The Splitting of the Moon:Quantitative Evaluation of Global-Scale Lunar Structural Discontinuities, Predictions and Empirical Tests

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Abstract

This study proposes a methodological framework for transforming historical observational narratives found in early Islamic sources, including hadith literature and Qur'anic references, into a testable scientific hypothesis within lunar geophysics. The objective is not to evaluate theological validity, but to reconstruct a hypothetical macroscopic lunar bifurcation event as a physically constrained problem based on observer-dependent geometric interpretation. By translating descriptive accounts into angular separation constraints, we derive a lunar surface fracture axis consistent with a great-circle geometry aligned approximately with the Moon's central meridian (0° ± 20° longitude).The model predicts that any genuine global-scale lunar (splitting) event would necessarily produce detectable geophysical signatures, including continuous structural discontinuities, gravitational anomalies, thermal residuals, seismic asymmetries, and mineralogical shock bands along the inferred meridional zone. We further define specific observational targets on the near-side lunar surface, particularly within central mare–highland transition regions such as Sinus Medii and adjacent mare structures. Current high-resolution datasets from lunar orbital missions, including gravity mapping, thermal imaging, and seismic records, are discussed in the context of these predictions. While no evidence of a global-scale fracture consistent with the proposed model is currently observed, the framework establishes a falsifiable prediction structure and identifies precise regions for future targeted exploration. This approach introduces an "observer-constrained event reconstruction" methodology, linking historical descriptions with quantitative planetary science models to generate empirically testable geophysical hypotheses.

Keywords: Historical astronomy, Islamic sources, lunar geology, Moon fracture hypothesis, observer-constrained reconstruction, planetary geophysics, great-circle geometry, lunar surface anomalies, gravitational mapping, testable astrophysical predictions

1. Introduction

Reports of unusual celestial phenomena have been documented across multiple pre-modern civilizations, often interpreted within religious, symbolic, or proto-scientific frameworks. In early Islamic tradition, descriptions associated with lunar visual anomalies are preserved within hadith literature and exegetical commentaries, where such events are contextualized as extraordinary observational occurrences rather than ordinary astronomical phenomena. These narratives have historically been transmitted as part of a broader epistemic system in which celestial events were interpreted through both theological and empirical observation lenses.

Within classical Islamic historiography, celestial events were frequently correlated with social and historical contexts, reflecting an early attempt to integrate observational astronomy with narrative tradition. Similar interpretations of anomalous astronomical phenomena can also be found in Greco-Roman and Indian astronomical records, where unusual lunar or solar appearances were catalogued without modern physical explanation.

In particular, systematic analyses of ancient observational astronomy indicate that pre-modern societies frequently recorded anomalous lunar and solar appearances, although these accounts were typically interpreted within cultural or symbolic frameworks rather than physical models (Neugebauer, 1957; Ruggles, 2015; Stephenson, 2003). Such historical records are of interest to modern science primarily as qualitative datasets that may, in principle, be reinterpreted under constrained physical models of observational geometry.

From a modern Islamic historiographical perspective, certain early textual traditions describe extraordinary lunar visual phenomena preserved within hadith literature and classical exegesis. While these texts are not physical measurement records in the modern scientific sense, they represent structured observational narratives embedded in early historical documentation systems (Zulia, 2024; Donner, 2010; Rubin, 1995). Similar to other ancient astronomical traditions, these accounts can be analyzed as descriptive records of perceived celestial events rather than direct physical measurements of astrophysical processes (Neugebauer, 1957; Evans, 1998).

Modern planetary science provides a strict physical framework for evaluating any hypothesis involving macroscopic structural alteration of the Moon. The gravitational binding energy and mechanical stability of the lunar body impose severe energetic constraints on any scenario involving global-scale fragmentation or reassembly (Melosh, 1989; Taylor, 2016). Furthermore, giant impact and catastrophic disruption models of lunar formation demonstrate that large-scale structural reconfiguration of the Moon requires energies comparable to planetary-scale collisions, which are not supported by any known late-Holocene astrophysical processes (Asplund, 2005; Benz et al., 1986; Stewart & Leinhardt, 2012).

High-resolution lunar geophysical datasets collected over the past decades have significantly constrained the possibility of undocumented global-scale structural discontinuities. Gravity field mapping from the Gravity Recovery and Interior Laboratory (GRAIL) mission reveals a highly coherent internal mass distribution without evidence of a planet-wide fracture system (Zuber et al., 2013; Wieczorek et al., 2013). Complementary topographic data from the Lunar Reconnaissance Orbiter Laser Altimeter (LOLA) further support a geologically consistent lunar crust dominated by impact basins and volcanic structures rather than global tectonic rupture zones (Smith et al., 2010; Neumann et al., 2015; Robinson et al., 2010).

Seismic observations obtained during the Apollo missions also provide constraints on the Moon's internal structure and tectonic activity. These datasets indicate localized seismic events and crustal heterogeneity but do not support the existence of a global-scale fracture or rejoining event in the recent geological past (Latham et al., 1970; Nakamura, 1983; Lognonné & Johnson, 2015). Similarly, thermal infrared measurements from orbital instruments such as the Diviner Lunar Radiometer demonstrate spatially heterogeneous but stable thermal properties consistent with regolith evolution and impact gardening processes rather than catastrophic thermal resurfacing events (Paige et al., 1999; Vasavada et al., 1999; Bandfield et al., 2011).

Despite the lack of empirical evidence for macroscopic lunar fragmentation, historical observational narratives remain of methodological interest in the context of inverse problems in planetary science. Recent advances in geophysical inverse theory demonstrate that observational descriptions, when properly formalized, can be mapped into constrained parameter spaces that yield testable predictions about planetary surfaces (Tarantola, 2005; Kaipio & Somersalo, 2005; Menke, 2018). In this context, observer-constrained reconstruction approaches allow qualitative historical descriptions to be translated into geometrically defined hypotheses that can be evaluated against modern lunar datasets (Turyshev, 2017; Ashtekar, 2020).

The objective of this study is therefore not to validate historical causality claims, but to construct a geometrically constrained framework that transforms narrative observational reports into falsifiable physical predictions. Specifically, we aim to derive a hypothetical lunar fracture axis based on observer-dependent angular constraints and evaluate its consistency with current lunar geophysical, gravitational, and thermal datasets. This approach situates historical observational records within a testable planetary science framework and enables the formulation of empirically constrained hypotheses regarding lunar surface structure (Melosh, 1989; Wieczorek et al., 2013; Zuber et al., 2013; Tarantola, 2005).

2. Methodological Framework

This section presents a structured methodological pipeline for transforming qualitative historical observational descriptions into quantitatively testable physical hypotheses. The framework is organized into three sequential stages: (i) historical-to-scientific translation, (ii) geometric constraint modeling, and (iii) physical testability evaluation. Together, these stages constitute an Observer-Constrained Reconstruction (OCR) approach, which systematically maps narrative-based celestial observations onto measurable planetary-scale geophysical parameters.

2.1 Historical-to-Scientific Translation

The initial step consists of converting qualitative narrative descriptions into a well-defined set of measurable physical observables. Historical accounts are treated not as direct physical measurements but as **constrained observational statements** that reflect human perception under specific geometric and environmental conditions. Consequently, descriptive terms such as “splitting,” “separation,” “fission,” or “dual appearance” are reformulated into angular and spatial variables that can be embedded within a physically interpretable model.

Let the observed narrative event be represented as a **descriptive operator** *D*, which is mapped to a measurable parameter set P:

$$D \rightarrow P = \{\theta, \phi, \Delta\theta, t, I\} \quad (1)$$

where:

- θ, ϕ represent angular coordinates (e.g., altitude and azimuth, or celestial coordinates),
- $\Delta\theta$ denotes the **angular separation** between perceived lunar segments,
- t represents **temporal uncertainty** (time of observation, duration, historical dating ambiguity),
- I indicates **observational intensity or clarity** (e.g., qualitative descriptors like “bright,” “clear,” “obscured,” or “momentary”).

This transformation ensures that non-quantitative historical language is systematically embedded into a physically interpretable parameter space, enabling subsequent geometric and physical analysis without imposing anachronistic precision.

2.2 Geometric Constraint Modeling

The second step establishes a rigorous **geometric reconstruction of the observational reference frame**. The observer’s location is fixed as a primary reference point, and all celestial geometry is expressed relative to this frame. In this study, the observation point is defined as **Mecca** (latitude ≈ 21.4° N, longitude ≈ 39.8° E), providing a fixed geodetic reference for angular reconstruction. This choice is motivated by the historical provenance of the narrative, but the methodology remains generalizable to any geographic location.

Let the observer position vector be defined in an Earth-centered coordinate system as r_o, and the lunar position vector as r_m. The **line-of-sight unit vector** from the observer to the Moon is then given by:

$$\hat{n} = \frac{r_m - r_o}{\lVert r_m - r_o \rVert} \quad (2)$$

The **angular separation** between two perceived lunar segments (corresponding to two distinct visual components reported in the narrative) is defined as:

$$\Delta\theta = \cos^{-1}(\hat{n}_1 \cdot \hat{n}_2) \quad (3)$$

where $\hat{n}_1$ and $\hat{n}_2$represent the reconstructed directional vectors of the two perceived lunar segments. A critical geometric inference follows: within this framework, a horizontal separation in the observer's sky-plane (i.e., a split appearing side-by-side along the local horizon) implies a vertical great-circle constraint on the lunar surface. More precisely, a horizontal angular separation maps to a plane of separation that is approximately vertical relative to the observer's local horizon. When this plane is extended to intersect the spherical Moon, it defines a great circle — a north-south aligned meridional plane.Thus, the observational sky-plane geometry is rigorously mapped to lunar surface coordinates, enabling the derivation of a constrained fracture axis expressed in selenographic coordinates.

2.3 Physical Testability Principle

The final step enforces strict physical falsifiability conditions. Any hypothesized macroscopic lunar splitting event — if it were to have occurred — must necessarily produce measurable geophysical signatures that persist over geological timescales. These signatures must be detectable through modern observational datasets, including:

- High-resolution gravity mapping (e.g., GRAIL),
- Seismic analysis (e.g., Apollo Passive Seismic Experiment),
- Thermal infrared imaging (e.g., Diviner),
- Topographic reconstruction (e.g., LOLA).

This principle is formalized as a null-test condition:

$$H_0 : S_{obs} \cap S_{pred} = \emptyset \tag{4}$$

$$H_1 : S_{obs} \approx S_{pred} \tag{5}$$

where:

- S_{pred} represents the predicted set of geophysical signature**s** derived from the hypothesized event (e.g., linear gravity anomaly, meridional thermal band, seismic velocity discontinuity),
- S_{obs} represents the observed lunar dataset obtained from modern missions.

A valid physical hypothesis requires the rejection of H_0 in favor of H_1 under statistically significant agreement between predicted and observed geophysical constraints. In other words, the predicted signatures must be found where expected, and at levels above detection thresholds and natural background variability. Furthermore, any global-scale structural event must satisfy fundamental conservation constraints, including energy conservation and the mechanical stability conditions of planetary bodies:

$$E_{event} \geq U_{bind} \tag{6}$$

where U_{bind} is the gravitational binding energy of the Moon (approximately 1.2×10^{29}J). This inequality represents a necessary — though not sufficient — physical condition. Violation implies physical infeasibility under known classical mechanics, independent of any historical or narrative considerations.

3. Observer-Constrained Geometric Reconstruction

This section develops a quantitative reconstruction of the reported observational configuration using an observer-centered geometric framework. By fixing the observation point and translating qualitative descriptions into angular constraints, the apparent separation of the lunar disk is mapped onto a corresponding separation plane intersecting the lunar sphere. This allows the derivation of a physically testable fracture axis consistent with spherical geometry and great-circle constraints.

3.1 Observation Site Definition

The observation is modeled from a fixed terrestrial reference location corresponding to (latitude ≈ 21.4° N, longitude ≈ 39.8° E). The **local horizon system** (altitude–azimuth) provides the natural coordinate frame for describing the apparent position of celestial objects as seen by an Earth-based observer. Let the observer's position be defined in Earth-centered coordinates as:

$$r_o = R_E \begin{bmatrix} \cos\phi_o \cos\lambda_o \\ \cos\phi_o \sin\lambda_o \\ \sin\phi_o \end{bmatrix} \tag{7}$$

where:

- R_E is the mean radius of the Earth,
- ϕ_o is the observer's geodetic latitude,
- λ_o is the observer's longitude.

The apparent position of the Moon is expressed in the **local horizontal coordinate system** using two angles:

- **Altitude** h (angular height above the horizon),
- **Azimuth** A (horizontal angle measured from north, or from a reference direction).

The corresponding unit direction vector from the observer to the Moon is:

$$\hat{n} = \begin{bmatrix} \cos h \sin A \\ \cos h \cos A \\ \sin h \end{bmatrix} \tag{8}$$

This formulation defines the line-of-sight geometry entirely relative to the observer's local horizon plane. It assumes the Moon is a point source for directional purposes — a valid approximation when considering angular separations between two distinct segments of the lunar disk, as the Moon's angular diameter ($\approx 0.5°$) is small compared to the hypothesized separation.

3.2 Angular Separation Analysis

The historical description implies that two distinct lunar segments were observed simultaneously with a horizontal separation in the sky. In angular terms, this corresponds to a separation primarily along the azimuthal direction, with negligible or zero difference in altitude. Let the total angular separation between the two perceived lunar segments be expressed in terms of azimuthal difference:

$$\Delta\theta \approx \mid \Delta A \mid \cos h \tag{9}$$

where:

- ΔA is the azimuthal difference between the two observed segments,
- h is the common altitude (assumed equal for both segments, as the separation is horizontal),
- The factor cos*h* projects the azimuthal difference onto the celestial sphere's great-circle arc.

A horizontal separation in the sky-plane means that the separation vector lies parallel to the local horizon. When this geometric relationship is projected backward from the observer through the lunar sphere, it implies a vertical separation plane — a plane that contains the observer, the Moon, and is oriented perpendicular to the local horizon.

Thus, the observed horizontal appearance maps uniquely to a vertical plane passing through the lunar sphere. This is a critical geometric inference: the orientation of the separation plane is fixed by the observer's horizon geometry, independent of the specific numerical value of Δθ.

3.3 Derivation of Fracture Axis

The separation plane derived from the observer's perspective must correspond to a great-circle plane on the lunar surface. This follows from a fundamental property of spherical geometry: any planar division of a sphere that passes through the sphere's center defines a great circle. If the Moon were physically split along such a plane, the resulting fracture would trace a great circle on its surface. Let the normal vector of the separation plane be denoted as n_f. The condition for the plane to intersect the lunar sphere along a great circle is:

$$n_f \cdot r_m = 0 \tag{10}$$

where r_m represents position vectors on the lunar surface (relative to the Moon's center). Given the horizontal nature of the observed separation, the separation plane is approximately aligned with the Earth–Moon line of sight and oriented vertically. Consequently, the intersection of this plane with the lunar surface produces a meridional (north–south oriented) great circle — i.e., a line of constant longitude running from the north pole to the south pole. This leads directly to the central meridian constraint:

$$\lambda_f \approx \lambda_{subEarth} \pm \Delta\lambda \tag{11}$$

where:

- λ_f is the selenographic longitude of the hypothesized fracture axis,
- $\lambda_{subEarth}$ is the sub-Earth longitude (the central meridian of the Moon visible from Earth at the time of observation),
- Δλ is an uncertainty term accounting for:
    - **Lunar libration** (the Moon's nodding and wobbling motion, which shifts the visible hemisphere by up to ≈7º in longitude over time),
    - **Observational ambiguity** (imprecision in the historical description, lack of exact time stamp),
    - **Geometric approximations** (e.g., assuming perfect horizontality).

In practice, this constraint confines the possible splitting axis to a narrow longitudinal band centered around the near-side meridian of the Moon. For a typical Earth-centered observation without extreme libration, $\lambda_{subEarth}$ is close to 0˚ (the center of the lunar disk). Therefore:$\lambda_f \approx 0^\circ \pm 20^\circ$ .The $\pm 20^\circ$ range provides a conservative envelope encompassing maximum libration extremes and historical timing uncertainties.

4. Predicted Lunar Fracture Zone

Based on the observer-constrained geometric reconstruction presented in Section 3, a hypothetical macroscopic lunar separation event would correspond to a well-defined, spatially limited region on the lunar surface. This section defines the predicted fracture zone in terms of (i) longitudinal constraints, (ii) geometric orientation, and (iii) specific surface regions suitable for targeted observational testing using existing or future lunar datasets.

4.1 Central Longitude Band

The derived fracture axis is fundamentally constrained by the Earth-facing geometry of the Moon at the time of observation. Specifically, the separation plane must intersect the near-side hemisphere along a meridional band centered around the sub-Earth longitude (the central meridian visible from Earth at that moment). This constraint can be expressed as:

$$\lambda_f \approx 0^\circ \pm 20^\circ \tag{12}$$

where:

- λ_f represents the selenographic longitude of the hypothesized fracture axis,
- 0° corresponds to the **central meridian** of the Moon's near side (the midpoint of the visible disk under average libration conditions),
- The ±20∘ range accounts for cumulative uncertainties, including:
    - **Lunar libration** (periodic nodding and wobbling that shifts the visible hemisphere by up to ≈7°–8 ° in longitude),
    - **Observation angle** (the exact azimuth and altitude of the Moon at the undocumented time of the event),
    - **Temporal ambiguity** (lack of precise date and hour in the historical record, preventing exact reconstruction of libration state).

The resulting band defines a narrow, well-circumscribed region on the lunar near side where any large-scale fracture — or signs of subsequent rejoining — would be expected to be found, if such an event had physically occurred. Outside this longitudinal range, the geometric projection from the observer's horizon plane would not produce a meridional great circle, making any surface feature incompatible with the reported horizontal separation.

4.2 Meridional Fracture Geometry

The predicted fracture geometry corresponds to a great-circle plane aligned along the lunar north–south direction. This configuration follows directly from the horizontal angular separation observed in the sky-plane (Section 3.2), which maps uniquely to a vertical separation plane intersecting the spherical lunar surface. The fracture plane can be mathematically defined by its normal vector condition:

$$n_f \cdot r_m = 0 \tag{13}$$

where:

- n_f is the unit normal vector of the fracture plane (perpendicular to the plane of separation),
- r_m represents position vectors on the lunar surface (relative to the Moon's center).

This planar geometry implies three distinct physical consequences, assuming the event were real:

1. **A continuous meridional line** — The fracture would trace a full or partial great circle from the lunar north pole to the south pole, crossing the equator at the central longitude band.
2. **Symmetry between the eastern and western hemispheres** — The separation plane divides the Moon into two halves. Any geophysical asymmetry (e.g., crustal thickness, thermal signature, gravity gradient) would be expected to mirror across this plane or show a sharp discontinuity exactly along it.
3. **A global-scale discontinuity** — Unlike local faults or graben systems, a great-circle fracture would represent a planetary-scale structural boundary, potentially affecting the Moon's rotational dynamics, internal wave propagation, and long-term thermal evolution.

Therefore, any hypothesized macroscopic splitting and rejoining event should manifest as a meridional feature extending from the Moon's north pole to its south pole, precisely aligned with the central longitude band defined in Equation (12).

Important clarification: The original text contains the phrase "virtual refraction event" and "virtual meridian feature." These are interpreted as typographical or conceptual errors. The intended meaning is "hypothetical fracture event" and "hypothetical meridional feature" — i.e., a feature that would exist if the event had occurred. The corrected wording is used here.

4.3 Key Surface Regions (Search Targets)

Considering the longitudinal constraints ($\lambda_f \approx 0° \pm 20°$) and the meridional geometry, the most promising regions to detect remnant traces are located in the **central near-side areas** of the Moon. Table 1 shows primary target zones.These regions represent locations where the predicted fracture axis intersects well-studied geological units, maximizing the detectability of subtle anomalies against known background variability.

Table 1. Primary Target Zones

Zone	Location (Approximate)	Geological Significance	Detection Potential
Sinus Medii	Center of near side (~0° longitude, ~5° N)	Geometric center of the visible lunar disk; lies exactly on the predicted axis	Critical for detecting any meridional lineament, structural offset, or thermal band crossing the equator
Mare Nubium transition zone	Southern central near side (~0–20° S, 0–20° W)	Complex mare-highland boundary with heterogeneous composition and topography	May amplify or preserve structural or thermal anomalies due to lithological contrasts
Eastern Mare Imbrium boundary	Northwestern central near side (~20–40° N, 0–20° W)	Transition between the large Imbrium impact basin and adjacent highland terrain	Provides potential **asymmetric sensitivity** along the fracture axis; any offset or discontinuity would be detectable across this sharp geological contrast

These three zones are not exhaustive but represent **optimal search areas** based on:

- Proximity to the central meridian,
- Availability of high-resolution orbital data,
- Geological diversity (enhancing anomaly contrast),
- Historical coverage by previous missions (Apollo, LRO, GRAIL, etc.).

Top Priority Observational Targets

Within the above zones, the following geophysical signatures should be investigated at the highest priority:

1. **Structural discontinuities** — Linear scarps, ridge offsets, or crater alignments precisely following a meridional great circle.
2. **Thermal anomalies** — Persistent temperature deviations (diurnal or annual) along the fracture axis, detectable by infrared radiometry.

3. **Gravity discrepancies** — Meridional gradients in the gravitational field, crustal thickness variations, or asymmetrical mascon distribution across the predicted line.

Hypothesis Testing Statement

The alignment of these features along the central meridian band — if detected — would provide strong, multi-domain evidence supporting the hypothesis of a macroscopic lunar splitting event (or at least a large-scale meridional structural anomaly).
Their absence — across all three zones, at the resolution limits of current and near-future instruments — would rule out the hypothesis of a macroscopic lunar fracture and rejoining event as described in the historical narrative.

5. Expected Geophysical Signatures

If a macroscopic lunar fracture and subsequent reassembly event had occurred — involving the physical separation of the Moon along a great circle and its subsequent rejoining — it would be expected to leave persistent, detectable artifacts across multiple geophysical domains. These signatures must be:

- **Globally coherent** (traceable across the lunar body),
- **Spatially aligned** with the predicted meridional fracture axis ($\lambda f \approx 0° \pm 20°$),
- **Observable** through modern planetary datasets (topography, gravity, thermal, seismic, mineralogical).

This section outlines the five main classes of expected signatures and their measurable characteristics, providing a multi-domain falsification framework.

5.1 Structural Signatures

A global-scale fracture would manifest as a continuous structural discontinuity extending along the predicted meridional axis. Unlike local tectonic features (e.g., wrinkle ridges, graben), this feature would be expected to:

- Form a great circle aligned north–south, crossing the equator at the central meridian,
- Exhibit crustal displacement or offset (vertical or lateral) across the fracture line,
- Persist as a global tectonic or lithospheric boundary over geological timescales, unless completely erased by subsequent impact gardening or volcanism.

The structural continuity condition can be expressed mathematically using the divergence of the local displacement field u:

$$\nabla \cdot u \neq 0 \qquad along \qquad \lambda_f \tag{14}$$

where:

- u represents the local displacement vector (deformation relative to an undeformed reference state),
- A **non-zero divergence** along the fracture axis would indicate material separation (positive divergence) or compressional rejoining/recombination (negative divergence) processes.

Observational methods:
High-resolution laser altimetry (LOLA) and stereo imaging (LROC) can detect linear scarps, ridge offsets, crater truncations, and systematic elevation changes along the predicted meridian.

5.2 Gravitational Anomalies

A large-scale deformation and recombination event would almost certainly produce measurable **density contrasts** across the fracture plane. These contrasts arise from:

- Differential crustal thickness between the two sides,
- Partial melting and recrystallization altering bulk density,
- Fracture-related porosity or compaction.

These density differences would be reflected in the lunar gravitational field as:

- **Linear or meridional gravity anomalies** (gradients aligned with λf),
- **Variations in crustal thickness** inverted from gravity data,
- **Discontinuities in mass concentration (mascon)** distribution across the fracture axis.

The **gravitational potential anomaly** generated by a density contrast $\Delta\rho(r')$ can be approximated by the volume integral:

$$\Delta V(r) = G\int \frac{\Delta\rho(r')}{|r-r'|} d^3r' \tag{15}$$

where:

- G is the gravitational constant,
- $\Delta\rho(r')$ is the anomalous density distribution (difference from background),
- The integral extends over the volume of the fractured and reassembled zone.

A **coherent gravity anomaly** aligned with the central meridian — detectable as a linear gradient in spherical harmonic coefficients or as a line of deflection in vertical gravity — would provide strong evidence for large-scale internal restructuring.

Observational methods:
GRAIL mission gravity maps (spherical harmonics to degree and order 1200), localized Bouguer anomaly profiles, and crustal thickness models derived from gravity-topography admittance.

5.3 Thermal Signatures

Large-scale fracture and recombination processes would generate **significant heat** through multiple mechanisms:

- **Mechanical deformation** (plastic work, dislocation motion),
- **Frictional dissipation** along the fracture surfaces during separation and rejoining,
- **Recrystallization processes** (latent heat release, exothermic mineral reactions).

This heat input would result in **long-term thermal anomalies** observable as:

- **Residual heat bands** along the fracture axis (e.g., elevated surface or subsurface temperatures relative to surrounding terrain),
- **Differential cooling rates** across the fracture axis (asymmetry in thermal inertia or diurnal temperature cycles),
- **Altered thermophysical properties** (thermal conductivity, heat capacity) due to fracturing and annealing.

The **thermal evolution** of such a feature can be described by the heat diffusion equation:

$$\frac{\partial T}{\partial t} = \kappa \nabla^2 T \quad (16)$$

where:

- T is temperature,
- $\kappa = k/(\rho c_p)$ is thermal diffusivity (with k thermal conductivity, ρ density, c_p) specific heat capacity).

A lunar fracture zone would be expected to show deviations from background thermal equilibrium — either as persistent warm bands (if the event was geologically recent) or as thermal inertia contrasts (if the event altered regolith or surface properties).

Observational methods:
Diviner Lunar Radiometer (thermal infrared mapping), microwave radiometers (subsurface temperature), and future thermal imagers with high spatial resolution.

5.4 Seismic Signals

A global fracture plane would fundamentally alter the internal mechanical properties of the Moon, affecting seismic wave propagation. Even if the fracture later rejoined, the former boundary would remain as a structural discontinuity in elastic moduli, density, or anisotropy.

Expected seismic signatures include:

- **Velocity discontinuities** across the fracture axis (P-wave and S-wave speed jumps),
- **Reflection and refraction** of seismic waves at the fracture plane,
- **Anisotropic wave propagation patterns** (direction-dependent velocities) aligned with the meridional fabric.

Seismic wave behavior in an isotropic elastic medium is described by the P-wave velocity:

$$v_p = \sqrt{\frac{K + \frac{4}{3}\mu}{\rho}} \quad (17)$$

where:

- v_p is the compressional wave velocity,
- K is the bulk modulus (resistance to volume change),
- μ is the shear modulus (resistance to shape change),
- ρ is density.

Spatial variations in K, μ, or ρ across the fracture plane would produce measurable asymmetries in travel times, amplitude ratios, and wave polarization — detectable if seismic sources and receivers are appropriately placed.

Observational methods:
Apollo Passive Seismic Experiment data (limited global coverage), future lunar seismic networks (e.g., Farside Seismic Suite), and active seismic experiments.

5.5 Mineralogical Evidence

A large-scale deformation event (whether impact-driven, tidal, or internal) would induce high pressure and temperature conditions along the fracture plane, leading to:

- Shock metamorphism (planar deformation features, diaplectic glass),
- Partial melting and recrystallization (formation of glassy veins, polycrystalline aggregates),
- Formation of aligned mineral fabrics (foliation, lineation) parallel to the fracture axis.

These processes would produce:

- Shock features in lunar rocks (e.g., masked feldspar, high-pressure silica polymorphs like stishovite or coesite),
- Glassy or recrystallized bands along the fracture trace,
- Mineral alignment (preferred crystallographic orientation) parallel to the meridional axis.

The degree of shock transformation can be related to pressure conditions via the Hugoniot relation:

$$P_{shock} \propto \rho v_{impact}^2 \tag{18}$$

where:

- P_{shock} is the peak shock pressure,
- ρ is the density of the target material,
- v_{impact} is the impact velocity (or equivalent deformation velocity).

Although the fracture event is not necessarily caused by an impact, similar pressure and temperature regimes could arise during catastrophic structural deformation — e.g., tidal disruption, rapid internal phase transitions, or energetic rejoining. Any such event would leave a mineralogical fingerprint.

Observational methods:
Orbital visible/near-infrared spectroscopy (e.g., Moon Mineralogy Mapper — M³), future landed missions with X-ray diffraction (XRD) or Raman spectroscopy, and sample return from the central meridional band.

6. Data Sources and Observational Tools

The evaluation of the proposed fracture hypothesis requires the integration of multiple high-resolution lunar datasets spanning topography, gravity, thermal behavior, and internal structure. Modern lunar exploration missions — including orbital remote sensing and surface seismic experiments — provide comprehensive observational coverage that enables the detection of global-scale geophysical anomalies. This section outlines the principal data sources and analytical tools used for testing the predicted signatures defined in Section 5. Each dataset serves as an independent constraint; convergence (or divergence) across multiple domains determines the fate of the hypothesis.

6.1 Orbital Topography Missions

High-resolution topographic data are essential for identifying **large-scale surface discontinuities** and possible **linear structural features** aligned with the predicted meridional axis ($\lambda_{\mathrm{f}} \approx 0^\circ \pm 20^\circ$). Laser altimetry instruments aboard lunar orbiters have produced global elevation models with meter-scale vertical accuracy and decameter-scale horizontal resolution.

Topographic height is typically represented as a function of spherical coordinates:

$$h(\theta, \phi) = r(\theta, \phi) - R_{ref} \tag{19}$$

where:

- r(θ,ϕ) is the radial distance from the Moon's center to the surface at colatitude θ and longitude ϕ,
- R_{ref} is a reference radius (e.g., 1737.4 km, the mean lunar radius).

Primary instrument and dataset:

- **Lunar Orbiter Laser Altimeter (LOLA)** aboard the Lunar Reconnaissance Orbiter (LRO):
  - Global digital elevation model (DEM) with ~5 m vertical precision and ~60 m horizontal spacing,
  - Derived products: slope maps, roughness maps, and topographic profile extraction.

Detection capabilities relevant to the hypothesis:

- **Linear surface breaks** — continuous scarps or troughs following a meridional great circle,
- **Elevation offsets** across potential fracture zones (e.g., one side of the meridian systematically higher than the other),
- **Large-scale meridional anomalies** — persistent topographic gradients not associated with known impact basins or volcanic constructs.

Analytical approach:
Extract topographic profiles along constant-longitude lines within λf±5˚. Compare with profiles at adjacent longitudes (±10˚,±30˚) to identify statistically significant, meridionally coherent deviations.

6.2 Gravity Mapping Datasets

Gravitational field measurements provide critical insight into subsurface density distributions and internal structural continuity. High-precision data from dual-spacecraft missions allow the reconstruction of the lunar gravitational potential with unprecedented spatial resolution and accuracy. The gravity field is commonly expressed using a spherical harmonic expansion:

$$V(r,\theta,\phi) = \frac{GM}{r}\left[1 + \sum_{l=2}^{\infty}\sum_{m=0}^{l}\left(C_{lm}cosm\phi + S_{lm}sinm\phi\right)P_{lm}(cos\theta)\right] \qquad (20)$$

where:

- G is the gravitational constant,
- M is the lunar mass,
- C_{lm} and S_{lm} are the spherical harmonic coefficients (Stokes coefficients),
- P_{lm} are the associated Legendre polynomials.

Primary mission and dataset:

- **Gravity Recovery and Interior Laboratory (GRAIL)** :
  - Dual spacecraft (Ebb and Flow) providing a gravity field complete to spherical harmonic degree and order 1200 (spatial resolution ~5 km),
  - Derived products: free-air gravity anomalies, Bouguer anomalies, crustal thickness maps.

Detection capabilities relevant to the hypothesis:

- **Mascon distributions** — large positive gravity anomalies associated with impact basins; a meridional fracture would disrupt or offset mascon symmetry,
- **Density gradients** — linear changes in Bouguer anomaly across the predicted axis,
- **Possible meridional gravity anomalies** — coherent, north–south aligned gravity lineaments not explained by impact or volcanic sources.

Analytical approach:
Compute longitudinal derivatives of the gravity field ($\partial g/\partial \phi$) along the central meridian. Search for statistically significant discontinuities or linear trends that correlate with the fracture axis.

6.3 Infrared Thermal Imaging

Thermal observations provide information on surface and near-surface material properties, including thermal inertia, regolith thickness, and heat flow. Infrared radiometry allows detection of anomalous thermal behavior that may indicate past high-energy deformation events — such as residual heat from frictional dissipation or altered thermophysical properties along a fracture zone.

The **surface temperature evolution** follows the radiative equilibrium equation:

$$(1-A)S = \epsilon\sigma T^4 \tag{21}$$

where:

- A is the Bond albedo,
- S is the incident solar flux (function of latitude, season, and local time),
- ϵ is the infrared emissivity,
- σ is the Stefan–Boltzmann constant,
- T is the surface temperature.

In practice, diurnal and seasonal temperature variations are governed by thermal inertia $\Gamma=\sqrt{k\rho c_p}$, where k is thermal conductivity, ρ is density, and c_p is specific heat capacity.

Primary instrument and dataset:

- **Diviner Lunar Radiometer Experiment** (also aboard LRO):
  - Nine spectral channels (0.3–400 μm), including three thermal infrared channels,
  - Global maps of bolometric temperature, thermal inertia, and rock abundance,
  - Spatial resolution: ~200 m to ~1 km depending on product.

Detection capabilities relevant to the hypothesis:

- **Persistent temperature anomalies** — localized warm or cool bands along the predicted axis that cannot be explained by albedo or topographic shading,
- **Differential cooling patterns** across structural boundaries — e.g., faster cooling (lower thermal inertia) on one side of the meridian versus the other,
- **Possible linear thermal lineaments** corresponding to fracture zones — coherent, narrow, north–south aligned thermal features.

Analytical approach:
Co-register thermal inertia maps with topographic and gravity data. Extract transects across the central meridian and search for statistically significant, persistent thermal contrasts that align with the fracture axis.

6.4 Seismic Datasets from Lunar Experiments

Seismic data provide **direct constraints on the Moon's internal structure** and mechanical properties. Measurements from lunar surface experiments enable the study of wave propagation, attenuation, and internal layering — including the possible detection of a deep, meridional structural boundary.

The **seismic wave travel time** between a source and receiver is given by the ray integral:

$$t = \int \frac{ds}{v(s)} \tag{22}$$

where:

- d_s is an infinitesimal path element along the ray,
- v(s) is the local wave velocity (P-wave or S-wave speed) along the propagation path.

Primary datasets:

- **Apollo Passive Seismic Experiment** (Apollo 12, 14, 15, 16):
    - Operated from 1969 to 1977,
    - Detected moonquakes (deep, thermal, impact-induced) and provided constraints on crustal and mantle velocity structure,
    - Limited global coverage — all stations on the near side, concentrated in the equatorial region.

Detection capabilities relevant to the hypothesis:

- **Velocity discontinuities** — abrupt changes in v_{p} or vs with depth or lateral position, potentially marking a fracture plane,
- **Internal boundaries** — reflectors that produce distinct later phases (e.g., P-to-S conversions),
- **Anisotropic wave propagation** — direction-dependent velocities that would indicate aligned fractures or mineral fabrics along the meridional axis.

Limitations:

- Sparse station distribution (only four operating simultaneously at best),
- Limited source coverage (most moonquakes are deep and diffuse),
- No direct sampling of the predicted meridional axis at depth with current data.

Analytical approach:
Re-analyze Apollo seismic records for evidence of meridionally correlated travel time anomalies. Future missions (e.g., Farside Seismic Suite, proposed lunar seismic networks) would be required for definitive testing.

7. Future Testable Predictions

The proposed observer-constrained framework enables the formulation of forward-looking, testable predictions that can be evaluated using next-generation lunar exploration technologies — including high-resolution orbital remote sensing, subsurface tomography, in-situ drilling, and advanced thermal mapping. These predictions focus on detecting coherent geophysical signatures aligned with the central meridional band ($\lambda f \approx 0^{\circ} \pm 20$) and are explicitly designed to be falsifiable through high-resolution measurements across multiple observational domains.

Each prediction is accompanied by a null condition: if the predicted signature is not detected at levels significantly above natural background variability, the hypothesis is correspondingly weakened or falsified.

7.1 High-Resolution Meridian Scans

Future orbital missions equipped with ultra-high-resolution imaging and laser altimetry systems are expected to perform targeted scans along the predicted central meridian (λ≈0˚±20). While current datasets (e.g., LOLA, LROC) already provide global coverage at moderate resolution, dedicated meridional survey campaigns could achieve finer spatial sampling and higher signal-to-noise ratios along the axis of interest.

Primary objective: Detect any continuous global structural discontinuity consistent with a large-scale great-circle fracture. Such a feature would manifest as:

- A long, meridionally aligned lineament extending across multiple geological units (mare basalts, highland crust, impact basin rings),
- Systematic elevation offsets or scarps with a consistent sense of displacement (e.g., west side down relative to east side),
- Crater truncation or deformation along the lineament, indicating post-fracture modification.

Detection sensitivity can be enhanced by gradient-based feature extraction:

$$| \nabla h(\theta, \phi) | \rightarrow max\ along\ \lambda_f \tag{23}$$

where:

- $h(\theta,\phi)$ is the topographic height,
- ∇h is the spatial gradient (slope),
- A **persistent gradient alignment** — i.e., a linear zone of elevated slope values perfectly following a great circle — would indicate a possible structural discontinuity.

Mission concepts:

- Extended LRO mission with targeted meridian-tracking orbits,
- Next-generation laser altimeters (e.g., 1–2 m vertical precision, 10 m horizontal sampling),
- Stereo imaging campaigns with sub-meter resolution along the central band.

Falsification condition:
No statistically significant, continuous, meridionally aligned lineament is detected at resolutions better than 10 m vertically and 50 m horizontally along the entire 0˚±20˚ band.

7.2 Subsurface Tomography

Advances in orbital radar sounding and seismic tomography are expected to provide higher-resolution models of the lunar interior, extending from the near-surface to depths of tens of kilometers. These techniques can identify subsurface density contrasts and internal discontinuities aligned with the predicted fracture axis — features that may be completely buried by regolith or impact ejecta and thus invisible to topographic mapping. Tomographic inversion aims to reconstruct internal structural variation from surface measurements:

$$d=Gm \tag{24}$$

where:

- d represents the observational data vector (e.g., radar echo times, seismic travel times),
- G is the forward operator (physics-based model linking model parameters to observations),
- m is the model parameter vector (e.g., dielectric permittivity, seismic velocity, density).

Specific techniques:

- Radar sounding (e.g., Lunar Radar Sounder on Kaguya, future higher-frequency sounders): detects subsurface reflectors (layering, faults, voids) down to ~1–5 km depth,
- Seismic tomography (future networks): resolves velocity variations at depths of 10–100 km, potentially imaging a deep fracture plane,
- Gravity gradiometry (future missions): detects lateral density variations at kilometer scales.

Expected anomaly:
A statistically significant, coherent anomaly — such as a continuous radar reflector or seismic velocity discontinuity — aligned along the central meridional band and extending to significant depth (at least several kilometers).

Falsification condition:
No subsurface discontinuity (radar, seismic, or gravity) is detected along the predicted axis at depths accessible to next-generation instruments, with anomaly amplitudes below the 3-sigma detection threshold.

7.3 Deep Drilling Missions

In-situ exploration through deep drilling missions offers the most direct and conclusive method for testing mineralogical predictions. Future missions targeting the central meridional region could search for physical evidence of high-pressure, high-temperature deformation that would be diagnostic of a large-scale fracture and rejoining event.

Target materials and features:

- **Recrystallized mineral layers** — indicating annealing following deformation,
- **Shock-induced structural changes** — planar deformation features (PDFs), diaplectic glass, high-pressure polymorphs (e.g., stishovite, coesite),
- **Glassy or partially melted zones** — evidence of frictional heating or rapid cooling,
- **Mineral alignment (foliation/lineation)** parallel to the predicted fracture axis.

Detection probability as a function of sampling depth z can be modeled as:

$$P_{detect} = 1 - e^{-\alpha z} \tag{25}$$

where:

- z is the drilling depth (in meters or kilometers),
- α is the concentration parameter representing the volumetric abundance of anomalous material along the depth profile (units: length−1),
- Higher α means more pervasive alteration; lower α requires deeper drilling to achieve the same detection probability.

Mission concepts:

- Robotic drill landers (e.g., evolved version of NASA's TRIDENT or ESA's ProSPA) capable of reaching 1–5 m depth,
- Future sample return missions from the central meridional band (Sinus Medii or Mare Nubium transition zone),
- Human exploration (Artemis) with deep coring capabilities (10 m+).

Falsification condition:
Multiple drill cores from the central meridional band (minimum 3–5 sites) show no evidence of shock metamorphism, recrystallization bands, or mineral alignment that cannot be explained by known impact or volcanic processes. Absence of such evidence at depths >10 m would strongly falsify the hypothesis.

7.4 Thermal Mapping at High Sensitivity

Next-generation thermal instruments with enhanced sensitivity (sub-Kelvin temperature resolution) and finer spatial scales (10–50 m) are expected to resolve subtle temperature anomalies that may be missed by current instruments (e.g., Diviner's ~200 m–1 km resolution). The goal is to identify linear thermal features corresponding to:

- Residual heat signatures — if the fracture/rejoining event was geologically recent (last few million years),
- Differential cooling patterns — indicating altered thermal inertia or subsurface structure,
- Thermal conductivity contrasts — due to fracturing, annealing, or porosity variations along the axis.

Temperature deviation from equilibrium can be quantified as:

$$\Delta T = T_{obs} - T_{model} \tag{26}$$

where:

- T_{obs} is the observed brightness temperature (diurnal or annual average),
- T_{model} is the predicted equilibrium temperature based on albedo, topography, and thermal inertia from surrounding regions.

A statistically coherent temperature anomaly aligned with the central meridian — persistent across multiple local times and seasons — would indicate potential subsurface heterogeneity consistent with the proposed model.

Mission concepts:

- High-resolution thermal mapper (e.g., 50 m pixel, 0.2 K sensitivity) on future lunar orbiter,
- Surface thermal probes (heat flow experiments) deployed at multiple sites along the meridional band,
- Nighttime thermal imaging to minimize solar heating effects and reveal subsurface thermal contrasts.

Falsification condition:
No persistent, linear thermal anomaly ($\Delta T > 3\sigma$ of background variability) is detected along the central meridional band in high-resolution thermal maps. Observed temperature variations are fully explained by albedo, slope, and known geological heterogeneity.

8. Region-Specific Search Strategy

To maximize the detectability of potential geophysical signatures associated with the hypothesized fracture axis, a hierarchical and region-focused search strategy is defined. This approach prioritizes areas on the lunar near side based on:

- Geometric constraints derived from the observer-based reconstruction (Section 3),
- Expected spatial distribution of artifacts (Section 4),
- Geological sensitivity — regions where anomalies are most likely to be preserved or amplified (Section 5).

The goal is to systematically evaluate regions with the highest probability of preserving coherent structural, gravitational, thermal, and mineralogical signatures while accounting for uncertainties in libration, observation angle, and historical ambiguity. Table 2. Shows the strategy for three concentric priority level.

Table 2. The strategy is organized into **three concentric priority levels**:

Priority Level	Longitudinal Range	Purpose
Zone 1 (Primary)	$\lambda \leq 10^{\circ}$	Direct, high-confidence test of the central axis
Zone 2 (Extended)	$10^{\circ} < \lambda \leq 20^{\circ}$	Account for libration and observational uncertainty
Zone 3 (Secondary)	Within Zones 1–2, at mare–highland boundaries	Amplify subtle anomalies via geological contrasts

8.1 Priority Zone 1: Central Meridian (0° ± 10°)

The primary search region is defined as a narrow longitudinal band centered around the lunar central meridian. This zone corresponds directly to the predicted fracture axis derived from geometric modeling (Section 3.3) and therefore represents the highest probability for detecting global-scale signatures — if they exist. The spatial constraint for this region is expressed as:

$$|\lambda| \leq 10^{\circ} \tag{27}$$

where λ is the selenographic longitude relative to the sub-Earth meridian (0°). This ±10∘ range represents the **core uncertainty envelope** after accounting for mean libration effects and a conservative estimate of observational geometry. Table 3 shows priority observational targets within the central meridional zone ($|\lambda| \leq 10^{\circ}$), including expected surface features and corresponding detection methods.

Rationale for ±10°:

- Mean libration amplitude in longitude is ~7.5°,
- Observational ambiguity (lack of precise timestamp) adds ~2–3°,
- The remaining margin accommodates geometric approximations.

Table 3. Priority observational targets

Target Feature	Description	Detection Method
Continuous meridional lineaments	Unbroken, north-south aligned scarps or troughs crossing multiple geological units	LOLA topography, LROC imaging
Symmetry-breaking surface features	Asymmetric crater distributions, offset ridges, or systematic elevation differences across the meridian	Slope mapping, hillshade analysis

Structural discontinuities	Faults, fractures, or graben systems that align precisely with the axis and show evidence of lateral or vertical offset	Gradient-based feature extraction (Eq. 23)

Within this zone, observational efforts should focus on:

Significance:
Given its direct alignment with the predicted fracture axis, this region provides the most stringent test of the hypothesis. A negative result here — no coherent anomalies at the resolution limits of current or near-future instruments — would strongly falsify the model.

8.2 Priority Zone 2: Extended Longitudinal Band (±20°)

The **secondary priority region** expands the search to a broader longitudinal range to account for uncertainties associated with:

- **Lunar libration** — the Moon's nodding motion shifts the visible hemisphere by up to ~8° in longitude over time,
- **Observation angle** — the exact azimuth and altitude of the Moon at the undocumented time of the event,
- **Historical ambiguity** — imprecision in the narrative description (e.g., "horizontal separation" may have been approximate),
- **Preservation effects** — a fracture might be partially buried or eroded, with remnants appearing off the exact meridian.

This extended constraint is defined as:

$$|\lambda| \leq 20^\circ \qquad (28)$$

The ±20◦ band serves as a **buffer region** where partially preserved, diffuse, or libration-shifted signatures may exist. Table 4. Shows expected features within Zone 2:

Table 4. Expected features within Zone 2:

Feature Type	Description	Observational Signature
Weak or discontinuous lineaments	Fracture segments that are not globally continuous but appear as isolated, aligned segments	Intermittent linear features in topographic or image data
Gradual density variations	Diffuse gravity gradients rather than sharp discontinuities	Smooth Bouguer anomaly changes across 10–20° of longitude
Thermal gradients	Temperature anomalies that extend outward from the central band, decaying with distance	Broad, low-amplitude ΔT patterns in thermal maps

Systematic analysis across this region enables the detection of **broader-scale patterns** that may not be strictly confined to the central meridian — for example, a fracture that has been rotated or displaced by subsequent tectonic activity.

8.3 Secondary Zones: Mare–Highland Boundaries

In addition to the meridional bands, **special attention** should be given to regions where **major geological transitions** occur — particularly **mare–highland boundaries**. These regions are inherently sensitive to structural perturbations for several reasons:

- **Mechanical contrast** — mare basalts are denser and more ductile than anorthositic highland crust; stress concentrates at boundaries,
- **Thermal contrast** — mare and highland terrains have different thermal inertia and albedo, enhancing detectability of anomalies,
- **Preservation potential** — boundaries are often sites of faulting and deformation, making them natural recorders of tectonic events.

The detection likelihood in such regions can be modeled as being proportional to the spatial density gradient across the geological boundary:

$$Psignal \propto \frac{\partial \rho}{\partial x} \tag{29}$$

where:

- $\partial\rho/\partial x$ represents the spatial density gradient (or, more generally, any contrast in physical property: density, thermal inertia, seismic velocity, composition),
- Larger gradients amplify subtle anomalies, making them easier to detect above background noise.

Table 5. Key observational targets within mare–highland boundaries:

Target Region	Location (relative to central band)	Geological Context	Expected Anomaly Amplification
Interfaces between mare basalts and highland crust	Crossing the meridian at multiple latitudes	Sharp compositional and mechanical contrast	Structural offsets, thermal gradients
Boundaries of large impact basins intersecting the meridional band	e.g., Imbrium, Nubium, Serenitatis margins	Basin rings concentrate stress; fractures may follow ring structures	Gravity anomalies, mascon discontinuities
Regions exhibiting compositional heterogeneity	Anywhere within ±20° with mixed lithologies	Diverse mineralogy increases contrast for shock or thermal signatures	Mineralogical anomalies, spectral variations

Table 5. shows key observational targets within mare–highland boundaries function of secondary zones:
These areas act as natural amplifiers for detecting otherwise subtle geophysical signatures. They are critical for cross-validating observations obtained within the primary meridional regions:

- A positive detection in a mare-highland boundary strengthens confidence that a real anomaly exists.
- A negative detection in a boundary zone, despite high sensitivity, would argue against the presence of any significant meridional structure.

9. Discussion

This section evaluates the consistency between the predicted geophysical signatures derived from the observer-constrained model (Sections 3–5) and the currently available lunar datasets (Section 6). It further considers alternative geological explanations for observed lunar features that might superficially resemble predicted fracture signatures and discusses the limitations inherent in existing observational capabilities. The goal is to provide a balanced, critical assessment of the hypothesis in light of empirical evidence.

9.1 Consistency Between Predicted and Observed Lunar Data

The proposed model predicts a specific set of **global, meridionally aligned geophysical signatures** concentrated within the central longitudinal band ($\lambda f \approx 0^\circ \pm 20^\circ$):

- **Structural discontinuities** — continuous great-circle scarps or troughs (Section 5.1),
- **Gravity anomalies** — linear density contrasts or crustal thickness jumps (Section 5.2),
- **Thermal anomalies** — persistent heat bands or differential cooling patterns (Section 5.3),
- **Seismic asymmetries** — velocity discontinuities or anisotropic propagation (Section 5.4),
- **Mineralogical evidence** — shock features, recrystallization, or aligned mineral fabrics (Section 5.5).

Current high-resolution datasets do not reveal evidence of a continuous global structural discontinuity aligned with the lunar central meridian. A systematic comparison between predicted and observed signatures, summarized in Table 6, reveals no evidence for any of the predicted geophysical anomalies aligned with the central meridional band.

Table 6. Consistency assessment between predicted geophysical signatures derived from the observer-constrained model and observed lunar datasets across five independent domains.

Predicted Signature	**Observed Status**	**Key Evidence (or Lack Thereof)**
Structural lineament	**Not detected**	LOLA topography shows no continuous, meridionally aligned scarp; surface dominated by impact basins and volcanic plains
Gravity gradient	**Not detected**	GRAIL gravity field shows heterogeneous but spatially consistent mass distributions; no symmetry-breaking meridional feature
Thermal anomaly	**Not detected**	Diviner thermal maps show temperature distributions governed by regolith properties, albedo, and solar insolation — no persistent linear heat band
Seismic discontinuity	**Not detected**	Apollo seismic data support layered but laterally continuous internal structure; no evidence of a global fracture plane
Mineralogical signature	**Not detected**	Orbital spectroscopy (M^3) shows no meridional band of shock-metamorphosed or recrystallized material

Conclusion from consistency analysis:
The overall lack of alignment between predicted global signatures and observed data supports the null hypothesis (H_0): no macroscopic lunar fracture and reassembly event occurred within the resolution limits and geological timescales accessible to current datasets.

However, this conclusion is provisional — it applies to global-scale, well-preserved features. Smaller-scale, deeply buried, or partially erased signatures cannot be definitively ruled out with existing data (see Section 9.3).

9.2 Alternative Explanations: Geological vs. Catastrophic Processes

Observed lunar features that might superficially resemble linear or fracture-like structures can be explained through well-established geological processes that do not require global-scale catastrophic events..

9.2.1 Conventional Geological Mechanisms

Table 7. Conventional geological processes that can produce linear or arcuate surface features on the Moon, their typical morphological expressions, and their potential to mimic the predicted global meridional fracture signature

Process	Typical Features	Potential for Mimicry
Impact basin formation	Concentric rings, radial ejecta patterns, crater chains	Arcuate or linear features, but not single, continuous meridional great circles
Volcanic flooding and mare emplacement	Flow fronts, buried craters, mare ridges	Linear mare ridges can appear fracture-like, but are typically discontinuous and basin-associated
Tectonic deformation	Wrinkle ridges, graben, lobate scarps	Localized linear features; no global meridional continuity
Impact gardening and regolith evolution	Surface smoothing, crater degradation	Can obscure or modify pre-existing features, but does not create coherent global lineaments

Table 7 lists four well-established geological mechanisms—impact basin formation, volcanic flooding, tectonic deformation, and impact gardening—each capable of producing linear or arcuate features that could be mistaken for a global fracture, yet none generate a single, continuous, pole-to-pole great circle. These processes can produce linear or arcuate surface features that may mimic fracture-like patterns over limited spatial extents (tens to hundreds of kilometers). However, none produce a single, continuous, great-circle fracture extending from pole to pole along the central meridian — the specific prediction of the observer-constrained model.

9.2.2 Energetic Implausibility of Catastrophic Scenarios

From a physical standpoint, catastrophic fracture-and-reassembly scenarios require extremely high energy inputs, comparable to or exceeding large-scale impact events. The minimum energy condition is given by Equation (6):$E_{event} \geq U_{bind} \approx 1.2 \times 10^{29}\,J$

For context:

- The **Chicxulub impact** (dinosaur extinction) released ~10^{23} J — five orders of magnitude smaller.
- The **South Pole–Aitken basin** (largest lunar impact) released ~10^{26}J — still three orders of magnitude smaller.
- A **Moon-disrupting event** would require an impactor of ~100–500 km diameter or a close planetary encounter.

Such processes would produce widespread and unmistakable effects across all geophysical domains:

- Global crustal disruption — not just a single fracture, but pervasive brecciation and melting,
- Extensive melting — global or hemispheric magma ocean,
- Long-term thermal disequilibrium — detectable residual heat,
- Complete resetting of crater chronology — no preservation of ancient surfaces.

The absence of such universal signatures strongly favors conventional geological explanations over catastrophic hypotheses.

9.2.3 Parsimony Argument

Applying Occam's razor: the simplest explanation consistent with all observations is that the Moon has never undergone a global-scale fracture and reassembly in its resolvable geological history. The observed surface features are adequately explained by impact cratering, volcanism, and local tectonics — processes that are well-understood and independently verified.

9.3 Limitations of Current Datasets

Despite the high precision and comprehensive coverage of modern lunar observations, several fundamental limitations must be acknowledged. These limitations prevent the definitive exclusion of smaller-scale or partially preserved features that might be consistent with a modified version of the hypothesis. Table 8 identifies five key limitations—subsurface spatial resolution, seismic coverage, thermal modeling uncertainty, mineralogical sampling gaps, and temporal degradation—each of which could conceal evidence of a fracture event that is not globally coherent or well preserved.

Table 8. Current observational and methodological limitations that prevent the definitive exclusion of smaller-scale, deeply buried, or partially preserved features consistent with a modified fracture hypothesis.

Limitation Category	Specific Constraint	Consequence for Hypothesis Testing
Spatial resolution (subsurface)	Radar sounding depth ~1–5 km, resolution ~100 m; no deep seismic tomography	Deep fracture plane (>5 km) could remain undetected
Seismic coverage	Only 4 Apollo stations, all on near side, none along central meridian	Global or deep discontinuities may be missed
Thermal modeling	Regolith heterogeneity introduces uncertainty in thermal inertia (±10–20%)	Subtle ΔT < 1 K may be buried in noise
Mineralogical sampling	No returned samples from central meridional band; orbital spectroscopy limited to top ~100 μm	Shock features or recrystallization could be present but unobserved
Temporal degradation	Impact gardening, cratering, and volcanism over ~4.5 Ga may erase or obscure ancient fractures	Very old features (>3 Ga) may be unrecognizable

These limitations can be formalized as a **total observational uncertainty**:

$$\sigma_{total}^2 = \sigma_{obs}^2 + \sigma_{model}^2 \tag{30}$$

where:

- σ_{obs} represents measurement uncertainty (instrument noise, calibration errors, spatial sampling),
- σ_{model} reflects limitations in theoretical interpretation (e.g., ambiguity in inversion, unknown source properties).

Practical implication:
While current datasets are sufficient to rule out large-scale, well-preserved global fracture signatures, they cannot entirely exclude:

- Smaller-scale features (<10 km wide, <100 km long),
- Deeply buried discontinuities (>5 km depth),
- Partially erased or degraded structures (ancient, >3 Ga),
- Subtle anomalies ($\Delta T < 1$ K, $\Delta g < 1$ mGal).

Future missions with higher resolution, broader coverage, and in-situ capabilities (Section 7) will be required to close these remaining loopholes.

10. Prospective Contributions

This study introduces a novel interdisciplinary framework that integrates historical observational narratives with modern planetary science methodologies. By formalizing qualitative descriptions into geometrically constrained and physically testable models, the approach establishes a new pathway for academic inquiry at the intersection of astronomy, geophysics, and the history of science.

10.1 Methodological Innovation: Observer-Constrained Reconstruction

The primary contribution is the development of an Observer-Constrained Planetary Event Reconstruction (OPER) methodology. This framework enables the systematic transformation of qualitative observational records — often dismissed as unverifiable — into quantitative constraints that can be tested against modern datasets.

The general mapping can be expressed as:

$$O_{hist} \rightarrow C_{geom} \rightarrow P_{phys} \tag{31}$$

where:

- O_{hist} represents historical observations (descriptive, narrative, non-quantitative),
- C_{geom} denotes derived geometric constraints (angles, planes, great circles),
- P_{phys} corresponds to physically testable predictions (geophysical signatures, search regions).

This structured pipeline provides a reproducible, transparent methodology for evaluating historical astronomical claims within a modern scientific framework — without requiring belief in or rejection of their original cultural or religious context.

10.2 Bridging Historical Observations with Planetary Science

A key conceptual contribution lies in establishing a bridge between pre-modern observational records and contemporary planetary geophysics. Rather than treating historical narratives as purely symbolic, mythological, or beyond scientific inquiry, this approach interprets them as constrained observational inputs that can inform hypothesis generation.

This integration enables:

- **Reinterpretation of historical records** as qualitative datasets with geometric information content,

- **Formulation of geometrically consistent planetary models** based on observer-centric constraints,
- **Application of modern remote sensing and geophysical tools** for validation or falsification.

Such a framework expands the scope of planetary science by incorporating **non-traditional data sources** — including historical, archaeological, and textual records — into hypothesis-driven research.

10.3 Defining Precise Target Regions for Future Exploration

The study also provides a clearly defined spatial strategy for future lunar exploration by identifying concrete search regions aligned with the predicted meridional band (Section 8). These regions represent optimal targets for high-resolution investigation using orbital and in-situ instruments.

The prioritization function for target regions can be expressed as:

$$R_{priority} = f(\lambda, S_{geom}, S_{phys}) \tag{32}$$

where:

- λ is selenographic longitude,
- S_{geom} represents geometric alignment with the central meridian,
- S_{phys} denotes the expected strength of geophysical signatures (from Section 5).

This formulation enables mission planners to optimize resource allocation and observational focus based on physically motivated, quantitatively defined criteria — rather than ad hoc or purely aesthetic considerations.

10.4 Generalizability Beyond Lunar Science

Although applied here to a specific lunar narrative, the OPER methodology is **generalizable** to other historical astronomical claims, including:

- **Ancient eclipse records** (constraining Earth's rotation history),
- **Supernova observations** (e.g., SN 1054, SN 1006),
- **Comet sightings** (orbital reconstruction),
- **Transient lunar phenomena (TLP)** reported across multiple cultures.

In each case, the same three-stage pipeline (historical → geometric → physical) can be applied, provided that the observational description contains sufficient angular or spatial information to constrain the geometry.

10.5 Limitations of the Prospective Contribution

It is important to acknowledge that the OPER methodology does **not**:

- **Validate historical causality** — a geometric match between prediction and observation does not prove that the described event actually occurred as narrated,
- **Replace conventional geological analysis** — all positive detections must still be evaluated against alternative explanations (Section 9.2),
- **Eliminate observational uncertainty** — the method translates ambiguity, it does not remove it.

Nevertheless, the framework provides a rigorous, falsifiable, and reproducible approach to a class of questions that have traditionally been relegated to either uncritical acceptance or outright dismissal.

11. Conclusion

This study has presented a systematic, reproducible framework for transforming historically reported observational narratives into quantitatively testable hypotheses within the domain of lunar geophysics. By applying an observer-constrained reconstruction (OCR) approach, qualitative descriptive accounts were translated into explicit geometric constraints, leading to the derivation of a specific meridional fracture axis on the lunar near side, confined to a central longitudinal band ($\lambda_f \approx 0^\circ \pm 20^\circ$). This geometrically defined axis was subsequently used to generate a set of falsifiable, multi-domain predictions, including structural continuity (a continuous great-circle lineament), gravitational anomalies (linear density contrasts), thermal behavior (persistent heat bands or differential cooling), seismic response (velocity discontinuities and anisotropic propagation), and mineralogical evidence (shock metamorphism, recrystallization, and aligned mineral fabrics). A comprehensive comparison between these predicted signatures and currently available high-resolution lunar datasets (LRO/LOLA, GRAIL, Diviner, Apollo seismic records, and M^3 spectroscopy) indicates no evidence for a global-scale fracture or reassembly event consistent with the proposed model. Observed lunar features are more consistently explained by well-established geological processes such as impact cratering, volcanic resurfacing, and local tectonic deformation, while fundamental physical constraints—including the Moon's gravitational binding energy ($\approx 1.2\times10^{29}$) and mechanical stability—impose stringent limitations on the feasibility of such a large-scale structural fracture in the recent geological past. Nevertheless, the primary contribution of this work lies not in confirming a specific physical event but in demonstrating a novel methodological pathway that integrates historical observational inputs with modern planetary science tools. By establishing a clear, transparent chain from narrative description to geometric modeling and physical testability, this approach provides a rigorous and reproducible framework for evaluating similar claims across different astronomical contexts, including ancient eclipse records, historical supernovae, comet sightings, and transient lunar phenomena. Future advancements in lunar exploration—such as higher-resolution surface mapping, improved subsurface imaging (radar sounding and seismic tomography), and expanded in-situ measurements (deep drilling and sample return)—may further refine the limits within which such hypotheses can be tested. Until such data become available, the absence of coherent, global-scale geophysical signatures aligned with the predicted fracture axis strongly supports the null hypothesis that no macroscopic lunar fracture and reassembly event has occurred within the resolvable geological past. Ultimately, this study highlights the value of interdisciplinary approaches in expanding the methodological boundaries of planetary science while maintaining strict adherence to empirical testability and physical consistency.

Funding information

There is no funding for this paper

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