

A 3D Rapid Prototyping Method for Visualizing Earth’s Expansion Through Handcrafted Models: A Chthonian Planet Perspective

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Abstract

Modeling the physical evolution of Earth as a self-organizing particle system remains a formidable computational challenge, particularly over geological timescales spanning hundreds of millions to billions of years. Given the astronomical number of interacting particles, direct one-to-one physical simulation is currently unfeasible. This study introduces a rapid prototyping methodology that approximates the macroscale geometric effects of Earth’s hypothesized volumetric expansion, especially over the last c. 180 million years, through analog modeling techniques. By iteratively reconstructing present-day continental crust positions on progressively smaller-radius spheres, a consistent and coherent geometric fit among continents emerges. Within this framework, Earth is conceptualized as a chthonian planet undergoing long-term volumetric expansion driven by internal relaxation following an early-stage compressed state. This approach offers a physically motivated, low-resolution visualization platform and challenges conventional rigid-plate tectonic models, encouraging further investigation of planetary-scale geodynamics under relaxed structural constraints.

Keywords: Earth, Expansion, Chthonian Planet, Analog Modeling, Relaxation, Rapid Prototyping

1 Introduction

Earth’s geodynamic history may include a process of volumetric expansion [1, 2], a hypothesis traditionally viewed as incompatible with plate tectonic supercontinent cycle [3, 4]. This study aims to: (1) physically model the geometric fit of continental crust on smaller-radius spheres representative of Earth’s past configurations, employing tangible 3D analog rapid prototyping methods; and (2) propose a physically plausible mechanism for this expansion by interpreting Earth as a chthonian planet [5]—initially more compact and denser, progressively relaxing over geological time.

The chthonian model hypothesizes Earth’s formation under extreme pressures, potentially as a gas giant core, followed by expansion due to pressure release and internal phase transitions. The formation of new oceanic crust over the last c. 180 million years (Figure 1) is interpreted not as crustal recycling but as a surface manifestation of global volumetric relaxation.

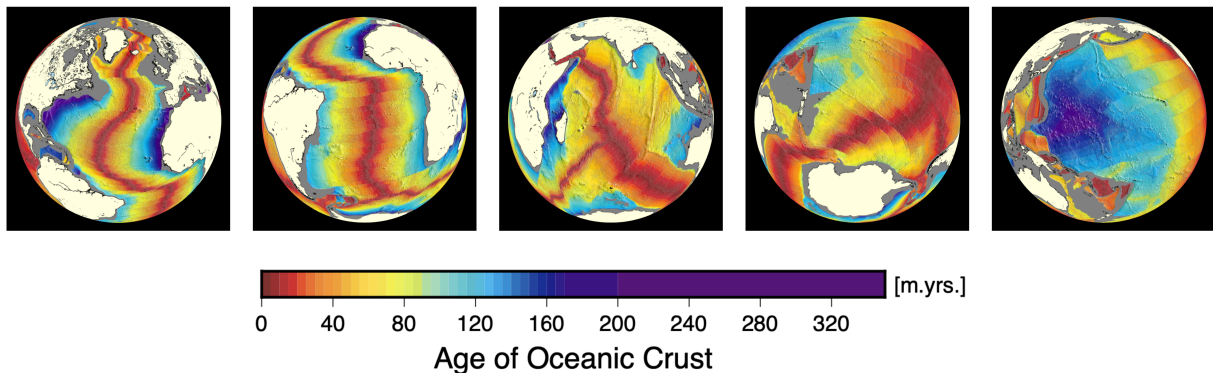


Figure 1: Various views of the Earth showing oceanic crustal ages, for the vast majority of up to c. 180 million years. Reproduced from [6].

2 Methodology

Visualizations of the potential appearances of exoplanets—of which several thousand have already been discovered and the number continues to increase [7]—serve as a valuable tool for constructing preliminary models of their surfaces and atmospheres based on limited observational data [8]. In contrast, Earth remains the most thoroughly studied planet, with its morphology and internal structure well characterized through a combination of satellite remote sensing and direct geophysical investigations.

3D rapid prototyping methods—commonly used today in the natural sciences, especially medicine, to produce objects such as organ models or custom surgical guides [9]—are here adapted for geological applications, enabling tangible and iterative visualization of a large-scale physical phenomenon.

2.1 Delineation of Continental Crust Boundaries

Defining continental crust boundaries presents considerable challenges. Here, boundaries are manually delineated using 2D vertical gravity gradient (VGG) maps [10], supplemented by geophysical datasets [6]. Despite some subjectivity, this method achieves high spatial accuracy (Figure 2). Independent verification of delineations is recommended for robustness.

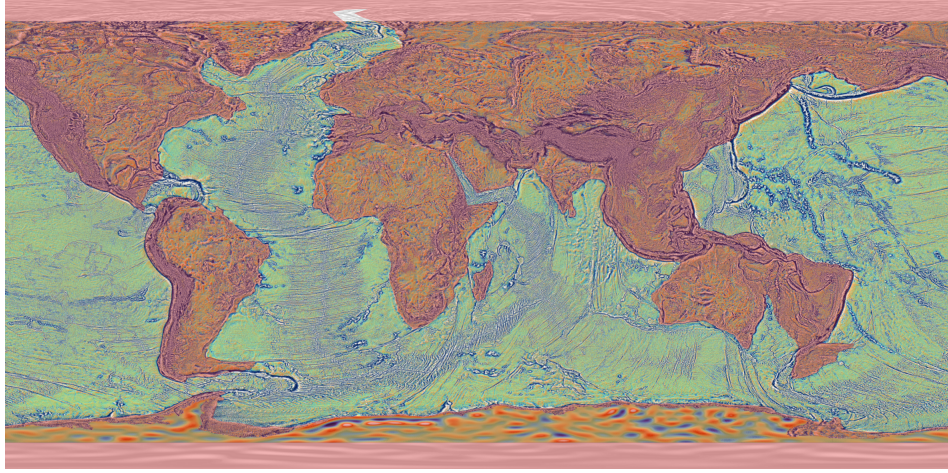


Figure 2: 2D VGG map after delineation of continental crust. Adapted from [10].

2.2 Construction of the Analog Model

A 3D-printed sphere representing the modern Earth is prepared with marked continental crust regions from Figure 2, custom 3D-printed cutters enable precise extraction of continental shapes from pliable modeling medium, the modeling clay (Figure 3). These fixed-size continental cutouts are then fitted onto smaller-radius spheres to simulate Earth’s hypothesized past states.

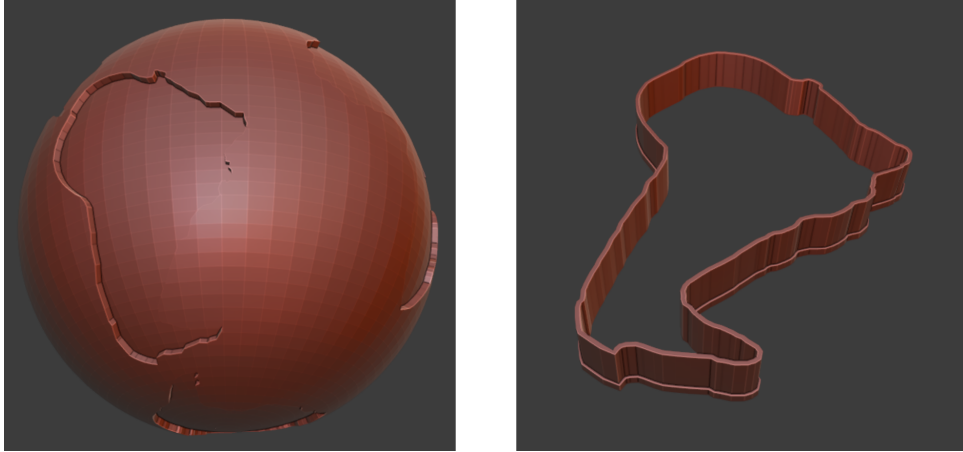


Figure 3: A 3D model of a sphere with regions of continental crust and a 3D model of a continent cutter for South America.

2.3 Materials and Tools

The project integrates FDM (Fused Deposition Modeling) and SLA (Stereolithography) 3D printing, professional handheld 3D laser scanning, VGG satellite data [10], and geophysical mapping [6] to inform model construction. Modeling clay serves as the analog material for

the continental crust due to its malleability and shape retention, facilitating iterative fitting on spheres of varying radii.



Figure 4: An example from an intermediate phase of the modeling experiments, demonstrating that the connection between Africa and South America is more accurately achieved—and progressively improved—as the Earth’s radius decreases.

3 Results

Applying the method to spheres representing Earth’s reduced radii yields a coherent and logical continental fit, most notably on a sphere approximating Earth’s size c. 180 million years ago—the estimated age of the oldest preserved oceanic lithosphere (with minor older exceptions). The reconstructed configurations align temporally and spatially with geophysical data; for example, India’s shift from northern to southern paleolatitudes corresponds with present geological studies [11].

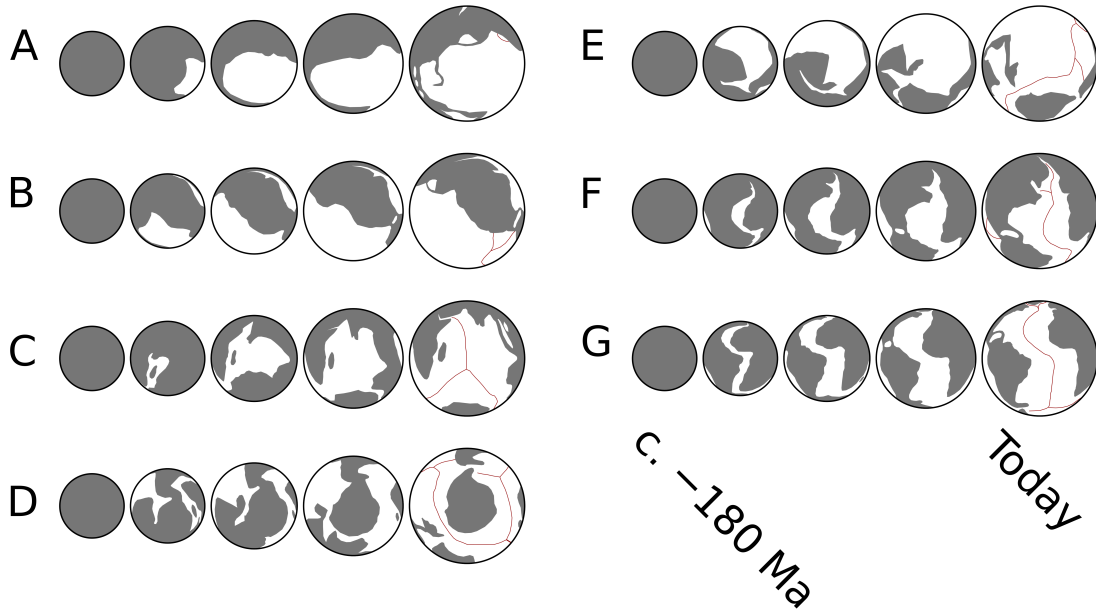


Figure 5: Technical sketches of Earth’s expansion based on the rapid prototyping modeling method, viewed from multiple angles. A: Opening of the space between Eurasia and North America, now occupied by the Pacific Ocean. B: View of North America. C: Divergence of continental masses between Antarctica and India. D: Expansion focused around the Antarctic region. E: Separation of Zealandia from South America, accompanied by significant deformation of continental crust. F: Spreading near the Mid-Atlantic Ridge between North America and Eurasia. G: Spreading near the Mid-Atlantic Ridge between Africa and South America. Red lines on the largest models indicate major extensional rupture zones.

The model reveals both brittle and ductile deformation domains: some crustal units exhibit brittle separation with preserved geometries, while others—such as Southeast Asia—demonstrate the inferred plastic flow over pre-existing oceanic crust (Figure 6). Shape congruences extend beyond classical Pangea reconstructions [3, 4], notably around symmetric mid-oceanic ridges (e.g., Mid-Atlantic Ridge), which act as extensional rupture axes consistent with volumetric expansion.

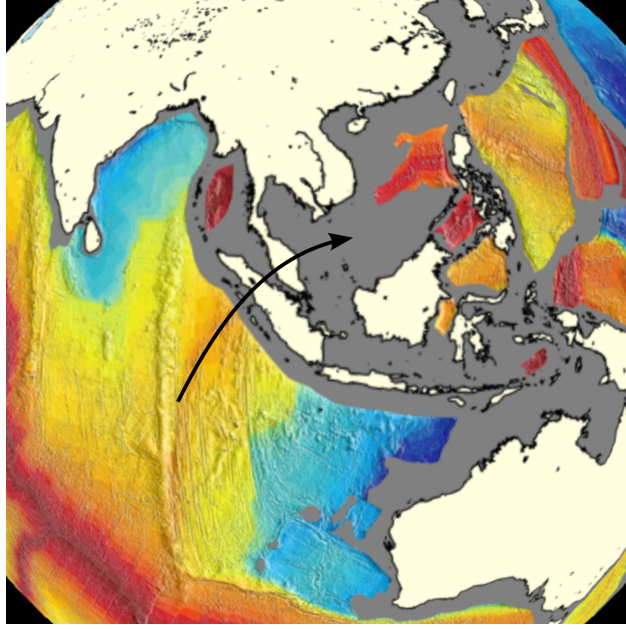


Figure 6: The continuation of the concealed oceanic crust is indicated by an arrow and is presumed to have been subsequently overlain by molten continental crust, which gave rise to the present-day region of Southeast Asia, characterized by intense volcanism and seismic activity. Although this remains a highly tentative assumption, the inferred continuity of the oceanic crust is supported by the sharp boundary delineated by the advancing continental mass.

Further analysis of the similarity in the shapes of continental margins (e.g., Africa/South America, South America/Zealandia) within the VGG 3D model—while preserving Earth’s present volume—supports the interpretation of rotations around the axes of major extensional ruptures distributed globally, not limited to the classical Pangea configuration [3]. This observation reinforces the hypothesis that rigid or semi-rigid continental blocks must be accommodated on a spherical surface of smaller radius, with the necessary curvature adjustments, in accordance with the physics of lithospheric shell deformation under planetary expansion.

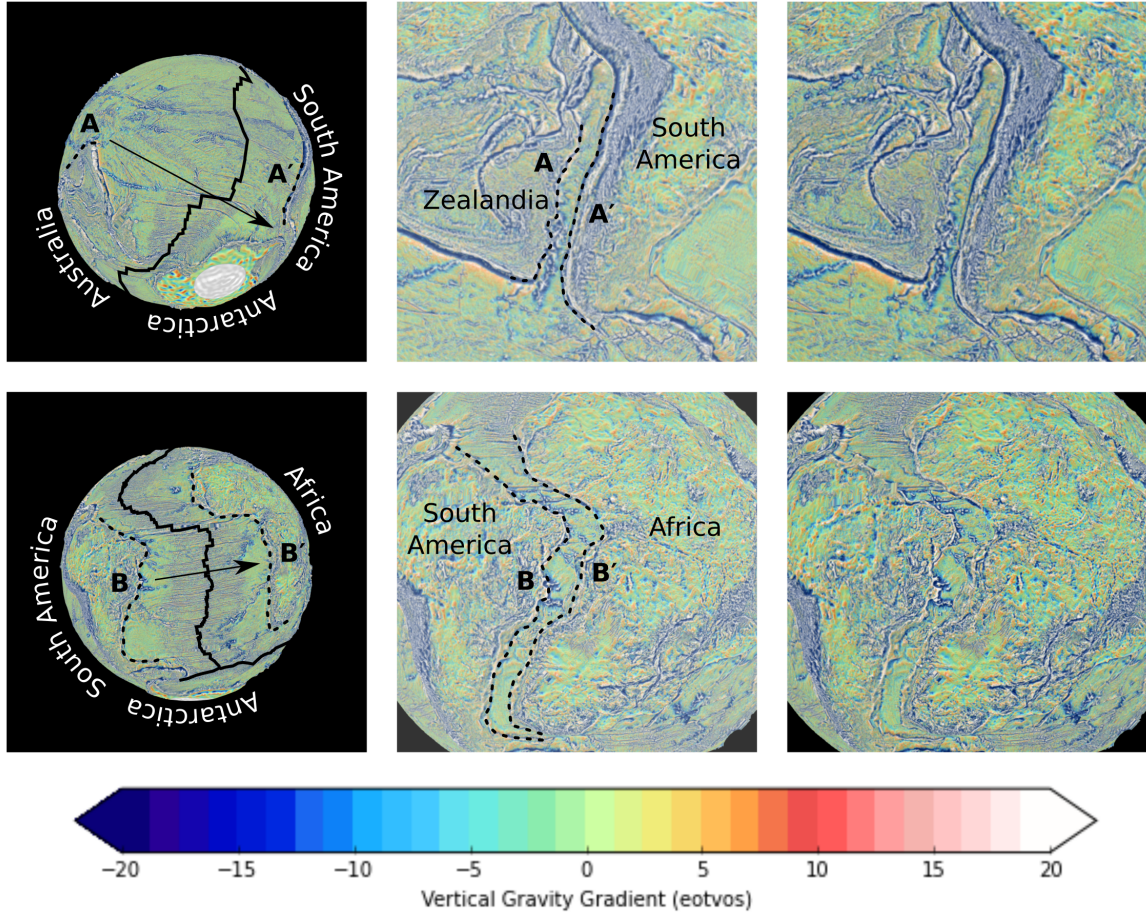


Figure 7: The continental margins of Africa/South America and Zealandia/South America from the 3D VGG model brought into proximity. The solid lines represent the corresponding expansive ruptures, while the dashed lines mark the continental margins; the shape similarity is evident. Adapted from [9].

4 Discussion

4.1 Justification for Using Modeling Clay

While modeling clay does not mimic the rheology of natural crustal rocks, its mechanical viscoplastic properties satisfy geometric modeling objectives: it is moldable, stable, shape-retentive, and reusable across multiple sphere sizes, enabling consistent testing of fixed-shape continental fits.

4.2 Continental Crust as a Viscoplastic Shell

Continental crust is approximated as a viscoplastic shell over geological timescales (c. 180 million years). Although subject to additional internal plastic deformation and external erosion, these processes are largely negligible for the modeled scale, supported by consistent lithospheric coherence and approximate conservation of continental surface area.

4.3 Limitations and Scope

The analog model does not simulate geomechanical properties such as brittle failure or viscoelastic flow and thus cannot address detailed geodynamics. Instead, it focuses on first-order geometric constraints and spatial relationships imposed by expansion.

4.4 Physical Mechanism of Earth’s Expansion

A major challenge to the expanding Earth hypothesis lies in its apparent contradiction with fundamental conservation laws, particularly mass and energy conservation. A critical question is whether Earth’s radius increase entails an increase in mass, and if so, what the source of this additional mass would be.

This study explicitly rejects the concept of spontaneous mass creation within Earth’s interior, as no empirical evidence supports such a process. Mass generation has not been observed in comparable celestial bodies—such as the Moon, Mars, or asteroids—and would conflict with well-established physical principles. Considering Earth’s age of approximately 4.5 billion years, the hypothesis that mass would suddenly begin increasing mainly in the last c. 180 million years is both physically implausible and cosmologically unsupported.

According to the law of conservation of mass and energy, matter cannot be created or destroyed but only transformed. Einstein’s mass-energy equivalence ($E = mc^2$) further reinforces this principle [12], implying that any increase in mass must be accompanied by an equivalent energy input—an effect not observed in the Earth system.

Instead, this work proposes a physically consistent alternative: Earth’s volumetric expansion is driven by long-term internal relaxation of a previously compressed planetary body—a chthonian planet [5]. In this conceptual model, Earth originally formed under extreme pressure conditions, potentially as the dense core of a primordial gas giant. Subsequent atmospheric stripping, interior cooling, and phase transitions allowed Earth’s materials to relax volumetrically, releasing stored mechanical energy without adding mass.

This relaxation involves nonlinear, pressure- and temperature-dependent phase transitions within Earth’s interior—such as changes in material structure and density gradients—that reduce overall density and increase planetary volume. The construction of any expansion model for a planetary core undergoing atmospheric loss must rely on numerous theoretical assumptions, reflecting the extreme internal conditions associated with nonlinear material phase behavior [13]. One of the earliest and simplest approaches to this problem, the Maxwell viscoelastic model, was applied to the relaxation of a homogeneous sphere in the pioneering work of Mocquet et al. [14]. These authors also proposed a wide range of scenarios for exoplanetary relaxation timescales across the universe, from sudden releases of stored mechanical energy to gradual relaxation processes lasting billions of years—or, in the case of

superdense exoplanets, remaining in an unrelaxed state over geological timescales.

The Earth’s expansion, originally proposed by Hilgenberg [1], is therefore a thermodynamically sound phenomenon, driven by changes in internal structure and density rather than additional mass accretion or creation. This interpretation resolves the mass conservation paradox inherent in classical expanding Earth hypotheses.

Moreover, extensional tectonic features such as symmetric mid-ocean ridges can be physically interpreted as rupture zones accommodating volumetric growth, consistent with this relaxation-driven expansion scenario. As the Earth expands, lithospheric regions undergo plastic deformation (Figure 6), while certain rigid continental blocks exhibit brittle separation preserving their macroscopic shape identities (Figure 7).

In summary, the chthonian planet relaxation model provides a mechanistically plausible explanation for Earth’s volumetric expansion that:

- respects conservation of mass-energy,
- accounts for geophysical observations of oceanic crust ages and spatial distribution,
- explains extensional tectonic features as volumetric adjustment phenomena,
- aligns with theoretical viscoelastic planetary relaxation frameworks,
- challenges the rigid-plate tectonics paradigm by incorporating large-scale planetary relaxation—addressing challenges already revealed by detailed millimeter-scale measurements of Earth’s crustal behavior [15].

Future work should integrate the chthonian model with more detailed rheological and thermodynamic simulations to better constrain the timescales and material properties governing Earth’s long-term expansion.

5 Conclusions

This study introduces an analog rapid prototyping method demonstrating a consistent geometric fit of continental crust on progressively smaller Earth radii, supporting the expanding Earth hypothesis. Interpreting Earth as a chthonian planet undergoing internal relaxation provides a plausible physical mechanism for volumetric growth, challenging rigid-plate tectonics and encouraging further multidisciplinary exploration of planetary-scale geodynamics.

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