Morphological Signatures of Planetary Fusion: A Unifying Framework for Earth's Deep Heterogeneities

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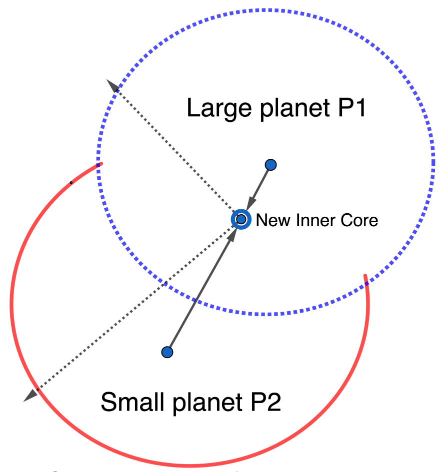
Author Note: This work builds upon a previous preprint published on EarthArXiv (https://doi.org/10.31223/X5G451). The present version expands the original proposal by contextualizing collision–fusion dynamics under conditions described in the literature, where low-velocity impacts may result in complete planetary mass merging.

ABSTRACT

Studies show that the theoretical feasibility, described in the literature, of gravitational interactions between celestial bodies under certain conditions may result in collisions with complete fusion of masses is acknowledged. Accordingly, the objective is to characterize their long-term structural and biological consequences. This study presents a testable conceptual model in which geophysical, geological, and biological predictions are compared with observable evidence throughout Earth's evolutionary history. The hypothesis examines possible morphological signatures of analogous planetary collision–fusion processes and their compatibility with the deep heterogeneities observed in Earth's internal dynamics and surface composition. The effects of gravitational forces during approach, impact, and fusion suggest compatibility with morphological remnants of successful protoplanetary mergers. The model integrates mountain belts, continental fragmentation, mineral and metal deposits, and mass extinctions, unifying them in a single framework alongside geophysical evidence such as magnetic anomalies, hotspots, LLSVPs, ULVZs, water in the transition zone, and hydrocarbon reservoirs. In astronomy, these features are discussed as possible expressions of cyclical planetary reorganizations and potential correlations between recurrent events in the evolution of life and the planet.

Keywords: planetary accretion, mantle heterogeneity, supercontinent cycles, geomagnetic evolution, core–mantle structure, collision–fusion hypothesis, deep water cycle, mass extinctions, planetary geodynamics



Conceptual sequence of mutual gravitational capture and planetary fusion (MGC-PC model)

Introduction

The evolution of Earth and the development of life throughout geological time are duly recorded in various disciplines. Life evolved from water to dominate the emerged lands, while the planet's structure evolved from an undifferentiated body to a layered structure, basically composed of an inner and outer core, mantle, and crust. Studies show that the inner core might not be a rigid sphere, raising questions about its actual structure. In turn, the mantle presents heterogeneities that include phenomena such as the South Atlantic Anomaly (SAMA), regions of hot spots, the presence of subducted crust at depth, and the accumulation of water in the transition zone. In addition, compounds derived from organic matter, such as hydrocarbons and hydrogen, have also been detected at great depths as well as on the surface. At the surface, other characteristics include plate motion, the formation of mountain belts and continental fragmentation, and the wide distribution of mineral and hydrocarbon reserves.

These observations are well documented, although multiple mechanisms have been proposed to explain them and have been progressively refined as new evidence emerged. Given the recurring coexistence of these features across time and scale, this study proposes a unified mechanism in which geophysical, geological, and biological phenomena can be interpreted as expressions of long-lasting morphological signatures generated by collision–fusion events between protoplanets.

This manuscript presents a testable conceptual model, considering planetary collision–fusion scenarios previously suggested as physically plausible (for example, Genda et al., 2012).

Thus, it evaluates its compatibility with multidisciplinary observational evidence, exploring its potential geodynamic, environmental, and biological implications for the integrated evolution of the Earth system.

Results: Parameter Analysis, Planetary Merging, and Morphological Modeling

Following the methodological framework, this analysis describes the expected morphological signatures throughout the collision–fusion process, from the gravitational approach phase to the complete reorganization of the resulting body. The results presented here synthesize and expand the geophysical and biological components of the MGC-PC model (Damian, 2025), with a focus on testable implications for Earth's internal structure, mantle heterogeneities, and both surface and biological evolution.

Approach and Collision Dynamics: From the moment the bodies begin to approach, tidal forces progressively intensify as their velocity vectors align in the same direction (Figure 1). The centers of gravity shift forward, deforming both bodies into ellipsoidal shapes and promoting the gradual uplift of the crust, forming belts due to the rotational movement. Upon reaching the Roche limit, the primary crust of the smaller body fractures, while its opposite side is preserved, which will become a higher and older surface of the new body.

At impact, the slightly ellipsoidal crust of the larger planet comes into contact with the fractured face of the smaller one, possibly striking its mantle directly in an environment likely covered by oceanic waters. Crustal weakening on the antipodal side of the impact can be expected if interpreted geometrically in light of the Borsuk–Ulam theorem.

The collision generates an asymmetric mass with a displaced center of gravity, initially located near the contact point (Figure 1c) but within the larger body. In the contact zone, a transient Hydrobiological Ring forms, composed of loose surface material, water, sediments, organic matter, and gases.

Protoplanetary Fusion Process: The initially bilobed mass tends towards sphericity, pulled by the center of gravity, displacing the inner nuclei towards the new gravitational center, generating a low-pressure zone behind it and dragging volatiles along. Meanwhile, simultaneously, the larger planet becomes coated with a layer of mantle material from the smaller body mixed with part of its own outer core, resulting in geophysical heterogeneities. Between the larger planet and this overlying mantle, an asymmetric interface zone develops, significantly deeper on the opposite side (Figure 1d). Within this interface zone, much of the material from the Hydrobiological Ring becomes trapped, allowing interactions among mantle, crust, water, biological matter, and other elements, under extremely high pressure.

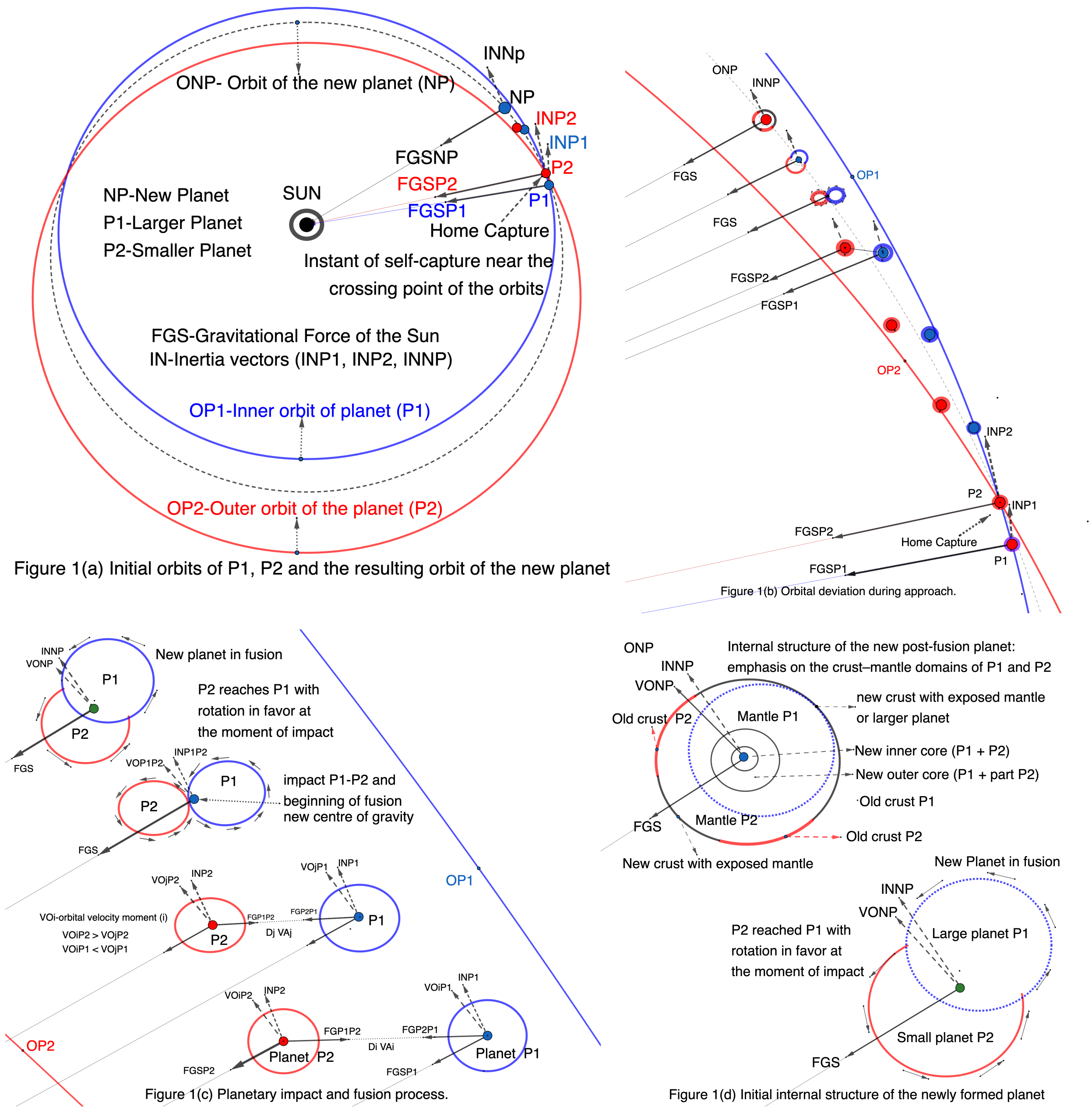


Figure 1(a) Initial orbits of P1, P2 and the resulting orbit of the new planet

Figure 1(b) Orbital deviation during approach.

Figure 1(c) Planetary impact and fusion process.

Figure 1(d) Initial internal structure of the newly formed planet

Meanwhile, the preserved crust of the smaller planet, fragmented into continental blocks, floats over the moving mantle, initially pushing magma ahead of it due to the smaller radius of curvature. This process will possibly form an interconnected network of cracks that decrease in length and width, but increase in number. Between these blocks, the lighter magma emerges first, located just below the crust, marking the initial limit of the movement, followed by denser, deeper material.

In the final stages, as the gravitational center stabilizes, the motion of the residual mantle ceases upon contact with oceanic waters, allowing the formation of a circular or ring-shaped structure that marks the end of the fusion process, with the original crust of the larger body preserved at its center. The tendency toward sphericity represents the final gravitational signature of the fusion process, whose persistence can be compared to observable features in Earth's crust and mantle.

Structural and Morphological Outcome: This event also promotes a reconfiguration of rotation and orbit, axial tilt, and other planetary movements, influenced by the molten masses, solar gravity, and satellite interactions. The precession of the equinoxes changes drastically, reflecting the new gravitational configuration and the absence of the previously adjacent body. The process also involves changes in density, expansion of the planetary surface by approximately 60%, increased gravitational force and internal pressure, promoting the migration of heavy elements such as iron towards the inner layers.

The new surface exhibits three domains of crustal reorganization:

- older regions from the smaller body, fragmented into continental blocks;
- new regions formed between continental blocks through mantle upwelling, possibly raised to different altitudes due to density contrasts;
- a circular low basin at the impact site, possibly exposing the original crust of the larger planet at its center.

As the new surface solidifies, new tectonic plates would form, initiating the lateral movements observed today. These events may also have triggered immediate and secondary extinctions driven by limited adaptability, while aquatic and terrestrial ecosystems, and resilient or adaptable species likely survived each transitional phase.

Discussion

The proposed model may explain deep mantle heterogeneities, magnetic renewal, crustal fragmentation, and biological transitions as parts of an integrated evolutionary process involving the inner planets and life on Earth. Figure 2 — Conceptual stages of the MGC-PC process, from gravitational approach to post-impact stabilization. Figure 3 — Predicted morphological signatures of an MGC-PC event versus observable evidence on Earth.

Mutual Gravity Capture (MGC-PC) : Earth-like planets with water, life, and atmosphere Minor Planet (SP), Major Planet (LP); Tidal force (TF); Roche limit (RL); Hill Boundary (HL)	
Approximation and Impact *Capture when entering the "HL"; Angular momentum exchange*	• *Increase in "TF" and rotational movement forms a mountain range with increasing height* • *Center of gravity moves to the front face, and the planets acquire an ellipsoidal shape* • *In the "RL" the front crust of the "SP" breaks, preserving its opposite side with geological records* • *Megatsunamis push everything in the frontal direction (water, volatiles, animals and plants) forming a type of Hydrobiological Ring when the "LP" impacts the mantle of the "SP"* • *Water comes into contact with the mantle from the impact until stabilization* • *The impact fragments the opposite crust of the "SP" into continental blocks*
Water and Crust Dynamics *Seeds, spores, and cysts transported by water*	• Movement of magma stabilizes, forming a semicircular mountain range at the impact site. The crust of the "LP" may be exposed • Redistribution of water may form salt layers and sedimentary basins on a surface up to 60% larger and with a distinct water volume • New surface with 1/3 old crust and 2/3 new exposed mantle, which cools in contact with water • Organic matter trapped on the surface under layers of sediment (salt or ice) • Water and organic matter trapped in the interface zone, being able to produce hydrocarbons • Mantle minerals are transported and deposited in sedimentary basins or on the ocean floor • Volcanism, mantle exposure and chaotic atmosphere cause ocean acidification
Merger Process and the New Planet *The inner nuclei merge at the center of mass.*	• Inner core of the "SP" moves to the center and creates a low-pressure zone, being able to drag part of the outer core of the "SP" and the water • Mantle and outer core of the "SP" mix while it moves over the "LP", resulting in heterogeneities and an interface zone forms between the "LP" and the mantle layer above • Part of the material from the Hydrobiological Ring is buried and part is redistributed by the waters • Preserved crust fragments into continental blocks and separates, which can form elongated basins and mountain ranges between them • Continental blocks adjust the radius of curvature, which can form mountain ranges along the front continental margins and a network of fissures • The new protoplanetary mass acquires stable sphericity • New tectonic plates are expected to form

Figure 2 — Steps of the MGC-PC process resulting from Mutual Gravitational Capture (MGC)

Morphological signatures resulting from fusion: The MGC-PC model predicts that the merging of two differentiated bodies leaves recurring structural marks on the resulting planet. These signatures, derived from regular physical processes, include features in the core, mantle, crust, mineralogy, and biosphere.

Core and Mantle *Differential core rotation during stabilization*	*• Inner core migrates to the center, can generate bubbles with the outer core material • Core grows fast by bringing the cores together by adding water, nickel and iron • Distinct initial rotation between the cores, tendency to consolidation*	*• Periods of weak magnetic field, independent poles, reversal magnetic poles • Highly heterogeneous, anisotropic and dynamically segmented inner core, with variations in density, composition, and rotation inconsistent with a body uniform. Possibility of the nucleus in a superionic state, and SAMA being an iron-nickel bubble*
	• Heterogeneous mixing between the mantle and part of the outer core of the Minor Planet • Crust of the planet largest buried asymmetrical depth • Interface zone between the crust of the larger planet, covered by the mixture outer mantle-core of the minor planet • Water, volatiles and organic matter trapped interface zone	*• Oceans of water in the transition zone (410-610 km), calcium-rich rocks (300 km), oil in the mantle (250 km) and hydrogen reserves in the interior of the mantle • Deep mantle heterogeneities, such as LLSVPs, ULVZs, and thermal zones anomalous (Hotspots and mantle plumes) and zircons with distinct temporal ages and distinct layers of upper and lower mantle • Yellowstone with sulfur concentration as well as the outer core*
Geography of the Crust *Belts Mountain contimenal blocks, New Plates Tectonics*	*• Preserved crust forming the ephemeral supercontent, fragmented on impact in blocks that move along with the mantle, independent of the larger planet inside • Ancient semicircular basins surrounded by mountain belts • Elongated basins newly formed and among those glad by the exposed mantle cooled by direct contact with water • Regions progressively rejuvenated by tectonics and volcanism*	*• Supercontient formation and fragmentation cycle (Kernoland, Columbia, Rodinia, Pannotia, Gondwana and Pangaea). Current continents 5 major blocs • Pacific and elongated Atlantic and Indian basins • At the boundaries of plate tectonics and volcanism, the mantle rises to the surface • TPW: Global reorientation of the lithosphere due to internal mass changes*
	• Semi-circular mountain belts at the impact site and semi-linear between continental blocks, including over continents and their edges • Network of interconnected shallow and deep channels within the continental crust • New plate tectonics after crustal cooling and with new movements • The antipodic region to impact may result in a weakened crust	*• Young mountain belts: Semi-circular ring of fire, other semi-linear: Alpine-Himalayas, Andean, Mid-Oceanic Ridges. Ancient belts: Urals, Appalachians, Scandinavians • Network of rivers have a progressive rate of magnitude of length and width in inverse relation to quantity • Chaotic Africa region corresponds to opposite side of the center of the Ring of Fire*
Mineralogy *Counted water with Exposed Cloak*	*• Water-mantle thermal shock transforms and transports metals and minerals (soluble and insoluble gifts) of the mantle, which at the bottom of the ocean, recent and ancient • Dead organic matter can be deposited on the ocean or continental floor under layers of sediment, such as ice or salt • Water and organic matter in the interface zone or on the surface can interact with other elements and form hydrocarbons, such as petroleum, hydrogen, and methane*	*• Theories of abiogenic, interior, mantle and biogenic petroleum on the surface • Ancient seas contain oil and gas reserves • Hydrogen found in the mantle and methane beneath the Antarctic ice sheets • Salt and pre-salt layers occur on the coast of the internal oceans and reserves of metals in ancient seas and on the ocean floor • Fate of organic matter from mass extinctions is unknown*
Biology e Habitat *Evolution of life and the planet*	• Increase in surface, change in water volumes and in continental x oceanic areas • Evaporation and heavy rainfall, warming of the waters with temporary acidification • Chaotic atmosphere, new proportion-composition of gases, followed by stabilization • Extinction in fusion and in new habitat, continuity of life can include contributions of both protoplanets. Survival: seeds and exposed aquantic life • Rapid sedimentation on fossils that may be displaced from habitats	*• Marine life: microbial up to 750 Ma, multicellular up to Cambrian Explosion 541 Ma • Life appears on the continents from 450 Ma, first plants, forests and amphibians, and follows terrestrial diversification • Last 540 Ma there were 5 major extinctions at times periods of change biological diversification and large-scale magmatism episodes • Causes of K-PG debate with time displacement of up to 300,000 years*
Astronomy *Mass and Energy*	• Records in sedimentary rocks or fossils record the moment their formations • Tidal force raises the crust until it breaks head-on and impacts it fragments • Center of gravity seeks the sphericity of the mass, and fusion alters motions in the space. New patterns of translation, rotation, obliquity, and precession of the equinoxes • On the Hill sphere with aligned orbital vectors favors local gravitational interaction • Gravitational interaction between two proto-planets can destabilize their satellites	*• Earth has had days of the year when it has 435 to 369 • Mass and angular momentum alter rotation and orbital dynamics • The approach between massive bodies intensifies tidal forces, and there is a limit on the which the smaller body breaks (Roche) • Differentiated bodies tend to sphericity (minimize gravitational potential energy) • Within Hill's sphere, the mutual attraction between bodies dominates over that of the Sun •Orbital proximity between bodies can destabilize satellites*

Figure 2 — Steps of the MGC-PC process resulting from Mutual Gravitational Capture (MGC)

Geophysics and Deep Structure of the New Planet: The fusion of differentiated bodies reorganizes the mantle and crust, merging inner cores that may rotate independently before the stabilization of angular momentum. Multiple seismological and geophysical observations indicate that Earth's core is highly heterogeneous, anisotropic, and dynamically segmented, with variations in density, composition, and rotation inconsistent with a uniform body (Wang W. et al., 2024; Vidale et al., 2025), there are even studies that suggest a superionic state (He et al., 2022).

Each MGC-PC event, in addition to increasing the core radius, would raise internal pressure and promote the migration of iron toward the center. The renewed geodynamo around ~550 Ma, marked by the intensification of the magnetic field, and the inner core's growth to about 50% of its current radius by ~450 Ma (Zhou et al., 2022), may record episodes of coupling.

The MGC-PC model proposes that, during fusion, the mantle of the smaller body partially mixes with its outer core, forming a layer that coats the larger planet and generates long-lasting heterogeneities. Water, volatiles, and other materials are likely trapped between this layer and the crust of the larger planet.

The presence of mineralized water in the mantle transition zone (Pearson et al., 2014; Gu et al., 2022; Huang et al., 2005) and calcium-rich rocks at depths of about 300 km (Brenker et al., 2005) constitutes evidence supporting this scenario. Hotspot regions and Yellowstone may reflect the mixing of the mantle with its outer core. Savage et al. (2015) indicate that the outer core is rich in sulfur, and Nordstrom et al. (2009) report sulfurous waters and yellow-stained rocks in Yellowstone. The migration of the smaller body's inner core toward the new center of mass would have dragged liquids and volatiles, forming persistent compositional bubbles, possibly explaining the South Atlantic Magnetic Anomaly (SAMA) proposed by Finlay et al. (2020).

Compatibility is observed between the buried crust of the larger planet and deep mantle heterogeneities, such as LLSVPs, ULVZs, and plumes (Dannberg et al., 2023; Hansen et al., 2023; Torsvik et al., 2016; Wang J. et al., 2024). Occurrences of zircons commonly associated with subducted crust, with ages of approximately 165, 190, 222, 314, 640, and even 2,500 Ma (Rojas-Agramonte et al., 2024), suggest links with ancient events of the MGC-PC.

Physical and Geochemical Geography - Orogenies, Supercontinents, and Mineralogy: Orogenic belts record cyclic geological events at different stages of Earth's crustal evolution. The ages attributed to ancient orogenic belts (>200 Ma) can be grouped into intervals that coincide with other major geological events, suggesting a common mechanism of formation. A more recent MGC-PC event would be reflected in four main mechanisms:

- structures associated with the subduction of the larger planet, possibly represented today by the interior of the Pacific Ring of Fire;
- the release of low-density magma during the onset of continental rifting, forming mid-ocean ridges;
- crustal uplift driven by strong tidal forces during planetary approach, expressed in the Alpine–Himalayan orogeny;
- curvature adjustment along continental margins, visible in the Andean belt.

Supercontinents: The MGC-PC hypothesis proposes that the merging of planetary masses produces a new body with a significantly larger volume and curvature radius, accompanied by an abrupt surface expansion of about 60%. The model does not assume the progressive migration of plates to assemble a supercontinent but instead the partial preservation of the smaller body's crust, forming a transient supercontinent that fragments into blocks at the moment of impact. These blocks float independently over the mantle covering the larger planet, creating fissures to accommodate the new curvature radius, and some may undergo differential subsidence, as exemplified by Zealandia. Thus, within the MGC-PC framework, the supercontinent cycle represents a transient process of formation and fragmentation, analogous to that described in supercontinent studies, combined with the expansion of the surface area. In addition, the differential motion of continental blocks relative to the new planetary center during fusion, although distinct, can be interpreted as a phenomenon analogous to classical True Polar Wander (TPW) (Vaes & van Hinsbergen, 2025).

The "New Planet" consolidates a new tectonics, in which the surface includes young regions formed by magma, crustal blocks preserved from the smaller body, and possibly remnants of the crust from the larger body at the impact site. Parts of this surface will continue to be rejuvenated by tectonic and volcanic activity, as is already happening, until a new event alters the system.

A continental fragmentation cycle is associated with variations in mantle flow, core dynamics, magnetic field behavior, and global environmental changes (Nance et al., 2019; Pastor-Galán et al., 2019; Scotese et al., 2021).

Hydrocarbons: In an MGC-PC event, extinct organic matter is lost or transported by water and may be buried in interface zones, accumulated in continental basins, or deposited on the ocean floor. Once accumulated, this matter would be subjected to pressure from the deep mantle or sedimentary layers such as ice at the poles and salt on continental margins. Incidentally, indicating the same origin for biogenic and abiogenic models (Kutcherov & Krayushkin, 2010), including for methane generation (Sleep et al., 2012). According to Höök et al. (2010), there is stronger empirical support for a predominantly biogenic origin.

This context extends to hydrocarbon reservoirs in continental regions that previously corresponded to inland seas, and to methane seepage from the Antarctic seabed (Seabrook et al., 2025).

Minerals and metals: Accepted models indicate that since the solidification of Earth's crust, mantle material has been continuously brought to the surface through tectonic and volcanic activity. Continental regions also contain deposits formed in magmatic and hydrothermal environments, later concentrated by weathering or redistributed by erosion. On the ocean floor, seawater dissolves soluble minerals, mechanically fragments insoluble phases, and thermal shock at the water–mantle interface can temporarily ionize metals. In this state, these elements tend to organize according to their chemical, physical, and geochemical affinities and precipitate under varying conditions of temperature, pressure, and the presence of sedimentary particles such as sand or organic matter. Evidence reported by Fischer-Gödde et al. (2024) confirms the presence of metals both in seawater and in continental deposits formed at different times, which once corresponded to oceanic basins.

The MGC-PC model suggests a complementary mechanism in which oceanic waters come into direct contact with the exposed mantle of newly formed oceanic regions, extracting minerals and metals and subsequently redistributing them across the seafloor. This process is fully consistent with the geological literature. Consequently, such regions exhibit the highest potential for the accumulation of these materials, and ancient oceanic basins represent zones of elevated mineral potential.

Paleontology – Extinctions and Evolution of Life: The so-called "Cambrian Explosion" also represents a rapid multifactorial diversification, without a single identifiable cause (Zhang & Shu, 2013). Subsequently, several extinction events occurred, five of which are considered large-scale events, coinciding with periods of environmental change and large-scale magmatism episodes (Montañez, 2022; Courtillot et al., 2003; Long et al., 2025; Brusatte et al., 2015).

The event that eliminated non-avian dinosaurs remains under active debate, particularly concerning its primary triggers. A temporal offset of up to ~300,000 years between the Chicxulub impact, the extinction peak, and Deccan volcanism has been reported by Renne et al. (2013) and Keller et al. (2020). A potential second impact was considered but later rejected. Additionally, fully vertical neck postures in sauropods appear physiologically unrealistic (Seymour & Lillywhite, 2000; Snelling & Seymour, 2024).

The MGC-PC event suggests a simultaneous destabilization of the crust and atmosphere accompanied by a reorganization of ocean–continent proportions, a physical mechanism capable of triggering major extinction episodes, complementary to previous models. Planetary fusion could simultaneously favor the survival of aquatic or sheltered organisms and the plant kingdom, while imposing selective pressures for adaptation to the transformed environment. Seeds, spores, and cysts carried by water during the fusion could have found favorable environments for germination, such as swamps and deltas, possibly since the formation of the first stable terrestrial environments.

Each coupling event would have increased gravity, intensified the magnetic field, altered oceanic conditions, and modified both atmospheric density and solar irradiation. In this context, new ecological strategies were favored, in a pattern that resembles biological evolution with long periods of stability separated by abrupt episodes:

- up to ~1.8 Ga: microbial life is present in the oceans;
- from ~1.8 Ga to ~750 Ma: microbial life diversifies in marine environments;
- from ~1.2 Ga to ~750 Ma: ocean oxygenation occurs;
- from ~750 to ~540 Ma: multicellular life emerges in the waters;
- from ~540 to ~450 Ma: period of the Cambrian explosion, expansion of marine ecosystems and appearance of the first vertebrates;
- from ~450 to ~360 Ma: the first plants and forests and amphibians appear on the continents;
- from ~360 to ~250 Ma: terrestrial ecosystems diversify
- from ~250 to ~66 Ma: dinosaur dominance
- from ~66 Ma to today: life expands in aquatic environments and over continents

These biological phases may be showing changes in the surface, in the composition of atmospheric gases, and in global environmental changes. Importantly, low levels of CO_2 combined with high concentrations of O_2 may have favored the emergence of complex organisms and larger brains (Bardi, 2025).

Cycles of Geodynamic, Orbital and Climatic Change: During Earth's evolution, a sequence of MGC-PC cycles may have occurred, each characterized by a substantial increase in solid, liquid, and gaseous mass, accompanied by a reorganization of orbital, geophysical, and crustal configurations.

Between approximately 2.4 and 2.0 Ga, multiple lines of evidence mark the first major evolutionary leap of Earth (Figure 4c), a period when oceanic water was already widespread and the Great Oxidation Event took place. Rocks from this interval record an active geodynamo, with a global magnetic field whose intensity possibly ranged between <10 and ~30 μT, in contrast with the present ~50 μT of Earth. These records are essential for constraining the mass of the proto-Earth at that time, and therefore for estimating the number of MGC-PC event cycles.

Although still preliminary, Figure 4 proposes a temporal scale composed of eight events over the past 2.4 Ga, considering the most relevant observable evidence that characterizes each cycle. Simulations of mass evolution and the number of cycles can be refined through the analysis of geological and magnetic records, as well as by correlating the temporal intervals with Proterozoic Milankovitch cycles (Meyers & Malinverno, 2018). The intensity of the magnetic field observed between 2.4 and 2.0 Ga serves as a minimum-mass constraint: If the initial protoplanetary mass were comparable to that of Eris, approximately eight cycles would be required to reach the present-day configuration of Earth, whereas a lunar-scale initial mass would require about six. These values indicate that the number of cycles depends on the assumed initial mass and may change as additional parameters and evidence are incorporated.

Logical considerations suggest that, near Earth's current orbital region, the original protoplanets may have been distributed in an approximately symmetric configuration, with roughly half occupying inner and half outer positions. The merger process would have gradually shifted these orbits toward Earth's present path, driven by recurrent gravitational interactions that enabled collisions, satellite capture or destabilization, and the ejection of smaller objects. Orbital migration, the capture and removal of minor bodies, and the destabilization of satellites are well documented and widely accepted processes (Ipatov, 2024; Kane et al., 2021; Rabago et al., 2019; Blanc et al., 2025).

This leads us to consider that close encounters between protoplanets could result in the destabilization of small satellites or in collisions involving small protoplanets. The Moon, for example, could have originated and evolved similarly to other protoplanets and been captured when Earth was still a proto-Earth and its mass varied from values similar to Ganymede's to approximately half its current mass. In this context, events such as Chicxulub and the extinctions at approximately 483 Ma and 201 Ma could be analyzed.

It is worth noting that glacial varves, tidal rhythmites, and shell fossils—records of climatic cycles, tides, and orbital dynamics—indicate that Earth's past orbital or rotational configuration corresponded to approximately 435–369 days per year (Williams, 2000; Mazumder, 2004; de Winter, 2020; Wells, 1963). These records may reflect variations in Earth's mean distance from the Sun or changes in its rotation rate.

Water Cycle in Earth's Evolutionary History*:* The MGC-PC model proposes that variations in surface area and liquid-water volume between the two merged bodies influenced ocean depth and the proportion of continental landmass through geological time. Some of this water may have been buried during fusion events within interface zones, where it interacted with the mantle under high pressure.

The relationship between liquid-water volume is substantially altered, both increasing and decreasing, while the surface area growth by up to 60%. This ratio of water volume versus surface area is related to terrestrial colonization by plants and animals only in the last ~470 Ma. Consistently, with climatic cycles, tectonics and recurring sea level variations over the last 540 million years as pointed out by Scotese et al. (2021).

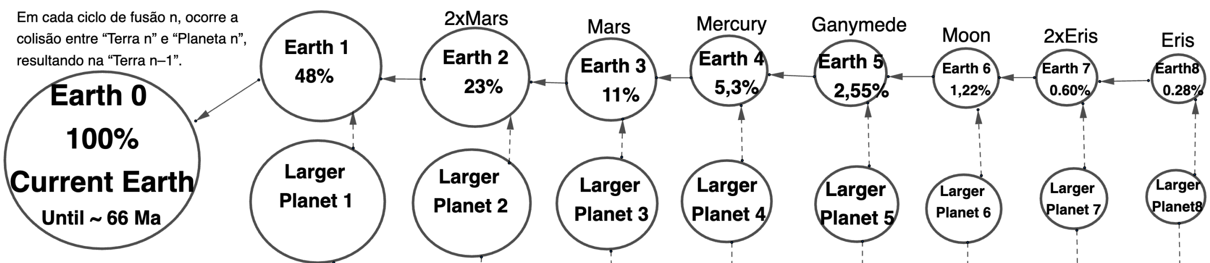


Figure 4 (a): the planetary evolution timeline

Time span of existence eartyh (i) ===>	~270-250Ma to ~66Ma	~380-360Ma to ~270-250Ma	~450-440Ma to ~380-360Ma	~550-540Ma to ~450-440Ma	~750Ma to ~550-540Ma	~1,2Ma to ~750Ma	~2.4-2.0 Ga to ~1.2 Ga	~4.5 Ga to ~2.4-2.0 Ga
Mass ratio 48% x 52% => Result:	Earth(i=1)+ Planet(i=1)	Earth(i=2) + Planet(i=2)	Earth(i=3) + Planet(i=3)	Earth(i=4) + Planet(i=4)	Earth(i=5) + Planet(i=5)	Earth(i=6) + Planet(i=6)	Earth(i=7) + Planet(i=7)	Earth(i=8) + Planet(i=8)
Mass smaller planet (i) x current Earth	48.00%	23%	11%	5.3%	2.55%	1.22%	0.60%	0.28%
Densidade Earth (i)	5,20E+03	4,88E+03	4,53E+03	4,18E+03	3,93E+03	3,43E+03	3,33E+03	3.09E+03
Mass Earth (i) smaller planet	2.87E+24	1.38E+24	6.61E+23	3.17E+23	1.52E+23	7.30E+22	3.51E+22	1.68E+22
Mass larger planet (i)	3.11E+24	1.49E+24	7.16E+23	3.43E+23	1.65E+23	7.91E+22	3.80E+22	1.82E+22
Resultant mass: Earth (i-1)	5.97E+24	2.87E+24	1.38E+24	6.60E+23	3.17E+23	1,52E+23	7.30E+22	3.51E+22
Resultant volume: Earth (i-1) - km	1.08E+12	5.51E+11	2.82E+11	1.46E+11	7.58E+10	3,87E+10	2.13E+10	1.05E+10
Resultant surface: Earth (i-1) - km²	5.10E+08	3.25E+08	2.08E+08	1.34E+08	8.67E+07	5.53E+07	3.72E+07	2.33E+07
Maximum ancient cratons: Earth (0)	32%	20%	13%	8,5%	5,4%	3,6%	2,5%	1,5%
Resultant radius: Earth (i-1)	6,371	5,087	4,068	3,265	2,626	2,098	1,720	1,360
Radius of smaller planet (i)	5,087	4,068	3,265	2,626	2,098	1,720	1,360	1,092
Radius of larger planet (i)	5,224	4,178	3,353	2,697	2,155	1,766	1,397	1,121
Gravitational force Earth (i-1)	9.82	7.39	5,55	4.14	3.07	2.31	1.65	1.26
Escape velocity Earth (i) - km/s	8.67	6.72	5.20	4.01	3.11	2.38	1.85	1.43
Escape velocity larger planet (i) - km/s	8.91	6.90	5.34	4.12	3.20	2.45	1.90	1.47
Escape velocity of the system - km/s	8.79	6.81	5.27	4.07	3.15	2.41	1.88	1.45
System Impact Velocity - km/s, n=1	8.79	6.81	5.27	4.07	3.15	2.41	1.88	1.45
System Impact Velocity - km/s, n=0,8	7.86	6.09	4.71	3.64	2.82	2.16	1.68	1.30
Radius Hill Earth (i) - km	1,170,885	916,772	717,825	562,025	440,050	344,548	269,772	211,224
Radius Hill larger planet (i) - km	1,202,545	941,561	737,201	577,222	451,949	353,864	277,066	216,936

Figure 4 (b): the numerical data

Event (1) ~66 Ma Earth 50% + Planet 1 = Current Earth	Event(2) 270–250Ma Earth 2 (2xMars) + Planet 2 = Earth 1	Event (3) ~380–360 Ma Earth 3 (Mars) + Planet 3 = Earth 2
Detailed in sections 4.1 to 4.7 .Core and Magnetic Anomalies .Mantle heterogeneity .Orogenic processes, crustal restructuring and geodynamic implications .Petroleum and mineral reserves .Biological evolution, extinctions .Varve-type sedimentary rocks, tidal rhythmites, and shell fossils	.Establishment of terrestrial life from ~360 to ~250 Ma ·Permian extinction ~252 Ma .Uralian orogeny with final subduction around ~250 Ma .Oblique collision between Laurentia and Gondwana ~320 to ~270 Ma, resulting in the Alleghanian orogeny .Opening of the Meso-Tethys Ocean ~280 Ma and the Neo-Tethys Ocean ~230 Ma .Subduction of the Paleo-Pacific plate ~260–250 Ma .Triassic–Jurassic extinction (~201 Ma) .Fossils ~84 Ma, 370 days per year .Subtropical forests and natural wildfires in North Africa ~84 Ma	.Emergence of plant life, followed by forests and amphibians from ~450 to ~360 Ma .Devonian extinction ~372 to ~359 Ma .Uralian orogeny (~380 Ma): subduction of the Paleo-Uralian Ocean, collision of the Kazakh block with the Siberian craton (~320 to ~280 Ma) .Opening of the Paleo-Tethys Ocean ~380 Ma .Diversification of vascular plants ~375 to ~359 Ma .Expansion of the first large trees ~359 Ma .Mass extinction with decline of aquatic vertebrates and abrupt climate chages at 359 Ma
Event (4) ~450–440 Ma Earth 4 (Meercury) + Planet 4 = Earth 3	**Event (5) ~550–540 Ma** Earth 5 (Ganymedes) + Planet 5 = Earth 4	**Event (6) ~750 Ma** Earth 6 (Moon) + Planet 6 = Earth 5
.Expansion of marine life and appearance of the first vertebrates from ~540 to ~450 Ma ·Ordovician–Silurian extinction ~443 Ma ·Closure of the Iapetus Ocean ~430–420 Ma and Caledonian orogeny .Inner core radius grew to ~50% of present size at ~450 Ma	.Multicellular marine life from ~750 to ~540 Ma ·Cambrian Explosion ~541 Ma .Very weak geomagnetic field, began regenerating around ~550 Ma .Fragmentation of the supercontinent Pannotia ~625 to ~–550 Ma .Formation Iapetus Ocean ~600 to ~500 Ma	.Microbial life in the oceans from ~1.2 Ga to ~750 Ma ·Breakup Rodinia ~750 Ma ."Snowball Earth" glaciations ~717 to ~635 Ma and ~584 to ~579 Ma, low geodynamic activity, atmospheric changes, variations in insolation .Tidal records around ~620 Ma indicate a solar year of ~400 ± 7 days
Event (7) ~1.2 Ga Earth 7 (2xEris) + Planet 7 = Earth 6	**Event (8) ~2.4–2.0 Ga** Earth 8 (Eris) + Planet 8=Earth 7	**Event (8) ~4.6–2.4 Ga** Up to this point, the Earth about 50% the mass of Eris
. Microbial life in the oceans from ~2.0 to ~1.2 Ga ·Dissolution of the Columbia supercontinent ~1.2 Ga, lithosphere–mantle reorganization and ~90° rotation of the North China Craton. ·Tidal rhythm records ~2.1 to ~1.6 Ma indicate 384 days per year	. Microbial life in the oceans from ~2.4 to ~2.0 Ga ·Fragmentation of Kenorland ~2.45 to ~1850 Ma, early formation of the Huronian Basin and the Animikie Basin ·Tidal rhythm records ~2.45 to 2.1 Ma indicate 384–435 days per year	.Formation of a solid crust and presence of liquid water by ~4.4 Ga .First geomagnetic field in a differentiated Earth ~4.0 to ~3.5 Ga .Microbial life in the oceans from ~3.8 Ga onward .Onset of oxygenic photosynthesis (O_2-producing) at ~2.7 Ga .Extensive Banded Iron Formations developed in iron-rich oceans with low oxygen levels.

Figure 4 (c): the geological events

Geological evidence compiled from standard literature.

Conclusion

The proposed model is disruptive in scope and integrative in structure, complementing existing theories by examining planetary collisions and mergers as a potential mechanism. It describes a process in which an abrupt increase in mass occurs, during which the mantle of the smaller body spreads over the larger one, while part of its crust is preserved.

The signatures of this event include mantle heterogeneities, inner core growth, orbital variations, mass extinctions, and orogenic processes. The model proposes that the inner core may exhibit compositional stratification compatible with a multi-spherical configuration. Immersed in a liquid medium, it may have undergone progressive solidification through successive stages.

Earth may have undergone MGC-PC events that, in some cases, coincided with continental fragmentation or mass extinctions, with the most recent possibly associated with the K–Pg extinction. Model validation can be achieved through targeted simulations and focused research addressing the following aspects:

- Seismic modeling of the inner core as a structure resulting from the aggregation of multiple spheres;
- Compatibility between mantle heterogeneities (hotspots, SAMA, LLSVPs, and ULVZs) and interactions within the transition zone involving water, volatiles, and buried crust;
- Integrated reinterpretation of tectonic, orogenic, extinction, and biological evolution cycles in light of MGC-PC events.

In summary, the MGC-PC hypothesis proposes a conceptual reorganization grounded in testable evidence, offering new perspectives for understanding planetary geophysical evolution in collision scenarios occurring below the critical destruction threshold. This approach suggests that tectonic and continental simulations should consider the geophysical conditions preceding and following each potential collision-fusion event. In synthesis, reinterpreting observable evidence through the MGC-PC framework expands the space for testable hypotheses concerning the evolution of Earth and life over geological time, functioning as a complement to existing interpretations.

Methodology

The literature suggests that gravitational interactions may lead to comet ejection, satellite capture or destabilization, catastrophic disruption, or complete fusion between planetary bodies. This study focuses on the latter scenario: collisions that result in full mass merger and generate long-term morphological signatures. Genda et al. (2012) indicate that collisions below a critical velocity may produce complete fusion, and also note that under certain conditions this critical threshold may exceed the escape velocity of the system.

. In their model, the critical velocity depends on the mass ratio (γ), impact angle (θ), and empirical coefficients (c_1–c_5) derived from hydrodynamic simulations (see Eq. 1 in Genda et al., 2012). Other studies suggest that head-on impacts are generally more destructive than low- to moderate-angle collisions (<45°), which, depending on the mass ratio, may result in complete mergers or grazing encounters (Kegerreis et al., 2020; Denman et al., 2022). High-angle impacts (>60°) tend to produce hit-and-run or glancing events (Asphaug et al., 2006; Emsenhuber & Asphaug, 2019).

Energy dissipation occurs through mantle deformation, crustal fracturing, and partial atmospheric loss. The dissipation rate in impact scenarios involving ocean-covered surfaces is described by Genda & Abe (2005).

Assuming these parameters are satisfied (mass ratio, presence of water, low impact angle, and subcritical velocity) in a collision between nearby protoplanets, the fusion process should be examined in terms of the enduring morphological signatures left at the following stages:

- Approach: the effects of tidal forces, center-of-mass dynamics, and the Roche limit;
- Impact: the consequences and propagation dynamics of impact forces;
- Fusion: the behavior of volatiles, atmosphere, crust, and internal layers (mantle, inner and outer core).

The hypothesis can be tested by comparing the theoretical predictions of the signatures expected during the approach, impact, and fusion phases with scientifically observed geophysical, geological, and paleobiological evidence. Occurrences should be evaluated on a temporal scale covering at least the past 750 Ma, in order to identify spatial and chronological correlations between predictions and observations.

This evidence includes mantle heterogeneities, inner-core anisotropies, crustal impacts, mineralogical patterns, and the behavior of water and the atmosphere, including their influence on animal and plant life. The robustness of the model will be assessed by the consistency between the predicted signatures and the empirical patterns reported in the geophysical and paleontological literature.

Given that such planetary fusion is physically viable under the conditions described by Genda et al. (2012) and expanded upon in Damian (2025), this article positions itself within the domain of structurally testable hypotheses, offering predictions comparable with observed evidence from astronomy, geophysics, biology, and paleontology, without relying on mere exploratory simulations.

Based on the physical conditions and parameters described by Genda et al. (2012), the application of the model requires a specific methodological framework aimed at identifying compatible evidence and reinterpreting geophysical and biological data within a new conceptual framework. The application of the model follows an active epistemological principle:

(i) analysis of the collision–fusion process, identifying the enduring morphological signatures from the onset of the event, taking into account the interplay of forces and the dynamic behavior of the constituent masses (core, mantle, water, volatiles, and gases) leading to the re-establishment of sphericity in the newly formed body;

(ii) identification of observable evidence on Earth and its reinterpretation within the proposed conceptual framework, without interference or attempts to fit conclusions derived from other models.

This criterion is essential for identifying alternative explanations to questions such as:

- Why do distinct and significant events seem to occur in recurring temporal cycles?
- Why did life first develop in aquatic environments and only during the last ~470 Ma become dominant on land?
- Where did the organic matter associated with mass extinctions go?
- Regardless of its origin, why is similar petroleum found both at the surface and within the mantle?
- If all surface minerals and metals exist in the mantle, why are nearly all continental deposits concentrated in former oceanic basins and at different depths?
- Could recent orogenic belts result from a single process that was repeated in ancient belts?
- Have tectonic plates always existed and recycled, or could they have been completely reformulated?
- How were oceans of water introduced into the deep mantle?
- Could the transition zone separating the upper and lower mantle have variable thickness, with possible structural and chemical asymmetries yet to be resolved?
- Could mantle heterogeneities share a common mechanism of origin?
- Do magnetic anomalies and the irregular evolution of the geomagnetic field occur in temporal cycles? Could they be related to variations in core mass?

These questions establish the investigative scope, positioning the MGC-PC model within the realm of scientifically verifiable hypotheses, offering predictions that can be compared with known geophysical and biological observations.

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Figure captions

Figure 1 – Dynamic sequence of planetary merger.

Figure 2 – Steps of the MGC-PC process resulting from Mutual Gravitational Capture (MGC).

Figure 3 – Persistent morphological signatures generated by the MGC process.

Figure 4 – Planetary Coupling Cycle Diagram (MGC-PC)

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