plate-Tectonic, astro-ballistic, reactivation, and hybrid alternatives wherever they are scientifically applicable.

9.4 Causal-Level Upgrade Rule

A causal-level upgrade requires:

1. completion of the current-level test;
2. no unresolved mandatory upstream edge;
3. a valid intervention or discriminating test where the next level requires one;
4. comparison against the registered alternative family;
5. and an independent status and version record.

Geometry may not jump directly from `CAUSAL-L0` to causal necessity. Mechanical admissibility may not jump directly to historical occurrence. Fit may not jump directly to causal dominance.

9.5 Alternative-Space Completeness

For target i, define

$$I_{X,i}^{\text{complete}} = \prod_{x \in \mathfrak{X}_i^{\text{required}}} I_x^{\text{registered and tested}}. \tag{57}$$

A causal-dominance or replacement decision is ineligible when this indicator is zero because a required plausible explanation has not been implemented or tested.

10 Chronology, Reconstruction, and Material-Lineage Registries

10.1 Evidence-Origin Classification

Every chronology or paleogeographic item is assigned one origin class:

- `MEASUREMENT-PROXIMAL`;
- `MODEL-DERIVED`;
- `MATERIAL-LINEAGE-HYPOTHESIS`;
- `ABC-PROPOSED`;

- or `UNVERIFIED-SOURCE-MATERIAL`.

A model-derived coordinate or history may not be displayed by the AI companion as though it were a direct observation.

10.2 Chronology Record

Each chronology item receives

$$\begin{aligned}\mathbf{C}_i = \big(&\mathrm{ID}_i, \mathrm{claim}_i, \mathrm{age\ type}_i, a_i, \Delta a_i, \mathrm{dating\ method}_i,\\ &\mathrm{material\ target}_i, \mathrm{event\ relation}_i, \mathrm{reactivation\ relation}_i, \mathrm{source\ class}_i,\\ &\mathrm{required\ ordering}_i, \mathrm{tested\ ordering}_i, \mathrm{dependent\ claims}_i, \mathrm{status}_i\big).\end{aligned} \tag{58}$$

Age types include event, marker, seed, reactivation, expression, deposition, crystallization, metamorphism, cooling, and observation.

10.3 Reconstruction-Branch Record

Each paleogeographic or reference-frame branch receives

$$\begin{aligned}\mathbf{R}_i = \big(&\mathrm{ID}_i, \mathrm{frame}_i, \mathrm{model}_i, \mathrm{version}_i, \mathrm{age\ interval}_i,\\ &\mathrm{input\ constraints}_i, \mathrm{lineage\ assumptions}_i, \mathrm{transform}_i, \mathrm{uncertainty}_i,\\ &\mathrm{calibration\ data}_i, \mathrm{held\ out\ data}_i, \mathrm{dependent\ claims}_i, \mathrm{status}_i\big).\end{aligned} \tag{59}$$

No branch is tagged `GROUND-TRUTH`. A branch may be `REGISTERED`, `TESTED`, `DISFAVORED`, `REJECTED`, or `UNRESOLVED`.

10.4 Material-Lineage Record

Each proposed present-to-past correspondence receives

$$\begin{aligned}\mathbf{L}_i = \big(&\mathrm{ID}_i, \mathrm{present\ domain}_i, \mathrm{candidate\ ancestor}_i, \mathrm{start\ age}_i, \mathrm{end\ age}_i,\\ &\mathrm{transition\ types}_i, \mathrm{supporting\ evidence}_i, \mathrm{missing\ edges}_i, \mathrm{alternatives}_i,\\ &\mathrm{dependent\ geometry}_i, \mathrm{dependent\ mechanics}_i, \mathrm{falsifier}_i, \mathrm{status}_i\big).\end{aligned} \tag{60}$$

The transition types include rotation, deformation, fragmentation, merger, accretion, terrane transfer, subduction, recycling, exhumation, erosion, reactivation, and overprint.

10.5 Human-Review Conflict Gate

When an external source appears to conflict with an ABC claim, the AI companion must first classify the conflict as one of:

- conflict with a measurement-proximal constraint;
- conflict with a model-derived reconstruction;

- conflict with terminology or scope;
- conflict caused by different material-lineage assumptions;
- or apparent conflict requiring author clarification.

A potentially theory-altering conflict is entered into a human-review queue before it is promoted into the manuscript as a conclusion. The queue must state the exact claim, the exact evidence, the assumed lineage, the scope of consequence, and the question requiring resolution. This rule prevents silent import of model-dependent conclusions while preserving direct empirical conflicts for explicit review.

10.6 No Silent External-Causality Import

The atlas may cite external work for measurements, methods, dating, regional observations, and candidate alternatives. It may not silently substitute an external causal narrative for an unimplemented equation or missing test. Likewise, an unresolved external explanation does not count as positive evidence for ABC Sequencing.

11 Data and Source Registries

11.1 Dataset Record

Each dataset receives

$$\begin{aligned}\mathbf{D}_i = \big(&\mathrm{ID}_i, \mathrm{title}_i, \mathrm{owner}_i, \mathrm{version}_i, \text{release date}_i,\\ &\mathrm{content}_i, \text{spatial scope}_i, \text{temporal scope}_i, \mathrm{resolution}_i,\\ &\text{coordinate system}_i, \mathrm{processing}_i, \mathrm{uncertainty}_i, \mathrm{access}_i,\\ &\mathrm{license}_i, \text{origin class}_i, \text{source locator}_i, \text{acquisition date}_i, \text{raw hash}_i,\\ &\text{transformation IDs}_i, \text{unit convention}_i, \text{use class}_i, \text{leakage status}_i, \mathrm{missingness}_i,\\ &\text{dependent claims}_i, \text{archive status}_i, \mathrm{status}_i\big).\end{aligned} \tag{61}$$

11.2 Evidence-Origin Axis

Every dataset, source, parameter, and result receives one primary origin class and may receive secondary lineage tags. The allowed primary classes are:

- `MEASUREMENT-PROXIMAL`;
- `CURATED-PRIMARY-DATASET`;
- `REFERENCE-MODEL`;
- `RECONSTRUCTED-OR-INVERTED`;
- `AUTHOR-DECLARED`;
- `INTERNAL-PROVENANCE`;
- `MANUSCRIPT-DERIVED`;

- `SIMULATED-MODEL-OUTPUT`;
- `INTERPRETIVE-INFERENCE`; and
- `UNVERIFIED-UNAVAILABLE-OR-MISSING`.

Origin class is independent of epistemic status. A widely used reference model remains model-derived. A calculation may be perfectly reproduced while its input selection or causal interpretation remains unresolved.

11.3 Transformation-Lineage Record

For transformation q, define

$$\begin{aligned}\mathbf{T}_q = (&\mathrm{ID}_q, \text{input IDs}_q, \text{operation}_q, \text{software}_q, \text{version}_q, \text{parameters}_q,\\ &\text{unit conversion}_q, \text{coordinate transform}_q, \text{rounding}_q, \text{exclusions}_q, \text{output IDs}_q, \text{hash}_q, \text{review}_q).\end{aligned} \tag{62}$$

Manual transcription, digitization, georeferencing, interpolation, smoothing, resampling, filtering, aggregation, and coordinate conversion are registered transformations.

11.4 Derived-Result Provenance Record

For result r, define

$$\begin{aligned}\mathbf{R}_r^{\text{prov}} = (&\mathrm{ID}_r, \text{input dataset IDs}_r, \text{parameter IDs}_r, \text{equation or method IDs}_r,\\ &\text{transformation IDs}_r, \text{code commit}_r, \text{environment}_r, \text{units}_r, \text{precision}_r,\\ &\text{uncertainty}_r, \text{output hash}_r, \text{status}_r).\end{aligned} \tag{63}$$

A derived result without traceable inputs and a reproducible method remains `UNRESOLVED-PROVENANCE`, even when the numerical value appears plausible.

11.5 Archive, Checksum, and Access Requirements

Every frozen raw file and processed artifact must receive:

- a stable filename and internal ID;
- a cryptographic checksum;
- acquisition or creation date;
- source locator and access condition;
- license or permission status;
- raw-versus-processed designation;
- transformation-parent IDs; and

- an immutable archived copy where legally permitted.

A changed file with the same human-readable title is a new version and must not silently inherit the old verification state.

11.6 Current Corpus Provenance Snapshot

Table 4: Current corpus provenance snapshot.

ID	Item family	Primary origin	Current status
P5-PROV-001	Five ABC manuscripts	Internal provenance and current corpus source	Canonical Corpus Freeze 1.0 manuscripts; not independent confirmation
P5-PROV-002	The Great Dying Challenge and WP List Creation	Internal author working documents	Exact source-file versions and dates remain to be verified
P5-PROV-003	Flagship coordinates and 256 Ma initiating age	Author-declared inputs inherited from internal investigation	Coordinate definitions, uncertainty, and independent age marker remain unresolved
P5-PROV-004	Paper-I geometry values	Manuscript-derived calculations	Reproducible from declared inputs; causal interpretation unresolved
P5-PROV-005	Paper-II energy, speed, fraction, and rheological screens	Internal search ranges and declared assumptions	Exploratory until mechanically derived, calibrated, or independently constrained
P5-PROV-006	External scientific references	Primary publications, reference models, datasets, and methods	Support only the exact measurements, methods, and context registered for each citation
P5-PROV-007	Paper-III and Paper-IV required global datasets	External data families and model-derived reconstructions	Architecture defined; empirical datasets are not yet assembled as a frozen execution package
P5-PROV-008	AI-assisted draft material	Drafting and organizational assistance	Not a scientific source; all retained claims require human authorship and traceable evidence

11.7 Dataset Use Classes

A dataset must be marked as:

- source input;
- calibration;
- reconstruction;
- validation;

- held-out test;
- prospective validation;
- control;
- or illustrative only.

11.8 No Test-Data Leakage

A dataset used to alter:

- event selection;
- parameters;
- model branches;
- thresholds;
- or score definitions

cannot remain labeled as independent test data.

11.9 Source Record

Each source receives

$$\begin{aligned}\mathbf{S}_i = \big(&\mathrm{ID}_i, \mathrm{citation}_i, \mathrm{source\ type}_i, \mathrm{authority}_i, \mathrm{version}_i,\\ &\mathrm{location}_i, \mathrm{exact\ support}_i, \mathrm{quote\ or\ paraphrase}_i, \mathrm{access\ date}_i,\\ &\mathrm{verification}_i, \mathrm{claims\ supported}_i, \mathrm{conflicts}_i, \mathrm{notes}_i\big).\end{aligned} \tag{64}$$

11.10 Source Types

Source type is one of:

- primary measurement;
- primary dataset;
- primary research publication;
- review;
- reference model;
- institutional documentation;
- author white paper;
- author working document;
- manuscript calculation;
- AI-assisted draft material;

- or unverified secondary material.

11.11 Source Support Granularity

A source record should identify:

- page;
- section;
- equation;
- figure;
- table;
- data column;
- or exact passage

where available.

11.12 Source Verification States

Allowed source states are:

- `NOT-LOCATED`;
- `LOCATED`;
- `METADATA-VERIFIED`;
- `PASSAGE-VERIFIED`;
- `DATA-VERIFIED`;
- `CONFLICTING`;
- `PARTIAL-SUPPORT`;
- `NO-SUPPORT`;
- `SUPERSEDED`.

11.13 Source-Derived Does Not Mean Supported

A claim may accurately reproduce an author source document while the source document itself remains speculative.

The atlas must therefore distinguish:

$$\text{faithful source extraction} \tag{65}$$

from

$$\text{independent scientific support.} \tag{66}$$

11.14 Source Conflict

For sources S_i and S_j,

$$\mathcal{C}_{S,ij} = \text{Conflict}\left(S_i, S_j\right). \tag{67}$$

The conflict record must include:

- disputed quantity or statement;
- source authority;
- methodological differences;
- chronology;
- uncertainty;
- and resolution status.

12 Model, Method, and Result Registries

12.1 Model Record

Each model receives

$$\begin{aligned}\mathbf{M}_i = \big(&\text{ID}_i, \text{name}_i, \text{version}_i, \text{purpose}_i, \text{scope}_i,\\ &\text{governing equations}_i, \text{assumptions}_i, \text{parameters}_i, \text{initial conditions}_i,\\ &\text{boundary conditions}_i, \text{data}_i, \text{solver}_i, \text{outputs}_i,\\ &\text{validation}_i, \text{limitations}_i, \text{status}_i, \text{dependent claims}_i\big).\end{aligned} \tag{68}$$

12.2 Method Record

Each method receives

$$\begin{aligned}\mathbf{H}_i = \big(&\text{ID}_i, \text{name}_i, \text{algorithm}_i, \text{inputs}_i, \text{outputs}_i,\\ &\text{assumptions}_i, \text{software}_i, \text{version}_i, \text{precision}_i,\\ &\text{validation}_i, \text{failure modes}_i, \text{status}_i\big).\end{aligned} \tag{69}$$

12.3 Result Record

Each result receives

$$\begin{aligned}\mathbf{R}_i = (&\mathrm{ID}_i, \mathrm{statement}_i, \mathrm{value}_i, \mathrm{uncertainty}_i, \mathrm{units}_i,\\ &\mathrm{model}_i, \mathrm{method}_i, \mathrm{inputs}_i, \mathrm{code}_i, \mathrm{run}_i,\\ &\mathrm{reproduction}_i, \mathrm{claims\ supported}_i, \mathrm{status}_i).\end{aligned} \tag{70}$$

12.4 Negative Results

Negative results must be registered.

Examples include:

- empty viable sets;
- failed geometry;
- failed chronology;
- failed conservation;
- null-model equivalence;
- unsupported branch selection;
- and failure to reproduce.

12.5 Failed Runs

A failed computational run is not deleted from the audit record.

Its record must include:

- model version;
- parameter set;
- failure mode;
- solver message;
- physical interpretation;
- and whether the failure excludes a parameter region.

12.6 Result-to-Claim Rule

A result supports a claim only through an explicit edge:

$$\mathrm{RES} \xrightarrow{\mathrm{SUPPORTS}} \mathrm{CLM}. \tag{71}$$

The edge must state:

- strength of support;
- scope;

- assumptions;
- uncertainty;
- and competing interpretations.

13 Prediction Registry

13.1 Prediction Definition

A prediction is a model output frozen before the relevant validation evidence is used to construct or alter the model.

13.2 Prediction Record

Each prediction receives

$$\begin{aligned}\mathbf{P}_i^{\text{pred}} = \big(&\text{ID}_i, \text{exact prediction}_i, \text{model}_i, \text{version}_i, \text{freeze date}_i,\\ &\text{data cutoff}_i, \text{target}_i, \text{location}_i, \text{depth}_i, \text{age}_i,\\ &\text{magnitude}_i, \text{direction}_i, \text{uncertainty}_i, \text{control}_i,\\ &\text{scoring rule}_i, \text{validation data}_i, \text{outcome}_i, \text{status}_i\big).\end{aligned} \tag{72}$$

13.3 Prediction Classes

Predictions are classified as:

- spatial;
- directional;
- chronological;
- quantitative;
- categorical;
- structural;
- geophysical;
- negative;
- or comparative.

13.4 Prediction Specificity

For prediction domain $\mathcal{D}_P$ and total eligible domain $\mathcal{D}_E$, define specificity

$$S_{\text{spec}} = 1 - \frac{\text{Measure}\,(\mathcal{D}_P)}{\text{Measure}\,(\mathcal{D}_E)}. \tag{73}$$

A broad prediction covering most eligible outcomes receives less evidentiary weight.

13.5 Prediction Statuses

Allowed prediction statuses are:

- `DRAFT`;
- `FROZEN`;
- `AWAITING-DATA`;
- `PARTIALLY-TESTED`;
- `SUPPORTED`;
- `FAILED`;
- `AMBIGUOUS`;
- `INVALIDATED-BY-LEAKAGE`;
- `SUPERSEDED`.

13.6 No Retroactive Prediction

An observation already known or used in model development cannot later be labeled an advance prediction.

It may be labeled:

$$\texttt{RETRODICTION} \tag{74}$$

or

$$\texttt{RECONSTRUCTION.} \tag{75}$$

13.7 Prediction Outcome

Prediction outcome must report:

- exact observed value;
- uncertainty;
- comparison with the prediction;
- score;
- whether the test was independent;
- and whether the model changed afterward.

14 Falsification Registry

14.1 Falsifier Definition

A falsifier is a declared condition under which a claim, model branch, model family, paper-level thesis, or series-level thesis is rejected or downgraded.

14.2 Falsifier Record

Each falsifier receives

$$\begin{aligned}\mathbf{F}_i = \big(&\mathrm{ID}_i, \mathrm{target}_i, \mathrm{scope}_i, \mathrm{condition}_i, \mathrm{measurement}_i,\\ &\mathrm{threshold}_i, \mathrm{uncertainty}_i, \mathrm{test}_i, \mathrm{data}_i, \text{decision rule}_i,\\ &\mathrm{consequence}_i, \mathrm{propagation}_i, \mathrm{unaffected}_i, \mathrm{status}_i, \text{decision record}_i\big).\end{aligned} \tag{76}$$

14.3 Falsifier Scopes

A falsifier is classified as:

- parameter-set;
- equation;
- assumption;
- mechanism branch;
- regional claim;
- event;
- event sequence;
- paper-level thesis;
- global model version;
- comparative model;
- replacement thesis;
- or entire series.

14.4 Threshold-Class Registry

Each falsifier record must identify one threshold class:

$$\kappa_i^T \in \{T0, T1, T2, T3, T4\}\,. \tag{77}$$

T2 working thresholds may report sensitivity but cannot independently trigger confirmatory rejection. T3 and T4 thresholds must preserve the freeze date, rationale, calibration or power basis, model version, and data cutoff. A threshold entered after inspection is `POST-HOC` and cannot support a confirmatory decision.

14.5 Hard Falsifiers, Downgrading Conditions, and Missing Evidence

A hard falsifier has the form

$$I_i^{\text{hard}} = 1 \quad \text{and} \quad T > T_{\text{crit}} \Rightarrow \text{reject declared target.} \tag{78}$$

A soft falsifier or downgrading condition has the form

$$T > T_{\text{warn}} \Rightarrow \text{reduce status or confidence.} \tag{79}$$

Missing data, an unexecuted simulation, an unfrozen threshold, or a failed attempt to establish superiority has the form

$$I_i^{\text{hard}} = 0 \Rightarrow \text{unresolved or not established,} \tag{80}$$

not *reject target*. The three outcomes must not be conflated.

14.6 Decision Outcome Vocabulary

Status-changing decisions use the following distinct outcomes:

- `UNTESTED`;
- `DATA-INSUFFICIENT`;
- `UNRESOLVED`;
- `NOT-ESTABLISHED`;
- `DISFAVORED`;
- `REJECTED`;
- `FALSIFIED`;
- `SUPPORTED`;
- `REPLICATED`.

`NOT-ESTABLISHED` is used when a higher evidentiary burden, such as causal necessity, superiority, or replacement, is not met without a direct contradiction of the underlying model.

14.7 Falsifier Status

Allowed states are:

- `DEFINED`;

- `TEST-READY`;
- `TESTED-NOT-TRIGGERED`;
- `TRIGGERED`;
- `PARTIALLY-TRIGGERED`;
- `DATA-INSUFFICIENT`;
- `INVALID-TEST`;
- `SUPERSEDED`.

14.8 No Cross-Failure Inflation

A triggered falsifier rejects only its declared target and downstream claims whose required support paths depend on that target.

It does not automatically reject:

- unrelated regional claims;
- alternate mechanism branches;
- alternate event assignments;
- alternate event sequences;
- or future model versions that do not require the failed node.

A paper-level failure means failure of that paper's declared thesis, not erasure of every calculation, negative result, regional observation, or method contained in the paper.

14.9 No Falsifier Evasion

A falsifier cannot be avoided by:

- changing the claim after the test;
- narrowing the scope after failure;
- changing the threshold after inspection;
- replacing the model version without recording the failure;
- or reclassifying the failed prediction as illustrative.

14.10 Failure Propagation

If target node v_i fails, the affected descendant set is

$$\mathrm{Desc}\left(v_i\right) = \left\{v_j : v_i \rightsquigarrow v_j\right\}. \tag{81}$$

Only descendants connected through required dependency edges inherit the failure.

A descendant does not inherit failure when at least one independently valid alternate support path remains and the claim does not explicitly require the failed node. For a model family containing alternate event sequences, failure of one sequence removes only that sequence from the family-level union.

15 Dependency-Graph Architecture

15.1 Complete Atlas Graph

The atlas graph is

$$\mathcal{G}_A = (\mathcal{N}_A, \mathcal{E}_A, \tau_V, \tau_E), \tag{82}$$

where:

$$\mathcal{N}_A = \text{typed atlas nodes}, \tag{83}$$
$$\mathcal{E}_A = \text{typed relationships}, \tag{84}$$
$$\tau_V = \text{node-type function}, \tag{85}$$
$$\tau_E = \text{edge-type function}. \tag{86}$$

15.2 Claim Dependency Subgraph

For claim c, define

$$\mathcal{G}_c = \text{Subgraph}\left[\mathcal{G}_A, \text{Anc}(c) \cup \{c\} \cup \text{Desc}(c)\right]. \tag{87}$$

15.3 Required Upstream Paths

A principal claim should have paths to:

- one or more equations or derivations;
- assumptions;
- parameters;
- data or source records;
- a test;
- and a falsifier.

15.4 Dependency Depth

For upstream node u and claim c,

$$d_{\text{dep}}(u,c) = \min\{\text{number of edges in a directed path } u \rightsquigarrow c\}. \tag{88}$$

15.5 Claim Criticality

For node v, define weighted downstream criticality

$$K(v) = \sum_{u \in \text{Desc}(v)} w_u. \tag{89}$$

A node with high $K(v)$ requires priority verification.

15.6 Dependency Bottleneck

A node is a bottleneck when many high-level claims depend on it and no independent alternate path exists.

15.7 Alternate Support Paths

For claim c, define the number of independent support paths

$$N^{\text{ind}}_{\text{path}}(c). \tag{90}$$

Multiple paths derived from the same source or dataset do not count as independent.

15.8 Circular Support

A circular-support cycle exists when

$$v_i \rightsquigarrow v_i \tag{91}$$

through edges intended to establish support.

Examples include:

- a reconstruction used to validate the assumptions that produced the reconstruction;
- a model output used as independent input evidence;
- or two claims citing one another without an external anchor.

15.9 Circularity Rule

A support cycle receives:

$$\texttt{CIRCULAR-SUPPORT}. \tag{92}$$

It cannot independently raise a claim's support status.

15.10 Dependency Completeness

For claim c, define required edge-type set

$$\mathcal{R}_c = \{\text{DERIVES\_FROM}, \text{REQUIRES}, \text{USES\_DATA}, \text{TESTED\_BY}, \text{FALSIFIED\_BY}\}. \quad (93)$$

Dependency completeness is

$$Q_{\text{dep},c} = \frac{\left|\mathcal{R}_c \cap \mathcal{E}_c^{\text{present}}\right|}{|\mathcal{R}_c|}. \quad (94)$$

This score measures documentation completeness, not validity.

15.11 Failure Cut Set

A set of nodes $\mathcal{K}$ is a failure cut set for conclusion C when removing $\mathcal{K}$ eliminates every valid support path to C.

$$\mathcal{K} = \text{Cut}\left(\mathcal{G}_A, C\right). \quad (95)$$

15.12 Series-Level Replacement Node

The series-level replacement claim must be traceable through at least one complete eligible event sequence rather than through the flagship event alone:

$$\begin{aligned} \text{P4 replacement} \leftarrow \big(&\text{event– indexed P1/P2 eligibility}, \text{P3 global reconstruction}, \\ &\text{P4 comparison}, \text{prediction}, \text{replication}\big). \end{aligned} \quad (96)$$

The Aegean–Everest–Mariana event is the flagship instantiation of the event-specific chain. It is not a universal single-point dependency unless the frozen global model declares it necessary.

16 Status Vocabulary

16.1 Status Must Be Multiaxial

One label cannot adequately represent provenance, scientific role, epistemic status, verification, and publication status.

Each atlas item therefore receives a status vector

$$\mathbf{S}_i = \left(S_i^{\text{prov}}, S_i^{\text{role}}, S_i^{\text{ep}}, S_i^{\text{ver}}, S_i^{\text{pub}}\right). \quad (97)$$

16.2 Provenance Axis

Allowed provenance states include:

- `EXTERNAL-PRIMARY`;
- `EXTERNAL-SECONDARY`;
- `AUTHOR-SOURCE`;
- `MANUSCRIPT-DERIVED`;
- `COMPUTATIONAL-OUTPUT`;
- `AI-ASSISTED-ORGANIZATION`;
- `UNRESOLVED-PROVENANCE`.

16.3 Scientific-Role Axis

Allowed role states include:

- `OBSERVATION`;
- `ASSUMPTION`;
- `PARAMETER`;
- `DEFINITION`;
- `CALCULATION`;
- `MODEL-OUTPUT`;
- `PREDICTION`;
- `COMPARISON`;
- `DECISION-RULE`;
- `FALSIFIER`.

16.4 Epistemic-Status Axis

Allowed epistemic states include:

- `SUPPORTED`;
- `CONDITIONALLY-SUPPORTED`;
- `CONSISTENT-WITH`;
- `UNRESOLVED`;
- `UNSUPPORTED`;
- `DISFAVORED`;
- `FALSIFIED`;

- SUPERSEDED;
- NOT-APPLICABLE.

16.5 Verification Axis

Allowed verification states include:

- UNVERIFIED;
- PARTIALLY-VERIFIED;
- SOURCE-VERIFIED;
- CALCULATION-VERIFIED;
- INDEPENDENTLY-VERIFIED;
- REPRODUCED;
- INDEPENDENTLY-REPRODUCED;
- VERIFICATION-FAILED.

16.6 Publication Axis

Allowed publication states include:

- WORKING-DRAFT;
- AUTHOR-REVIEWED;
- FROZEN;
- REVISED;
- RETIRED;
- SUPERSEDED.

16.7 Example Status Vector

A source-derived event-energy range that has been accurately extracted but not independently validated may be labeled:

$$\mathbf{S} = (\texttt{AUTHOR-SOURCE}, \texttt{PARAMETER}, \texttt{UNRESOLVED}, \texttt{SOURCE-VERIFIED}, \texttt{WORKING-DRAFT}) . \tag{98}$$

16.8 No Status Compression

The preceding item must not be simplified to:

$$\texttt{VERIFIED} \tag{99}$$

because only the source extraction has been verified.

The physical value remains unresolved.

16.9 Support Upgrade Requirements

To upgrade an item to `SUPPORTED`, the atlas must identify:

- the supporting evidence;
- the applicable assumptions;
- the successful test;
- the uncertainty;
- the absence of a triggered decisive falsifier;
- and the approving decision record.

17 Verification and Audit Rules

17.1 Rule V1: Exact Extraction

Claims, equations, and source passages must be extracted without silently changing meaning.

17.2 Rule V2: Source and Interpretation Separation

The atlas must distinguish:

$$\text{what the source states} \tag{100}$$

from

$$\text{what the manuscript infers.} \tag{101}$$

17.3 Rule V3: Calculation and Assumption Separation

A calculation may be correct relative to its inputs while the inputs remain unsupported.

Both statuses must remain visible.

17.4 Rule V4: Observation and Reconstruction Separation

An observation is not the same as a reconstruction derived from a model.

17.5 Rule V5: Reconstruction and Prediction Separation

A model fit to known evidence produces a reconstruction or retrodiction, not an advance prediction.

17.6 Rule V6: Geometry and Causation Separation

A spatial alignment does not establish:

- common origin;
- chronology;
- mechanics;
- or causal transmission.

17.7 Rule V7: Modern and Paleogeographic Separation

Modern-coordinate relationships must not be presented as event-time relationships without reconstruction.

17.8 Rule V8: Branch and Model Separation

Failure of one mechanism branch does not automatically reject every branch.

Survival of one branch does not validate the entire model family.

17.9 Rule V9: Regional and Global Separation

Regional support must not be promoted to global replacement without a nonempty global viable-set intersection.

17.10 Rule V10: Model Output and Independent Evidence Separation

A model output cannot be reused as independent support for the model that produced it.

17.11 Rule V11: Missing Evidence Visibility

Missing data, missing sources, missing uncertainty, and missing tests must remain explicit.

17.12 Rule V12: Negative Results Preservation

Failed calculations, failed branches, unfavorable null results, and triggered falsifiers remain in the atlas.

17.13 Rule V13: No Silent Reconciliation

Contradictory values or claims must be recorded as contradictory until explicitly resolved.

17.14 Rule V14: No Status Inheritance Without Dependency

A downstream claim inherits failure only through a required dependency edge.

17.15 Rule V15: No AI Authority Substitution

AI-generated prose, summaries, or classifications do not replace primary sources, calculations, or human scientific decisions.

17.16 Rule V16: Reproducibility Before Compression

A concise atlas summary may be generated only after the underlying record remains reproducible.

17.17 Rule V17: Version Visibility

The atlas must identify which version of a paper, equation, model, data release, or source record it represents.

17.18 Rule V18: Decision Traceability

Every status-changing decision must have a traceable human-approved record.

18 Contradiction, Supersession, and Consistency Audit

18.1 Contradiction Classes

The atlas recognizes:

Direct contradiction
: Two statements assert mutually exclusive propositions.

Numerical inconsistency
: Two values intended to represent the same quantity disagree beyond declared uncertainty.

Symbol inconsistency
: The same symbol has incompatible meanings.

Unit inconsistency
: Values or equations use incompatible units.

Chronological inconsistency
: A proposed effect precedes its required cause.

Scope inconsistency
: A local result is stated globally or a conditional result is stated unconditionally.

Dependency inconsistency
: A claim depends on an item that has failed or been superseded.

Model-version inconsistency
: Results from different model versions are combined as one model.

Source inconsistency
: A manuscript statement does not match the cited source.

Status inconsistency

An unresolved or unsupported item is described elsewhere as established.

18.2 Contradiction Record

For items i and j,

$$\mathbf{C}_{ij}^{\mathrm{conf}} = (\mathrm{ID}_i, \mathrm{ID}_j, \mathrm{class}, \mathrm{description}, \mathrm{severity}, \mathrm{resolution}, \mathrm{decision}) . \tag{102}$$

18.3 Severity Classes

Contradiction severity is:

- editorial;
- local numerical;
- interpretive;
- branch-level;
- paper-level;
- or series-critical.

18.4 Supersession

When item i replaces item j,

$$v_i \xrightarrow{\text{SUPERSEDES}} v_j . \tag{103}$$

The supersession record must state:

- why the change occurred;
- whether evidence changed;
- whether the change is editorial or scientific;
- which downstream items are affected;
- and whether new validation is required.

18.5 Intentional Scope Difference

Two statements may appear inconsistent while applying to different:

- model branches;
- time intervals;
- coordinate systems;

- reference frames;
- parameter regimes;
- or claim scopes.

Such a case is marked:

$$\texttt{SCOPE-DIFFERENTIATED} \tag{104}$$

only after the difference is explicitly documented.

18.6 Unresolved Conflict

A conflict not yet resolved receives:

$$\texttt{UNRESOLVED-CONFLICT}. \tag{105}$$

No preferred value or statement may be silently selected.

18.7 Cross-Paper Consistency Vector

For shared item x, define

$$\mathbf{x}_{\text{series}} = (x_{P1}, x_{P2}, x_{P3}, x_{P4}, x_{P5}) . \tag{106}$$

Consistency requires agreement within declared scope and uncertainty.

18.8 Consistency Residual

For numeric shared item,

$$\chi^2_{x,\text{series}} = \sum_p \frac{(x_p - x_*)^2}{\sigma^2_{x,p}}. \tag{107}$$

18.9 Canonical Shared Value

A canonical shared value is designated only after:

- source verification;
- calculation verification;
- unit verification;
- cross-paper reconciliation;
- and human approval.

19 Human-Readable and Machine-Readable Navigation

19.1 Human-Readable Atlas

The PDF atlas should provide:

- cross-paper tables;
- claim summaries;
- exact claim text;
- equation locations;
- source locations;
- dependency diagrams;
- status labels;
- prediction outcomes;
- falsification matrices;
- and replication status.

19.2 Machine-Readable Companion

The companion package should include:

- comma-separated-value files;
- structured JavaScript Object Notation files;
- graph edge lists;
- equation registries;
- source ledgers;
- model-version ledgers;
- and prediction records.

19.3 Minimum Machine Registry Files

```
paper-v-atlas/
|
|-- manuscript/
|   ‘-- main.tex
|
|-- registries/
|   |-- claims.csv
|   |-- equations.csv
|   |-- assumptions.csv
```

```
|   |-- parameters.csv
|   |-- datasets.csv
|   |-- sources.csv
|   |-- models.csv
|   |-- methods.csv
|   |-- results.csv
|   |-- predictions.csv
|   |-- falsifiers.csv
|   |-- decisions.csv
|   |-- causal-edges.csv
|   |-- causal-paths.csv
|   |-- alternatives.csv
|   |-- interventions.csv
|   `-- revisions.csv
|
|-- graph/
|   |-- nodes.csv
|   |-- edges.csv
|   |-- dependencies.json
|   |-- contradictions.json
|   `-- failure-propagation.json
|
|-- paper-atlases/
|   |-- paper-i/
|   |-- paper-ii/
|   |-- paper-iii/
|   `-- paper-iv/
|
|-- audits/
|   |-- symbol-audit.csv
|   |-- unit-audit.csv
|   |-- chronology-audit.csv
|   |-- source-audit.csv
|   |-- contradiction-audit.csv
|   |-- status-audit.csv
|   `-- replication-audit.csv
|
`-- README.md
```

19.4 Query Functions

The atlas should support queries such as:

- show every unsupported claim in Paper II;
- show every equation used by one replacement claim;

- show all claims depending on one event-energy range;
- show all source-derived values still awaiting verification;
- show all predictions that have not been tested;
- show every triggered falsifier;
- show all downstream claims affected by one failed assumption;
- show all contradictions involving paleogeographic coordinates;
- show every parameter that changed after model freeze;
- and show the minimum failure cut set for the replacement thesis.

19.5 Reader Entry Points

A reader may enter the atlas through:

- paper;
- claim;
- equation;
- event;
- parameter;
- dataset;
- source;
- prediction;
- falsifier;
- or final decision.

19.6 Claim Navigation Chain

For claim C_i, the reader path is

$$C_i \to \{E_i, A_i, P_i, D_i, S_i, T_i, F_i\}\,. \tag{108}$$

19.7 Falsifier Navigation Chain

For falsifier F_i, the reader path is

$$F_i \to \{\text{target}, \text{test}, \text{threshold}, \text{data}, \text{outcome}, \text{affected descendants}\}\,. \tag{109}$$

19.8 Replacement Navigation Chain

The final replacement node must permit navigation backward through:

$$\begin{aligned}\text{Replacement decision} \to \{&\text{Paper-IV score}, \text{prediction}, \text{complexity}, \text{nulls}, \\ &\text{Paper-III reconstruction}, \text{Paper-II mechanics}, \text{Paper-I geometry}\}.\end{aligned} \tag{110}$$

19.9 Atlas Completeness Dashboard

For registry class g, define completeness

$$Q_g = \frac{N_g^{\text{complete}}}{N_g^{\text{registered}}}. \tag{111}$$

The dashboard should report:

- total registered items;
- complete records;
- incomplete dependencies;
- unverified sources;
- unaudited equations;
- unresolved contradictions;
- untested predictions;
- triggered falsifiers;
- and unreproduced results.

19.10 Atlas Integrity Principle

Atlas-integrity principle.
The value of Paper V is not the appearance of completeness.
Its value is the accurate visibility of completeness and incompleteness.
An unresolved dependency recorded honestly is more scientifically useful than a polished but unsupported connection.

---

20 Atlas Architecture Synthesis

This atlas-architecture synthesis records:

1. Paper V as a verification and navigation atlas rather than a fifth causal argument;
2. the governing claim-to-falsifier chain;

3. sole human authorship and AI-assistance limits;
4. the companion's included and excluded functions;
5. the five-paper corpus;
6. the authority hierarchy for canonical manuscripts, primary sources, calculations, author documents, drafts, AI material, and process records;
7. conflict and source-control rules;
8. the corpus-freeze record;
9. the typed atlas-node ontology;
10. the typed dependency-edge ontology;
11. the canonical identifier grammar;
12. permanent and versioned identifiers;
13. cross-paper identifiers;
14. complete claim-record architecture;
15. claim classes, scopes, polarity, and conditional structure;
16. claim support and completeness vectors;
17. orphan-claim detection;
18. equation-record architecture;
19. dimensional, symbolic, limiting-case, and numerical audits;
20. equation-verification states;
21. assumption and parameter registries;
22. hidden-assumption detection;
23. parameter freeze, change, and sensitivity rules;
24. dataset and source registries;
25. calibration, validation, test, and prospective-data distinctions;
26. source-support granularity;
27. source verification and conflict states;
28. model, method, result, and failed-run registries;
29. prediction records and prohibition against retroactive prediction;
30. falsifier records, scopes, thresholds, and failure propagation;
31. the complete dependency-graph architecture;
32. node criticality, bottlenecks, alternate support paths, circularity, and failure cut sets;

33. multiaxial provenance, role, epistemic, verification, and publication statuses;
34. eighteen atlas verification rules;
35. contradiction, supersession, scope-difference, and cross-paper consistency audits;
36. human-readable and machine-readable atlas structures;
37. reader entry points and query functions;
38. registry-completeness metrics; and
39. the atlas-integrity principle.

The following sections construct the complete Paper-I atlas:

- Paper-I claim registry;
- Paper-I exact claim hierarchy;
- flagship geometry registry;
- coordinate and distance registry;
- midpoint and great-circle audit;
- chord and incidence audit;
- chronology registry;
- source-material registry;
- assumption and parameter registry;
- equation registry;
- numerical-result registry;
- geometric null-model registry;
- Paper-I prediction registry;
- Paper-I falsification registry;
- Paper-I contradiction and supersession audit;
- Paper-I dependency graph;
- and Paper-I atlas status dashboard.

21 Paper-I Atlas Scope

21.1 Paper-I Function

Paper I introduces the flagship candidate relationship:

$$\text{Aegean entrance} \rightarrow \text{Everest midpoint} \rightarrow \text{Mariana exit.} \tag{112}$$

Its primary burden is not to establish complete transmission mechanics.

Its primary burden is to determine whether the proposed relationship is:

- geometrically reproducible;
- chronologically admissible;
- robust to coordinate choice;
- robust to paleogeographic reconstruction;
- statistically distinguishable from plausible null models;
- and sufficiently specific to justify mechanical testing in Paper II.

21.2 Paper-I Atlas Objects

The Paper-I atlas contains:

$$\mathfrak{A}_{P1} = \{\mathfrak{C}_{P1}, \mathfrak{E}_{P1}, \mathfrak{AS}_{P1}, \mathfrak{P}_{P1}, \mathfrak{D}_{P1}, \mathfrak{S}_{P1}, \mathfrak{R}_{P1}, \mathfrak{F}_{P1}, \mathfrak{G}_{P1}\}\,. \tag{113}$$

21.3 Three Distinct Geometry Questions

Paper I must keep separate:

G1. Are the Aegean–Everest and Everest–Mariana surface distances approximately equal?

G2. Does Everest lie near the exact midpoint of the Aegean–Mariana great-circle arc?

G3. Does Everest lie close to the Aegean–Mariana great-circle path?

These questions are mathematically related but not equivalent.

21.4 Present-Day and Event-Time Geometry

The present-coordinate state is

$$\mathbf{Q}_{P1}^{\text{present}} = \left(\mathbf{x}_A^0, \mathbf{x}_E^0, \mathbf{x}_M^0\right). \tag{114}$$

The required event-time state is

$$\mathbf{Q}_{P1}^{256} = \left(\mathbf{x}_A^{256}, \mathbf{x}_E^{256}, \mathbf{x}_M^{256}\right). \tag{115}$$

The present-day calculation is auditable now.

The event-time calculation requires a defensible reconstruction.

21.5 Paper-I Atlas Constraint

The atlas must not convert:

$$\text{present-coordinate near-equidistance} \tag{116}$$

into

$$\text{event-time causal midpoint.} \tag{117}$$

The second statement requires additional evidence.

22 Paper-I Claim Registry

22.1 Claim Registry Table

Table 5: Principal Paper-I claim registry.

ID	Claim	Role	Current status
ABC-P1-CLM-001	The Mini Aegean, Everest, and Mariana locations form a candidate entrance–midpoint–exit relationship.	Foundational	UNRESOLVED
ABC-P1-CLM-002	Using the registered present coordinates, the Aegean–Everest surface distance is approximately equal to the Everest–Mariana surface distance.	Calculated	CALCULATION-VERIFIED
ABC-P1-CLM-003	The bilateral present-coordinate distance difference is 44.808 km.	Calculated	CALCULATION-VERIFIED
ABC-P1-CLM-004	The bilateral asymmetry under the declared normalization is 0.373044%.	Calculated	CALCULATION-VERIFIED
ABC-P1-CLM-005	The exact present-coordinate midpoint direction of the Aegean–Mariana minor great-circle arc is approximately 40.846036°N, 92.180310°E.	Calculated	CALCULATION-VERIFIED
ABC-P1-CLM-006	Everest is separated from that exact present-coordinate midpoint by approximately 13.558849°, or 1507.675 km on the adopted spherical Earth.	Calculated	CALCULATION-VERIFIED
ABC-P1-CLM-007	The source-document working midpoint-viability band of 5° or less is not satisfied by the registered present coordinates.	Negative result	FALSIFIED-PRESENT-COORDINATES
ABC-P1-CLM-008	Everest lies close to the halfway station after projection onto the Aegean–Mariana great-circle path, with an along-track offset of approximately 23.408 km.	Calculated	CALCULATION-VERIFIED
ABC-P1-CLM-009	Everest is not close to the present Aegean–Mariana great-circle path; its cross-track distance is approximately 1507.497 km.	Negative result	CALCULATION-VERIFIED
ABC-P1-CLM-010	The Aegean–Everest–Mariana routed path exceeds the direct Aegean–Mariana surface path by approximately 267.302 km.	Calculated	CALCULATION-VERIFIED

ID	Claim	Role	Current status
ABC-P1-CLM-011	The present coordinates support near-equal bilateral surface distances but do not support literal present-day midpoint collinearity.	Geometric	CALCULATION-VERIFIED
ABC-P1-CLM-012	Deep-time reconstruction is decisive for determining whether the flagship midpoint relationship improves, persists, or fails at the proposed event age.	Methodological	TEST-REQUIRED
ABC-P1-CLM-013	The direct spherical chord between the registered Aegean and Mariana points is approximately 10150.567 km.	Calculated	CALCULATION-VERIFIED
ABC-P1-CLM-014	The maximum depth of that idealized spherical chord is approximately 2519.878 km.	Calculated	CALCULATION-VERIFIED
ABC-P1-CLM-015	Under the ideal spherical geometry, the chord remains outside the core and passes primarily through mantle material.	Geometric	CONDITIONALLY-SUPPORTED
ABC-P1-CLM-016	The chord enters approximately 52.808799° below the local horizontal, or 37.191201° from the inward radial direction.	Calculated	CALCULATION-VERIFIED
ABC-P1-CLM-017	The idealized straight chord is not a low-angle or grazing trajectory.	Interpretive	CALCULATION-VERIFIED
ABC-P1-CLM-018	Present-coordinate geometry alone does not establish event chronology, mechanical transmission, causal linkage, or replacement of Plate Tectonics .	Methodological	REQUIREMENT-DEFINED
ABC-P1-CLM-019	The source energy range of 10^{29} to 10^{31} J is a search interval rather than a validated event-energy estimate.	Parameter status	UNRESOLVED
ABC-P1-CLM-020	The source document presents the flagship event as a hypothesis rather than an established historical fact.	Source-derived	SOURCE-VERIFIED
ABC-P1-CLM-021	The source document's non-replacement positioning is superseded by the current series' explicitly testable replacement thesis.	Revision status	SUPERSEDED-POSITIONING
ABC-P1-CLM-022	The geometric relationship must outperform selection-aware spatial and chronological null models before receiving statistical significance.	Statistical	UNTESTED
ABC-P1-CLM-023	Failure of the literal present-coordinate midpoint criterion does not by itself reject every regional or deep-time event hypothesis.	Scope control	REQUIREMENT-DEFINED
ABC-P1-CLM-024	The source identifies geometry failure, a tomographic null, exit-energy incompatibility, and Hawaii decoupling as explicit falsification classes.	Source-derived	SOURCE-VERIFIED

22.2 Claim-Hierarchy Structure

The Paper-I claim hierarchy is:

$$\begin{aligned} \text{P1 flagship} \Leftarrow \{&\text{coordinate validity}, \text{present geometry}, \text{paleogeography}, \\ &\text{chronology}, \text{null rejection}, \text{source support}, \text{mechanical eligibility}\}. \end{aligned} \tag{118}$$

22.3 Current Claim Boundary

Paper I presently registers several calculation-verified geometric quantities derived from the declared coordinate set.

It does not presently establish:

- a verified 256 Ma paleogeographic midpoint;
- a statistically exceptional alignment;
- a physically viable through-Earth event;
- or global causal replacement.

23 Flagship Coordinate and Geometry Registry

23.1 Registered Coordinate Set

The current audit uses:

Table 6: Paper-I registered flagship coordinates.

ID	Location	Latitude	Longitude	Status
ABC-P1-DAT-001	Mini Aegean	36.47°N	22.95°E	Author-source coordinate
ABC-P1-DAT-002	Everest	27.99°N	86.93°E	Author-source coordinate
ABC-P1-DAT-003	Mariana / Challenger Deep target	11.32°N	142.25°E	Author-source coordinate

23.2 Coordinate Vector

For location i,

$$\mathbf{q}_i = (\phi_i, \lambda_i)\,, \tag{119}$$

where latitude and longitude are converted to radians before trigonometric evaluation.

23.3 Spherical Unit Vector

$$\widehat{\mathbf{u}}_i = \begin{pmatrix} \cos\phi_i \cos\lambda_i \\ \cos\phi_i \sin\lambda_i \\ \sin\phi_i \end{pmatrix}. \tag{120}$$

23.4 Coordinate Status

The coordinates have been used consistently in the internal numerical audit.

Before publication they still require:

- external location verification;
- exact feature-definition verification;

- coordinate-system verification;
- coordinate uncertainty;
- and justification for the selected representative point.

23.5 Point-Definition Sensitivity

For perturbation radius δ_i, define coordinate neighborhood

$$\mathcal{N}_i(\delta_i) = \{\mathbf{x} : d_{\mathcal{S}}(\mathbf{x}, \mathbf{x}_i) \le \delta_i\}. \tag{121}$$

The geometry must be recomputed across:

$$\mathcal{N}_A \times \mathcal{N}_E \times \mathcal{N}_M. \tag{122}$$

23.6 Coordinate-Selection Requirement

The selected point for each region must be defined independently of the desired geometric result.

A coordinate chosen after maximizing alignment contributes search flexibility and must be counted in the null model.

24 Surface-Distance and Midpoint Audit

24.1 Central Angle

For points i and j,

$$\Delta\sigma_{ij} = \arccos\left[\sin\phi_i \sin\phi_j + \cos\phi_i \cos\phi_j \cos(\lambda_j - \lambda_i)\right]. \tag{123}$$

24.2 Surface Distance

Using

$$R_\oplus = 6371 \text{ km}, \tag{124}$$

the spherical surface distance is

$$d_{ij} = R_\oplus \Delta\sigma_{ij}. \tag{125}$$

24.3 Audited Bilateral Distances

The registered coordinates give:

$$d_{AE} = 5983.318 \text{ km}, \tag{126}$$
$$d_{EM} = 6028.126 \text{ km}. \tag{127}$$

24.4 Bilateral Difference

$$\Delta d_{\text{bilateral}} = |d_{AE} - d_{EM}| = 44.808 \text{ km}. \tag{128}$$

24.5 Bilateral Asymmetry

Define

$$A_{\text{bilateral}} = 100 \frac{|d_{AE} - d_{EM}|}{\frac{1}{2}(d_{AE} + d_{EM})}. \tag{129}$$

The audited value is

$$A_{\text{bilateral}} = 0.373044\%. \tag{130}$$

24.6 Exact Great-Circle Midpoint

For non-antipodal points A and M,

$$\widehat{\mathbf{u}}_{\text{mid}} = \frac{\widehat{\mathbf{u}}_A + \widehat{\mathbf{u}}_M}{\|\widehat{\mathbf{u}}_A + \widehat{\mathbf{u}}_M\|}. \tag{131}$$

Convert the midpoint vector to latitude and longitude:

$$\phi_{\text{mid}} = \arcsin\left(u_{\text{mid},z}\right), \tag{132}$$
$$\lambda_{\text{mid}} = \operatorname{atan2}\left(u_{\text{mid},y}, u_{\text{mid},x}\right). \tag{133}$$

The audited midpoint direction is

$$(\phi_{\text{mid}}, \lambda_{\text{mid}}) = (40.846036°\text{N}, 92.180310°\text{E}). \tag{134}$$

24.7 Everest Midpoint Misfit

The angular midpoint misfit is

$$\Delta\sigma_{E,\text{mid}} = 13.558849°. \tag{135}$$

The surface separation is

$$d_{E,\mathrm{mid}} = 1507.675 \text{ km.} \tag{136}$$

24.8 Source Viability Band

The author source used the working criterion

$$\Delta\sigma_{E,\mathrm{mid}} \leq 5^\circ. \tag{137}$$

For the registered present coordinates,

$$13.558849^\circ > 5^\circ. \tag{138}$$

The literal present-coordinate midpoint branch therefore fails that working criterion.

24.9 Meaning of the Negative Result

This result rejects the statement:

> Everest is within 5° of the exact present-coordinate Aegean–Mariana great-circle midpoint.

It does not by itself determine:

- the 256 Ma reconstructed midpoint;
- whether another feature definition is justified;
- whether near-bilateral distance remains statistically unusual;
- or whether a different regional event hypothesis survives.

25 Great-Circle, Cross-Track, and Along-Track Audit

25.1 Direct Aegean–Mariana Surface Distance

The audited direct surface distance is

$$d_{AM} = 11744.141 \text{ km.} \tag{139}$$

25.2 Routed Distance Through Everest

$$d_{AEM} = d_{AE} + d_{EM}. \tag{140}$$

Using the audited distances,

$$d_{AEM} = 12011.444 \text{ km.} \tag{141}$$

25.3 Path Excess

$$\Delta d_{\text{path}} = d_{AEM} - d_{AM}. \tag{142}$$

The full-precision audit gives approximately

$$\Delta d_{\text{path}} = 267.302 \text{ km}. \tag{143}$$

Small differences in the displayed subtraction may result from rounding the component distances before display.

25.4 Initial Bearing

For points i and j, define initial bearing

$$\theta_{ij} = \operatorname{atan2}\left[\sin\Delta\lambda\cos\phi_j, \cos\phi_i\sin\phi_j - \sin\phi_i\cos\phi_j\cos\Delta\lambda\right]. \tag{144}$$

25.5 Cross-Track Distance

The signed cross-track angular distance from Everest to the Aegean–Mariana great circle is

$$\delta_{\text{xt}} = \arcsin\left[\sin\delta_{AE}\sin\left(\theta_{AE} - \theta_{AM}\right)\right]. \tag{145}$$

The absolute surface cross-track distance is

$$d_{\text{xt}} = R_\oplus \left|\delta_{\text{xt}}\right|. \tag{146}$$

The audited value is

$$d_{\text{xt}} = 1507.497 \text{ km}. \tag{147}$$

25.6 Along-Track Distance

The along-track angular distance from Aegean to the perpendicular projection of Everest is

$$\delta_{\text{at}} = \arccos\left[\frac{\cos\delta_{AE}}{\cos\delta_{\text{xt}}}\right]. \tag{148}$$

The offset from the exact halfway station is

$$\Delta d_{\text{half}} = R_\oplus \left|\delta_{\text{at}} - \frac{\Delta\sigma_{AM}}{2}\right|. \tag{149}$$

The audited value is

$$\Delta d_{\mathrm{half}} = 23.408 \text{ km}. \tag{150}$$

25.7 Interpretation

The present-coordinate result is therefore:

$$\boxed{\text{nearly halfway along-track} \quad \text{but} \quad \text{far off-track}} \tag{151}$$

Near-halfway station and near-collinearity must not be conflated.

25.8 Great-Circle Claim Status

The audited geometry supports:

- near-bilateral surface distance;
- near-halfway projected station;
- a substantial cross-track separation;
- and failure of exact present-day midpoint collinearity.

26 Chord, Depth, and Incidence Audit

26.1 Aegean–Mariana Central Angle

The audited central angle is

$$\Delta\sigma_{AM} = 105.617599^\circ. \tag{152}$$

26.2 Chord Length

For a spherical Earth,

$$L_{\mathrm{chord}} = 2R_\oplus \sin\left(\frac{\Delta\sigma_{AM}}{2}\right). \tag{153}$$

The audited value is

$$L_{\mathrm{chord}} = 10150.567 \text{ km}. \tag{154}$$

26.3 Half-Chord Length

$$L_{\mathrm{half}} = \frac{L_{\mathrm{chord}}}{2} = 5075.284 \text{ km}. \tag{155}$$

26.4 Closest Radial Distance

The minimum radial distance from Earth's center is

$$r_{\min} = R_\oplus \cos\left(\frac{\Delta\sigma_{AM}}{2}\right). \tag{156}$$

26.5 Maximum Chord Depth

$$h_{\max} = R_\oplus - r_{\min} = R_\oplus \left[1 - \cos\left(\frac{\Delta\sigma_{AM}}{2}\right)\right]. \tag{157}$$

The audited value is

$$h_{\max} = 2519.878 \text{ km}. \tag{158}$$

26.6 Core-Crossing Status

Under this ideal spherical geometry, the closest radial distance remains outside the core.

The corresponding statement is geometric only.

It does not establish:

- coherent projectile survival;
- shock propagation;
- phase-front survival;
- or mechanical viability.

26.7 Incidence Below the Local Horizontal

For the straight chord,

$$\alpha_h = \frac{\Delta\sigma_{AM}}{2}. \tag{159}$$

Therefore,

$$\alpha_h = 52.808799^\circ. \tag{160}$$

26.8 Incidence From the Inward Radial

$$\alpha_r = 90^\circ - \alpha_h = 37.191201^\circ. \tag{161}$$

26.9 Trajectory Classification

The straight chord is relatively steep with respect to the local horizontal.

The atlas therefore classifies low-angle or grazing descriptions as incompatible with this registered spherical chord unless a different path geometry is explicitly defined.

26.10 Constant-Speed Transit Diagnostic

For constant path speed v,

$$t_{\text{chord}} = \frac{L_{\text{chord}}}{v}. \tag{162}$$

For the exploratory range

$$10\ \mathrm{km\,s^{-1}} \leq v \leq 30\ \mathrm{km\,s^{-1}}, \tag{163}$$

the constant-speed diagnostic is approximately

$$338\ \mathrm{s} \lesssim t_{\text{chord}} \lesssim 1015\ \mathrm{s}. \tag{164}$$

This is not a shock-travel time and not a validated event duration.

27 Paper-I Chronology Registry

27.1 Chronology Records

Table 7: Paper-I chronology registry.

ID	Chronology item	Current value	Status
`ABC-P1-PAR-001`	Proposed flagship event age	256 Ma	Author-source; independently unresolved
`ABC-P1-ASM-001`	Aegean, Everest, and Mariana response domains are causally related to one event initiated at the specific age 256 Ma	Not yet independently demonstrated	`ASSUMPTION`
`ABC-P1-ASM-002`	The selected domains preserve interpretable signatures or carrier states from the specific initiating event	Not yet demonstrated	`UNRESOLVED`
`ABC-P1-MET-001`	Paleogeographic reconstruction time	Event-time reconstruction at the nominal initiating age 256 Ma	`NOT-COMPLETED`
`ABC-P1-PRD-001`	Reconstructed midpoint relation	Must be calculated from reconstructed material coordinates	`AWAITING-RECONSTRUCTION`

ID	Chronology item	Current value	Status
ABC-P1-FAL-001	Chronological incompatibility	Relevant structures or signatures demonstrably postdate or predate the required event relationship	DEFINED

27.2 Chronology Separation

The atlas freezes the flagship initiating-event parameter as

$$a_{\text{init},F} = 256 \text{ Ma}, \tag{165}$$

and records its empirical uncertainty separately as $\sigma_{a,\text{init},F}$. The initiating age is distinct from:

- the age of any prompt physical marker;
- the age of an inherited seed or carrier state;
- formation age of the selected entrance structure;
- formation age of the selected midpoint structure;
- formation age of the selected terminal structure;
- age of reactivation;
- age of uplift or subsidence;
- age of visible expression; and
- age of present morphology or observation.

27.3 No Chronology by Naming

Naming a framework after a geological interval does not establish that the proposed process occurred during that interval.

The age requires independent support.

27.4 Required Chronology Test

The chronology test must evaluate:

$$\mathcal{T}_{P1} = \left(a_{\text{init},F}, \sigma_{a,\text{init},F}, a_{\text{marker}}, a_{\text{seed}}, a_{\text{response}}, a_{\text{reactivation}}, a_{\text{expression}}\right). \tag{166}$$

A valid causal ordering must exist within uncertainty, with the nominal initiating-event identity held fixed at 256 Ma.

28 Paper-I Source and Data Registry

28.1 Source Registry

Table 8: Current Paper-I source registry.

ID	Source	Primary Paper-I use	Status
ABC-P1-SRC-001	*The Great Dying Challenge*	Flagship Aegean–Everest–Mariana hypothesis, source coordinates, working equations, midpoint band, exploratory energy range, and source falsifiers	SOURCE-EXTRACTED
ABC-P1-SRC-002	*WP List Creation*	Candidate entrance, midpoint, exit, Pacific, and broader structural interpretations	SPECULATIVE-AUTHOR-SOURCE
ABC-P1-SRC-003	*GS_PDF*	Broad schematic and conceptual context	AUTHORITY-AMBIGUOUS
ABC-P1-SRC-004	*8-8-2025 4096 Math, AI, KickStarter*	Broad multi-event catalog and exploratory extension	HIGHLY-SPECULATIVE
ABC-P1-SRC-005	Paper-I audited geometry calculation	Recalculated spherical distances, midpoint, cross-track, along-track, chord, depth, and incidence	CALCULATION-VERIFIED
ABC-P1-SRC-006	Canonical Paper-I manuscript	Approved current wording, scope, claim hierarchy, and falsification architecture	CANONICAL-MANUSCRIPT

28.2 Source-One Scope

ABC-P1-SRC-001 explicitly presents the flagship relationship as a hypothesis.

It does not establish the event as fact.

It also contains a prior statement that the hypothesis was not intended as a replacement of Plate Tectonics.

That positioning has been superseded by the current series but must remain visible in the source ledger.

28.3 Source-Two Scope

ABC-P1-SRC-002 contains candidate interpretations including:

- an Aegean entrance;
- a Mariana terminal response;
- an Everest midpoint or pressure-path interpretation;
- radial or directional faulting;
- trench scouring;
- Pacific structural effects;

- and broader Plate-Tectonic critique.

These remain author predictions or hypotheses unless independently supported.

28.4 External Data Gap

The current Paper-I source package does not yet contain a complete primary external dataset for:

- verified feature coordinates;
- 256 Ma paleogeographic positions;
- formation ages of the selected structures;
- uncertainty distributions;
- or selection-aware null construction.

28.5 Data Registry

Table 9: Current Paper-I data registry.

ID	Dataset	Use	Status
ABC-P1-DAT-001	Mini Aegean registered coordinate	Entrance-point geometry	Author-source
ABC-P1-DAT-002	Everest registered coordinate	Midpoint geometry	Author-source
ABC-P1-DAT-003	Mariana registered coordinate	Terminal-point geometry	Author-source
ABC-P1-DAT-004	Audited present-coordinate geometry output	Distance, midpoint, path, chord, and incidence registry	Reproduced
ABC-P1-DAT-005	Event-time paleogeographic reconstruction ensemble	Required 256 Ma geometry	Not yet assembled
ABC-P1-DAT-006	Selection-aware spatial null ensemble	Geometric significance	Not yet assembled
ABC-P1-DAT-007	Independent chronology dataset	Event and structural-age evaluation	Not yet assembled

29 Paper-I Assumption and Parameter Registry

29.1 Assumption Registry

Table 10: Principal Paper-I assumptions.

ID	Assumption	Primary effect	Status
ABC-P1-ASM-003	Earth is represented as a sphere for the initial geometry audit.	Distance, midpoint, chord	Explicit
ABC-P1-ASM-004	A mean Earth radius of 6371 km is adequate for the registered audit.	All lengths	Explicit
ABC-P1-ASM-005	The three source coordinates adequately represent the selected features.	All geometry	Unverified
ABC-P1-ASM-006	The listed coordinate precision is adequate for the current audit.	Numerical precision	Unverified

ID	Assumption	Primary effect	Status
ABC-P1-ASM-007	The Aegean–Mariana minor great-circle arc is the intended direct surface path.	Midpoint and path	Explicit
ABC-P1-ASM-008	The specific nominal initiating-event age is 256 Ma.	Chronology	Unresolved
ABC-P1-ASM-009	The source working midpoint band of 5° is scientifically meaningful.	Midpoint decision	Unvalidated
ABC-P1-ASM-010	The exploratory energy interval 10^{29} to 10^{31} J contains a physically relevant branch.	Paper-II handoff	Unvalidated
ABC-P1-ASM-011	The exploratory speed interval 10 to 30 $\mathrm{km\,s^{-1}}$ is relevant to the candidate event.	Mass and transit	Unvalidated
ABC-P1-ASM-012	A representative density of 3000 $\mathrm{kg\,m^{-3}}$ is suitable for exploratory size conversion.	Equivalent diameter	Illustrative
ABC-P1-ASM-013	A straight spherical chord is a useful first-order path diagnostic.	Depth and incidence	Conditional
ABC-P1-ASM-014	Present-coordinate geometry may be meaningfully compared with a later paleogeographic reconstruction.	Audit design	Methodological
ABC-P1-ASM-015	Selection-aware null models can approximate the opportunity space from which the three targets were chosen.	Significance	Test design

29.2 Parameter Registry

Table 11: Principal Paper-I parameters.

ID	Parameter	Value or range	Status
ABC-P1-PAR-002	Earth radius	6371 km	Fixed audit convention
ABC-P1-PAR-003	Aegean latitude	36.47°N	Author-source
ABC-P1-PAR-004	Aegean longitude	22.95°E	Author-source
ABC-P1-PAR-005	Everest latitude	27.99°N	Author-source
ABC-P1-PAR-006	Everest longitude	86.93°E	Author-source
ABC-P1-PAR-007	Mariana latitude	11.32°N	Author-source
ABC-P1-PAR-008	Mariana longitude	142.25°E	Author-source
ABC-P1-PAR-009	Proposed event age	256 Ma	Author-source; unresolved
ABC-P1-PAR-010	Midpoint viability band	$\leq 5°$	Source working threshold
ABC-P1-PAR-011	Exploratory energy	10^{29} to 10^{31} J	Search interval
ABC-P1-PAR-012	Exploratory speed	10 to 30 $\mathrm{km\,s^{-1}}$	Search interval
ABC-P1-PAR-013	Illustrative density	3000 $\mathrm{kg\,m^{-3}}$	Assumed
ABC-P1-PAR-014	Coordinate perturbation radius	To be declared	Unresolved
ABC-P1-PAR-015	Null-model conditioning variables	To be frozen	Unresolved

29.3 Parameter Sensitivity Priority

The highest-priority sensitivity parameters are:

1. feature-coordinate definitions;
2. paleogeographic reconstruction;

3. event age;
4. midpoint threshold;
5. search-space definition;
6. and target-selection rules.

30 Paper-I Equation Registry

30.1 Equation Registry Table

Table 12: Principal Paper-I equation registry.

ID	Equation	Primary role	Audit status
`ABC-P1-EQN-001`	equation (120)	Coordinate-to-vector conversion	Dimension checked
`ABC-P1-EQN-002`	equation (123)	Spherical angular distance	Numerically reproduced
`ABC-P1-EQN-003`	equation (125)	Surface distance	Numerically reproduced
`ABC-P1-EQN-004`	equation (129)	Normalized bilateral comparison	Numerically reproduced
`ABC-P1-EQN-005`	equation (131)	Exact spherical midpoint	Numerically reproduced
`ABC-P1-EQN-006`	equation (142)	Routed-path excess	Numerically reproduced
`ABC-P1-EQN-007`	equation (145)	Great-circle cross-track misfit	Numerically reproduced
`ABC-P1-EQN-008`	equation (149)	Projected halfway offset	Numerically reproduced
`ABC-P1-EQN-009`	equation (153)	Straight chord length	Numerically reproduced
`ABC-P1-EQN-010`	equation (157)	Maximum spherical chord depth	Numerically reproduced
`ABC-P1-EQN-011`	equation (159)	Incidence below local horizontal	Derivation checked
`ABC-P1-EQN-012`	equation (162)	Constant-speed transit diagnostic	Numerically reproduced
`ABC-P1-EQN-013`	$E_K = \frac{1}{2}mv^2$	Exploratory energy–mass conversion	Standard identity
`ABC-P1-EQN-014`	$m = 2E_K/v^2$	Exploratory mass inference	Dimension checked
`ABC-P1-EQN-015`	$D = 2\,(3m/4\pi\rho)^{1/3}$	Equivalent spherical diameter	Dimension checked
`ABC-P1-EQN-016`	$\Pi_U = E/U_\oplus$	Planetary binding-energy diagnostic	Conditional benchmark
`ABC-P1-EQN-017`	$p_{\text{null}} = \left[1 + \sum_r \mathbf{1}(T_r \leq T_{\text{obs}})\right]/(N_R+1)$	Empirical null probability	Not yet executed

30.2 Equation-Audit Boundary

The geometric equations have been symbolically and numerically checked for the registered inputs.

The mechanical equations remain conditional on:

- event energy;
- velocity;
- density;
- interaction regime;
- and material response.

30.3 No Mechanical Validation From Geometry Equations

The geometric equations constrain path geometry.

They do not establish the physical existence of the path-producing event.

31 Paper-I Numerical Result Registry

Table 13: Audited Paper-I numerical results.

ID	Result	Value	Status
ABC-P1-RES-001	Aegean–Everest surface distance	5983.318 km	Reproduced
ABC-P1-RES-002	Everest–Mariana surface distance	6028.126 km	Reproduced
ABC-P1-RES-003	Bilateral distance difference	44.808 km	Reproduced
ABC-P1-RES-004	Bilateral asymmetry	0.373044%	Reproduced
ABC-P1-RES-005	Aegean–Mariana surface distance	11744.141 km	Reproduced
ABC-P1-RES-006	Routed surface distance through Everest	12011.444 km	Reproduced
ABC-P1-RES-007	Path excess	267.302 km	Reproduced
ABC-P1-RES-008	Exact midpoint latitude	40.846036°N	Reproduced
ABC-P1-RES-009	Exact midpoint longitude	92.180310°E	Reproduced
ABC-P1-RES-010	Everest midpoint angular misfit	13.558849°	Reproduced
ABC-P1-RES-011	Everest midpoint surface separation	1507.675 km	Reproduced
ABC-P1-RES-012	Everest cross-track distance	1507.497 km	Reproduced
ABC-P1-RES-013	Everest projected halfway offset	23.408 km	Reproduced
ABC-P1-RES-014	Aegean–Mariana central angle	105.617599°	Reproduced
ABC-P1-RES-015	Straight chord length	10150.567 km	Reproduced
ABC-P1-RES-016	Half-chord length	5075.284 km	Reproduced
ABC-P1-RES-017	Maximum chord depth	2519.878 km	Reproduced
ABC-P1-RES-018	Incidence below local horizontal	52.808799°	Reproduced
ABC-P1-RES-019	Incidence from inward radial	37.191201°	Reproduced
ABC-P1-RES-020	Constant-speed chord transit at 30 $\mathrm{km\,s^{-1}}$	Approximately 338 s	Diagnostic
ABC-P1-RES-021	Constant-speed chord transit at 10 $\mathrm{km\,s^{-1}}$	Approximately 1015 s	Diagnostic

31.1 Exploratory Mechanical Range

Using

$$m = \frac{2E}{v^2}, \tag{167}$$

the declared search intervals give approximately

$$2.22 \times 10^{20} \lesssim m \lesssim 2.00 \times 10^{23} \text{ kg}. \tag{168}$$

At

$$\rho = 3000 \text{ kg m}^{-3}, \tag{169}$$

the equivalent spherical diameter range is approximately

$$521 \text{ km} \lesssim D \lesssim 5031 \text{ km}. \tag{170}$$

These are consequences of exploratory inputs, not validated object properties.

31.2 Planetary Binding Benchmark

For an Earth binding-energy benchmark of approximately

$$U_\oplus \approx 2.24 \times 10^{32} \text{ J}, \tag{171}$$

the exploratory event-energy ratio is approximately

$$4.5 \times 10^{-4} \lesssim \frac{E}{U_\oplus} \lesssim 4.5 \times 10^{-2}. \tag{172}$$

Being below the binding-energy benchmark does not establish planetary survival or event viability.

32 Paper-I Null and Selection Registry

32.1 Geometric Test Statistics

Candidate Paper-I statistics include:

$$T_1 = A_{\text{bilateral}}, \tag{173}$$
$$T_2 = \Delta\sigma_{E,\text{mid}}, \tag{174}$$
$$T_3 = d_{\text{xt}}, \tag{175}$$
$$T_4 = \Delta d_{\text{path}}, \tag{176}$$
$$T_5 = \mathcal{J}_{\text{geometry}}, \tag{177}$$

where smaller values indicate stronger geometric agreement under the declared definition.

32.2 Uniform Third-Point Null

Hold Aegean and Mariana fixed and draw a random third point:

$$\mathbf{x}_E^{(r)} \sim p_{\text{uniform}}\left(\mathcal{S}_\oplus\right). \tag{178}$$

This is a simple baseline but does not reproduce geological selection opportunity.

32.3 Elevation-Conditioned Null

If Everest was selected because it is a major mountain feature, the null should draw from a comparable mountain or high-elevation target set:

$$\mathbf{x}_E^{(r)} \sim p\left(\mathbf{x} \mid \mathcal{O}_{\text{mountain}}\right). \tag{179}$$

32.4 Entrance-Exit Opportunity Null

Candidate entrance and exit points should be sampled from comparable structural opportunity classes rather than from an unrestricted sphere.

$$\left(\mathbf{x}_A^{(r)}, \mathbf{x}_M^{(r)}\right) \sim p\left(\mathbf{x}_A, \mathbf{x}_M \mid \mathcal{O}_A, \mathcal{O}_M\right). \tag{180}$$

32.5 Complete Triplet Null

The complete null draws all three targets from frozen eligible sets:

$$\left(\mathbf{x}_A^{(r)}, \mathbf{x}_E^{(r)}, \mathbf{x}_M^{(r)}\right) \sim p\left(\mathcal{O}_A, \mathcal{O}_E, \mathcal{O}_M\right). \tag{181}$$

32.6 Paleogeographic Null

Null triplets must also be reconstructed to the same proposed event time using the same reconstruction uncertainty.

32.7 Chronology-Permutation Null

Retain locations while permuting eligible event or structure ages:

$$\left\{t_i^{(r)}\right\} = \text{Permute}\left[\{t_i\}\right]. \tag{182}$$

32.8 Search-Space Ledger

The Paper-I search ledger must include:

- all entrance candidates considered;
- all midpoint candidates considered;
- all exit candidates considered;
- all coordinate definitions considered;
- all event ages considered;
- all path conventions considered;
- all midpoint thresholds considered;
- all geometric statistics considered;
- and all rejected alternatives.

32.9 Selection-Adjusted Probability

For the best statistic found over the complete search,

$$p_{\text{sel}} = \Pr\left(T_{\min}^{\text{null}} \leq T_{\text{obs}} \mid \mathcal{S}_{\text{search}}\right). \tag{183}$$

32.10 Current Null Status

No complete selection-aware Paper-I null result is presently registered.

The geometric relationship therefore has no confirmed statistical significance in the current atlas.

33 Paper-I Prediction Registry

Table 14: Current Paper-I prediction registry.

ID	**Prediction**	**Required validation**	**Status**
`ABC-P1-PRD-002`	A defensible 256 Ma reconstruction will reduce the Everest-to-midpoint misfit relative to the present-coordinate value.	Independent paleogeographic reconstruction	Draft

ID	Prediction	Required validation	Status
ABC-P1-PRD-003	The reconstructed bilateral Aegean–Everest and Everest–Mariana distances will remain unusually similar.	Reconstruction plus null ensemble	Draft
ABC-P1-PRD-004	The selected Aegean region will contain entrance-compatible structural or chronological signatures aligned with the modeled path.	Independent regional data	Draft
ABC-P1-PRD-005	The selected Mariana region will contain terminal-response signatures compatible with the modeled path and chronology.	Independent regional and deep data	Draft
ABC-P1-PRD-006	The Everest region will contain a midpoint or off-axis response compatible with the reconstructed event geometry rather than only a modern geographic coincidence.	Independent chronology and structure	Draft
ABC-P1-PRD-007	Opportunity-matched control triplets will produce weaker combined geometry and chronology than the flagship triplet.	Selection-aware null simulation	Draft
ABC-P1-PRD-008	A deep-Earth test will identify a path-compatible anomaly or exclude the preserved-corridor branch.	Paper-II tomography test	Conditional
ABC-P1-PRD-009	Terminal energy and deformation at the Mariana target will remain compatible with the mechanically surviving Paper-II branch.	Paper-II exit analysis	Conditional

33.1 Prediction-Freeze Requirement

The preceding predictions are not advance predictions until each record contains:

- a model version;
- a freeze date;
- a data cutoff;
- spatial bounds;
- quantitative uncertainty;
- a scoring rule;
- and negative-control regions.

33.2 Current Prediction Classification

Until frozen, these entries are model expectations or draft predictions.

They must not receive prospective evidentiary credit.

34 Paper-I Falsification Registry

Table 15: Paper-I falsification registry.

ID	Falsification condition	Consequence	Status
`ABC-P1-FAL-002`	The exact present-coordinate midpoint misfit exceeds the source working band of 5°.	Reject literal present-coordinate midpoint criterion.	Triggered
`ABC-P1-FAL-003`	A defensible 256 Ma reconstruction also places Everest outside the frozen midpoint-viability band.	Reject reconstructed literal-midpoint branch.	Test required
`ABC-P1-FAL-004`	The bilateral geometry is common under selection-aware, opportunity-matched null models.	Reject statistical exceptionalism.	Untested
`ABC-P1-FAL-005`	The apparent relationship disappears under reasonable coordinate and feature-definition perturbations.	Reject coordinate-robust geometry.	Untested
`ABC-P1-FAL-006`	The proposed causal signatures have ages incompatible with a common 256 Ma event.	Reject common chronology.	Untested
`ABC-P1-FAL-007`	The entrance, midpoint, or terminal feature is misidentified in the source record.	Reject affected feature assignment.	Untested
`ABC-P1-FAL-008`	No mechanically admissible Paper-II branch can use the Paper-I geometry.	Reject mechanical handoff.	Deferred
`ABC-P1-FAL-009`	Adequately resolved tomography shows no compatible deep-path anomaly where one is required by the preserved-corridor branch.	Reject preserved-corridor branch.	Source-defined
`ABC-P1-FAL-010`	No admissible exit-energy fraction produces a physically compatible Mariana terminal response.	Reject terminal-response branch.	Source-defined
`ABC-P1-FAL-011`	The proposed Hawaii secondary-displacement relationship is geometrically, chronologically, or mechanically decoupled.	Reject Hawaii secondary branch.	Source-defined
`ABC-P1-FAL-012`	The event-time path fails after material-coordinate reconstruction.	Reject flagship event assignment.	Untested
`ABC-P1-FAL-013`	Independent reproduction cannot recover the audited geometry from the registered inputs.	Reject calculation integrity.	Not triggered

34.1 Triggered Falsifier Interpretation

`ABC-P1-FAL-002` is presently triggered.

Its scope is limited to the literal present-coordinate midpoint criterion.

It does not automatically trigger:

- the event-time paleogeographic falsifier;
- the near-bilateral-distance claim;

- the projected-halfway claim;
- every regional event interpretation;
- or the entire five-paper series.

34.2 Paper-Level Falsification Condition

Define the Paper-I flagship viable set as

$$\mathcal{V}_{P1} = \mathcal{V}_{\mathrm{coord}} \cap \mathcal{V}_{\mathrm{geom}} \cap \mathcal{V}_{\mathrm{paleo}} \cap \mathcal{V}_{\mathrm{chron}} \cap \mathcal{V}_{\mathrm{null}}. \tag{184}$$

Its current status is

$$\mathrm{status}\left(\mathcal{V}_{P1}\right) = \texttt{UNRESOLVED}. \tag{185}$$

The Paper-I flagship claim fails if subsequent evaluation yields

$$\mathcal{V}_{P1} = \varnothing. \tag{186}$$

35 Paper-I Contradiction and Supersession Audit

Table 16: Paper-I contradiction, clarification, and supersession audit.

ID	Issue	Resolution	Status
`ABC-P1-REV-001`	The original source stated that the hypothesis was not a replacement for Plate Tectonics.	The present series explicitly tests a replacement thesis. The original source statement remains preserved as prior positioning.	Superseded
`ABC-P1-REV-002`	The source used a working midpoint-viability band of $\leq 5^\circ$, while the audited present misfit is 13.558849°.	The present-coordinate literal-midpoint branch is marked failed. The event-time reconstruction remains separately testable.	Resolved negative result
`ABC-P1-REV-003`	Near-equal bilateral distances were previously liable to be described as a midpoint relationship.	The atlas separates bilateral equidistance, exact midpoint, cross-track distance, and projected halfway station.	Clarified
`ABC-P1-REV-004`	The exploratory energy interval could be read as a validated estimate.	It is now explicitly classified as a search interval.	Clarified
`ABC-P1-REV-005`	Earlier exploratory mass calculations were inconsistent with the declared energy and velocity limits.	The corrected range is 2.22×10^{20} to 2.00×10^{23} kg.	Superseded numeric result

ID	Issue	Resolution	Status
ABC-P1-REV-006	The phrase "passed through Earth" could imply an intact coherent body.	The series now defines transmission operationally as directionally concentrated transfer, with coherent, fragmented, shock, phase-front, and hybrid branches tested separately.	Scope clarified
ABC-P1-REV-007	A below-binding-energy comparison could be interpreted as establishing planetary survival.	The binding-energy ratio is retained only as a benchmark. Survival requires separate mechanical tests.	Clarified
ABC-P1-REV-008	The ideal chord could be characterized as low-angle.	The audited incidence is 52.808799° below the local horizontal, so the registered chord is not low-angle.	Resolved by calculation

35.1 Supersession Principle

A superseded statement remains part of the historical audit.

It no longer controls the current scientific wording.

35.2 No Retrospective Erasure

The failed present-coordinate midpoint criterion must remain visible even if a later paleogeographic reconstruction improves the fit.

The later result would represent a separate reconstructed claim.

36 Paper-I Dependency Graph and Criticality

36.1 Paper-I Dependency Graph

$$\mathcal{G}_{P1} = (\mathcal{N}_{P1}, \mathcal{E}_{P1}) . \tag{187}$$

36.2 Core Dependency Chain

$$\begin{aligned}\text{Flagship geometry} \Leftarrow \{&\text{coordinates}, \text{distance equations}, \text{midpoint equation}, \\ &\text{path equations}, \text{paleogeography}, \text{chronology}, \text{nulls}\}.\end{aligned} \tag{188}$$

36.3 Cross-Paper Handoff Chain

$$\begin{aligned}\text{P1 admissible geometry} &\to \text{P2 mechanical transmission} \to \text{P3 global reconstruction} \\ &\to \text{P4 adjudication}.\end{aligned} \tag{189}$$

36.4 Critical Nodes

Table 17: Paper-I dependency-criticality priorities.

Node	Criticality	Reason
Registered coordinates	High	Every geometric result depends directly on the selected points.
Feature definitions	High	Alternative point definitions may materially alter the geometry.
Paleogeographic reconstruction	Series-critical	The event-time midpoint and path cannot be adjudicated without it.
Event chronology	Series-critical	A causal relationship fails if the required structures are chronologically incompatible.
Selection-aware null	High	Near-equidistance has no statistical interpretation without the opportunity space.
Exact midpoint calculation	High	It directly tests the source midpoint criterion.
Cross-track calculation	High	It distinguishes halfway station from path collinearity.
Chord geometry	Medium-to-high	It defines the path handed to Paper II.
Exploratory energy range	High for Paper II	Mechanical viability and inferred mass depend strongly on it.
Midpoint threshold	Medium	It controls one decision branch but requires independent justification.

36.5 Present Midpoint Cut Set

For the literal present-coordinate midpoint claim, a minimum cut set is

$$\mathcal{K}_{\text{mid,present}} = \{\text{coordinates}, \text{midpoint equation}, \text{viability threshold}\}\,. \tag{190}$$

36.6 Flagship Event Cut Set

For the broader flagship event claim, a representative cut set is

$$\mathcal{K}_{\text{flagship}} = \left\{ \begin{array}{l} \text{event chronology}, \text{paleogeographic path}, \text{selection null}, \\ \text{Paper II mechanical viability} \end{array} \right\}. \tag{191}$$

Failure of any mandatory element may prevent the global flagship claim from surviving.

36.7 High-Priority Verification Order

The recommended verification order is:

1. verify exact feature definitions and coordinates;
2. construct the paleogeographic reconstruction ensemble;
3. verify the proposed chronology;

4. freeze the eligible target and search spaces;
5. run the selection-aware null models;
6. freeze Paper-I predictions;
7. and hand only the surviving geometry to Paper II.

37 Paper-I Atlas Status

37.1 Status Dashboard

Table 18: Current Paper-I atlas status dashboard.

Registry domain	**Current status**	**Required next step**
Present-coordinate geometry	Audited and numerically reproduced	Independent calculation reproduction
Coordinate provenance	Extracted from author source	External feature and coordinate verification
Bilateral-distance claim	Numerically supported	Selection-aware significance test
Literal present midpoint	Source criterion failed	Retain as triggered branch falsifier
Projected halfway station	Numerically supported	Coordinate-sensitivity audit
Great-circle collinearity	Not supported by present coordinates	Event-time reconstruction
Chord geometry	Audited under spherical approximation	Ellipsoidal and reconstructed-path sensitivity
Event chronology	Author-source only	Independent chronology compilation
Paleogeography	Not completed	Reconstruction ensemble
Null models	Defined but not executed	Freeze opportunity space and simulate
Energy range	Exploratory search interval	Paper-II physical constraint
Predictions	Draft or conditional	Freeze before validation
Source verification	Partial	Embedded source-by-claim audit
Paper-I viability	Unresolved	Complete geometry, chronology, and null intersection

37.2 Verified Paper-I Outputs

The strongest current Paper-I outputs are the reproducible present-coordinate calculations:

- bilateral surface distances;
- bilateral asymmetry;
- exact midpoint direction;
- midpoint separation;
- cross-track distance;
- projected halfway offset;

- path excess;
- chord length;
- chord depth;
- and incidence angle.

37.3 Current Negative Result

The registered present coordinates do not satisfy the source working criterion that Everest lie within 5° of the exact Aegean–Mariana midpoint.

This is a genuine negative result and remains part of the atlas.

37.4 Current Unresolved Questions

Paper I still requires:

- verified coordinate definitions;
- event-time reconstruction;
- independent structural chronology;
- coordinate perturbation analysis;
- opportunity-matched null models;
- multiple-selection accounting;
- frozen predictions;
- and independent reproduction.

37.5 Paper-I Atlas Conclusion

Paper-I atlas conclusion.
The registered present coordinates produce a reproducible near-equality between the Aegean–Everest and Everest–Mariana surface distances and place Everest close to the halfway station after projection onto the Aegean–Mariana great-circle path.
The same coordinates place Everest approximately 13.558849° from the exact midpoint and approximately 1507.497 km from the great-circle path.
The present-coordinate literal-midpoint criterion therefore fails its source working threshold.
The broader flagship hypothesis remains unresolved because its decisive tests require event-time paleogeography, chronology, selection-aware null models, and the mechanical viability examined in Paper II.

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38 Paper-I Atlas Synthesis

This Paper-I atlas synthesis records:

1. the complete Paper-I atlas scope;
2. separation of equidistance, exact midpoint, cross-track distance, and halfway station;
3. a twenty-four-item principal Paper-I claim registry;
4. the registered Aegean, Everest, and Mariana coordinates;
5. coordinate provenance and sensitivity requirements;
6. the spherical surface-distance equations;
7. the audited bilateral distances;
8. the audited 44.808 km difference;
9. the audited 0.373044% bilateral asymmetry;
10. the exact present-coordinate midpoint direction;
11. the 13.558849° Everest midpoint misfit;
12. the triggered present-coordinate 5° midpoint falsifier;
13. the direct and routed path calculations;
14. the 1507.497 km cross-track distance;
15. the 23.408 km projected-halfway offset;
16. the 267.302 km path excess;
17. the chord, half-chord, depth, and incidence audit;
18. the finding that the registered straight chord is not low-angle or grazing;
19. the Paper-I chronology registry;
20. the Paper-I source and data registry;
21. the explicit external-data gaps;
22. the Paper-I assumption registry;
23. the Paper-I parameter registry;
24. the Paper-I equation registry;
25. the complete numerical-result registry;
26. the corrected exploratory mass and diameter ranges;
27. the binding-energy benchmark limitation;
28. the geometric null-model architecture;
29. the search-space and selection ledger requirements;
30. the Paper-I prediction registry;

31. the Paper-I falsification registry;
32. compartmentalized interpretation of the triggered midpoint falsifier;
33. the contradiction and supersession audit;
34. the Paper-I dependency graph;
35. critical-node and failure-cut-set identification;
36. the recommended verification order;
37. the Paper-I status dashboard; and
38. the formal Paper-I atlas conclusion.

The following sections construct the complete Paper-II atlas:

- Paper-II mechanical claim registry;
- operational transmission definitions;
- entrance-coupling branches;
- coherent, fragmented, shock, phase-front, and hybrid transmission models;
- differentiated-Earth path registry;
- energy, mass, momentum, and size audits;
- pressure, temperature, damage, melt, phase, and density registries;
- dimensionless-number corrections;
- transit-time distinctions;
- midpoint-inheritance registry;
- terminal-response and exit-energy registry;
- Earth-survival and angular-momentum registry;
- global-marker registry;
- Mauna Kea secondary-hypothesis registry;
- Paper-II equation registry;
- Paper-II assumption and parameter registry;
- Paper-II prediction and falsification registries;
- Paper-II contradiction and supersession audit;
- Paper-II dependency graph;
- Paper-II viable-set atlas; and
- Paper-II status dashboard.

39 Paper-II Atlas Scope

39.1 Paper-II Function

Paper II evaluates whether any mechanically admissible process can transmit a directionally concentrated disturbance from the Paper-I entrance geometry through a differentiated Earth and produce compatible midpoint and terminal states.

For candidate event k, its central question is

$$\boxed{\mathcal{V}_{II,k} \neq \varnothing} \tag{192}$$

where $\mathcal{V}_{II,k}$ is the intersection of all required mechanical and planetary viability conditions for event k. In the flagship registry, $k = F$.

39.2 Paper-II Does Not Presume an Intact Projectile

The phrase

passed through Earth

is operationally defined as:

$$\begin{gathered}\text{continuous and directionally concentrated transfer of energy,}\\ \text{momentum, stress, or material-state change}\end{gathered} \tag{193}$$

between entrance and terminal regions.

It does not require that one coherent solid body remain intact across the full path.

39.3 Paper-II Branches

The Paper-II mechanism family is

$$\mathfrak{M}_{II} = \{\mathcal{M}_{\mathrm{coh}}, \mathcal{M}_{\mathrm{frag}}, \mathcal{M}_{\mathrm{shock}}, \mathcal{M}_{\mathrm{phase}}, \mathcal{M}_{\mathrm{hyb}}\}, \tag{194}$$

where:

$$\begin{aligned}
\mathcal{M}_{\mathrm{coh}} &= \text{coherent-body penetration,} && (195)\\
\mathcal{M}_{\mathrm{frag}} &= \text{fragmented penetration column,} && (196)\\
\mathcal{M}_{\mathrm{shock}} &= \text{shock-dominated transmission,} && (197)\\
\mathcal{M}_{\mathrm{phase}} &= \text{fracture or phase-front transmission,} && (198)\\
\mathcal{M}_{\mathrm{hyb}} &= \text{hybrid transmission.} && (199)
\end{aligned}$$

39.4 Paper-II Atlas Objects

The Paper-II atlas contains

$$\mathfrak{A}_{P2} = \{\mathfrak{C}_{P2}, \mathfrak{E}_{P2}, \mathfrak{AS}_{P2}, \mathfrak{P}_{P2}, \mathfrak{D}_{P2}, \mathfrak{S}_{P2}, \mathfrak{M}_{P2}, \mathfrak{R}_{P2}, \mathfrak{F}_{P2}, \mathfrak{G}_{P2}\}\,. \tag{200}$$

39.5 Paper-II Handoff Burden

Paper II must provide Paper III with a physically admissible terminal state rather than a verbal assertion.

The handoff state is

$$\mathbf{Q}^{(k)}_{\mathrm{III},0} = (\mathcal{B}_{\mathrm{ABC}}, \mathbf{J}_{\mathrm{plate}}, \Delta T, \Delta\rho, \mathbf{D}, \Delta\phi, \chi_m, \Delta\mathbf{C}, \Delta\boldsymbol{\sigma}, \mathbf{u}, \Delta\mathbf{g}, \Delta\boldsymbol{\omega})\,. \tag{201}$$

Only fields generated by a surviving Paper-II branch may enter this handoff.

40 Paper-II Mechanical Claim Registry

Table 19: Principal Paper-II mechanical claim registry.

ID	Claim	Role	Current status
`ABC-P2-CLM-001`	Paper II tests whether any mechanically admissible transmission branch connects the Paper-I entrance geometry to compatible midpoint and terminal states.	Foundational	`ARCHITECTURE-DEFINED`
`ABC-P2-CLM-002`	The phrase "passed through Earth" does not require coherent-body survival.	Definition	`DEFINITION-REGISTERED`
`ABC-P2-CLM-003`	The ideal Paper-I chord passes primarily through mantle material and does not cross the core.	Geometric input	`CONDITIONALLY-SUPPORTED`
`ABC-P2-CLM-004`	The lower-mantle path dominates the idealized chordal transit.	Path interpretation	`CALCULATION-VERIFIED`
`ABC-P2-CLM-005`	The energy interval 10^{29} to 10^{31} J is an exploratory search range rather than a validated event-energy estimate.	Parameter status	`UNRESOLVED`
`ABC-P2-CLM-006`	The velocity interval 10 to 30 $\mathrm{km\,s^{-1}}$ is an exploratory search range.	Parameter status	`UNRESOLVED`
`ABC-P2-CLM-007`	The corrected energy–velocity conversion gives a mass range of approximately 2.22×10^{20} to 2.00×10^{23} kg.	Calculated	`CALCULATION-VERIFIED`
`ABC-P2-CLM-008`	At 3000 $\mathrm{kg\,m^{-3}}$, the corresponding equivalent spherical diameter range is approximately 521 to 5031 km.	Calculated	`CONDITIONAL-CALCULATION`
`ABC-P2-CLM-009`	The corresponding momentum range is approximately 6.67×10^{24} to 2.00×10^{27} $\mathrm{kg\,m\,s^{-1}}$.	Calculated	`CALCULATION-VERIFIED`
`ABC-P2-CLM-010`	The event-energy interval is below the adopted Earth gravitational-binding-energy benchmark.	Calculated benchmark	`CALCULATION-VERIFIED`

ID	Claim	Role	Current status
ABC-P2-CLM-011	Being below the gravitational-binding-energy benchmark does not establish planetary survival.	Physical limitation	REQUIREMENT-DEFINED
ABC-P2-CLM-012	The coherent-body branch carries the strongest burden because it must preserve a directionally coherent material body through extreme pressure, heating, deformation, and drag.	Comparative branch	STRONGLY-BURDENED
ABC-P2-CLM-013	A fragmented penetration column may preserve directional momentum without preserving one intact body.	Mechanism branch	UNTESTED
ABC-P2-CLM-014	A shock-dominated branch may transmit energy and stress without transporting most projectile mass to the terminal region.	Mechanism branch	UNTESTED
ABC-P2-CLM-015	A fracture or phase-front branch may transmit a directional material state through damage, phase change, or mechanically linked failure.	Mechanism branch	UNTESTED
ABC-P2-CLM-016	A hybrid branch may combine material penetration, fragmentation, shock, melt, damage, and later mechanical relaxation.	Mechanism branch	UNTESTED
ABC-P2-CLM-017	The constant-speed chord-transit interval of approximately 338 to 1015 s is a kinematic diagnostic and not a shock-travel time.	Timescale	CALCULATION-VERIFIED
ABC-P2-CLM-018	The previously invoked long-timescale effective viscosity produces $\mathrm{Re} \approx 5.12 \times 10^{-7}$, not $\mathrm{Re} \gg 1$.	Corrected diagnostic	CALCULATION-VERIFIED
ABC-P2-CLM-019	The corrected Froude diagnostic is approximately $\mathrm{Fr} = 2.52$ under the declared scaling assumptions.	Corrected diagnostic	CONDITIONAL-CALCULATION
ABC-P2-CLM-020	The corrected Rossby diagnostic is approximately $\mathrm{Ro} = 21.4$, not less than or equal to unity.	Corrected diagnostic	CONDITIONAL-CALCULATION
ABC-P2-CLM-021	The Deborah-number interval is approximately 3.125 to 312.5 under the declared relaxation and loading times.	Corrected diagnostic	CONDITIONAL-CALCULATION
ABC-P2-CLM-022	The long-timescale mantle viscosity used in the Reynolds-number diagnostic may be inappropriate for the short transient regime.	Model limitation	UNRESOLVED
ABC-P2-CLM-023	The assumed terminal energy fraction is 0.1 to 0.5 and is not yet derived.	Parameter status	ASSUMPTION
ABC-P2-CLM-024	The resulting corrected terminal-energy range is 10^{28} to 5×10^{30} J.	Calculated	CONDITIONAL-CALCULATION
ABC-P2-CLM-025	The terminal-energy range does not extend automatically to 10^{31} J when the maximum assumed terminal fraction is 0.5.	Corrected result	CALCULATION-VERIFIED
ABC-P2-CLM-026	A viable branch must produce a compatible entrance, path, midpoint, terminal, planetary-survival, rotational, and marker state simultaneously.	Viability rule	ARCHITECTURE-DEFINED
ABC-P2-CLM-027	No complete Paper-II transmission branch has yet been numerically demonstrated.	Status	UNRESOLVED
ABC-P2-CLM-028	The Paper-II framework is capable of rejecting all proposed branches through an empty viable-set intersection.	Falsifiability	ARCHITECTURE-DEFINED
ABC-P2-CLM-029	A nonempty mechanical branch would establish conditional admissibility, not historical occurrence.	Scope control	REQUIREMENT-DEFINED

ID	Claim	Role	Current status
ABC-P2-CLM-030	The Mauna Kea secondary-displacement concept is a separate, source-derived hypothesis and is not required for the principal Aegean–Mariana transmission branch.	Secondary scope	UNRESOLVED
ABC-P2-CLM-031	Paper III may use only the actual fields produced by a surviving Paper-II branch.	Handoff rule	REQUIREMENT-DEFINED
ABC-P2-CLM-032	A branch that matches terminal geometry but violates conservation, survival, chronology, or global-marker constraints is not mechanically viable.	Physical rule	REQUIREMENT-DEFINED

40.1 Current Mechanical Status

Paper II presently defines a detailed mechanical search and falsification architecture.

It does not presently establish that:

- a coherent body survived;
- a fragmented column remained sufficiently directional;
- a shock remained sufficiently concentrated;
- a phase front traversed the required path;
- or a hybrid branch satisfies all constraints.

41 Operational Transmission Definitions

41.1 Transmission Record

For branch b, define

$$\mathbf{T}_b = (\mathbf{Q}_{A,b}, \mathbf{Q}_{P,b}, \mathbf{Q}_{H,b}, \mathbf{Q}_{M,b}, \mathbf{Q}_{\oplus,b}), \tag{202}$$

where:

$$\mathbf{Q}_{A,b} = \text{entrance state}, \tag{203}$$

$$\mathbf{Q}_{P,b} = \text{path state}, \tag{204}$$

$$\mathbf{Q}_{H,b} = \text{midpoint or interior-response state}, \tag{205}$$

$$\mathbf{Q}_{M,b} = \text{terminal state}, \tag{206}$$

$$\mathbf{Q}_{\oplus,b} = \text{whole-Earth response.} \tag{207}$$

41.2 Directional Concentration

Let transported energy-flux vector be

$$\mathbf{q}_{E,b}\left(\mathbf{x},t\right). \tag{208}$$

For candidate path direction $\widehat{\mathbf{d}}_P$, define directional concentration

$$C_{E,b} = \frac{\displaystyle\int_{\mathcal{T}_P} \max\left[\mathbf{q}_{E,b}\cdot\widehat{\mathbf{d}}_P, 0\right]\,dA\,dt}{\displaystyle\int_{\mathcal{S}} \|\mathbf{q}_{E,b}\|\,dA\,dt}. \tag{209}$$

A branch must declare the minimum directional concentration required for terminal attribution.

41.3 Momentum Transmission Fraction

$$f_{p,b} = \frac{\|\mathbf{p}_{M,b}\|}{\|\mathbf{p}_{A,b}\|}. \tag{210}$$

41.4 Energy Transmission Fraction

$$f_{E,b} = \frac{E_{M,b}}{E_{A,b}}. \tag{211}$$

41.5 Coherence Fraction

For branch-specific coherence measure $\mathcal{C}_b$,

$$f_{\mathcal{C},b} = \frac{\mathcal{C}_{M,b}}{\mathcal{C}_{A,b}}. \tag{212}$$

Coherence may refer to:

- material continuity;
- directional momentum;
- stress-front continuity;
- fracture connectivity;
- phase-front continuity;
- or thermal-path continuity.

41.6 Transit Completion

A branch completes transit only if

$$\mathcal{T}_b^{\text{complete}} = I_{\text{entrance},b} I_{\text{path},b} I_{\text{midpoint},b} I_{\text{terminal},b} I_{\text{survival},b} = 1. \tag{213}$$

41.7 No Single Universal Transit Metric

The coherent branch and shock branch cannot be judged by one identical coherence variable.

Each branch must use a physically appropriate transmission metric while remaining subject to common conservation and terminal-response tests.

42 Entrance-Coupling Registry

42.1 Pre-Entrance State

The pre-entrance state is

$$\mathbf{Q}_A^- = \left(m_p, \mathbf{v}_p, E_p, \mathbf{L}_p, \rho_p, T_p, \mathbf{C}_p, \mathbf{Q}_{A,\oplus}^-\right). \tag{214}$$

42.2 Post-Coupling State

The post-coupling state is

$$\mathbf{Q}_A^+ = (\mathbf{u}, \Delta T, \Delta P, \mathbf{D}, \chi_m, \Delta\phi, \Delta\rho, \mathbf{J})_A. \tag{215}$$

42.3 Entrance Partition Fractions

Define fractions

$$(f_{\rm trans}, f_{\rm heat}, f_{\rm fract}, f_{\rm melt}, f_{\rm eject}, f_{\rm atm}, f_{\rm ocean}, f_{\rm bulk}), \tag{216}$$

subject to

$$\sum_a f_a = 1 \tag{217}$$

within declared numerical error.

42.4 Entrance-Coupling Efficiency

$$\eta_A = \frac{E_{\rm path}^+}{E_{\rm incident}}. \tag{218}$$

42.5 Directional-Coupling Efficiency

$$\eta_A^{\rm dir} = \frac{\mathbf{p}_{\rm path}^+ \cdot \widehat{\mathbf{d}}_P}{\|\mathbf{p}_{\rm incident}\|}. \tag{219}$$

42.6 Entrance Registry

Table 20: Paper-II entrance-coupling registry.

ID	Quantity	Required determination	Status
ABC-P2-PAR-001	Incident energy	Branch-specific value within tested bounds	Unresolved
ABC-P2-PAR-002	Incident momentum	Derived from branch mass and velocity	Conditional
ABC-P2-PAR-003	Entrance angle	Paper-I chord or alternative path geometry	Geometry-audited
ABC-P2-PAR-004	Entrance coupling efficiency	Forward-model result	Unresolved
ABC-P2-PAR-005	Directional coupling efficiency	Forward-model result	Unresolved
ABC-P2-PAR-006	Atmospheric and oceanic loss	Environment-specific calculation	Unresolved
ABC-P2-PAR-007	Entrance damage volume	Constitutive simulation	Unresolved
ABC-P2-PAR-008	Entrance melt fraction	Thermomechanical simulation	Unresolved
ABC-P2-PAR-009	Entrance ejecta fraction	Material-response simulation	Unresolved
ABC-P2-PAR-010	Path-injected stress and velocity field	Paper-II numerical output	Unresolved

42.7 Entrance Falsification Principle

A branch fails at entrance if the event cannot inject enough directionally concentrated energy or momentum into the required path after atmospheric, oceanic, ejecta, fracture, heating, and bulk-motion losses are counted.

43 Transmission-Branch Registry

43.1 Branch Record

For branch b,

$$\begin{aligned}\mathbf{B}_b^{II} = (&\mathrm{ID}_b, \mathrm{definition}_b, \mathrm{governing\ model}_b, \mathrm{required\ inputs}_b, \\ &\mathrm{survival\ criterion}_b, \mathrm{terminal\ criterion}_b, \mathrm{status}_b).\end{aligned} \tag{220}$$

43.2 Branch Registry Table

Table 21: Paper-II transmission-branch registry.

ID	Branch	Minimum mechanical burden	Status
ABC-P2-MOD-001	Coherent-body penetration	Preserve sufficient material integrity, directional momentum, and path continuity through the full chord while surviving pressure, heating, deformation, drag, fragmentation, and terminal deceleration.	Strongly burdened
ABC-P2-MOD-002	Fragmented penetration column	Maintain a sufficiently concentrated and directionally correlated fragment or melt column despite dispersion and coupling losses.	Untested

ID	Branch	Minimum mechanical burden	Status
`ABC-P2-MOD-003`	Shock-dominated transmission	Generate a stress or shock field that remains sufficiently directional, energetic, and temporally coherent to produce the required terminal response.	Untested
`ABC-P2-MOD-004`	Fracture or phase-front transmission	Create a connected damage, fracture, phase, or transformation front that propagates through the required differentiated path.	Untested
`ABC-P2-MOD-005`	Hybrid transmission	Generate a physically coupled combination of coherent material, fragmentation, shock, melt, damage, and later relaxation without double-counting energy or momentum.	Untested

43.3 Coherent-Body Integrity Metric

For coherent mass m_{coh},

$$f_{\mathrm{coh}} = \frac{m_{\mathrm{coh},M}}{m_{\mathrm{coh},A}}. \tag{221}$$

43.4 Fragment Dispersion Metric

For fragment positions $\mathbf{x}_k$,

$$\sigma^2_{\perp,\mathrm{frag}} = \frac{\sum_k m_k \left\|\mathbf{x}_{k,\perp} - \overline{\mathbf{x}}_\perp\right\|^2}{\sum_k m_k}. \tag{222}$$

43.5 Shock Directionality Metric

For stress tensor $\boldsymbol{\sigma}$,

$$C_\sigma = \frac{\displaystyle\int_{\mathcal{T}_P} \left|\widehat{\mathbf{d}}_P \cdot \boldsymbol{\sigma}\widehat{\mathbf{d}}_P\right| \, dV}{\displaystyle\int_{\mathcal{V}_\oplus} \|\boldsymbol{\sigma}\| \, dV}. \tag{223}$$

43.6 Damage Connectivity Metric

For damage field $D(\mathbf{x}, t)$, define the threshold domain

$$\mathcal{D}_D = \left\{\mathbf{x} : D(\mathbf{x}, t) \geq D_{\mathrm{crit}}\right\}. \tag{224}$$

The phase or fracture-front branch requires a connected path between entrance and terminal neighborhoods.

43.7 Hybrid Non-Double-Counting Rule

The hybrid energy partition must satisfy

$$E_{\mathrm{coh}} + E_{\mathrm{frag}} + E_{\mathrm{shock}} + E_{\mathrm{phase}} + E_{\mathrm{loss}} = E_{\mathrm{incident}} \tag{225}$$

within declared numerical tolerance.

44 Differentiated-Earth Path Registry

44.1 Path Coordinate

Let s measure distance along the idealized Paper-I chord:

$$0 \leq s \leq L_{\mathrm{chord}}. \tag{226}$$

44.2 Layered Background State

The background Earth state is

$$\mathbf{Q}_{\oplus,0}(r) = \left(\rho_0(r), P_0(r), T_0(r), K_0(r), G_0(r), \eta_0(r), \mathbf{C}_0(r), \phi_0(r)\right). \tag{227}$$

44.3 Path State

For branch b,

$$\mathbf{Q}_{P,b}(s,t) = \left(\rho_b, P_b, T_b, \mathbf{u}_b, \boldsymbol{\sigma}_b, D_b, \chi_{m,b}, \Delta\phi_b, \mathbf{C}_b\right). \tag{228}$$

44.4 Registered Path Geometry

The current spherical-path inputs are:

$$L_{\mathrm{chord}} = 10150.567 \text{ km}, \tag{229}$$
$$h_{\max} = 2519.878 \text{ km}, \tag{230}$$
$$\alpha_h = 52.808799^\circ. \tag{231}$$

44.5 Layer-Exposure Functional

For Earth layer ℓ,

$$L_\ell = \int_0^{L_{\mathrm{chord}}} I_\ell\left[r(s)\right]\, ds, \tag{232}$$

where I_ℓ is one inside layer ℓ and zero elsewhere.

44.6 Path-Integrated Resistance

For effective resistance density $\mathcal{R}_b(s)$,

$$W_{\mathrm{res},b} = \int_0^{L_{\mathrm{chord}}} \mathcal{R}_b(s)\,ds. \tag{233}$$

44.7 Path-Integrated Heating

$$Q_{\mathrm{path},b} = \int_0^{t_f} \int_{\mathcal{T}_P} \dot{q}_b\,dV\,dt. \tag{234}$$

44.8 Path-Integrated Damage

$$\mathcal{D}_{\mathrm{path},b} = \int_0^{t_f} \int_{\mathcal{T}_P} \dot{D}_b\,dV\,dt. \tag{235}$$

44.9 Differentiated-Path Requirements

A complete path model must include:

- depth-dependent density;
- depth-dependent pressure;
- temperature;
- elastic and viscous response;
- phase transitions;
- compressibility;
- melting;
- damage;
- curvature;
- gravity;
- and rotational effects where dynamically relevant.

44.10 Path Approximation Status

The spherical chord is a geometry input.

It is not yet a validated physical trajectory through a rotating, heterogeneous, deformable, differentiated Earth.

45 Energy, Mass, Momentum, and Size Audit

45.1 Exploratory Energy Interval

$$10^{29} \le E_K \le 10^{31}\ \mathrm{J}. \tag{236}$$

45.2 Exploratory Velocity Interval

$$10^4 \leq v \leq 3 \times 10^4 \ \mathrm{m\,s^{-1}}. \tag{237}$$

45.3 Mass From Kinetic Energy

$$E_K = \frac{1}{2}mv^2 \tag{238}$$

gives

$$m = \frac{2E_K}{v^2}. \tag{239}$$

The extreme combinations yield:

$$m_{\min} = \frac{2 \times 10^{29}}{(3 \times 10^4)^2} \approx 2.22 \times 10^{20} \ \mathrm{kg}, \tag{240}$$

and

$$m_{\max} = \frac{2 \times 10^{31}}{(10^4)^2} = 2.00 \times 10^{23} \ \mathrm{kg}. \tag{241}$$

45.4 Equivalent Spherical Diameter

For density ρ_p,

$$D_p = 2\left(\frac{3m}{4\pi\rho_p}\right)^{1/3}. \tag{242}$$

At

$$\rho_p = 3000 \ \mathrm{kg\,m^{-3}}, \tag{243}$$

the range is approximately

$$521 \ \mathrm{km} \lesssim D_p \lesssim 5031 \ \mathrm{km}. \tag{244}$$

45.5 Momentum

$$p = mv. \tag{245}$$

The extreme audited values are approximately

$$6.67 \times 10^{24} \lesssim p \lesssim 2.00 \times 10^{27} \ \mathrm{kg\,m\,s^{-1}}. \tag{246}$$

45.6 Energy-to-Binding Ratio

For benchmark

$$U_\oplus \approx 2.24 \times 10^{32} \text{ J}, \tag{247}$$

define

$$\Pi_U = \frac{E_K}{U_\oplus}. \tag{248}$$

The range is approximately

$$4.5 \times 10^{-4} \lesssim \Pi_U \lesssim 4.5 \times 10^{-2}. \tag{249}$$

45.7 Audit Interpretation

These calculations establish consequences of the declared exploratory ranges.

They do not establish:

- the actual event energy;
- the actual projectile mass;
- the actual projectile density;
- the actual velocity;
- the physical existence of a coherent body;
- or survival of Earth.

45.8 Range-Correlation Requirement

Energy, mass, velocity, density, and size cannot be sampled as independent arbitrary parameters when connected by the preceding equations.

The parameter registry must preserve their covariance.

46 Thermodynamic, Damage, Melt, and Phase Registry

46.1 Energy Equation

A branch-specific thermal equation may be written

$$\rho c_P \frac{DT}{Dt} = \nabla \cdot (k\nabla T) + \boldsymbol{\sigma} : \dot{\boldsymbol{\epsilon}} + Q_{\text{shock}} + Q_{\text{phase}} - Q_{\text{loss}}. \tag{250}$$

46.2 Damage Evolution

$$\frac{DD}{Dt} = \mathcal{F}_D\left(P, T, \boldsymbol{\sigma}, \dot{\boldsymbol{\epsilon}}, D, \phi, \chi_m, \mathbf{C}\right). \tag{251}$$

46.3 Melt-Fraction Evolution

$$\frac{D\chi_m}{Dt} = \Gamma_m - \Lambda_m, \tag{252}$$

where Γ_m and Λ_m represent production and freezing or removal.

46.4 Phase Evolution

For phase fractions ϕ_α,

$$\sum_\alpha \phi_\alpha = 1. \tag{253}$$

The phase evolution is

$$\frac{D\phi_\alpha}{Dt} = \mathcal{F}_{\phi_\alpha}\left(P, T, \mathbf{C}, \dot{P}, \dot{T}, t\right). \tag{254}$$

46.5 Density Perturbation

$$\Delta\rho = \Delta\rho_T + \Delta\rho_P + \Delta\rho_C + \Delta\rho_\phi + \Delta\rho_m + \Delta\rho_D. \tag{255}$$

46.6 Constitutive State Registry

Table 22: Paper-II thermodynamic and material-state registry.

ID	Field	Required output	Status
ABC-P2-RES-001	Pressure perturbation	$\Delta P(\mathbf{x}, t)$	Unresolved
ABC-P2-RES-002	Temperature perturbation	$\Delta T(\mathbf{x}, t)$	Unresolved
ABC-P2-RES-003	Damage field	$D(\mathbf{x}, t)$	Unresolved
ABC-P2-RES-004	Melt fraction	$\chi_m(\mathbf{x}, t)$	Unresolved
ABC-P2-RES-005	Phase perturbation	$\Delta\phi(\mathbf{x}, t)$	Unresolved
ABC-P2-RES-006	Density perturbation	$\Delta\rho(\mathbf{x}, t)$	Unresolved
ABC-P2-RES-007	Elasticity perturbation	$\Delta\mathbf{C}(\mathbf{x}, t)$	Unresolved
ABC-P2-RES-008	Residual stress	$\Delta\boldsymbol{\sigma}(\mathbf{x}, t)$	Unresolved
ABC-P2-RES-009	Velocity field	$\mathbf{u}(\mathbf{x}, t)$	Unresolved

46.7 Thermodynamic Falsification Principle

A branch fails if the pressure, temperature, melt, damage, or phase state required for transmission is incompatible with:

- material survival;

- planetary survival;
- terminal energy;
- predicted geophysical remnants;
- or subsequent Paper-III evolution.

47 Dimensionless-Number and Timescale Audit

47.1 Purpose

Dimensionless numbers may help identify dominant physical regimes.

They do not validate a model when their characteristic scales or material properties are inappropriate.

47.2 Reynolds Number

$$\mathrm{Re} = \frac{\rho v L}{\eta}. \tag{256}$$

Using the previously declared scaling and

$$\eta = 10^{21}\ \mathrm{Pa\,s}, \tag{257}$$

the corrected value is

$$\mathrm{Re} \approx 5.12 \times 10^{-7}. \tag{258}$$

This does not support a claim that $\mathrm{Re} \gg 1$.

47.3 Reynolds-Number Limitation

The effective viscosity 10^{21} Pa s is commonly associated with long-timescale mantle deformation in the current model architecture.

Whether it is meaningful for a short, extreme transient must be tested rather than assumed.

47.4 Froude Number

$$\mathrm{Fr} = \frac{v}{\sqrt{gL}}. \tag{259}$$

The audited value under the declared scaling is

$$\mathrm{Fr} \approx 2.52. \tag{260}$$

47.5 Rossby Number

$$\mathrm{Ro} = \frac{v}{2\Omega L}. \tag{261}$$

The corrected diagnostic is

$$\mathrm{Ro} \approx 21.4. \tag{262}$$

This does not support the earlier implication that $\mathrm{Ro} \leq 1$ under the same scale selection.

47.6 Deborah Number

$$\mathrm{De} = \frac{\tau_{\mathrm{relax}}}{\tau_{\mathrm{load}}}. \tag{263}$$

The audited interval is

$$3.125 \lesssim \mathrm{De} \lesssim 312.5. \tag{264}$$

47.7 Constant-Speed Transit Time

$$t_{\mathrm{proj}} = \frac{L_{\mathrm{chord}}}{v} \tag{265}$$

gives

$$338\ \mathrm{s} \lesssim t_{\mathrm{proj}} \lesssim 1015\ \mathrm{s}. \tag{266}$$

47.8 Shock-Transit Time

For local wave speed $c_s(s)$,

$$t_{\mathrm{shock}} = \int_0^{L_{\mathrm{chord}}} \frac{ds}{c_s(s)}. \tag{267}$$

This is distinct from projectile transit.

47.9 Damage-Front Transit

For damage-front speed $v_D(s,t)$,

$$t_D = \int_0^{L_{\mathrm{chord}}} \frac{ds}{v_D(s,t)}. \tag{268}$$

47.10 Thermal-Diffusion Timescale

For length scale L and thermal diffusivity κ,

$$\tau_{\text{diff}} = \frac{L^2}{\kappa}. \tag{269}$$

47.11 Timescale Registry

Table 23: Paper-II timescale registry.

ID	Timescale	Meaning	Status
`ABC-P2-PAR-011`	Projectile transit	Constant-speed chord diagnostic	Calculated
`ABC-P2-PAR-012`	Shock transit	Wave or shock propagation	Not calculated
`ABC-P2-PAR-013`	Damage-front transit	Fracture or phase-front propagation	Not calculated
`ABC-P2-PAR-014`	Material relaxation	Stress, viscoelastic, or phase relaxation	Unresolved
`ABC-P2-PAR-015`	Thermal diffusion	Cooling and thermal-memory decay	Unresolved
`ABC-P2-PAR-016`	Healing	Damage and permeability recovery	Unresolved
`ABC-P2-PAR-017`	Long-time geodynamic response	Paper-III inheritance interval	Unresolved

47.12 Dimensionless-Audit Conclusion

The corrected dimensionless diagnostics do not establish one dominant transmission regime.

They identify scale-selection and constitutive questions that must be resolved branch by branch.

48 Midpoint-Inheritance Registry

48.1 Midpoint Is a Response Region

Paper II does not require the surface Everest coordinate to lie exactly on the present ideal chord.

It evaluates whether a reconstructed midpoint or nearby interior response region could receive a mechanically compatible state.

48.2 Midpoint State

Define

$$\mathbf{Q}_H^+ = (\Delta P_H, \Delta T_H, \mathbf{D}_H, \chi_{m,H}, \Delta\phi_H, \Delta\rho_H, \Delta\mathbf{C}_H, \Delta\boldsymbol{\sigma}_H, \mathbf{u}_H)\,. \tag{270}$$

48.3 Midpoint Localization Kernel

For path distance $d_P(\mathbf{x})$ and midpoint distance $d_H(\mathbf{x})$,

$$K_H(\mathbf{x}) = \exp\left[-\frac{d_P^2(\mathbf{x})}{2\sigma_P^2} - \frac{d_H^2(\mathbf{x})}{2\sigma_H^2}\right]. \tag{271}$$

The widths σ_P and σ_H must be physically derived or explicitly penalized as fitted flexibility.

48.4 Midpoint Inheritance Variables

The Paper-II midpoint registry includes:

- residual compression;
- residual extension;
- anisotropic damage;
- phase change;
- density contrast;
- thermal anomaly;
- melt;
- elastic anisotropy;
- and long-time stress inheritance.

48.5 Midpoint Persistence

For state component q_H,

$$P_{H,q}(t) = \frac{\|q_H(t)\|}{\left\|q_H(t_H^+)\right\|}. \tag{272}$$

48.6 Midpoint Claim Boundary

A calculated midpoint-state field would not by itself establish that the modern Everest system was caused by the event.

That inference additionally requires:

- event-time geometry;
- chronological compatibility;
- long-time persistence;
- structural amplification;
- and comparison with alternative mechanisms.

48.7 Midpoint Falsifier

The midpoint-inheritance branch fails if no admissible Paper-II model produces a sufficiently localized, persistent, and chronologically compatible state in the reconstructed response region.

49 Terminal Response and Exit-Energy Registry

49.1 Terminal State

Define

$$\mathbf{Q}_M^{+} = (E_M, \mathbf{p}_M, \Delta P_M, \Delta T_M, \mathbf{D}_M, \chi_{m,M}, \Delta\phi_M, \Delta\rho_M, \mathbf{u}_M, \mathbf{Q}_{\text{eject},M})\,. \tag{273}$$

49.2 Terminal Energy Fraction

$$f_{\text{exit}} = \frac{E_M}{E_A}. \tag{274}$$

The working range is

$$0.1 \leq f_{\text{exit}} \leq 0.5. \tag{275}$$

This range is assumed rather than derived.

49.3 Corrected Terminal-Energy Range

$$E_M = f_{\text{exit}} E_A. \tag{276}$$

With the declared search ranges,

$$10^{28} \leq E_M \leq 5 \times 10^{30} \text{ J}. \tag{277}$$

49.4 Terminal Momentum Fraction

$$f_{p,\text{exit}} = \frac{\|\mathbf{p}_M\|}{\|\mathbf{p}_A\|}. \tag{278}$$

49.5 Terminal Direction Residual

For modeled terminal momentum direction $\widehat{\mathbf{p}}_M$ and path direction $\widehat{\mathbf{d}}_P$,

$$\Delta\theta_M = \arccos\left[\widehat{\mathbf{p}}_M \cdot \widehat{\mathbf{d}}_P\right]. \tag{279}$$

49.6 Terminal Mechanism Classes

The terminal response may include:

- direct material emergence;
- subsurface deceleration;
- excavation;
- collapse;

- fracture;
- phase change;
- melt generation;
- distributed deformation;
- deep density reorganization;
- and later structural reactivation.

49.7 No Automatic Trench Attribution

A modern trench cannot be treated as a direct terminal crater merely because it occupies the target region.

Paper III and Paper IV must distinguish:

- direct excavation;
- collapse;
- bending;
- underthrusting;
- inherited weakness;
- later descent;
- and hybrid evolution.

49.8 Terminal Compatibility Record

$$\mathbf{C}_{M,b} = (C_{\text{location}}, C_{\text{energy}}, C_{\text{momentum}}, C_{\text{direction}}, C_{\text{depth}}, C_{\text{chronology}}, C_{\text{geophysics}})_b . \tag{280}$$

49.9 Terminal Falsifier

A branch fails terminal response if its predicted energy, momentum, geometry, depth, timing, or subsurface state cannot produce the required terminal observations without violating whole-Earth constraints.

50 Earth Survival and Angular-Momentum Registry

50.1 Planetary Survival Is Multidimensional

Survival requires more than

$$E < U_{\oplus}. \tag{281}$$

The survival state includes

$$\mathbf{Q}_{\oplus}^{\mathrm{surv}} = (\Delta E_{\oplus}, \Delta\mathbf{L}_{\oplus}, \Delta\boldsymbol{\omega}_{\oplus}, \Delta I_{\oplus}, \Delta T_{\oplus}, \Delta\rho_{\oplus}, \Delta R_{\oplus}, M_{\mathrm{loss}}, Q_{\mathrm{atm}}, Q_{\mathrm{ocean}}) \,. \tag{282}$$

50.2 Total Energy Closure

$$E_{\mathrm{incident}} = E_{\mathrm{internal}} + E_{\mathrm{kinetic}} + E_{\mathrm{gravity}} + E_{\mathrm{fracture}} + E_{\mathrm{phase}} + E_{\mathrm{ejecta}} + E_{\mathrm{escape}} + E_{\mathrm{radiated}}. \tag{283}$$

50.3 Total Momentum Closure

$$\mathbf{p}_{\mathrm{incident}} = \mathbf{p}_{\mathrm{Earth}} + \mathbf{p}_{\mathrm{ejecta}} + \mathbf{p}_{\mathrm{atmosphere}} + \mathbf{p}_{\mathrm{ocean}} + \mathbf{p}_{\mathrm{escape}}. \tag{284}$$

50.4 Angular Momentum

For incident position $\mathbf{r}_A$ and momentum $\mathbf{p}_A$,

$$\Delta\mathbf{L}_{\mathrm{inc}} = \mathbf{r}_A \times \mathbf{p}_A. \tag{285}$$

The whole-Earth angular-momentum balance is

$$\Delta\mathbf{L}_{\mathrm{inc}} = \Delta\mathbf{L}_{\oplus} + \Delta\mathbf{L}_{\mathrm{ejecta}} + \Delta\mathbf{L}_{\mathrm{escape}} + \Delta\mathbf{L}_{\mathrm{other}}. \tag{286}$$

50.5 Rotation Change

For Earth inertia tensor $\mathbf{I}_{\oplus}$,

$$\Delta\boldsymbol{\omega}_{\oplus} \approx \mathbf{I}_{\oplus}^{-1}\Delta\mathbf{L}_{\oplus} \tag{287}$$

under a small-change approximation.

50.6 Survival Registry

Table 24: Paper-II whole-Earth survival registry.

ID	Constraint	Required evaluation	Status
`ABC-P2-FAL-001`	Gravitational disruption	Energy, mass loss, deformation, and binding	Untested
`ABC-P2-FAL-002`	Rotational incompatibility	Angular momentum and rotation change	Untested
`ABC-P2-FAL-003`	Atmospheric incompatibility	Heating, loss, chemistry, and persistence	Untested
`ABC-P2-FAL-004`	Oceanic incompatibility	Displacement, vaporization, circulation, and sediment response	Untested
`ABC-P2-FAL-005`	Crustal and mantle incompatibility	Global fracture, melt, strain, and density state	Untested

ID	Constraint	Required evaluation	Status
`ABC-P2-FAL-006`	Thermal incompatibility	Whole-Earth temperature and heat budget	Untested

50.7 Survival Principle

A branch that leaves Earth gravitationally bound may still fail because it predicts incompatible rotation, heating, mass loss, global deformation, atmospheric effects, or oceanic effects.

51 Global Marker Registry

51.1 Purpose

A large global event should generate more than one favorable local geometry.

The predicted marker suite must follow from the modeled event state.

51.2 Marker Classes

The Paper-II marker registry includes candidate:

- pressure markers;
- thermal markers;
- melt markers;
- phase-transition markers;
- shock markers;
- damage markers;
- ejecta markers;
- atmospheric markers;
- oceanic markers;
- magnetic markers;
- isotopic markers;
- sedimentary markers;
- and global chronological markers.

51.3 Marker Prediction Record

For marker class g,

$$\mathbf{M}_{g,b} = (\text{type}, \text{location}, \text{magnitude}, \text{age}, \text{duration}, \text{preservation}, \text{control})_{g,b}\,. \tag{288}$$

51.4 Marker Presence Likelihood

$$p\left(\mathbf{D}_g^{\mathrm{obs}} \mid \mathcal{M}_b, \boldsymbol{\Theta}_b\right). \tag{289}$$

51.5 Marker Absence

Absence is informative only when the model predicts:

- sufficient production;
- sufficient preservation;
- adequate sampling;
- and adequate detection power.

51.6 Global-Marker Viable Set

$$\mathcal{V}_{\mathrm{markers},b} = \bigcap_g \mathcal{V}_{g,b}. \tag{290}$$

51.7 Global-Marker Falsifier

A branch fails the marker test if it necessarily predicts a detectable, well-preserved, globally distributed marker suite that is absent in adequate independent data.

52 Mauna Kea Secondary-Hypothesis Registry

52.1 Scope

The Mauna Kea concept is registered as a secondary displacement hypothesis.

It is not a required component of the primary Aegean–Mariana transmission branch.

52.2 Source-Derived Parameter Range

The source hypothesis used:

$$10^{19} \leq m_K \leq 10^{21}\ \mathrm{kg}, \tag{291}$$

and

$$10^{-2} \leq \Delta v_K \leq 1\ \mathrm{m\,s^{-1}}. \tag{292}$$

52.3 Secondary Energy

$$E_K^{\mathrm{sec}} = \frac{1}{2} m_K \left(\Delta v_K\right)^2. \tag{293}$$

The exact endpoint range implied by the registered mass and velocity bounds is

$$5 \times 10^{14} \leq E_K^{\text{sec}} \leq 5 \times 10^{20} \text{ J}. \tag{294}$$

The broader 10^{15} to 10^{21} J interval is retained only as the rounded source-document envelope, not as the exact consequence of the registered endpoint values.

The corresponding momentum-increment envelope is

$$10^{17} \leq \Delta p_K = m_K \Delta v_K \leq 10^{21} \text{ kg m s}^{-1}. \tag{295}$$

52.4 Secondary-Hypothesis Record

Table 25: Mauna Kea secondary-hypothesis registry.

ID	Item	Required support	Status
ABC-P2-CLM-033	A secondary block or material displacement occurred.	Independent material and trajectory evidence	Unresolved
ABC-P2-PAR-018	Secondary mass	Independent volume and density constraint	Source-derived
ABC-P2-PAR-019	Velocity increment	Mechanical reconstruction	Source-derived
ABC-P2-RES-010	Secondary energy	Calculation from source bounds	Conditional
ABC-P2-FAL-007	Geometric decoupling	No admissible directional relationship	Defined
ABC-P2-FAL-008	Chronological decoupling	Required structures or movement are age-incompatible	Defined
ABC-P2-FAL-009	Mechanical decoupling	No admissible energy and momentum transfer	Defined

52.5 Secondary-Hypothesis Limitation

The energy calculation does not establish:

- the displaced mass;
- the displacement direction;
- the event age;
- the source location;
- or the causal connection.

53 Paper-II Equation Registry

Table 26: Principal Paper-II equation registry.

ID	Equation	Role	Status
ABC-P2-EQN-001	equation (193)	Operational transmission definition	Defined

ID	Equation	Role	Status
ABC-P2-EQN-002	equation (209)	Directional energy concentration	Framework equation
ABC-P2-EQN-003	equation (210)	Momentum transmission fraction	Framework equation
ABC-P2-EQN-004	equation (211)	Energy transmission fraction	Framework equation
ABC-P2-EQN-005	equation (217)	Entrance energy partition	Conservation requirement
ABC-P2-EQN-006	equation (219)	Directional entrance coupling	Framework equation
ABC-P2-EQN-007	equation (225)	Hybrid branch energy closure	Conservation requirement
ABC-P2-EQN-008	equation (228)	Differentiated path state	State definition
ABC-P2-EQN-009	equation (238)	Kinetic energy	Audited
ABC-P2-EQN-010	equation (239)	Mass from energy and speed	Numerically reproduced
ABC-P2-EQN-011	equation (242)	Equivalent spherical size	Numerically reproduced
ABC-P2-EQN-012	equation (245)	Linear momentum	Numerically reproduced
ABC-P2-EQN-013	equation (248)	Binding-energy diagnostic	Numerically reproduced
ABC-P2-EQN-014	equation (250)	Thermal evolution	Conditional model
ABC-P2-EQN-015	equation (251)	Damage evolution	Constitutive model required
ABC-P2-EQN-016	equation (255)	Density-state decomposition	Framework equation
ABC-P2-EQN-017	equation (256)	Reynolds diagnostic	Corrected
ABC-P2-EQN-018	equation (259)	Froude diagnostic	Corrected
ABC-P2-EQN-019	equation (261)	Rossby diagnostic	Corrected
ABC-P2-EQN-020	equation (263)	Deborah diagnostic	Corrected
ABC-P2-EQN-021	equation (265)	Projectile transit diagnostic	Numerically reproduced
ABC-P2-EQN-022	equation (267)	Shock transit	Not evaluated
ABC-P2-EQN-023	equation (270)	Midpoint inheritance state	State definition
ABC-P2-EQN-024	equation (276)	Terminal-energy transfer	Conditional
ABC-P2-EQN-025	equation (283)	Whole-Earth energy closure	Required
ABC-P2-EQN-026	equation (284)	Whole-Earth momentum closure	Required
ABC-P2-EQN-027	equation (286)	Whole-Earth angular-momentum closure	Required
ABC-P2-EQN-028	equation (293)	Secondary-displacement energy	Conditional
ABC-P2-EQN-029	equation (290)	Marker viability	Decision architecture
ABC-P2-EQN-030	equation (201)	Paper-III handoff state	Canonical handoff

53.1 Equation-Audit Priority

The highest-priority Paper-II audits are:

1. constitutive laws for transient extreme deformation;
2. entrance-partition closure;
3. branch-specific drag and resistance;
4. phase and melt evolution;
5. differentiated-Earth wave propagation;
6. whole-Earth energy closure;
7. angular-momentum closure;
8. terminal response;
9. and long-time inheritance.

54 Paper-II Assumption and Parameter Registry

54.1 Principal Assumptions

Table 27: Principal Paper-II assumptions.

ID	Assumption	Status
ABC-P2-ASM-001	The Paper-I chord is a suitable first-order path for mechanical testing.	Conditional
ABC-P2-ASM-002	The specific nominal initiating-event age is 256 Ma.	Unresolved
ABC-P2-ASM-003	The energy interval 10^{29} to 10^{31} J contains the relevant mechanical branch.	Unvalidated
ABC-P2-ASM-004	The velocity interval 10 to 30 $\mathrm{km\,s^{-1}}$ contains the relevant branch.	Unvalidated
ABC-P2-ASM-005	A representative projectile density of 3000 $\mathrm{kg\,m^{-3}}$ is useful for illustrative diameter conversion.	Illustrative
ABC-P2-ASM-006	A directionally concentrated disturbance can be meaningfully separated from globally distributed losses.	Model assumption
ABC-P2-ASM-007	The terminal energy fraction lies between 0.1 and 0.5.	Unvalidated
ABC-P2-ASM-008	Branch-specific constitutive laws can represent the extreme transient.	Unresolved
ABC-P2-ASM-009	Material-state inheritance can persist long enough to influence later geodynamics.	Unresolved
ABC-P2-ASM-010	Global markers can be predicted and distinguished from background geological processes.	Test assumption
ABC-P2-ASM-011	The long-timescale effective viscosity used in one Reynolds diagnostic is meaningful for the selected scale.	Questioned
ABC-P2-ASM-012	The Mauna Kea mass and velocity ranges are relevant to a secondary displacement hypothesis.	Source-derived

54.2 Principal Parameter Registry

Table 28: Principal Paper-II parameters.

ID	Parameter	Value or range	Status
ABC-P2-PAR-020	Chord length	10150.567 km	Geometry-audited
ABC-P2-PAR-021	Maximum chord depth	2519.878 km	Geometry-audited
ABC-P2-PAR-022	Incidence below horizontal	52.808799°	Geometry-audited
ABC-P2-PAR-023	Incident energy	10^{29} to 10^{31} J	Search range
ABC-P2-PAR-024	Incident velocity	10 to 30 $\mathrm{km\,s^{-1}}$	Search range
ABC-P2-PAR-025	Derived mass	2.22×10^{20} to 2.00×10^{23} kg	Conditional
ABC-P2-PAR-026	Illustrative density	3000 $\mathrm{kg\,m^{-3}}$	Assumed
ABC-P2-PAR-027	Equivalent diameter	521 to 5031 km	Conditional
ABC-P2-PAR-028	Momentum	6.67×10^{24} to 2.00×10^{27} $\mathrm{kg\,m\,s^{-1}}$	Conditional
ABC-P2-PAR-029	Terminal energy fraction	0.1 to 0.5	Assumed
ABC-P2-PAR-030	Terminal energy	10^{28} to 5×10^{30} J	Conditional
ABC-P2-PAR-031	Effective viscosity used in audit	10^{21} Pa s	Scale-questioned
ABC-P2-PAR-032	Reynolds number	5.12×10^{-7}	Corrected diagnostic
ABC-P2-PAR-033	Froude number	2.52	Corrected diagnostic
ABC-P2-PAR-034	Rossby number	21.4	Corrected diagnostic
ABC-P2-PAR-035	Deborah number	3.125 to 312.5	Corrected diagnostic
ABC-P2-PAR-036	Projectile transit	338 to 1015 s	Kinematic diagnostic

54.3 Highest-Sensitivity Parameters

The principal viability-sensitive quantities include:

- event energy;
- velocity;
- mass;
- density;
- entrance-coupling efficiency;
- terminal energy fraction;
- branch-specific constitutive response;
- damage and healing times;
- melt fraction;
- phase kinetics;
- path geometry;
- and whole-Earth momentum partition.

55 Paper-II Prediction Registry

Table 29: Paper-II prediction registry.

ID	Prediction	Status
`ABC-P2-PRD-001`	At least one transmission branch occupies a nonempty physically admissible parameter region.	Draft
`ABC-P2-PRD-002`	The coherent branch will be more constrained than the fragmented, shock, phase-front, or hybrid branches.	Model expectation
`ABC-P2-PRD-003`	The lower-mantle interval will dominate path resistance and material response for the registered chord.	Conditional
`ABC-P2-PRD-004`	A surviving branch will generate a spatially concentrated residual damage, density, phase, thermal, or anisotropy field along some portion of the path.	Draft
`ABC-P2-PRD-005`	A surviving branch will produce a mechanically compatible midpoint inheritance state.	Draft
`ABC-P2-PRD-006`	A surviving branch will produce a terminal state within the corrected 10^{28} to 5×10^{30} J search range.	Conditional
`ABC-P2-PRD-007`	The terminal region will contain subsurface structure distinguishable from unrelated background tectonic evolution.	Draft
`ABC-P2-PRD-008`	Whole-Earth angular-momentum and energy closure will exclude substantial portions of the exploratory parameter space.	Model expectation
`ABC-P2-PRD-009`	The event model will predict a global-marker suite that can be tested independently.	Draft
`ABC-P2-PRD-010`	The Mauna Kea secondary-displacement branch, if retained, will require independent geometric, chronological, and mechanical support.	Conditional
`ABC-P2-PRD-011`	The fields passed to Paper III will occupy a substantially smaller parameter space than the initial exploratory ranges.	Model expectation

55.1 Prediction-Freeze Requirement

No Paper-II prediction receives prospective credit until it includes:

- a frozen branch;
- frozen parameters;
- spatial and depth bounds;
- magnitude uncertainty;
- a preservation model;
- a validation dataset;
- a control region;
- and a scoring rule.

56 Paper-II Falsification Registry

Table 30: Paper-II falsification registry.

ID	Falsification condition	Consequence
`ABC-P2-FAL-010`	No admissible entrance-coupling state injects sufficient directional energy or momentum into the path.	Reject all transmission branches requiring that entrance.
`ABC-P2-FAL-011`	The coherent body necessarily fragments, vaporizes, disperses, or loses directional momentum before completing the path.	Reject coherent-body branch.
`ABC-P2-FAL-012`	Fragments disperse beyond the frozen path width or fail terminal directionality.	Reject fragmented-column branch.
`ABC-P2-FAL-013`	Shock energy becomes too diffuse, attenuated, or temporally incoherent to generate the required terminal state.	Reject shock-dominated branch.
`ABC-P2-FAL-014`	No connected fracture, damage, or phase front reaches the terminal region.	Reject fracture or phase-front branch.
`ABC-P2-FAL-015`	The hybrid branch violates energy or momentum closure or relies on double counting.	Reject hybrid branch.
`ABC-P2-FAL-016`	All branches require constitutive parameters outside physically admissible ranges.	Reject Paper-II mechanical viability.
`ABC-P2-FAL-017`	The required event energy or momentum predicts unacceptable whole-Earth disruption.	Reject affected parameter region.
`ABC-P2-FAL-018`	The required angular-momentum transfer predicts an incompatible rotation change.	Reject affected branch or parameter region.
`ABC-P2-FAL-019`	The terminal response requires energy above the corrected terminal range or above available incident energy.	Reject terminal branch.
`ABC-P2-FAL-020`	The midpoint response cannot be localized or preserved under an admissible branch.	Reject midpoint-inheritance branch.
`ABC-P2-FAL-021`	Adequately resolved independent observations exclude the predicted deep corridor where preservation is required.	Reject preserved-corridor branch.
`ABC-P2-FAL-022`	Required global markers are absent despite adequate production, preservation, sampling, and detection.	Reject branch requiring those markers.
`ABC-P2-FAL-023`	The same parameter set cannot satisfy entrance, path, midpoint, terminal, survival, rotation, and marker conditions.	Paper-II viable set is empty.
`ABC-P2-FAL-024`	Independent solvers cannot reproduce the branch under the registered inputs.	Reject confirmatory mechanical support.
`ABC-P2-FAL-025`	The Mauna Kea branch fails geometry, chronology, or mechanical transfer.	Reject secondary hypothesis only.
`ABC-P2-FAL-026`	The Paper-II handoff includes fields not generated by any surviving branch.	Reject Paper-III causal handoff.

56.1 Branch-Specific Failure

Failure of one branch does not automatically reject all others.

The complete Paper-II thesis fails when:

$$\mathcal{V}_{II} = \varnothing. \tag{296}$$

56.2 Historical-Occurrence Limitation

If

$$\mathcal{V}_{II} \neq \varnothing, \tag{297}$$

the result establishes only that at least one modeled branch remains mechanically admissible under the tested assumptions.

It does not prove that the event occurred.

57 Paper-II Contradiction and Supersession Audit

Table 31: Paper-II contradiction, correction, and supersession audit.

ID	Issue	Resolution
`ABC-P2-REV-001`	Earlier mass values were inconsistent with the stated energy and speed limits.	The corrected range is 2.22×10^{20} to 2.00×10^{23} kg.
`ABC-P2-REV-002`	The equivalent size range inherited the earlier mass inconsistency.	At 3000 $\mathrm{kg\,m^{-3}}$, the corrected range is approximately 521 to 5031 km.
`ABC-P2-REV-003`	A prior Reynolds-number interpretation implied $\mathrm{Re} \gg 1$.	Using the declared viscosity and scales gives $\mathrm{Re} \approx 5.12 \times 10^{-7}$.
`ABC-P2-REV-004`	A prior Rossby-number interpretation implied $\mathrm{Ro} \leq 1$.	The corrected value is approximately $\mathrm{Ro} = 21.4$.
`ABC-P2-REV-005`	The terminal-energy range was previously liable to extend to 10^{31} J.	With $f_{\mathrm{exit}} \leq 0.5$, the corrected maximum is 5×10^{30} J.
`ABC-P2-REV-006`	The phrase "passed through Earth" could be read as requiring an intact projectile.	The canonical operational definition permits coherent, fragmented, shock, phase-front, and hybrid transmission.
`ABC-P2-REV-007`	Projectile transit and shock transit were liable to be conflated.	The atlas separates projectile, shock, damage-front, relaxation, and thermal timescales.
`ABC-P2-REV-008`	A below-binding-energy ratio could be interpreted as survival proof.	The ratio remains only one benchmark within a multidimensional survival test.

ID	Issue	Resolution
`ABC-P2-REV-009`	Modern trench morphology could be treated as a direct exit crater.	Paper II records a terminal state; Papers III and IV compare excavation, collapse, bending, underthrusting, descent, and hybrid evolution.
`ABC-P2-REV-010`	The Mauna Kea concept could be interpreted as required by the flagship event.	It is compartmentalized as a separate secondary hypothesis.

57.1 Correction Preservation

Corrected values must replace superseded numerical values in active calculations.

The superseded values remain visible in the revision ledger.

57.2 No Selective Use of Superseded Values

A model version may not use:

- the corrected mass range;
- the earlier larger terminal-energy maximum;
- and the earlier favorable dimensionless interpretation

as though they belonged to one internally consistent parameter set.

58 Paper-II Dependency Graph and Viable Set

58.1 Paper-II Dependency Graph

$$\mathcal{G}_{P2} = (\mathcal{N}_{P2}, \mathcal{E}_{P2})\,. \tag{298}$$

58.2 Core Mechanical Chain

$$\begin{aligned}\text{Paper II viability} \Leftarrow \{&\text{Paper I geometry, entrance coupling, branch propagation,}\\ &\text{midpoint state, terminal state, survival, rotation, markers}\}.\end{aligned} \tag{299}$$

58.3 Branch Viable Sets

Define:

$$\mathcal{V}_{\text{coh}} = \text{coherent-body viable set,} \tag{300}$$
$$\mathcal{V}_{\text{frag}} = \text{fragmented-column viable set,} \tag{301}$$
$$\mathcal{V}_{\text{shock}} = \text{shock-transmission viable set,} \tag{302}$$
$$\mathcal{V}_{\text{phase}} = \text{phase-front viable set,} \tag{303}$$
$$\mathcal{V}_{\text{hyb}} = \text{hybrid viable set.} \tag{304}$$

58.4 Mechanism-Union Set

The union of branch-specific mechanical possibilities is

$$\mathcal{V}_{\text{mech}} = \mathcal{V}_{\text{coh}} \cup \mathcal{V}_{\text{frag}} \cup \mathcal{V}_{\text{shock}} \cup \mathcal{V}_{\text{phase}} \cup \mathcal{V}_{\text{hyb}}. \tag{305}$$

58.5 Complete Paper-II Viable Set

The canonical Paper-II viable set is

$$\boxed{\mathcal{V}_{II} = \mathcal{V}_{\text{entrance}} \cap \mathcal{V}_{\text{path}} \cap \mathcal{V}_{\text{midpoint}} \cap \mathcal{V}_{\text{terminal}} \cap \mathcal{V}_{\text{survival}} \cap \mathcal{V}_{\text{rotation}} \cap \mathcal{V}_{\text{markers}}} \tag{306}$$

subject to

$$\mathbf{\Theta}_{II} \in \mathcal{V}_{\text{mech}}. \tag{307}$$

58.6 Shared-Parameter Requirement

The same parameter realization must satisfy all component sets.

It is not sufficient for:

- one energy to satisfy entrance;
- another to satisfy terminal response;
- another mass to satisfy survival;
- and another branch to satisfy markers.

58.7 Paper-II Critical Nodes

Table 32: Paper-II critical dependency nodes.

Node	**Criticality**	**Reason**
Paper-I path	Series-critical	Every Paper-II branch depends on admissible geometry.
Energy range	High	Mass, size, momentum, heating, survival, and terminal response depend on it.
Velocity range	High	Mass, transit, pressure, and momentum depend on it.
Entrance coupling	Series-critical	No branch begins without sufficient directional transfer.
Constitutive laws	Series-critical	Branch propagation and survival depend on material response.
Terminal fraction	High	Controls available exit energy and terminal mechanism.
Whole-Earth momentum	Series-critical	Constrains translation, rotation, ejecta, and survival.

Node	Criticality	Reason
Marker predictions	High	Provide independent global consequences.
Persistence laws	High	Control Paper-III inheritance.
Branch selection	High	Determines which equations and observables apply.

58.8 Paper-II Failure Cut Set

A representative minimum failure cut set is

$$\mathcal{K}_{P2} = \{\mathcal{V}_A, \mathcal{V}_{\text{mech}}, \mathcal{V}_M, \mathcal{V}_\oplus\}\,. \tag{308}$$

If any mandatory component is empty for all branches, the Paper-II viable set is empty.

58.9 Paper-III Handoff Rule

The Paper-III input is

$$\mathbf{Q}^{(k)}_{\text{III},0} = \mathbf{Q}^{(k)}_{\text{III},0}\,[\mathbf{\Theta}^*_{II}]\,, \qquad \mathbf{\Theta}^*_{II} \in \mathcal{V}_{II}. \tag{309}$$

No field may be inserted merely because Paper III requires it.

59 Paper-II Atlas Status

59.1 Status Dashboard

Table 33: Current Paper-II atlas status dashboard.

Registry domain	Current status	Required next step
Operational transmission	Defined	Freeze branch-specific measurable thresholds
Paper-I path	Spherical geometry audited	Paleogeographic and nonspherical sensitivity
Energy range	Exploratory	Independent physical constraint
Velocity range	Exploratory	Independent physical constraint
Mass and size	Corrected calculations	Constrain density and branch identity
Momentum	Corrected calculation	Whole-Earth partition model
Coherent branch	Strongly burdened	Extreme-transient material simulation
Fragmented branch	Defined	Dispersion and directional-coupling simulation
Shock branch	Defined	Differentiated-Earth wave simulation
Phase-front branch	Defined	Damage and phase-connectivity simulation

Registry domain	Current status	Required next step
Hybrid branch	Defined	Coupled model with no double counting
Dimensionless diagnostics	Corrected	Replace questionable scales with branch-specific scales
Projectile transit	Calculated diagnostic	Do not use as shock time
Midpoint inheritance	State defined	Forward-model amplitude and persistence
Terminal energy	Corrected conditional range	Derive transmission fraction
Earth survival	Architecture defined	Energy, momentum, rotation, atmosphere, and ocean simulation
Global markers	Classes defined	Quantitative prediction and preservation model
Mauna Kea branch	Source-derived secondary hypothesis	Independent geometry, chronology, and mechanics
Paper-II predictions	Draft or conditional	Freeze before validation
Paper-II viable set	Defined	Numerically evaluate all intersections
Paper-III handoff	Schema frozen	Populate only from surviving branch

59.2 Verified Paper-II Outputs

The strongest current Paper-II outputs are:

- the operational transmission definition;
- the five-branch mechanism taxonomy;
- the corrected mass range;
- the corrected equivalent-diameter range;
- the corrected momentum range;
- the energy-to-binding benchmark;
- the corrected Reynolds diagnostic;
- the corrected Froude diagnostic;
- the corrected Rossby diagnostic;
- the corrected Deborah interval;
- the distinction between projectile and shock transit;
- the corrected terminal-energy range;
- and the complete nested viable-set architecture.

59.3 Current Negative and Restrictive Results

The atlas records that:

- the coherent-body branch is strongly burdened;
- the earlier favorable Reynolds interpretation fails under the declared viscosity;
- the earlier favorable Rossby interpretation fails under the corrected calculation;
- the terminal-energy maximum is lower than previously implied;
- and the gravitational-binding benchmark does not establish survival.

59.4 Current Unresolved Questions

Paper II still requires:

- branch-specific transient constitutive models;
- entrance-coupling simulation;
- differentiated-Earth path simulation;
- shock and damage-front propagation;
- thermodynamic and phase evolution;
- terminal-response simulation;
- whole-Earth energy closure;
- momentum and angular-momentum closure;
- rotation constraints;
- atmospheric and oceanic constraints;
- global-marker prediction;
- preservation modeling;
- and independent reproduction.

59.5 Paper-II Atlas Conclusion

Paper-II atlas conclusion.
Paper II defines five distinct transmission branches and a complete mechanical viability architecture linking entrance coupling, differentiated-Earth passage, midpoint-response inheritance, terminal response, whole-Earth survival, rotation, and global markers.
Several numerical and interpretive corrections are now explicit: the corrected mass range is 2.22×10^{20} to 2.00×10^{23} kg; the equivalent spherical diameter range at the assumed density is approximately 521 to 5031 km; the momentum range is 6.67×10^{24} to 2.00×10^{27} $\mathrm{kg\,m\,s^{-1}}$; the Reynolds diagnostic is approximately 5.12×10^{-7}; the Rossby diagnostic is approximately 21.4; and the corrected terminal-energy range is 10^{28} to 5×10^{30} J.
These corrections constrain the search but do not establish a viable event.
The present Paper-II status remains unresolved because no branch has yet been shown to occupy the complete intersection

$$\mathcal{V}_A \cap \mathcal{V}_P \cap \mathcal{V}_H \cap \mathcal{V}_M \cap \mathcal{V}_\oplus \cap \mathcal{V}_{\mathrm{rot}} \cap \mathcal{V}_{\mathrm{markers}}.$$

Only a state generated from that surviving intersection may be passed to Paper III.

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60 Paper-II Atlas Synthesis

This Paper-II atlas synthesis records:

1. the complete Paper-II atlas scope;
2. a thirty-two-item principal mechanical claim registry;
3. the operational meaning of through-Earth transmission;
4. coherent, fragmented, shock, phase-front, and hybrid branches;
5. branch-specific coherence and propagation metrics;
6. entrance-state and entrance-partition registries;
7. entrance and directional-coupling efficiencies;
8. the differentiated-Earth path-state registry;
9. path-integrated resistance, heating, and damage;
10. the corrected energy, velocity, mass, diameter, and momentum audit;
11. the gravitational-binding benchmark and its limitation;
12. the thermodynamic, damage, melt, phase, density, elasticity, stress, and velocity-field registries;
13. the corrected Reynolds-number diagnostic;
14. the corrected Froude-number diagnostic;
15. the corrected Rossby-number diagnostic;

16. the corrected Deborah-number interval;
17. the separation of projectile, shock, damage-front, relaxation, thermal, and geological timescales;
18. the midpoint-inheritance state and persistence registry;
19. the terminal-state registry;
20. the assumed terminal-energy fraction;
21. the corrected 10^{28} to 5×10^{30} J terminal-energy range;
22. the whole-Earth energy, momentum, angular-momentum, and survival registries;
23. the global-marker registry;
24. the compartmentalized Mauna Kea secondary-hypothesis registry;
25. the thirty-item Paper-II equation registry;
26. the Paper-II assumption registry;
27. the Paper-II parameter registry;
28. the Paper-II prediction registry;
29. the complete branch-specific and paper-level falsification registry;
30. the Paper-II correction and supersession audit;
31. the Paper-II dependency graph;
32. the branch-union mechanical set;
33. the complete nested Paper-II viable set;
34. the shared-parameter requirement;
35. the critical-node and failure-cut-set analysis;
36. the formal Paper-III handoff restriction;
37. the Paper-II status dashboard; and
38. the formal Paper-II atlas conclusion.

The following sections construct the complete Paper-III atlas:

- Paper-III claim registry;
- conditional Paper-II handoff audit;
- event-sequence registry;
- plate and block lineage registry;
- boundary-nucleation and connectivity registry;
- fragmentation, merger, and terrane-transfer registry;

- boundary-type and reactivation registry;
- event-to-plate impulse registry;
- mass, inertia, force, torque, and Euler-vector registry;
- direction, speed, acceleration, and plate-circuit registry;
- mountain, trench, ridge, basin, plateau, volcanism, terrane, and suture registries;
- global reconstruction and null-model registry;
- Paper-III equation registry;
- Paper-III assumption and parameter registry;
- Paper-III prediction registry;
- Paper-III falsification registry;
- Paper-III contradiction and supersession audit;
- Paper-III dependency graph;
- Paper-III integrated viable set; and
- Paper-III atlas status dashboard.

61 Paper-III Atlas Scope

61.1 Paper-III Function

Paper III tests whether mechanically surviving outputs from Paper II can generate a coherent global history of:

- plate-boundary nucleation;
- plate and block partition;
- fragmentation and merger;
- directional motion inheritance;
- Euler-vector evolution;
- relative plate velocity;
- continental displacement;
- mountain localization;
- trench development;
- ridge and rift initiation;
- basin formation;
- plateau uplift;

- volcanic-path localization;
- terrane transfer;
- suture formation;
- and continuing structural reactivation.

61.2 Paper-III Central Burden

For one frozen candidate sequence $\mathcal{S}$, the central Paper-III question is

$$\boxed{\mathcal{V}_{III,\mathcal{S}} \neq \varnothing} \tag{310}$$

where $\mathcal{V}_{III,\mathcal{S}}$ contains only globally connected, chronologically admissible, mechanically inherited, kinematically closed, and structurally compatible reconstructions using that same sequence.

61.3 Conditional Entry

Paper III is conditional upon event-specific upstream viability:

$$\forall k \in \mathcal{S}, \qquad \mathcal{V}_{I,k} \cap \mathcal{V}_{II,k} \neq \varnothing. \tag{311}$$

If any required event lacks an admissible upstream state, Paper III cannot create the missing state through later reconstruction. The failed event removes sequences that require it, not independently specified alternatives.

61.4 Shared Observational Ground

Paper III accepts measured continental and plate motion as evidence.

It distinguishes:

$$\text{continental drift} \tag{312}$$

from

$$PlateTectonics \text{ as a primary causal framework.} \tag{313}$$

The existence of motion is not disputed.

The proposed replacement concerns the primary historical organization of boundaries, directions, relative velocities, and structural inheritance.

61.5 Paper-III Replacement Proposition

The Paper-III proposition is:

A sequenced history of large astro-ballistic events may have created, partitioned, redirected, weakened, densified, heated, fractured, or otherwise organized the lithospheric and mantle state from which major plate boundaries, plate-motion directions, relative plate velocities, and large surface structures developed and continue to evolve.

This is a model proposition, not a presently established result.

61.6 Paper-III Atlas Objects

The Paper-III atlas contains

$$\mathfrak{A}_{P3} = \{\mathfrak{C}_{P3}, \mathfrak{E}_{P3}, \mathfrak{AS}_{P3}, \mathfrak{P}_{P3}, \mathfrak{D}_{P3}, \mathfrak{S}_{P3}, \mathfrak{M}_{P3}, \mathfrak{R}_{P3}, \mathfrak{F}_{P3}, \mathfrak{G}_{P3}\}\,. \tag{314}$$

61.7 No Event-Sequence Credit by Assignment

A structure receives no causal credit merely because it has been assigned to an event.

Credit requires an explicit path:

$$\text{event} \to \text{mechanical state} \to \text{boundary or material inheritance} \to \text{motion} \to \text{structure}. \tag{315}$$

62 Paper-III Claim Registry

Table 34: Principal Paper-III claim registry.

ID	Claim	Role	Current status
ABC-P3-CLM-001	Paper III uses only the mechanically surviving fields generated by Paper II.	Handoff rule	REQUIREMENT-DEFINED
ABC-P3-CLM-002	A single flagship event is not assumed to generate the complete global tectonic system.	Scope rule	ARCHITECTURE-DEFINED
ABC-P3-CLM-003	The candidate global model uses a chronologically ordered sequence of events acting on an evolving Earth state.	Foundational	UNTESTED
ABC-P3-CLM-004	Later events act nonlinearly on structures inherited from earlier events.	Sequence rule	MODEL-ASSUMPTION
ABC-P3-CLM-005	Modern plate names and boundaries cannot be projected unchanged through all geological time.	Lineage rule	REQUIREMENT-DEFINED
ABC-P3-CLM-006	Plates and tectonic blocks must be represented as evolving material domains with explicit lineage.	Methodological	ARCHITECTURE-DEFINED
ABC-P3-CLM-007	A candidate event may nucleate, connect, reactivate, redirect, or terminate boundaries through inherited damage, stress, density, thermal, phase, or displacement fields.	Mechanism claim	UNTESTED
ABC-P3-CLM-008	A boundary network must form connected plate-enclosing domains rather than disconnected favorable line segments.	Boundary rule	REQUIREMENT-DEFINED

ID	Claim	Role	Current status
ABC-P3-CLM-009	Boundary type must be predicted from relative motion and material state rather than assigned after observing the modern boundary.	Causal rule	REQUIREMENT-DEFINED
ABC-P3-CLM-010	Later events may reactivate, invert, branch, extend, or terminate earlier boundaries.	Sequence mechanism	UNTESTED
ABC-P3-CLM-011	Plate fragmentation, merger, and terrane transfer must conserve material identity and lineage.	Material rule	REQUIREMENT-DEFINED
ABC-P3-CLM-012	Event-derived impulse may initialize or redirect plate motion but cannot be treated as perpetual unattenuated power.	Physical rule	REQUIREMENT-DEFINED
ABC-P3-CLM-013	Present plate motion requires ongoing gravitational, buoyancy, mantle, boundary, and resistance terms in addition to any inherited event state.	Motion rule	ARCHITECTURE-DEFINED
ABC-P3-CLM-014	Euler vectors must be generated as model outputs rather than inserted as the explanation of their own observed motion.	Kinematic rule	REQUIREMENT-DEFINED
ABC-P3-CLM-015	Plate speeds, directions, accelerations, decelerations, and rotations must be predicted from one dynamically consistent solution.	Motion claim	UNTESTED
ABC-P3-CLM-016	The global velocity field must satisfy plate-circuit closure, triple-junction compatibility, and area accounting.	Closure rule	REQUIREMENT-DEFINED
ABC-P3-CLM-017	Measured velocity cannot be used simultaneously as the free causal input and the evidence that supposedly proves the model.	Circularity rule	REQUIREMENT-DEFINED
ABC-P3-CLM-018	Directional inheritance must outperform a counterfactual in which the inherited state is isotropized.	Causal test	UNTESTED
ABC-P3-CLM-019	Mountain-system location and orientation must be predicted from the event-boundary-motion state rather than mapped afterward.	Structural claim	UNTESTED
ABC-P3-CLM-020	Modern mountain height must not be equated directly with ancient impact pressure.	Interpretive limit	REQUIREMENT-DEFINED
ABC-P3-CLM-021	Terminal zones may evolve through excavation, collapse, bending, underthrusting, inherited weakness, descent, or hybrid combinations.	Mechanism taxonomy	ARCHITECTURE-DEFINED
ABC-P3-CLM-022	A modern trench is not automatically a direct terminal crater.	Scope control	REQUIREMENT-DEFINED
ABC-P3-CLM-023	Ridge and rift systems require extension, material production, melt supply, segmentation, and chronology rather than a geometric event trace alone.	Structural rule	REQUIREMENT-DEFINED
ABC-P3-CLM-024	Basin formation may combine excavation, extension, flexure, thermal subsidence, dynamic support loss, loading, and later inversion.	Mechanism taxonomy	ARCHITECTURE-DEFINED
ABC-P3-CLM-025	Plateau uplift requires a compatible balance of crustal thickening, buoyancy, thermal state, dynamic support, phase state, and erosion.	Structural rule	REQUIREMENT-DEFINED
ABC-P3-CLM-026	Volcanic provinces require spatial, chronological, transport, thermal, and compositional consistency.	Structural rule	REQUIREMENT-DEFINED
ABC-P3-CLM-027	Terrane docking and suture formation must preserve provenance, paleolatitude, rotation, mass, and chronology.	Assembly rule	REQUIREMENT-DEFINED

ID	Claim	Role	Current status
ABC-P3-CLM-028	The event sequence must predict why major structures occur where and when they do.	Global causal claim	UNTESTED
ABC-P3-CLM-029	A successful reconstruction must outperform no-event, randomized-event, shuffled-age, randomized-boundary, and isotropized-inheritance nulls.	Statistical rule	UNTESTED
ABC-P3-CLM-030	The model must predict withheld structures or regions rather than only reconstruct those used during development.	Prediction rule	UNTESTED
ABC-P3-CLM-031	The same event sequence and shared parameter architecture must jointly fit boundaries, motions, structures, chronology, and whole-Earth budgets.	Integrated claim	UNTESTED
ABC-P3-CLM-032	Regional event support does not establish a global replacement model.	Scope rule	REQUIREMENT-DEFINED
ABC-P3-CLM-033	Paper III fails globally if no one admissible sequence generates the major boundary network, motion field, and structural system.	Falsifiability	ARCHITECTURE-DEFINED
ABC-P3-CLM-034	No complete numerical Paper-III reconstruction has yet demonstrated the global viable set.	Status	UNRESOLVED
ABC-P3-CLM-035	A nonempty Paper-III viable set would establish conditional reconstruction viability, not automatic replacement of Plate Tectonics .	Scope control	REQUIREMENT-DEFINED
ABC-P3-CLM-036	Direct comparison with the strongest defensible Plate-Tectonic model is reserved for Paper IV.	Paper boundary	ARCHITECTURE-DEFINED

62.1 Paper-III Claim Boundary

Paper III presently establishes a structured forward-model and falsification architecture.

It does not presently establish:

- the historical event sequence;
- the event-derived origin of the global boundary network;
- event-derived Euler poles;
- event-derived modern plate speeds;
- or event-derived global surface structure.

63 Conditional Paper-II Handoff Audit

63.1 Canonical Handoff State

The Paper-II to Paper-III handoff is

$$\mathbf{Q}^{(k)}_{\mathrm{III},0} = (\mathcal{B}_{\mathrm{ABC}}, \mathbf{J}_{\mathrm{plate}}, \Delta T, \Delta\rho, \mathbf{D}, \Delta\phi, \chi_m, \Delta\mathbf{C}, \Delta\boldsymbol{\sigma}, \mathbf{u}, \Delta\mathbf{g}, \Delta\boldsymbol{\omega}) . \tag{316}$$

63.2 Handoff Field Registry

Table 35: Paper-II to Paper-III handoff-field registry.

ID	Field	Paper-III function	Current status
ABC-P3-DAT-001	$\mathcal{B}_{\mathrm{ABC}}$	Initial candidate boundary and damage architecture	Unpopulated
ABC-P3-DAT-002	$\mathbf{J}_{\mathrm{plate}}$	Plate- or block-integrated impulse	Unpopulated
ABC-P3-DAT-003	ΔT	Thermal weakening, buoyancy, melt, and persistence	Unpopulated
ABC-P3-DAT-004	$\Delta\rho$	Buoyancy, gravity, descent, uplift, and mantle response	Unpopulated
ABC-P3-DAT-005	$\mathbf{D}$	Damage, weakness, permeability, and boundary localization	Unpopulated
ABC-P3-DAT-006	$\Delta\phi$	Phase and density inheritance	Unpopulated
ABC-P3-DAT-007	χ_m	Melt generation and volcanic-path localization	Unpopulated
ABC-P3-DAT-008	$\Delta\mathbf{C}$	Elasticity and anisotropy inheritance	Unpopulated
ABC-P3-DAT-009	$\Delta\boldsymbol{\sigma}$	Residual stress and directional boundary activation	Unpopulated
ABC-P3-DAT-010	$\mathbf{u}$	Initial material velocity and momentum distribution	Unpopulated
ABC-P3-DAT-011	$\Delta\mathbf{g}$	Event-modified gravitational forcing	Unpopulated
ABC-P3-DAT-012	$\Delta\boldsymbol{\omega}$	Rotation or vorticity perturbation	Unpopulated

63.3 Handoff Admissibility Indicator

For field q_j,

$$I_{H,j} = I_{\mathrm{generated}} I_{\mathrm{conserved}} I_{\mathrm{resolved}} I_{\mathrm{versioned}} I_{\mathrm{uncertainty}}. \tag{317}$$

63.4 Complete Handoff Condition

$$I_H^{\mathrm{complete}} = \prod_j I_{H,j} \tag{318}$$

for every field required by the selected Paper-III branch.

63.5 No Invented Handoff Fields

If Paper II does not generate a required field, Paper III must:

- remove the dependent branch;
- derive the field from another admissible state;
- or label the field as an independent initial condition whose information cost is counted.

63.6 Handoff Failure

Paper III is causally invalid if its successful reconstruction depends on event-derived fields that were not produced by any surviving Paper-II solution.

64 Sequenced Event-Catalog Registry

64.1 Event Catalog

The candidate event catalog is

$$\mathcal{E} = \{\mathcal{E}_1, \mathcal{E}_2, \ldots, \mathcal{E}_{N_E}\}. \tag{319}$$

64.2 Individual Event Record

Each event is

$$\begin{aligned}\mathcal{E}_k = (&\mathrm{ID}_k, t_k, \mathbf{x}_{A,k}, \mathbf{x}_{M,k}, \widehat{\mathbf{d}}_k, E_k, \mathbf{p}_k, \\ &\mathcal{M}_k, \mathbf{Q}_{H,k}, \mathbf{Q}_{M,k}, \mathbf{\Sigma}_k, \mathrm{status}_k).\end{aligned} \tag{320}$$

64.3 Required Event Metadata

Each event must record:

- proposed age;
- age uncertainty;
- entrance definition;
- terminal definition;
- reconstructed coordinates;
- path geometry;
- mechanism branch;
- energy and momentum range;
- surviving Paper-II state;
- candidate affected material domains;
- predicted boundaries;
- predicted motion change;
- predicted structures;
- controls;
- and direct falsifiers.

64.4 Event Sequence

The time-ordered sequence is

$$\mathcal{S}_E = \left(\mathcal{E}_{\pi(1)}, \mathcal{E}_{\pi(2)}, \ldots, \mathcal{E}_{\pi(N_E)}\right), \tag{321}$$

with

$$t_{\pi(1)} < t_{\pi(2)} < \cdots < t_{\pi(N_E)} \tag{322}$$

in forward-time coordinates.

64.5 Nonlinear State Recursion

Let the Earth state immediately before event k be $\mathbf{Q}_k^-$.

Then

$$\mathbf{Q}_k^+ = \mathcal{F}_{E,k}\left[\mathbf{Q}_k^-, \mathcal{E}_k\right]. \tag{323}$$

Between events,

$$\mathbf{Q}_{k+1}^- = \mathcal{U}\left[\mathbf{Q}_k^+, t_k, t_{k+1}\right]. \tag{324}$$

64.6 No Linear Superposition by Default

The total state is not assumed to be

$$\mathbf{Q}_{\text{final}} = \sum_k \mathbf{Q}_{E,k}. \tag{325}$$

Later events may interact with:

- prior boundaries;
- prior density anomalies;
- prior plate partitions;
- prior stress;
- prior velocity;
- prior topography;
- and prior mantle circulation.

64.7 Event-Catalog Status

The broader multi-event catalog remains provisional.

No event receives Paper-III causal credit until its Paper-I geometry, Paper-II mechanics, chronology, and reconstruction dependencies are registered.

64.8 Event-Selection Complexity

For event k, the effective selection cost includes:

$$k_{E,k} = k_t + k_A + k_M + k_d + k_E + k_{\text{branch}} + k_{\text{assignment}}. \tag{326}$$

65 Plate, Block, and Material-Lineage Registry

65.1 Evolving Material Domain

Plate or block i at time t is

$$\mathcal{P}_i(t) = \{\mathbf{x} : \mu_i(\mathbf{x}, t) > 0\}, \tag{327}$$

where μ_i is the material-membership fraction.

65.2 Fractional Membership

$$0 \le \mu_i(\mathbf{x}, t) \le 1. \tag{328}$$

At each material point,

$$\sum_i \mu_i(\mathbf{x}, t) = 1 \tag{329}$$

unless material destruction, creation, or unresolved classification is explicitly represented.

65.3 Plate State

For plate or block i,

$$\mathbf{Q}_{P_i}(t) = (\mathcal{P}_i, M_i, \mathbf{x}_{c,i}, \mathbf{I}_i, \mathbf{v}_{c,i}, \boldsymbol{\omega}_i, \mathbf{L}_i, \mathbf{B}_i, \mathbf{C}_i). \tag{330}$$

65.4 Material-Lineage Graph

$$\mathcal{G}_L = (\mathcal{V}_L, \mathcal{E}_L), \tag{331}$$

where nodes represent material domains at defined times and edges represent:

- persistence;

- fragmentation;
- merger;
- transfer;
- accretion;
- underthrusting;
- burial;
- erosion;
- or destruction.

65.5 Lineage Edge Record

$$\mathbf{L}_{ij} = \Big(\text{source}_i, \text{target}_j, \text{mass fraction}, \text{time}, \text{mechanism}, \text{uncertainty}\Big). \tag{332}$$

65.6 Material-Mass Closure

For domain i,

$$\frac{dM_i}{dt} = \dot{M}_{\text{in},i} - \dot{M}_{\text{out},i} + \dot{M}_{\text{create},i} - \dot{M}_{\text{destroy},i}. \tag{333}$$

65.7 Modern-Plate Projection Prohibition

A present plate polygon may not be projected unchanged to an earlier event time unless its lineage demonstrates that the same material domain existed in that form.

65.8 Lineage Registry Status

Table 36: Paper-III material-lineage registry status.

Registry item	**Required content**	**Current status**
Ancient material domains	Time-resolved domain geometries and uncertainty	Not assembled
Fragmentation records	Parent, children, mass fractions, timing	Architecture defined
Merger records	Source domains, contact geometry, timing	Architecture defined
Terrane transfer	Source, path, rotation, destination	Architecture defined
Destruction and burial	Material loss and preservation	Unresolved
Modern lineage	Links from ancient domains to modern plates and terranes	Not assembled

66 Boundary Nucleation and Connectivity Registry

66.1 Boundary-Nucleation Potential

Define

$$
\begin{aligned}
\mathcal{N}_B(\mathbf{x},t) = \mathcal{F}_B\big[&D, \|\Delta\boldsymbol{\sigma}\|, \Delta T, \Delta\rho, \Delta\phi, \chi_m, \\
&\nabla\mathbf{u}, \mathbf{C}, \mathbf{Q}_{\text{pre}}, \mathbf{Q}_{\text{later}}\big].
\end{aligned}
\tag{334}
$$

66.2 Candidate Boundary Domain

$$
\mathcal{B}^0(t) = \{\mathbf{x} : \mathcal{N}_B(\mathbf{x},t) \geq \mathcal{N}_{B,\text{crit}}\}. \tag{335}
$$

66.3 Boundary Persistence

For boundary element e,

$$
P_{B,e}(t) = \mathcal{F}_P\left(D_e, T_e, \Delta\rho_e, \phi_e, \boldsymbol{\sigma}_e, \mathbf{v}_e^{\text{rel}}, t\right). \tag{336}
$$

66.4 Global Boundary Graph

$$
\mathcal{G}_B(t) = (\mathcal{V}_B(t), \mathcal{E}_B(t)), \tag{337}
$$

where vertices represent junctions and edges represent connected boundary segments.

66.5 Boundary Edge Record

$$
\mathbf{B}_e = \left(\Gamma_e, \gamma_e, w_e, \tau_e, \mathbf{v}_e^{\text{rel}}, \mathbf{Q}_e, t_{\text{init}}, t_{\text{react}}, t_{\text{term}}\right). \tag{338}
$$

66.6 Connectivity Matrix

$$
A_{ij}^B = \begin{cases} 1, & \text{if boundary nodes } i \text{ and } j \text{ are connected,} \\ 0, & \text{otherwise.} \end{cases} \tag{339}
$$

66.7 Plate-Enclosure Test

A candidate network must partition the surface into material domains with closed or physically terminated boundaries.

For predicted plate domain p,

$$
\partial\mathcal{P}_p \subseteq \mathcal{B} \cup \mathcal{T}_{\text{physical}}, \tag{340}
$$

where $\mathcal{T}_{\text{physical}}$ contains justified terminations.

66.8 Boundary Comparison Metrics

Paper III registers:

- Hausdorff distance;
- average symmetric boundary distance;
- orientation residual;
- curvature residual;
- topology residual;
- adjacency residual;
- spectral graph distance;
- cycle rank;
- junction compatibility;
- and plate-enclosure success.

66.9 Boundary Viable Set

$$\mathcal{V}_B = \mathcal{V}_{\text{nuc}} \cap \mathcal{V}_{\text{conn}} \cap \mathcal{V}_{\text{encl}} \cap \mathcal{V}_{\text{type}} \cap \mathcal{V}_{\text{chron}} \cap \mathcal{V}_{\text{persist}}. \tag{341}$$

66.10 Boundary Falsification Principle

The event-boundary claim fails if no common event sequence produces a connected, chronologically consistent, materially persistent boundary network without manual boundary-by-boundary construction.

67 Fragmentation, Merger, and Terrane-Transfer Registry

67.1 Fragmentation Operator

For parent domain $\mathcal{P}_i^-$,

$$\mathcal{F}_{\text{frag}} : \mathcal{P}_i^- \to \left\{\mathcal{P}_{i1}^+, \mathcal{P}_{i2}^+, \ldots, \mathcal{P}_{in}^+\right\}. \tag{342}$$

67.2 Fragmentation Mass Closure

$$M_i^- = \sum_{a=1}^{n} M_{ia}^+ + M_{\text{loss}} \tag{343}$$

within declared uncertainty.

67.3 Merger Operator

$$\mathcal{F}_{\text{merge}} : \left\{\mathcal{P}_1^-, \ldots, \mathcal{P}_n^-\right\} \to \mathcal{P}_m^+. \tag{344}$$

67.4 Terrane-Transfer Matrix

Let $T_{ij}(t)$ be the mass or material fraction transferred from source domain i to destination domain j:

$$0 \leq T_{ij}(t) \leq 1. \tag{345}$$

67.5 Terrane State

For terrane u,

$$\mathbf{Q}_{T_u} = (M_u, \mathbf{x}_u, \mathbf{R}_u, \mathbf{v}_u, \mathbf{C}_u, \mathbf{A}_u, \mathbf{M}_u, \mathbf{S}_u)\,. \tag{346}$$

67.6 Transfer Requirements

A terrane-transfer claim must predict:

- source domain;
- separation time;
- separation mechanism;
- path;
- rotation;
- velocity;
- paleolatitude;
- destination;
- docking time;
- and suture geometry.

67.7 No Terrane Assignment by Similarity Alone

Lithological or chronological similarity may support provenance.

It does not independently establish the transport mechanism or path.

67.8 Fragmentation and Transfer Falsifier

The branch fails if required fragmentation, transfer, rotation, or merger violates material mass, chronology, paleogeography, or structural continuity.

68 Boundary Type, Propagation, and Reactivation Registry

68.1 Relative Velocity Decomposition

For boundary unit normal $\widehat{\mathbf{n}}$ and tangent $\widehat{\mathbf{t}}$,

$$v_n = \mathbf{v}_{\mathrm{rel}} \cdot \widehat{\mathbf{n}}, \tag{347}$$

$$v_t = \mathbf{v}_{\mathrm{rel}} \cdot \widehat{\mathbf{t}}. \tag{348}$$

68.2 Boundary-Type State

$$\tau_B = \mathcal{F}_\tau \left(v_n, v_t, D, T, \rho, H_\ell, \mu, P, \mathbf{Q}_{\mathrm{inherit}}\right). \tag{349}$$

68.3 Candidate Boundary Types

The registry permits:

- opening;
- closing;
- shear;
- collision;
- underthrusting;
- descent;
- diffuse deformation;
- inactive inherited boundary;
- reactivated boundary;
- and hybrid boundary.

68.4 Boundary Propagation

For boundary tip $\mathbf{x}_{\mathrm{tip}}$,

$$\frac{d\mathbf{x}_{\mathrm{tip}}}{dt} = \mathbf{v}_{\mathrm{tip}} \left(\boldsymbol{\sigma}, D, T, \Delta\rho, \mathbf{Q}_{\mathrm{pre}}\right). \tag{350}$$

68.5 Branching Criterion

A branch may form when

$$\mathcal{B}_{\mathrm{branch}} \left(\boldsymbol{\sigma}, D, \mathbf{C}, \mathbf{v}_{\mathrm{rel}}\right) \geq B_{\mathrm{crit}}. \tag{351}$$

68.6 Reactivation Function

For inherited boundary e,

$$R_e(t) = \mathcal{F}_R \left(D_e, \Delta\boldsymbol{\sigma}_{\mathrm{later}}, T_e, P_e, \mu_e, \mathbf{v}_e^{\mathrm{rel}}\right). \tag{352}$$

68.7 Boundary Inversion

Boundary inversion occurs when the sign or dominant mode changes:

$$\mathrm{sign}\,[v_n(t_1)] \neq \mathrm{sign}\,[v_n(t_2)] \tag{353}$$

or when the dominant tangential or vertical mode changes.

68.8 Termination

A boundary may terminate through:

- stress decay;
- material strengthening;
- junction capture;
- collision;
- burial;
- later-event overprinting;
- or geometric exhaustion.

68.9 Boundary-Type Falsifier

The event-derived network fails if its predicted boundary types, polarities, propagation directions, branch points, reactivations, or terminations are incompatible with observed motion and chronology.

69 Event-to-Plate Impulse Registry

69.1 Impulse-Density Field

For event k,

$$\mathbf{j}_k(\mathbf{x}) = \int_{t_k^-}^{t_k^+} \mathbf{f}_k(\mathbf{x}, t)\, dt. \tag{354}$$

69.2 Plate-Integrated Linear Impulse

For plate or block i,

$$\mathbf{J}_{i,k} = \int_{\mathcal{P}_i(t_k)} \mu_i(\mathbf{x}, t_k)\mathbf{j}_k(\mathbf{x})\, dV. \tag{355}$$

69.3 Plate-Integrated Angular Impulse

$$\Delta\mathbf{L}_{i,k} = \int_{\mathcal{P}_i(t_k)} (\mathbf{x} - \mathbf{x}_{c,i}) \times \mu_i \mathbf{j}_k\, dV. \tag{356}$$

69.4 Impulse Partition

For event k,

$$f_{\text{plates},k} + f_{\text{mantle},k} + f_{\text{deform},k} + f_{\text{ocean},k} + f_{\text{atm},k} + f_{\text{ejecta},k} + f_{\text{bulk},k} = 1. \tag{357}$$

69.5 Rigid and Deforming Components

$$\mathbf{J}_{i,k} = \mathbf{J}_{i,k}^{\text{rigid}} + \mathbf{J}_{i,k}^{\text{deform}} + \mathbf{J}_{i,k}^{\text{internal}}. \tag{358}$$

69.6 Immediate Velocity Change

For center-of-mass velocity,

$$\Delta \mathbf{v}_{c,i,k} = \frac{\mathbf{J}_{i,k}^{\text{rigid}}}{M_i}. \tag{359}$$

69.7 Immediate Angular-Velocity Change

$$\Delta \boldsymbol{\omega}_{i,k} = \mathbf{I}_i^{-1} \Delta \mathbf{L}_{i,k} \tag{360}$$

under a rigid-response approximation.

69.8 Impulse-Memory Kernel

$$\mathbf{v}_{i,k}^{\text{inherit}}(t) = \mathbf{K}_{i,k}^{v} \left(t - t_k\right) \Delta \mathbf{v}_{c,i,k}. \tag{361}$$

69.9 No Perpetual Impulse

A physically admissible memory kernel must include:

- attenuation;
- redistribution;
- coupling;
- resistance;
- and later forcing.

69.10 Impulse Falsifier

The event-to-plate impulse branch fails if the event cannot partition sufficient linear and angular momentum into the relevant ancient material domains without violating whole-Earth conservation.

70 Plate Mass, Inertia, Force, Torque, and Euler-Vector Registry

70.1 Plate Mass

$$M_i(t) = \int_{\mathcal{P}_i(t)} \rho(\mathbf{x}, t)\, dV. \tag{362}$$

70.2 Center of Mass

$$\mathbf{x}_{c,i}(t) = \frac{1}{M_i} \int_{\mathcal{P}_i(t)} \rho \mathbf{x}\, dV. \tag{363}$$

70.3 Inertia Tensor

$$\mathbf{I}_i = \int_{\mathcal{P}_i} \rho \left[\|\mathbf{r}\|^2 \mathbf{1} - \mathbf{r}\mathbf{r}^{\mathsf{T}} \right] dV, \qquad \mathbf{r} = \mathbf{x} - \mathbf{x}_{c,i}. \tag{364}$$

70.4 Linear-Momentum Evolution

$$\frac{d}{dt} (M_i \mathbf{v}_{c,i}) = \mathbf{F}_i^{\text{event}} + \mathbf{F}_i^{g} + \mathbf{F}_i^{b} + \mathbf{F}_i^{m} + \mathbf{F}_i^{B} + \mathbf{F}_i^{R}. \tag{365}$$

70.5 Angular-Momentum Evolution

$$\frac{d\mathbf{L}_i}{dt} = \boldsymbol{\tau}_i^{\text{event}} + \boldsymbol{\tau}_i^{g} + \boldsymbol{\tau}_i^{b} + \boldsymbol{\tau}_i^{m} + \boldsymbol{\tau}_i^{B} + \boldsymbol{\tau}_i^{R}. \tag{366}$$

70.6 Force Registry

The force terms include:

- event impulse or inherited event forcing;
- gravitational-potential gradients;
- buoyancy;
- mantle traction;
- boundary traction;
- flexure;
- topographic-potential gradients;
- and resistance.

70.7 Torque Registry

The torque terms include:

- event angular impulse;
- distributed gravitational torque;
- boundary torque;
- mantle traction torque;

- collision torque;
- and rotational resistance.

70.8 Power Balance

$$\mathcal{P}_i = \mathbf{F}_i \cdot \mathbf{v}_{c,i} + \boldsymbol{\tau}_i \cdot \boldsymbol{\omega}_i. \tag{367}$$

70.9 Dissipation Condition

$$\mathcal{D}_i \geq 0. \tag{368}$$

70.10 Euler Velocity

For surface position $\mathbf{r}$ on plate i,

$$\mathbf{v}_i(\mathbf{r}, t) = \boldsymbol{\omega}_i(t) \times \mathbf{r} + \mathbf{v}_i^{\mathrm{def}}(\mathbf{r}, t). \tag{369}$$

70.11 Finite Rotation

$$\mathbf{R}_i(t_2, t_1) = \mathcal{T} \exp \left[\int_{t_1}^{t_2} \boldsymbol{\Omega}_i(t)\, dt \right], \tag{370}$$

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

70.12 Euler-Pole Drift

$$\frac{d\boldsymbol{\omega}_i}{dt} = \mathcal{F}_\omega \left(\mathbf{I}_i, \dot{\mathbf{I}}_i, \boldsymbol{\tau}_i, \mathbf{L}_i \right). \tag{371}$$

70.13 Euler-Vector Falsifier

The event-derived motion claim fails if observed Euler vectors can be reproduced only by fitting them independently rather than deriving them from the registered impulse, force, torque, and inertia history.

71 Direction, Speed, Acceleration, and Plate-Circuit Registry

71.1 Velocity Contribution Decomposition

$$\mathbf{v}_i = \mathbf{v}_i^{\mathrm{inherit}} + \mathbf{v}_i^{g} + \mathbf{v}_i^{b} + \mathbf{v}_i^{m} + \mathbf{v}_i^{B} + \mathbf{v}_i^{\mathrm{later}} + \mathbf{v}_i^{\mathrm{def}}. \tag{372}$$

71.2 Relative Plate Velocity

For plates i and j,

$$\mathbf{v}_{ij}^{\mathrm{rel}} = \mathbf{v}_j - \mathbf{v}_i. \tag{373}$$

71.3 Direction Residual

$$\Delta\theta_{v,i} = \arccos\left[\frac{\mathbf{v}_i^{\text{obs}} \cdot \mathbf{v}_i^{\text{pred}}}{\left\|\mathbf{v}_i^{\text{obs}}\right\| \left\|\mathbf{v}_i^{\text{pred}}\right\|}\right]. \tag{374}$$

71.4 Speed Residual

$$\epsilon_{v,i} = v_i^{\text{obs}} - v_i^{\text{pred}}. \tag{375}$$

71.5 Acceleration

$$\mathbf{a}_i = \frac{d\mathbf{v}_i}{dt}. \tag{376}$$

71.6 Speed-Hierarchy Score

For observed and predicted plate-speed orderings, define a rank agreement diagnostic

$$\mathcal{R}_v = 1 - \frac{6\sum_i \left(r_i^{\text{obs}} - r_i^{\text{pred}}\right)^2}{N\left(N^2 - 1\right)}. \tag{377}$$

This is a defined diagnostic and not a substitute for magnitude agreement.

71.7 Plate-Circuit Closure

For a closed plate circuit

$$i_1 \to i_2 \to \cdots \to i_n \to i_1, \tag{378}$$

closure requires

$$\sum_{a=1}^{n} \boldsymbol{\omega}_{i_a i_{a+1}} = \mathbf{0} \tag{379}$$

within uncertainty.

71.8 Triple-Junction Compatibility

At junction J,

$$\mathbf{v}_{12}^J + \mathbf{v}_{23}^J + \mathbf{v}_{31}^J = \mathbf{0}. \tag{380}$$

71.9 Global Area Accounting

$$\dot{A}_{\text{create}} - \dot{A}_{\text{consume}} - \dot{A}_{\text{deform}} = \dot{A}_{\text{surface}} \tag{381}$$

within the chosen Earth-shape convention.

71.10 Directional-Inheritance Counterfactual

Replace directional inheritance tensor $\mathbf{H}$ with its isotropic part:

$$\mathbf{H} \to \frac{\operatorname{tr}(\mathbf{H})}{3}\mathbf{1}. \tag{382}$$

The necessity of directional inheritance is

$$N_{\mathrm{dir}} = \mathcal{J}_{\mathrm{iso}} - \mathcal{J}_{\mathrm{full}}. \tag{383}$$

71.11 Plate-Motion Viable Set

$$\begin{aligned}\mathcal{V}_V =& \mathcal{V}_J \cap \mathcal{V}_I \cap \mathcal{V}_F \cap \mathcal{V}_\tau \cap \mathcal{V}_\omega \\ & \cap \mathcal{V}_v \cap \mathcal{V}_{\mathrm{rel}} \cap \mathcal{V}_{\mathrm{circ}} \cap \mathcal{V}_A \cap \mathcal{V}_{\mathrm{power}}.\end{aligned} \tag{384}$$

72 Mountain, Trench, Ridge, Basin, Plateau, and Volcanic Registry

72.1 Unified Surface-Structure State

For structure class g,

$$\mathbf{Q}_{S,g} = \left(\mathcal{D}_g, \Gamma_g, \mathbf{A}_g, \mathbf{T}_g, \mathbf{Q}_g^{\mathrm{deep}}, \mathbf{Q}_g^{\mathrm{material}}, \mathbf{Q}_g^{\mathrm{motion}}\right). \tag{385}$$

72.2 Mountain-System Registry

Define orogenic nucleation potential

$$\mathcal{N}_O = \mathcal{F}_O\left(-v_n, \Delta\boldsymbol{\sigma}, H_c, D, \mu, \Delta\rho, T, \mathbf{Q}_{\mathrm{inherit}}\right). \tag{386}$$

The candidate orogenic seed domain is

$$\mathcal{O}^0 = \left\{\mathbf{x} : \mathcal{N}_O \geq N_{O,\mathrm{crit}}\right\}. \tag{387}$$

Surface elevation evolves as

$$\frac{\partial h}{\partial t} = U_{\mathrm{tect}} + U_{\mathrm{buoy}} + U_{\mathrm{mag}} + U_{\mathrm{dyn}} - E_{\mathrm{ero}} - S_{\mathrm{subs}}. \tag{388}$$

A mountain claim must predict:

- location;
- orientation;
- shortening;
- crustal thickness;

- uplift;
- erosion;
- chronology;
- and deep structure.

72.3 Trench and Terminal-Zone Registry

Define terminal-zone potential

$$\mathcal{N}_T = \mathcal{F}_T \left(D, \Delta\rho, \Delta P, \Delta T, \mathbf{v}_{\mathrm{rel}}, H_\ell, \mu, \mathbf{Q}_M\right). \tag{389}$$

The trench mechanism classes are:

- direct excavation or collapse;
- underthrusting;
- plate bending;
- descent;
- inherited-fracture reactivation;
- rollback or migration;
- and hybrid evolution.

For flexural rigidity

$$D_f = \frac{EH^3}{12\left(1-\nu^2\right)}, \tag{390}$$

an illustrative plate-bending equation is

$$D_f \nabla^4 w + \Delta\rho g w = q. \tag{391}$$

72.4 Ridge and Rift Registry

Define extensional seed potential

$$\mathcal{N}_R = \mathcal{F}_{\mathrm{rift}} \left(v_n^+, D, \Delta T, \chi_m, H_\ell, \mathbf{Q}_{\mathrm{inherit}}\right). \tag{392}$$

Material production must satisfy

$$\dot{A}_{\mathrm{new}} = \int_{\Gamma_R} v_{\mathrm{open}} \, d\ell. \tag{393}$$

A ridge or rift claim must predict:

- axis location;
- orientation;
- opening rate;
- material-age gradient;
- segmentation;
- transform offsets;
- melt production;
- and chronology.

72.5 Basin Registry

The basin subsidence decomposition is

$$\begin{aligned} S_B(t) = &S_{\text{event}} + S_{\text{ext}} + S_{\text{thermal}} + S_{\text{flex}} \\ &+ S_{\text{load}} + S_{\text{dynamic}} + S_{\text{boundary}} + S_{\text{comp}}. \end{aligned} \tag{394}$$

A basin claim must predict:

- basin domain;
- axis;
- depth;
- subsidence curve;
- accommodation;
- sediment fill;
- thermal history;
- and inversion.

72.6 Plateau Registry

Plateau elevation may be decomposed as

$$h_P = h_{\text{crust}} + h_{\text{buoy}} + h_{\text{thermal}} + h_{\text{dynamic}} + h_{\text{phase}} + h_{\text{event}} - h_{\text{eros}}. \tag{395}$$

A first-order isostatic screening relationship is

$$\Delta h \sim H \frac{\Delta\rho}{\rho_m}. \tag{396}$$

This is a screening relation, not a complete plateau model.

72.7 Volcanic-Province Registry

Define volcanic localization potential

$$\mathcal{N}_V = \mathcal{F}_V \left(\chi_m, \mathbf{k}_{\text{perm}}, \Delta P, \Delta T, D, \mathbf{v}_m, \mathcal{B}\right). \tag{397}$$

Melt transport satisfies

$$\frac{\partial \left(\phi_m \rho_m\right)}{\partial t} + \nabla \cdot \left(\phi_m \rho_m \mathbf{v}_m\right) = \Gamma_m - \Lambda_m. \tag{398}$$

A volcanic claim must predict:

- source region;
- melt volume;
- transport path;
- timing;
- duration;
- composition;
- and deep geophysical state.

72.8 Surface-Structure Viable Set

$$\mathcal{V}_S = \mathcal{V}_O \cap \mathcal{V}_{\text{trench}} \cap \mathcal{V}_R \cap \mathcal{V}_{BA} \cap \mathcal{V}_{PL} \cap \mathcal{V}_{VO} \cap \mathcal{V}_{TE}. \tag{399}$$

73 Terrane, Suture, and Continental-Assembly Registry

73.1 Terrane Provenance Vector

For terrane u,

$$\mathbf{Q}_u^{\text{prov}} = \left(\mathbf{C}_u, \mathbf{A}_u, \mathbf{M}_u, \mathbf{S}_u, \mathbf{P}_u, \mathbf{T}_u\right), \tag{400}$$

representing composition, age, magnetization, structure, paleolocation, and chronology.

73.2 Terrane Trajectory

$$\frac{d\mathbf{x}_u}{dt} = \mathbf{v}_u \left(\mathbf{x}_u, t\right). \tag{401}$$

73.3 Terrane Rotation

$$\frac{d\mathbf{R}_u}{dt} = \mathbf{\Omega}_u \mathbf{R}_u. \tag{402}$$

73.4 Docking Condition

A candidate docking occurs when:

$$d\left(\partial \mathcal{T}_u, \partial \mathcal{P}_j\right) \leq d_{\text{dock}} \tag{403}$$

and relative motion, chronology, deformation, and material evidence are compatible.

73.5 Suture Record

$$\mathbf{Q}_{S_u} = \left(\Gamma_u, t_{\text{contact}}, t_{\text{closure}}, \mathbf{D}_u, \mathbf{M}_u, \mathbf{C}_u, \mathbf{Q}_u^{\text{deep}}\right). \tag{404}$$

73.6 Assembly Graph

$$\mathcal{G}_{\text{asm}} = \left(\mathcal{N}_{\text{terr}}, \mathcal{E}_{\text{contact}}\right), \tag{405}$$

where nodes are terranes and continental blocks and edges are dated contacts or sutures.

73.7 Assembly Requirements

The event-sequence model must predict:

- which terranes separate;
- which trajectories they follow;
- which rotations occur;
- which boundaries close;
- where docking occurs;
- which sutures form;
- and the order of assembly.

73.8 Assembly Falsifier

The terrane and continental-assembly claim fails if predicted trajectories, paleolatitudes, rotations, provenance, docking ages, sutures, or mass continuity are incompatible.

74 Global Reconstruction and Null-Model Registry

74.1 Global State

The Paper-III global state is

$$\mathbf{Q}_G(t) = (\mathcal{P}(t), \mathcal{B}(t), \mathbf{V}(t), \mathbf{Q}_S(t), \mathbf{Q}_m(t), \mathbf{Q}_g(t)) . \tag{406}$$

74.2 Sequence Recursion

For event and interevent steps,

$$\mathbf{Q}^{-}_{G,k+1} = \mathcal{U}\left[\mathcal{F}_{E,k}\left(\mathbf{Q}^{-}_{G,k}, \mathcal{E}_k\right), t_k, t_{k+1}\right] . \tag{407}$$

74.3 Global Observation Vector

$$\mathbf{D}^{\text{obs}}_{\text{III}} = (\mathbf{D}_B, \mathbf{D}_V, \mathbf{D}_C, \mathbf{D}_S, \mathbf{D}_T, \mathbf{D}_G) . \tag{408}$$

74.4 Global Prediction

$$\widehat{\mathbf{D}}_{\text{III}} = \mathcal{O}_{\text{III}}\left[\mathbf{Q}_G(t), \boldsymbol{\Theta}_{\text{III}}\right] . \tag{409}$$

74.5 Integrated Misfit

$$\begin{aligned} \mathcal{J}_{\text{III}} =& w_B \mathcal{J}_B + w_V \mathcal{J}_V + w_C \mathcal{J}_C + w_S \mathcal{J}_S \\ &+ w_T \mathcal{J}_T + w_G \mathcal{J}_G + \mathcal{P}_{\text{phys}} + \mathcal{P}_{\text{complex}} + \mathcal{P}_{\text{causal}}. \end{aligned} \tag{410}$$

74.6 No-Event Null

$$\mathcal{E} \to \varnothing. \tag{411}$$

74.7 Randomized-Event Null

Randomize:

- event coordinates;
- ages;
- directions;
- energies;
- and event-to-structure assignments.

74.8 Shuffled-Age Null

$$\left\{t_k^{(r)}\right\} = \text{Permute}\left[\{t_k\}\right] . \tag{412}$$

74.9 Randomized-Boundary Null

Preserve network size or degree distribution while randomizing boundary placement:

$$\mathcal{G}_B^{(r)} \sim p\left(\mathcal{G} \mid N_V, N_E, p_{\text{degree}}\right) . \tag{413}$$

74.10 Isotropized-Inheritance Null

$$\mathbf{Q}_{\text{inherit}} \to \text{Iso}\left(\mathbf{Q}_{\text{inherit}}\right). \tag{414}$$

74.11 Leave-One-Event-Out Test

For event k,

$$N_{E,k} = \mathcal{J}_{III,-k} - \mathcal{J}_{III,\text{full}}. \tag{415}$$

74.12 Leave-One-Region-Out Test

For region r,

$$S_{-r} = \log p\left(\mathbf{D}_r^{\text{obs}} \mid \mathbf{D}_{-r}, \mathcal{M}_{\text{III}}\right). \tag{416}$$

74.13 Held-Out Structure Test

Fit the model without structure class g, then predict:

$$p\left(\mathbf{D}_g^{\text{obs}} \mid \mathbf{D}_{-g}, \mathcal{M}_{\text{III}}\right). \tag{417}$$

74.14 Empirical Null Probability

$$p_{\text{null}} = \frac{1 + \sum_{r=1}^{N_R} \mathbf{1}\left[\mathcal{J}_{\text{III}}^{(r)} \le \mathcal{J}_{\text{III}}^{\text{obs}}\right]}{N_R + 1}. \tag{418}$$

74.15 Global Reconstruction Requirement

A successful Paper-III reconstruction must outperform realistic null models after event selection, regional assignments, response lags, boundary thresholds, and structure assignments are counted.

75 Paper-III Equation Registry

Table 37: Principal Paper-III equation registry.

ID	Equation	Primary role	Status
`ABC-P3-EQN-001`	equation (316)	Paper-II conditional handoff	Canonical schema
`ABC-P3-EQN-002`	equation (319)	Event-catalog definition	Framework equation
`ABC-P3-EQN-003`	equation (323)	Nonlinear event update	Framework equation
`ABC-P3-EQN-004`	equation (324)	Interevent evolution	Framework equation
`ABC-P3-EQN-005`	equation (327)	Evolving plate or block domain	State definition

ID	Equation	Primary role	Status
ABC-P3-EQN-006	equation (329)	Material-membership closure	Conservation requirement
ABC-P3-EQN-007	equation (331)	Material-lineage graph	Framework equation
ABC-P3-EQN-008	equation (334)	Boundary nucleation	Conditional model
ABC-P3-EQN-009	equation (335)	Thresholded boundary domain	Conditional model
ABC-P3-EQN-010	equation (337)	Global boundary topology	State definition
ABC-P3-EQN-011	equation (341)	Boundary viability	Decision architecture
ABC-P3-EQN-012	equation (342)	Plate fragmentation	Framework equation
ABC-P3-EQN-013	equation (345)	Terrane transfer	Framework equation
ABC-P3-EQN-014	equation (349)	Boundary-type prediction	Conditional model
ABC-P3-EQN-015	equation (352)	Boundary reactivation	Conditional model
ABC-P3-EQN-016	equation (355)	Plate-integrated impulse	Framework equation
ABC-P3-EQN-017	equation (356)	Angular impulse	Framework equation
ABC-P3-EQN-018	equation (357)	Impulse closure	Conservation requirement
ABC-P3-EQN-019	equation (364)	Plate inertia	Framework equation
ABC-P3-EQN-020	equation (365)	Plate linear dynamics	Governing equation
ABC-P3-EQN-021	equation (366)	Plate rotational dynamics	Governing equation
ABC-P3-EQN-022	equation (367)	Power accounting	Physical requirement
ABC-P3-EQN-023	equation (369)	Euler-vector surface velocity	Kinematic equation
ABC-P3-EQN-024	equation (370)	Finite plate rotation	Kinematic equation
ABC-P3-EQN-025	equation (372)	Motion-source decomposition	Framework equation
ABC-P3-EQN-026	equation (373)	Relative boundary motion	Kinematic equation
ABC-P3-EQN-027	equation (379)	Plate-circuit closure	Physical constraint
ABC-P3-EQN-028	equation (380)	Triple-junction compatibility	Physical constraint
ABC-P3-EQN-029	equation (384)	Plate-motion viability	Decision architecture
ABC-P3-EQN-030	equation (388)	Mountain and elevation evolution	Conditional model

ID	Equation	Primary role	Status
ABC-P3-EQN-031	equation (391)	Trench and flexural bending	Conditional model
ABC-P3-EQN-032	equation (393)	Ridge-area production	Physical accounting
ABC-P3-EQN-033	equation (394)	Basin subsidence decomposition	Conditional model
ABC-P3-EQN-034	equation (395)	Plateau-support decomposition	Conditional model
ABC-P3-EQN-035	equation (398)	Volcanic melt transport	Governing equation
ABC-P3-EQN-036	equation (405)	Terrane assembly	Graph model
ABC-P3-EQN-037	equation (407)	Whole-sequence state evolution	Framework equation
ABC-P3-EQN-038	equation (410)	Integrated reconstruction score	Comparison equation
ABC-P3-EQN-039	equation (418)	Empirical null probability	Statistical test
ABC-P3-EQN-040	equation (399)	Surface-expression viability	Decision architecture

75.1 Equation-Audit Priority

The highest-priority Paper-III equation audits are:

1. consistency with the actual Paper-II output fields;
2. material-lineage conservation;
3. boundary-threshold derivation;
4. event impulse partition;
5. plate inertia evolution;
6. force and torque balance;
7. power and dissipation;
8. Euler-vector generation;
9. global velocity closure;
10. surface-structure mass and energy budgets;
11. and integrated score identifiability.

76 Paper-III Assumption and Parameter Registry

76.1 Principal Assumptions

Table 38: Principal Paper-III assumptions.

ID	Assumption	Status
ABC-P3-ASM-001	At least one Paper-II branch produces a nonempty admissible state.	Unresolved
ABC-P3-ASM-002	The candidate event catalog contains historically real events.	Unresolved
ABC-P3-ASM-003	Event-derived material-state inheritance persists across relevant geological intervals.	Unresolved
ABC-P3-ASM-004	The selected event sequence is sufficiently complete to reconstruct the major global system.	Unresolved
ABC-P3-ASM-005	Ancient material domains can be reconstructed with usable uncertainty.	Methodological assumption
ABC-P3-ASM-006	Boundary-nucleation thresholds can be physically constrained.	Unresolved
ABC-P3-ASM-007	Event-derived impulse can be partitioned among ancient plates and blocks.	Unresolved
ABC-P3-ASM-008	Long-time gravitational and buoyancy maintenance can preserve or amplify event-derived directional organization.	Unresolved
ABC-P3-ASM-009	Mantle and boundary coupling can be represented without inserting observed motion as a free causal input.	Model assumption
ABC-P3-ASM-010	Evolving plates can be approximated by rigid rotation plus explicit internal deformation where required.	Conditional
ABC-P3-ASM-011	Surface structures preserve enough historical information to distinguish candidate causal sequences.	Unresolved
ABC-P3-ASM-012	Null models can reproduce the relevant geological opportunity space.	Statistical assumption
ABC-P3-ASM-013	Event-to-structure response lags can be physically constrained.	Unresolved
ABC-P3-ASM-014	Regional material and rheological differences can be represented without unrestricted local tuning.	Unresolved
ABC-P3-ASM-015	One shared parameter architecture can satisfy all mandatory global domains.	Primary test assumption

76.2 Parameter Classes

The Paper-III parameter registry includes:

- event ages;
- event coordinates;
- path directions;
- event energies;
- impulse-partition fractions;
- damage thresholds;
- boundary-nucleation thresholds;
- healing and persistence times;

- thermal and density anomalies;
- plate and block masses;
- inertia tensors;
- boundary mobilities;
- mantle-coupling coefficients;
- friction;
- viscosity;
- buoyancy coefficients;
- response lags;
- structure-specific thresholds;
- preservation functions;
- and score weights.

76.3 Parameter Registry Table

Table 39: Principal Paper-III parameter groups.

ID	Parameter group	Primary role	Status
ABC-P3-PAR-001	Event-catalog parameters	Sequence definition	Unfrozen
ABC-P3-PAR-002	Material-lineage parameters	Ancient plate and block identities	Unassembled
ABC-P3-PAR-003	Boundary thresholds	Nucleation, persistence, and reactivation	Unconstrained
ABC-P3-PAR-004	Impulse partition	Plate, mantle, deformation, and loss allocation	Unconstrained
ABC-P3-PAR-005	Plate mass and inertia	Linear and rotational response	Unassembled
ABC-P3-PAR-006	Mantle-coupling parameters	Long-time traction and dissipation	Unconstrained
ABC-P3-PAR-007	Boundary-mobility parameters	Relative motion and boundary type	Unconstrained
ABC-P3-PAR-008	Persistence kernels	Long-time inheritance	Unconstrained
ABC-P3-PAR-009	Structure-response parameters	Mountains, trenches, ridges, basins, plateaus, volcanism	Unconstrained
ABC-P3-PAR-010	Chronology and lag parameters	Causal ordering and response delay	Unfrozen
ABC-P3-PAR-011	Null-model parameters	Opportunity-matched significance	Unfrozen
ABC-P3-PAR-012	Integrated score weights	Global model ranking	Unfrozen

76.4 No Independent Regional Retuning

A global model may use regionally varying material properties when those variations are independently constrained.

It may not assign separate unconstrained values to each region solely to improve fit without counting the added flexibility.

77 Paper-III Prediction Registry

Table 40: Paper-III prediction registry.

ID	Prediction	Current status
ABC-P3-PRD-001	A frozen event sequence will generate a connected global candidate boundary network without manually drawing each modern boundary.	Draft
ABC-P3-PRD-002	The predicted boundary network will enclose major plates and tectonic blocks with correct topology.	Draft
ABC-P3-PRD-003	Boundary types and polarities will follow from predicted relative motion and material state.	Draft
ABC-P3-PRD-004	Event-derived angular impulse and later forcing will generate Euler vectors within frozen uncertainty.	Draft
ABC-P3-PRD-005	The model will reproduce the global hierarchy of plate-motion directions and speeds.	Draft
ABC-P3-PRD-006	Predicted plate circuits and triple junctions will close.	Draft
ABC-P3-PRD-007	Directional inheritance will outperform an isotropized-inheritance counterfactual.	Draft
ABC-P3-PRD-008	The event-boundary-motion state will predict withheld mountain-system locations and orientations.	Draft
ABC-P3-PRD-009	Terminal-zone modeling will predict trench polarity, geometry, and deep structure without assigning them afterward.	Draft
ABC-P3-PRD-010	Ridge and rift modeling will predict opening direction, age gradients, segmentation, and material production.	Draft
ABC-P3-PRD-011	Basin modeling will predict subsidence histories and later inversion.	Draft
ABC-P3-PRD-012	Plateau modeling will predict uplift domain, crustal support, and persistence.	Draft
ABC-P3-PRD-013	Volcanic modeling will predict melt pathways, timing, and source characteristics.	Draft
ABC-P3-PRD-014	Terrane and suture modeling will predict trajectories, rotations, docking locations, and assembly order.	Draft
ABC-P3-PRD-015	Removing one genuinely causal event will degrade specific predicted boundaries, motions, or structures.	Draft
ABC-P3-PRD-016	Randomized event sequences will perform worse than the frozen sequence after selection correction.	Draft
ABC-P3-PRD-017	The global model will predict withheld regions using shared parameters.	Draft
ABC-P3-PRD-018	The final Paper-III state will generate concrete comparison inputs for Paper IV without importing the observed solution as a free parameter.	Conditional

77.1 Prediction-Freeze Requirements

Each prediction must specify:

- event-catalog version;
- Paper-II handoff version;
- spatial domain;
- depth;
- age;
- direction;
- magnitude;
- uncertainty;
- negative-control domain;
- and validation dataset.

77.2 Current Prediction Status

The Paper-III entries remain draft model predictions.

They do not yet qualify as independent prospective evidence.

78 Paper-III Falsification Registry

Table 41: Paper-III falsification registry.

ID	Falsification condition	Consequence
`ABC-P3-FAL-001`	The Paper-III reconstruction requires fields not generated by any surviving Paper-II branch.	Reject event-derived causal handoff.
`ABC-P3-FAL-002`	No chronologically admissible event catalog can be constructed.	Reject sequenced-event reconstruction.
`ABC-P3-FAL-003`	Ancient plate and block lineages cannot be reconstructed without material contradiction.	Reject historical plate partition.
`ABC-P3-FAL-004`	The event-derived boundary field remains disconnected or fails to enclose major plates.	Reject global boundary-generation claim.
`ABC-P3-FAL-005`	Boundary geometry requires manual segment-by-segment placement.	Reject predictive boundary origin.
`ABC-P3-FAL-006`	Predicted boundary type or polarity conflicts with relative motion and material state.	Reject boundary-dynamics branch.
`ABC-P3-FAL-007`	Boundary initiation, reactivation, inversion, or termination chronology fails.	Reject event-boundary sequence.
`ABC-P3-FAL-008`	Fragmentation or merger violates material-mass closure.	Reject affected lineage branch.

ID	Falsification condition	Consequence
ABC-P3-FAL-009	Terrane transfer violates provenance, paleolatitude, rotation, or chronology.	Reject affected transfer assignment.
ABC-P3-FAL-010	Event-to-plate impulse cannot be partitioned consistently among ancient material domains.	Reject impulse-inheritance branch.
ABC-P3-FAL-011	Predicted Euler vectors require independent fitting to observed Euler vectors.	Reject causal Euler-vector generation.
ABC-P3-FAL-012	The force and torque system does not close.	Reject plate-dynamic solution.
ABC-P3-FAL-013	The motion solution requires negative dissipation or unavailable power.	Reject motion-maintenance branch.
ABC-P3-FAL-014	Predicted plate directions or speeds systematically fail.	Reject global motion inheritance.
ABC-P3-FAL-015	Plate circuits or triple junctions fail closure.	Reject global velocity field.
ABC-P3-FAL-016	Directional-inheritance isotropization leaves the solution materially unchanged.	Reject directional inheritance as primary.
ABC-P3-FAL-017	Mountain systems occur outside predicted compression and inheritance domains.	Reject orogenic-localization branch.
ABC-P3-FAL-018	Trench geometry or deep structure cannot be produced by any admissible terminal-zone mechanism.	Reject trench branch.
ABC-P3-FAL-019	Ridge and rift age gradients, opening rates, or material production fail.	Reject extensional branch.
ABC-P3-FAL-020	Basin location, subsidence, or inversion chronology fails.	Reject basin branch.
ABC-P3-FAL-021	Plateau uplift and persistence require unavailable crustal, thermal, buoyant, or dynamic support.	Reject plateau branch.
ABC-P3-FAL-022	Volcanic location, timing, melt path, or composition fails.	Reject volcanic-localization branch.
ABC-P3-FAL-023	Terrane docking, suture location, or assembly order fails.	Reject continental-assembly branch.
ABC-P3-FAL-024	Observed structures precede their assigned causal events.	Reject affected event-to-structure assignments.
ABC-P3-FAL-025	Randomized or shuffled event sequences perform comparably.	Reject special sequence significance.
ABC-P3-FAL-026	The model fails held-out regions or structure classes.	Reject global predictive generality.
ABC-P3-FAL-027	Removing claimed major events produces negligible degradation.	Reject those events as necessary global organizers.
ABC-P3-FAL-028	The apparent advantage disappears after event, assignment, lag, threshold, and preservation flexibility are counted.	Reject adjusted reconstruction preference.
ABC-P3-FAL-029	The same parameter set cannot jointly satisfy boundaries, motion, structures, chronology, and whole-Earth budgets.	Paper-III viable set is empty.
ABC-P3-FAL-030	Independent implementations cannot reproduce the integrated reconstruction.	Reject confirmatory Paper-III support.

78.1 Primary Paper-III Falsifier

The primary global falsifier is:

> No mechanically admissible and chronologically ordered event sequence produces one common solution for the major boundary network, plate directions, relative velocities, speed hierarchy, continental displacement, and global surface structures.

78.2 Compartmentalized Failure

A failed global reconstruction does not automatically reject every regional event hypothesis.

A regional claim remains viable only if its own:

- Paper-I geometry;
- Paper-II mechanics;
- chronology;
- structure;
- and direct falsifier

remain satisfied.

79 Paper-III Contradiction and Supersession Audit

Table 42: Paper-III contradiction, clarification, and supersession audit.

ID	Issue	Current resolution
`ABC-P3-REV-001`	A single flagship event could be interpreted as the entire global causal framework.	Paper III requires a sequenced event catalog acting on an evolving state.
`ABC-P3-REV-002`	Modern plate polygons could be projected backward unchanged.	The canonical model uses time-dependent material domains and explicit lineage.
`ABC-P3-REV-003`	Ancient impulse could be interpreted as directly sustaining modern plate speed.	Impulse is limited to initialization, redirection, or inherited state; ongoing force and power terms are required.
`ABC-P3-REV-004`	Observed plate velocity could be used as both input and validation.	The atlas prohibits causal credit from circular velocity insertion.
`ABC-P3-REV-005`	Euler poles could be treated as fitted descriptive parameters.	For causal replacement they must be model outputs.
`ABC-P3-REV-006`	Boundary lines could be judged by visual resemblance alone.	Connectivity, enclosure, topology, type, chronology, and persistence are mandatory.
`ABC-P3-REV-007`	A mountain system could be directly mapped to ancient event pressure.	Modern topography requires long-time shortening, buoyancy, erosion, thermal, magmatic, and dynamic evolution.
`ABC-P3-REV-008`	A modern trench could be labeled a direct exit crater.	Terminal excavation, collapse, bending, underthrusting, descent, and hybrid alternatives are compared.

ID	Issue	Current resolution
ABC-P3-REV-009	A ridge could be attributed to an event trace without material production.	Opening rate, age progression, melt supply, segmentation, and global area accounting are required.
ABC-P3-REV-010	Regional success could be described as global replacement.	The atlas separates local, regional, multi-regional, and global viable sets.
ABC-P3-REV-011	Multiple favorable structures could be assigned independently to events.	The integrated model requires one connected chronology and shared parameter architecture.
ABC-P3-REV-012	A model could use different event states for boundary, motion, and surface-structure success.	The same branch and parameter realization must propagate through the complete dependency chain.

79.1 No Combination of Incompatible Versions

A Paper-III run may not combine:

- an event catalog from one version;
- a boundary threshold from another;
- an impulse partition from a third;
- and a structure assignment from a fourth

without registering the combination as a new model version.

80 Paper-III Dependency Graph and Integrated Viable Set

80.1 Paper-III Dependency Graph

$$\mathcal{G}_{P3} = (\mathcal{N}_{P3}, \mathcal{E}_{P3}) \,. \tag{419}$$

80.2 Core Dependency Chain

$$\begin{aligned} \text{Paper III reconstruction} \Leftarrow \{&\text{Paper II state}, \text{event sequence}, \text{material lineage}, \\ &\text{boundary network}, \text{impulse}, \text{force and torque}, \\ &\text{velocity field}, \text{surface structures}, \text{chronology}, \text{nulls}\}. \end{aligned} \tag{420}$$

80.3 Component Viable Sets

For one frozen eligible event sequence $\mathcal{S}$, define all component sets in one common lifted parameter space:

$$
\begin{aligned}
\mathcal{V}_{\mathrm{mech},\mathcal{S}} &= \text{intersection of event-indexed Paper-I/Paper-II eligibility}, && (421)\\
\mathcal{V}_{B,\mathcal{S}} &= \text{boundary-network viability}, && (422)\\
\mathcal{V}_{V,\mathcal{S}} &= \text{plate-motion, impulse, force, and torque viability}, && (423)\\
\mathcal{V}_{S,\mathcal{S}} &= \text{surface-structure viability}, && (424)\\
\mathcal{V}_{C,\mathcal{S}} &= \text{continental and material-lineage viability}, && (425)\\
\mathcal{V}_{T,\mathcal{S}} &= \text{chronology viability}, && (426)\\
\mathcal{V}_{G,\mathcal{S}} &= \text{integrated global-geophysical viability}, && (427)\\
\mathcal{V}_{N,\mathcal{S}} &= \text{null-model and selection-control viability}, && (428)\\
\mathcal{V}_{P,\mathcal{S}} &= \text{advance-prediction viability}. && (429)
\end{aligned}
$$

Event-catalog and lineage requirements are subconstraints of the mechanical, boundary, continental, and chronology sets; event-to-domain impulse is a subconstraint of the motion set. They are not counted again as independent top-level gates under alternate short symbols.

80.4 Complete Paper-III Viable Set

$$
\boxed{
\begin{aligned}
\mathcal{V}_{\mathrm{III},\mathcal{S}} &= \mathcal{V}_{\mathrm{mech},\mathcal{S}} \cap \mathcal{V}_{B,\mathcal{S}} \cap \mathcal{V}_{V,\mathcal{S}} \cap \mathcal{V}_{S,\mathcal{S}} \cap \mathcal{V}_{C,\mathcal{S}} \\
&\quad \cap \mathcal{V}_{T,\mathcal{S}} \cap \mathcal{V}_{G,\mathcal{S}} \cap \mathcal{V}_{N,\mathcal{S}} \cap \mathcal{V}_{P,\mathcal{S}}, \\
\mathcal{V}_{\mathrm{III}} &= \bigcup_{\mathcal{S}\in\mathfrak{S}_{\mathrm{elig}}} \mathcal{V}_{\mathrm{III},\mathcal{S}}.
\end{aligned}
}
\tag{430}
$$

80.5 Shared-Parameter Requirement

The complete set must contain one common parameter realization:

$$
\boldsymbol{\Theta}^*_{\mathrm{III}} \in \mathcal{V}_{\mathrm{III}}. \tag{431}
$$

80.6 No Cross-Branch Compensation

The following does not establish viability:

- one event branch generating boundaries;
- another incompatible branch generating motion;
- a third branch generating mountains;
- and a fourth parameter set satisfying chronology.

80.7 Critical Nodes

Table 43: Paper-III critical dependency nodes.

Node	**Criticality**	**Reason**
Paper-II handoff	Series-critical	All event-derived boundary and motion claims depend on it.
Event catalog	Series-critical	The sequence defines the proposed causal history.
Material lineage	Series-critical	Ancient impulse and boundaries must act on real material domains.
Boundary network	Series-critical	Plate partition and relative motion depend on it.
Impulse partition	High	Controls initial translation, rotation, deformation, and losses.
Force and torque	Series-critical	Modern motion requires physically available continuing dynamics.
Euler vectors	High	They connect rotational dynamics to measured surface velocities.
Chronology	Series-critical	Effects cannot precede assigned causes.
Surface structures	High	The model must explain more than abstract plate motion.
Null models	High	The event sequence must outperform opportunity-matched alternatives.
Held-out prediction	Series-critical for confirmation	Reconstruction alone does not establish causal replacement.

80.8 Representative Failure Cut Set

A representative Paper-III failure cut set is

$$\mathcal{K}_{P3,\mathcal{S}} = \{\mathcal{V}_{\mathrm{mech},\mathcal{S}}, \mathcal{V}_{B,\mathcal{S}}, \mathcal{V}_{V,\mathcal{S}}, \mathcal{V}_{C,\mathcal{S}}, \mathcal{V}_{T,\mathcal{S}}\}\,. \tag{432}$$

If any of these mandatory sets is empty for every event sequence, the global Paper-III reconstruction fails.

80.9 Paper-IV Handoff

The Paper-IV comparison input is

$$\mathbf{Q}_{IV,0} = (\mathcal{E}^*, \mathcal{P}^*, \mathcal{B}^*, \mathbf{V}^*, \mathbf{Q}_S^*, \mathbf{\Theta}_{\mathrm{III}}^*, \mathbf{\Sigma}_{\mathrm{III}}^*)\,, \tag{433}$$

where

$$\mathbf{\Theta}_{\mathrm{III}}^* \in \mathcal{V}_{\mathrm{III}}. \tag{434}$$

Paper IV may compare only an actual surviving Paper-III model, not an idealized verbal summary.

81 Paper-III Atlas Status

81.1 Status Dashboard

Table 44: Current Paper-III atlas status dashboard.

Registry domain	**Current status**	**Required next step**
Paper-II handoff	Schema defined; fields unpopulated	Generate from a surviving Paper-II branch
Event catalog	Conceptual and provisional	Freeze events, ages, coordinates, branches, and uncertainties
Material lineage	Architecture defined	Assemble time-dependent plates, blocks, and terranes
Boundary nucleation	Forward model defined	Derive and test physical thresholds
Boundary connectivity	Metrics defined	Generate global network and plate enclosure
Boundary chronology	Required	Compile initiation, reactivation, inversion, and termination ages
Fragmentation and merger	Operators defined	Populate material-mass histories
Terrane transfer	Registry defined	Reconstruct provenance, paths, and rotations
Event impulse	Equations defined	Compute plate- and block-specific partition
Plate mass and inertia	Equations defined	Assemble time-dependent material models
Force and torque	Registry defined	Construct physically closed dynamics
Euler vectors	Required model outputs	Generate and compare with observation
Plate directions and speeds	Comparison architecture defined	Run global forward model
Plate circuits	Closure equations defined	Evaluate global compatibility
Mountain systems	Localization and evolution framework defined	Predict withheld systems and chronology
Trenches	Mechanism alternatives defined	Predict geometry, polarity, and deep structure
Ridges and rifts	Opening and production framework defined	Predict age gradients and segmentation
Basins	Subsidence framework defined	Predict complete subsidence and inversion histories
Plateaus	Support decomposition defined	Predict uplift, root, and persistence
Volcanism	Melt-path framework defined	Predict source, transport, age, and composition
Terranes and sutures	Assembly graph defined	Predict docking and contact order
Global reconstruction	State and misfit architecture defined	Execute one end-to-end sequence
Null models	Defined	Freeze opportunity space and simulate
Predictions	Draft	Freeze before validation
Integrated viable set	Defined	Evaluate shared parameter intersection

Registry domain	Current status	Required next step
Paper-IV handoff	Schema defined	Populate only from a surviving Paper-III solution

81.2 Established Paper-III Architecture

The strongest current Paper-III outputs are:

- the conditional Paper-II handoff rule;
- the nonlinear event-sequence architecture;
- the evolving material-domain representation;
- the plate and terrane lineage graph;
- the boundary-nucleation and connectivity framework;
- boundary-type and reactivation rules;
- event-to-plate linear and angular impulse equations;
- plate mass and inertia definitions;
- force, torque, power, and dissipation accounting;
- Euler-vector generation requirements;
- plate-circuit and triple-junction closure;
- directional-inheritance counterfactuals;
- mountain, trench, ridge, basin, plateau, volcanic, terrane, and suture forward-model registries;
- global reconstruction and null-model architecture;
- and the complete integrated viable set.

81.3 Current Restrictive Results

The atlas establishes that:

- event impulse alone cannot sustain modern plate motion;
- modern plate polygons cannot be projected unchanged through time;
- observed velocity cannot validate a model that inserted the same velocity as a free cause;
- visual boundary or structural similarity is insufficient;
- regional success cannot establish global replacement;
- and one common event sequence and parameter realization must satisfy all mandatory domains.

81.4 Current Unresolved Questions

Paper III still requires:

- a mechanically surviving Paper-II state;
- a frozen event catalog;
- ancient plate and terrane lineages;
- boundary-generation simulation;
- impulse partition;
- force and torque closure;
- Euler-vector generation;
- plate-speed prediction;
- complete structural forward models;
- chronology-wide reconstruction;
- null simulations;
- held-out predictions;
- and independent reproduction.

81.5 Paper-III Atlas Conclusion

Paper-III atlas conclusion.
Paper III defines a complete causal reconstruction architecture linking mechanically surviving event states to evolving material domains, boundary nucleation, plate partition, event-derived impulse, continuing force and torque, Euler-vector evolution, relative plate velocity, and large-scale surface structure.
Its central scientific burden is not satisfied by finding individual geometric correspondences. The candidate must produce one chronologically ordered and materially continuous global solution in which:

$$\mathcal{V}_{\mathrm{III}} = \mathcal{V}_H \cap \mathcal{V}_E \cap \mathcal{V}_L \cap \mathcal{V}_B \cap \mathcal{V}_J \cap \mathcal{V}_V \cap \mathcal{V}_S \cap \mathcal{V}_C \cap \mathcal{V}_N \cap \mathcal{V}_P$$

is nonempty.
No such complete numerical solution is presently registered.
Paper III therefore remains a falsifiable global reconstruction program rather than a demonstrated causal replacement.
Only a surviving Paper-III state may enter the direct comparative adjudication of Paper IV.

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82 Paper-III Atlas Synthesis

This Paper-III atlas synthesis records:

1. the complete Paper-III atlas scope;
2. a thirty-six-item principal Paper-III claim registry;
3. the conditional Paper-II handoff audit;
4. field-by-field handoff admissibility;
5. the prohibition against invented event-derived handoff fields;
6. the sequenced event-catalog registry;
7. nonlinear event and interevent state recursion;
8. event-selection complexity accounting;
9. evolving plate and tectonic-block material domains;
10. fractional material membership and closure;
11. plate, block, and terrane lineage graphs;
12. material-mass continuity;
13. boundary-nucleation potential;
14. thresholded boundary domains;
15. boundary persistence;
16. the global boundary graph;
17. plate-enclosure and connectivity tests;
18. the complete boundary viable set;
19. fragmentation, merger, and terrane-transfer operators;
20. boundary-type, propagation, branching, reactivation, inversion, and termination registries;
21. event-to-plate linear and angular impulse equations;
22. impulse partition and memory;
23. plate mass, center-of-mass, and inertia definitions;
24. linear- and angular-momentum evolution;
25. force, torque, power, and dissipation registries;
26. Euler-vector, finite-rotation, and Euler-pole-drift equations;
27. direction, speed, acceleration, and relative-motion registries;
28. plate-circuit and triple-junction closure;
29. global area accounting;
30. directional-inheritance isotropization;

31. the complete plate-motion viable set;
32. mountain-system localization and elevation evolution;
33. trench and terminal-zone mechanism alternatives;
34. ridge, rift, and new-area production;
35. basin subsidence and inversion;
36. plateau support and persistence;
37. volcanic melt generation and transport;
38. terrane provenance, trajectory, rotation, docking, and suture formation;
39. the continental-assembly graph;
40. the global sequence-reconstruction state;
41. the integrated Paper-III misfit;
42. no-event, randomized-event, shuffled-age, randomized-boundary, and isotropized-inheritance nulls;
43. leave-one-event-out, leave-one-region-out, and held-out-structure tests;
44. a forty-item principal Paper-III equation registry;
45. the Paper-III assumption registry;
46. the Paper-III parameter-group registry;
47. the Paper-III prediction registry;
48. the thirty-item Paper-III falsification registry;
49. the contradiction and supersession audit;
50. the Paper-III dependency graph;
51. the complete integrated Paper-III viable set;
52. shared-parameter and no-cross-branch-compensation rules;
53. critical-node and failure-cut-set analysis;
54. the formal Paper-IV handoff restriction;
55. the Paper-III status dashboard; and
56. the formal Paper-III atlas conclusion.

The following sections construct the complete Paper-IV adjudication atlas:

- Paper-IV comparison scope;
- shared-observation registry;
- Plate-Tectonic, astro-ballistic, hybrid, regional, baseline, and null model registries;

- matched-input and matched-output rules;
- initial-condition and boundary-information accounting;
- boundary-generation comparison;
- plate-motion and Euler-vector comparison;
- force, torque, work, power, and dissipation comparison;
- mountain, trench, ridge, basin, plateau, volcanism, terrane, gravity, seismic, magnetic, and heat-flow comparison registries;
- chronology-wide and paleogeographic comparison;
- causal-coverage and causal-depth registries;
- model evidence, posterior probability, and equivalence;
- effective complexity and description length;
- null, selection, and multiple-testing registries;
- advance-prediction registry;
- hybrid causal decomposition;
- regional versus global classification;
- complete Paper-IV viable set;
- formal replacement decision tree;
- Paper-IV claim and falsification atlases;
- replication registry;
- cross-paper replacement dependency graph; and
- Paper-IV atlas status dashboard.

83 Paper-IV Atlas Scope

83.1 Paper-IV Function

Paper IV directly compares the causal and predictive adequacy of:

$$\mathcal{M}_{\mathrm{PT}}, \qquad \mathcal{M}_{\mathrm{ABC}}, \qquad \mathcal{M}_{\mathrm{HYB}}, \tag{435}$$

together with regional, baseline, and null models.

Paper IV does not ask whether continents and plates move.

That observation is shared.

Its central question is:

Which model family best explains and predicts the origin, organization, evolution, and continuing dynamics of the global boundary, plate-motion, continental, structural, chronological, and deep-geophysical system?

83.2 Primary Comparative Burden

For at least one preregistered eligible sequence $\mathcal{S}$, the astro-ballistic model qualifies as a primary replacement candidate only if:

$$\mathcal{V}_{IV,\mathcal{S},\mathrm{ABC}} \neq \varnothing \tag{436}$$

and the resulting model-family union achieves a frozen, complexity-adjusted, predictive advantage over the strongest defensible Plate-Tectonic comparison model.

83.3 Paper-IV Atlas Objects

The Paper-IV atlas contains:

$$\mathfrak{A}_{P4} = \{\mathfrak{C}_{P4}, \mathfrak{E}_{P4}, \mathfrak{AS}_{P4}, \mathfrak{P}_{P4}, \mathfrak{D}_{P4}, \mathfrak{S}_{P4}, \mathfrak{M}_{P4}, \mathfrak{R}_{P4}, \mathfrak{F}_{P4}, \mathfrak{G}_{P4}\}\,. \tag{437}$$

83.4 Eligible Outcomes

Paper IV permits the following outcomes:

Rejected
: The global astro-ballistic model is physically, chronologically, statistically, or predictively incompatible.

Local or regional
: Selected event-derived hypotheses survive without global replacement.

Complementary
: Event inheritance improves selected observation classes while Plate Tectonics remains the primary framework.

Hybrid preferred
: Both model families and their interaction are necessary.

Causal equivalence
: Available evidence does not distinguish the primary causal framework.

Astro-ballistic replacement candidate
: The astro-ballistic model achieves complete viability and clear adjusted predictive superiority.

Shared failure
: None of the tested model families adequately explains the complete shared evidence domain.

83.5 No Replacement by Rhetoric

The final classification must follow the frozen evidence, equations, counterfactuals, complexity accounting, prediction scores, and decision thresholds.

The terminology

replacement

does not itself establish replacement.

84 Paper-IV Comparison Claim Registry

Table 45: Principal Paper-IV comparison claim registry.

ID	Claim	Role	Current status
ABC-P4-CLM-001	Observed continental and plate motion is shared evidence among the compared model families.	Foundational	FRAME-DEFINED
ABC-P4-CLM-002	The comparative dispute concerns primary causal organization rather than the existence of motion.	Scope	FRAME-DEFINED
ABC-P4-CLM-003	The astro-ballistic model must survive Papers I through III before receiving replacement consideration.	Eligibility	REQUIREMENT-DEFINED
ABC-P4-CLM-004	All compared models must predict the same frozen observation domain.	Comparison rule	REQUIREMENT-DEFINED
ABC-P4-CLM-005	The astro-ballistic model must be compared with strong defensible Plate-Tectonic implementations rather than a weakened caricature.	Fairness rule	REQUIREMENT-DEFINED
ABC-P4-CLM-006	Boundary origin and boundary-conditioned motion prediction are distinct causal burdens.	Comparison rule	ARCHITECTURE-DEFINED
ABC-P4-CLM-007	Initial boundary, thermal, density, compositional, rheological, and velocity information contributes to model complexity.	Complexity rule	REQUIREMENT-DEFINED
ABC-P4-CLM-008	A model that begins with a near-modern boundary network has not independently derived that network.	Causal rule	REQUIREMENT-DEFINED
ABC-P4-CLM-009	Euler vectors and plate velocities must be generated rather than inserted as free explanations of their own observations.	Circularity rule	REQUIREMENT-DEFINED
ABC-P4-CLM-010	Ancient event impulse cannot be treated as perpetual unattenuated power.	Physical rule	REQUIREMENT-DEFINED
ABC-P4-CLM-011	Present motion requires explicit force, torque, work, resistance, and dissipation accounting.	Physical rule	REQUIREMENT-DEFINED
ABC-P4-CLM-012	Boundary comparison must include geometry, topology, type, motion, chronology, persistence, and plate enclosure.	Comparison rule	ARCHITECTURE-DEFINED
ABC-P4-CLM-013	Motion comparison must include Euler poles, directions, speeds, relative velocities, accelerations, plate circuits, and junction closure.	Comparison rule	ARCHITECTURE-DEFINED
ABC-P4-CLM-014	Structural comparison must include mountains, trenches, ridges, rifts, basins, plateaus, volcanism, terranes, and sutures.	Comparison rule	ARCHITECTURE-DEFINED

ID	Claim	Role	Current status
ABC-P4-CLM-015	Deep-geophysical comparison must include gravity, geoid, seismic velocity, attenuation, anisotropy, magnetics, and heat flow.	Comparison rule	ARCHITECTURE-DEFINED
ABC-P4-CLM-016	Modern spatial agreement is insufficient when event-time paleogeography or chronology fails.	Historical rule	REQUIREMENT-DEFINED
ABC-P4-CLM-017	A model must be evaluated for both causal breadth and causal depth.	Coverage rule	ARCHITECTURE-DEFINED
ABC-P4-CLM-018	A model receives no global replacement credit for observation classes it omits.	Coverage rule	REQUIREMENT-DEFINED
ABC-P4-CLM-019	A defining mechanism must be necessary under controlled ablation.	Causal rule	REQUIREMENT-DEFINED
ABC-P4-CLM-020	Model evidence and predictive ranking must be evaluated across defensible priors, data partitions, and reconstruction ensembles.	Statistical rule	ARCHITECTURE-DEFINED
ABC-P4-CLM-021	The final comparison permits an explicit equivalence or causal non-resolution result.	Decision rule	ARCHITECTURE-DEFINED
ABC-P4-CLM-022	Raw numerical parameter count understates model flexibility.	Complexity rule	REQUIREMENT-DEFINED
ABC-P4-CLM-023	Event selection, initial states, regional tuning, mechanism switching, lags, preservation, reference frames, and revisions contribute to effective complexity.	Complexity rule	REQUIREMENT-DEFINED
ABC-P4-CLM-024	The proposed event sequence must outperform null models preserving geological and observational opportunity.	Statistical rule	UNTESTED
ABC-P4-CLM-025	Repeatedly inspected test data become calibration data.	Validation rule	REQUIREMENT-DEFINED
ABC-P4-CLM-026	A replacement claim requires successful advance prediction, not only retrospective reconstruction.	Prediction rule	REQUIREMENT-DEFINED
ABC-P4-CLM-027	Prediction specificity and negative-control performance must be scored.	Prediction rule	ARCHITECTURE-DEFINED
ABC-P4-CLM-028	A hybrid model must establish the necessity of both parent components and any interaction term.	Hybrid rule	REQUIREMENT-DEFINED
ABC-P4-CLM-029	Regional success must be distinguished from global transferability.	Scope rule	REQUIREMENT-DEFINED
ABC-P4-CLM-030	The same shared parameter architecture must satisfy the mandatory comparison domains.	Integration rule	REQUIREMENT-DEFINED
ABC-P4-CLM-031	The astro-ballistic model qualifies as a replacement candidate only with a nonempty viable set, causal necessity, predictive superiority, and complexity-adjusted preference.	Replacement rule	ARCHITECTURE-DEFINED
ABC-P4-CLM-032	A preferred hybrid must outperform both parent models after combined complexity is counted.	Hybrid rule	REQUIREMENT-DEFINED
ABC-P4-CLM-033	A regional event hypothesis may survive even when the global replacement thesis fails.	Compartmentalization	REQUIREMENT-DEFINED
ABC-P4-CLM-034	A favorable geometric or statistical result cannot compensate for mechanical or conservation failure.	No-compensation rule	REQUIREMENT-DEFINED
ABC-P4-CLM-035	Independent replication is required for a confirmatory replacement preference.	Replication rule	REQUIREMENT-DEFINED

ID	Claim	Role	Current status
ABC-P4-CLM-036	No complete Paper-IV numerical adjudication is presently registered.	Status	UNRESOLVED

85 Shared Observation and Data Registry

85.1 Shared Observation Vector

The shared observation domain is

$$\mathbf{D}_{\mathrm{IV}}^{\mathrm{shared}} = \big(\mathbf{D}_{\mathrm{bdry}}, \mathbf{D}_{\mathrm{vel}}, \mathbf{D}_{\mathrm{cont}}, \mathbf{D}_{\mathrm{chron}}, \mathbf{D}_{\mathrm{surf}}, \mathbf{D}_{\mathrm{grav}}, \mathbf{D}_{\mathrm{seis}}, \mathbf{D}_{\mathrm{mag}}, \mathbf{D}_{\mathrm{therm}}, \mathbf{D}_{\mathrm{pred}}\big). \tag{438}$$

85.2 Shared-Data Registry

Table 46: Paper-IV shared-observation registry.

ID	Observation class	Required content	Status
ABC-P4-DAT-001	Boundaries	Location, geometry, topology, type, width, motion, age, persistence	Not assembled
ABC-P4-DAT-002	Plate and block motion	Velocities, Euler vectors, relative motion, finite rotations, accelerations	Not assembled
ABC-P4-DAT-003	Continents and terranes	Positions, rotations, shapes, adjacency, provenance, material lineage	Not assembled
ABC-P4-DAT-004	Chronology	Event, boundary, deformation, uplift, subsidence, descent, volcanism ages	Not assembled
ABC-P4-DAT-005	Surface structures	Mountains, trenches, ridges, basins, plateaus, volcanic provinces, sutures	Not assembled
ABC-P4-DAT-006	Gravity and geoid	Potential, anomaly, gradients, resolution, covariance	Not assembled
ABC-P4-DAT-007	Seismology	Velocity, travel time, attenuation, anisotropy, discontinuities, resolution	Not assembled
ABC-P4-DAT-008	Magnetics	Anomaly fields, magnetization, remanence, resetting, uncertainty	Not assembled
ABC-P4-DAT-009	Thermal state	Heat flow, subsurface temperature, thermal history, uncertainty	Not assembled
ABC-P4-DAT-010	Advance predictions	Frozen claims, controls, validation observations, outcomes	Not frozen

85.3 Data Partition

Every dataset must be assigned to:

- model construction;
- calibration;

- reconstruction;
- validation;
- independent holdout;
- prospective validation;
- or negative control.

85.4 Shared Uncertainty

For shared observation vector $\mathbf{D}$, the comparison requires covariance

$$\boldsymbol{\Sigma}_{\mathrm{IV}} = \mathrm{Cov}\left(\mathbf{D}_{\mathrm{IV}}^{\mathrm{shared}}\right). \tag{439}$$

85.5 Resolution Matching

Model outputs must be compared after application of the relevant observation operator:

$$\widehat{\mathbf{D}}_q = \mathcal{O}\left[\mathbf{Q}_q\right]. \tag{440}$$

A high-resolution model field must not be compared directly with a lower-resolution observation without applying the observation and resolution operator.

85.6 No Unequal Evidence Burden

One model family may not receive access to:

- more calibration data;
- broader uncertainty;
- more flexible regional parameters;
- or more favorable exclusions

without explicit accounting.

86 Competing Model-Family Registry

86.1 Complete Model Family

The complete family is

$$\mathfrak{M}_{\mathrm{IV}} = \{\mathfrak{M}_{\mathrm{PT}}, \mathfrak{M}_{\mathrm{ABC}}, \mathfrak{M}_{\mathrm{HYB}}, \mathfrak{M}_{\mathrm{REG}}, \mathfrak{M}_0, \mathfrak{M}_{\mathrm{RAND}}\}. \tag{441}$$

86.2 Model Registry

Table 47: Paper-IV competing-model registry.

ID	Model family	Required specification	Status
ABC-P4-MOD-001	Plate-Tectonic family	Initial state, boundaries, rheology, mantle coupling, force and torque, material evolution, predicted observations	Unimplemented
ABC-P4-MOD-002	Astro-ballistic family	Surviving Papers I–III state, event sequence, inheritance, continuing forces, predicted observations	Unimplemented
ABC-P4-MOD-003	Hybrid family	Explicit PT and ABC components, interactions, shared parameters, ablation design	Unimplemented
ABC-P4-MOD-004	Regional models	Bounded geographic and causal scope, transfer tests, local parameters	Unimplemented
ABC-P4-MOD-005	No-structure baseline	Minimal or null initial architecture and forcing	Unimplemented
ABC-P4-MOD-006	Randomized-event family	Opportunity-matched randomized locations, ages, orientations, and assignments	Unimplemented
ABC-P4-MOD-007	Boundary-conditioned baseline	Observed or reconstructed boundary architecture supplied without independent origin claim	Unimplemented
ABC-P4-MOD-008	Kinematic baseline	Observed motion represented without primary causal derivation	Unimplemented

86.3 Plate-Tectonic Family Is Not One Model

The Plate-Tectonic comparison must include more than one defensible implementation where materially different:

- initial conditions;
- rheologies;
- mantle-flow architectures;
- boundary conditions;
- force partitions;
- and reconstruction methods

produce different predictions.

86.4 Astro-Ballistic Eligibility

The astro-ballistic family may enter Paper IV only through a registered Paper-III state:

$$\boldsymbol{\Theta}^*_{\mathrm{III}} \in \mathcal{V}_{\mathrm{III}}. \tag{442}$$

86.5 Hybrid Definition

A hybrid model must define:

$$\mathbf{Q}_H = \mathcal{F}_H \left[\mathbf{Q}_{\text{PT}}, \mathbf{Q}_{\text{ABC}}, \mathbf{Q}_{\text{int}}\right]. \tag{443}$$

It may not be labeled hybrid merely because it uses vocabulary from both frameworks.

87 Matched Comparison and Eligibility Rules

87.1 Matched Input Domain

For each model q,

$$\mathbf{X}_q^{\text{allowed}} = \mathbf{X}_{\text{shared}} \cup \mathbf{X}_q^{\text{model}-\text{specific}}. \tag{444}$$

Model-specific inputs must be declared and counted.

87.2 Matched Output Domain

Every eligible model must predict the mandatory output vector

$$\mathbf{Y}_{\text{IV}} = \left(\mathbf{Y}_{\text{bdry}}, \mathbf{Y}_{\text{vel}}, \mathbf{Y}_{\text{cont}}, \mathbf{Y}_{\text{surf}}, \mathbf{Y}_{\text{deep}}, \mathbf{Y}_{\text{chron}}, \mathbf{Y}_{\text{pred}}\right). \tag{445}$$

87.3 Matched Spatial Domain

The comparison must use common:

- geographic regions;
- depth ranges;
- spatial masks;
- excluded areas;
- and resolution.

87.4 Matched Time Domain

The models must be evaluated over the same:

- geological intervals;
- event windows;
- boundary histories;
- motion intervals;
- and prediction cutoffs.

87.5 Eligibility Record

For model q,

$$\mathbf{E}_q^{\text{IV}} = (I_{\text{physical}}, I_{\text{complete}}, I_{\text{versioned}}, I_{\text{reproducible}}, I_{\text{matched}}, I_{\text{testable}}) . \tag{446}$$

87.6 Eligibility Condition

$$I_{\text{eligible},q} = \prod_a I_{a,q}. \tag{447}$$

87.7 No Unequal Completion Standard

A detailed astro-ballistic model must not be compared with an undefined verbal Plate-Tectonic category.

Likewise, a fully implemented Plate-Tectonic model must not be compared with an undefined verbal astro-ballistic category.

87.8 No Post-Ranking Model Redefinition

Once the model families and score are frozen, a losing model may be revised only as a new version requiring a new validation cycle.

88 Initial-Condition and Boundary-Information Accounting

88.1 Initial State

For model q,

$$\mathbf{Q}_{q,0} = (\mathbf{Q}_{\text{thermal}}, \mathbf{Q}_{\text{density}}, \mathbf{Q}_{\text{composition}}, \mathbf{Q}_{\text{rheology}}, \mathbf{Q}_{\text{boundary}}, \mathbf{Q}_{\text{velocity}})_{q,0} . \tag{448}$$

88.2 Initial-State Description Length

$$L_{\text{IC},q} = -\log p \left(\mathbf{Q}_{q,0} \mid \mathcal{M}_q\right) . \tag{449}$$

88.3 Boundary Information

For initial boundary network $\mathcal{B}_{q,0}$,

$$L_{B,0,q} = -\log p \left(\mathcal{B}_{q,0} \mid \mathcal{M}_q\right) . \tag{450}$$

88.4 Velocity Information

For initial motion state $\mathbf{V}_{q,0}$,

$$L_{V,0,q} = -\log p \left(\mathbf{V}_{q,0} \mid \mathcal{M}_q\right) . \tag{451}$$

88.5 Information-Credit Rule

A model receives causal credit for a structure only to the degree that the structure is generated rather than inserted.

88.6 Boundary-Origin Ablation

Compare:

$$\mathcal{M}_q^{\text{generated boundary}} \tag{452}$$

with

$$\mathcal{M}_q^{\text{supplied boundary}}. \tag{453}$$

The boundary-origin contribution is

$$N_{B,q} = \mathcal{J}_q^{\text{supplied boundary}} - \mathcal{J}_q^{\text{generated boundary}} \tag{454}$$

after accounting for the information inserted in the supplied network.

88.7 Initial-State Sensitivity

For ensemble $\mathbf{Q}_{q,0}^{(r)}$,

$$\mathcal{S}_{\text{IC},q} = \text{Var}_r \left[\mathcal{J}_{IV,q}^{(r)} \right]. \tag{455}$$

88.8 Initial-Condition Falsifier

A model does not independently explain the target architecture if its apparent success requires an initial state already containing most of the architecture under comparison.

89 Boundary and Plate-Partition Comparison Registry

89.1 Observed and Predicted Networks

Let:

$$\mathcal{G}_B^{\text{obs}} = \left(\mathcal{V}_B^{\text{obs}}, \mathcal{E}_B^{\text{obs}} \right) \tag{456}$$

and

$$\widehat{\mathcal{G}}_{B,q} = \left(\widehat{\mathcal{V}}_{B,q}, \widehat{\mathcal{E}}_{B,q} \right). \tag{457}$$

89.2 Boundary Geometry Misfit

$$\mathcal{J}_{B,\mathrm{geom},q} = w_H \widetilde{d}_{H,q} + w_A \widetilde{d}_{\mathrm{ASD},q} + w_\theta \chi^2_{\theta,q} + w_\kappa \chi^2_{\kappa,q}. \tag{458}$$

89.3 Boundary Topology Misfit

$$\mathcal{J}_{B,\mathrm{top},q} = w_{\mathrm{adj}} D_{\mathrm{adj},q} + w_{\mathrm{spec}} D_{\mathrm{spec},q} + w_{\mathrm{cycle}} D_{\mathrm{cycle},q} + w_{\mathrm{junction}} D_{\mathrm{junction},q}. \tag{459}$$

89.4 Boundary-Type Misfit

$$\mathcal{J}_{B,\mathrm{type},q} = -\sum_e \log p_q \left(\tau_e^{\mathrm{obs}} \mid \mathbf{Q}_{e,q}^{\mathrm{pred}}\right). \tag{460}$$

89.5 Boundary-Chronology Misfit

$$\chi^2_{B,T,q} = \left(\mathbf{T}_B^{\mathrm{obs}} - \mathbf{T}_{B,q}^{\mathrm{pred}}\right)^{\mathsf{T}} \mathbf{\Sigma}_{B,T}^{-1} \left(\mathbf{T}_B^{\mathrm{obs}} - \mathbf{T}_{B,q}^{\mathrm{pred}}\right). \tag{461}$$

89.6 Plate-Partition Overlap

For observed plate i and predicted domain j,

$$\mathrm{IoU}_{ij} = \frac{\mathrm{Area}\left(\mathcal{P}_i^{\mathrm{obs}} \cap \mathcal{P}_{j,q}^{\mathrm{pred}}\right)}{\mathrm{Area}\left(\mathcal{P}_i^{\mathrm{obs}} \cup \mathcal{P}_{j,q}^{\mathrm{pred}}\right)}. \tag{462}$$

89.7 Boundary Comparison Score

$$\begin{aligned} \mathcal{J}_{\mathrm{boundary},q} =& \mathcal{J}_{B,\mathrm{geom},q} + \mathcal{J}_{B,\mathrm{top},q} + \mathcal{J}_{B,\mathrm{type},q} \\ &+ w_T \chi^2_{B,T,q} + w_P \mathcal{J}_{\mathrm{partition},q} + w_C \mathcal{P}_{B,\mathrm{complex},q}. \end{aligned} \tag{463}$$

89.8 Boundary-Origin Necessity

Remove the model-specific boundary-origin mechanism:

$$N_{\mathrm{boundary},q} = \mathcal{J}_{\mathrm{boundary},q,-\mathrm{origin}} - \mathcal{J}_{\mathrm{boundary},q}. \tag{464}$$

89.9 Boundary Falsifier

A model fails boundary comparison if it cannot generate or consistently inherit the global network, plate partition, boundary types, and chronology without manual boundary-by-boundary construction or high-information insertion.

90 Motion, Euler-Vector, Force, Torque, and Power Comparison

90.1 Observed Motion Vector

$$\mathbf{D}_{\mathrm{vel}}^{\mathrm{obs}} = \left(\mathbf{v}, \boldsymbol{\omega}, \mathbf{v}^{\mathrm{rel}}, \mathbf{R}, \mathbf{a}, \mathbf{C}_{\mathrm{circuit}}\right)^{\mathrm{obs}}. \tag{465}$$

90.2 Predicted Motion Vector

For model q,

$$\widehat{\mathbf{D}}_{\mathrm{vel},q} = \mathcal{F}_{V,q}\left[\mathbf{Q}_{q,0}, \mathbf{F}_q, \boldsymbol{\tau}_q, \mathcal{B}_q, t\right]. \tag{466}$$

90.3 Velocity Misfit

$$\chi^2_{V,q} = \left(\mathbf{D}^{\mathrm{obs}}_{\mathrm{vel}} - \widehat{\mathbf{D}}_{\mathrm{vel},q}\right)^{\mathsf{T}} \boldsymbol{\Sigma}_V^{-1} \left(\mathbf{D}^{\mathrm{obs}}_{\mathrm{vel}} - \widehat{\mathbf{D}}_{\mathrm{vel},q}\right). \tag{467}$$

90.4 Euler-Vector Residual

$$\Delta\boldsymbol{\omega}_{i,q} = \boldsymbol{\omega}_i^{\mathrm{obs}} - \boldsymbol{\omega}_{i,q}^{\mathrm{pred}}. \tag{468}$$

90.5 Force Closure

$$\mathbf{R}_{F,i,q} = \frac{d\left(M_i \mathbf{v}_{c,i}\right)}{dt} - \sum_a \mathbf{F}_{a,i,q}. \tag{469}$$

90.6 Torque Closure

$$\mathbf{R}_{\tau,i,q} = \frac{d\mathbf{L}_i}{dt} - \sum_a \boldsymbol{\tau}_{a,i,q}. \tag{470}$$

90.7 Power Residual

$$R_{\mathcal{P},i,q} = \mathcal{P}_{\mathrm{input},i,q} - \mathcal{P}_{\mathrm{stored},i,q} - \mathcal{P}_{\mathrm{diss},i,q} - \mathcal{P}_{\mathrm{out},i,q}. \tag{471}$$

90.8 Dissipation Constraint

$$\mathcal{P}_{\mathrm{diss},i,q} \geq 0. \tag{472}$$

90.9 Motion Comparison Score

$$\begin{aligned}\mathcal{J}_{\mathrm{motion},q} =& w_v \chi^2_{V,q} + w_\omega \chi^2_{\omega,q} + w_{\mathrm{rel}} \chi^2_{\mathrm{rel},q} \\ &+ w_{\mathrm{circ}} \chi^2_{\mathrm{circ},q} + w_F \chi^2_{F,q} + w_\tau \chi^2_{\tau,q} \\ &+ w_{\mathcal{P}} \chi^2_{\mathcal{P},q} + \mathcal{P}_{\mathrm{motion-complex},q}.\end{aligned} \tag{473}$$

90.10 Motion Necessity

For defining mechanism m,

$$N^V_{m,q} = \mathcal{J}_{\mathrm{motion},q,-m} - \mathcal{J}_{\mathrm{motion},q}. \tag{474}$$

90.11 Motion Falsifier

A model fails motion comparison if it reproduces velocity only by inserting observed Euler poles, violates force or torque closure, requires unavailable power, predicts negative dissipation, or fails the global direction and speed hierarchy.

91 Surface-Structure Comparison Registry

91.1 Shared Surface-Structure Vector

$$\mathbf{D}_{\text{surf}}^{\text{obs}} = (\mathbf{D}_O, \mathbf{D}_{TR}, \mathbf{D}_R, \mathbf{D}_{BA}, \mathbf{D}_{PL}, \mathbf{D}_{VO}, \mathbf{D}_{TE}) \,. \tag{475}$$

91.2 Structure Record

For structure g,

$$\mathbf{S}_g = \left(\mathcal{D}_g, \Gamma_g, \mathbf{A}_g, \mathbf{T}_g, \mathbf{Q}_g^{\text{deep}}, \mathbf{Q}_g^{\text{material}}\right). \tag{476}$$

91.3 Spatial Comparison

$$\mathcal{J}_{g,\text{spatial},q} = w_H d_{H,g,q} + w_A d_{\text{ASD},g,q} + w_I \left(1 - \text{IoU}_{g,q}\right). \tag{477}$$

91.4 Orientation Comparison

$$\chi^2_{\theta,g,q} = \sum_i \frac{\left[\theta_{g,i}^{\text{obs}} - \theta_{g,i,q}^{\text{pred}}\right]^2}{\sigma^2_{\theta,g,i}}. \tag{478}$$

91.5 Magnitude and Material Comparison

$$\chi^2_{Q,g,q} = \left(\mathbf{Q}_g^{\text{obs}} - \mathbf{Q}_{g,q}^{\text{pred}}\right)^{\mathsf{T}} \mathbf{\Sigma}_g^{-1} \left(\mathbf{Q}_g^{\text{obs}} - \mathbf{Q}_{g,q}^{\text{pred}}\right). \tag{479}$$

91.6 Chronology Comparison

$$\chi^2_{T,g,q} = \left(\mathbf{T}_g^{\text{obs}} - \mathbf{T}_{g,q}^{\text{pred}}\right)^{\mathsf{T}} \mathbf{\Sigma}_{T,g}^{-1} \left(\mathbf{T}_g^{\text{obs}} - \mathbf{T}_{g,q}^{\text{pred}}\right). \tag{480}$$

91.7 Class-Specific Requirements

Table 48: Mandatory surface-structure comparison variables.

Class	**Mandatory comparison variables**
Mountains	Location, axis, shortening, elevation, crustal thickness, roots, chronology, erosion, deep support
Trenches	Location, curvature, depth, polarity, migration, bending, descent, mass flux, chronology
Ridges and rifts	Axis, opening direction, rate, material-age gradient, segmentation, transform offsets, melt supply
Basins	Geometry, subsidence, accommodation, thermal history, sediment fill, loading, inversion
Plateaus	Location, elevation, root, buoyancy, thermal state, dynamic support, persistence
Volcanic provinces	Location, timing, melt volume, source, transport, composition, duration
Terranes and sutures	Provenance, paleolatitude, trajectory, rotation, docking, contact order, deep structure

91.8 Surface Comparison Score

$$\mathcal{J}_{\mathrm{surface},q} = \sum_g w_g \left(\mathcal{J}_{g,\mathrm{spatial},q} + \chi^2_{\theta,g,q} + \chi^2_{Q,g,q} + \chi^2_{T,g,q} \right) + \mathcal{P}_{S,\mathrm{complex},q}. \tag{481}$$

91.9 Surface-Structure Falsifier

A model fails the global surface comparison if the same admissible state cannot predict the locations, orientations, dimensions, materials, deep structures, and chronologies of the mandatory structural classes.

92 Deep-Geophysical Comparison Registry

92.1 Deep-State Vector

$$\mathbf{Q}_{\mathrm{deep},q} = (\rho_q, T_q, \mathbf{C}_q, \phi_q, \chi_{m,q}, D_q, \mathbf{M}_q, \mathbf{u}_q)\,. \tag{482}$$

92.2 Gravity Prediction

$$\Delta \mathbf{g}_q(\mathbf{x}) = G \int_{\mathcal{V}_\oplus} \Delta\rho_q(\mathbf{x}') \frac{\mathbf{x}' - \mathbf{x}}{\|\mathbf{x}' - \mathbf{x}\|^3}\, dV'. \tag{483}$$

92.3 Seismic Prediction

$$\mathbf{D}^{\mathrm{pred}}_{\mathrm{seis},q} = \mathcal{O}_{\mathrm{seis}}\left[T_q, \rho_q, \mathbf{C}_q, \phi_q, \chi_{m,q}, D_q, \mathbf{u}_q\right]. \tag{484}$$

92.4 Magnetic Prediction

$$\mathbf{D}^{\mathrm{pred}}_{\mathrm{mag},q} = \mathcal{O}_{\mathrm{mag}}\left[\mathbf{M}_q, T_q, \mathbf{C}_q, t\right]. \tag{485}$$

92.5 Thermal Prediction

$$\rho c_P \frac{DT}{Dt} = \nabla \cdot (k \nabla T) + Q \tag{486}$$

with surface heat flow

$$q_H = -k \nabla T \cdot \hat{\mathbf{n}}. \tag{487}$$

92.6 Deep-Geophysical Misfit

$$\begin{aligned} \mathcal{J}_{\mathrm{deep},q} =& w_g \chi^2_{\mathrm{grav},q} + w_s \chi^2_{\mathrm{seis},q} + w_m \chi^2_{\mathrm{mag},q} \\ &+ w_h \chi^2_{\mathrm{heat},q} + w_c \mathcal{P}_{\mathrm{cross-consistency},q}. \end{aligned} \tag{488}$$

92.7 Cross-Geophysical Consistency

The same material state must jointly predict:

- density-sensitive gravity;
- elasticity- and phase-sensitive seismic structure;

- temperature- and composition-sensitive magnetics;
- and thermal state.

92.8 No Independent Field Tuning

A model may not use one density field for gravity, another incompatible field for seismology, and another thermal field for heat flow unless their physical relationship is explicitly modeled.

92.9 Deep-Geophysical Falsifier

A model fails deep-geophysical comparison if its required density, temperature, phase, damage, composition, or melt state predicts mutually incompatible gravity, seismic, magnetic, or heat-flow observations.

93 Chronology and Paleogeographic Comparison Registry

93.1 Time Convention

Let a_{start} be the oldest modeled age and let internal forward time be

$$\tau \in [0, a_{\text{start}}] , \tag{489}$$

with geological age before present

$$a = a_{\text{start}} - \tau. \tag{490}$$

For cause c and effect e,

$$\tau_c \le \tau_e \tag{491}$$

or equivalently

$$a_c \ge a_e. \tag{492}$$

93.2 Chronology Vector

$$\mathbf{D}_T^{\text{obs}} = (\mathbf{T}_E, \mathbf{T}_B, \mathbf{T}_V, \mathbf{T}_C, \mathbf{T}_S, \mathbf{T}_G) . \tag{493}$$

93.3 Chronological Violation

For required edge $c \to e$,

$$I^T_{ce,q} = \begin{cases} 1, & \tau^{\text{pred}}_{c,q} > \tau^{\text{pred}}_{e,q}, \\ 0, & \text{otherwise.} \end{cases} \tag{494}$$

93.4 Chronology Score

$$\mathcal{J}_{T,q} = \chi^2_{T,q} + \lambda_{\text{viol}} \sum_{c \to e} I^T_{ce,q} + \mathcal{P}_{\text{lag},q}. \tag{495}$$

93.5 Material Reconstruction

For present material point $\mathbf{x}_0$,

$$\mathbf{x}_q(\tau) = \mathcal{R}_q^{-1}\left[\mathbf{x}_0, \tau, a_{\text{start}}\right]. \tag{496}$$

93.6 Paleogeographic State

$$\mathbf{D}_C^{\text{obs}}(\tau) = \left(\mathcal{P}, \mathcal{C}, \Gamma_C, \mathbf{x}_C, \mathbf{R}_C, \mathbf{A}_C, \mathbf{M}_C, \mathbf{X}_C, \mathcal{N}_C\right)_\tau. \tag{497}$$

93.7 Paleogeographic Comparison Score

$$\begin{aligned}\mathcal{J}_{C,q} = & w_x \widetilde{d}_{C,q} + w_S\left(1 - \text{IoU}_{C,q}\right) + w_R \chi^2_{R,q} \\ & + w_A D_{A,q} + w_M \chi^2_{\text{material},q} + w_P \chi^2_{\text{paleo},q} \\ & + w_L \mathcal{P}_{\text{lineage},q}.\end{aligned} \tag{498}$$

93.8 Event-Time Path Test

For event path $\mathcal{P}_{k,q}(\tau_k)$ and target material domain $\mathcal{D}_{k,q}(\tau_k)$,

$$d^{\text{event}}_{k,q} = \min_{\mathbf{x} \in \mathcal{D}_{k,q}(\tau_k)} d\left[\mathcal{P}_{k,q}(\tau_k), \mathbf{x}\right]. \tag{499}$$

93.9 Chronology and Paleogeography Falsifier

A model fails historical comparison if its proposed causes occur after their effects, its response lags are fitted independently after inspection, or its claimed event relationships disappear in event-time material coordinates.

94 Causal Coverage and Necessity Registry

94.1 Observation-Class Set

$$\mathfrak{D}_{\text{IV}} = \{\text{boundary}, \text{motion}, \text{continent}, \text{surface}, \text{deep}, \text{chronology}, \text{prediction}\}. \tag{500}$$

94.2 Coverage Indicator

For class g and model q,

$$I^{\text{cov}}_{g,q} = \begin{cases} 1, & \mathcal{J}_{g,q} \le \mathcal{J}_{g,\text{crit}}, \\ 0, & \text{otherwise}. \end{cases} \tag{501}$$

94.3 Weighted Coverage

$$f_{\mathrm{cov},q} = \frac{\sum_g w_g I^{\mathrm{cov}}_{g,q}}{\sum_g w_g}. \tag{502}$$

94.4 Causal-Depth Scale

For class g,

$$L^C_{g,q} \in \{0, 1, 2, 3, 4, 5, 6\}, \tag{503}$$

where:

0 No account.

1 Compatibility only.

2 Representation or reconstruction.

3 Kinematic prediction.

4 Dynamic explanation.

5 Historical causal organization.

6 Successful advance prediction.

94.5 Mean Causal Depth

$$\overline{L}^C_q = \frac{\sum_g w_g L^C_{g,q}}{\sum_g w_g}. \tag{504}$$

94.6 Causal-Chain Completion

For required chain c,

$$f_{\mathrm{chain},c,q} = \frac{N^{\mathrm{supported}}_{c,q}}{N^{\mathrm{required}}_c}. \tag{505}$$

94.7 Mechanism Necessity

For mechanism m,

$$N_{m,q} = \mathcal{J}_{IV,q,-m} - \mathcal{J}_{IV,q}. \tag{506}$$

94.8 Event Necessity

For event k,

$$N_{E,k} = \mathcal{J}_{IV,-k} - \mathcal{J}_{IV,\mathrm{full}}. \tag{507}$$

94.9 Interaction Necessity

For mechanisms a and b,

$$N_{a\times b} = \mathcal{J}_{-a} + \mathcal{J}_{-b} - \mathcal{J}_{-a,-b} - \mathcal{J}_{\text{full}}. \tag{508}$$

94.10 Coverage Score

$$\begin{aligned}\mathcal{J}_{\text{coverage},q} =& w_f\left(1 - f_{\text{cov},q}\right) + w_L\left(1 - \frac{\overline{L}_q^C}{6}\right)\\ &+ w_C\left(1 - \overline{f}_{\text{chain},q}\right) + \mathcal{P}_{\text{gap},q} + \mathcal{P}_{\text{regional},q}.\end{aligned} \tag{509}$$

94.11 Causal-Coverage Falsifier

A model does not establish global replacement if it succeeds only by omitting mandatory observation classes, leaving required causal links unmodeled, or assigning separate regional mechanisms after examining each result.

95 Model Evidence, Equivalence, and Ranking Registry

95.1 Likelihood

For model q,

$$\mathcal{L}_q = p\left(\mathbf{D}_{\text{IV}}^{\text{shared}} \mid \mathbf{\Theta}_q, \mathcal{M}_q\right). \tag{510}$$

95.2 Common Comparison Contract

The atlas must register the shared data domain, train–validation–test partition, observation model, uncertainty convention, model priors, missing-data rule, score direction, and freeze date before any model comparison. Bayes factors require commensurable likelihoods and proper priors; information criteria require the same fitted data and likelihood domain. A statistic is ineligible when its comparison contract is missing.

95.3 Marginal Evidence

$$\mathcal{Z}_q = \int \mathcal{L}_q p\left(\mathbf{\Theta}_q \mid \mathcal{M}_q\right)\, d\mathbf{\Theta}_q. \tag{511}$$

95.4 Bayes Factor

Bayesian evidence is reported alongside information criteria, description length, and predictive validation rather than as an isolated ranking device [32, 33, 34, 36].

$$K_{ij} = \frac{\mathcal{Z}_i}{\mathcal{Z}_j}. \tag{512}$$

95.5 Posterior Model Probability

$$p\left(\mathcal{M}_q \mid \mathbf{D}\right) = \frac{\mathcal{Z}_q p(\mathcal{M}_q)}{\sum_j \mathcal{Z}_j p(\mathcal{M}_j)}. \tag{513}$$

95.6 Cross-Validated Predictive Score

$$S_{\mathrm{CV},q} = \sum_{r=1}^{N_F} \log p\left(\mathbf{D}_r \mid \mathbf{D}_{-r}, \mathcal{M}_q\right). \tag{514}$$

95.7 Prospective Predictive Score

$$S_{\mathrm{adv},q} = \log p\left(\mathbf{D}_{\mathrm{new}} \mid \mathbf{D}_{\mathrm{train}}, \mathcal{M}_q\right). \tag{515}$$

95.8 Integrated Ranking Vector

$$\mathbf{R}_q = \left(\log \mathcal{Z}_q, S_{\mathrm{CV},q}, S_{\mathrm{adv},q}, -\mathrm{IC}_q, -\mathcal{J}_{IV,q}\right). \tag{516}$$

95.9 No Unregistered Scalar Rank Averaging

The ranking vector contains noncommensurate quantities. The atlas must not average its components or convert them to ordinal wins unless the transformation, normalization, direction, weights, and sensitivity analysis were frozen before final evaluation.

95.10 Equivalence

For paired differences $\Delta\mathcal{J}_{ij} = \mathcal{J}_{IV,i} - \mathcal{J}_{IV,j}$ and $\Delta S_{ij} = S_{\mathrm{adv},i} - S_{\mathrm{adv},j}$, operational equivalence requires the frozen uncertainty intervals to lie completely inside

$$-\delta_J \le \Delta\mathcal{J}_{ij} \le \delta_J \tag{517}$$

and

$$-\delta_S \le \Delta S_{ij} \le \delta_S. \tag{518}$$

The interval type, level, paired resampling unit, and margins are part of the threshold-freeze record. Point estimates alone do not establish equivalence.

95.11 Ranking Stability

For analysis ensemble r,

$$P_{i<j} = \Pr_r\left(\mathcal{J}_{IV,i}^{(r)} < \mathcal{J}_{IV,j}^{(r)}\right). \tag{519}$$

95.12 Prior Sensitivity

$$\mathcal{Z}_q^{(s)} = \int \mathcal{L}_q \Pi_q^{(s)}\, d\mathbf{\Theta}_q. \tag{520}$$

95.13 Model-Ranking Falsifier

A replacement preference is not established if the ranking reverses across defensible priors, data partitions, reference frames, reconstruction ensembles, or scoring rules, or if the models remain within the frozen equivalence interval.

96 Effective Complexity and Description-Length Registry

96.1 Raw Parameter Count

$$k_q = \dim\left(\boldsymbol{\Theta}_q\right). \tag{521}$$

96.2 Effective-Complexity Ledger

$$\begin{aligned}\mathbf{k}_{\text{flex},q} = \big(&k_{\text{numeric}}, k_{\text{initial}}, k_{\text{boundary}}, k_{\text{event}}, k_{\text{history}}, k_{\text{regional}}, k_{\text{assignment}}, \\ &k_{\text{threshold}}, k_{\text{lag}}, k_{\text{preservation}}, k_{\text{branch}}, k_{\text{frame}}, k_{\text{selection}}, k_{\text{revision}}\big).\end{aligned} \tag{522}$$

The vector is an audit ledger, not an automatically additive effective parameter count. Any scalar complexity estimate must identify its estimator or its nonoverlapping description-length code.

96.3 Event-Catalog Complexity

$$k_{\mathcal{E}} = k_{N_E} + \sum_{j=1}^{N_E} \left(k_{t,j} + k_{x,j} + k_{d,j} + k_{E,j} + k_{M,j} + k_{\text{assign},j}\right). \tag{523}$$

96.4 Search-Space Description Length

With a frozen dimensionless search multiplicity

$$\widetilde{\mathcal{V}}_{\text{search},q} = \prod_c \frac{\mathcal{V}_{c,q}}{\mathcal{V}_{c,q}^{\text{ref}}}, \tag{524}$$

define

$$L_{\text{search},q} = \log \widetilde{\mathcal{V}}_{\text{search},q}. \tag{525}$$

The reference measure, resolution, coordinate system, and log base must be registered.

96.5 Revision Description Length

$$L_{\text{rev},q} = \sum_{v=2}^{N_v} L\left(\mathcal{M}_q^{(v)} \mid \mathcal{M}_q^{(v-1)}\right). \tag{526}$$

96.6 Data Description Length

$$L\left(\mathbf{D} \mid \mathcal{M}_q\right) = -\log p\left(\mathbf{D} \mid \widehat{\boldsymbol{\Theta}}_q, \mathcal{M}_q\right). \tag{527}$$

96.7 Total Description Length

$$L_{\text{tot},q} = L(\mathcal{M}_q) + L_{\text{IC},q} + L_{B,0,q} + L_{V,0,q} + L_{\mathcal{E},q} + L_{\text{search},q} + L_{\text{rev},q} + L\left(\mathbf{D} \mid \mathcal{M}_q\right). \tag{528}$$

96.8 Causal Compression

$$C_q = \frac{I_{\mathbf{D}}}{L_{\text{tot},q}}. \tag{529}$$

96.9 Complexity Registry

Table 49: Paper-IV hidden-flexibility registry.

Flexibility class	**Examples**	**Status**
Initial state	Thermal, density, compositional, rheological, boundary, velocity architecture	Must count
Event selection	Location, age, direction, energy, path, branch	Must count
Assignment	Event-to-boundary, event-to-structure, terrane-to-source	Must count
Regional tuning	Local friction, viscosity, coupling, thresholds	Must count
Mechanism switching	Excavation, bending, underthrusting, descent, hybrid	Must count
Response lags	Event-to-boundary, event-to-uplift, event-to-volcanism delays	Must count
Preservation	Erosion, burial, metamorphism, destruction, detection	Must count
Reference frame	Alternative paleogeographic and mantle frames	Must count
Revision	Parameter or model changes after viewing outcomes	Must count
Exclusion rules	Removed regions, structures, observations, or intervals	Must count

96.10 Encoding Compatibility

Causal compression and total description length are compared only when all model and data encodings use the same log base, observation domain, and coding convention. The atlas records overlapping flexibility categories so they are not charged twice.

96.11 Complexity Falsifier

A claimed model advantage fails if it disappears after all effective flexibility, initial information, selection, and revision costs are included.

97 Null, Selection, and Multiple-Testing Registry

97.1 Null Family

$$\mathfrak{N}_{\text{IV}} = \{\mathcal{N}_{\text{uniform}}, \mathcal{N}_{\text{opportunity}}, \mathcal{N}_{\text{boundary}}, \mathcal{N}_{\text{plate}}, \mathcal{N}_{\text{chron}}, \mathcal{N}_{\text{direction}}, \mathcal{N}_{\text{assignment}}, \mathcal{N}_{\text{state}}, \mathcal{N}_{\text{topology}}, \mathcal{N}_{\text{frame}}\}. \tag{530}$$

97.2 Null Registry

Table 50: Paper-IV null-model registry.

Null	**Preserved and randomized properties**	**Status**
Uniform spatial	Randomizes event positions over the eligible sphere	Not run
Geological opportunity	Preserves comparable exposure, structural density, preservation, and data availability	Not run
Boundary conditioned	Samples comparable structurally complex boundary regions	Not run
Plate preserving	Samples within comparable reconstructed plate or block domains	Not run
Chronology permutation	Retains spatial states while permuting ages	Not run
Direction randomization	Retains locations and magnitudes while randomizing orientation	Not run
Assignment shuffle	Retains events and structures while randomizing their assignments	Not run
Inherited-state shuffle	Preserves state distributions while randomizing spatial arrangement	Not run
Topology preserving	Retains graph size and degree distribution while randomizing embedding	Not run
Reference-frame ensemble	Samples defensible reconstruction and mantle reference frames	Not run

97.3 Empirical Null Probability

For score where lower is better,

$$p_{q,\mathrm{null}} = \frac{1 + \sum_{r=1}^{N_R} \mathbf{1}\left[\mathcal{J}_{IV,q}^{(r)} \leq \mathcal{J}_{IV,q}^{\mathrm{obs}}\right]}{N_R + 1}. \tag{531}$$

97.4 Full-Pipeline Null Requirement

Every null realization must rerun the complete search and selection pipeline available to the observed analysis. The atlas records whether event selection, assignment, thresholds, reference frames, exclusions, and model-version choices were reoptimized under each null. Otherwise the empirical null probability is classified `SELECTION-UNDERCORRECTED`.

97.5 Complete Search Ledger

The selection ledger must include:

- all tested events;
- all tested coordinates;
- all tested ages;
- all tested paths;

- all tested mechanism branches;
- all tested structures;
- all tested thresholds;
- all tested score definitions;
- all tested reference frames;
- all exclusions;
- and all revisions.

97.6 Family-Wise Error

For m independent tests,

$$\alpha_{\mathrm{FWER}} = 1 - (1 - \alpha_{\mathrm{ind}})^{m} . \tag{532}$$

This identity is illustrative under independence. Spatially, chronologically, or hierarchically dependent tests require a preregistered dependence-aware procedure, preferably a permutation or max-statistic null constructed over the complete search process.

A conservative per-test threshold is

$$\alpha_{\mathrm{ind}} = \frac{\alpha_{\mathrm{family}}}{m}. \tag{533}$$

97.7 False-Discovery Control

The procedure and its dependence assumptions are registered explicitly [35].

For ordered probabilities $p_{(1)} \leq \cdots \leq p_{(m)}$, retain the largest k satisfying

$$p_{(k)} \leq \frac{k}{m} q_{\mathrm{FDR}} \tag{534}$$

when the assumptions of the selected procedure are met.

97.8 Selection-Adjusted Probability

$$p_{\mathrm{sel}} = \Pr\left(T_{\max} \geq T_{\mathrm{obs}} \mid \mathcal{N}, \mathcal{S}_{\mathrm{search}}\right). \tag{535}$$

97.9 Holdout Depletion

$$\mathbf{D}_{\mathrm{test}}^{(v)} = \mathbf{D}_{\mathrm{test}}^{(v-1)} \setminus \mathbf{D}_{\mathrm{viewed}}^{(v)}. \tag{536}$$

97.10 Null and Selection Falsifier

A confirmatory replacement result fails if its significance disappears under opportunity-matched nulls, complete search-space correction, multiple-testing control, or model-version accounting.

98 Advance-Prediction Registry

98.1 Prediction Record

Every Paper-IV prediction is registered as

$$\begin{aligned}\mathbf{P}_{j,q} = \big(&\text{ID}, \text{model}, \text{version}, \text{claim}, \text{location}, \text{depth},\\ &\text{orientation}, \text{magnitude}, \text{age}, \text{uncertainty}, \text{control},\\ &\text{data cutoff}, \text{freeze date}, \text{score}, \text{falsifier}\big).\end{aligned} \tag{537}$$

98.2 Prediction Classes

The Paper-IV prediction program includes:

AP1. unknown boundary continuation;

AP2. boundary type and relative motion;

AP3. plate or block velocity;

AP4. Euler-pole direction;

AP5. concealed damage corridor;

AP6. crustal-thickness structure;

AP7. mountain root;

AP8. trench continuity and deep descent;

AP9. ridge or rift segmentation;

AP10. basin subsidence;

AP11. volcanic transport path;

AP12. terrane ancestry;

AP13. gravity anomaly;

AP14. seismic velocity anomaly;

AP15. seismic anisotropy;

AP16. magnetic resetting;

AP17. heat-flow anomaly;

AP18. and negative-control domain.

98.3 Predictive Distribution

$$p\left(\mathbf{D}_{\text{new}} \mid \mathbf{D}_{\text{train}}, \mathcal{M}_q\right) = \int p\left(\mathbf{D}_{\text{new}} \mid \boldsymbol{\Theta}_q, \mathcal{M}_q\right) p\left(\boldsymbol{\Theta}_q \mid \mathbf{D}_{\text{train}}, \mathcal{M}_q\right)\, d\boldsymbol{\Theta}_q. \tag{538}$$

98.4 Continuous Prediction Score

$$S_{j,q}^{\mathrm{cont}} = -\frac{1}{2}\left(\mathbf{y}_j^{\mathrm{obs}} - \mathbf{y}_{j,q}^{\mathrm{pred}}\right)^{\mathsf{T}} \mathbf{\Sigma}_j^{-1}\left(\mathbf{y}_j^{\mathrm{obs}} - \mathbf{y}_{j,q}^{\mathrm{pred}}\right). \tag{539}$$

98.5 Binary Prediction Score

$$S_{j,q}^{\mathrm{bin}} = y_j \log p_{j,q} + (1 - y_j)\log(1 - p_{j,q}). \tag{540}$$

98.6 Spatial Specificity

For prediction domain $\mathcal{D}_{P,q}$ and eligible domain $\mathcal{D}_E$,

$$S_{\mathrm{spec},q} = 1 - \frac{\mathrm{Measure}(\mathcal{D}_{P,q})}{\mathrm{Measure}(\mathcal{D}_E)}. \tag{541}$$

98.7 Negative Prediction Domain

Each model must publish

$$\mathcal{D}_q^0 \tag{542}$$

where the predicted structure or anomaly should not occur.

98.8 Predictive Superiority

Model i predictively outperforms model j when

$$S_{\mathrm{adv},i} - S_{\mathrm{adv},j} > \Delta S_{\mathrm{adv,crit}}. \tag{543}$$

98.9 Prediction Status

No complete frozen Paper-IV advance-prediction program is presently registered.

98.10 Advance-Prediction Falsifier

A model does not establish replacement if it reconstructs known evidence but fails registered withheld or prospective predictions, predicts excessive false positives in negative-control domains, or performs no better than competing models.

98.11 Predictive-Score Completeness Rule

For continuous probabilistic predictions, the atlas must store the full proper score, including predictive covariance normalization when models state different uncertainties. A residual-only quadratic term is not a complete comparative log score. Spatial penalties and tuning constants must be frozen without test-data leakage.

99 Hybrid Causal-Decomposition Registry

99.1 Hybrid Components

$$\mathbf{Q}_H = \mathcal{F}_H \left[\mathbf{Q}_{\mathrm{PT}}, \mathbf{Q}_{\mathrm{ABC}}, \mathbf{Q}_{\mathrm{int}}\right]. \tag{544}$$

99.2 Parent Ablations

$$\mathcal{M}_{H,-\mathrm{ABC}} = \text{hybrid without astro-ballistic inheritance,} \tag{545}$$

$$\mathcal{M}_{H,-\mathrm{PT}} = \text{hybrid without the defining Plate-Tectonic component,} \tag{546}$$

$$\mathcal{M}_{H,-\mathrm{int}} = \text{hybrid without interaction terms.} \tag{547}$$

99.3 Parent Necessity

$$N_{\mathrm{ABC}|H} = \mathcal{J}_{H,-\mathrm{ABC}} - \mathcal{J}_H, \tag{548}$$

$$N_{\mathrm{PT}|H} = \mathcal{J}_{H,-\mathrm{PT}} - \mathcal{J}_H, \tag{549}$$

$$N_{\mathrm{int}|H} = \mathcal{J}_{H,-\mathrm{int}} - \mathcal{J}_H. \tag{550}$$

With lower $\mathcal{J}$ preferred, positive values mean the removed component was necessary. The hybrid passes only when all three component-specific thresholds are satisfied; the contributions are not summed to allow one component to compensate for another.

99.4 Class-Specific Attribution

For observation class g,

$$\Delta\mathcal{J}_{g,\mathrm{ABC}|H} = \mathcal{J}_{g,H,-\mathrm{ABC}} - \mathcal{J}_{g,H}, \tag{551}$$

and

$$\Delta\mathcal{J}_{g,\mathrm{PT}|H} = \mathcal{J}_{g,H,-\mathrm{PT}} - \mathcal{J}_{g,H}. \tag{552}$$

99.5 Dominance Fraction

$$f^H_{\mathrm{ABC},g} = \frac{\Delta\mathcal{J}_{g,\mathrm{ABC}|H}}{\Delta\mathcal{J}_{g,\mathrm{ABC}|H} + \Delta\mathcal{J}_{g,\mathrm{PT}|H} + \epsilon}. \tag{553}$$

99.6 Hybrid Classification

A hybrid may be:

Event initiated
Events generate architecture later maintained by geodynamics.

Event localized
Events determine where later processes concentrate.

Event redirected
Events materially redirect an existing system.

Event amplified
Events strengthen an existing process.

Event regional
Event effects are necessary only in selected regions.

Event incidental
Removing event inheritance produces negligible degradation.

Event incompatible
Event inheritance worsens the admissible solution.

99.7 Hybrid Complexity

$$k_{\mathrm{eff},H} = k_{\mathrm{shared}} + k_{\mathrm{ABC,unique}} + k_{\mathrm{PT,unique}} + k_{\mathrm{interaction}}. \tag{554}$$

99.8 Hybrid Preference

$$\mathcal{J}_{IV,H} < \min\left[\mathcal{J}_{IV,\mathrm{ABC}}, \mathcal{J}_{IV,\mathrm{PT}}\right] - \delta_H \tag{555}$$

and all required parent and interaction necessity conditions must hold.

99.9 Hybrid Falsifier

A hybrid claim fails if one parent component or the interaction is unnecessary, if the hybrid advantage disappears under complexity accounting, or if the hybrid merely combines incompatible parent solutions.

99.10 Hybrid Interaction and Dominance Guardrails

Difference-in-differences interaction diagnostics are scale dependent and remain descriptive unless the refitting rule and estimand are frozen. Parent dominance fractions use only nonnegative necessity contributions; if neither parent has a positive contribution, dominance is undefined. Hybrid search, interaction-form selection, and revisions receive the same complexity and selection accounting as the parent families.

100 Regional Versus Global Classification

100.1 Regional Partition

$$\mathfrak{R}_G = \{\mathcal{R}_1, \mathcal{R}_2, \ldots, \mathcal{R}_{N_R}\}. \tag{556}$$

100.2 Regional Score

For region r,

$$\mathcal{J}_{r,q}. \tag{557}$$

100.3 Regional Viability

$$\mathcal{V}_{r,q} = \left\{\boldsymbol{\Theta}_q : \mathcal{J}_{r,q} \le \mathcal{J}_{r,\mathrm{crit}}\right\}. \tag{558}$$

100.4 Global Regional Intersection

$$\mathcal{V}_{\mathrm{global},q} = \bigcap_{r=1}^{N_R} \mathcal{V}_{r,q}. \tag{559}$$

100.5 Regional Transferability

Fit in region r, predict region s:

$$S_{r \to s,q} = \log p\left(\mathbf{D}_s \mid \widehat{\boldsymbol{\Theta}}_{q,r}, \mathcal{M}_q\right). \tag{560}$$

100.6 Parameter Heterogeneity

$$H_{\Theta,q} = \frac{1}{N_R} \sum_r \left(\boldsymbol{\mu}_{r,q} - \boldsymbol{\mu}_q^{\mathrm{global}}\right)^\mathsf{T} \boldsymbol{\Sigma}_{\Theta,q}^{-1} \left(\boldsymbol{\mu}_{r,q} - \boldsymbol{\mu}_q^{\mathrm{global}}\right). \tag{561}$$

100.7 Classification Rules

A result is classified as:

Global
: One shared architecture succeeds across mandatory regions.

Multi-regional
: The model succeeds in several regions with limited shared variation.

Regional
: The model succeeds in one or a few regions but fails transfer.

Local
: The model explains one structure or locality.

Geometric only
: Spatial agreement survives but physical, chronological, or predictive tests fail.

Unsupported
: The viable regional set is empty.

100.8 Regional-to-Global Falsifier

Regional support does not establish global replacement when the same parameter architecture fails transfer, requires independent tuning, or produces an empty intersection across mandatory regions.

101 Complete Paper-IV Viable Set and Decision Tree

101.1 Explicit Component Viable Sets

Define:

$$\begin{aligned}
\mathcal{V}^{\mathrm{IV}}_{\mathrm{boundary},q} &= \text{boundary and plate-partition viability}, && (562)\\
\mathcal{V}^{\mathrm{IV}}_{\mathrm{motion},q} &= \text{velocity, force, torque, and power viability}, && (563)\\
\mathcal{V}^{\mathrm{IV}}_{\mathrm{surface},q} &= \text{surface-structure viability}, && (564)\\
\mathcal{V}^{\mathrm{IV}}_{\mathrm{deep},q} &= \text{deep-geophysical viability}, && (565)\\
\mathcal{V}^{\mathrm{IV}}_{\mathrm{chron},q} &= \text{chronology viability}, && (566)\\
\mathcal{V}^{\mathrm{IV}}_{\mathrm{paleo},q} &= \text{paleogeographic viability}, && (567)\\
\mathcal{V}^{\mathrm{IV}}_{\mathrm{coverage},q} &= \text{causal coverage and necessity viability}, && (568)\\
\mathcal{V}^{\mathrm{IV}}_{\mathrm{null},q} &= \text{null and selection-control viability}, && (569)\\
\mathcal{V}^{\mathrm{IV}}_{\mathrm{predict},q} &= \text{advance-prediction viability}, && (570)\\
\mathcal{V}^{\mathrm{IV}}_{\mathrm{rep},q} &= \text{replication viability}. && (571)
\end{aligned}$$

101.2 Complete Model Viable Set

$$\begin{aligned}
\mathcal{V}_{IV,q} =& \mathcal{V}^{\mathrm{IV}}_{\mathrm{boundary},q} \cap \mathcal{V}^{\mathrm{IV}}_{\mathrm{motion},q} \cap \mathcal{V}^{\mathrm{IV}}_{\mathrm{surface},q}\\
& \cap \mathcal{V}^{\mathrm{IV}}_{\mathrm{deep},q} \cap \mathcal{V}^{\mathrm{IV}}_{\mathrm{chron},q} \cap \mathcal{V}^{\mathrm{IV}}_{\mathrm{paleo},q}\\
& \cap \mathcal{V}^{\mathrm{IV}}_{\mathrm{coverage},q} \cap \mathcal{V}^{\mathrm{IV}}_{\mathrm{null},q} \cap \mathcal{V}^{\mathrm{IV}}_{\mathrm{predict},q} \cap \mathcal{V}^{\mathrm{IV}}_{\mathrm{rep},q}.
\end{aligned} \tag{572}$$

101.3 Astro-Ballistic Series Eligibility

$$\mathcal{V}_{II} \neq \varnothing, \qquad \mathcal{V}_{\mathrm{III}} \neq \varnothing, \qquad \mathcal{V}_{IV,\mathrm{ABC}} \neq \varnothing. \tag{573}$$

101.4 Integrated Score

$$\begin{aligned}
\mathcal{J}_{IV,q} =& w_B \mathcal{J}_{\mathrm{boundary},q} + w_V \mathcal{J}_{\mathrm{motion},q} + w_S \mathcal{J}_{\mathrm{surface},q}\\
& + w_D \mathcal{J}_{\mathrm{deep},q} + w_T \mathcal{J}_{T,q} + w_C \mathcal{J}_{C,q}\\
& + w_{\mathrm{cov}} \mathcal{J}_{\mathrm{coverage},q} + \mathcal{P}_{\mathrm{physical},q} + \mathcal{P}_{\mathrm{complex},q}\\
& + \mathcal{P}_{\mathrm{null},q} + \mathcal{P}_{\mathrm{selection},q} + \mathcal{P}_{\mathrm{prediction},q} + \mathcal{P}_{\mathrm{replication},q}.
\end{aligned} \tag{574}$$

101.5 Comparative Threshold Freeze Gate

The replacement conditions below are evaluable only after freezing δ_{IV}, $\Delta S_{\mathrm{adv,crit}}$, $N_{\mathrm{ABC,crit}}$, the equivalence interval, the mandatory observation classes, the effective-complexity rule, and the replication agreement criterion. Until that record exists, the atlas status is `THRESHOLDS-NOT-FROZEN` and no final ranking is confirmatory.

101.6 Replacement Conditions

The astro-ballistic model qualifies as a primary replacement candidate only if:

$$\mathcal{V}_{IV,\mathrm{ABC}} \neq \varnothing, \tag{575}$$

$$\mathcal{J}_{IV,\mathrm{ABC}} < \mathcal{J}_{IV,\mathrm{PT}} - \delta_{\mathrm{IV}}, \tag{576}$$

$$S_{\mathrm{adv,ABC}} > S_{\mathrm{adv,PT}} + \Delta S_{\mathrm{adv,crit}}, \tag{577}$$

and

$$N_{\mathrm{ABC}} > N_{\mathrm{ABC,crit}}. \tag{578}$$

101.7 Formal Decision Sequence

D1. Test Paper-II mechanical eligibility.

D2. Test Paper-III global reconstruction eligibility.

D3. Test boundary and plate-partition viability.

D4. Test motion, force, torque, and power viability.

D5. Test surface and deep-geophysical viability.

D6. Test chronology and paleogeography.

D7. Test opportunity-matched nulls and selection correction.

D8. Test causal necessity.

D9. Test advance prediction.

D10. Test effective complexity.

D11. Compare the hybrid model.

D12. Require independent replication.

101.8 Outcome Function

$$\mathcal{O}_{\mathrm{IV}} = \mathcal{D}\left[\mathcal{V}_{IV,q}, \mathcal{J}_{IV,q}, S_{\mathrm{adv},q}, N_{m,q}, p_{q,\mathrm{null}}, \mathbf{R}_q\right]. \tag{579}$$

101.9 Complete-Viability Falsifier

A frozen astro-ballistic global model version is rejected when a completed valid test yields an empty integrated viable set, mandatory domains require incompatible parameter states, or a hard physical or chronological condition is violated.

Primary replacement candidacy is not established when causal necessity, clear held-out predictive superiority, complexity-adjusted preference, or independent replication is absent. Those comparative outcomes may disfavor replacement without falsifying every regional, event-level, or complementary claim.

102 Paper-IV Claim and Falsification Registry

102.1 Principal Decision Claims

Table 51: Principal Paper-IV adjudication claims.

ID	Decision claim	Current status
ABC-P4-CLM-037	The Plate-Tectonic comparison family achieves a nonempty complete viable set.	Untested
ABC-P4-CLM-038	The astro-ballistic comparison family achieves a nonempty complete viable set.	Untested
ABC-P4-CLM-039	The hybrid family achieves a nonempty complete viable set.	Untested
ABC-P4-CLM-040	The astro-ballistic component is necessary under ablation.	Untested
ABC-P4-CLM-041	The defining Plate-Tectonic component is necessary under ablation.	Untested
ABC-P4-CLM-042	Both parent components and their interaction are necessary in a preferred hybrid.	Untested
ABC-P4-CLM-043	The astro-ballistic model outperforms realistic null models.	Untested
ABC-P4-CLM-044	The astro-ballistic model retains its advantage after effective complexity is counted.	Untested
ABC-P4-CLM-045	The astro-ballistic model predicts withheld evidence better than the Plate-Tectonic family.	Untested
ABC-P4-CLM-046	Independent teams reproduce the primary ranking.	Untested
ABC-P4-CLM-047	Astro-Ballistic Chronostratigraphic Sequencing qualifies as a primary replacement candidate.	Unknown

102.2 Integrated Falsification Registry

Table 52: Integrated Paper-IV falsification registry.

ID	Falsification condition	Consequence
ABC-P4-FAL-001	The Paper-II mechanical viable set is empty.	Reject global astro-ballistic replacement.

ID	Falsification condition	Consequence
ABC-P4-FAL-002	The Paper-III global reconstruction viable set is empty.	Reject global astro-ballistic replacement.
ABC-P4-FAL-003	The candidate cannot generate or consistently inherit a global boundary network.	Reject boundary-origin replacement.
ABC-P4-FAL-004	Predicted boundary topology, types, or chronology fail.	Reject boundary architecture.
ABC-P4-FAL-005	Observed Euler vectors must be fitted independently.	Reject causal rotation generation.
ABC-P4-FAL-006	Predicted directions, speeds, or relative motions fail.	Reject global motion solution.
ABC-P4-FAL-007	Plate circuits, junctions, or area accounting fail.	Reject kinematic closure.
ABC-P4-FAL-008	Force or torque does not close.	Reject dynamic motion solution.
ABC-P4-FAL-009	Required power is unavailable or dissipation is unphysical.	Reject motion maintenance.
ABC-P4-FAL-010	Ancient impulse must remain unattenuated to sustain present motion.	Reject impulse-maintenance branch.
ABC-P4-FAL-011	Mountain location, orientation, roots, work, or chronology fail.	Reject global orogenic explanation.
ABC-P4-FAL-012	Trench geometry, polarity, deep descent, or chronology fail.	Reject trench explanation.
ABC-P4-FAL-013	Ridge or rift opening, age gradients, segmentation, or production fail.	Reject extensional explanation.
ABC-P4-FAL-014	Basin geometry, subsidence, thermal history, or inversion fail.	Reject basin explanation.
ABC-P4-FAL-015	Plateau support, elevation, root, or persistence fail.	Reject plateau explanation.
ABC-P4-FAL-016	Volcanic location, timing, melt path, or composition fail.	Reject volcanic explanation.
ABC-P4-FAL-017	Terrane trajectories, provenance, rotations, sutures, or docking fail.	Reject assembly explanation.
ABC-P4-FAL-018	Required density structure conflicts with gravity or geoid observations.	Reject density architecture.
ABC-P4-FAL-019	Required material state conflicts with seismic observations.	Reject deep-state architecture.
ABC-P4-FAL-020	Required pressure-temperature history conflicts with magnetic evidence.	Reject magnetic-history branch.
ABC-P4-FAL-021	Required thermal state conflicts with heat-flow observations.	Reject thermal-history branch.
ABC-P4-FAL-022	Gravity, seismic, magnetic, and thermal fits require incompatible material states.	Reject integrated deep-geophysical model.
ABC-P4-FAL-023	Proposed effects precede their required causes.	Reject affected causal sequence.
ABC-P4-FAL-024	Required lags are fitted independently after outcome inspection.	Reject temporal causal compression.
ABC-P4-FAL-025	Key relationships disappear in event-time material coordinates.	Reject affected event assignment.
ABC-P4-FAL-026	Mandatory observation classes are omitted.	Reject global explanatory coverage.
ABC-P4-FAL-027	Mandatory classes require incompatible parameter states.	Reject integrated model.

ID	Falsification condition	Consequence
ABC-P4-FAL-028	Removing astro-ballistic inheritance produces negligible degradation.	Reject primary astro-ballistic causation.
ABC-P4-FAL-029	Removing defining Plate-Tectonic components produces negligible degradation.	Reject their claimed primary role.
ABC-P4-FAL-030	A preferred hybrid does not require both parents and interaction.	Reject joint hybrid attribution.
ABC-P4-FAL-031	Opportunity-matched randomized event catalogs perform comparably.	Reject sequence specificity.
ABC-P4-FAL-032	Permuted ages or assignments perform comparably.	Reject chronology or assignment specificity.
ABC-P4-FAL-033	Significance disappears after complete search correction.	Reject confirmatory statistical support.
ABC-P4-FAL-034	Validation depends on repeatedly inspected holdouts.	Reclassify result as exploratory.
ABC-P4-FAL-035	The model advantage disappears after effective complexity accounting.	Reject causal preference.
ABC-P4-FAL-036	The candidate fails registered withheld predictions.	Reject predictive replacement.
ABC-P4-FAL-037	The candidate predicts excessive false positives in negative-control domains.	Reject predictive specificity.
ABC-P4-FAL-038	The model succeeds only through independent regional tuning.	Reject global generality.
ABC-P4-FAL-039	The strongest comparison model has greater marginal evidence.	Reject astro-ballistic preference.
ABC-P4-FAL-040	The comparison model has stronger held-out predictive performance.	Reject astro-ballistic replacement.
ABC-P4-FAL-041	Model differences remain inside the equivalence interval.	Report causal non-resolution.
ABC-P4-FAL-042	Independent teams cannot reproduce the ranking or viable-set intersection.	Reject confirmatory preference.
ABC-P4-FAL-043	The complete astro-ballistic Paper-IV viable set is empty.	Reject formal replacement thesis.
ABC-P4-FAL-044	The hybrid does not outperform both parent models after penalties.	Hybrid preference unsupported.
ABC-P4-FAL-045	No tested model adequately predicts the complete shared domain.	Report shared failure.

102.3 No Cross-Compensation

The following compensations are prohibited:

- geometry for mechanics;
- local boundary fit for global motion failure;
- statistical fit for conservation failure;
- surface fit for deep-geophysical failure;
- reconstruction for failed prediction;

- or regional success for global-transfer failure.

103 Replication and Cross-Paper Dependency Graph

103.1 Replication Levels

Paper-IV replication includes:

R1. source and selection audit;

R2. Papers I–III handoff reproduction;

R3. independent implementation of all model families;

R4. shared-data and uncertainty freeze;

R5. component comparisons;

R6. causal ablations;

R7. null and selection analysis;

R8. advance-prediction validation;

R9. and final adjudication.

103.2 Replication Record

$$\begin{aligned}\mathbf{R}_{\mathrm{rep},j} = \big(&\text{team}, \text{model version}, \text{code version}, \text{data version},\\ &\text{inputs}, \text{solver}, \text{seed}, \text{outputs}, \text{differences},\\ &\text{ranking}, \text{viable set}, \text{status}\big).\end{aligned} \tag{580}$$

103.3 Replication Statuses

Allowed statuses are:

- `REPRODUCED`;
- `PARTIALLY-REPRODUCED`;
- `NOT-REPRODUCED`;
- `MODEL-DEPENDENT`;
- `FRAME-DEPENDENT`;
- `SELECTION-DEPENDENT`;
- `STATISTICALLY-NONDISTINCT`;
- `PREDICTIVELY-UNSUPPORTED`;
- `FALSIFIED`.

103.4 Cross-Paper Dependency Graph

The complete series graph is

$$\mathcal{G}_{\text{series}} = (\mathcal{V}_{P1} \cup \mathcal{V}_{P2} \cup \mathcal{V}_{P3} \cup \mathcal{V}_{P4}, \mathcal{E}_{\text{cross}}) \,. \tag{581}$$

103.5 Series Dependency Chain

$$\begin{aligned}\text{Replacement decision} \Leftarrow \{&\text{Paper IV comparison}, \text{Paper III reconstruction},\\ &\text{Paper II mechanics}, \text{Paper I geometry},\\ &\text{advance prediction}, \text{null control}, \text{replication}\}.\end{aligned} \tag{582}$$

103.6 Cross-Paper Critical Nodes

Table 53: Series-level critical dependency nodes.

Node	**Criticality**	**Reason**
Paper-I paleogeography	Series-critical	The flagship event geometry must survive event-time reconstruction.
Paper-I selection null	High	The initial geometry requires selection-aware significance.
Paper-II viable set	Series-critical	No event-derived state exists if all mechanical branches fail.
Paper-II whole-Earth closure	Series-critical	Energy, momentum, rotation, and survival constrain all later claims.
Paper-III material lineage	Series-critical	Events must act on reconstructable ancient material domains.
Paper-III boundary network	Series-critical	Plate partition and relative motion depend on it.
Paper-III motion solution	Series-critical	The model must generate directions, speeds, and Euler vectors.
Paper-III chronology	Series-critical	Effects cannot precede proposed causes.
Paper-IV shared evidence	Series-critical	All models must be compared on the same observation domain.
Paper-IV effective complexity	High	Uncounted flexibility can reverse model preference.
Paper-IV prediction program	Series-critical for confirmation	Reconstruction alone cannot establish replacement.
Independent replication	Series-critical for confirmation	Final preference must survive independent implementation.

103.7 Series Failure Cut Set

A representative series-level failure cut set is

$$\mathcal{K}_{\text{series}} = \{\mathcal{V}_{P1}, \mathcal{V}_{II}, \mathcal{V}_{\text{III}}, \mathcal{V}_{IV,\text{ABC}}, \mathcal{V}_{\text{predict}}, \mathcal{V}_{\text{rep}}\} \,. \tag{583}$$

103.8 Failure Propagation

Failure of an upstream node propagates only through required dependency edges.

For example:

- failure of the flagship event does not reject every other candidate event;
- failure of the coherent branch does not reject every transmission branch;
- failure of global replacement does not reject every regional event hypothesis;
- and failure of one model family does not establish the truth of another.

103.9 Replacement Decision Node

The final series-level node is

$$\texttt{ABC-X-DEC-001.} \tag{584}$$

Its record must contain:

- eligible model families;
- data freeze;
- model versions;
- component viable sets;
- integrated scores;
- model evidence;
- predictive scores;
- causal ablations;
- null probabilities;
- effective complexity;
- replication status;
- decision thresholds;
- and final classification.

104 Paper-IV Atlas Status

104.1 Status Dashboard

Table 54: Current Paper-IV atlas status dashboard.

Registry domain	**Current status**	**Required next step**
Comparison scope	Defined	Freeze exact comparison question
Shared observation domain	Classes defined	Assemble versioned datasets and covariance
Plate-Tectonic family	Required specification defined	Implement strong defensible model ensemble
Astro-ballistic family	Eligibility defined	Populate from surviving Paper-III model
Hybrid family	Architecture defined	Implement explicit parent and interaction terms
Regional models	Classification defined	Freeze regional partitions and transfer tests
Matched comparison	Rules defined	Freeze input, output, spatial, and temporal domains
Initial-state accounting	Architecture defined	Calculate information and sensitivity
Boundary comparison	Metrics defined	Generate and compare complete networks
Motion comparison	Metrics defined	Generate Euler vectors, speeds, forces, torques, and power
Surface structures	Mandatory classes defined	Run common-state structural comparisons
Deep geophysics	Forward operators defined	Generate resolution-matched predictions
Chronology	Causal order defined	Assemble dated dependency graph
Paleogeography	Material reconstruction defined	Run reconstruction ensemble
Causal coverage	Depth and coverage scales defined	Score all mandatory classes
Causal necessity	Ablation equations defined	Run mechanism and event removals
Model evidence	Framework defined	Compute likelihoods and evidence
Equivalence	Decision architecture defined	Freeze equivalence intervals
Effective complexity	Registry defined	Count hidden flexibility and description length
Null models	Families defined	Run opportunity-matched ensembles
Selection correction	Rules defined	Complete search and revision ledgers
Advance predictions	Classes defined	Freeze predictions before validation
Hybrid decomposition	Ablations defined	Compute parent and interaction necessity
Regional classification	Rules defined	Evaluate transferability and shared parameters
Complete viable set	Explicitly defined	Evaluate each model-family intersection
Decision tree	Defined	Freeze thresholds before final comparison
Replication	Protocol defined	Independent implementation and prediction validation
Final decision	Node defined	Currently unresolved

104.2 Established Paper-IV Architecture

The strongest current Paper-IV outputs are:

- the matched model-family architecture;
- the shared observation domain;
- eligibility and fairness rules;
- initial-condition and boundary-information accounting;
- boundary and plate-partition comparison metrics;
- motion, Euler-vector, force, torque, and power comparison;
- surface and deep-geophysical comparison;
- explicit forward-time chronology;
- event-time paleogeographic reconstruction;
- causal coverage and causal-depth metrics;
- mechanism and event necessity tests;
- model evidence and equivalence;
- effective-complexity and description-length accounting;
- opportunity-matched null families;
- multiple-testing and holdout-depletion controls;
- advance-prediction scoring;
- hybrid causal decomposition;
- regional-versus-global classification;
- the complete model viable set;
- the formal replacement decision sequence;
- and the cross-paper dependency graph.

104.3 Current Unresolved Questions

Paper IV still requires:

- an eligible Paper-III astro-ballistic model;
- strong implemented Plate-Tectonic comparison models;
- an explicit hybrid model;
- frozen shared datasets;
- complete uncertainty and covariance models;

- boundary and velocity forward runs;
- structural and deep-geophysical predictions;
- chronology-wide reconstruction;
- effective-complexity calculation;
- null simulations;
- frozen advance predictions;
- prospective validation;
- and independent replication.

104.4 Paper-IV Atlas Conclusion

Paper-IV atlas conclusion.
Paper IV defines a complete comparative decision architecture for determining whether Astro-Ballistic Chronostratigraphic Sequencing should be rejected, restricted to regional or complementary status, combined with Plate Tectonics in a hybrid model, classified as causally equivalent, or retained as a primary replacement candidate.
The replacement decision requires one mechanically admissible, chronologically ordered, paleogeographically valid, and globally connected astro-ballistic model that predicts:

$$\text{boundaries} + \text{plate motion} + \text{continental history} + \text{surface structure} + \text{deep geophysics}$$

from a shared parameter architecture.
That model must remain necessary under ablation, outperform realistic nulls, survive complete selection and complexity accounting, predict withheld evidence, and be independently reproduced.
No completed Paper-IV adjudication is presently registered.
The current status is therefore not replacement, rejection, hybrid preference, or equivalence. It is:

$$\boxed{\text{formal comparative framework established; empirical adjudication unresolved}}$$

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105 Paper-IV Atlas Synthesis

This Paper-IV atlas synthesis records:

1. the complete Paper-IV atlas scope;
2. the seven permitted final outcome classes;
3. a thirty-six-item principal comparison claim registry;

4. the shared boundary, motion, continental, chronological, surface, gravity, seismic, magnetic, thermal, and prediction data registry;
5. shared covariance and resolution-matching requirements;
6. Plate-Tectonic, astro-ballistic, hybrid, regional, baseline, and randomized model-family registries;
7. matched input, output, spatial, and temporal comparison rules;
8. model eligibility records;
9. initial-state, boundary, and velocity information accounting;
10. boundary-origin ablation and sensitivity;
11. boundary geometry, topology, type, chronology, and plate-partition comparison;
12. boundary-mechanism necessity;
13. velocity and Euler-vector residuals;
14. force, torque, power, and dissipation comparison;
15. motion-mechanism ablation;
16. mountain, trench, ridge, basin, plateau, volcanic, terrane, and suture comparison requirements;
17. integrated surface-structure scoring;
18. gravity, seismic, magnetic, and thermal forward operators;
19. cross-geophysical consistency;
20. explicit forward-time and age-before-present conventions;
21. chronology and paleogeographic comparison;
22. event-time material-coordinate testing;
23. causal coverage, causal depth, and chain completion;
24. mechanism, event, and interaction necessity;
25. likelihood, marginal evidence, Bayes factors, posterior model probability, cross-validation, and prospective scores;
26. model equivalence and ranking stability;
27. raw and effective complexity;
28. initial-state, event-catalog, search-space, and revision description length;
29. causal compression;
30. uniform, opportunity-matched, boundary-conditioned, plate-preserving, chronological, directional, assignment, inherited-state, topology, and reference-frame null models;
31. empirical null probabilities;

32. complete search-space and selection ledgers;
33. family-wise and false-discovery controls;
34. holdout-depletion accounting;
35. the complete advance-prediction registry;
36. continuous, binary, spatial-specificity, and negative-control prediction scoring;
37. hybrid parent and interaction ablation;
38. hybrid dominance and outcome classification;
39. regional viable sets, transferability, and parameter heterogeneity;
40. explicit boundary, motion, surface, deep, chronology, paleogeography, coverage, null, prediction, and replication viable sets;
41. the complete Paper-IV model viable set;
42. the integrated adjudication score;
43. the primary replacement conditions;
44. the formal twelve-step decision sequence;
45. eleven principal adjudication claims;
46. a forty-five-item integrated Paper-IV falsification registry;
47. the no-cross-compensation rule;
48. the replication-level architecture;
49. the cross-paper series dependency graph;
50. series-critical nodes and the series failure cut set;
51. the final replacement-decision node;
52. the Paper-IV status dashboard; and
53. the formal Paper-IV atlas conclusion.

The following sections complete the cross-paper audit and close the companion atlas:

- cross-paper claim hierarchy;
- series-wide equation registry;
- symbol and notation audit;
- unit and dimensional audit;
- shared parameter registry;
- chronology-consistency audit;
- source-verification ledger;

- unsupported-claim registry;
- contradiction and supersession atlas;
- circular-support audit;
- minimum failure cut sets;
- series-wide prediction atlas;
- series-wide falsification atlas;
- reader query and navigation tables;
- machine-readable companion schema;
- replication-package specification;
- final production checklist;
- integrated limitations;
- Paper-V conclusions; and
- the final five-paper series status.

106 Cross-Paper Claim Hierarchy

106.1 Series-Level Proposition

The formal series-level proposition is:

Astro-Ballistic Chronostratigraphic Sequencing accepts observed continental and plate motion while challenging Plate Tectonics as the primary causal framework of global crustal organization.

The candidate framework proposes that major plate boundaries, plate-motion directions, relative plate velocities, mountain systems, trenches, basins, fracture networks, volcanic provinces, and displaced terranes are inherited and continuing consequences of a sequenced history of large astro-ballistic events.

106.2 Series Claim Node

The series-level claim is registered as

$$C_{\text{series}} = \texttt{ABC-X-CLM-001}. \tag{585}$$

106.3 Event-Indexed and Global Scientific Gates

For each candidate event k, define an event-specific eligibility pair

$$G_{E,k} = (G_{I,k}, G_{II,k}), \tag{586}$$

where $G_{I,k}$ is geometric, paleogeographic, chronological, and selection-aware eligibility, and $G_{II,k}$ is mechanical transmission and planetary-compatibility eligibility.

The globally eligible event set is

$$\mathcal{E}_{\text{elig}} = \{k : G_{I,k} = 1 \text{ and } G_{II,k} = 1\} . \tag{587}$$

The series-level replacement claim then depends on:

$$C_{\text{series}} \Leftarrow \{\mathcal{E}_{\text{elig}}, G_{\text{III}}, G_{\text{IV}}, G_{\text{prediction}}, G_{\text{replication}}\} . \tag{588}$$

106.4 Flagship Paper-I Gate

Paper I asks whether the flagship event F satisfies:

$$G_{I,F} = (G_{\text{coord},F}, G_{\text{geometry},F}, G_{\text{paleo},F}, G_{\text{chronology},F}, G_{\text{null},F}) . \tag{589}$$

Its present status is mixed:

- the registered present-coordinate geometry is reproducible;
- near-bilateral distance is reproduced;
- the literal present-coordinate midpoint criterion fails its source working threshold;
- event-time paleogeography remains unresolved;
- chronology remains unresolved;
- and selection-aware significance remains unresolved.

106.5 Flagship Paper-II Gate

Paper II asks whether at least one transmission branch for the flagship event satisfies:

$$G_{II,F} = (G_{\text{entrance}}, G_{\text{path}}, G_{\text{midpoint}}, G_{\text{terminal}}, G_{\text{survival}}, G_{\text{rotation}}, G_{\text{markers}}) . \tag{590}$$

The gate remains unresolved because no complete branch has been shown to occupy the full Paper-II viable set.

106.6 Paper-III Gate

Paper III asks whether one mechanically admissible sequence produces:

$$G_{\text{III}} = (G_{\text{lineage}}, G_{\text{boundary}}, G_{\text{impulse}}, G_{\text{motion}}, G_{\text{surface}}, G_{\text{chronology}}, G_{\text{prediction}}) . \tag{591}$$

The gate remains unresolved because no complete global numerical reconstruction is presently registered.

106.7 Paper-IV Gate

Paper IV asks whether the astro-ballistic model achieves:

$$G_{\mathrm{IV}} = (G_{\mathrm{matched}}, G_{\mathrm{coverage}}, G_{\mathrm{necessity}}, G_{\mathrm{complexity}}, G_{\mathrm{null}}, G_{\mathrm{advance}}, G_{\mathrm{replication}}) . \tag{592}$$

No complete comparative adjudication is presently registered.

106.8 Claim Hierarchy

The series hierarchy is

$$\begin{aligned} C_{\mathrm{series}} \Leftarrow \{&C_{\mathrm{replacement}}, C_{\mathrm{global\ reconstruction}}, C_{\mathrm{mechanical\ viability}}, \\ &C_{\mathrm{event\ eligibility}}, C_{\mathrm{advance\ prediction}}, C_{\mathrm{replication}}\}. \end{aligned} \tag{593}$$

106.9 Claim-Level Separation

The atlas distinguishes:

Table 55: Cross-paper claim-level separation.

Claim level	**Meaning**	**Current status**
Calculated geometry	A value follows reproducibly from declared coordinates and equations.	Partially verified
Geometric relationship	A spatial pattern exists under a declared coordinate and path definition.	Partially supported
Chronological relationship	The required features and events have compatible ages.	Unresolved
Mechanical eligibility	At least one branch satisfies transmission and planetary constraints.	Unresolved
Historical occurrence	The mechanically eligible event actually occurred.	Unresolved
Regional inheritance	A specific region preserves a causal event-derived state.	Unresolved
Global reconstruction	One sequence explains major boundaries, motions, and structures.	Unresolved
Comparative preference	One model family outperforms strong competitors.	Unresolved
Primary replacement	Astro-ballistic sequencing is the preferred primary causal framework.	Not established

106.10 No Automatic Claim Promotion

The following promotions are prohibited:

$$\text{calculated} \not\Rightarrow \text{observed}, \tag{594}$$

$$\text{geometrically compatible} \not\Rightarrow \text{causal}, \tag{595}$$

$$\text{mechanically possible} \not\Rightarrow \text{historically occurred}, \tag{596}$$

and

$$\text{regional support} \not\Rightarrow \text{global replacement}. \tag{597}$$

106.11 Current Series Claim Status

The current series-level status vector is

$$\begin{aligned}\mathbf{S}_{\text{series}} = \big(&\texttt{AUTHOR-MANUSCRIPT}, \texttt{MODEL-PROPOSITION}, \texttt{UNRESOLVED},\\ &\texttt{PARTIALLY-VERIFIED}, \texttt{WORKING-MANUSCRIPT}\big).\end{aligned} \tag{598}$$

107 Series-Wide Equation Registry

107.1 Equation-Family Architecture

The series equation registry is partitioned into:

$$\mathfrak{E}_{\text{series}} = \{\mathfrak{E}_{\text{geometry}}, \mathfrak{E}_{\text{mechanics}}, \mathfrak{E}_{\text{lineage}}, \mathfrak{E}_{\text{boundary}}, \mathfrak{E}_{\text{motion}}, \mathfrak{E}_{\text{structure}}, \mathfrak{E}_{\text{comparison}}, \mathfrak{E}_{\text{decision}}\}. \tag{599}$$

107.2 Cross-Paper Equation Registry

Table 56: Principal series-wide equation families.

Family	**Representative equations**	**Primary burden**	**Status**
Spherical geometry	Central angle, surface distance, midpoint, cross-track, along-track	Paper-I reproducible geometry	Audited
Chord geometry	Chord length, closest radius, maximum depth, incidence	Paper-I to Paper-II path definition	Audited
Energy and momentum	$E_K = \frac{1}{2}mv^2$, $p = mv$, energy and momentum closure	Paper-II mechanical scale and conservation	Partially audited
Thermomechanics	Energy, damage, melt, phase, density, constitutive evolution	Paper-II transmission state	Unimplemented
Dimensionless diagnostics	Reynolds, Froude, Rossby, Deborah numbers	Regime diagnostics	Corrected
Material lineage	Membership, fragmentation, merger, transfer, mass closure	Paper-III historical domains	Framework defined
Boundary generation	Nucleation, persistence, connectivity, reactivation	Paper-III plate partition	Framework defined

Family	Representative equations	Primary burden	Status
Plate dynamics	Impulse, inertia, force, torque, power, Euler velocity	Paper-III motion generation	Framework defined
Structural evolution	Elevation, flexure, ridge production, basin subsidence, melt transport	Paper-III surface prediction	Framework defined
Geophysical forward models	Gravity integral, seismic operator, magnetic operator, heat equation	Paper-IV deep comparison	Framework defined
Statistical comparison	Likelihood, marginal evidence, null probability, held-out scores	Paper-IV model adjudication	Framework defined
Complexity accounting	Effective parameters, information cost, description length	Paper-IV adjusted ranking	Framework defined
Viable-set intersections	Paper-I through Paper-IV admissible sets	Failure and eligibility	Canonical
Decision equations	Necessity, superiority, equivalence, final outcome	Replacement classification	Canonical

107.3 Equation Dependency Chain

The principal equation dependency is

$$\begin{aligned}\mathfrak{E}_{\text{decision}} \Leftarrow \{&\mathfrak{E}_{\text{comparison}}, \mathfrak{E}_{\text{structure}}, \mathfrak{E}_{\text{motion}},\\ &\mathfrak{E}_{\text{boundary}}, \mathfrak{E}_{\text{mechanics}}, \mathfrak{E}_{\text{geometry}}\}.\end{aligned} \tag{600}$$

107.4 Equation Verification Vector

For equation e_i,

$$\mathbf{V}_{e_i} = (V_{\text{source}}, V_{\text{symbol}}, V_{\text{dimension}}, V_{\text{derivation}}, V_{\text{numeric}}, V_{\text{independent}})_{e_i}. \tag{601}$$

107.5 Equation Audit States

The complete equation audit uses:

- `REGISTERED`;
- `SYMBOL-CHECKED`;
- `UNIT-CHECKED`;
- `DIMENSION-CHECKED`;
- `DERIVATION-CHECKED`;
- `NUMERICALLY-REPRODUCED`;
- `INDEPENDENTLY-REPRODUCED`;
- `CONDITIONAL`;
- `INCONSISTENT`;

- `SUPERSEDED`.

107.6 Equation-Source Separation

The atlas distinguishes:

- standard mathematical identities;
- standard physical governing equations;
- author-defined diagnostic equations;
- author-defined score functions;
- model-specific constitutive relationships;
- and final decision rules.

107.7 Author-Defined Diagnostics

Author-defined diagnostics include quantities such as:

- bilateral asymmetry;
- combined geometric scores;
- boundary-nucleation potential;
- directional-inheritance necessity;
- causal-depth scores;
- effective-complexity decomposition;
- and integrated viable-set decisions.

These must not be described as standard scientific laws.

107.8 Equation Completion Requirement

Before confirmatory publication, every principal equation must have:

$$I_{e_i}^{\mathrm{complete}} = I_{\mathrm{definition}} I_{\mathrm{variables}} I_{\mathrm{units}} I_{\mathrm{assumptions}} I_{\mathrm{domain}} I_{\mathrm{test}} I_{\mathrm{status}}. \tag{602}$$

108 Symbol, Notation, Unit, and Dimensional Audit

108.1 Canonical Unit System

The canonical computational unit system is the International System of Units:

$$\mathrm{m}, \quad \mathrm{kg}, \quad \mathrm{s}, \quad \mathrm{K}, \quad \mathrm{Pa}, \quad \mathrm{J}, \quad \mathrm{W}. \tag{603}$$

Displayed geological distances may use kilometres after explicit conversion.

108.2 Angle Convention

All trigonometric calculations use radians internally.

Angles may be displayed in degrees:

$$\theta_{\mathrm{rad}} = \theta_{\mathrm{deg}} \frac{\pi}{180}. \tag{604}$$

108.3 Time Convention

The canonical internal time is forward time τ, increasing toward the present:

$$0 \leq \tau \leq a_{\mathrm{start}}. \tag{605}$$

Age before present is

$$a = a_{\mathrm{start}} - \tau. \tag{606}$$

A cause preceding an effect satisfies:

$$\tau_c \leq \tau_e \tag{607}$$

or

$$a_c \geq a_e. \tag{608}$$

108.4 Geological Age Notation

The flagship symbol

$$a_{\mathrm{init},F} = 256 \text{ Ma} \tag{609}$$

means that the model assigns a nominal initiating-event age of 256 million years before present. It is a specific hypothesis parameter, not a claim of zero chronometric uncertainty. Empirical age uncertainty is stored separately and may not be converted into an unrestricted event search interval.

A duration should be written explicitly as:

$$\Delta t = 1 \text{ Myr} \tag{610}$$

or an equivalent unambiguous duration notation.

108.5 Canonical Viable-Set Names

To remove short-subscript ambiguity, the preferred names are:

$$\begin{aligned}
\mathcal{V}_{\text{handoff}} &= \text{mechanical handoff viability}, && (611)\\
\mathcal{V}_{\text{event}} &= \text{event-sequence viability}, && (612)\\
\mathcal{V}_{\text{lineage}} &= \text{material-lineage viability}, && (613)\\
\mathcal{V}_{\text{boundary}} &= \text{boundary-network viability}, && (614)\\
\mathcal{V}_{\text{impulse}} &= \text{event-to-material impulse viability}, && (615)\\
\mathcal{V}_{\text{motion}} &= \text{plate-motion viability}, && (616)\\
\mathcal{V}_{\text{surface}} &= \text{surface-structure viability}, && (617)\\
\mathcal{V}_{\text{chronology}} &= \text{chronological viability}, && (618)\\
\mathcal{V}_{\text{paleogeography}} &= \text{paleogeographic viability}, && (619)\\
\mathcal{V}_{\text{deep}} &= \text{deep-geophysical viability}, && (620)\\
\mathcal{V}_{\text{null}} &= \text{null-model viability}, && (621)\\
\mathcal{V}_{\text{prediction}} &= \text{advance-prediction viability}, && (622)\\
\mathcal{V}_{\text{replication}} &= \text{replication viability}. && (623)
\end{aligned}$$

108.6 Legacy Short Subscripts

Earlier expressions using:

$$\mathcal{V}_B, \quad \mathcal{V}_V, \quad \mathcal{V}_S \tag{624}$$

should be interpreted by local definition.

For final machine-readable registries, the explicit long-subscript names are authoritative.

108.7 Boundary and Basin Symbols

To avoid using B for both boundary and basin:

$$\begin{aligned}
\mathcal{B} &= \text{boundary network}, && (625)\\
\mathbf{Q}_{\text{basin}} &= \text{basin state}, && (626)\\
\mathcal{V}_{\text{boundary}} &= \text{boundary viability}, && (627)\\
\mathcal{V}_{\text{basin}} &= \text{basin viability}. && (628)
\end{aligned}$$

108.8 Velocity and Volcanism Symbols

To avoid using V for both velocity and volcanism:

$$
\begin{aligned}
\mathbf{v} &= \text{velocity}, && (629)\\
\mathbf{Q}_{\text{volc}} &= \text{volcanic state}, && (630)\\
\mathcal{V}_{\text{motion}} &= \text{motion viability}, && (631)\\
\mathcal{V}_{\text{volcanic}} &= \text{volcanic viability}. && (632)
\end{aligned}
$$

108.9 Time-Ordering Operator

The symbol

$$\mathcal{T}\exp\left[\int \boldsymbol{\Omega}\, dt\right] \tag{633}$$

uses $\mathcal{T}$ as the time-ordering operator.

Terrane collections should use:

$$\mathfrak{T}_{\text{terrane}} \tag{634}$$

rather than an unqualified $\mathcal{T}$.

108.10 Identity Tensor

The symbol

$$\mathbf{1} \tag{635}$$

means the identity tensor when used in expressions such as the inertia tensor or isotropization operator.

108.11 Damage

The damage variable is

$$0 \leq D \leq 1 \tag{636}$$

unless a different constitutive definition is explicitly declared.

The bold symbol

$$\mathbf{D} \tag{637}$$

may represent a spatial damage field or a data vector only when the scope is explicit.

108.12 Melt Fraction

The melt fraction is

$$0 \leq \chi_m \leq 1. \tag{638}$$

108.13 Phase Fractions

For phases α,

$$0 \leq \phi_\alpha \leq 1, \qquad \sum_\alpha \phi_\alpha = 1. \tag{639}$$

108.14 Density Perturbation

The sign convention is:

$$\Delta\rho = \rho - \rho_0. \tag{640}$$

Thus:

$$\Delta\rho > 0 \tag{641}$$

means denser than the reference state.

108.15 Vertical Displacement Convention

For vertical displacement w, the selected sign must be declared for each model.

The preferred convention is:

$$w > 0 \quad \text{upward}. \tag{642}$$

Subsidence terms are therefore negative unless represented as positive subsidence magnitudes inside a separate decomposition.

108.16 Trench Displacement Convention

For trench or flexural decompositions, each component must state whether it is:

- a signed vertical displacement;
- a positive downward-deflection magnitude;
- or a positive contribution to trench depth.

No additive trench equation is valid without one common sign convention.

108.17 Stress and Pressure

Pressure is positive in compression:

$$P > 0 \quad \text{for compression.} \tag{643}$$

The stress-tensor sign convention must be stated independently in each constitutive implementation.

108.18 Dimensional Audit Table

Table 57: Principal dimensional-audit requirements.

Quantity	**Dimensions**	**Primary audit**
Distance	L	Coordinates, surface paths, chord, structures
Velocity	$\mathrm{L\,T^{-1}}$	Projectile, wave, plate, melt
Acceleration	$\mathrm{L\,T^{-2}}$	Plate dynamics and gravity
Mass	M	Projectile, plate, terrane, ejecta
Momentum	$\mathrm{M\,L\,T^{-1}}$	Entrance, terminal, plate impulse
Angular momentum	$\mathrm{M\,L^2\,T^{-1}}$	Earth and plate rotation
Energy	$\mathrm{M\,L^2\,T^{-2}}$	Event, heat, fracture, gravity
Power	$\mathrm{M\,L^2\,T^{-3}}$	Motion maintenance and dissipation
Pressure and stress	$\mathrm{M\,L^{-1}\,T^{-2}}$	Shock, deformation, phase response
Density	$\mathrm{M\,L^{-3}}$	Buoyancy, gravity, mass
Dynamic viscosity	$\mathrm{M\,L^{-1}\,T^{-1}}$	Reynolds and rheology
Thermal conductivity	$\mathrm{M\,L\,T^{-3}\,K^{-1}}$	Heat equation and heat flow
Heat flow	$\mathrm{M\,T^{-3}}$	Surface thermal prediction
Flexural rigidity	$\mathrm{M\,L^2\,T^{-2}}$	Plate bending

108.19 Notation-Audit Status

The present manuscript defines the notation architecture.

A final automated symbol audit must still identify:

- duplicate symbol definitions;
- undefined symbols;
- inconsistent bolding;
- inconsistent time variables;
- inconsistent unit displays;
- and reused subscripts with incompatible meanings.

109 Shared Parameter Registry

109.1 Shared-Parameter Record

A shared parameter is registered as

$$\mathbf{P}_i^X = (\mathrm{ID}, \mathrm{name}, \mathrm{symbol}, \mathrm{value}, \mathrm{range}, \mathrm{units}, \mathrm{source}, \mathrm{scope}, \mathrm{status})\,. \tag{644}$$

109.2 Principal Shared Parameters

Table 58: Principal cross-paper parameter registry.

ID	Parameter	Value or range	Current status
`ABC-X-PAR-001`	Mean Earth radius	6371 km	Geometry convention
`ABC-X-PAR-002`	Mini Aegean latitude	36.47°N	Author-source coordinate
`ABC-X-PAR-003`	Mini Aegean longitude	22.95°E	Author-source coordinate
`ABC-X-PAR-004`	Everest latitude	27.99°N	Author-source coordinate
`ABC-X-PAR-005`	Everest longitude	86.93°E	Author-source coordinate
`ABC-X-PAR-006`	Mariana latitude	11.32°N	Author-source coordinate
`ABC-X-PAR-007`	Mariana longitude	142.25°E	Author-source coordinate
`ABC-X-PAR-008`	Proposed flagship age	256 Ma	Unresolved
`ABC-X-PAR-009`	Present midpoint threshold	$\leq 5^\circ$	Source working threshold
`ABC-X-PAR-010`	Exploratory event energy	10^{29} to 10^{31} J	Search interval
`ABC-X-PAR-011`	Exploratory event speed	10 to 30 $\mathrm{km\,s^{-1}}$	Search interval
`ABC-X-PAR-012`	Illustrative projectile density	3000 $\mathrm{kg\,m^{-3}}$	Assumed
`ABC-X-PAR-013`	Derived mass	2.22×10^{20} to 2.00×10^{23} kg	Conditional calculation
`ABC-X-PAR-014`	Equivalent diameter	521 to 5031 km	Conditional calculation
`ABC-X-PAR-015`	Momentum	6.67×10^{24} to 2.00×10^{27} $\mathrm{kg\,m\,s^{-1}}$	Conditional calculation
`ABC-X-PAR-016`	Terminal energy fraction	0.1 to 0.5	Unvalidated assumption
`ABC-X-PAR-017`	Terminal energy	10^{28} to 5×10^{30} J	Conditional calculation
`ABC-X-PAR-018`	Long-timescale viscosity diagnostic	10^{21} Pa s	Transient relevance questioned
`ABC-X-PAR-019`	Coordinate perturbation bounds	To be frozen	Unresolved
`ABC-X-PAR-020`	Paleogeographic uncertainty	Reconstruction dependent	Unresolved
`ABC-X-PAR-021`	Boundary thresholds	Model dependent	Unconstrained
`ABC-X-PAR-022`	Persistence kernels	Model dependent	Unconstrained
`ABC-X-PAR-023`	Integrated score weights	To be preregistered	Unfrozen
`ABC-X-PAR-024`	Equivalence thresholds	To be preregistered	Unfrozen
`ABC-X-PAR-025`	Prediction-superiority threshold	To be preregistered	Unfrozen

109.3 Parameter Dependency

The event scale obeys:

$$m = \frac{2E}{v^2}, \tag{645}$$

$$D = 2\left(\frac{3m}{4\pi\rho}\right)^{1/3}, \tag{646}$$

and

$$p = mv. \tag{647}$$

The atlas must preserve the resulting covariance.

109.4 Parameter Authority Order

For shared parameter p_i, authority follows:

1. verified primary measurement or dataset;
2. reproducible calculation from verified inputs;
3. frozen model parameter with declared prior;
4. author-source search interval;
5. provisional working value.

109.5 Parameter Conflict Rule

If papers use different values for the same shared parameter, the difference must be classified as:

- physically different scope;
- updated source value;
- revised calculation;
- branch-specific value;
- or unresolved inconsistency.

110 Series-Wide Chronology Audit

110.1 Flagship Initiating-Age Canonicalization

The series-wide atlas records

$$a_{\mathrm{init},F} = 256 \text{ Ma}, \qquad \sigma_{a,\mathrm{init},F} = \texttt{TO-BE-CONSTRAINED}. \tag{648}$$

The first quantity identifies the specific initiating-event hypothesis. The second records uncertainty in independent chronological support. A sensitivity analysis may vary within a frozen uncertainty envelope but may not silently turn the specific age into a broad movable interval.

The dependency consequence is scoped:

$$\neg\mathcal{V}_{a,F} \Longrightarrow \neg C_{a,F} \quad \text{and} \quad \neg\mathcal{V}_{\mathcal{S}:F\in\mathcal{S}}, \tag{649}$$

where $C_{a,F}$ is the flagship age claim and the second term applies only to sequences that require the flagship event. No implication to an independent event or the complete model family is permitted without an additional dependency edge.

110.2 Chronology Graph

The chronology graph is

$$\mathcal{G}_T = (\mathcal{N}_T, \mathcal{E}_T)\,, \tag{650}$$

where nodes are dated events, states, boundaries, motions, and structures, and directed edges represent required causal precedence.

110.3 Chronology Node

$$\mathbf{T}_i = (\mathrm{ID}_i, \tau_i, a_i, \sigma_{\tau,i}, \mathrm{source}_i, \mathrm{meaning}_i, \mathrm{status}_i)\,. \tag{651}$$

110.4 Causal Edge

For cause i and effect j,

$$e^T_{ij} = (i, j, \Delta\tau_{ij}, \mathcal{K}_{ij}, \mathrm{status}_{ij})\,, \tag{652}$$

where $\mathcal{K}_{ij}$ is a physically defined response kernel.

110.5 Causal Ordering Probability

For uncertain ages,

$$P^{\mathrm{order}}_{ij} = \Pr(\tau_i \le \tau_j)\,. \tag{653}$$

110.6 Response-Lag Distribution

$$p\,(\Delta\tau_{ij} \mid \mathcal{M}, \boldsymbol{\Theta}) \tag{654}$$

must be derived from the mechanism or independently constrained.

110.7 Chronology Audit Table

Table 59: Series-wide chronology audit requirements.

Chronology domain	Required audit	Current status
Flagship event	Independent support for the proposed 256 Ma age	Unresolved
Entrance structure	Formation, reactivation, and modern-expression ages	Unassembled
Midpoint structure	Formation, uplift, deformation, and inheritance ages	Unassembled
Terminal structure	Formation, descent, migration, and reactivation ages	Unassembled
Additional events	Independent ages and uncertainties	Provisional
Boundary initiation	Initial failure or localization age	Unassembled
Boundary reactivation	Later activation and inversion ages	Unassembled
Plate-motion changes	Finite-rotation and velocity-change intervals	Unassembled
Mountain growth	Shortening, thickening, uplift, and erosion history	Unassembled
Ridge and rift evolution	Opening and material-age progression	Unassembled
Basin history	Subsidence, sedimentation, loading, and inversion	Unassembled
Volcanism	Initiation, peak, migration, and termination	Unassembled
Terrane transfer	Separation, transport, docking, and suturing	Unassembled

110.8 Event-Time Coordinate Requirement

Every candidate event path must use material coordinates at event time:

$$\mathbf{x}_i(\tau_k) = \mathcal{R}^{-1}\left[\mathbf{x}_i(a_{\text{start}}), \tau_k, a_{\text{start}}\right]. \tag{655}$$

110.9 Modern-Coordinate Prohibition

A present-day great circle must not be described as an ancient event path without:

- plate or block reconstruction;
- terrane lineage;
- reference-frame declaration;
- reconstruction uncertainty;
- and event-time recalculation.

110.10 Chronology Viable Set

$$\mathcal{V}_{\text{chronology}} = \bigcap_{i \to j} \left\{ \boldsymbol{\Theta} : P_{ij}^{\text{order}} \geq P_{\text{order,crit}} \right\}. \tag{656}$$

110.11 Chronology Failure

The relevant claim fails when:

$$\mathcal{V}_{\text{chronology}} = \varnothing. \tag{657}$$

111 Source-Verification and Unsupported-Claim Ledger

111.1 Source-Verification Principle

The atlas records what the available author materials support.

It does not treat an author source as independent confirmation of the author's hypothesis.

111.2 Verified Internal Source Classes

The current internal source corpus includes:

- the canonical Papers I through V;
- *The Great Dying Challenge*;
- *WP List Creation*;
- broad exploratory author documents;
- audited internal calculations;
- and drafting and revision records.

111.3 Source-Support Classes

For claim c_i, source support is classified as:

- exact source support;
- partial source support;
- author inference from source;
- model-derived;
- calculated from source inputs;
- source conflict;
- source absent;
- or independent external support not yet assembled.

111.4 Source-Verification Ledger

Table 60: Current source-verification ledger.

Source domain	What is presently supported	What remains unsupported
Flagship source	The author proposed the Aegean–Everest–Mariana hypothesis, working coordinates, energy search interval, midpoint band, and falsifiers.	Independent historical and physical validation

Source domain	What is presently supported	What remains unsupported
Working claim inventory	The author considered entrance, midpoint, exit, Pacific, trench, mountain, and global-tectonic extensions.	Independent evidence for those extensions
Canonical Paper I	Current geometry, claim boundaries, and falsification architecture	External paleogeography, chronology, and nulls
Canonical Paper II	Current branch taxonomy, corrected calculations, and viable-set architecture	Complete mechanical simulation
Canonical Paper III	Current reconstruction architecture and global falsifiers	Complete global reconstruction
Canonical Paper IV	Current comparison and decision architecture	Completed comparative adjudication
Canonical Paper V	Current claim, equation, data, prediction, and falsification ontology	Full populated machine-readable atlas

111.5 Unsupported-Claim Registry

The following claims remain unsupported or unresolved unless additional verified evidence is added:

Table 61: Principal unresolved or unsupported claims.

ID	Unresolved claim	Required support
`ABC-X-CLM-002`	A large event occurred at the proposed flagship age.	Independent chronology and event evidence
`ABC-X-CLM-003`	The selected Aegean point is an entrance structure.	Regional geology and event diagnostics
`ABC-X-CLM-004`	The selected Mariana point is a terminal structure.	Regional and deep-Earth diagnostics
`ABC-X-CLM-005`	Everest preserves a causal midpoint response.	Event-time geometry, chronology, mechanics
`ABC-X-CLM-006`	The flagship path existed in event-time material coordinates.	Paleogeographic reconstruction
`ABC-X-CLM-007`	The flagship relationship is statistically exceptional.	Selection-aware null models
`ABC-X-CLM-008`	At least one transmission branch is mechanically viable.	Numerical Paper-II solution
`ABC-X-CLM-009`	The event satisfies whole-Earth survival and rotation constraints.	Energy, momentum, and angular-momentum closure
`ABC-X-CLM-010`	A persistent event-derived path remains observable.	Preservation model and independent observations
`ABC-X-CLM-011`	The broader event catalog represents real historical events.	Event-by-event evidence
`ABC-X-CLM-012`	Events generated the major global boundary network.	Paper-III forward reconstruction
`ABC-X-CLM-013`	Events generated the major global plate-motion hierarchy.	Dynamic Euler-vector and velocity prediction

ID	Unresolved claim	Required support
ABC-X-CLM-014	Events generated global mountain, trench, ridge, basin, plateau, and volcanic organization.	Shared-state structural prediction
ABC-X-CLM-015	The model explains terrane and continental assembly.	Lineage, trajectory, and chronology
ABC-X-CLM-016	The model predicts deep gravity, seismic, magnetic, and thermal fields.	Forward geophysical tests
ABC-X-CLM-017	The model outperforms realistic null sequences.	Preregistered null analysis
ABC-X-CLM-018	The astro-ballistic component is necessary.	Ablation analysis
ABC-X-CLM-019	The model outperforms strong Plate-Tectonic implementations.	Matched Paper-IV comparison
ABC-X-CLM-020	The model predicts withheld or new evidence.	Frozen advance predictions
ABC-X-CLM-021	The final ranking is independently reproducible.	Independent replication
ABC-X-CLM-022	Astro-Ballistic Chronostratigraphic Sequencing qualifies as a primary replacement.	All preceding requirements

111.6 Source-Verification Completion

A claim is source-complete only when:

$$I_{S,c}^{\text{complete}} = I_{\text{source}} I_{\text{passage}} I_{\text{interpretation}} I_{\text{version}} I_{\text{provenance}}. \tag{658}$$

111.7 External Bibliography Limitation

The complete external primary-source bibliography has not been assembled inside the present companion draft.

No unverified external citation is invented in the embedded bibliography.

112 Contradiction, Supersession, and Circularity Atlas

112.1 Cross-Paper Revision Ledger

Table 62: Principal cross-paper revisions and clarifications.

ID	Earlier issue	Canonical resolution
ABC-X-REV-001	Original source positioning stated that the flagship hypothesis was not a replacement of Plate Tectonics.	The current series explicitly tests a replacement thesis while preserving the earlier source wording as superseded positioning.
ABC-X-REV-002	Near-equal bilateral distances could be described as an exact midpoint.	The atlas separates bilateral equality, exact midpoint, cross-track distance, and projected halfway station.
ABC-X-REV-003	The present-coordinate Everest midpoint relationship was presented too strongly.	The exact present midpoint misfit is 13.558849°, outside the source 5° band.

ID	Earlier issue	Canonical resolution
ABC-X-REV-004	A modern great-circle path could be interpreted as an event-time path.	Event-time material-coordinate reconstruction is mandatory.
ABC-X-REV-005	Earlier mass values were inconsistent with energy and velocity bounds.	The corrected mass range is 2.22×10^{20} to 2.00×10^{23} kg.
ABC-X-REV-006	Earlier equivalent-size values inherited the mass inconsistency.	The corrected illustrative diameter range is 521 to 5031 km.
ABC-X-REV-007	A Reynolds-number statement implied $\mathrm{Re} \gg 1$.	The declared scaling gives $\mathrm{Re} \approx 5.12 \times 10^{-7}$.
ABC-X-REV-008	A Rossby-number statement implied rotational dominance.	The declared scaling gives $\mathrm{Ro} \approx 21.4$.
ABC-X-REV-009	Projectile transit could be confused with shock travel.	Projectile, shock, damage-front, relaxation, and thermal times are separate.
ABC-X-REV-010	The terminal-energy range could extend to the incident maximum.	With $f_{\mathrm{exit}} \leq 0.5$, the corrected maximum is 5×10^{30} J.
ABC-X-REV-011	Below-binding energy could be treated as proof of survival.	Binding energy is one benchmark inside a multidimensional survival test.
ABC-X-REV-012	"Passed through Earth" could imply an intact projectile.	The operational definition permits coherent, fragmented, shock, phase-front, and hybrid transmission.
ABC-X-REV-013	Ancient event impulse could be treated as direct perpetual power.	Impulse may initialize or redirect motion; continuing forces and power are required.
ABC-X-REV-014	Modern plate polygons could be projected unchanged through time.	The canonical reconstruction uses evolving material domains and lineage.
ABC-X-REV-015	Modern trenches could be labeled direct exit craters.	Excavation, collapse, bending, underthrusting, descent, and hybrid mechanisms are tested separately.
ABC-X-REV-016	Regional success could imply global replacement.	Local, regional, multi-regional, complementary, hybrid, and global classifications are separated.

112.2 Circularity Classes

The series audits the following circularity classes:

Coordinate-selection circularity
: Feature coordinates are selected to improve the geometry and then treated as independent evidence.

Reconstruction circularity
: A reconstruction is tuned to the proposed path and then used to validate the path.

Velocity circularity
: Observed plate velocities are inserted as causal inputs and then reported as predictions.

Boundary circularity
: Modern boundaries are supplied to the model and then described as generated.

Structure-assignment circularity
: Structures are assigned to events after inspection and then counted as predictive success.

Source circularity
: An author hypothesis is cited as independent confirmation of the same author hypothesis.

Model-output circularity
: A model-generated state is reused as independent evidence for the model.

Holdout circularity
: A repeatedly viewed test set is still labeled independent.

Decision circularity
: Thresholds are altered after observing which model wins.

112.3 Circularity Indicator

For claim c,

$$I_c^{\text{circ}} = \begin{cases} 1, & \text{if every support path returns to model-selected information,} \\ 0, & \text{if at least one independent support path exists.} \end{cases} \tag{659}$$

112.4 Circular Support Status

A circular claim receives:

$$\texttt{CIRCULAR-SUPPORT} \tag{660}$$

and cannot be upgraded through that support path.

112.5 Contradiction Resolution Record

A resolved contradiction requires:

$$\mathbf{D}_{\text{resolve}} = (\text{conflict ID}, \text{evidence}, \text{decision}, \text{affected nodes}, \text{version}, \text{reviewer}, t)\,. \tag{661}$$

113 Cross-Paper Dependency and Failure-Cut Analysis

113.1 Complete Dependency Graph

The complete dependency graph is

$$\mathcal{G}_X = (\mathcal{N}_X, \mathcal{E}_X)\,, \tag{662}$$

with

$$\mathcal{N}_X = \mathcal{N}_{P1} \cup \mathcal{N}_{P2} \cup \mathcal{N}_{P3} \cup \mathcal{N}_{P4} \cup \mathcal{N}_{P5}. \tag{663}$$

113.2 Series Dependency Spine

$$\begin{aligned} C_{\text{replacement}} \Leftarrow & C_{\text{comparison}} \Leftarrow C_{\text{reconstruction}} \\ \Leftarrow & C_{\text{mechanics}} \Leftarrow C_{\text{geometry}}. \end{aligned} \tag{664}$$

113.3 Parallel Confirmation Dependencies

The replacement claim also requires:

$$C_{\text{replacement}} \Leftarrow \{C_{\text{prediction}}, C_{\text{null}}, C_{\text{complexity}}, C_{\text{replication}}\}. \tag{665}$$

113.4 Mandatory Gate Set

For one candidate event sequence $\mathcal{S}$, the mandatory gate set is

$$\mathcal{G}_{\text{mandatory},\mathcal{S}} = \{G_{I,k}, G_{II,k}\}_{k\in\mathcal{S}} \cup \{G_{III,\mathcal{S}}, G_{IV,\mathcal{S}}, G_{\text{prediction}}, G_{\text{replication}}\}. \tag{666}$$

113.5 Series Eligibility Set

For an eligible sequence $\mathcal{S}$, define the physical and historical series eligibility set

$$\mathcal{V}^{\text{elig}}_{\text{series},\mathcal{S}} = \left[\bigcap_{k\in\mathcal{S}} (\mathcal{V}_{I,k} \cap \mathcal{V}_{II,k})\right] \cap \mathcal{V}_{III,\mathcal{S}} \cap \mathcal{V}^{\text{elig}}_{IV,\mathcal{S},\text{ABC}}. \tag{667}$$

The model-family series eligibility set is the union over preregistered eligible sequences:

$$\boxed{\mathcal{V}^{\text{elig}}_{\text{series}} = \bigcup_{\mathcal{S}\in\mathfrak{S}_{\text{elig}}} \mathcal{V}^{\text{elig}}_{\text{series},\mathcal{S}}.} \tag{668}$$

Failure of one event or one sequence removes only the affected terms from this union. The model family becomes globally ineligible only when the entire union is empty. Replacement qualification additionally requires the separate null, prediction, complexity, causal-necessity, and replication gates.

113.6 Series-Level Eligibility Failure Condition

$$\mathcal{V}^{\text{elig}}_{\text{series}} = \varnothing \Rightarrow \text{global astro-ballistic model family ineligible.} \tag{669}$$

When the eligibility union is nonempty but one or more qualification gates fail or remain unresolved, replacement is disfavored, not established, or unresolved rather than physically falsified.

113.7 Minimum Failure Cut Sets

Representative model-family cut sets include:

$$\mathcal{K}_1 = \{\mathcal{V}_{\mathrm{III}}\}\,, \tag{670}$$
$$\mathcal{K}_2 = \{\mathcal{V}_{IV,\mathrm{ABC}}\}\,, \tag{671}$$
$$\mathcal{K}_3 = \{\mathcal{V}_{\mathrm{prediction}}\}\,, \tag{672}$$
$$\mathcal{K}_4 = \{\mathcal{V}_{\mathrm{replication}}\}\,. \tag{673}$$

An event-specific set such as $\mathcal{V}_{II,F}$ is a cut set only for sequences that require event F. It becomes a model-family cut set only if every eligible global sequence requires that same event.

113.8 Compound Cut Set

The flagship-specific chain has cut set

$$\mathcal{K}_{\mathrm{flagship}} = \{\mathcal{V}_{\mathrm{paleogeography}}, \mathcal{V}_{\mathrm{chronology}}, \mathcal{V}_{II}\}\,. \tag{674}$$

113.9 Failure Propagation Matrix

Table 63: Cross-paper failure propagation.

Failed node	**Direct propagation**	**Does not automatically reject**
Present midpoint criterion	Rejects literal present-coordinate midpoint branch	Event-time reconstruction
Flagship paleogeography	Rejects flagship event assignment	Other candidate events
Coherent transmission	Rejects coherent-body branch	Other Paper-II branches
All Paper-II branches	Rejects Paper-II handoff and global event-derived reconstruction	Non-event geological observations
Global boundary generation	Rejects global Paper-III causal reconstruction	Regional event hypotheses
Global motion generation	Rejects primary global motion replacement	Local structural inheritance
Advance prediction	Rejects confirmatory replacement status	Exploratory reconstruction
Independent replication	Rejects confirmatory preference	Original exploratory result
Astro-ballistic model	Rejects that candidate	Plate Tectonics or hybrid by logical necessity
Plate-Tectonic model	Rejects that implementation	Astro-ballistic model by logical necessity

113.10 No Converse Inference

Failure of model A does not establish model B:

$$\neg A \not\Rightarrow B. \tag{675}$$

113.11 Criticality Ranking

The highest-priority series nodes are:

1. Paper-I event-time geometry;
2. Paper-I chronology;
3. Paper-II complete mechanical viability;
4. Paper-II whole-Earth closure;
5. Paper-III material lineage;
6. Paper-III global boundary generation;
7. Paper-III force, torque, and Euler-vector solution;
8. Paper-IV matched strong comparison;
9. Paper-IV effective complexity;
10. advance prediction;
11. and independent replication.

114 Series-Wide Prediction Atlas

114.1 Prediction Packet

Every prediction packet contains:

$$\begin{aligned}\mathbf{P}_j = \big(&\mathrm{ID}, \mathrm{paper}, \mathrm{model}, \mathrm{version}, \mathrm{exact\ claim}, \\ &\mathrm{location}, \mathrm{depth}, \mathrm{age}, \mathrm{direction}, \mathrm{magnitude}, \\ &\mathrm{uncertainty}, \mathrm{negative\ domain}, \mathrm{data\ cutoff}, \\ &\mathrm{freeze\ date}, \mathrm{test}, \mathrm{score}, \mathrm{falsifier}\big).\end{aligned} \tag{676}$$

114.2 Prediction Families

Table 64: Series-wide prediction families.

Paper	**Prediction family**	**Current status**
Paper I	Event-time midpoint, reconstructed bilateral geometry, entrance, midpoint, terminal signatures, null superiority	Draft
Paper II	Surviving transmission branch, deep path state, midpoint-response inheritance, terminal state, global markers, survival exclusions	Draft

Paper	Prediction family	Current status
Paper III	Boundary network, plate partition, Euler vectors, speed hierarchy, mountains, trenches, ridges, basins, plateaus, volcanism, terranes	Draft
Paper IV	Withheld boundary continuation, motion, concealed structure, gravity, seismic, magnetic, thermal, and negative-control outcomes	Not frozen

114.3 Prediction Eligibility

A prediction is prospectively eligible when:

$$I_P^{\text{eligible}} = I_{\text{frozen}} I_{\text{specific}} I_{\text{uncertainty}} I_{\text{control}} I_{\text{independent data}} I_{\text{score}}. \tag{677}$$

114.4 Prediction Specificity

Spatial specificity is

$$S_{\text{spatial}} = 1 - \frac{A_{\text{pred}}}{A_{\text{eligible}}}. \tag{678}$$

Temporal specificity is

$$S_{\text{temporal}} = 1 - \frac{\Delta t_{\text{pred}}}{\Delta t_{\text{eligible}}}. \tag{679}$$

Directional specificity may be represented as

$$S_{\text{direction}} = 1 - \frac{\Delta \theta_{\text{pred}}}{\pi}. \tag{680}$$

114.5 Combined Specificity

$$S_{\text{spec}} = S_{\text{spatial}} S_{\text{temporal}} S_{\text{direction}} S_{\text{magnitude}}. \tag{681}$$

114.6 Prediction Scoring

For prediction j,

$$S_j = \log p\left(\mathbf{D}_j^{\text{obs}} \mid \mathbf{P}_j\right) - \lambda_{\text{FP}} N_j^{\text{false positive}}. \tag{682}$$

114.7 Prediction Ledger Requirements

The ledger must preserve:

- failed predictions;

- ambiguous predictions;
- partial predictions;
- revised predictions;
- data leakage;
- and false positives.

114.8 Prediction Failure Rule

A prediction is not rescued by:

- widening its domain after inspection;
- changing its sign;
- changing its date window;
- substituting another structure;
- or reclassifying it as illustrative.

114.9 Current Prediction Status

The series contains many defined prediction classes but no complete frozen and prospectively validated prediction program.

The current prediction status is:

$$\texttt{ARCHITECTURE-DEFINED-PROSPECTIVE-VALIDATION-PENDING}. \tag{683}$$

115 Series-Wide Falsification Atlas

115.1 Falsification Hierarchy

The series falsification hierarchy is:

$$\mathfrak{F}_{\text{series}} = \{\mathfrak{F}_{\text{calculation}}, \mathfrak{F}_{\text{event}}, \mathfrak{F}_{\text{mechanism}}, \mathfrak{F}_{\text{regional}}, \mathfrak{F}_{\text{global}}, \mathfrak{F}_{\text{replacement}}\}. \tag{684}$$

115.2 Series-Wide Falsification Registry

Table 65: Principal series-wide falsifiers.

ID	Falsification condition	Scope
ABC-X-FAL-001	Independent calculation cannot reproduce the registered geometry.	Calculation integrity
ABC-X-FAL-002	Verified feature coordinates materially eliminate the geometric relationship.	Flagship geometry

ID	Falsification condition	Scope
ABC-X-FAL-003	Event-time reconstruction fails the frozen path and midpoint criteria.	Flagship event
ABC-X-FAL-004	The proposed feature ages are incompatible with one causal event.	Flagship chronology
ABC-X-FAL-005	Opportunity-matched nulls produce the geometry commonly.	Flagship significance
ABC-X-FAL-006	All coherent, fragmented, shock, phase-front, and hybrid branches fail.	Paper-II mechanics
ABC-X-FAL-007	Required energy, momentum, or angular momentum violates planetary constraints.	Paper-II survival
ABC-X-FAL-008	No admissible terminal state exists.	Paper-II terminal branch
ABC-X-FAL-009	Required global markers are absent under adequate detection.	Paper-II marker branch
ABC-X-FAL-010	Paper III requires fields not generated by a surviving Paper-II state.	Cross-paper handoff
ABC-X-FAL-011	No material-lineage reconstruction exists.	Paper-III history
ABC-X-FAL-012	No event sequence generates a connected global boundary network.	Paper-III boundaries
ABC-X-FAL-013	No event sequence generates a closed global motion solution.	Paper-III motion
ABC-X-FAL-014	The model requires fitted observed Euler vectors.	Paper-III causation
ABC-X-FAL-015	The model violates force, torque, power, or dissipation constraints.	Paper-III dynamics
ABC-X-FAL-016	The same state cannot predict the required structural classes.	Paper-III surface
ABC-X-FAL-017	Structures precede their assigned causes.	Paper-III chronology
ABC-X-FAL-018	Randomized event sequences perform comparably.	Paper-III specificity
ABC-X-FAL-019	The model fails withheld regions or structure classes.	Paper-III prediction
ABC-X-FAL-020	The astro-ballistic model fails matched Paper-IV eligibility.	Paper-IV comparison
ABC-X-FAL-021	The model omits mandatory observation classes.	Paper-IV coverage
ABC-X-FAL-022	The astro-ballistic mechanism is unnecessary under ablation.	Paper-IV causation
ABC-X-FAL-023	Its advantage disappears after effective complexity is counted.	Paper-IV ranking
ABC-X-FAL-024	A strong comparison model has higher marginal evidence.	Paper-IV preference
ABC-X-FAL-025	A strong comparison model predicts withheld evidence better.	Paper-IV prediction
ABC-X-FAL-026	Model differences remain within frozen equivalence thresholds.	Paper-IV non-resolution
ABC-X-FAL-027	Independent teams do not reproduce the qualification result or ranking.	Replacement confirmation
ABC-X-FAL-028	The complete series eligibility set is empty.	Global model-family eligibility
ABC-X-FAL-029	No tested model explains the complete shared domain.	Shared failure

115.3 Series-Level Hard Falsifier

The frozen global astro-ballistic model family is rejected on hard eligibility grounds only when a completed evaluation of the registered T0 physical and chronological conditions gives:

$$\mathcal{V}_{\text{series}}^{\text{elig}} = \varnothing. \tag{685}$$

T3 or T4 comparative-gate failure prevents or disfavors replacement qualification but does not empty this eligibility union. If one or more mandatory eligibility sets have not been evaluated, the series status is unresolved rather than empty.

115.4 Series-Level Non-Resolution

The result is causal non-resolution when:

$$\mathcal{V}_{\text{ABC}} \neq \varnothing, \qquad \mathcal{V}_{\text{PT}} \neq \varnothing, \tag{686}$$

but:

$$|\mathcal{J}_{\text{ABC}} - \mathcal{J}_{\text{PT}}| \leq \delta_J \tag{687}$$

and predictive differences remain inside the frozen equivalence interval.

115.5 Compartmentalized Survival

A local or regional claim may survive global failure only if:

$$\mathcal{V}_r = \mathcal{V}_{\text{geometry},r} \cap \mathcal{V}_{\text{mechanics},r} \cap \mathcal{V}_{\text{chronology},r} \cap \mathcal{V}_{\text{prediction},r} \neq \varnothing. \tag{688}$$

116 Reader Navigation and Query Architecture

116.1 Reader Entry Modes

A reader may enter through:

- a paper;
- a section;
- a claim;
- an equation;
- a parameter;
- a source;
- a dataset;

- an event;
- a boundary;
- a structure;
- a prediction;
- a falsifier;
- a contradiction;
- a model version;
- or the final decision.

116.2 Claim Navigation

For claim c_i,

$$\begin{aligned}\mathcal{N}(c_i) = \{&\text{text}, \text{location}, \text{status}, \text{equations}, \text{assumptions},\\ &\text{parameters}, \text{data}, \text{tests}, \text{falsifiers}, \text{descendants}\}.\end{aligned} \tag{689}$$

116.3 Equation Navigation

For equation e_i,

$$\mathcal{N}(e_i) = \{\text{LaTeX}, \text{variables}, \text{units}, \text{source}, \text{derivation}, \text{domain}, \text{uses}, \text{results}, \text{audit}\}. \tag{690}$$

116.4 Prediction Navigation

For prediction p_i,

$$\mathcal{N}(p_i) = \{\text{claim}, \text{freeze}, \text{data cutoff}, \text{domain}, \text{uncertainty}, \text{control}, \text{score}, \text{outcome}\}. \tag{691}$$

116.5 Falsifier Navigation

For falsifier f_i,

$$\mathcal{N}(f_i) = \{\text{target}, \text{condition}, \text{threshold}, \text{data}, \text{test}, \text{status}, \text{propagation}\}. \tag{692}$$

116.6 Final Decision Navigation

The final decision node must permit navigation to:

- every mandatory gate;
- every component viable set;
- every model score;

- every complexity penalty;
- every advance prediction;
- every triggered falsifier;
- every replication result;
- and every unresolved dependency.

116.7 Reader Query Table

Table 66: Representative reader queries.

Reader question	**Atlas response**
Which Paper-I claims are numerically reproduced?	Return Paper-I claims linked to reproduced result nodes.
Which flagship claims failed?	Return the triggered present-coordinate midpoint falsifier and its limited descendants.
Which parameters remain assumptions?	Return all parameter nodes with role `ASSUMPTION` or epistemic state `UNRESOLVED`.
Which Paper-II branch is viable?	Return branch viable sets and current simulation status.
Which Paper-III claims depend on a coherent body?	Traverse required edges from the coherent-branch node.
Which claims use the 10^{29} to 10^{31} J range?	Return all descendant claims, equations, and results.
Which claims depend on event-time paleogeography?	Return all descendants of the paleogeographic reconstruction node.
Which predictions are genuinely frozen?	Return prediction nodes with complete freeze and data-cutoff records.
Which falsifiers have triggered?	Return all nodes with status `TRIGGERED`.
What blocks the replacement decision?	Return the unresolved mandatory gate set and minimum failure cut sets.
What survives if the flagship event fails?	Return claims without required dependency paths through the flagship node.
Which model currently wins?	Return `NO-COMPLETED-ADJUDICATION`.

116.8 Atlas Dashboard

The dashboard reports:

$$\mathbf{D}_{\text{dash}} = (N_{\text{claims}}, N_{\text{equations}}, N_{\text{sources}}, N_{\text{predictions}}, N_{\text{falsifiers}}, N_{\text{contradictions}}, N_{\text{complete}}, N_{\text{unresolved}}) . \tag{693}$$

116.9 Reader Integrity Rule

A navigation summary must always preserve:

- exact status;
- scope;
- uncertainty;
- and unresolved dependencies.

117 Machine-Readable Companion Schema

The machine-readable package follows the general goals of findable, accessible, interoperable, reusable, versioned, and provenance-preserving research objects [37, 38, 39].

117.1 Canonical Package

The machine-readable companion package is:

```
abc-sequencing-atlas/
|
|-- README.md
|-- LICENSE.txt
|-- CITATION.cff
|-- CHANGELOG.md
|
|-- manuscript/
|   |-- paper-i/
|   |   `-- main.tex
|   |-- paper-ii/
|   |   `-- main.tex
|   |-- paper-iii/
|   |   `-- main.tex
|   |-- paper-iv/
|   |   `-- main.tex
|   `-- paper-v/
|       `-- main.tex
|
|-- registries/
|   |-- claims.csv
|   |-- equations.csv
|   |-- assumptions.csv
|   |-- parameters.csv
|   |-- datasets.csv
|   |-- sources.csv
|   |-- models.csv
|   |-- methods.csv
|   |-- results.csv
|   |-- predictions.csv
```

```
|   |-- falsifiers.csv
|   |-- decisions.csv
|   |-- causal-edges.csv
|   |-- causal-paths.csv
|   |-- alternatives.csv
|   |-- interventions.csv
|   |-- contradictions.csv
|   |-- scope-reservations.csv
|   |-- coverage-manifest.json
|   |-- answer-contract.json
|   `-- revisions.csv
|
|-- graph/
|   |-- nodes.csv
|   |-- edges.csv
|   |-- dependencies.json
|   |-- failure-cuts.json
|   |-- chronology.json
|   `-- lineage.json
|
|-- data/
|   |-- raw/
|   |-- processed/
|   |-- calibration/
|   |-- validation/
|   |-- holdout/
|   |-- prospective/
|   `-- controls/
|
|-- code/
|   |-- geometry/
|   |-- mechanics/
|   |-- reconstruction/
|   |-- comparison/
|   |-- nulls/
|   |-- prediction/
|   `-- audit/
|
|-- environments/
|   |-- environment.yml
|   |-- requirements.txt
|   |-- container.def
|   `-- system-info.txt
|
```

```
|-- runs/
|   |-- paper-i/
|   |-- paper-ii/
|   |-- paper-iii/
|   |-- paper-iv/
|   `-- replication/
|
|-- audits/
|   |-- source-audit.csv
|   |-- symbol-audit.csv
|   |-- unit-audit.csv
|   |-- dimensional-audit.csv
|   |-- chronology-audit.csv
|   |-- circularity-audit.csv
|   |-- selection-audit.csv
|   |-- prediction-audit.csv
|   |-- companion-readiness.csv
|   `-- replication-audit.csv
|
`-- releases/
    |-- manifest.json
    |-- checksums.txt
    `-- release-notes.md
```

117.2 Claim Schema

The minimum claim object is:

```
{
  "id": "ABC-P3-CLM-014",
  "type": "claim",
  "paper": "P3",
  "exact_text": "",
  "summary": "",
  "class": "",
  "scope": "",
  "provenance": "",
  "scientific_role": "",
  "epistemic_status": "",
  "verification_status": "",
  "publication_status": "",
  "dependencies": [],
  "supporting_results": [],
  "tests": [],
  "falsifiers": [],
```

```
  "downstream_claims": [],
  "version": "",
  "notes": ""
}
```

117.3 Equation Schema

```
{
  "id": "ABC-P2-EQN-010",
  "type": "equation",
  "paper": "P2",
  "latex": "",
  "label": "",
  "role": "",
  "source": "",
  "derivation": "",
  "variables": [],
  "units": [],
  "assumptions": [],
  "domain": [],
  "limits": [],
  "numerical_uses": [],
  "audit_status": [],
  "supported_claims": [],
  "version": ""
}
```

117.4 Prediction Schema

```
{
  "id": "ABC-P4-PRD-001",
  "type": "prediction",
  "model_id": "",
  "model_version": "",
  "exact_prediction": "",
  "location": {},
  "depth": {},
  "age": {},
  "direction": {},
  "magnitude": {},
  "uncertainty": {},
  "negative_control": {},
  "data_cutoff": "",
  "freeze_date": "",
  "scoring_rule": "",
```

```
  "threshold_class": "T3_or_T4",
  "decision_threshold": "",
  "threshold_rationale": "",
  "validation_dataset": "",
  "outcome": "",
  "status": ""
}
```

117.5 Falsifier Schema

```
{
  "id": "ABC-X-FAL-028",
  "type": "falsifier",
  "target_id": "ABC-X-CLM-001",
  "scope": "series",
  "condition": "",
  "measurement": "",
  "threshold": "",
  "threshold_class": "",
  "threshold_freeze_date": "",
  "threshold_rationale": "",
  "uncertainty": "",
  "test_id": "",
  "dataset_ids": [],
  "decision_rule": "",
  "consequence": "",
  "propagation": [],
  "status": "",
  "decision_id": ""
}
```

117.6 Edge Schema

```
{
  "source": "ABC-P2-EQN-010",
  "target": "ABC-P2-RES-001",
  "relationship": "CALCULATED_BY",
  "required": true,
  "scope": "",
  "version": "",
  "notes": ""
}
```

117.7 Causal Edge Schema

```
{
```

```
  "id": "ABC-P3-CED-001",
  "type": "causal_edge",
  "source_id": "",
  "target_id": "",
  "mechanism": "",
  "causal_level": "CAUSAL-L0_to_L6",
  "mandatory": true,
  "assumption_ids": [],
  "mediator_ids": [],
  "confounder_ids": [],
  "dataset_ids": [],
  "test_ids": [],
  "alternative_ids": [],
  "intervention_ids": [],
  "threshold_ids": [],
  "status": "",
  "version": ""
}
```

117.8 Alternative Explanation Schema

```
{
  "id": "ABC-P4-ALT-001",
  "type": "alternative_explanation",
  "target_id": "",
  "model_family": "",
  "exact_explanation": "",
  "scope": "",
  "shared_dataset_ids": [],
  "unique_predictions": [],
  "parameter_ids": [],
  "assumption_ids": [],
  "effective_complexity": {},
  "discriminating_test_ids": [],
  "ablation_test_ids": [],
  "status": "",
  "version": ""
}
```

117.9 Intervention Schema

```
{
  "id": "ABC-P4-INT-001",
  "type": "intervention",
  "target_component_id": "",
```

```
  "operation": "remove_or_replace_or_mediator_ablation",
  "reduced_model_id": "",
  "coherence_gate": {},
  "shared_inputs_preserved": [],
  "compensating_changes": [],
  "loss_before": {},
  "loss_after": {},
  "causal_interpretation_eligible": false,
  "status": "",
  "version": ""
}
```

117.10 CSV Claim Fields

The canonical claim columns are:

```
id,
paper,
type,
exact_text,
summary,
class,
scope,
polarity,
provenance,
scientific_role,
epistemic_status,
verification_status,
publication_status,
location,
source_ids,
equation_ids,
assumption_ids,
parameter_ids,
dataset_ids,
result_ids,
test_ids,
falsifier_ids,
downstream_ids,
version,
notes
```

117.11 Version Record

```
{
  "release_id": "",
```

```
  "corpus_version": "",
  "paper_versions": {},
  "data_versions": {},
  "code_commit": "",
  "environment_hash": "",
  "registry_hash": "",
  "release_date": "",
  "approved_by": ""
}
```

117.12 Registry-Coverage Manifest

The machine-readable release must contain a coverage manifest that states which paper-level scientific objects have been represented in the atlas and which have merely been specified but not yet materialized as external registry files.

```
{
  "corpus_version": "",
  "paper_versions": {},
  "coverage": {
    "P1": {
      "claims": "represented",
      "equations": "represented",
      "assumptions": "represented",
      "parameters": "represented",
      "data_sources": "represented",
      "predictions": "represented",
      "falsifiers": "represented",
      "dependencies": "represented"
    }
  },
  "machine_registry_materialization": "partial_or_complete",
  "validation_status": "",
  "notes": []
}
```

The term `represented` means that the frozen Paper-V atlas contains an explicit human-readable registry architecture for the object class. It does not mean that every corresponding external CSV or JSON row has already been populated or independently validated.

117.13 Companion Answer Contract

Every machine-generated scientific answer must emit an auditable answer record. The minimum record is:

```
{
  "query_id": "",
```

```
  "corpus_version": "",
  "claim_ids": [],
  "exact_claim_text": [],
  "status": [],
  "scope": [],
  "equation_ids": [],
  "assumption_ids": [],
  "dataset_ids": [],
  "source_ids": [],
  "dependency_ids": [],
  "prediction_ids": [],
  "falsifier_ids": [],
  "negative_result_ids": [],
  "scope_reserved": false,
  "unresolved_items": [],
  "authority_conflict": false,
  "answer": ""
}
```


A companion response is not scientifically authoritative merely because it is fluent. Its authority is bounded by the frozen records it can cite.

117.14 Machine Validation Rules

Every release must test:

- unique identifiers;
- valid relationship types;
- no missing required references;
- no orphan principal claims;
- every principal claim has an explicit scope and current status;
- every scoped falsifier records its direct consequence and any permitted downstream propagation;
- every registered negative result remains machine-visible;
- every scope-reserved hypothesis carries zero current evidentiary credit and zero rescue permission;
- valid status vocabulary;
- valid units;
- valid version links;
- acyclic required-support graph;
- and reproducible checksums.

117.15 Machine-Readable Integrity

The PDF and machine-readable registries must refer to the same corpus freeze.

A mismatch receives:

$$\texttt{CORPUS-MISMATCH}. \tag{694}$$

118 Registry Completeness and AI-Companion Readiness Audit

118.1 Purpose of This Audit

This audit tests whether Paper V can serve as the controlled verification layer for Papers I–IV without silently converting incomplete research work into completed empirical results. The audit concerns registry coverage, authority, answer discipline, and failure propagation. It does not assert that the external machine-readable registry package has already been fully populated or independently validated.

118.2 Authority Order for Companion Answers

When two representations disagree, the companion applies the following precedence:

1. the frozen source paper governs the exact wording, equation, and scientific statement made in that paper;
2. Paper V governs the cross-paper registry mapping, status vocabulary, dependency architecture, and companion operating rules;
3. external CSV, JSON, graph, or database records must match the same frozen corpus version;
4. an AI-generated answer may summarize these records but may not supersede them.

If the frozen paper and Paper-V registry cannot be reconciled, the answer must report

$$\texttt{CORPUS-MISMATCH} \tag{695}$$

and route the conflict to human review rather than choosing a preferred version.

118.3 Cross-Paper Registry-Coverage Matrix

Table 67: Document-level registry coverage at the Pass-16 readiness audit.

Paper	Atlas coverage	Readiness interpretation
I	Claims; geometry and equations; chronology; data and sources; assumptions and parameters; numerical results; nulls; predictions; falsifiers; dependencies; negative results	`DOCUMENT-REPRESENTED`. Exact machine rows and frozen source-file hashes remain a release task.

Paper	Atlas coverage	Readiness interpretation
II	Mechanical claims; transmission branches; equations; assumptions and parameters; model states; results; predictions; falsifiers; viable sets; dependencies	`DOCUMENT-REPRESENTED`. Full branch simulations remain scientifically unresolved and cannot be inferred by the companion.
III	Claims; event-catalog structure; material lineage; boundaries; impulse and motion; surface structures; equations; assumptions; data families; predictions; falsifiers; dependency graph	`DOCUMENT-REPRESENTED`. A complete global numerical solution is not yet demonstrated.
IV	Comparison claims; datasets; model families; eligibility; score direction; complexity; nulls; predictions; hybrids; decisions; falsifiers; replication requirements	`DOCUMENT-REPRESENTED`. The comparison architecture is present; the final empirical adjudication has not been executed.
V	Cross-paper status, hierarchy, equations, parameters, chronology, source verification, dependencies, predictions, falsifiers, machine schema, replication rules, and companion constraints	`ATLAS-REPRESENTED`. External machine-registry materialization and schema validation remain incomplete.

118.4 Minimum Principal-Claim Coverage Rule

Before the companion may answer a principal scientific claim as anything stronger than `UNRESOLVED`, the registry must expose, where applicable:

1. the exact claim and scope;
2. the current epistemic and verification status;
3. its supporting equation or declared non-equational basis;
4. its assumptions and parameters;
5. the relevant data and source provenance;
6. its dependency and support path;
7. its prediction or explicit statement that no frozen prediction yet exists;
8. its scoped falsifier or explicit statement that the claim is not yet confirmatory-test ready;
9. any registered negative result; and
10. the governing corpus version.

Absence of one of these fields must be visible as missing evidence or missing registry coverage. It must not be filled from model memory.

118.5 Negative-Result Preservation Rule

A negative result cannot disappear because a broader framework remains open. The companion must preserve the exact scope of a negative result and must distinguish it from broader failure propagation. In particular, the present-coordinate literal midpoint misfit remains reportable even while material-lineage or event-time reconstruction branches remain unresolved.

118.6 Non-Domino Failure Rule

For a target claim with eligible support paths $\mathcal{P}_c$, failure of one path removes that path. The companion may report the broader claim as rejected only when the frozen decision architecture requires every eligible support path to fail, or when a separately registered mandatory gate fails. A local failure therefore cannot be promoted automatically to series-wide falsification.

118.7 Initiating-Age Rule

The flagship initiating-event age is the author-declared specific nominal age

$$a_{\mathrm{init},F} = 256 \text{ Ma.} \tag{696}$$

The companion must not broaden this value into an adjustable rescue interval. Younger marker, reactivation, or visible-expression ages must be reported as distinct chronology fields rather than silently redefining the initiating age.

118.8 Scope-Reserved Hypothesis Firewall

Additional directional and material-displacement hypotheses intentionally reserved for later work have

$$\text{current credit} = 0, \qquad \text{rescue permission} = 0. \tag{697}$$

The companion must not infer, reconstruct, enumerate, or use those hypotheses as present evidence. Conversely, an observation deliberately outside the current frozen claim scope is not automatically a failed prediction unless it belongs to a separately declared mandatory coverage class.

118.9 Answer-State Discipline

The companion must preserve the distinction among:

- `SUPPORTED-WITHIN-SCOPE`;
- `UNRESOLVED`;
- `NOT-ESTABLISHED`;

- `DISFAVORED`;
- `REJECTED`;
- and `CORPUS-MISMATCH`.

A fluent explanation is not permitted to collapse these states into a binary true-or-false judgment.

118.10 Pass-16 Readiness Classification

The present corpus is classified as follows:

$$R_{\text{document}} = \texttt{READY-FOR-CONTROLLED-COMPANION-PROTOTYPE}, \tag{698}$$
$$R_{\text{machine}} = \texttt{PARTIAL-MATERIALIZATION}, \tag{699}$$
$$R_{\text{empirical}} = \texttt{UNRESOLVED}. \tag{700}$$

The first status means that the manuscript corpus contains enough explicit claim, status, dependency, falsification, and operating-rule architecture to build and test a constrained companion against the documents. It does not mean that the complete external registry database, all simulations, all empirical tests, or the replacement decision have been completed.

119 Independent Replication Package

119.1 Replication Objective

The replication package must allow an independent team to reproduce:

1. Paper-I geometry;
2. Paper-II corrected calculations;
3. each Paper-II mechanical branch;
4. Paper-III boundary and motion reconstruction;
5. Paper-IV matched model comparison;
6. the null-model analysis;
7. the prediction scores;
8. and the final classification.

119.2 Replication Levels

Table 68: Independent replication levels.

Level	Name	Requirement
R0	Document reproduction	Compile the frozen manuscript package.

Level	Name	Requirement
R1	Calculation reproduction	Recover registered geometry and arithmetic outputs.
R2	Code reproduction	Run released code and recover released outputs.
R3	Independent implementation	Reimplement equations without using the original solver code.
R4	Data replication	Reconstruct the source and data pipeline independently.
R5	Model replication	Recover viable sets and model rankings.
R6	Prediction replication	Validate frozen predictions with independent data.
R7	Decision replication	Recover the final classification under the frozen decision rule.

119.3 Required Run Manifest

Every computational run includes:

$$\begin{aligned}\mathbf{M}_{\text{run}} = \big(&\text{run ID}, \text{model ID}, \text{code version}, \text{data version}, \text{parameters},\\ &\text{seed}, \text{hardware}, \text{software}, \text{outputs}, \text{status}\big).\end{aligned} \tag{701}$$

119.4 Deterministic and Stochastic Runs

A deterministic run must reproduce within declared numerical tolerance.

A stochastic run must reproduce:

- the declared distribution;
- summary statistics;
- uncertainty intervals;
- and model-ranking frequency.

119.5 Independent Solver Requirement

At least one confirmatory implementation should use:

- independently written code;
- independently assembled data;
- independently selected numerical methods;
- and independent reviewers.

119.6 Replication Difference Record

For original result y_o and replicated result y_r,

$$\Delta y = y_r - y_o. \tag{702}$$

For covariance $\mathbf{\Sigma}$,

$$d_{\mathrm{rep}}^2 = \Delta\mathbf{y}^\mathsf{T}\mathbf{\Sigma}^{-1}\Delta\mathbf{y}. \tag{703}$$

119.7 Replication Classification

Exact reproduction
: Outputs match within numerical tolerance.

Statistical reproduction
: Stochastic outputs match the expected distribution.

Scientific reproduction
: Independent implementation reaches the same substantive result.

Partial reproduction
: Some results reproduce and others do not.

Non-reproduction
: The primary result does not reproduce.

Underdetermined
: Missing information prevents meaningful replication.

119.8 Replication Failure

A confirmatory series conclusion fails when independent replication cannot recover:

- the mandatory viable sets;
- the principal model ranking;
- or the registered advance-prediction advantage.

120 Final Production and Publication Checklist

120.1 Manuscript Checklist

Table 69: Final manuscript checklist.

Requirement	Done	Status note
Five canonical one-file manuscripts	☐	Freeze final versions
Consistent titles and subtitles	☐	Series audit
Sole-author and AI-assistance disclosure	☐	Present in Paper V
Consistent first-person singular	☐	Editorial audit
Continental drift and Plate Tectonics distinguished	☐	Terminology audit

Requirement	Done	Status note
All equations numbered and referenced	☐	Compile audit
All symbols defined	☐	Automated symbol audit
All units consistent	☐	Unit audit
All tables fit page width	☐	PDF review
All figures have data provenance	☐	Figure registry
No unsupported factual statement presented as established	☐	Claim audit
No assumption presented as observation	☐	Status audit
No model output presented as independent evidence	☐	Circularity audit
All negative results retained	☐	Revision audit
All superseded results identified	☐	Supersession audit
Embedded bibliography verified	☐	External bibliography incomplete

120.2 Source Checklist

- verify every bibliographic record;
- verify every page and passage citation;
- distinguish primary and secondary sources;
- preserve author-source status;
- record conflicting sources;
- and remove unsupported authority claims.

120.3 Data Checklist

- freeze raw data;
- preserve original files;
- document transformations;
- declare coordinate reference systems;
- declare spatial and temporal resolution;
- preserve uncertainty and covariance;
- separate calibration and validation;
- protect untouched holdouts;
- and release data-use licenses.

120.4 Code Checklist

- release source code;

- freeze code versions;
- document dependencies;
- provide environment files;
- preserve random seeds;
- provide tests;
- provide example runs;
- provide complete run manifests;
- and provide expected outputs.

120.5 Claim Checklist

- assign every principal claim an identifier;
- preserve exact wording;
- assign scope;
- assign provenance;
- assign epistemic status;
- assign verification status;
- link equations;
- link assumptions;
- link parameters;
- link data;
- link tests;
- link falsifiers;
- and link downstream descendants.

120.6 Prediction Checklist

- freeze model version;
- freeze data cutoff;
- state exact location;
- state depth;
- state age;
- state direction;
- state magnitude;

- state uncertainty;
- identify negative controls;
- freeze scoring rule;
- and preserve failed predictions.

120.7 Comparison Checklist

- implement strong competing models;
- use matched data;
- use matched output domains;
- count initial information;
- count effective flexibility;
- test causal ablations;
- run null models;
- test equivalence;
- preserve shared failure as an eligible outcome;
- and freeze decision thresholds.

120.8 Replication Checklist

- reproduce calculations internally;
- commission independent implementation;
- preserve differences;
- test alternate reference frames;
- test alternate reconstruction ensembles;
- test alternate defensible priors;
- test held-out predictions;
- and publish replication status.

120.9 Release Checklist

A complete release requires:

$$I_{\text{release}} = I_{\text{manuscript}} I_{\text{registry}} I_{\text{data}} I_{\text{code}} I_{\text{environment}} I_{\text{audit}} I_{\text{manifest}}. \tag{704}$$

121 Integrated Limitations

121.1 Hypothesis Maturity

The series defines a broad, falsifiable causal framework.

It does not presently provide a completed numerical demonstration of the global replacement thesis.

121.2 Flagship Geometry

The present-coordinate geometry contains both a positive and a negative result:

- near-bilateral surface-distance equality is reproducible;
- literal present-coordinate midpoint collinearity fails the source working threshold.

Event-time reconstruction remains decisive.

121.3 Coordinate Selection

The registered points originate from author source documents.

External feature-definition verification and coordinate uncertainty remain incomplete.

121.4 Paleogeography

The series requires event-time material coordinates but does not presently include a complete paleogeographic reconstruction ensemble.

121.5 Chronology

The proposed flagship age and broader event sequence require independent chronological support.

121.6 Mechanical Transmission

Paper II defines five mechanism branches but does not provide a validated end-to-end transient simulation for any branch.

121.7 Constitutive Uncertainty

Extreme transient response may exceed the validated domain of standard long-timescale rheological approximations.

121.8 Event Scale

The energy, velocity, mass, density, diameter, terminal fraction, and momentum ranges are exploratory or conditionally derived.

They are not independently measured event properties.

121.9 Planetary Survival

A below-binding-energy comparison does not establish survival.

Complete energy, momentum, angular-momentum, atmospheric, oceanic, thermal, and structural consequences remain unresolved.

121.10 Deep-Earth Preservation

The expected survival time and observability of damage, phase, thermal, density, anisotropy, or melt-path signatures remain uncertain.

121.11 Event Catalog

The broader multi-event catalog remains provisional and requires event-by-event geometry, chronology, mechanics, and controls. Some additional directional and material-displacement hypotheses are intentionally `SCOPE-RESERVED`; they receive no current evidentiary credit and are not available as rescue events. Their non-disclosure therefore limits current catalog completeness but does not change the outcome of any test whose mandatory claim set was frozen without them.

121.12 Material Lineage

Ancient plate, block, and terrane material domains have not yet been assembled into the required global lineage graph.

121.13 Boundary Generation

The boundary-nucleation, connectivity, persistence, and reactivation equations define a forward-model architecture but have not yet generated the observed global system.

121.14 Motion Generation

The series requires event-derived impulse, continuing gravity, buoyancy, mantle coupling, boundary traction, force, torque, power, and dissipation.

No complete global motion solution is presently registered.

121.15 Surface Structures

Mountains, trenches, ridges, basins, plateaus, volcanism, terranes, and sutures have defined prediction architectures but not completed common forward solutions.

121.16 Deep Geophysics

Gravity, seismic, magnetic, and thermal forward operators remain to be implemented through one mutually consistent material state.

121.17 Model Comparison

No complete matched comparison with strong Plate-Tectonic and hybrid implementations is presently registered.

121.18 Complexity

The effective information cost of:

- event selection;
- initial conditions;
- regional parameters;
- mechanism choices;
- structure assignments;
- lags;
- preservation;
- reference frames;
- exclusions;
- and revisions

has not yet been numerically calculated.

121.19 Null Models

Opportunity-matched null ensembles have been defined but not completed.

121.20 Multiple Testing

The full historical search space has not yet been reconstructed.

121.21 Advance Prediction

The series defines prospective prediction requirements but does not present a complete frozen validation campaign.

121.22 Independent Replication

No independent team has yet reproduced the complete series.

121.23 Source Completeness

The present companion does not contain the complete externally verified primary-source bibliography required for final scientific publication.

121.24 AI Limitations

AI assistance may:

- improve organization;
- expose contradictions;
- assist symbolic formatting;
- and accelerate registry construction.

AI assistance does not independently establish:

- source truth;
- mathematical correctness;
- physical validity;
- historical occurrence;
- or scientific acceptance.

121.25 Atlas Completeness

Paper V defines the atlas architecture in substantial detail.

The machine-readable registries remain to be populated and audited against the final frozen manuscripts.

121.26 Publication Status

The complete five-paper series remains a working research program until:

- sources are verified;
- calculations are independently reproduced;
- simulations are completed;
- predictions are frozen and tested;
- and the comparative decision is executed.

122 Paper-V Conclusions

122.1 Companion Function

Paper V creates the verification and navigation layer for the four-paper scientific core within the five-paper corpus.

Its governing chain is:

$$\boxed{\text{Claim} \to \text{Equation} \to \text{Assumption} \to \text{Parameter} \to \text{Data} \to \text{Test} \to \text{Falsifier}} \tag{705}$$

122.2 Epistemic Separation

The atlas formally separates:

- source extraction from independent support;
- calculation from observation;
- assumption from result;
- reconstruction from prediction;
- compatibility from causation;
- regional viability from global replacement;
- and model architecture from completed validation.

122.3 Negative Results

The atlas preserves negative and restrictive findings, including:

- failure of the literal present-coordinate midpoint threshold;
- substantial present cross-track separation;
- corrected event mass and size ranges;
- corrected Reynolds and Rossby diagnostics;
- corrected terminal-energy limits;
- the strong burden on coherent-body penetration;
- the inability of ancient impulse alone to sustain modern motion;
- and the absence of a completed global viable set.

122.4 Scientific Discipline

The atlas is designed to prevent the series from receiving credit through:

- selective geometry;
- post hoc event assignment;
- hidden parameter tuning;
- circular use of observed motion;
- omitted failed runs;
- unexplained model switching;
- uncounted complexity;
- or retrospective prediction.

122.5 Series-Level Decision State

The present decision state is

$$\mathbf{D}_{\text{series}}^{\text{current}} = \begin{pmatrix} \text{framework articulated,} \\ \text{equation and claim architecture registered,} \\ \text{selected calculations audited,} \\ \text{major falsifiers defined,} \\ \text{mechanical viability unresolved,} \\ \text{global reconstruction unresolved,} \\ \text{comparative adjudication unresolved,} \\ \text{advance validation pending,} \\ \text{independent replication pending} \end{pmatrix}. \tag{706}$$

122.6 Current Classification

The current classification is:

$$\boxed{\begin{array}{c} \text{Astro-Ballistic Chronostratigraphic Sequencing is a formally specified,} \\ \text{falsifiable candidate causal framework.} \\ \text{Its global replacement thesis is not yet empirically adjudicated.} \end{array}} \tag{707}$$

122.7 Replacement Standard

A primary replacement result requires:

$$\boxed{\mathcal{V}_{\text{series}}^{\text{elig}} \neq \varnothing} \tag{708}$$

together with:

- mechanical admissibility;
- event-time geometric and chronological validity;
- at least one surviving sequence with one global boundary and motion solution;
- common-state structural and geophysical prediction;
- causal necessity;
- realistic null superiority;
- effective-complexity adjustment;
- advance-prediction superiority;
- and independent replication.

122.8 Final Atlas Principle

Final atlas principle.
The purpose of this companion is not to make the series appear more certain than it is.
Its purpose is to make the actual structure of uncertainty inspectable.
A claim that survives the atlas should survive because its sources, equations, assumptions, parameters, data, tests, predictions, and falsifiers remain connected under independent scrutiny.
A claim that fails should remain visible as a scientifically useful failure.
Astro-Ballistic Chronostratigraphic Sequencing should stand or fall through that complete record.

A Canonical Identifier Grammar

A.1 Identifier Form

$$\texttt{ABC-Pn-TYP-NNN} \tag{709}$$

or for cross-paper items:

$$\texttt{ABC-X-TYP-NNN}. \tag{710}$$

A.2 Paper Codes

Code	Meaning
P1	Paper I
P2	Paper II
P3	Paper III
P4	Paper IV
P5	Paper V
X	Cross-paper or series-level item

A.3 Entity Codes

Code	Entity
CLM	Claim
EQN	Equation
ASM	Assumption
PAR	Parameter
DAT	Dataset
SRC	Source
MOD	Model
MET	Method
RES	Result
PRD	Prediction
FAL	Falsifier
FIG	Figure
TAB	Table
DEC	Decision
REV	Revision

B Canonical Status Vocabulary

B.1 Provenance

- `EXTERNAL-PRIMARY`;
- `EXTERNAL-SECONDARY`;

- `AUTHOR-SOURCE`;
- `MANUSCRIPT-DERIVED`;
- `COMPUTATIONAL-OUTPUT`;
- `AI-ASSISTED-ORGANIZATION`;
- `UNRESOLVED-PROVENANCE`.

B.2 Scientific Role

- `OBSERVATION`;
- `ASSUMPTION`;
- `PARAMETER`;
- `DEFINITION`;
- `CALCULATION`;
- `MODEL-OUTPUT`;
- `PREDICTION`;
- `COMPARISON`;
- `DECISION-RULE`;
- `FALSIFIER`.

B.3 Epistemic Status

- `SUPPORTED`;
- `CONDITIONALLY-SUPPORTED`;
- `CONSISTENT-WITH`;
- `UNRESOLVED`;
- `UNSUPPORTED`;
- `DISFAVORED`;
- `FALSIFIED`;
- `SUPERSEDED`;
- `NOT-APPLICABLE`.

B.4 Verification Status

- `UNVERIFIED`;
- `PARTIALLY-VERIFIED`;

- `SOURCE-VERIFIED`;
- `CALCULATION-VERIFIED`;
- `INDEPENDENTLY-VERIFIED`;
- `REPRODUCED`;
- `INDEPENDENTLY-REPRODUCED`;
- `VERIFICATION-FAILED`.

B.5 Publication Status

- `WORKING-DRAFT`;
- `AUTHOR-REVIEWED`;
- `FROZEN`;
- `REVISED`;
- `RETIRED`;
- `SUPERSEDED`.

B.6 Architecture and Requirement Status

These statuses record that a rule, frame, definition, or architecture has been written. They do not indicate empirical confirmation:

- `REQUIREMENT-DEFINED`;
- `ARCHITECTURE-DEFINED`;
- `FRAME-DEFINED`;
- `DEFINITION-REGISTERED`;
- `TEST-REQUIRED`;
- `TEST-READY`.

C Required Record Templates

C.1 Claim Template

Field	**Required entry**
Identifier	Stable canonical ID
Exact claim	Approved text
Location	Paper, section, paragraph, equation, figure, or table
Class and scope	Scientific class and geographic or logical scope
Provenance	Source or derivation
Status vector	Provenance, role, epistemic, verification, publication

Field	Required entry
Dependencies	Required upstream nodes
Evidence	Supporting results and sources
Uncertainty	Declared uncertainty
Test	Operational evaluation
Falsifier	Rejection condition
Descendants	Affected downstream claims

C.2 Equation Template

- identifier;
- exact LaTeX;
- paper and label;
- role;
- variables;
- units;
- assumptions;
- source or derivation;
- domain of validity;
- limiting cases;
- numerical uses;
- supported claims;
- and audit status.

C.3 Prediction Template

- identifier;
- exact prediction;
- model and version;
- data cutoff;
- freeze date;
- location;
- depth;
- age;
- direction;

- magnitude;
- uncertainty;
- negative-control domain;
- scoring rule;
- validation data;
- outcome;
- and status.

C.4 Falsifier Template

- identifier;
- target;
- scope;
- condition;
- measurement;
- threshold;
- uncertainty;
- test;
- data;
- consequence;
- propagation;
- and decision record.

D Viable-Set Summary

D.1 Paper-I Viability

$$\mathcal{V}_I = \mathcal{V}_{\text{coordinates}} \cap \mathcal{V}_{\text{geometry}} \cap \mathcal{V}_{\text{paleogeography}} \cap \mathcal{V}_{\text{chronology}} \cap \mathcal{V}_{\text{null}}. \tag{711}$$

D.2 Paper-II Viability

$$\mathcal{V}_{II} = \mathcal{V}_{\text{entrance}} \cap \mathcal{V}_{\text{path}} \cap \mathcal{V}_{\text{midpoint}} \cap \mathcal{V}_{\text{terminal}} \cap \mathcal{V}_{\text{survival}} \cap \mathcal{V}_{\text{rotation}} \cap \mathcal{V}_{\text{markers}}. \tag{712}$$

D.3 Paper-III Viability

$$\begin{aligned}\mathcal{V}_{\text{III}} =& \mathcal{V}_{\text{handoff}} \cap \mathcal{V}_{\text{event}} \cap \mathcal{V}_{\text{lineage}} \cap \mathcal{V}_{\text{boundary}} \\ & \cap \mathcal{V}_{\text{impulse}} \cap \mathcal{V}_{\text{motion}} \cap \mathcal{V}_{\text{surface}} \cap \mathcal{V}_{\text{chronology}} \\ & \cap \mathcal{V}_{\text{null}} \cap \mathcal{V}_{\text{prediction}}.\end{aligned} \tag{713}$$

D.4 Paper-IV Astro-Ballistic Eligibility and Qualification

$$\begin{aligned}\mathcal{V}_{IV,\mathrm{ABC}}^{\mathrm{elig}} =& \mathcal{V}_{\mathrm{boundary}}^{\mathrm{IV}} \cap \mathcal{V}_{\mathrm{motion}}^{\mathrm{IV}} \cap \mathcal{V}_{\mathrm{surface}}^{\mathrm{IV}} \cap \mathcal{V}_{\mathrm{deep}}^{\mathrm{IV}} \\ & \cap \mathcal{V}_{\mathrm{chronology}}^{\mathrm{IV}} \cap \mathcal{V}_{\mathrm{paleogeography}}^{\mathrm{IV}} \cap \mathcal{V}_{\mathrm{coverage}}^{\mathrm{IV}}.\end{aligned} \tag{714}$$

Register the separate qualification-gate vector

$$\mathbf{G}_{IV,\mathrm{ABC}} = \left(G_{\mathrm{null}}, G_{\mathrm{prediction}}, G_{\mathrm{complexity}}, G_{\mathrm{causal}}, G_{\mathrm{replication}}\right). \tag{715}$$

A nonempty eligibility set may coexist with failed or unresolved qualification gates. That state prevents replacement qualification but does not constitute physical falsification.

D.5 Series Viability

For one eligible sequence $\mathcal{S}$,

$$\mathcal{V}_{\mathrm{series},\mathcal{S}}^{\mathrm{elig}} = \left[\bigcap_{k\in\mathcal{S}} (\mathcal{V}_{I,k} \cap \mathcal{V}_{II,k})\right] \cap \mathcal{V}_{III,\mathcal{S}} \cap \mathcal{V}_{IV,\mathcal{S},\mathrm{ABC}}^{\mathrm{elig}}. \tag{716}$$

The series model-family viability is

$$\mathcal{V}_{\mathrm{series}}^{\mathrm{elig}} = \bigcup_{\mathcal{S}\in\mathfrak{S}_{\mathrm{elig}}} \mathcal{V}_{\mathrm{series},\mathcal{S}}^{\mathrm{elig}}. \tag{717}$$

E Final Decision Record Template

E.1 Decision Record

$$\begin{aligned}\mathbf{D}_{\mathrm{final}} = \big(&\text{decision ID}, \text{corpus freeze}, \text{data freeze}, \text{model versions}, \\ &\text{eligible models}, \text{viable sets}, \text{component scores}, \\ &\text{integrated scores}, \text{model evidence}, \text{predictive scores}, \\ &\text{complexity}, \text{nulls}, \text{ablations}, \text{replication}, \\ &\text{triggered falsifiers}, \text{classification}, \text{reviewers}\big).\end{aligned} \tag{718}$$

E.2 Allowed Classifications

- `REJECTED`;
- `NOT-ESTABLISHED`;
- `DISFAVORED`;
- `LOCAL`;
- `REGIONAL`;
- `MULTI-REGIONAL`;

- `COMPLEMENTARY`;
- `HYBRID-PREFERRED`;
- `CAUSALLY-EQUIVALENT`;
- `ABC-REPLACEMENT-CANDIDATE`;
- `PLATE-TECTONIC-PREFERENCE`;
- `SHARED-FAILURE`;
- `UNRESOLVED`.

F Final Five-Paper Status

Table 73: Final status of the five-paper research program at completion of the Paper-V manuscript architecture.

Paper	Completed manuscript function	Scientific status
I	Flagship geometry, chronology, selection, and falsification framework	Present geometry audited; decisive paleogeography and chronology unresolved
II	Differentiated-Earth transmission, survival, and handoff framework	Corrected audit completed; no full viable branch yet demonstrated
III	Boundary, motion, continental, structural, and global reconstruction framework	Complete causal architecture; no full global numerical solution yet demonstrated
IV	Matched comparison, complexity, prediction, hybrid, and replacement decision framework	Formal adjudication architecture completed; empirical decision unresolved
V	Claims, equations, data, source, prediction, falsification, dependency, and replication atlas	Atlas architecture and document-level registry coverage audited; external machine registries and independent empirical audits remain incomplete

F.1 Final Series Status Statement

The five-paper manuscript program now contains a continuous, cross-referenced, falsifiable architecture extending from flagship geometry through mechanical transmission, global reconstruction, comparative adjudication, and independent verification.

The program does not presently claim that the global replacement thesis has been empirically demonstrated.

Its present achievement is the construction of the scientific case and verification architecture that must be calculated, sourced, tested, compared, falsified, and replicated. Paper V is document-ready for a controlled AI-companion prototype, while machine-registry materialization and empirical adjudication remain incomplete.

G AI-Companion Operating Constraints

G.1 Permitted Functions

An AI companion may:

- locate registered claims;
- display equations;
- trace dependencies;
- identify unresolved assumptions;
- display source status;
- calculate declared equations;
- identify triggered falsifiers;
- compare manuscript versions;
- and generate audit reports.

G.2 Prohibited Functions

An AI companion must not:

- invent a source;
- invent a dataset;
- silently alter a claim;
- promote an assumption to evidence;
- promote a reconstruction to prediction;
- conceal a negative result;
- alter a threshold after inspection;
- merge incompatible model versions;
- or issue an unexplained final scientific judgment.

G.3 Model-Comparison Guardrails

An AI companion must not average noncommensurate model-comparison statistics, infer equivalence from small point differences, treat an unresolved qualification gate as physical falsification, or promote a nonempty eligibility set to replacement qualification. It must report score direction, uncertainty, freeze status, comparison contract, and the exact failed or unresolved gate.

G.4 Required Response Structure

When answering a scientific query, the companion should report:

1. the exact registered claim;
2. the current status;
3. the supporting equations;
4. the assumptions;
5. the data and sources;
6. the unresolved dependencies;
7. the falsifier;
8. and the relevant version.

G.5 No Hidden Authority

The companion must state when:

- evidence is absent;
- a source is unverified;
- an equation is author-defined;
- a result is conditional;
- a prediction is not frozen;
- or a decision has not been executed.

H Open Work Register

Table 74: Priority open-work register.

Priority	Work item	Primary dependency
1	Freeze and compile all five canonical manuscripts.	Corpus control
2	Materialize the complete machine-readable registries from the frozen Paper-V atlas and run schema validation.	Paper V
3	Verify every source and bibliographic entry.	Source integrity
4	Verify flagship coordinates and feature definitions.	Paper I
5	Construct event-time paleogeographic reconstruction ensemble.	Papers I, III, IV
6	Compile independent chronology.	Papers I, III, IV
7	Freeze and run selection-aware Paper-I null models.	Paper I
8	Implement Paper-II branch simulations.	Paper II
9	Complete whole-Earth energy, momentum, and rotation closure.	Paper II

Priority	Work item	Primary dependency
10	Build ancient material-lineage graph.	Paper III
11	Implement boundary-generation and connectivity model.	Paper III
12	Implement global force, torque, and Euler-vector model.	Paper III
13	Implement structural and deep-geophysical forward models.	Papers III and IV
14	Implement strong Plate-Tectonic and hybrid comparison models.	Paper IV
15	Calculate effective complexity and search costs.	Paper IV
16	Freeze advance predictions.	Papers III and IV
17	Preserve untouched prospective validation data.	Paper IV
18	Commission independent implementation and replication.	Series confirmation
19	Execute the final decision rule.	All papers
20	Release the versioned manuscript, data, code, and atlas package.	Publication

Embedded Bibliography

The internal entries below preserve the provenance of the five-paper corpus and its author working documents. The external entries support standard scientific context, governing methods, comparison requirements, and reproducibility architecture. Their inclusion does not constitute independent verification or endorsement of the ABC event assignments or replacement thesis.

References

[1] Fine, Justin B *Astro-Ballistic Chronostratigraphic Sequencing I: Aegean Entrance, Everest Midpoint, Mariana Exit*. Ontomics Research & Technical Due Diligence LLC. Canonical Corpus Freeze 1.0, August 7, 2026.

[2] Fine, Justin B *Astro-Ballistic Chronostratigraphic Sequencing II: Transmission Through a Differentiated Earth*. Ontomics Research & Technical Due Diligence LLC. Canonical Corpus Freeze 1.0, August 7, 2026.

[3] Fine, Justin B *Astro-Ballistic Chronostratigraphic Sequencing III: From Event Geometry to Continents, Trenches, Mountains, and Basins*. Ontomics Research & Technical Due Diligence LLC. Canonical Corpus Freeze 1.0, August 7, 2026.

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Final Declaration

The canonical five-paper manuscript corpus is frozen as `ABC-CF1-2026-08-07`, Canonical Corpus Freeze 1.0, dated August 7, 2026. This freeze records the current scientific architecture and status ledger; it does not claim completion of unresolved simulations, empirical comparisons, preregistered thresholds, or independent replication.

Justin B Fine is the sole human author of this manuscript series.

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